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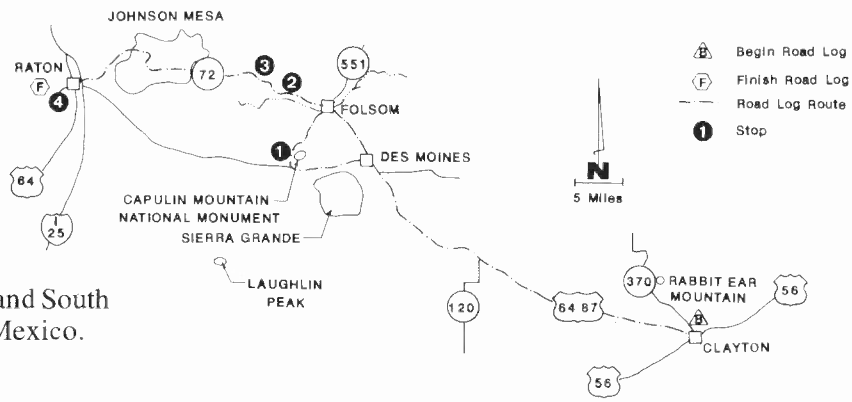
THIRD-DAY ROAD LOG, FROM CLAYTON TO DES MOINES, CAPULIN, CAPULIN MOUNTAIN NATIONAL MONUMENT, FOLSOM, RATON AND THE CRETACEOUS/TERTIARY BOUNDARY ON GOAT HILL

ADRIAN P. HUNT, SPENCER G. LUCAS and BARRY S. KUES

SATURDAY, SEPTEMBER 26, 1987



Assembly point: Intersection of Locust Street and South First Street, Clayton, New Mexico.
Departure time: 8:00 a.m.
Distance: 107.4 mi
Stops: 4

SUMMARY

The third day's tour of the plains and mesas between Clayton and Raton emphasizes (1) volcanic rocks of the Clayton-Raton volcanic field; (2) Folsom archaeological site; (3) Late Cretaceous stratigraphy; and (4) the Cretaceous/Tertiary boundary.

We first proceed west through a landscape dominated by volcanoes and flows of the Clayton basalts and Sierra Grande andesite. At Stop 1, there is an opportunity to examine the excellently preserved cinder cone at Capulin Mountain. We then travel north to Folsom past a variety of volcanic features associated with Capulin Mountain. At Folsom we turn west and travel through a terrane of Upper Cretaceous rocks. We rise from the Lytle Sandstone (Lower Cretaceous) up to the Niobrara Formation (Turonian; Upper Cretaceous). At Stop 2, we examine the cyclical sequence of the Upper Cretaceous Greenhorn Formation. Heading further west we stop at the Folsom archaeological site. We then ascend Johnson Mesa and travel through a variety of flows and cones on the mesa. As we descend the western side of Johnson Mesa we pass through a younger, Upper Cretaceous sequence well exposed on the mesa walls. Still heading west we arrive at Raton and then ascend Goat Hill to view an iridium-rich outcrop at the Cretaceous-Tertiary boundary. This day's trip, and the field conference, ends at Goat Hill. Participants may then descend Goat Hill into the town of Raton where there is easy access to I-25.

Mileage

0.0 **Turn right** onto First Street **and proceed N** on US-87. **0.5**

0.5 **Traffic light;** proceed straight. **0.4**

0.9 **Road forks** at junction of US-64/US-87 and NM-370; **bear left** on US-64/US-87 and cross bridge. The route between Clayton and Raton is dominated by a sequence of volcanic rocks (Fig. 3.1) that represents the easternmost extent of Late Cenozoic volcanism in the United States. In brief, this sequence consists (in ascending order) of: (1) Raton basalts (7.2–3.5 m.y.), which are alkali olivine basalts and cap mesas in the eastern portion of the area; (2) Clayton basalts (2.5–2.2 m.y.), which are similar in composition to the Raton basalts and form an extensive sheet between Clayton and Sierra Grande; (3) Red Mountain dacite, which erupted through the Raton basalt on Johnson Mesa and other mesas in the western portion of the area; (4) Sierra Grande andesite (1.9–0.05 m.y.), which forms Sierra Grande between Clayton and Capulin; (5) Folsom basalts (Folsom sequence of Clayton basalt of Baldwin and Muehlberger, 1959; feldspathoidal lava of Stormer, 1972b), which range in age from 1.8 to 0.1 m.y. and are restricted to cones and flows near Folsom; and (6) Capulin basalt (18,000–4,500 b.p.), which forms Capulin and Baby Capulin Mountains and Twin Mountain and the Purvine Hills (Baldwin and Muehlberger, 1959; Stormer, 1972a, b; Kudo, 1976). Most of the information concerning the numerous volcanic features that we will see today was obtained from Baldwin and Muehlberger (1959) and Muehlberger et al. (1961). **0.2**

1.1 Highway crosses bridge. Good views of Rabbit Ear Mountain at 2:00, Bible Top Butte at 1:00 and Mount Dora at 12:00. Rabbit Ear Mountain was an important

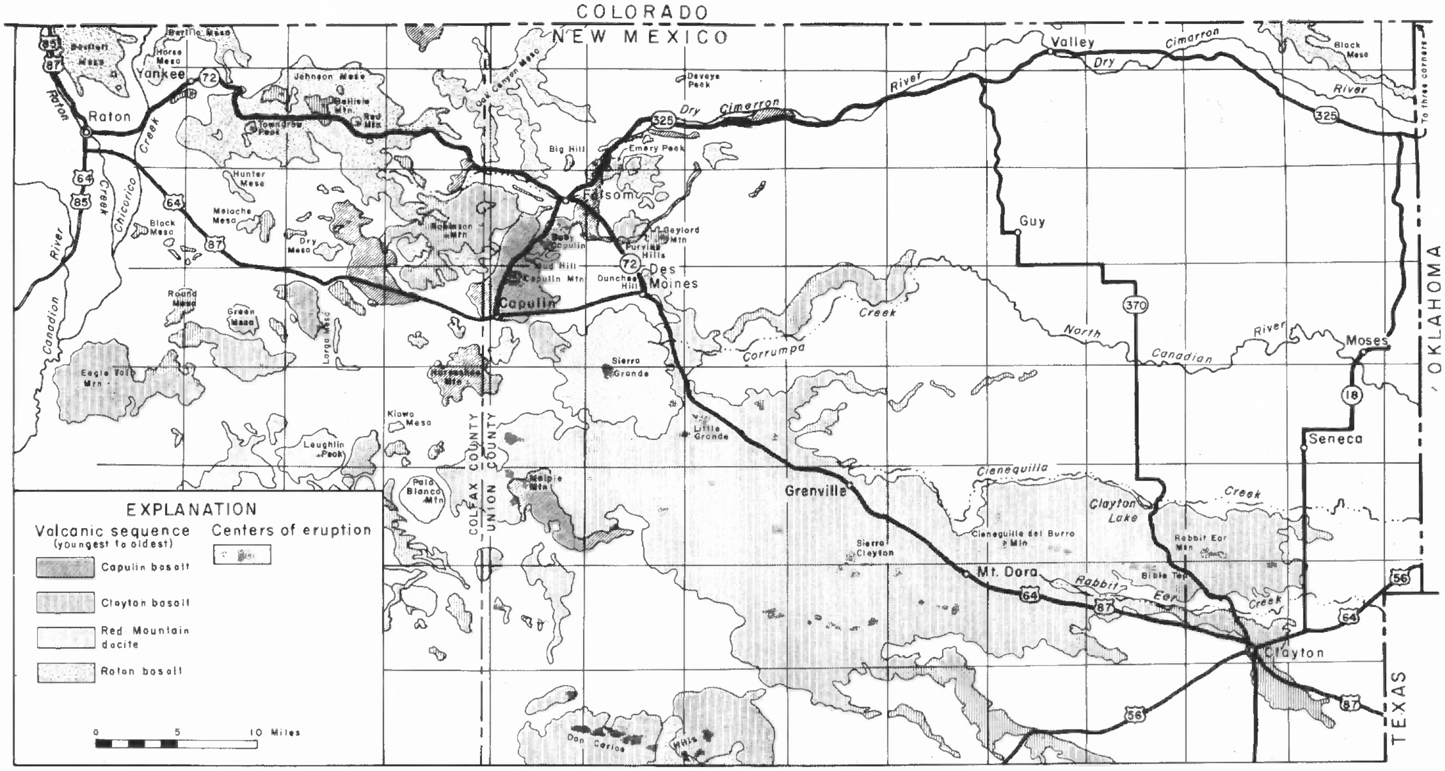


FIGURE 3.1. Distribution of volcanic rocks in northeastern New Mexico (after Muehlberger et al., 1961).

landmark on the Santa Fe Trail, which passed a few mi to the north. Travelers were within sight of the mountain for about four days, and some stopped for a day of rest along Seneca Creek, sending representatives ahead to Santa Fe to make arrangements with Mexican customs officials. Rabbit Ear Mountain was not named for any resemblance to rabbit ears. Instead, the name comes from that of a Cheyenne chief, Orejas de Conejo, whose ears had frozen; he was killed in battle and buried on the mountain. The Clayton Chamber of Commerce affirms that from west of Clayton "Rabbit Ear Mountain clearly [*sic*] resembles the profile of an Indian chief lying in state, the smaller peak resembles his hands folded across his chest." One of the greatest battles in Spanish New Mexico history was fought near here. In 1717, a volunteer army of 500 Spaniards, intending to put an end to Comanche raids, killed several hundred of them and took 700 prisoners. For a long time afterward, New Mexico experienced little difficulty with the Comanches. Rabbit Ear Mountain is a Clayton basalt vent rising 600 ft above the surroundings. Erosion has removed all but the outer slope on its southmost flank. **0.6**

1.7 Clayton Historic Marker on left. **1.0**

2.7 Clayton basalts visible low to the left. For nearly the entire distance from Clayton to Des Moines, a distance of more than 40 mi, the highway is on Clayton basalt flows for which this is the type area (Collins, 1949). The broad upland surface across which we are traveling is a solid sheet of basalt to the west, near Sierra Grande, but in this area consists of several separate flows. In all areas the Clayton basalts rest upon sands and gravels of Ogallala-like material in broad ancient valleys that were cut into the Ogallala Formation. The vents that produced this extensive basalt sheet have not been positively identified. However, it is clear from the length and thinness of separate flows, and their wide distribution, that these Clayton basalts must have formed from highly fluid lava which was not likely to produce prominent cones. In contrast, the younger Folsom-sequence eruptions to the north formed steep-sided composite or pyroclastic cones and relatively restricted basalt flows. Petrographically the Clayton basalts are virtually identical. The east-west orientation of the basalt field, with tongues toward the east, suggest a source near Sierra Grande, although Sierra Grande itself is andesitic and could not have been the source of the Clayton basalts. **0.5**

3.2 Historic marker for Rabbit Ear Mountain and gravel pit, both on left. **0.5**

3.7 At 8:00 a gravel pit is visible in the Ogallala-like alluvium which forms the undulatory topography of this area. Playas are also visible at 8:00. **1.2**

4.9 Good view of Apache Canyon to the right with Clayton basalts capping the canyon walls. **2.8**

7.7 Bible Top Butte is prominent at 3:00. This small, flat-topped peak has a crease in the basalt cap, causing it to resemble an open book. **2.4**

10.1 Windmill to left and Mount Dora visible at 2:00. The highway is following the south side of Apache Creek. **1.9**

12.0 Highway passes under telephone lines. Good exposures of Clayton basalt flow at 1:00–4:00. **0.8**

12.8 Abandoned windmill at 9:00. Mount Dora is ahead at 12:00–1:00. Mount Clayton is at 12:00, at 11:30 is Horseshoe Mountain and at 10:00 the Hogback is visible in the foreground and Tripod Mountain in the middle ground. **3.2**

16.0 The large mountain at 3:00 is Mount Dora (or Cieneguilla del Burro Mountain; elevation 1,917 m), a broad shield volcano, about 3 mi in diameter. It was possibly the source for the Seneca flow of Clayton basalt, which extends for more than 15 mi to the east, along the south side of Seneca (Cieneguilla) Creek, skirting the northern edge of the Rabbit Ear Mountain volcanics. Mount Clayton is visible at 12:00 and the Kilburn Hills at 10:00. **2.1**

18.1 Turnoff to Sofia (NM-426); entering site of town of **Mount Dora.** Mount Dora (population 5), named for a sister-in-law of Stephen Dorsey, was established in 1907 as a shipping point for cattle, sheep and produce on the Colorado and Southern Railroad. The town thrived for the first 20 years of its existence, boasting three hotels, a bank and a population of about 400, but never recovered from the drought and depression years of the 1930's. Mount Dora served as a station on the ill-fated "Colmor cutoff," a branch of the AT&SF Railroad that was supposed to link Boise City, Oklahoma with the main line running through Las Vegas and Springer. Work commenced in 1930 from Mount Dora westward, but only 36 mi of track were laid, to a point near Farley, before the Depression caused work to cease. Trains ran twice a week along this line during the 1930's, but the track was torn up in 1942, for use as scrap metal during World War II. Only a few houses, mostly abandoned, remain of Mount Dora. **Proceed straight** on US-64/US-87. **0.5**

18.6 Leaving Mount Dora; the panorama ahead includes Sierra Grande at 12:00, Mount Clayton and Horseshoe Mountain at 11:00 and the Kilburn Hills at 9:00. **1.0**

19.6 Playa lakebed on left. **1.1**

20.7 Mount Clayton at 10:00 and Horseshoe Mountain at 9:30. Mount Clayton is an eroded, Clayton-age volcano (elevation 2,035 m); steeply dipping pyroclastic beds are present on the flanks of the cone. Mount Clayton was an important landmark (called Round Mound) on the Santa Fe Trail. Travelers sometimes climbed to its summit for a view of the surrounding countryside. Josiah Gregg (1844), in his "Commerce of the Prairies," described Round Mound as "a beautiful round-topped cone . . . which commands a full and advantageous view of the surrounding country, in some directions to a distance of a hundred miles or more." He also described seeing from Round Mound, herds of thousands of buffalo that would cover the prairie below when they migrated through in the fall. NM-120 runs south from Grenville to within a mile of Mount Clayton, for those modern travelers who might wish to climb it. From Mount Clayton the Santa Fe Trail continued to the next landmark, "Point of Rocks," about 30 mi to the southwest. **3.1**

23.8 Rest stop on right with Santa Fe Trail marker stating that the first wagons used on the Cimarron cutoff branch of the Santa Fe Trail crossed here in 1822 (Fig. 3.2). Mount Clayton prominent at 9:30. **2.0**

25.8 Eroded Clayton basalt exposures to left. **1.2**

27.0 Entering **Grenville** (elevation 5,990 ft; population 39). Pearce (1965) attributed the town's name to "a Mr. Grenville, a prominent man in the pioneer days," but it is more likely that the town was named for General Grenville Dodge, construction manager for the Fort Worth and Denver Railroad, on which Grenville began as a station and post office in 1888. With the influx of homesteaders and growth of farming during the early 1900's, Grenville assumed importance as a shipping point, and the town was platted in 1909 by J. F. Branson (who gave his name to Branson, Colorado, at the north end of Tollgate Canyon). A boom occurred in 1919, when the Snorty Gobbler oil well was brought in 5 mi north of town, but the boom ended in 1925 with the failure of the oil company. During its heyday in the 1910's and 1920's, Grenville had two banks, three hotels, a theater, four filling stations, three churches, a small hospital and a newspaper, the Grenville *Headlight* (1913–1915). When the population reached about 500 in 1920, the town incorporated, but declined greatly during the 1930's when most of the area's farmers moved away. Many of the houses in Grenville have either been torn down, burned or removed to other towns. With a population of 39, Grenville is one of the smallest incorporated towns in the United States. **0.2**

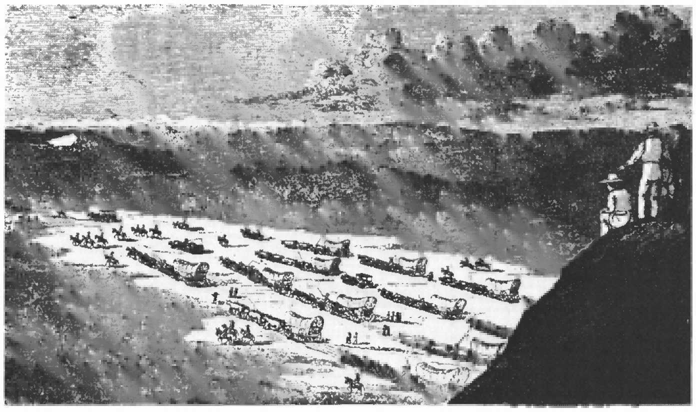


FIGURE 3.2. "March of the caravan" on the Santa Fe Trail in northeastern New Mexico (from Gregg, 1844).

27.2 **Junction** with NM-120 which enters highway from left; **proceed straight** on US-64/US-87. **0.2**

27.4 Leaving Grenville. **0.2**

27.6 Good views of Sierra Grande at 11:00 and Cow Mountain at 10:00. **4.1**

31.7 Highway crosses south tributary of Seneca Creek. **1.0**

32.7 Little Grande visible at 11:30 directly in front of Sierra Grande. **0.8**

33.5 Malpie Mountain is visible at 10:00 and at 9:30. Lonesome Mountain can be seen in the foreground and Barela Mountain in the farground. **0.5**

34.0 Cow Mountain, a large, low volcano, is at 9:00 about 2.5 mi from the highway. Its basalts are identical in composition to those on which we have been driving since leaving Clayton. Cow Mountain probably supplied much of the lava that produced the wide, basalt-covered flat in this area. **3.2**

37.2 Little Grande at 9:00 on left. This volcano displays the eroded edges of lava flows interlayered with cinders. Complex cross-layers of cinder beds on Little Grande are the result of the vent changing its shape and direction during formation of the volcano. Emery Peak is visible on the horizon and Carr Mountain in the foreground at 1:30. River Mesa can be seen at 2:30. **1.5**

38.7 To right in gulley beneath railroad tracks are outcrops of columnar basalt, part of the Van Cleve flow of the

Clayton basalts. The edge of the Van Cleve flow may be seen stretching off to the right between here and the rest stop ahead. **0.6**

39.3 **Rest area** on right. Dominating the landscape to the left is Sierra Grande, a large shield volcano with an average flank slope of about 8°. It is about 15 km in diameter and rises 600 m above the surrounding landscape to a maximum elevation of about 2,650 m. Parasitic cones and flows are visible on the east and north flanks. The main bulk of this volcano is composed of pyroxene andesites which are found nowhere else in the Raton-Clayton region. Volcanic breccias are present around the crest, although true craters are no longer preserved. The andesites of Sierra Grande overlie typical Clayton basalts, and have been dated at 1.9 m.y. (Stormer, 1972a). **2.9**

42.2 Good views of Emery Peak in distance at 1:00, Carr Mountain at 1:30 and Dunchee Hill at 12:30. **2.0**

44.2 First good view of Capulin Mountain at 10:00 as highway enters the outskirts of Des Moines. **0.5**

44.7 Enter **Des Moines** (elevation 6,622 ft; population 178). When the railroad came through in 1888, a station named for the capital of Iowa was established, but a town did not develop until 1907. By the end of that year Des Moines had a population of 300, numerous business establishments and a newspaper (the Des Moines *Swastika*), but a disastrous fire in 1908 wiped out much of the business center. In the mid-1910's an influx of new residents created a housing shortage, which one enterprising man alleviated by constructing cheap houses (actually little more than shacks) at a furious rate, some 75 in three months! By 1920 the population was about 800, and the town was an important trading and shipping point for an extensive dry farming and ranching area. Drought and the Depression caused a decline that has continued to this day, although a dry ice industry in the late 1930's temporarily slowed the decline.

One mile north of Des Moines at 2:30 is Dunchee Hill, a low eroded remnant of a volcano. A sill-like mass, apparently injected into the lower part of the cone, forms a horseshoe-shaped structure (open to the north) around what was probably the center of the cone. The vent area is mainly pyroclastic material; basalt flows extend southeast for at least 3 mi. As the Dunchee volcanics are not in contact with other flows, the age of eruption is not clear. However, the severe erosion of the cone suggests that it may represent one of the earliest Clayton-age eruptions in the area. **0.8**

45.5 Post office on left. **0.3**

45.8 **Junction** with NM-72 on right. Supplemental Road Log 6, from Des Moines to Folsom proceeds N on NM-72 from here. **Proceed straight** along northern margin of Sierra Grande. Capulin Mountain is visible at 2:00 with Robinson Peak in the distance at 2:15 and Mud Hill at 2:30. **0.6**

46.4 Rest stop and historical marker for new Goodnight Trail on right. "This famous old trail, up which more than 250,000 head of cattle were trailed to market, was blazed by Charles Goodnight in 1886. Most of the herds originated on the plains of Texas and were trailed by lean cowboys up the Pecos River to Ft. Sumner, then north to Colorado, Wyoming and Montana. U.S. 87 crosses trail here." The Goodnight Trail skirted the eastern base of Sierra Grande and headed north from there around the eastern end of Oak Canyon Mesa. **1.8**

48.2 At mile marker 332 several mountains can be seen: 9:00, Sierra Grande; 2:00, Capulin Mountain; 2:30, Mud Hill; 2:45, Baby Capulin; 3:00, Twin Peak and 4:00, Emery Peak (Fig. 3.3). **0.2**

48.4 Horseshoe Crater is visible at 10:00, Laughlin Peak at 10:30 and Palo Blanco Mountain at 9:30. **2.8**

51.2 Road enters highway from left. A cinder quarry at the base of Capulin Mountain can be seen at 2:00. Lava flows are visible from 12:00–1:45. **1.5**

52.7 Basalt in roadcuts to right represents the last (flow 3) of three main lava flows associated with Capulin Mountain. **0.7**

53.4 Historic marker for Capulin Mountain National Monument on right. The low unnamed hills to the left are capped by basalt. **0.8**

54.2 Enter **Capulin.** Capulin is Mexican-Spanish for "wild cherry." This village was first named Dedman in 1909 to honor E. J. Dedman, superintendent of the AT&SF Railroad. When Mr. Dedman died in 1914, the name was changed to Capulin because of the proximity to Capulin Mountain. **0.4**

54.6 **Turn right on NM-325.** Historic marker on right. **0.1**

54.7 Cross **cattleguard** and leave Capulin. **0.5**

55.2 Capulin flow 2 on right spotted with juniper trees. Flow 2 is extensively exposed on both sides of the road from here to past the Capulin Mountain turnoff. **0.6**

55.8 Highway crosses **cattleguard. 0.5**

56.3 Jose Butte at 10:00 with a prominent cap of columnar basalt. **0.6**

56.9 Highway crosses cattleguard and flow 2. **0.5**

57.4 **Turn right into Capulin Mountain National Monument. 0.1**

57.5 Capulin flow 2 at 10:00–12:00. Ridge on left is outer wall of a former lava pool. Lava broke through this wall and flowed down the slopes to the valley below. **0.2**

57.7 On left is grassy valley flanked with walls of basalt of flow 2. These walls are natural levees for the lava that poured out of the large central pool. **0.1**

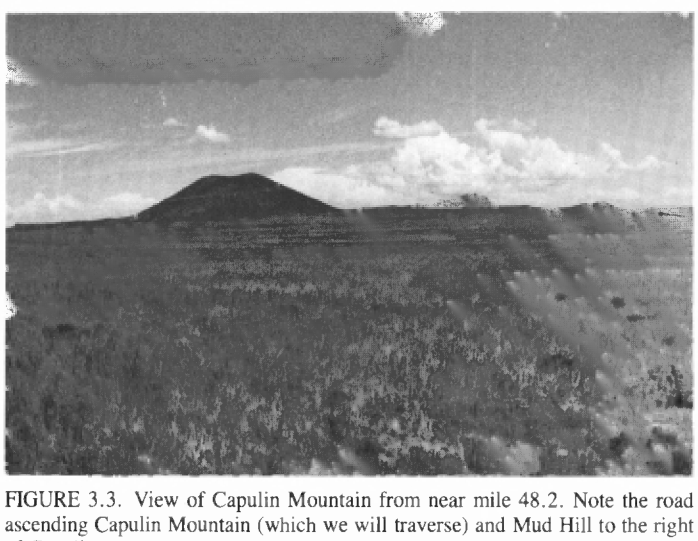


FIGURE 3.3. View of Capulin Mountain from near mile 48.2. Note the road ascending Capulin Mountain (which we will traverse) and Mud Hill to the right of Capulin.

57.8 Arrive at **Visitor Center. Stop to pay $3.00-per-vehicle fee** and **then proceed into monument. 0.1**

57.9 Road goes through gate and begins ascent of Capulin Mountain. **0.1**

58.0 Road to picnic area on right. The picnic area is between the natural levees for many of the large flows that moved south through here toward the village of Capulin. **0.1**

58.1 Bare hill ahead is the vent for lava from Capulin Mountain. Lava from this vent produced three main flows, each covering several square miles to the north, west and south of Capulin Mountain (Fig. 3.4). Capulin itself represents the buildup of pyroclastic debris blown by escaping gases into the air, to settle, red hot, on the developing cone. The eruptions occurred from 10,000 to 4,500 years b.p. The earliest basalt flow extends for several mi along the northwest side of NM-325, entering the valley of the Dry Cimarron near Folsom. A second, more extensive flow (through which we have just driven) covers the area between Capulin Mountain southward to the Village of Capulin. The third flow lies to the east of the second, extending from near the base of the mountain southward to US-64/US-87. This last flow is much smaller than the other two. The Capulin basalts are readily distinguished from others in the area by conspicuous, colorless plagioclase phenocrysts, which are rounded, resorbed or show "dusty" inclusion-rich zones (Baldwin and Muehlberger, 1959; Stormer, 1972b). Large olivine phenocrysts up to 1 cm in diameter are also abundant. In hand specimens, the Capulin Mountain basalts are dark gray, porphyritic and vesicular, with phenocrysts totaling about 10% of the rock. The groundmass is mainly composed of very fine-grained augite and plagioclase, with significant amounts of glass and tiny magnetite grains. **0.1**

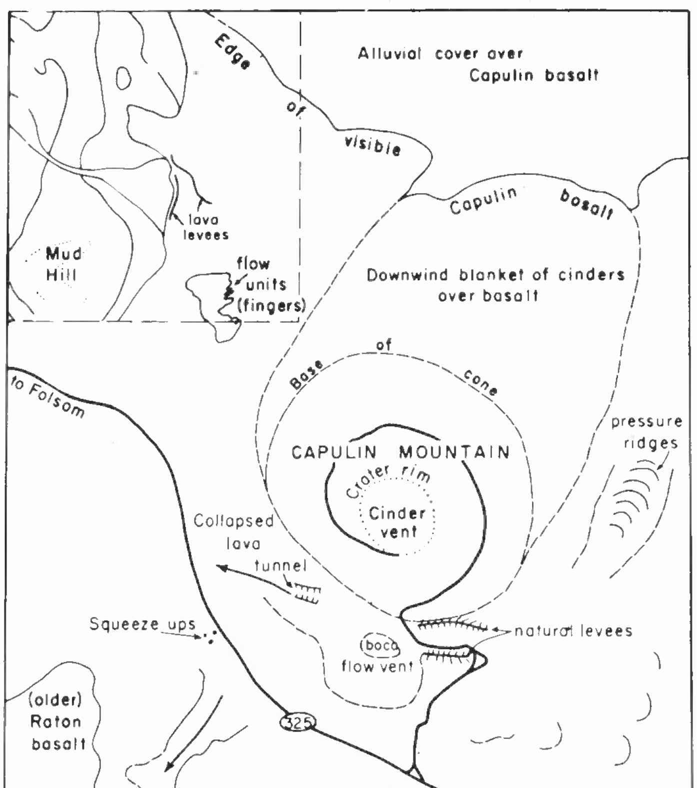


FIGURE 3.4. Volcanic features at and around Capulin Mountain (from Baldwin and Muehlberger, 1959).

58.2 Road turns right passing end of natural levee; lava vent to left. **0.2**

58.4 End of pavement. An unnamed conical dome is visible at 2:30. Also visible are Lonesome Mountain at 2:45, Malpie Mountain at 3:00 and Barela Mountain at 3:30. **0.3**

58.7 Stratified cinder in roadcut on left (Fig. 3.5). **0.1**

58.8 Sierra Grande at 2:00. The lava flow about 100 m beyond the base of Capulin Mountain below us has prominent pressure ridges. These formed as the upper surface of the lava solidified while the liquid lava below it kept moving. **0.4**

59.2 Cinder and ash to left for next 0.5 mi. At about mi 59.5, Twin Mountain is visible at 3:00, 5 mi to the northeast. **0.1**

59.3 Pull off to right. **Continue straight. 0.4**

59.7 Start of retaining wall. **0.2**

59.9 **STOP 1.** Parking lot at top of mountain lies on the edge of the main crater (Fig. 3.6). From this point there is an excellent panorama of the numerous volcanic features of the region (Fig. 3.7). Capulin Mountain (elevation 2,492 m) was a landmark for Spanish travelers from the 1700's. In the 1890's, government surveyors made notes on the size and shape of the mountain for the Homestead Act, and in 1916 President Woodrow Wilson proclaimed Capulin Mountain National Monument "as a striking example of recent cinder volcanoes and . . . of great scientific and geologic interest." The monument covers an area of 775 acres. The spiral road up the flanks of the volcano was constructed in 1925–1926 by local residents, using dynamite, picks and a horse-drawn grader. Since that time the road has been rebuilt, and the visitor's center was constructed in 1964. Reports that Capulin was erupting in 1906 caused some excitement among people in the vicinity, but were later traced to a fire some cowboys had started in the crater to scare away homesteaders. In 1986, 46,980 people visited Capulin Mountain National Monument (Albuquerque *Journal,* 2 August

FIGURE 3.5. Stratified cinders on flank of Capulin Mountain at mile 58.7.

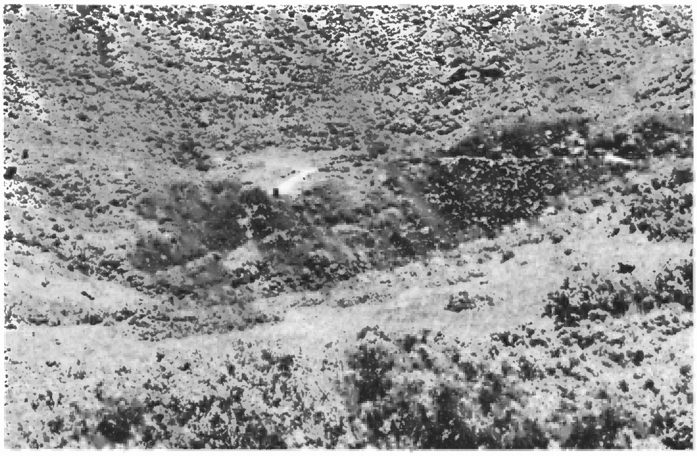


FIGURE 3.6. View into the crater of Capulin Mountain.

1986). After discussion of the volcanism of the area proceed down the mountain toward the Visitor Center. **2.1**

62.0 Visitor Center on left. **0.5**

62.5 **Turn right at the junction of NM-325** and proceed N toward Folsom. **0.3**

62.8 Highway crosses **cattleguard. 0.5**

63.3 Robinson Peak at 9:00. **0.5**

63.8 Highway crosses **cattleguard. 0.7**

64.5 Roadcuts in Capulin Basalt flow 1 to the left; Mud Hill is visible at 3:00. Mud Hill is a cone composed mainly of stratified, brown, pumiceous, lightly cemented ash fragments about 1 cm across. A fissure vent ("Great Wall") extending east from Mud Hill about a mile consists of a dike core and associated minor ash cones (Fig. 3.8). Small tongues of basalt extend north from the vent. The eruption of Mud Hill must have been violent; part of one side of the cone is missing, presumably blown away. A small remnant of the Mud Hill basalt is preserved on the hill to the left; most of the basalt was eroded away before the eruption of Capulin Mountain. **0.7**

65.2 Road curves gradually to left; Baby Capulin at 12:00 (Fig. 3.8). Behind and a little to the left of Baby Capulin is Emery Peak (pointed summit); the low dissected cinder cone at 1:30 is Twin Mountain, and the low hills behind Twin Mountain form Purvine Mesa. Baby Capulin is a small cinder cone with several small conelets on its south and east bases. Basalt from Baby Capulin flowed north and northeast into Pinabete Creek, and then into the main valley of the Dry Cimarron 1 mi east of Folsom. At this point it may have formed a lava lake and then flowed northeastward down the Dry Cimarron for another 20 mi. Eruption from Baby Capulin, and from Twin Mountain and Purvine Mesa, directly to the east, probably occurred nearly simultaneously, judging from petrographic similarity of their basalts and position along an east-west line. In places the Baby Capulin basalts overlie those of Twin Mountain and Purvine Mesa, and they flowed over the edge of Capulin Mountain lava near the highway immediately east of Baby Capulin. Thus, the eruption of Baby Capulin represents the last volcanic event in northwestern Union County. The basalt is dark gray, porphyritic and vesicular; the only common phenocrysts are composed of olivine. **0.2**

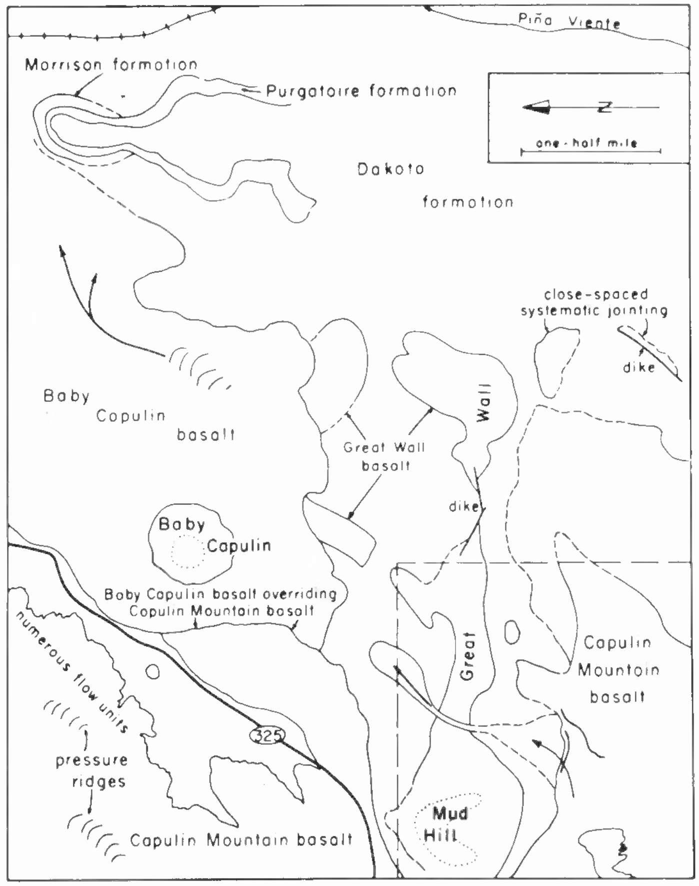


FIGURE 3.8. Volcanic features in the vicinity of Mud Hill and Baby Capulin (from Baldwin and Muehlberger, 1959).

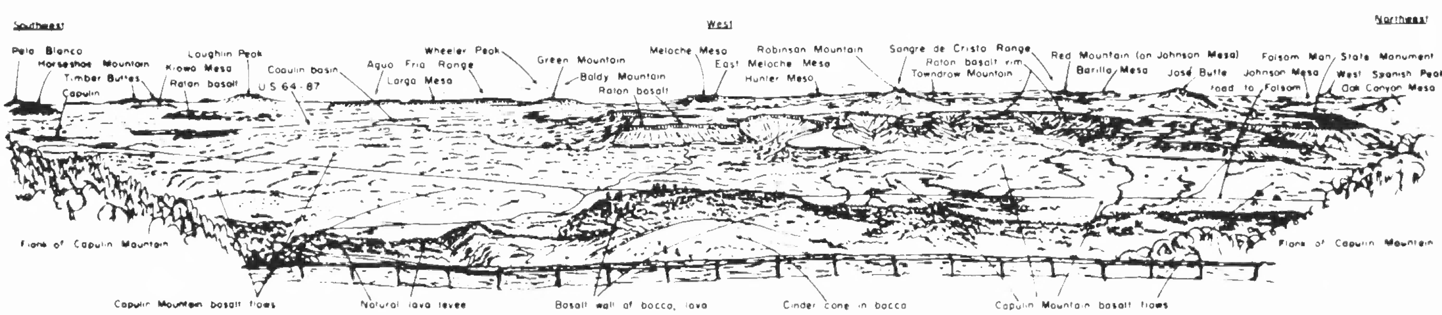


FIGURE 3.7. Panorama from parking lot on rim of Capulin Mountain (from Muehlberger et al., 1961).

65.4 Roadcuts in Baby Capulin basalt flows to left and right. **1.2**

66.6 Highway crosses **cattleguard.** Buffalo Head at 2:00 and Klondike Mesa at 1:00. **1.0**

67.6 Morrison Formation exposed to left. For the next 4 mi we will be traveling through outcrops of sedimentary rock of Late Jurassic and Early Cretaceous age. This sequence consists (in ascending order) of: (1) the Upper Jurassic Morrison Formation which consists of fluvial and lacustrine mudstone and sandstone; (2) the fluvial Lytle Formation of Early Cretaceous age; (3) the Lower Cretaceous Glencairn Formation of marine origin; (4) the fluvio-deltaic Mesa Rica Sandstone; (5) the floodplain siltstones and sandstones of the Pajarito Formation; and (6) the fluvio-deltaic Romeroville Sandstone of mid-Cretaceous age. **0.1**

67.7 Morrison Formation exposed to right and left; Folsom visible at 11:00. **0.2**

67.9 Morrison Formation exposures on right and left. **0.2**

68.1 Emery Peak at 12:00, Folsom in foreground. At 10:00, basaltic mass is Buffalo Head. **0.1**

68.2 Exposures of Morrison Formation. **0.2**

68.4 Enter **Folsom.** Folsom (population 73), named for President Grover Cleveland's wife Frances Folsom, began in 1888 as a railroad construction camp called Ragtown. It quickly developed into a bustling town with a substantial business center, many fine houses and a newspaper, the Folsom *Idea*. Wealthy Texans promoted the town as a health spa and tourist resort for travelers on the picturesque Trinidad to Clayton run. A pretentious three-story hotel was built in 1889 one mi east of town, and a small lake with a boat dock was created in front of it, but Folsom never caught on as a tourist town. It was important enough to become the seat of Union County for two years after the county was created in 1893. In 1896, a man named McSchooler opened a large general merchandise store, which was sold to Joseph Doherty in 1903. This store operated until 1959, and a few years later was converted into the Folsom Museum, which houses historical artifacts and some of the store's last inventory.

Folsom's importance as a shipping point on the Colorado and Southern Railroad was the main reason for its rapid growth, and by 1908 the town had about 500 residents. Its decline began on the night of 27 August 1908, with a devastating midnight flood that swept away most of the stores and houses, and drowned 17 people. A heavy rain over Johnson Mesa, 8 to 10 mi west of town, produced an onrushing torrent of water down the Dry Cimarron. Sarah Rooke, a telephone operator in Folsom, received warning of the flood and began immediately to call, one by one, as many residents as possible, urging them to leave their homes for higher ground. Her warnings were largely ignored, as the Dry Cimarron had never flooded enough to endanger the town. Rooke remained at her switchboard until the flood hit, was swept away, and her body was found in the town's wreckage 8 mi downstream. A monument to her bravery stands in the town cemetery.

Folsom rebuilt after the flood, incorporated in 1909 and held its own until the agricultural/economic crisis of the 1930's. By 1960 its population was only 142, and now only a quiet but interesting fragment of the town Folsom once was remains. **0.1**

68.5 **Turn left and follow NM-325. 0.1**

68.6 Highway crosses Colorado and Southern Railroad tracks. **0.1**

68.7 Lytle Formation exposed at 4:00 along the side of the Dry Cimarron, with Mesa Rica Sandstone above it at 3:00. **0.2**

68.9 At **junction with NM-72 turn left;** Folsom Hotel on right. Supplemental Road Log 6, from Travesser Park to Folsom, terminates here. **0.2**

69.1 Highway crosses Dry Cimarron. **0.1**

69.2 **Turn left on Raton Highway (NM-72).** Dry Cimarron can be seen at 11:00. **0.1**

69.3 Roadcuts of white sandstone of Lytle Formation to right and left. **0.4**

69.7 Highway crosses railroad tracks. Capulin Mountain can be seen at 9:00 with Mud Hill and Baby Capulin to left and Robinson Peak, a prominent deeply eroded vent, at 10:30. A basalt flow from Robinson Peak reached to within 1 mi west of Folsom. **0.5**

70.2 Low outcrops of Mesa Rica Sandstone to left and right. **1.2**

71.4 Highway crosses tributary of Dry Cimarron. **1.1**

72.5 Graneros Shale and Greenhorn Formation exposed. The Graneros and Greenhorn represent part of the trangressive phase of the Greenhorn marine cycle and record a transition from sublittoral to mid-basinal facies. The lower Graneros Shale is divided into an unnamed lower shale member, a medial Thatcher Member and an upper unnamed shale member (Kauffman et al., 1969). West of Raton, the Graneros is 112 ft thick at Gold Creek (Pillmore and Eicher, 1976). The overlying Greenhorn Formation is 130 ft thick at that locality (Pillmore and Eicher, 1976). The Graneros and Greenhorn in the Raton Basin are lithologically distinct from outcrops of the same formations in Cimarron County, Oklahoma (see Supplemental Road Log 2). From east to west, several trends can be recognized in the Greenhorn and Graneros: (1) increase in volume of quartz sand; (2) decrease in volume of calcarenite and chalk; and (3) thickening of both formations (Kauffman et al., 1969). These trends reflect a change in environments from mid-basin to basin margin (Kauffman et al., 1969). **0.1**

72.6 Highway crosses Fisher Creek. **0.3**

72.9 Left turn to Fisher Park; **proceed on NM-72. 0.6**

73.5 White Greenhorn Formation overlies gray Graneros Shale in roadcut to left. **0.4**

73.9 Greenhorn overlying Graneros in roadcut to left. **0.2**

74.1 Greenhorn overlying thick Graneros sequence in roadcuts. **0.2**

74.3 Resistant Greenhorn Formation overlying Graneros Shale in roadcuts. **0.1**

74.4 **STOP 2.** Excellent exposure of cyclic Greenhorn Formation in roadcut to right (Fig. 3.9). The Greenhorn Formation consists of three members in this area which are (in ascending order): the Lincoln Member, the Hartland Member and the Bridge Creek Limestone Member (Pillmore and Eicher, 1976). The Bridge Creek Limestone is exposed at this locality. The Bridge Creek is composed of alternating beds of pelagic limestone, pelagic/hemipelagic calcareous shale and thin bentonites

FIGURE 3.9. Cyclic deposits of the Greenhorn Formation at Stop 2.

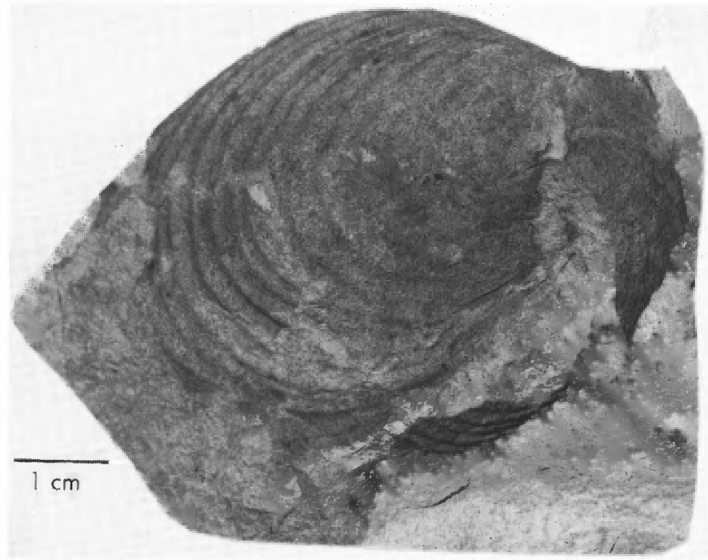


FIGURE 3.10. *Mytiloides* fossil from the Greenhorn Formation at Stop 2.

that can be correlated into western Kansas (Hattin, 1987, this guidebook). The limestones are predominantly biomicritic wackestones which are intensively bioturbated. The calcareous shales are less bioturbated, preserve primary lamination and range in texture from biomicritic wackestones to biosparitic grainstones. G. K. Gilbert, in 1895, was the first to suggest that the rhythmically-bedded Greenhorn reflected global climatic cycles. Now, Greenhorn rhythmites are thought to be caused by orbital forcing of climatic episodes that result in arid and humid climatic cycles which are best recorded in pelagic/hemipelagic sediments in deep sedimentary basins. The Bridge Creek contains abundant inoceramids, including *Mytiloides mytiloides* and *Mytiloides labiatus* (Fig. 3.10). After discussion of Cretaceous stratigraphy, continue west on NM-72. **0.7**

75.1 Enter **Colfax County.** We are soon to enter the Raton Basin (Fig. 3.11). The Raton Basin is a large, asymmetric depression of about 6,500 km^2 (2,500 mi^2) extending from Cimarron, New Mexico on the south to Huerfano Park, Colorado on the north. Formed during "Laramide time" (Late Cretaceous-Paleocene), it preserves about 12,000 ft (3,658 m) of terrestrial latest Cretaceous sedimentary rocks (Baltz, 1965). **0.1**

75.2 Highway crosses creek. The Fort Hays Limestone Member of the Niobrara Formation is exposed in the creek to the left. The Fort Hays is about 20 ft thick in this area and is composed of seven to ten beds of light-gray-weathering limestone separated by soft, calcareous shale (Scott et al., 1986). Inoceramids are common in this

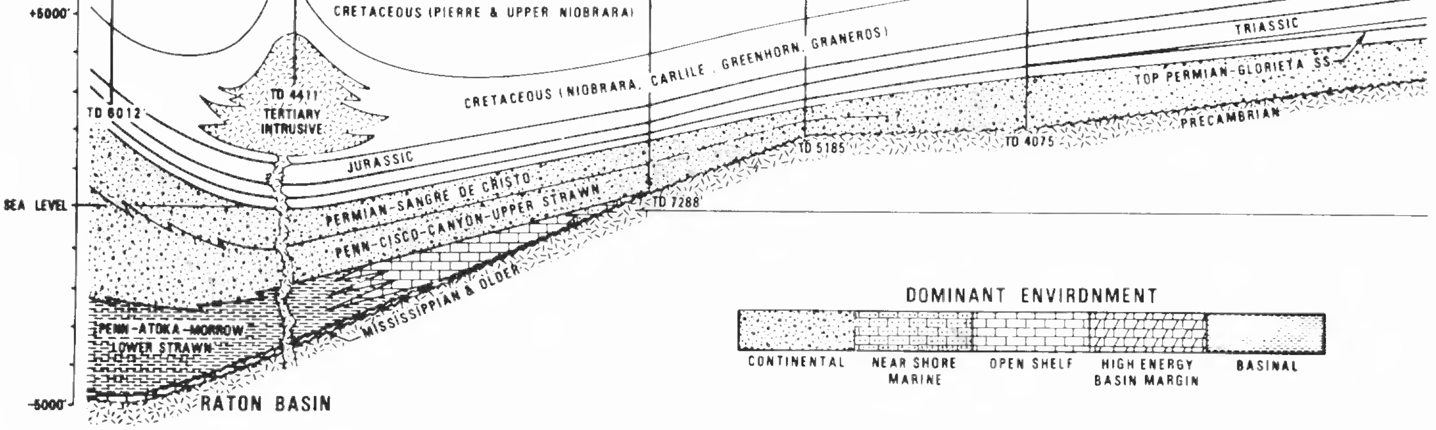


FIGURE 3.11. Structural cross section from Raton Basin to the Colfax-Union County line (from Roberts et al., 1976).

unit, but ammonites are rare. The rhythmically-interbedded limestones and shales represent isochronous beds that can be correlated into southern Colorado. This cyclic sedimentation probably was generated by orbitally-forced climatic variations (Laferriere, 1987, this guidebook). In northeastern New Mexico, the Fort Hays is latest Turonian-early Coniacian in age. **0.6**

75.8 Exposures of Niobrara Formation. **0.1**

75.9 Leaving the area dominated by the Clayton basalts; the next flows that will be visible are the Raton basalts, although Clayton volcanics locally overlie them. **0.7**

76.6 Raton basalts cap ridge from 9:00–11:00. **0.6**

77.2 **Bear left on pavement. 0.3**

77.5 Twin Buttes at 9:00. **0.3**

78.8 **STOP 3.** Marker on left for Folsom archaeological site. The excavations were to the south in the valley (Fig. 3.12A). Johnson Mesa dominates the horizon to the west (Fig. 3.12B) and Jose Butte is visible at 9:00. Sixty years ago this year, archaeologists began to report solid evidence that humans lived in North America during the last Ice Age. By 1927, there were two opposing schools of American archaeology who contended that either man's history in the New World only went back about 2,000 years or that he had hunted mammoth and bison at the end of the last Ice Age (Haynes, 1969). Viewpoints were so polarized that only "the undisturbed association of artifacts with bones of an extinct animal in geological deposits of Pleistocene age" (Haynes, 1969, p. 709) could resolve the dilemma. Folsom fulfilled these criteria.

The Folsom locality was first found in 1908 by George McJunkin, the black foreman of the Crowfoot Ranch, who noticed what turned out to be bones exposed ten feet down in a tributary of Wild Horse Arroyo, on the ranch property (Folsom, 1974). In 1925 this locality (Fig. 3.13) was brought to the attention of J. D. Figgins, Director of the Colorado Museum of Natural History (now Denver Museum of Natural History). On 14 July

FIGURE 3.12. Views from Stop 3. A, Looking south toward Twin Buttes. The Folsom site is in the valley just to the right of the photograph. B, Looking north at the Raton basalt on the edge of Johnson Mesa.

FIGURE 3.13. Two views of the Folsom site in 1926. A, The arroyo which cut through the bison-bone bed prior to excavation. "X marks the spot!" B, Part of the bison quarry in 1926 showing the bonebed in the left foreground with blocks containing the bones partly worked out. Both photographs from Cook (1927).

1926, a spear- or arrowhead was found closely associated with bones of a Pleistocene *Bison antiquus* at Folsom (Fig. 3.14) by a team from Denver (Folsom, 1974). In the face of frustrating disbelief from their colleagues, Figgins and his co-worker Cook published the evidence from Folsom and two other Paleo-Indian sites in Colorado and Oklahoma of the presence of Pleistocene man in North America (Cook, 1927; Figgins, 1927). During the summer of 1927, a second expedition found a fifth point, still embedded in the matrix. Immediately, all work was stopped and telegrams were sent to leading institutions requesting that representatives be sent to view the find. Barnum Brown of the American Museum of Natural History, Frank H. H. Roberts, Jr. of the Smithsonian and A. V. Kidder of Phillips Academy visited the site and verified its authenticity. Still, skepticism prevailed and it took another find in 1928 and another rash of telegrams and visits by distinguished scientists to turn the tide (Wormington, 1949).

Since then, many Folsom sites have been found with the majority lying in the area to the east of the Rocky Mountains (Agogino and Rovner, 1964). Additional evidence of Folsom occupation in northeastern New Mexico has been reported from Ute Dam and Newkirk (Stuart and Gauthier, 1984). Now, even earlier sites of the Clovis culture are known to date to at least 12,000 years b.p. (Cordell, 1976; Ternes, 1986).

A decade after the discovery of the Folsom site, in January 1935, J. C. McKinley of Branson, Colorado sent a human skull (Fig. 3.15) and partial skeleton to the Colorado Museum of Natural History in Denver. These bones were collected in the bank of the Cimarron River about eight mi (13 km) east of Folsom. Jesse Figgins, who had originally reported on the association of artifacts and extinct bison at Folsom, studied these remains. Although Figgins never explicitly stated so, it is clear that he believed them to pertain to the type of humans that made the Folsom artifacts. Figgins (1935, p. 2) further argued:

> The differences in the human skull, when compared with modern examples, are so marked that, in mammalogy and paleontology, there would be no question relative to the propriety of recognizing them as of specific importance. To continue the application of local designations to the growing list of discoveries of early human remains cannot fail to result in confusion. None occupies the position of a type, upon which to base comparisons, and there is need for a more systematized procedure in dealing with material of such importance as that representative of early American man. The geological evidence clearly established that the skeleton here discussed antedates all modern native types and it must be regarded from a standpoint of treatment as equivalent to that accorded the extinct quadrupeds of like age with which man was associated.

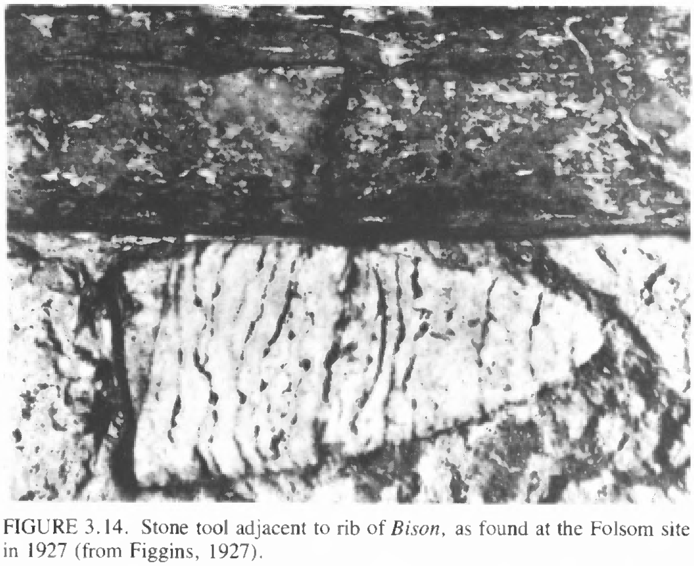


FIGURE 3.14. Stone tool adjacent to rib of *Bison*, as found at the Folsom site in 1927 (from Figgins, 1927).

FIGURE 3.15. The human skull for which Figgins coined the name *Homo novusmundus* (from Figgins, 1935).

Thus, Figgins made the human remains McKinley sent him the type specimen of a new species of human, *Homo novusmundus* ("New World man"), New Mexico's first and last putative species of extinct human. *Homo novusmundus* aroused lively interest in the newspapers of the day, but the scientific community took a circumpsect view of the find. Indeed, only two years after Figgins named it, the taxonomic concept *Homo novusmundus* was dealt a fatal blow. Figgins, with commendable scientific candor, sent the skull to Dr. Frank H. Roberts, Jr., an archaeologist at the Smithsonian Institution. With the consent of Figgins, Roberts made the skull available to some of America's most prominent physical anthropologists. The response, after examining it firsthand, was unanimous: *Homo novusmundus* was no different from the skulls of many American Indians found at archaeological sites and certainly belonged to *Homo sapiens*. Perhaps Hrdlička's (in Roberts, 1937, p. 174) comments best reflect the consensus:

> There is only one possible conclusion, which is that the Figgins skull is that of an American Indian of a somewhat inferior [*sic*] type but of a type the elements of which are rather common in certain parts of California and other regions. To make of this specimen a representative of a new species of man in America is fanciful and wholly unjustifiable.

In 1987 there are again arising two polarized schools of thought concerning the antiquity of man in the Americas. As in 1927, the majority believe that the age of the earliest human settlement in North America is firmly established (12,000 b.p.). However, as in 1927, there is a group for whom "tantalizing data from scattered sites suggest the New World was peopled earlier, and they anticipate a new turning point in archeological opinion" (Ternes, 1986, p. 8). A growing body of evidence is indicating occupation of the Americas more than 30,000 years ago (e.g., Guirdan and Delibrias, 1986). However, as in 1927, it will probably take the discovery of an undoubted artifact associated with a paleontological specimen (of pre-latest-Pleistocene age) to convince the skeptics. After discussion of the archaeology of the Folsom site, proceed west on NM-72. **0.6**

79.4 Highway passes through weathered Raton basalt. Begin ascent of Johnson Mesa. We will be traveling toward Raton across the top of this broad, gently-rolling plain for about 20 mi. Along its eastern edge, south of the highway here, Johnson Mesa has been dissected by tributaries of the Dry Cimarron. Much of the mesa is capped by Raton basalt flows, the oldest volcanic sequence in northeastern New Mexico, but locally cones and flows of the younger Clayton volcanics overlie the Raton basalt. Despite their geographical separation, there is little mineralogical difference between late Raton basalts, and the large flows of Clayton basalt between Clayton and Des Moines. Both are characterized by the occurrence of olivine as the only phenocryst mineral. The age of the Raton basalt ranges from 7.2 m.y. (older Raton basalt) to 3.5 m.y. (younger Raton basalt) according to Stormer (1972b). Numerous lakes and meadows have formed as low areas in the basalt cap have been widened and deepened through erosion and weathering. **0.5**

79.9 Terrace gravels to the right. **0.7**

80.6 Reach crest of Johnson Mesa; Red Mountain at 1:00. Excellent columnar jointing is visible in Bear Canyon at 2:00. **0.2**

80.8 Highway crosses creek. **0.3**

81.1 To the right is a fine view through Bear Canyon into Colorado. **0.9**

82.0 At 1:00 is Madrid Peak composed of Raton basalt; Red Mountain at 12:00. **0.8**

82.8 Unnamed lake on left. **2.2**

85.0 Red Mountain at 3:00 (Fig. 3.16). Red Mountain and Towndrow Peak, 6 mi to the west, are composed of the Red Mountain dacite, a series of hornblende andesites and dacites found as deeply eroded plugs, domes and flow remnants in this area. The oldest dated sample of Red Mountain dacite is 8.2 m.y., preceding the eruption of the Raton basalts, but stratigraphic sequences on Johnson, Hunter and Juan Torres Mesas indicate that some of these dacites are younger than the Raton basalts. Stormer (1972b) determined that the Red Mountain dacite could not have formed from a parent with the composition of the Raton-Clayton basalts, and suggested that the Red Mountain lavas originated by partial melting of an amphibolite in the lower crust. At 9:00 there is a view of Wilson Mesa with Flatiron Mesa behind it and Dry Mesa in the distance. **0.4**

FIGURE 3.16. View of conical Red Mountain (on left) from mile 85.0.

85.4 Road curves to the right around Red Mountain; Dale Mountain at 12:00 and Madrid Peak at 2:00. **1.2**

86.6 Sheep Mountain CO_2 plant on right. **0.3**

86.9 Passing quarry in Dale Mountain. This is a small volcanic peak that produced Clayton basalt flows. Lava from Dale Mountain moved eastward a distance of 20 mi, flowing down an old channel of the Dry Cimarron, off Johnson Mesa, to the Emery Peak basalt dam, north of Folsom. At 11:00 Towndrow Peak is visible. **1.1**

88.0 At mile marker 18 the Spanish Peaks can be seen at 1:00 and Hunter Mesa at 11:00. **0.5**

88.5 Church on left and cemetery on right. Johnson Peak is at 9:00 and Hunter Mesa at 11:00. **0.7**

89.2 Highway crosses creek. **1.8**

91.0 At mile marker 15 (crest of hill) Horse Mesa is visible at 1:30 and Little Mesa at 2:30. **0.5**

91.5 Towndrow Peak at 9:00 is composed of Red Mountain dacite. **2.0**

93.5 Horse Mesa is visible from 10:00–2:00, Little Mesa at 3:00 and Colorado at 2:00. **0.2**

93.9 Begin descent of Johnson Mesa into Yankee Canyon **0.5**

94.4 Note cinders and ash associated with the Raton basalt. **1.0**

95.4 Roadcut to right in Raton Formation; at 11:00 is a sandstone in the Raton Formation. From here onward we will see the Late Cretaceous-Paleocene strata well exposed in the Raton Basin (Fig. 3.17). In ascending order, they may be summarized as follows:

1. Pierre Shale—at least 1,900 ft (580 m) of gray and black, noncalcareous shale with intervals of limestone concretions. Tends to be silty in its upper part and grades upward into sandstone. The Pierre represents deposition in prodeltaic and offshore-marine environments in the Western Interior seaway during the late Cretaceous (Campanian-Maestrichtian). The Pierre forms steep slopes mantled by soil, talus and colluvium beneath cliffs of the Trinidad. Away from these cliffs it forms low, rolling hills; the city of Raton is built on the Pierre Shale.

2. Trinidad Sandstone—usually 80 to 100 ft (25 to 30 m) of white, yellow and gray, very fine- to medium-grained sandstone. The Trinidad was deposited in delta-front and barrier environments during the Maestrichtian regression of the seaway that deposited the Pierre Shale. It forms persistent, light-colored cliffs along the escarpment west of Raton that extend northward into Colorado and southward to about Cimarron.

3. Vermejo Formation—as much as 380 ft (115 m) of very fine- to medium-grained sandstone interbedded with mudstone, carbonaceous shale and coal beds, some of which are thick and extensive. The Vermejo was deposited in fluvio-deltaic plain and back-barrier envi-

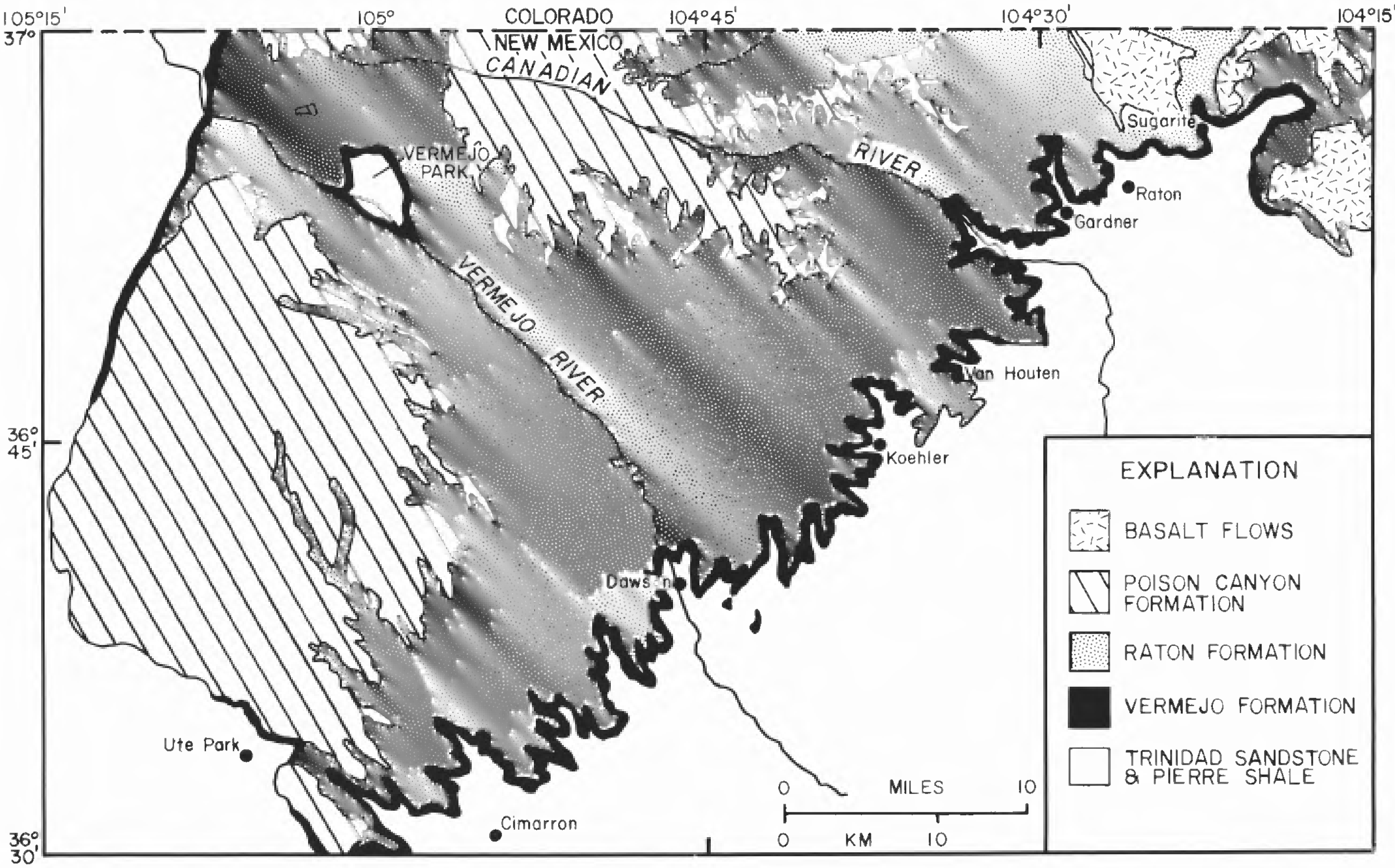


FIGURE 3.17. Generalized geologic map of the New Mexico portion of the Raton Basin (after Pillmore, 1976).

ronments behind the Trinidad coastline. It generally forms steep, debris-covered slopes above the cliffs of the Trinidad Sandstone.

4. Raton Formation—as much as 2,100 ft (640 m) of very fine- to fine-grained sandstone interbedded with siltstone, mudstone, carbonaceous shale, conglomerate and coal beds, many of which are of commercial quality. The base of the Raton Formation usually is readily recognized as a prominent, cliff-forming conglomeratic sandstone (Figs. 3.18, 3.19). The Raton Formation represents an array of fluvial depositional environments during latest Cretaceous and Paleocene time. The Raton forms steep slopes and cliffs composed of many stacked channel-sandbodies; it makes up most of the sides and tops of the escarpment north and west of Raton that we will see today.

5. Poison Canyon Formation—about 500–650 ft (150–200 m) of coarse-grained to conglomeratic sandstone with interbeds of soft, yellow, sandy, micaceous mudstone. It represents deposition by braided streams and coarse-grained meanderbelts during the Paleocene. The Poison Canyon Formation will not be seen during today's road log.

The above information was extracted mostly from Pillmore and Flores (1987). Much additional information on the Late Cretaceous-Paleocene of the Raton Basin can be found in the two New Mexico Geological Society Field Conference Guidebooks devoted just to this area (Northrop and Read, 1966; Ewing and Kues, 1976). **0.3**

95.7 The low white sandstone from 12:00–1:00 is the Trinidad Sandstone. **0.8**

96.5 Horse Mesa at 12:00. **0.4**

96.9 At telephone pole there is a good view of the Upper Cretaceous sequence. The white sandstone of the Trinidad Sandstone is most prominent with the dull Pierre Shale below it and the nonmarine Vermejo and Raton formations above. **1.5**

98.4 Highway crosses east fork of Chicorica Creek. **0.3**

98.7 Passing through Raton Formation. **0.7**

99.4 Highway crosses creek. **0.1**

99.5 Enter **Yankee,** the easternmost coal-mining town in the Raton Basin. This town was started in 1904 by a Wall Street brokerage firm, led by A. D. Eusing, promoter of the building of the AT&SF Railroad from Raton to Yankee. The town produced coal and was owned by the railroad, but was abandoned when the railroad failed. Coal mining was later resumed, but the town never had more than 200 inhabitants. **0.4**

99.9 Leave Yankee. On Horse Mesa at 2:00 there is a good sequence exposed from the Pierre Shale up to the Raton Formation. **0.6**

100.5 Highway crosses bridge. **0.1**

100.6 Good view of the Cretaceous/Paleocene section to the north (Fig. 3.18). **0.4**

101.0 Highway crosses bridge. **0.1**

FIGURE 3.18. View of slope of Horse Mesa from mile 101.6. Note Pierre Shale (P), Trinidad Sandstone (T), Vermejo Formation (V) and Raton Formation (R).

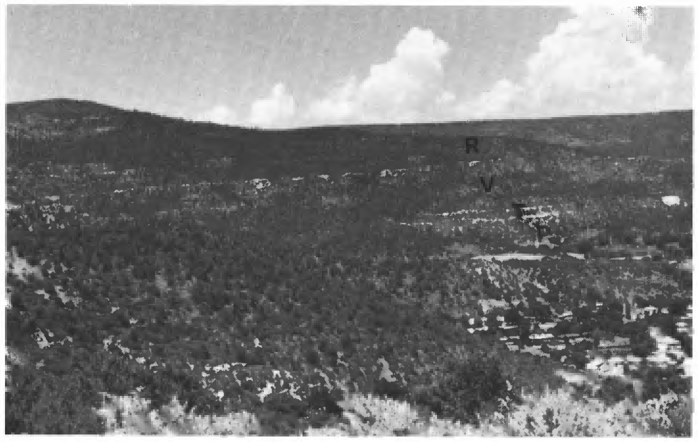


FIGURE 3.19. View to north of part of the southern flank of Bartlett Mesa from Stop 4. Note Pierre Shale (P), Trinidad Sandstone (T), Vermejo Formation (V) and Raton Formation (R).

101.1 **Junction with NM-526; turn left** to Raton. **0.2**
101.3 Eagle Tail Mesa is visible at 11:00 and Tinaja Mountain at 10:00. **0.5**
101.8 Highway is on Pierre Shale which is visible in roadcuts to the right and in the creek to the left. The Pierre is Campanian-Maestrichtian in age and contains at least 12 ammonite zones (Cobban, 1976). **0.6**
102.4 Fault in Pierre Shale to right. **1.1**
103.5 Park Plateau visible from 10:00–12:00. **0.3**
103.8 City of Raton visible at 11:00. Pierre Shale can be seen in roadcuts. **0.2**
104.0 Highway crosses Raton Creek. Pierre Shale visible in roadcuts. **0.5**
104.5 Entering greater **Raton. 0.4**
104.9 Highway bridge crosses over I-25 and Raton Creek. **0.2**
105.1 Goat Hill is prominent at 12:00 with white band of Trinidad Sandstone two-thirds of the way up. **Proceed down East Cook Avenue. 0.2**
105.3 At **junction with Lopez Street, bear right on East Cook Avenue. 0.6**
105.9 **Turn left at stop sign** and proceed under bridge. **0.1**
106.0 **Turn right** (north) **at intersection** with NM-87 and **enter left lane. 0.1**
106.1 **Turn left** (west) **on Moulton** (at Caveleys Pest Control and Melody Lane Motel). **0.4**
106.5 Road curves to left. **0.1**
106.6 Begin ascent of Goat Hill. The gray-brown Pierre Shale can be seen to the right. **0.2**
106.8 Trinidad Sandstone on left. **0.1**
106.9 Road curves right through Vermejo Formation. The Vermejo and overlying Raton contain an extremely rich fossil-flora which was initially described by Knowlton (1917), but that is greatly in need of revision. **0.2**
107.1 View to left of Raton volcanic field; roadcuts in Vermejo Formation. **0.1**
107.2 Passing through coal-bearing Vermejo Formation. **0.1**
107.3 Basal sandstone of Raton Formation to right. There is a prominent unconformity at the base of the Raton Formation. The underlying Vermejo Formation thins from more than 500 ft west of the Spanish Peaks in Colorado to about 50 ft at Raton (Johnson et al., 1966). The basal unit of the Raton Formation consists of a conglomeratic sandstone. **0.1**
107.4 **STOP 4.** Pull off to right. Good view to north of Cretaceous-Paleocene strata exposed on Bartlett Mesa (Fig. 3.19). Roadcut at left contains the Cretaceous-Tertiary boundary within the Raton Formation (Fig. 3.20). This is one of several sites in the Raton Basin where anomalously high iridium concentrations (Fig. 3.21) occur at the Cretaceous-Tertiary boundary in a nonmarine setting (Orth et al., 1981, 1987). Platinum group metals, including iridium, are generally depleted in the Earth's crust relative to their cosmic abundances. Therefore, anomalous amounts of iridium, which are found at the Cretaceous-Tertiary boundary at a number of localities worldwide, are postulated to have been caused by interaction between the Earth and an extraterrestrial body (impact of a large asteroid: Alvarez et al., 1980). After much controversy, this idea is now accepted by many geologists (but see Officer and Drake, 1985; Courtillot et al., 1986). The main unresolved question is how, if at all, this impact is related to the terminal Cretaceous extinctions. Simplistic models invoke dust clouds causing darkness and cessation of photosynthesis, and hence a breakdown in global food chains, as a cause of extinctions (Alvarez et al., 1981). However, little attention has been paid to the potentially dramatic sedimentologic

FIGURE 3.20. Cretaceous-Tertiary boundary exposed at Goat Hill. The white band near Adrian Hunt's right hand is the Ir-rich boundary clay.

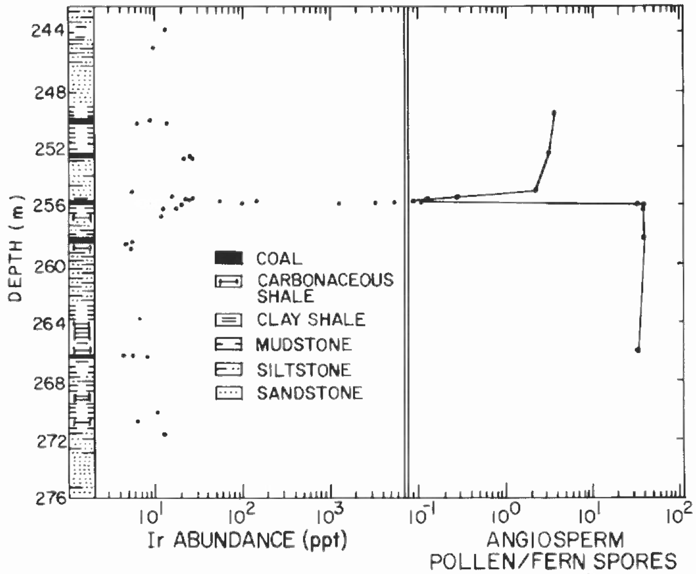


FIGURE 3.21. Ir abundances and ratio of angiosperm pollen to fern spores across the Cretaceous-Tertiary bounday in the York Canyon core (after Orth et al., 1981).

consequences of killing the global vegetational cover (Hunt, 1985). Any extinction hypothesis must also explain the selective nature of extinctions. Finally, demonstration of absolute synchrony of the extinctions at the end of the Cretaceous has not been forthcoming.

Here, at Goat Hill, the Ir-rich boundary clay is a rusty-weathering, 0.5 to 1-inch (1.3–2.5-cm) thick bed of kaolinitic clay that is difficult to distinguish from the enclosing mudstone and shale. Pillmore and Flores (1987) interpret the strata here to represent floodplain and swamp deposits. Furthermore, the coal zone here appears to be equivalent to the Sugarite coals in the lower part of the Raton Formation

End of road log for Third Day.