



Supplemental road log 1: From intersection of Piedra Lumbre road and NM-197 to Star Lake and Pueblo Alto Trading Posts

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SUPPLEMENTAL ROAD LOG 1, FROM INTERSECTION OF PIEDRA LUMBRE ROAD AND NM-197 TO STAR LAKE AND PUEBLO ALTO TRADING POSTS

EDWARD C. BEAUMONT and GRETCHEN K. HOFFMAN

SUMMARY

This trip begins at mileage 91.9 of the First-Day Road Log and continues west into the San Juan Basin. We will stay on NM-197 for the majority of the trip and will be on well-maintained dirt roads for the remainder of the journey. The route begins at the southeastern edge of the Star Lake coal field, on a sagebrush plain underlain by Lewis Shale. The highway heads southwest toward Trujillo Canyon and Torreon Wash, where the intertonguing relationships of the Lewis Shale–Cliff House Sandstone–Menefee Formation are well exposed. From the Torreon Wash bridge to the Torreon Trading Post, there are several “clinkered” shale and coal outcrops of the upper Menefee coal-bearing sequence along the route. This nonmarine, transgressive sequence was deposited shoreward of, and intertongues with, the barrier sandstones of La Ventana Tongue of the Cliff House Sandstone. Most of the coals in the Torreon area are thin, 2 to 3 ft thick, but southeast in the La Ventana coal field some upper Menefee coals attain a thickness of 9 ft.

West of the Torreon Trading Post the route ascends the Menefee–Cliff House–Lewis sequence through a canyon paralleling Vicente Arroyo. Outcrops in the canyon illustrate the intertonguing relationship between the Cliff House Sandstone and the Lewis Shale. The crest of the mesa is capped by a massive sandstone of the Cliff House Sandstone and an overlook 0.6 mi beyond the crest provides a panoramic view of the southeastern San Juan Basin. Continuing west on NM-197 the highway parallels the dip slope, 3–5° north-northwest, and we traverse the Lewis Shale–Cliff House Sandstone sequence for approximately 8 mi. To the south the skyline is dominated by Chaco Mesa, a predominant topographic feature in northeastern McKinley County. Chaco Mesa is capped by the Cliff House Sandstone and trends N60°W, parallel to the strandline of the Late Cretaceous sea in this region. The highway turns to the northwest and slowly ascends the section. Here the Lewis Shale is overlain by the regressive barrier sandstones of the Pictured Cliffs. Because of the similarity in depositional environments, the outcrops of the Pictured Cliffs sandstones along the highway are difficult to distinguish from those of the older Cliff House.

Turning north on the Star Lake compressor plant road, we enter an area known for its oil, gas and coal potential. The small oil field to the west of the road is called the Star Mesaverde and produces from sandstones in the lower Menefee Formation. Coal and “clinkered” shale outcrops in the vicinity are in the Fruitland Formation. The site of the old Star Lake Trading Post is near the center of the Star Lake coal field, defined by the Fruitland Formation outcrop from southeast of the town of Cuba to 6 mi west of Pueblo Pintado Trading Post, 11 mi to the northwest. Drilling by the New Mexico Bureau of Mines and Mineral Resources indicates the Fruitland Formation is on average 217 ft thick in the Star Lake field. The typical coal section contains seven economical seams (≥ 2.5 ft) that average 6.5 ft, with coals up to 20 ft thick.

The road log continues north and northwest from Star Lake Trading Post on the Gas Company of New Mexico's pipeline road. Near the Gas Company's compressor station is the transitional contact between the Fruitland and overlying Kirtland Formation. Northwest of the station the dark gray to black shale outcrops are in the Kirtland Formation, distinguished from the Fruitland by the lack of significant coals and, particularly noticeable in outcrop, by the lack of sandstones. The shale- and silt-dominated Kirtland sequence weathers to the badlands topography we see for several miles along the route until turning southwest on the road to Pueblo Alto, NM-93. The road traverses the Fruitland for about 1 mi, although outcrops are obscured by eolian sand. The route continues past Tanner Lake and on to the old Pueblo Alto Trading Post. Near the crest of the hill south of the trading post is the contact between the Pictured Cliffs and the Fruitland Formation. The dirt road intersects with NM-197 and the route continues east, back toward the intersection with the Star Lake plant road, where the log ends.

Mileage

0.0 Begin at intersection of Piedra Lumbre road with NM-197, northeast of Johnson Trading Post, mileage 91.9 on First-Day Road Log. Continue southwest on NM-197 toward Johnson Trading Post and Torreon. Sagebrush flats are on Lewis Shale for several miles; Mt. Taylor and Mesa Chivato on skyline at 11:00. Subsurface data in this vicinity reveal the presence of nine sandstone units ranging in thickness from 15 to 165 ft and composing 60% of an interval of 1050 ft. Although all are related with respect to their mode of origin and depositional environment, the lower 30-ft sandstone that immediately overlies the Menefee Formation can be considered the main body of the Cliff House Sandstone as it can be traced into the area from the north. The next five sandstones that occupy an interval of 700 ft are assigned to the La Ventana Tongue of the Cliff House. The three higher sands, not including the Pictured Cliffs, are considerably thinner and would appear to be the offshore equivalents of barrier sands forming the Cliff House in the Chaco Mesa area, 13.5 mi to the southwest. Thus the top of the Cliff House Sandstone can be seen to rise 1000 ft in this area in two major vertical buildups, the La Ventana Tongue and the Chaco Mesa sequence.

All of the shale units that intertongue with the Cliff House–La Ventana sequence are units of the Lewis Shale. The La Ventana tongues coalesce to the south and are in turn penetrated by tongues of coal-bearing upper Menefee Formation. This coal-bearing interval, representing the landward margin of the barrier buildup, is well exposed along the route of this Road Log as we approach Torreon. We have identified five major and 12 minor tongues of the upper Menefee in a stratigraphic interval of 550 ft. 0.2

- 0.2 Cabezon on distant skyline at 10:00. In the middle ground are oil storage tanks in the Media oil field. Production is from the Entrada Sandstone, a Middle Jurassic eolian deposit. **1.8**
- 2.0 Highway curves sharply to the left. **0.2**
- 2.2 Intersection on right; road to Ojo Encino and Star Lake. Continue south-southwest on NM-197. **0.1**
- 2.3 Johnson Trading Post on left side of highway. We are traveling on Lewis Shale. There have been a number of oil and gas ventures in this region with several minor discoveries. Logs from the oil and gas tests have provided stratigraphic data that have enabled New Mexico Bureau of Mines and Mineral Resources investigators to work out the relationships between the Lewis Shale, La Ventana Tongue of the Cliff House Sandstone, and the Menefee Formation in the subsurface, and to tie this picture to the outcrops in the vicinity of Torreon. **1.3**
- 3.6 Cattle guard **0.6**
- 4.2 Crest of hill. Cabezon and other Rio Puerco volcanic necks visible from 10:30–11:00. **1.6**
- 5.8 Road junction, **keep right**. Left fork leads to Torreon mission. **1.8**
- 7.6 Cross pipeline. **0.3**
- 7.9 Road descending into Trujillo Canyon. Outcrops on either side of wash are Lewis Shale slopes with bench-forming sandstone beds that represent tongues of the Cliff House Sandstone. **0.6**
- 8.5 Mile marker 22. **0.6**
- 9.1 Mesa to left of road, Black Mountain, is rimmed by a

tongue of the Cliff House Sandstone, according to mapping by Tabet and Frost (1979). **0.4**

9.5 Mile marker 23. **0.4**

- 9.9 Turn out on right side of road for **STOP 1**, which is a convenient place to observe the stratigraphic relationships between the Late Cretaceous outcrops (Fig. S1.1). At the base of the cliff from 11:00–1:00 is the upper Menefee Formation, overlain by the La Ventana Tongue of the Cliff House, in turn overlain by a tongue of the Lewis Shale. Massive sandstones in the Cliff House Sandstone are in the middle of the slope, and the mesa is capped by the Lewis Shale. This is a critical area on Tabet and Frost's map (1979). To the right of the highway and to the southwest, the massive sandstone in the low cliff on the far side of Torreon Wash is assigned to the Cliff House Sandstone. The apparently equivalent sandstone occurring on the east side of the Torreon Wash, east of the highway, was assigned by Tabet and Frost to the La Ventana Tongue of the Cliff House Sandstone. However, the massive sandstone at the top of the cliff on the east side of the highway above the Lewis Shale slope is a tongue of the Cliff House Sandstone, proper. On their map (sheet 3) Tabet and Frost (1979) suggested the lowest sandstone (La Ventana Tongue, east; Cliff House, west) pinches out to the north and is not present continuously from one side of the wash to the other, and thus the Lewis Shale is in contact with the upper Menefee Formation. While it can be seen that the sandstone thins, it is doubtful that it totally pinches out. The



FIGURE S1.1. View of Black Mesa from Torreon Wash, mile 9.9. Units shown in the photo from base to top of Black Mesa are Kmfu—upper coal member of the Menefee Formation, Kclv—La Ventana Tongue of the Cliff House, Kch—Cliff House Sandstone and KI—Lewis Shale.

apparent lack of sandstone in the intervening interval is more likely due to the presence of alluvial fill in the area of the wash.

Continue west on highway. **0.2**

- 10.1 Outcrop of carbonaceous shale at the base of the massive sandstone at 9:00 indicates the top of the upper Menefee Formation. **0.1**
- 10.2 New Mexico Bureau of Mines and Mineral Resources coal quality project drill site no. 18N4W10 is located a short distance south of the highway. Relationships between Menefee, Cliff House and Lewis tongues are visible in outcrops northwest of road, across Torreon Wash. Note the distinctive channel sandstones in cliff. **0.3**
- 10.5 Outcrops in upper Menefee Formation tongue in roadcut. **0.1**
- 10.6 Cattle guard. **0.2**
- 10.8 In the roadcut at the crest of the hill are carbonaceous shales in the upper Menefee Formation. **0.1**
- 10.9 At 9:00 the lower half of the cliff slope is upper Menefee Formation, obvious from the visible carbonaceous shale, overlain by an irregular, buff-colored channel sandstone that is in turn overlain by gray shale and a transitional unit of shale and thin-bedded sandstones, capped by a massive sandstone. The massive sandstone was assigned to the Cliff House Sandstone by Tabet and Frost (1979). The transitional unit is probably Lewis Shale, and the irregular buff sandstone in the middle of the slope is within the Menefee Formation. In this area, the Menefee is directly overlain by the Lewis Shale. This observation is made despite acknowledgment of the presence of a very thin carbonaceous to coaly streak at the base of the transition zone and above the lowest interval of Lewis-like shale. This thin carbonaceous to coaly streak is probably part of a minor tongue of the Menefee (Fig. S1.2). **0.4**
- 11.3 The "clinkered" shales or "red dog" seen ahead on the right side of the road are very common in outcrops in this area. The "clinker" formed as a result of oxidation of the coal beds in the upper Menefee and is used extensively for road metal. **0.1**
- 11.4 Service station and trading post, one of several in the Torreon area. **0.2**
- 11.6 Bend in road to the right. **0.1**
- 11.7 Paved road to left leads to Torreon Navajo Mission. **0.1**
- 11.8 Bridge over Torreon Wash. **0.2**
- 12.0 Old Torreon Indian School and teacherage to right of highway. **0.2**
- 12.2 Highway is in upper Menefee tongue with abundant "clinkered" shale in outcrops. **0.3**
- 12.5 Paved road to left leads to new Torreon Indian School. Most of the sandstone beds seen here are associated with the coal-bearing siltstone and shale sequence in the upper Menefee Formation, but some of the sandstones are Cliff House and can be traced in the subsurface to the northeast, in a seaward direction. The area to the south is extensively faulted. The combination of faulting and lenticular nonmarine strata make geologic interpretation

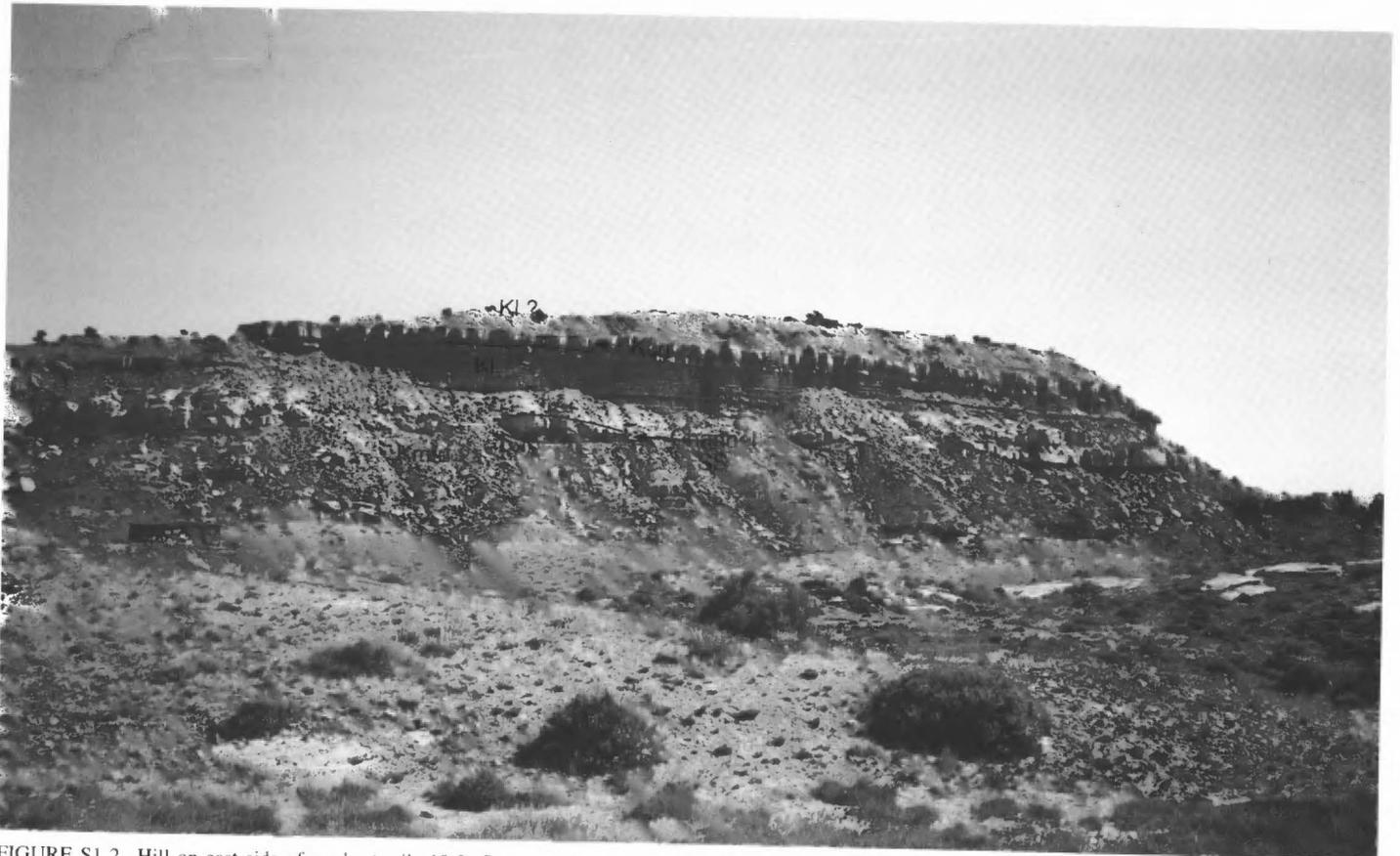


FIGURE S1.2. Hill on east side of road, at mile 10.9. Sequence from base to top of hill is: upper coal member of the Menefee Formation (Kmfu), transitional Lewis Shale (KI), capped by Cliff House Sandstone (Kch). Lewis Shale may overlie the Cliff House Sandstone on the crest of the hill.

- in this area difficult. Recognition of the shore-marginal marine components is difficult, but the area was quite adequately mapped by Tabet and Frost (1979). **0.7**
- 13.2 Torreon Trading Post; pull into parking lot for **STOP 2**. Note wooden posts on hill behind the trading post at 1:00. In the recent past these were part of a lookout tower, on which was mounted a closed-circuit TV camera, probably out of concern for the security of the trading post. Although apparently a harmonious community today, a knowledge of the post-World War II era in this area would suggest the concern was prudent. On either side of the highway are alternating shale and sandstone units. In the lower part of the sequence coal, burned coal and carbonaceous shale are present in the Menefee Formation, and the sandstones within the Menefee are evident close to the valley floor. Higher up the slope, sandstones in the Cliff House are interbedded with tongues of the Lewis Shale. Tabet and Frost (1979) mapped two major Cliff House sandstones in this area. The stratigraphic interval in which they occur is 140–160 ft thick. Left of the highway from 9:30–11:00 the sandstones of the Cliff House are quite evident as are the soft, slope-forming Lewis Shale tongues. Continue west on highway, which is north of and parallel to Vicente Arroyo, for the next 1.5 mi. **0.1**
- 13.3 Road junction. Dirt road leads south-southwest and serves as an access for several small Navajo settlements. **0.5**
- 13.8 From 10:00–11:00, mesa capped by massive tan sandstone tongues of the Cliff House Sandstone. **0.2**
- 14.0 Clinkered shale at 3:00, below Cliff House Sandstone. **0.6**
- 14.6 For a short distance in this area the Lewis Shale directly overlies the Menefee Formation, with no transgressive barrier-beach sandstones of the Cliff House present between the two units. However, the Lewis Shale tongue is overlain by a massive Cliff House sandstone tongue that is in turn overlain by more Lewis Shale. This sequence is visible to the right of the highway for about a mile. **0.2**
- 14.8 Highway curves to right and enters canyon. Note Menefee Formation–Cliff House Sandstone relationship. **0.4**
- 15.2 Highway rises stratigraphically through upper Menefee Formation and Cliff House Sandstone. Good outcrops of the upper Menefee Formation in roadcut. **0.2**
- 15.4 Mile marker 29. Intertonguing Lewis Shale and Cliff House Sandstone on both sides of highway. Alternations of Lewis Shale and Cliff House Sandstone represent oscillations in the shoreline and shifting of the facies landward and seaward. **0.5**
- 15.9 Ascending through the Lewis Shale–Cliff House Sandstone sequence. To left note the transition unit between the Lewis Shale tongue and the Cliff House Sandstone. **0.3**
- 16.2 Top of mesa. Dirt road to right leads to location of New Mexico Bureau of Mines and Mineral Resources coal quality drill site 18N4W17, which spudded in the prominent Cliff House Tongue, forming the rim of the canyon. The uppermost coal was encountered beneath alternating Cliff House Sandstone and Lewis Shale tongues at a depth of 311 ft, approximately at road level directly south along Vicente Arroyo. The top of the main body of the upper Menefee was penetrated at 550 ft. Continue on paved highway. **0.2**
- 16.4 Mile marker 30. **0.4**
- 16.8 Turnout on right provides panoramic view of the southeastern San Juan Basin (Fig. S1.3). This is an excellent spot to view the Lewis–Pictured Cliffs–Fruitland relationships. To the north, the interrelationship between the Lewis Shale and Cliff House Sandstone is visible in the foreground and middle ground along the margin of Torreon Wash, which drains north. We are looking essentially down dip-slope here. In the vicinity of the powerline that crosses southeast to northwest, the gently north-dipping Lewis Shale underlies the broad flat areas. Slightly east of north, mesas at a distance of 3–4 mi are Mesa de San Felipe and Sheep Queen Hill, capped by Pictured Cliffs Sandstone. The Pictured Cliffs is quite thin here and is overlain by the eastward thinning, coal-bearing Fruitland Formation. The Ojo Alamo Sandstone caps the farthest mesa (Eagle Mesa) that can be seen on the skyline to the north-northeast at a distance of 8 mi. The Ojo Alamo is underlain by the Kirtland Shale. Continue west on highway. **0.3**

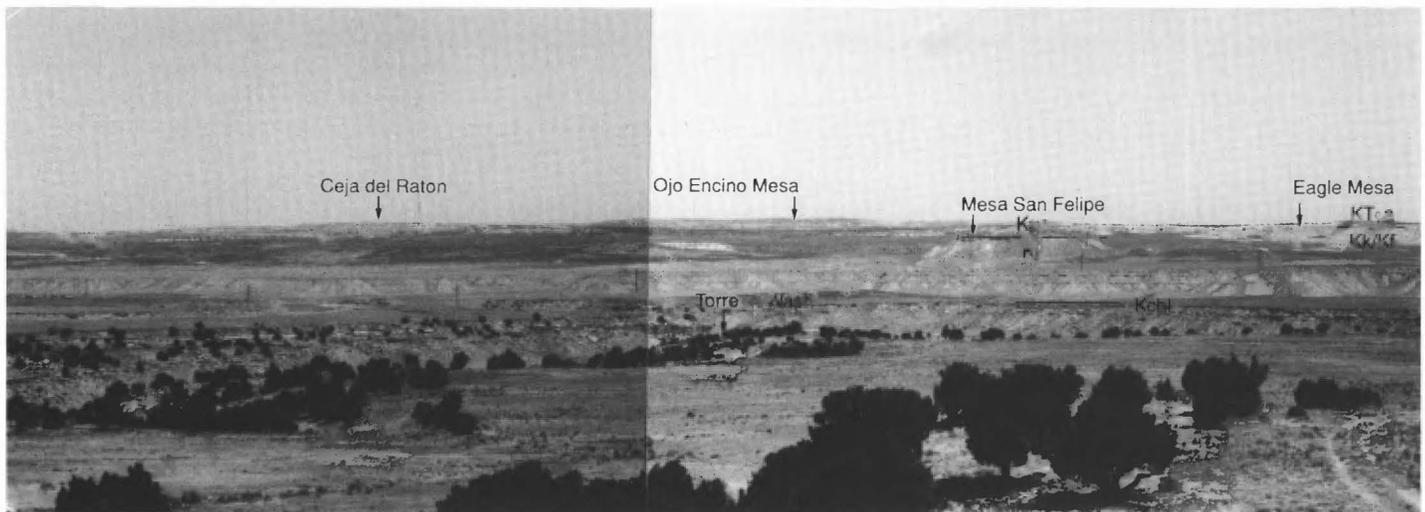


FIGURE S1.3. Panoramic view of San Juan Basin north of mile 16.8. Units indicated on photo are Kch—Cliff House Sandstone; Kl—Lewis Shale; Kpc—Pictured Cliffs Sandstone; Kk/Kf—Kirtland-Fruitland Formations, undivided; KToa—Ojo Alamo Sandstone.

- 17.1 Cattle guard; Sandoval and McKinley county line. Road is nearly traversing a dip slope (3–5° NNW) in the Lewis Shale, which is, despite the breadth of outcrop, relatively thin in this area. **0.9**
- 18.0 Buildings at 3:00 are the small Navajo village of Tinian. **0.6**
- 18.6 Road to left leads to small Navajo community, probably an extension of Tinian. **0.9**
- 19.5 Road to right leads to Tinian. **0.4**
- 19.9 Water tank. **0.6**
- 20.5 Road continues west on Lewis Shale. **1.9**
- 22.4 Sandstones and shale on left of highway across canyon belong to Lewis Shale and Cliff House Sandstone intertonguing sequence. The sandstones increase and the shales decrease in thickness southward. The massive sandstone originally identified as the Chacra Sandstone member of the Mesaverde Formation by Carl Dane (1936), now the Cliff House Sandstone, forms a long line of cliffs that are exposed between here and Chaco Canyon, to the south-southwest. Modern topographic maps identify this elongate trend of high country as “Chaco” Mesa whereas Dane referred to it as “Chacra” Mesa. This prominent physiographic feature can be traced west-northwest from 2 mi southwest of Torreon for a distance of about 40 mi. Its trend, N60°W, represents a strandline direction controlled by the culmination of the buildup of the Cliff House Sandstone. **0.3**
- 22.7 Skyline on left side of highway is formed by Chaco Mesa. **0.6**
- 23.3 Cross draw. Sandstones belong to the Cliff House; highway rises again into the Lewis Shale, which thins toward the southwest. About 70 mi west-northwest of here the Lewis Shale pinches out and the overlying Pictured Cliffs Sandstone and the underlying Cliff House Sandstone merge. Were it not eroded away, this same pinchout would be presumed to exist a short distance to the south of this location. **1.7**
- 25.0 Ascending the section, sandstones to right are in the transitional zone between the Lewis Shale and the Pictured Cliffs Sandstone. The Cliff House Sandstone is principally a transgressive unit with some minor and several fairly major regressive movements, whereas the Pictured Cliffs is primarily a regressive sandstone with minor transgressive components as the Cretaceous seas in this area made their final retreat to the northeast. **0.6**
- 25.6 Road rising into the Pictured Cliffs Sandstone. **0.6**
- 26.2 Sandstone bank to right of highway is Pictured Cliffs Sandstone underlain by Lewis Shale. **0.2**
- 26.4 Pictured Cliffs Sandstone capping hill at 3:00. **0.6**
- 27.0 Pictured Cliffs Sandstone in banks of wash at 10:00 and in far hill at 3:00. **1.0**
- 28.0 **Turn right** on dirt road with sign, Star Lake plant 4 mi., Ojo Encino day school 17 mi. Road is on the Pictured Cliffs Sandstone. **0.3**
- 28.3 Oil wells in the Star Mesaverde field produce from lower (Cleary Coal Member) Menefee Formation channel sandstones. Depths to the reservoir sandstones are from 1400 to 2200 ft. **0.5**
- 28.8 Oil well to left of road is Woolsley Oil Co. State 12+3 sec. 16, T19N, R6W. This is one of only six operating wells in this small field. **0.2**
- 29.0 Cattle guard. **0.6**

- 29.6 Cattle guard. Road bends to right. **0.5**
- 30.1 Junction with Navajo 91, **keep right**. Entering Star Lake coal field. “Clinkered” shales and outcrops of carbonaceous shale and coal of the Fruitland Formation may be seen to right of road. Site of old Star Lake Trading Post straight ahead. A very few years ago this was the site of an active trading post and a mission that ministered to the local Navajos. **0.2**
- 30.3 Remains of Star Lake Mission on left side of road. **0.1**
- 30.4 Small coal stock pile from small open pit operation to right. Coal in lower Fruitland Formation visible in open pit. Remains of the Star Lake Trading Post are visible on right side of road just beyond. Thick coal bed is visible in the bank behind trading post ruin. To left, twin cottonwoods mark bank of the former Star Lake. **0.1**
- 30.5 Pull off on left side of road for **STOP 3**, near small open pit from which coal samples were taken to determine their burning properties (Fig. S1.4). This is a good place to examine one of the Fruitland coal beds. Small partings are visible within the coal. The weathered condition of the coal and proximity to the surface would indicate fresh coal was never obtained at this locality. On the north side of the pit clinkered shales are visible, evidence of natural spontaneous combustion of the coal. Analyses from drill cores in this field indicate these are low sulfur, high ash coals of subbituminous A to high-volatile C bituminous rank.

The Star Lake coal field has been extensively drilled beginning in the mid-1960s. Several companies obtained exploration permits in the late 1960s to early 1970s to drill Star Lake field, including United Electric Coal Co., Peabody Coal Co. and Thermal Energy. Two properties were permitted by the State: Gallo Wash (T20–21N, R8W) leased by Valencia Energy, a subsidiary of Tucson Electric, and Star Lake (T19N, R6W), leased by Chaco Energy, a subsidiary of Texas Utilities. Today Gallo Wash is an inactive permitted mine area. The Star Lake project still has an active lease, but is no longer permitted. Development of this coal area has been dampened by the lack of economical transportation, and plans for a railroad have been stalled because of right-of-way problems. Conservative estimates of the strippable coal



FIGURE S1.4. Fruitland coal at sample pit, Star Lake Trading Post, mile 30.5. The exposed portion of this coal bed is approximately 5 ft thick; note the numerous shale partings.

reserves for the Star Lake field with less than 250 ft of overburden, is 2254 million tons. Peabody Coal and Santa Fe Industries have announced reserves of 162 million tons to depths of 150 ft for their Star Lake Mine property, just north of here. Most of these reserves have been leased by Chaco Energy Co.

Turn around at this point and return to main dirt road.

0.5

- 31.0 Road junction, **bear right**. Road is in the Fruitland Formation, which weathers easily and thus is poorly visible. **0.4**
- 31.4 Powerline of Public Service Co. of New Mexico. Continuing northward down slope of the Fruitland Formation. The coal is found in an interval of 150–180 ft within the Fruitland Formation. The potentially commercial coal beds, the thicker beds (8–20 ft), lie near the base of the Fruitland, close to the Pictured Cliffs Sandstone. **0.9**
- 32.3 Cattle guard. Road junction, **keep left**. Merge with Gas Company of New Mexico's pipeline road, bear northwest, to the left. This pipeline road provides access to many of the small communities in the San Juan Basin and is a true public service on the part of Gas Company of New Mexico. For purposes of orientation, the trend of this road is very close to N45°W throughout the traverse of this log. The route of the log passes through the heart of the Star Lake coal field. At this point the Fruitland Formation contains three coal beds greater than 2 ft. The uppermost bed, the Brown Seam, is in two benches aggregating about 14 ft in thickness and at a depth of 83 ft. The top of the Pictured Cliffs Sandstone is at about 140 ft. **0.4**
- 32.7 Gas Company of New Mexico Star Lake compressor plant at 12:00. **0.2**
- 32.9 Hill to right of road is in the barren Kirtland Shale. **0.1**
- 33.0 Road bends to the left. **0.1**
- 33.1 Entrance to Gas Company of New Mexico's Star Lake plant. **0.2**
- 33.3 Sharp curve to right. **0.2**
- 33.5 Sharp curve to left. Outcrops in distant hills to right are in Kirtland Formation. The distinction between the Fruitland and the Kirtland has been interpreted in various ways by different investigators. Reeside (1924) noted that the Fruitland contains "coal and indurated brown sandstone." He further stated that it is usual to pick the top of the highest sandstone as the top of the Fruitland. This definition is from the perspective of a field geologist mapping without the advantage of drill hole data. Coal geologists exploring through the medium of drilling are more inclined to use the uppermost significant coal as the top of the Fruitland. **1.3**
- 34.8 Rounded hill at 2:00 provides excellent exposures of the Kirtland Formation. Route of road approximately along the uppermost part of the Fruitland Formation. **0.1**
- 34.9 Cattle guard. **1.1**
- 36.0 The dark gray to black shales in the Kirtland seen in outcrop here have been misidentified as coal, but they are nothing more than carbonaceous shales. However, there are occasionally very thin coals in the Kirtland Formation. The coal resources in the Star Lake field have been well delineated by approximately 500 core and plug exploration holes drilled in the early 1970s.
- Five principal coal beds were recognized as having economic potential. Each of the major coal units has one to as many as five identifiable splits. **1.2**
- 37.2 Coals in the Fruitland Formation reach a maximum thickness of 30 ft, although they are "dirty" and contain numerous shale partings. The combination of physiography and coal make this area one of great economic potential. **0.3**
- 37.5 Crest of hill. Excellent view of upper beds of Fruitland Formation at 11:00, overlain by Kirtland Formation at 12:00 to 3:00. **0.4**
- 37.9 Road trends slightly north of strike of beds; thus are gradually ascending the section. At this point the principal coal, which is about 20 ft thick, lies 176 ft below the surface. The top of the Pictured Cliffs is at 210 ft. **0.3**
- 38.2 Crossing poorly defined Pueblo Alto Wash. **0.1**
- 38.3 Cattle guard. **0.1**
- 38.4 Outcrops of Kirtland Formation on both sides of road. The silty to shaly character of the Kirtland often forms badlands topography. **1.0**
- 39.4 **Turn left** to Pueblo Alto on Navajo 93. Road heading southwest is traversing the Fruitland, but exposures are obscured by eolian sand. **1.0**
- 40.4 PNM powerline. **0.3**
- 40.7 Road bends to left. **0.2**
- 40.9 Tanner Lake at 10:00. Tanner Lake is badly silted, so that at spill level the lake is barely 2 ft deep. **0.2**
- 41.1 Pueblo Alto Trading Post at 1:00. **0.6**
- 41.7 Road curves to right. **0.6**
- 42.3 Old Pueblo Alto Trading Post. Road turns left. **0.3**
- 42.6 Road crosses route of proposed Star Lake Railroad. **0.2**
- 42.8 Contact between the Fruitland Formation and underlying Pictured Cliffs Sandstone is obscured by surficial deposits in this area, but southward across the flat from Pueblo Alto the road slowly descends stratigraphically. The road rises toward the crest of the hill as it passes into the more resistant Pictured Cliffs Sandstone. **0.3**
- 43.1 Crest of hill. Pictured Cliff Sandstone poorly exposed. Road descending into valley of Lewis Shale. Sandstone cliffs in the far distance are in the Cliff House Sandstone. **1.1**
- 44.2 Stop sign, cattle guard, paved highway. **Turn left**. **1.3**
- 45.5 Cross wash; sandstones in margins of wash are Cliff House Sandstone. **0.3**
- 45.8 Water tower to right; new Pueblo Alto Trading Post to left of road. Water tower is part of a system installed to provide running water to relatively isolated Navajo dwellings in this checkerboarded part of the Navajo country. **0.9**
- 46.7 Sandstones at 9:00 are in the Pictured Cliff Sandstone. Sagebrush-covered flats to right are in the Lewis Shale. Highway approximately parallels the strike of the Lewis Shale and Pictured Cliffs Sandstone in this area. **3.1**
- 49.8 Roadcut in Lewis Shale. **0.8**
- 50.6 Note reverse dips on Pictured Cliffs Sandstones, indicating anticlinal structure. **1.1**
- 51.7 Ojo Encino Mesa; Star Lake road to left. Retrace route from mile 28 in this Road Log.

End of Supplemental Road Log 1.