Second-day road log: From Cortez to Mesa Verde National Park, Mancos and Durango

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SECOND-DAY ROAD LOG, FROM CORTEZ TO MESA VERDE NATIONAL PARK, MANCOS AND DURANGO

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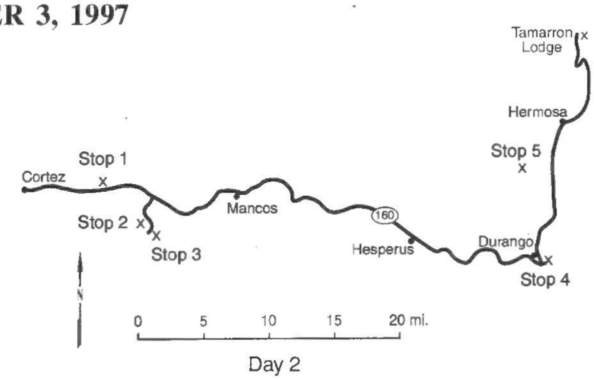
and STEVEN C. SEMKEN

FRIDAY, OCTOBER 3, 1997

Assembly point: Holiday Inn, Cortez
Departure time: 7:30 a.m.
Distance: 77.9 mi
Stops: 5



Summary

The route for Day 2 follows U.S. Highway 160 eastward from Cortez through Upper Cretaceous rocks. Beginning near the top of the Dakota Formation we climb into the Mancos Shale, which reaches a maximum thickness of 2300 ft locally, and ultimately reach the overlying Point Lookout Sandstone, a littoral and shoreface sandstone associated with a major regression during Santonian time. Subdivisions of the Mancos Shale, which are based mainly on the open-marine facies recognized east of here in eastern Colorado, will be examined as we enter the northern end of Mesa Verde National Park. A subsequent stop farther into the Park offers excellent views of the Mancos Valley and of the internal architecture of the Point Lookout Sandstone. As we journey eastward the very significant lateral changes in the Point Lookout—both in thickness and bedform—will be discussed in terms of depositional environments and position in the facies tract.

In Durango, at Horse Gulch, unusual sedimentary fractures in the Point Lookout Sandstone are well displayed as is the transition into the overlying, nonmarine coal-bearing section. On the north side of Durango we are treated to an excellent view of much of the Jurassic and Triassic section at Junction Creek. In descending order, the Jurassic section consists of the Morrison Formation, Junction Creek Sandstone (the lithostratigraphic equivalent and a synonym of Bluff Sandstone), a Summerville equivalent that includes a bed that has been called Bilk Creek Sandstone to the north near Ouray, the Pony Express Limestone (Todilto Formation), and the Entrada Sandstone. The underlying Upper Triassic rocks are assigned to the Chinle Group (local name—Dolores Formation) and consist of the Rock Point and Petrified Forest Formations and the Moss Back Formation at the base.

The base of the Morrison Formation here is very similar to that seen the previous day at Recapture Creek. The crossbedded sandstones of the Salt Wash Member rest unconformably on a thin, fine-grained red-bed sequence that in turn overlies the Junction Creek (= Bluff). The trip ends at our overnight accommodations in the Tamarron Lodge north of Durango.

Mileage

0.0 Parking lot of Holiday Inn, Cortez. Turn right and proceed E on US-160 toward Durango. **0.4**

0.4 Junction with Colorado Highway 145, which goes N to Dolores. At 12:00–1:00 note La Plata Mountains. Continue E on US-160. **0.3**

0.7 Sandstone ledge on right is top of Dakota Formation. The serrated mountains ahead about 22 mi distant are the La Plata Mountains, the northern sacred mountain of the Navajo people; their name for it is *Dibé Nitsaã* **0.3**

1.0 Floodplain of McElmo Creek; the highway here closely parallels the northern structural edge of the San Juan Basin. **0.9**

1.9 Road to left, Montezuma County 29, leads to Toten Reservoir, a local recreation and fishing spot. **0.2**

2.1 Road climbs out of McElmo Creek floodplain. **0.2**

2.3 Cuestas to left and right are Dakota Formation (Two Wells Sandstone). **0.8**

3.1 Carbonaceous shale in Dakota Formation on left. **0.6**

3.7 Montezuma County fairgrounds entrance to right; highway is locally on a Dakota dip-slope; note La Plata Mountains at 11:30. **1.0**

4.7 Point Lookout at 2:00, type locality of Point Lookout Sandstone. **1.5**

6.2 **STOP 1**, pull off to right and walk carefully across highway to north side. Here, we examine the Bridge Creek Member of the Mancos Shale, limestones and calcareous shales that were deposited at approximately the Cenomanian-Turonian boundary, about 93 Ma (Obradovich, 1993) throughout the Western Interior Seaway (Fig. 2.1). Characteristic Bridge Creek bivalve fossils here are the oyster-like *Pycnodonte newberryi* (Fig. 2.2) and the inoceramid *Mytiloides*

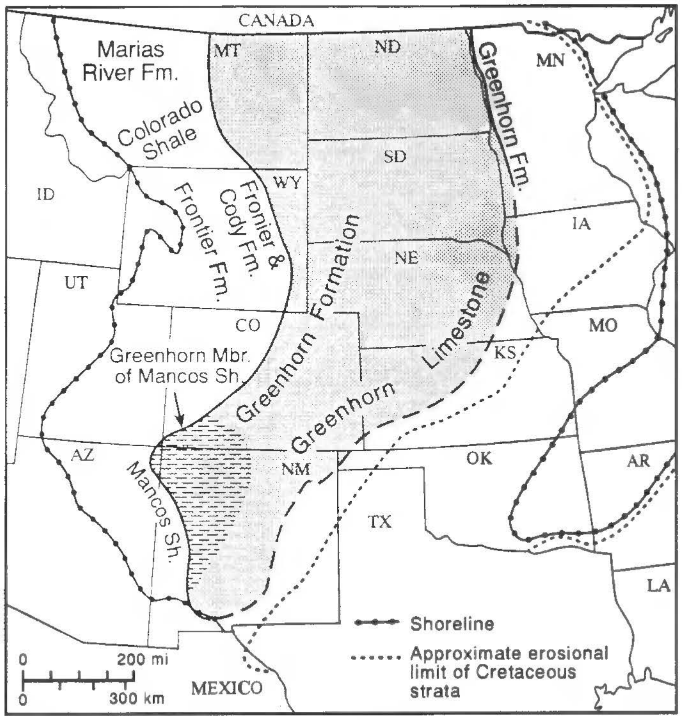


FIGURE 2.1. Distribution of the Greenhorn facies in the Western Interior Cretaceous Seaway (from Hattin, 1987).

mytiloides. In its type locality in eastern Colorado the Bridge Creek is the uppermost member of the Greenhorn Formation. This outcrop is near the westernmost limit of Greenhorn deposition, which took place in the Western Interior Seaway during the maximum global highstand of the Mesozoic. Low hills to left are capped by Bridge Creek Member of Mancos Shale. After stop continue east on US-160. **0.6**

6.8 San Juan Votech School on left. **1.6**

8.4 **Exit** on ramp to right to Mesa Verde National Park. **0.4**

8.8 Intersection and yield sign; **turn right** to enter the national park. Here, at an elevation of 6954 ft, we are at the divide between the west-flowing McElmo Creek and the south-flowing Mancos River. **0.4**

9.2 Northward projecting prominence on mesa ahead is Point Lookout, type area of sandstone of same name (Fig. 2.3). **0.2**

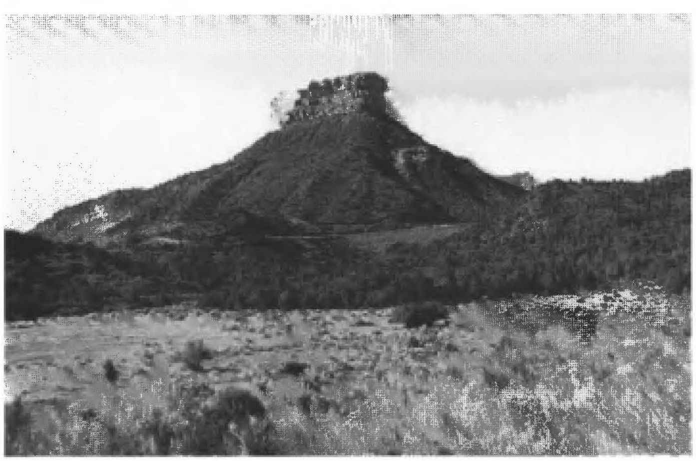


FIGURE 2.3. Point Lookout, capped by the Point Lookout Sandstone.

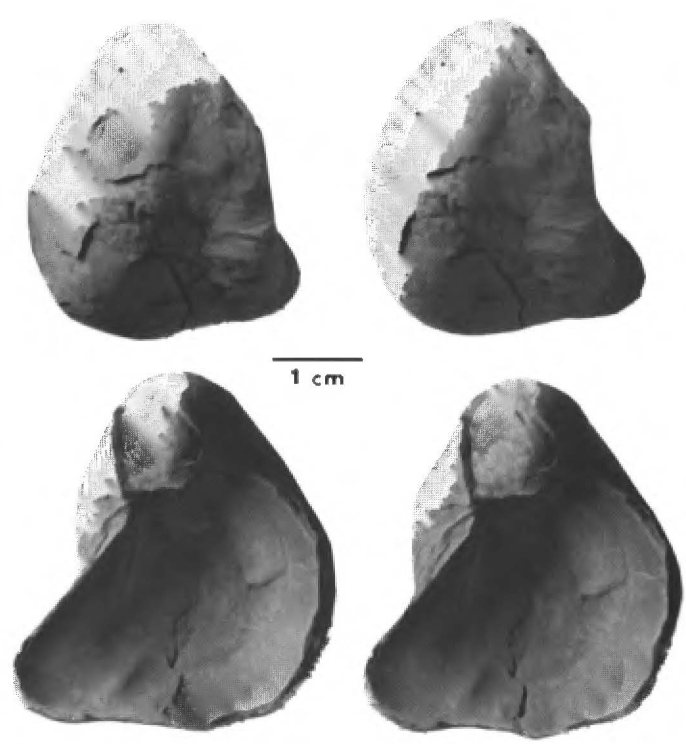


FIGURE 2.2. Stereophotographs of a characteristic specimen of the index bivalve *Pycnodonte newberryi*, collected at Stop 1.

THE HAYDEN SURVEY IN SOUTHWESTERN COLORADO AND ADJACENT AREAS, 1874–1876

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The U.S. Geological and Geographical Survey of the Territories, commonly called the "Hayden Survey," was one of four great surveys established after the Civil War to explore, map and assess the resources of the West. Topographical and geological mapping were the principal objectives of the survey, but archeological, botanical and zoological investigations were included. During the years 1874–1876, the "Hayden Survey" made important contributions to the geology and archeology of southwestern Colorado and adjacent areas.

In fall 1874, William Henry Jackson, Hayden's photographer, made a reconnaissance of the canyon of the Mancos River where ancient ruins had been reported by prospectors and miners. The expedition was led by Captain John Moss, a miner from Parrott City, Colorado. Ernest Ingersoll, a zoologist, accompanied Jackson's party. Using his pencil and paper as well as his camera, Jackson recorded for the world the cliff dwellings of the Mancos River Canyon as well as ruins and watchtowers in McElmo Canyon and the Hovenweep areas. Had Jackson gone up one of the side canyons of Mancos Canyon, he would have seen the huge apartment houses at Mesa Verde that were discovered in December 1888 by two cowboys who were searching for lost cattle.

During the 1875 field season, William Henry Holmes and George B. Chittenden began geologic and topographic mapping, respectively, in southwestern Colorado and adjacent areas in New Mexico, Arizona, and Utah. Holmes, the artist turned geologist, mapped and described the geology of the valleys of the San Juan, Mancos, LaPlata and Dolores Rivers, and McElmo and Montezuma Creeks.

Holmes named the Mesaverde Group from exposures in the large tableland previously named the Mesa Verde. He recognized a "Lower Escarpment", consisting of 180 ft of sandstone and a "Upper Escarpment" of

140–200 ft of sandstone. The two escarpments were separated by 500–800 ft of "coal measures." In 1919, A. J. Collier of the USGS named these units of the Mesaverde Group the Point Lookout, Menefee and Cliff House formations.

Some 600 to 900 ft above the Mesaverde Group, Holmes noted a 120-ft-thick sandstone, which he named the Pictured Cliffs Sandstone for a locality along the San Juan River. Holmes wrote, "the sandstone stratum is quite massive, and breaks down in great smooth-faced blocks. On these, thousands of fantastic figures have been engraved, recording, perhaps, the history of some former occupants of the valley. Beneath the massive stratum are several layers of brownish sandstone. To this group I give the name, suggested by the picture-writing. On the upper surface of the Pictured Cliffs sandstone and not more than 30 ft below the great bed of lignite I discovered a heavy bed of fossil shells, in which were a number of forms having Upper Cretaceous fasces [sic]." (Holmes, 1877, p. 250). Also in 1875, Holmes studied the intrusive geology of the LaPlata, Carrizo and El Late (Ute) Mountains. Holmes (1877, p. 274) named the highest point in the Carrizo Mountains as Pastora Peak for "...the fact it overlooks highland meadows in which Navajo shepherds keep their sheep." He joined with Jackson to study the ancient ruins that Jackson had seen briefly in the previous year.

The 1876 field season brought Holmes back to southwestern Colorado and southeastern Utah to study the geology of the Abajo and western San Miguel Mountains and the Dolores River Canyon. He continued his study of the ancient ruins he began the previous year. Jackson studied ruins in northeastern Arizona in 1876 and visited the Hopi villages.

Holmes and Jackson laid the foundations of the geology and archeology of southwestern Colorado and adjacent areas while with the "Hayden Survey". Artist-geologist Holmes sketched the geologic landscapes with such detail as to be clearer than some photographs. His geologic cross-sections were of equal detail. Artist-photographer Jackson with his bulky wet-glass-plate camera, recorded the prehistoric ruins of the Four Corners area and astounded the world.

9.4 Approaching toll booth at park entrance; pull off to left and park in R.V. lot (elevation 7100 ft). Top of Point Lookout is at 8427 ft.

STOP 2. Park and walk 0.5 mi to west to examine the Juana Lopez, Montezuma Valley and Smoky Hill Members of Mancos Shale. After stop proceed southward through toll booth into Mesa Verde. **1.4**

10.8 Cortez Member of Mancos Shale exposed in roadcut on right in hairpin turn. Note discontinuous dolomite mudstone bed (unit 495 of Leckie et al., this volume) and numerous thin distal storm sands. **1.4**

12.2 **STOP 3**. Overlook of Mancos Valley, and lunch stop. The panorama eastward from this vantage point is a moderately to highly incised topography developed on southward-tilted Upper Cretaceous strata; in ascending order, the Dakota Formation, Mancos Shale, and the Mesaverde Group consisting of Point Lookout, Menefee, and Cliff House Sandstone (Cliff House not visible here) (Fig. 2.4). In terms of structural domains we are at the northern edge of the Four Corners platform, a structural bench at an intermediate level between the major uplifts and the adjacent basins, e.g., the San Juan Basin, the margin of which is just 20 mi to the southeast (see Woodward et al., this volume).

The valley before you has been cut by the Mancos River. In this reach it flows westward for a short distance before its course turns southward (down-dip) and follows a canyon through Mesa Verde on its way to a confluence with the San Juan River near the Four Corners. The canyon, which lies entirely within the Ute Mountain Reservation, offers excellent exposures of the Point Lookout Sandstone (Santonian), as much as 300 ft thick locally, and the overlying, coal-bearing Menefee Formation. Less well known are the presence of a half-dozen small intrusive bodies and associated northeast-trending dikes compromised of minettes of Oligocene age (Condon, 1991); these are well exposed in the canyon and its tributaries. A 1:100,000 scale geologic map of this area has been compiled by Condon (1991).

FIGURE 2.4. View from Stop 3 of Cliffs of Point Lookout Sandstone above slopes of Mancos Shale.

The backdrop to the east is provided by the La Plata Mountains, whose highest peaks reach approximately 11,000 ft. The La Platas have long been known as an example of a laccolithic mountain. The domal uplift, 15 mi in diameter, was produced by the complex intrusion of intermediate rocks (diorite-monzonite porphyry) (Eckel, 1949), probably during earliest Tertiary time, and carved into the present shape by middle and late Tertiary erosion. The La Platas are home to some very interesting, historic mining districts. The most productive ore deposits were the veins and replacement bodies that contained gold and silver tellurides. One of the mines was the Wanakah, a name which was subsequently used by Eckel (1949) as a formal stratigraphic name for a Middle Jurassic unit, the Wanakah Formation.

The view immediately to the north is that of the Mancos-Point Lookout transition and adjacent strata (Fig. 2.5). The following minipaper describes this transition and the selection of criteria for placement of a formation contact.

THE MANCOS-TO-POINT-LOOKOUT TRANSITION: VERTICAL CORRELATION OF TWO PRINCIPAL REFERENCE SECTIONS AT MESA VERDE NATIONAL PARK

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The towering topographic feature named Point Lookout, which welcomes visitors to Mesa Verde National Park, inspired Collier (1919) to name its cliff exposures Point Lookout Sandstone and afforded specific

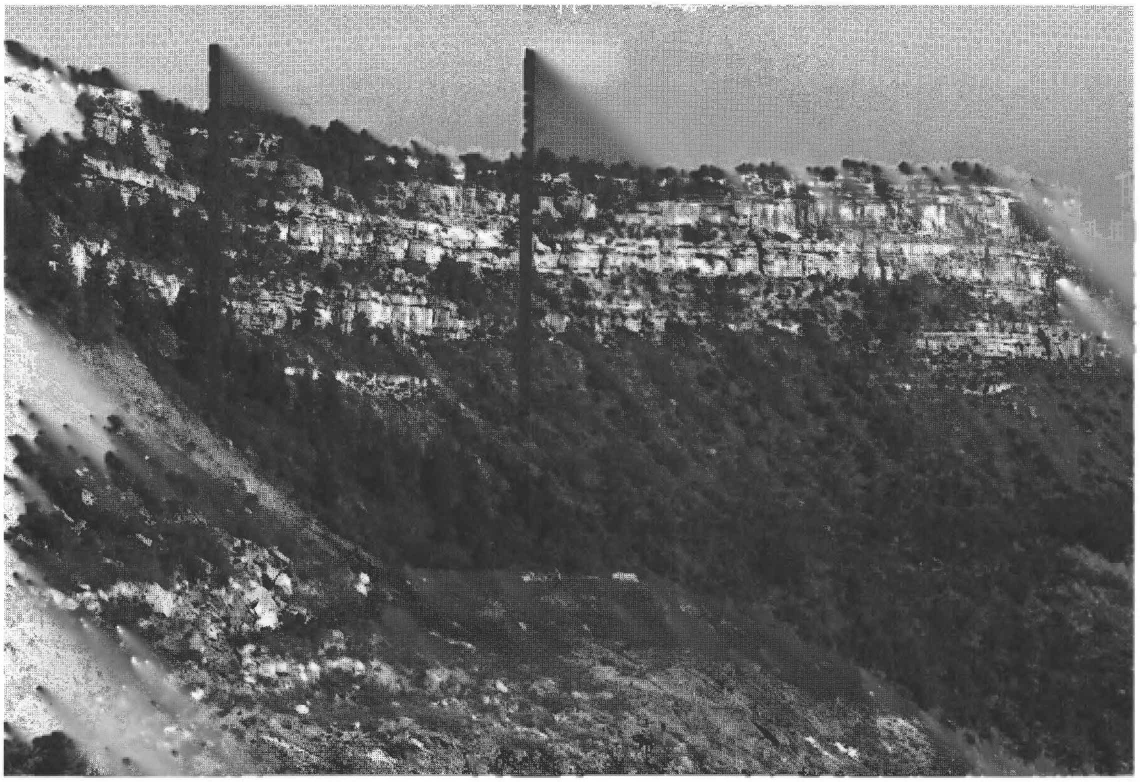

FIGURE 2.5. View of principal reference section of Point Lookout Sandstone. Black bars show sections in Figure 2.6.

geographic significance to the previously named "Lower Escarpment" (Hayden,1875). Because Collier's focus was on coal-bearing strata, he was (*and one could argue, wisely so!*) not inspired to scale the steep park-entrance cliffs and describe a detailed section. Numerous authors subsequently embraced the name Point Lookout and helped describe the formation across the San Juan Basin, yet a detailed principal reference section at Point Lookout remained lacking until recently (Zech and Wright Dunbar, this volume).

Similarly, Cross et al. (1899) named the Mancos Shale for exposures in and around Mancos Valley, yet established no specific type section. Others have since measured sections in the area, but those descriptions lacked the high-resolution detail necessary for accurate comparison of Mancos Valley strata to other time-equivalent sections in the Western Interior. Kirkland et al. (1995) and Leckie et al. (this volume) addressed this problem by designating a principal reference section of the Mancos Shale, located beneath Point Lookout at the entrance to Mesa Verde National Park.

The herein designated Mancos Shale principal reference section was continuously trenched and described from Dakota outcrops north of US-160 up the north and northwest facing lower slopes of Point Lookout (for specific location, see Leckie et al., this volume). Trenching stopped at approximately 677 m where the increased sandstone content of the section and talus cover rendered the technique ineffective. From that point to the top of the section at approximately 704 m, position and thickness of resistant sandstones was estimated.

An initial attempt to measure the Point Lookout principal reference section as a direct continuation of the Mancos section was abandoned due to the treacherous, technical climbing conditions required to ascend the cliff face at that location. Instead, reasonably safe access to the upper cliffs was found on the adjacent east-facing slopes visible from this stop (Fig. 2.5), and the Point Lookout Sandstone principal reference section was described at an offset to that of the Mancos. Four distinct ledges of resistant sandstone comprise the section (Fig. 2.6) with tops at approximately 15 m, 40 m, 68 m, and 94 m respectively. The lowest of these ledges is discontinuously exposed within a talus-covered zone of interbedded marine mudrocks and fine sandstones.

This transitional zone of interbedded mudrock and fine sandstone occupies the overlap position of the two principal reference sections. Lithologic characteristics are those typical of the inner shelf depositional environment (Wright-Dunbar et al., 1992). The majority of sandstone beds are less than one meter thick, are lenticular, and display both hummocky and wave-ripple cross-stratification. Sharp-based sandstones preserve offshore-directed scour features and tool marks. Ball-and-pillow structures are locally present within this interval. Combined, these features are characteristic of an inner shelf zone dominated by storm events (Montz et al., 1985) and influenced by local sediment instability. The very nature of these processes insures that both lateral and vertical lithologic variability will characterize this transition zone.

Correspondence of the two principal reference sections to produce a continuous detailed description and accurate thickness for the interval is shown in Figure 2.6. Even though measured on opposite sides of the mesa and with varying degrees of talus cover, there is good correspondence between the transition zones described. A point common to both sections, and one which can be traced quite well between them, is the base of the lowest continuous cliff-former (Point Lookout section at 23.5 m, Mancos section at 700.8 m). Having correlated the overlap between the two sections, it remained to define and place a contact between the Mancos Shale and Point Lookout Sandstone that could be recognized in both sections and upon which formation thickness could be based.

One common strategy for placing such transitional formation contacts is to set the top of the Mancos at the highest meter-thick mudrock, or conversely, to set the base of the Point Lookout at the lowest meter-thick sandstone. While this is simple to apply, it may not appropriately portray the distribution of lithologies within the section. High-frequency shoreline oscillations that produced this stratigraphic succession yielded thin, intertonguing mudrocks throughout the interval. It is common to find meter-thick mudrocks interleaved with massive Point Lookout sandstones where those mudrocks correspond to marine flooding surfaces. One example at this location occurs at about 49 m in the Point Lookout section, where a slope-forming unit separates the two lower continuous sandstone ledges. Applying this definition as the top of the Mancos Shale would include much of what we widely recognize as Point Lookout!

Accepting the lowest meter-thick sandstone as a top for the Mancos comes closer to defining a useful natural break, yet this also has drawbacks. The lowest meter-thick sandstone appears in both reference sections

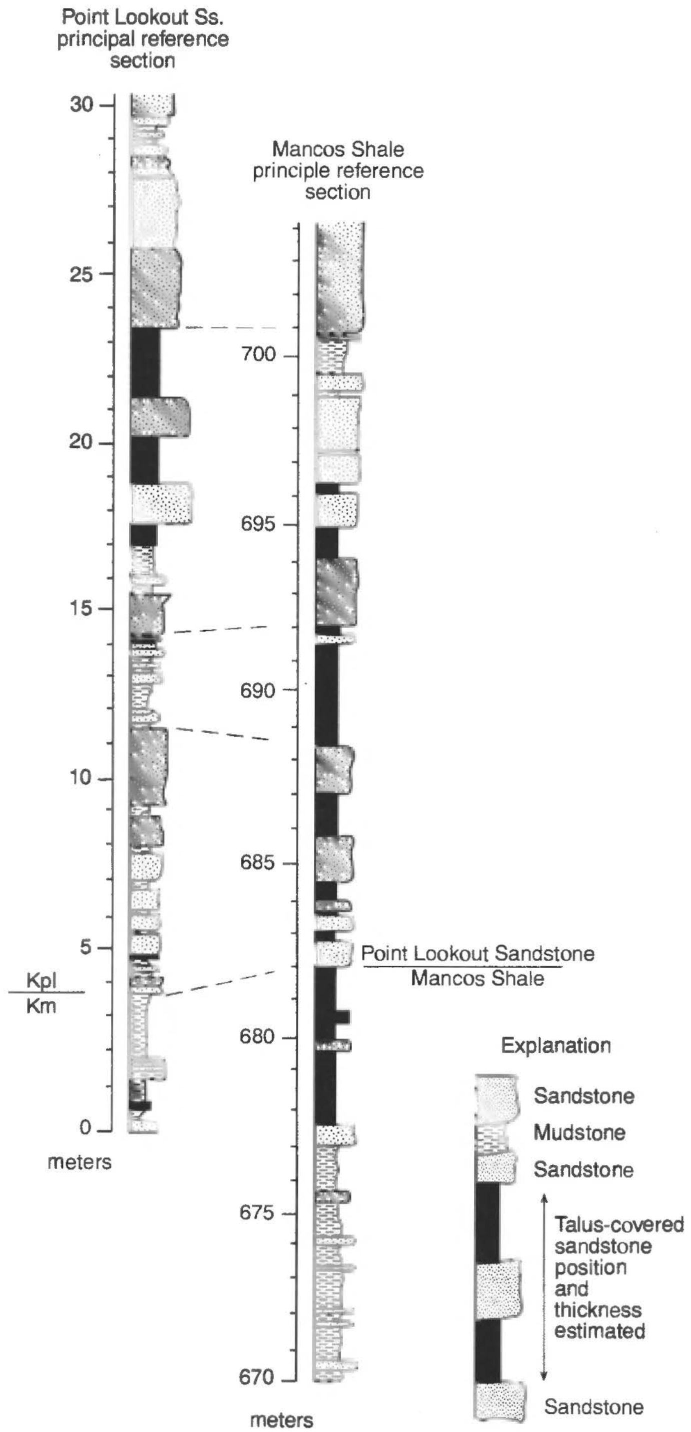

FIGURE 2.6. Measured sections of Point Lookout Sandstone at principal reference section.

at nearly the same level (Fig. 2.6; at 685 m in Mancos section; at 10 m in Point Lookout section). However, in both sections this sandstone is near the top of a resistant, sandstone-dominated interval that produces a discontinuous ledge-forming sandstone.

Our preference is to honor the sandstone-dominance of this entire ledge-forming interval, and thus place the basal contact of the Point Lookout at the bottom of this ledge-former (at 682 m in Mancos section; at 3.5 m in Point Lookout section) (Fig.2.6). Basic criteria for this pick are (1) Sandstone thickness exceeds mudrock thickness over an interval greater than 2 m; and (2) sandstones are clean (not argillaceous), and form hard, resistant beds with interbedded mudrocks.

Regardless of the criteria selected, the contact between the Mancos Shale and Point Lookout Sandstone will vary from location to location due to the irregular distribution of sandstone and mudrock within the transition zone. Our selection criteria assign the mudrock-dominated portion of the transition to the top of the Mancos Shale, and the sandstone-dominated portion to the Point Lookout Sandstone. Total thickness for the Mancos is 682 m. Total thickness of the Point Lookout is 90.5 m.

After stop return to Park entrance and US-160. **1.4**

13.6 As we approach hairpin turn in descent note Abajo Mountains at 1:00 and Sleeping Ute at 12:00. **2.0**

15.6 Intersection with on ramp to US-160; **turn right** and proceed E on US-160. **2.5**

18.1 Milepost marker 51. **1.3**

19.4 Menefee Mountain at 2:00, the type area of the coal-bearing Menefee Formation. **2.3**

21.7 Exit to right onto Business route 160 which leads through Mancos. Immediately after exit road crosses Chicken Creek, a northern tributary of Mancos River. **0.7**

22.4 On right note Western Excelsior Mill, a matchstick and excelsior factory, the town's largest industry. **0.8**

23.2 Scenic downtown Mancos with many original buildings; elevation 7030 ft. The first white settlers came to this valley in the winter of 1875–1876. With the building of cabins and permanent homes in 1876, Mancos can boast of becoming a town the same year Colorado gained statehood. Interestingly, most of these early settlers came here not from the east, but from the west, mainly San Francisco and California in general. They were bankrolled by financial institutions in San Francisco interested in tapping into the reported mineral wealth in the nearby La Plata Mountains. None of these people became established in the mining profession, choosing instead to return and take up a more agrarian existence in this peaceful valley. An excellent volume on the early history of the Mancos Valley was written by Fern Ellis (1976). **0.2**

23.4 Bridge over Mancos River. **0.9**

24.3 Re-enter US-160 eastbound. **1.6**

25.9 Road to left leads to Echo Basin Dude Ranch; continue east on US-160. **2.2**

28.1 Highway ascending through Mancos Shale; unit on crest of Menefee Mountain to right (under radio towers) is Point Lookout Sandstone. **0.9**

29.0 Summit of Mancos hill, elevation approximately 8080 ft. **0.2**

29.2 La Plata County line. La Plata Mountains at 12:00 are a laccolith intrusive. Thompson Park to right. **2.3**

31.5 Junction with Cherry Creek road at right; proceed east on US-160. Famous western author Louis L'Amour owned a ranch on the right in this valley. **0.8**

32.3 Maggie Rock at 2:30, capped with Point Lookout Sandstone. **1.6**

33.9 Historical marker recognizing the Dominguez-Escalante expedition of August 10, 1776; the expedition passed by here en route from New Mexico to Monterey Mission, the recently founded capital of California. Highway continues through terrain developed on Mancos Shale. **1.1**

35.0 Pass under powerline. **0.4**

35.4 Roadcuts in Mancos shale. Note laccolithic domes of La Plata Mountains to left. **1.6**

37.0 Highway here parallels E fork of Cherry Creek. Point Lookout Sandstone caps mesa to right. Just several miles south of this point (as the crow flies) is the National King Coal mine. This underground operation produces an excellent quality coal from thin coal beds in the Menefee Formation. This locality has seen rather continuous, though variable, production throughout the past 50 years. Since the railroad (narrow gauge) was ripped up in the decade following WW II, all production is now trucked. Markets are some distance away. Some is hauled to Albuquerque (Tijeras Canyon) where it is used by Rio Grande Portland Cement, the cement-manufacturing facility formerly operated by Holnam, Inc. Some is sold to industry in Phoenix, Arizona. The remainder is hauled to the railhead in Thoreau, New Mexico, where it is loaded onto coal cars, railed to Los Angeles, and purchased by a Japanese corporation. Annual production is approximately 250,000 tons. The mine employs 50 people.

The coal is of excellent quality, ranging between 13,000–14,000 BTU/lb, low sulfur (<1%) and low ash. To fully appreciate the significance of this, if the mine-mouth generating plants operated by Arizona Public Service Co. and by Public Service Co. of New Mexico in the Four Corners Area had coal of this quality available the annual tonnage required would be very nearly cut in half. **0.5**

37.5 Bench in Mancos Shale on left side of highway is old grade of Rio Grande Southern Railroad Line, which ran from Durango to Telluride via Mancos and Dolores. **1.5**

39.0 Ski Hesperus, world famous resort, on right. **0.7**

39.7 Road to left to Mayday, an old mining town 4.5 mi up the La Plata Canyon. The historical settlement of Parrott City was located at Mayday. At 7:00–8:00 is a good view of the La Plata Mountains. Sandstone ledge above and at 4:00 is very thin Point Lookout Sandstone.

On the other side of the mountains in the northeastern part of the La Plata mining district a high grade epithermal gold telluride deposit has attracted repeated attention since its discovery in 1880. Known as the Bessie G deposit the gold mineralization is associated with a steeply dipping quartz vein, 1 to 10 cm wide, hosted by Permian and Triassic (Dolores Formation) clastic sedimentary rocks. Gold and silver are present in the telluride minerals krennerite, sylvanite, and petsite, but 95% of the gold is in the native state (Saunder and May, 1986). Much of the silver, however, is contained in hessite (Ag_2Te). Overall Au/Ag ratio is approximately 0.8 to 1.0. Grade is in excess of an ounce per ton av. It is postulated (Saunders and May, 1986) that the Bessie G is underlain by a monzonite stock at depth that fed the more shallow laccolithic system, and which provided precious metals and tellurium to the hydrothermal system that produced the high-grade mineralization. **0.2**

HISTORY AND PRODUCTION OF THE LA PLATA MINING DISTRICT

excerpted from Edwin B. Eckel (1949)

Spanish explorers visited the La Plata mountains in the 18th century and reportedly found mines already in operation. Bancroft, in telling of Escalante's expedition of 1776 says:

> The eastern section of the La Plata range was called by Escalante Sierra de la Grulla. The La Plata River he called the San Joaquin, and in the canyon, says his narrative, were the mines sought for by Cachupin's explorers (circa 1750–60. E. B. E.) and which gave the name to the mountains, supposed to contain silver . . . . At the Rio Mancos, or San Lazaro, he again heard reports of mines.

There is no record of the early history but placer gold was found on the Animas River in 1861, near the present site of Durango. Mining in the La Plata district itself began in 1873. In that year, placer gold was discovered along the La Plata River by men from California and eastern Colorado. The miners immediately began construction of a large ditch to provide water for sluicing gravels near the mouth of the La Plata canyon. They recovered enough gold to maintain their interest for several years, but the outcome of their operations is not known. The Comstock vein also was discovered in 1873. According to Toll, A. K. Fleming, one of the discoverers, exhibited some of the ore during the following winter in Del Norte, where Capt. John Moss, an old California miner, was so impressed by it that he went with Fleming to the La Plata Mountains the following spring. On June 22, 1874, Captain Moss and Harry Lightner located the South Comstock lode, and A. K. Fleming, Almarion Root and Robert James located the North Comstock lode and millsite. In 1875, Moss bought Fleming's interest for $5,000 and then sold both claims to Tibircio Parrott for $10,000. The names of several of these pioneers were later given to prominent geographic features in the district.

La Plata County was organized in 1874, and Parrott City, whose site is now occupied by Mayday, was founded in the same year. Chittenden describes it thus:

> In 1874 the only settlement in the whole district (San Juan Basin) was on the La Plata at its head. It was at that time a very embryonic mining town, containing two log houses and a third in process of erection. It is called Parrott City, and since that time has grown quite considerably, having been made the county seat of La Plata County and supplied with a regular mail. Its support comes from the mines at the head of the stream, which consists of both quartz lodes and placer diggings, and have been pronounced quite valuable.

The nearest supply point was Del Norte, 100 mi east of the district, and separated from it by rugged mountains. In addition to this small settlement of miners on the La Plata River, there were a few ranches along the Animas River and in other parts of the San Juan Basin. Most of the ranchers, however, had been driven off by the Ute Indians about the same time that gold was discovered in the La Plata Mountains. Captain Moss, leader of the mining operations, must have been a competent diplomat as well as a miner, to judge from the following comment by Jackson on his meeting with Moss in September 1874, during the unrest among the Indians:

> Moss explained his own security in this threatening situation by saying that when he had brought in his party of miners a year earlier, he had made his own treaty with the head chiefs of the region. By this treaty he had acquired mining rights over 25 square miles along the La Plata, through the payment of a liberal annuity in sheep, horses, and some other things. This purchase had placed him and his companions on friendly terms with all the Indians of the region.

In spite of all difficulties, the prospectors persisted in their efforts. Holmes, in 1875, notes that "a great number of veins, many of which carry silver and gold," have been discovered, and mentions the placer operations at the mouth of the La Plata valley. He says:

> Until the summer of 1875 but little was done toward the exploration of the localities from which the ore-bearing gravel came. During the summer many hundreds of claims were located on lodes both of gold and silver. ...But little is known...of the value of more than a very few of the lodes. The Comstock...shows some very fine silver ore.

By 1880 Mancos had been established, Parrott City had grown to a town of 40 to 50 houses, and a weekly newspaper, the La Plata Miner, was being published. The general character of the ore deposits had become fairly well known. In addition to the Comstock several other mines, including the Ashland, the Century, the Cumberland and the Morovoratz had already produced some ore. In 1880 Durango was founded also, just south of the older town of Animas City, its growth being stimulated by the completion of the Denver & Rio Grande Western Railroad in 1881. It grew rapidly and soon replaced Animas City and Parrott City as the commercial center of southwesten Colorado.

In 1884 the county wagon road was extended to the head of the La Plata River. The town of La Plata, or La Plata City as it is called locally, was probably founded about the same time. For some years it had a population of more than 200 and possessed several stores and saloons, a livery stable, and a hotel. A small Catholic convent occupied log buildings about a mile south of the La Plata at some period during the early history of the camp. La

Plata gradually declined in importance and in 1937 it contained only about a dozen families.

By 1885 two unsuccessful attempts at milling the ores had been made. Freeman mentions the original 5-stamp Cumberland mill and an arrastre mill, the location of which is not known. The Cumberland mill was designed for extraction of free gold, although the Cumberland ore yielded only ruby silver.

Montezuma County, formed from the western part of La Plata County, was organized in 1889. The completion of the Rio Grande Southern Railroad branch line between Durango and Rico in 1891 may possibly have had something to do with the increased production from the district during the next decade. In 1897 nine mills were in existence, although some of them had already been abandoned.

Between 1897 and 1901 attention was temporarily diverted from the high-grade telluride deposits to the low-grade pyritic-gold deposits on Jackson Ridge and at the heads of Bedrock and Boren Creeks. At the turn of the century, hundreds of locations had been recorded and more than 200 claims had been patented. Many of the mines had produced some ore, but the total production of the district up to 1900 was comparatively small. Some of the mines discovered during the early years of the district had produced, intermittently, up to 1937, but not one of the mines opened before 1900 had then produced as much as $100,000.

The failure of the district to live up to expectations was variously attributed to high mining and transportation costs, poor judgment as to milling methods, litigation and excessive royalties. Undoubtedly several of these were and still are, contributing factors, but then as now the chief factor was the character of the ore deposits.

With the coming into production of the Neglected mine in 1901, the district entered upon a new era of real discoveries. The Valley View of Idaho vein was located in 1902 and the May Day deposits in 1903. These mines began production in 1904, reached a peak about 1907, and, in spite of many legal and other difficulties, remained the leading mines for many years. The Incas deposit was discovered in 1909 and yielded $260,000 within 3 years. No other large deposit was found until about 1923, when the Gold King vein, an extension of the old Eureka-Bulldozer vein, was uncovered. It did not begin large-scale production, however, for several years. In 1933 the sensational Red Arrow discovery was reported.

The latter half of the history of the camp has thus been characterized by discovery and exploitation of a few relatively large deposits. Each discovery stimulated exploration in other parts of the district for a few years, but few of the many efforts were rewarded. All the deposits that were to become largely productive were discovered at irregular intervals after the district had been combed by prospectors for more than 30 years. This fact tends to justify a hopeful view of the future of the district; its bearing is discussed in a later section. More than half of the nearly $6,000,000 total production of the camp was taken from two mines, the May Day and the Idaho, and four others, the Neglected, Gold King, Incas, and Red Arrow, have together yielded more than $1,000,000 worth of ore. More than two-thirds of the district's production has thus come from six mines.

Mining activity was at a low ebb in 1937 except for work at the Idaho, Red Arrow, and Gold King, which was shut down in June. Some work was being done by lessees and prospectors in various places, and several small exploratory programs were being carried on. At the close of the year only two mills were in operation. These were the Pioneer, which was treating ore from the Idaho mine and dump, and a small amalgamation mill treating high-grade ore from the Red Arrow. The Gold King mill, which ran for several months on ore previously broken at the mine, was shut down indefinitely on October 15, 1937. The May Day and the smaller Monarch and Lady Eleanora mills were in good condition but were not being operated. The Cumberland, Euclid, Doyle, Neglected, Oro Fino, Texas Chief and Tomahawk mills were either in ruins or in bad repair.

The production of the district for 1878–1937 totals $4.4 million in gold; $1.3 million in silver; and minor amounts of copper and lead. Some ore is now known to have been produced during the years 1874–77, but there are no authentic records for this period. An estimate of $15,000 total value for metals produced during these years is probably very liberal. No explanation can be found for the tremendous increase in silver production in 1894, and it would seem that the figures are in error. As 1892–94 were years of very large production in the neighboring camp of Rico, it seems reasonable to suggest that much of the ore represented by these figures originated in the camp.

39.9 Note old coal mine on slope at 2:00, developed in lower Menefee Formation. **0.2**

40.1 Colorado 140 intersection; 140 goes south through Hesperus, past site of old Fort Lewis (now CSU agricultural research station) approximately 4.0 mi south, and ultimately to Farmington, NM. Fort Lewis was the site of an Indian School, which later became Fort Lewis College and was moved to Durango. **1.0**

41.1 Crest of hill; as we proceed eastward highway begins descent into Animas River Valley. **0.2**

41.3 View from 9:00 to 11:30 of Animas River Valley. Barnroof Point at 9:00 is defended by thick basal sandstones of Point Lookout Sandstone. **3.0**

44.3 Lewis Shale, which overlies the coal-bearing Mesaverde Group, can be seen in roadcuts on left. Milepost 77 just ahead. **0.7**

45.0 Sandstones and carbonaceous shales of Menefee Formation (Mesaverde Group) in roadcuts for next 0.6 mi. **1.1**

46.1 Coal mines in Menefee Formation on left. **0.5**

46.6 Highway curves left; slow to examine basal portion of Point Lookout Sandstone in cliff on left. Note parasequence stacking of lower shoreface and storm-generated sandstones in the Point Lookout Sandstone (Fig. 2.7). **0.7**

47.3 At 9:00 to 10:00, Twin Peaks are capped by Point Lookout Sandstone; Lightner Creek Road (La Plata County 207) to left. **0.8**

48.1 Perins Peak at 12:00 is capped by Point Lookout Sandstone above wooded slope of Mancos Shale. Straight ahead is Smelter Mountain, also capped by Point Lookout. **0.5**

48.6 Wildcat Canyon Road to right; additional historic coal mines are present up this canyon. **0.3**

48.9 Enter greater Durango, whose name was probably selected because its physical setting is similar to Durango, Mexico, and was founded in 1880. Durango was born of controversy when smaller, agricultural Animas City, 2 mi north of the soon-to-be Durango townsite, refused to accept offers from the Denver and Rio Grande Railroad to develop it into a railroad center. Animas City was thus doomed and upstart Durango took hold with total railroad backing. The agriculture, coal and nearby hardrock mining ensured

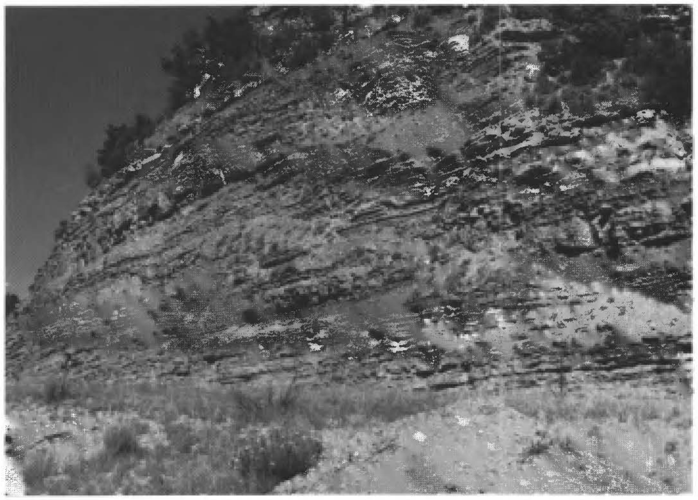

FIGURE 2.7. Lower shoreface and storm-generated Lookout Sandstone.

Durango of a prosperous economy, although it was pioneered and nurtured by Animas City. One example of base and precious metal mining attempts is provided by abandoned mines in the Cave Basin district at nearby Tuckerville (see mini-paper below).

The county seat of La Plata County, which then included what is now Montezuma County, was at Parrott City (later Mayday). Durango's growth was phenomenal and by July 1881 had more than 600 eligible voters. A contest for the county seat had already developed and a county-wide vote at that time resulted in relocation of the seat of government to Durango, carried in large part by the city which voted 605 to 9 in favor. It became "Rocky Mountain Boom Town," also the title of the book by Duane Smith (1992), from which the above information was taken. **0.6**

49.5 Mancos Shale crops out in canyons to left. **0.5**

TUCKER'S TUNNEL, TUCKERVILLE, HINSDALE COUNTY, COLORADO

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Tucker's Tunnel (Fig. 2.8) is the type locality for the mineral theisite, $Cu_5Zn_5(As, Sb)_2O_8(OH)_{14}$. It was found in 1980 by Nicholas Theis and Michael Madsen during the course of a geologic investigation and named in Theis' honor.

Tucker's Tunnel is located in the Cave Basin mining district, Hinsdale County, Colorado in the NE¼NE¼ sec. 13, T37N, R6W. It can be reached by taking the Middle Mountain road northerly about 12 mi from Vallecito Reservoir, to Tuckerville, and then heading south on a jeep road for 1 mi to the prospect. At Tuckerville a Forest Service gate may be locked, so it may be necessary to walk for the last mile. The road terminates at the prospect, half a mile north of Runlett Peak. It is located on the Granite Peak 7.5 minute quadrangle map. The area is only seasonally accessible, with Tuckerville at an elevation of 10,600 ft, and Tucker's Tunnel at 11,000 ft.

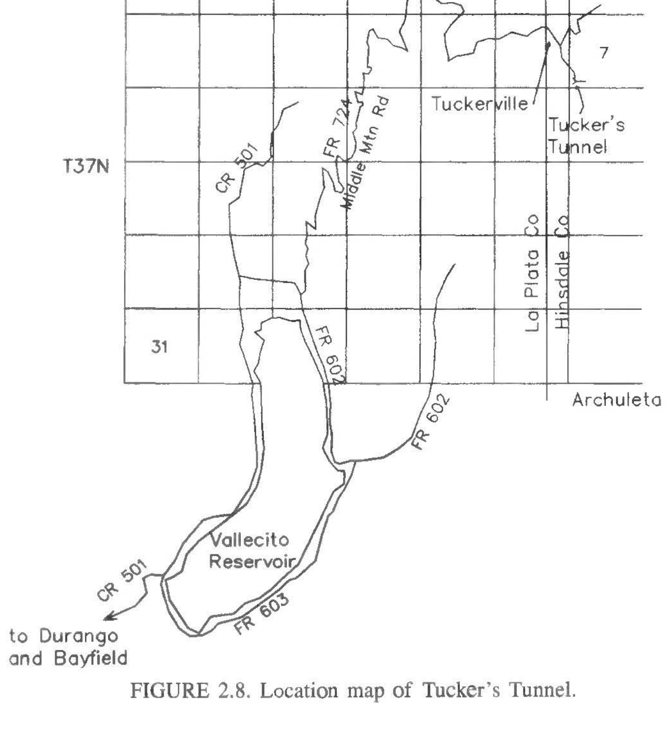

FIGURE 2.8. Location map of Tucker's Tunnel.

Outcroppings of ore were discovered in 1913 near the La Plata and Hinsdale County lines above the present Vallecito Reservoir. By 1914 a small rush was on. Speculation that 1000 men would crowd into the basin, followed by investors, were grossly optimistic. Cave Basin had many claims, but small production.

Recorded production from Cave Basin mining district, derived mainly from the Holbrook, Mary Murphy, and Silver Reef mines during 1913-1916, 1921, 1924 and 1928, totals 54 tons of ore. Twelve oz of gold, 237 oz of silver, 2900 pounds of copper and 1700 pounds of lead were recovered. Value of the output was assessed at $3,200. Production records show 49 tons of ore were shipped in 1934, yielding 80 oz of gold, and in 1935 and 1936, 13 tons yielding 29 oz of gold and 4 ounces of silver. Since then, exploration and assessment work seem to be about all that has taken place, leaving the short-lived town of Tuckerville abandoned. Tucker's Tunnel has collapsed and all tunnels in the area are apparently caved or flooded.

The Cave Basin mining district is adjacent to the south end of the San Juan volcanic field. The Tucker's Tunnel prospect sits in Paleozoic limestone belonging to either terra rosa that has filtered down from the Molas Formation into the karstic Leadville Limestone of Early Mississippian age, or to the Upper Devonian lower Ouray Limestone and the upper Elbert Formation. It is in an area with several parallel to subparallel brecciated, east-trending shear zones on the north flank of Runlett Peak. The shear zones are nearly vertical and cut nearly horizontal beds. The shear zones are probably genetically related to a major east-trending fault to the south that crosses the north base of Runlett Peak and drops lower Paleozoic strata against Precambrian Vallecito conglomerate. The prospect is radioactively anomalous (up to 700 gamma c.p.s.), and a wide range of elements are present, including some mercury and cobalt. This diverse group of elements allowed for the formation of a unique suite of minerals, with secondary copper minerals being the most common.

In William's article on the site, 23 mineral species were identified, but were not described. Eleven of these have not been observed by the author or described by others. This paper only describes species collected on the dump by the authors and identified by microprobe analysis (by P.F.H.), unless otherwise noted. All minerals are microscopic. The 11 species mentioned by Williams, but not observed by the authors, include: anglesite, $PbSO_4$; covellite, CuS; cuprite, Cu_2O; kolwezite, $(Cu,Co)_2(CO_3)(OH)_2$; parnauite, $Cu_9(AsO_4)_2(SO_4)(SO_4)(OH)_{10}$; partzite, $Cu_2Sb(O,OH)_7$(?); quartz, SiO_2; tenorite, CuO; tetrahedrite, $(Cu,Fe, Ag, Zn)_{12}Sb_4S_{13}$; uraninite, UO_2; and zeunerite, $Cu(UO_2)_2(AsO_4)_2 \cdot 10–16H_2O$. Mineral species collected by the authors or described by others include:

Adamite, $Zn_2(AsO_4)(OH)$, microscopic crystals (Robert Cobban, personal commun., 1993). Visual identification only.

Aurichalcite, $(Zn,Cu)_5(CO_3)_2(OH)_6$, common greenish-blue to sky-blue radiating aggregates. Rarely as euhedral acicular sprays.

Austinite, $CaZn(AsO_4)(OH)$, transparent light brown to yellow long prismatic to acicular crystals. Also as green acicular, zoned, cuprian-rich crystals.

Azurite, $Cu_3(CO_3)_2(OH)_2$, common blue crystals, and as fine-grained spherical aggregates in matrix.

Barite, $BaSO_4$, rare gemmy transparent orange crystals, which resemble wulfenite.

Calcite, $CaCO_3$, massive, fault-filling, fine- to coarse-grained brecciated blocks, commonly coated on fracture surfaces by secondary copper minerals. Also scalenohedral crystals to 8 mm in vugs.

Cerussite, $PbCO_3$, fine-grained grayish masses to 5 cm, sometimes enclosing relic galena grains.

Chalcocite, Cu_2S, massive fine-grained black aggregates, generally rounded, with coatings of secondary copper minerals on fractures and exteriors.

Chrysocolla, $(Cu,Al)_2H_2Si_2O_5(OH)_4 \cdot nH_2O$, blue masses and smears. Also pseudomorphs after other copper minerals.

Cinnabar, HgS, Common as powdery red-orange masses to 5 mm, resembling lead oxides. Rarely as red acicular crystals.

Conichalcite, $CaCu(AsO_4)(OH)$, as green spheres. Sometimes plumbian, intergrown with duftite-beta.

Digenite, Cu_9S_5, "small black pods scattered through the samples have a somewhat concentric structure and were identified as digenite."

Duftite, $PbCu(AsO_4)(OH)$, rarely as light yellowish-green prismatic crystals, but more often as poorly formed aggegates, sometimes coating galena crystals.

Duftite-beta, $CaCu(AsO_4)(OH)$, "an inadequately described species," intergrown with plumbian conichalcite

Galena, PbS, as relict grains surrounded by cerussite, also as euhedral cubic crystals to 1 mm, sometimes coated with duftite aggregates and, less commonly, hemimorphite crystals. These coatings can be so complete as to totally obscure the underlying galena crystals.

Hemimorphite, $Zn_4Si_2O_7(OH)_2 \cdot H_2O$, common as colorless to white tightly packed crystals up to 2 mm, sometimes coated or impregnated with manganese oxides, or possibly goethite, to a black or dark brown color, forming drusey vug coatings up to 1 cm. It is less common as individual crystals.

Malachite, $Cu_2(CO_3)(OH)_2$, "thin green crusts filling fractures in the digenite were found to be mixtures of malachite and metazuenerite." Or as fracture fillings and crusts on chalcocite. Various green stains and aggregates are quite common, but no euhedral crystals have been found.

Metazeunerite, $Cu(UO_2)_2(AsO_4)_2 \cdot 8H_2O$, mixed with malachite as thin green crusts in digenite. Identified with x-ray diffraction methods. Possibly the same as Williams' zeunerite.

Olivenite, $Cu_2(AsO_4)(OH)$, occurs sparsely as acicular olive-green crystals, less than 1 mm in size.

"*Psilomelane*," non-specific manganese oxides, common stains or dendrites on fracture surfaces, and as thin coatings in some vugs.

Sphalerite, (Zn,Fe)S, found in matrix as dark brown grains. A visual identification only.

Tennantite, $(Cu, Ag, Fe, Zn)_{12}As_4S_{13}$, as black grains in matrix.

Theisite, $Cu_5Zn_5(As,Sb)_2O_8(OH)_{14}$, Unweathered theisite is sky-blue, with the best samples being hexagonal plates, less than 0.7 mm in size, and showing a pearly luster. These samples are rare as it more often forms crystalline aggregates without any obvious single crystal definition. Weathered theisite is green to bluish-green in color. Brecciated blocks of the vein filling calcite are common on the dump and frequently have coatings of weathered greenish theisite. Although one is tempted to break up these blocks in a search for fresh theisite, one usually finds the interior to consist of massive calcite. Breccia, which shows veins of secondary minerals between the breccia fragments, is more productive in searching for unweathered theisite. Generally, about one third of all sky-blue aggregates turn out to be aurichalcite. A determination is easily accomplished with a simple acid test. Aurichalcite dissolves rapidly with effervescence in HCl, while theisite dissolves more slowly and without any effervescence. Testing of the hexagonal plates is unnecessary. These are certainly theisite.

Willemite, Zn_2SiO_4, rarely found as ill-formed light brown prismatic crystals.

Thanks to Virgil Lueth for allowing the use of the New Mexico Bureau of Mines and Mineral Resources microphotography equipment and reviewing the manuscript. Thanks to Nicholas Theis, Michael Madsen and Robert Cobban for information on the locality. Thanks to Charlie Maxwell for an early review of the paper.

50.0 Welcome to Durango, the tourist and recreational hub of southwestern Colorado. **0.6**

50.6 Cross Animas River; junction with US-550; Durango city limit. **Turn left** onto US-550. **0.2**

50.8 Intersection with College Drive at traffic light; **turn right** and proceed E. **0.7**

51.5 Intersection with 8th Avenue; **turn right** and proceed S. **0.2**

51.7 Intersection with 3rd Street; **turn left** and park. **0.1**

51.8 **STOP 4.** Walk 330 ft east to entrance to Horse Gulch and excellent outcrops of Point Lookout Sandstone. The sedimentary features displayed in the Point Lookout Sandstone will be the major topic of discussion. The soft-sediment deformation, distorted bedding and ball-and-pillow structures, all indicate rapid loading in the depositional environment. A major slump or gravity slide block will also be seen. In addition, the channeling (cut and backfill) throughout the section is at first glance suggestive of a fluvial environment. However, the type of bioturbation and burrowing infauna preserved in the rocks is that normally associated with marginal marine or delta mouth bar deposits in the Western Interior Seaway. On this basis we must look to a tidal channel or perhaps distributary mouth bar depositional environment. The criteria for recognition of tidal channel sandstones includes (1) opposed crossbed sets (herring-bone), (2) fine- to lower medium-grained sandstone with thinner beds of shale or mudstone representing slack-water conditions, and (3) an abundant trace fossil assemblage (ichnofauna). The criteria for recognition of distributary mouth bars includes (1) silty, fine-grained, low-angle to trough crossbedded sandstone, (2) soft sediment deformation features, (3) variable thickness, (4) woody or organic trash in discrete beds and (5) a relatively high percentage of lithic fragments including mica.

The Horse Gulch section (Fig. 2.9) preserves one of the best mouth-bar facies associations that we have seen thus far in the Point Lookout. We will walk up along the road through the Mancos transition, Point Lookout and into the Menefee Formation before descending down the cliff face to return to the vehicles. There are several normal

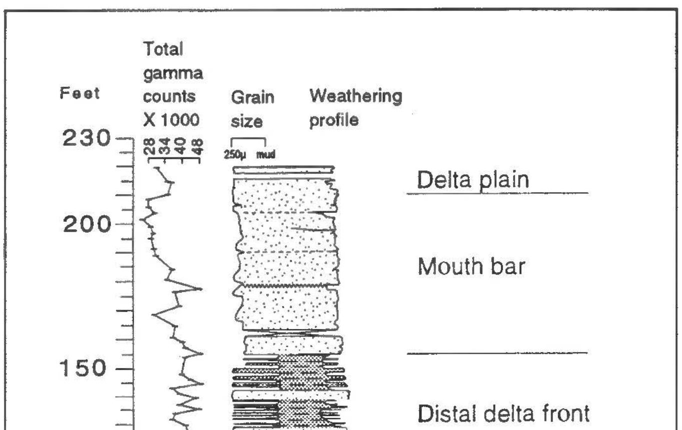

FIGURE 2.9. Measured section of Point Lookout Sandstone at Horse Gulch.

faults in the valley (minimal offset, down-to-the-west), so you have to double check position from time to time.

By far the most spectacular soft-sediment deformation (Fig. 2.10) that we have seen is here in Horse Gulch. While still within the alternating mudrocks and sandstones of the transition zone, you will see evidence for a large, completely deformed debris flow, as well as downslope movement of early cemented(?) sandstone bodies. Once again, the transition zone is "busily" interbedded with cm-scale and larger ripple beds throughout. Unlike the distal shoreface in Mancos Canyon, which received sand only by storm transport, the Durango transition zone seems to have been characterized by an abundant supply of fine sand to be reworked on the inner shelf by both fairweather and storm processes. This is consistent with the presence of a large distributary system, feeding sands into the marine environment under essentially a constant "rain out" scenario.

We will walk fairly quickly through the Point Lookout at road level because it is poorly exposed and somewhat disrupted by the faulting. You will get a much better view of this unit as we walk down the cliff at the end of this stop. Proceed up to the small stone quarry at the Point Lookout/Menefee contact. This quarry is an active source of local building materials, so it is difficult to say much about the exposure that doesn't change with the next blast of dynamite! But, you are likely to see in these thin-bedded mouth bar deposits evidence of trough and planar cross-beds, abundant organic debris and some heavy minerals on lamina surfaces, as well as some unusual Fe-cemented burrow(?) fills. This is a good place to get a feel for the complexity of sedimentary structures within this upper facies.

As we move over to the cliff top back to this same stratigraphic horizon you will find much more burrowing, with ample evidence for episodic deposition followed by hiatal phases. Also visible across the gulch is the "big picture" of the bedding relationships in this interpreted mouth bar body. Note the broad scour surfaces present throughout. These deposits comprise an overall coarsening-upward sandstone body as thick as 60 ft, constructed of individual, tabular to broadly lenticular beds 3–5 ft thick each. Beds are scour based typically fine-upward, are strongly bioturbated in the upper 12 in. and are capped by mudrock. Burrows include abundant *Ophiomorpha, Thalassinoides,* and *Cylindrichnus*; and lesser *Skolithos* and *Arenicolites.* Erosion at the base of an overlying bed may remove parts of the mudrock cap and burrowed horizon of the bed below. Swaley cross stratification (SCS) is present, particularly in the lower part of the lithofacies, but the dominant sedimentary structure is horizontal parallel lamination showing parting lineation. In the upper 6 to 10 ft of the facies, horizontal laminations are replaced by 1–3 ft thick lamina sets of trough- and planar-tabular cross-bedding in nested, non-channelized, scour-based beds. Sandstones are poorly sorted, and contain high amounts of mica, feldspar, and lithics compared to shoreface sandstones (Hicks, 1991; Crandall, 1992). Organic material is abundant, including finely disseminated debris and woody lag material on some scour surfaces.

Proximity to a fluvial source for these sandstones is well supported by the textural and mineralogical immaturity, as well as the abundance of wood and organic detritus. Sedimentary structures and bedding style indicate shallow marine progradation under conditions of repeated, waning-energy traction events. Each bed-forming event was initi-

FIGURE 2.10. View to north of basal units of Point Lookout Sandstone, showing soft-sediment deformation. Mancos Shale underlies the Point Lookout.

ated by a high-energy erosional phase generally followed by current-deposited horizontal laminations. Waning energy is marked by a vertical decrease in grain size that culminated locally with deposition of the mudrock caps. Bioturbation downward from the bedding top is also consistent with a late stage, very low-energy depositional or hiatal phase. Preservation potential of the low-energy mudrock caps is higher away from large channel outlets, away from these erosional frequency is likely greatest.

Upward transition from limited swaley cross stratification to horizontal laminations and, ultimately, high-angle cross-bedding indicates upward increasing importance of unidirectional currents over wave oscillation processes. These characteristics are consistent with fluctuating flow conditions that develop during episodic fluvial discharge events into the shallow marine setting. Laminated intervals developed during high-discharge flood events, whereas bioturbated and mudrock intervals were produced following the high-discharge event as the sediment surface was recolonized by burrowing organisms. High-angle cross beds in the upper few feet of the sandstone unit were produced by large, migrating subaqueous dunes and sandwaves.

These characteristics are consistent with a position within the proximal, friction-dominated mouth bar setting of a delta (Elliott, 1986). Friction-dominated river mouths develop best where fluvial channels enter a shallow inshore marine basin. As frictional interference with the seafloor occurs, flow decelerates, spreads and undergoes transition from channelized toward sheetflow conditions. The broadly lenticular to tabular beds that characterize the distributary mouth bar are interpreted to represent this transition. The tractional horizontal laminations, large dune forms and sand waves may be the result of deposition of mid-ground bars (common in friction-dominated river mouths) that cause the channel to bifurcate into a nested series of broad channels and bars (Elliott, 1986).

After stop return to US-550 via 3rd Street to 8th Avenue, College Drive and downtown Durango, where we cross the narrow-gauge tracks of the Durango-Silverton Railroad. Visitors to Durango, Colorado, are going to be treated to the unmistakable whistle and other fascinating sounds of the Durango & Silverton Narrow Gauge Railroad (D&SNG). This bit of preserved western history now provides America's premier railroading experience and will demonstrate to you that history need not be resigned to museums, old buildings, and text books. Narrow gauge, by the way, technically means anything less than the standard 4 ft 8½ in., but in the case of D&SNG it means specifically 36 in. (inside to inside). The narrow gauge allows the train to negotiate tighter turns and rugged mountain terrain.

The railroad was completed in 1882 and essentially provided for the initial settlement, and once settled served the area as the sustaining lifeline. In the late 1880s and into the next century, train service meant that your town had an efficient means of transporting goods and a reliable connection with the outside world.

A tragic fire in February, 1989, destroyed the Roundhouse in Durango and severely damaged six vintage locomotives stored inside. The Roundhouse was rebuilt to as near original as was humanly possible, and the six locomotives were repaired.

At present, trains depart daily, through the summer months, for Silverton—round-trip distance, 90 mi. But there is a winter train! **1.0**

52.8 Intersection with US-550; turn right and proceed N through Durango. **0.2**

53.0 Traffic light at 9th Street intersection. At 12:00 ahead, dip slope of Animas City Mountain is Dakota Formation above complete Jurassic section. **0.6**

53.6 Bridge over Animas River; note Mancos outcrops up river to right. **0.4**

54.0 Cross Junction Creek. **0.3**

54.3 Intersection with 25th Street; La Plata County fairgrounds on right. To left is Junction Street; **turn left** onto Junction Street. **0.7**

55.0 Dakota Formation caps Animas City Mountain ahead. **0.2**

55.2 Route becomes La Plata County 204 and parallels Junction Creek. **0.9**

56.1 Sandstone cliff on left side of canyon is Dakota Formation. **0.9**

57.0 Road curves sharply left. **0.2**

57.2 Junction; **turn right** onto La Plata County 205, also called Falls Creek Road. **0.2**

57.4 Dakota Formation caps mesa ahead from 12:00–2:00. **0.3**

57.7 At 1:00 note landslides in Brushy Basin Member of Morrison Formation; Brushy Basin is overlain by Dakota Formation; Chapman Reservoir on right. **0.8**

58.5 Crest of hill; good exposures on left and ahead of Salt Wash and overlying Brushy Basin Members of Morrison Formation. **0.5**

59.0 **STOP 5**, Type locality of "Junction Creek Sandstone." Pull off to right side of road and park. Here, we examine the Jurassic strata (Figs. 2.11, 2.12) and compare them to

FIGURE 2.11. Overview of Junction Creek section showing Rock Point (1), Entrada (2), Todilto (3), Summerville (4), Bluff (5), Recapture (6), and Salt Wash (7) units.

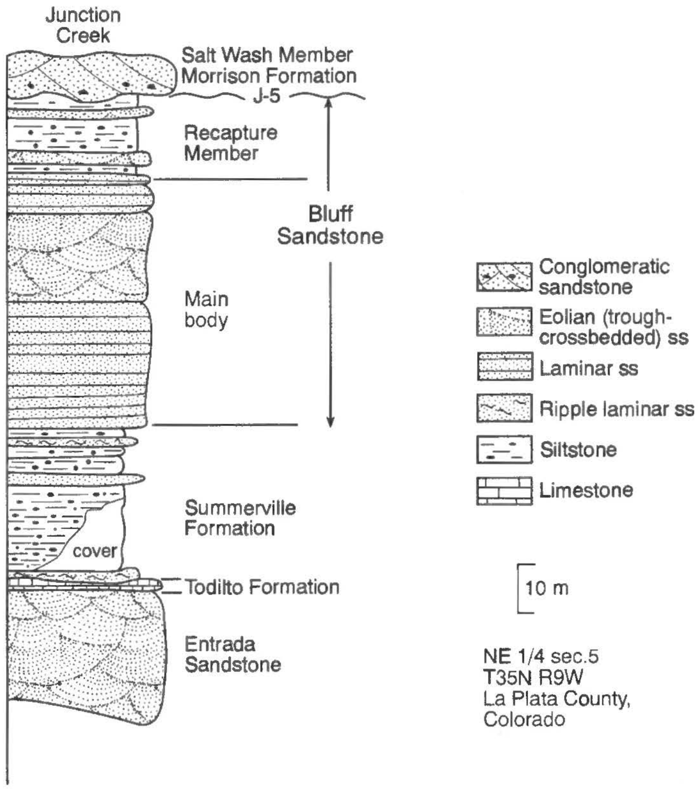

FIGURE 2.12. Measured stratigraphic section of Jurassic rocks at Junction Creek, Colorado.

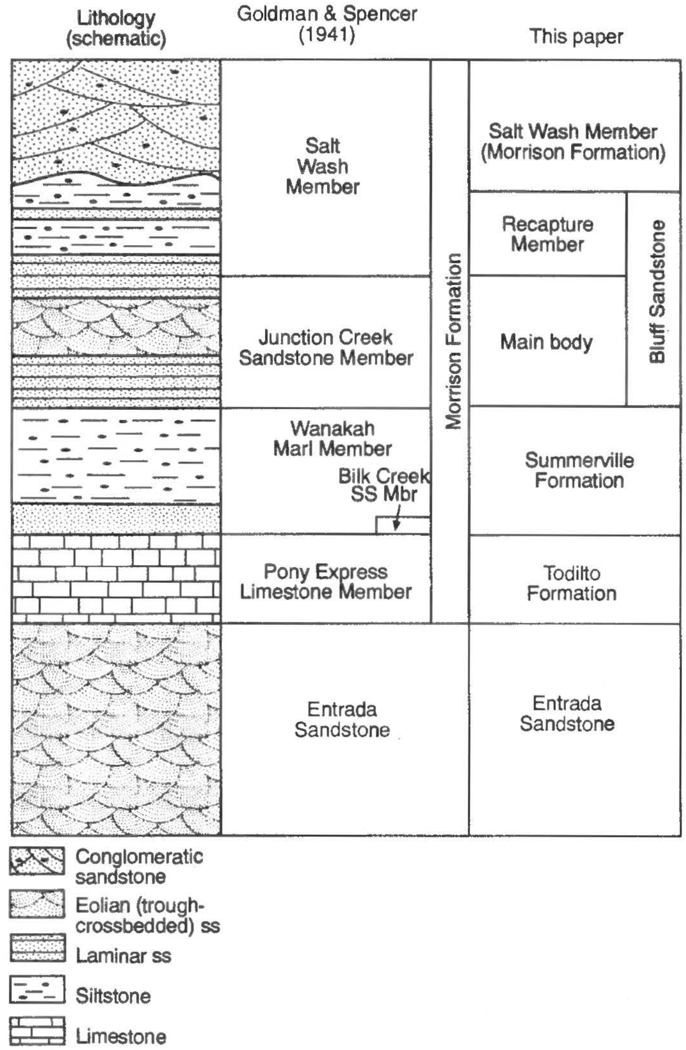

FIGURE 2.13. Comparison of old local and more recent regional stratigraphic nomenclature for Jurassic rocks exposed at Junction Creek.

the sections we saw yesterday in McElmo Canyon Bluff and Recapture Creek.

The Jurassic section exposed at Junction Creek just north of Durango, Colorado bears careful examination and comparison to the sections we examined yesterday to the west, in McElmo Canyon and Recapature Creek. A local and unnecessary (redundant) stratigraphic nomenclature created for the Jurassic rocks in this part of SW Colorado can be abandoned (Fig. 2.13). The section here thus is (in ascending order) (1) Rock Point Formation of Chinle Group—non-bentonitic red-bed siltstones and sandstones of Late Triassic (Rhaetian) age that represent sheet-flood and sand flat deposits; (2) J-2 unconformity—a major hiatus (Rhaetian to Callovian, about 50 Ma on the Harland et al., 1990 timescale); (3) Entrada Sandstone—about 200 ft of Callovian eolian sandstone deposited by a Middle Jurassic erg with predominant wind directions to the SW (Ver Hoeve, 1982); (4) Todilto Formation—4.3 ft of Callovian sapropelic limestone deposited in a paralic salina basin in response to the transgression of the Curtis seaway; (5) Summerville Formation—about 112 ft of Callovian-Oxfordian(?) red-bed siltstone and sandstone deposited on an arid coastal plain; (6) Bluff Sandstone (main body)—approximately 184 ft of Oxfordian(?) eolian sandstone deposited in the last Jurassic erg on the Colorado Plateau; a significant change in bedform characteristic of the Bluff—from laminar/massive to E-dipping foresets—occurs 100 ft above its base here; (7) Recapture Member of Bluff Sandstone—about 50 ft of strata remarkably similar to underlying Summerville lithologies, representing a return to arid coastal plain conditions; (8) J-5 unconformity—the base of the Morrison tectonosequence marks a significant tectonic reorganization of the Jurassic depositional basin, but the hiatus associated with the J-5 unconformity is geologically short, less than a stage-age; (9) Salt Wash Member of Morrison Formation—fluvially deposited conglomeratic sandstone lies at the base of the Morrison Formation.

Goldman and Spencer (1941) named the upper, white sandstone at this locality the Junction Creek Sandstone. It was recognized at the time as well as by later workers (Craig, 1955) that the Junction Creek, an eolianite, was lithologically and lithogenetically similar to and in the same stratigraphic position as the Bluff Sandstone. We concur, and conclude that here is another example of superfluous nomenclature. Applying the rule of priority, the name Bluff has precedence over Junction Creek, and thus we abandon the name Junction Creek and recognize these strata as Bluff Sandstone.

Of perhaps greater interest is the similarity of the upper part of the Bluff at this locality to that of the type locality at Bluff, Utah. These similarities include a prominently crossbedded facies with eastward-dipping foresets at the top of the main body, overlain by thin, horizontal redbeds that are water-laid and perhaps sabkha-related. These upper redbeds, which are seen at many localities in southwestern Colorado and northwestern New Mexico, signal a return to non-eolian deposition at the close of San Rafael Group time and are assigned to the Recapture Member of the Bluff Sandstone as they are in the type area. Thickness of the Recapture Member in the type area is 40–50 ft, similar to the thickness in this area. The Recapture Member was formerly assigned to the Morrison Formation in this area if it was recognized at all. Indeed, some workers of the U.S. Geological Survey (Condon and Peterson, 1986; O'Sullivan, 1995) would extend the base of the Morrison Formation down into the main body of the Bluff Sandstone to include the highly crossbedded facies. Their base of the Morrison was then described as an "unrecognized time boundary." We reject this approach to stratigraphy because it confuses chronostratigraphy with lithostratigraphy; compliance with the stratigraphic code requires that we envision formations as lithostratigraphic units and thus formation contacts can be neither unrecognized nor time boundaries.

The mappable base of the Morrison Formation is a scour surface of low relief developed on the Recapture Member of the Bluff. A grain-size change (coarser in Morrison) and a bedform change (trough crossbeds and other fluvial features) further identify this contact. At many localities, pedogenic carbonate development is evident at this contact, though not here.

Following stop retrace route to US-550. **4.7**

63.7 Intersection with Junction Street and U.S. 550; **turn left** and proceed north on U.S. 550. **0.7**

64.4 Traffic light at 32 St; Animas City Mountain ahead. Jurassic sandstones low on the mountain are Junction Creek (= Bluff) Sandstone (white ledge with E–NE-dipping crossbeds) overlain by Salt Wash Member of Morrison Formation sandstones under slope of Brushy Basin Member (Fig. 2.14). **0.8**

65.2 Note, X-Rock, a conjugate fracture pattern in the Bluff, a popular spot for novice rock climbers. **0.4**

65.6 At 1:00 on cliff note thin sandstone ledge above Bluff Sandstone. This is the basal Morrison Salt Wash Member. **0.4**

66.0 Entrada Sandstone on left. **0.2**

66.2 "Dolores Formation" (= Rock Point Formation) is exposed in roadcut on left (Fig. 2.15) beneath Entrada Sandstone in a section that dips moderately southward.

Upper Triassic strata in southwestern Colorado have long been referred to the Dolores Formation of Cross (1899) and Cross and Howe (1905). It has long been clear that the Dolores Formation, usually divided into three informal members, can be correlated with Chinle Group units in nearby southeastern Utah and northeastern Arizona (e.g., Stewart et al., 1972b, fig. 15). (Fig. 2.16).

The "lower member of the Dolores Formation" is as much as 90 ft of greenish-gray to tan, fine-grained quartzose sandstone and calcrete-pebble conglomerate, which locally contains siliceous pebbles. It rests unconformably on the Lower Permian Cutler Formation and is demonstrably correlative to the Moss Back Formation in SE Utah. The overlying "middle member of the Dolores Formation" is up to 270 ft of grayish red siltstone, mudstone, trough-crossbedded fine-grained sandstone and limestone-pebble conglomerate. These conglomerates are the "saurian conglomerates" of earlier works and produce phytosaurs and other vertebrate fossils of Revueltian (early Norian) age (Lucas, 1993). Thus, stratigraphic position, lithology and paleontology correlate the "middle member" to the upper part of the Petrified Forest Formation of the Chinle Group in NE Arizona.

The "upper member of the Dolores Formation" is as much as 540 ft of repetitively-bedded light brown and reddish brown siltstone and sandy siltstone. Fossil fishes of the late Norian fish assemblage of Huber et al., (1993) are known from the "upper member." Its stratigraphic position, lithology and paleontology equate it to the Rock Point Formation of the Chinle Group in adjacent states.

Use of the term Dolores Formation (e.g., Oriel and Dubiel, 1994) should be discontinued. In so doing, we recognize the priority Dolores has over Chinle but point out how little used the Colorado name has been compared to the much wider use of the Arizona name Chinle. **1.5**

67.7 Ledge at 9:00 is Moss Back Formation of Chinle Group. At 10:00, on nose of mesa with southwest dips, Rock Point-Entrada contact is well displayed. The highway at this point has descended stratigraphically into a thick section of Cutler Formation (Lower Permian). **2.1**

FIGURE 2.14. View to east across Animas Valley, of Rock Point (1), Entrada (2), Todilto-Summerville (3), Bluff (4), Recapture-Morrison (5), and Cretaceous (6) strata.

FIGURE 2.15. View of Upper Triassic Dolores Formation along west side of US-550 at mile 66.2; Dolores is overlain by sandstone ledges of lower part of Middle Jurassic Entrada Sandstone.

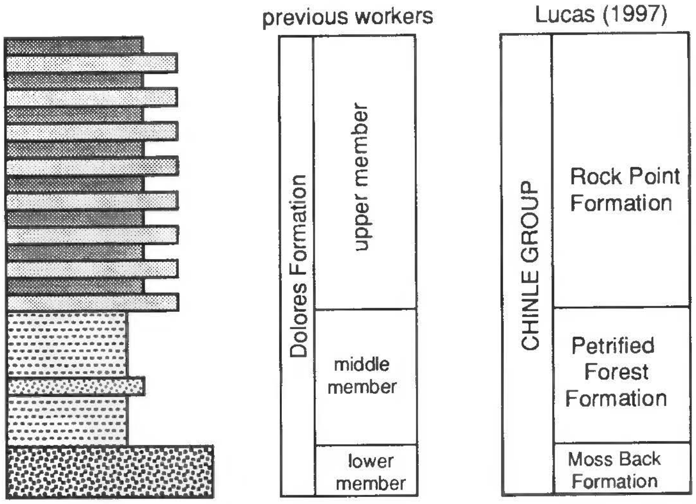

FIGURE 2.16. Comparison of local uper Triassic stratigraphic nomenclature with that of the regional Chinle units across the Colorado Plateau.

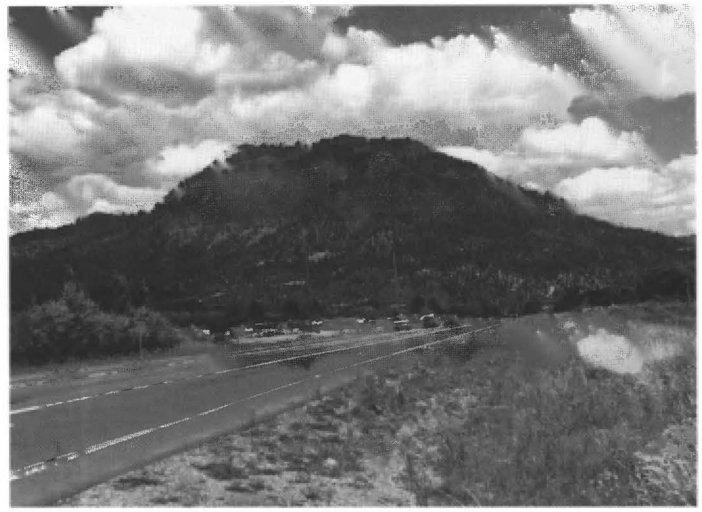

FIGURE 2.17. Hermosa cliffs expose Pennsylvanian carbonated-dominated strata of the Hermosa Group.

69.8 Cutler-Hermosa contact. **0.3**
70.1 Trimble, Colorado. **0.9**
71.0 Hermosa Cliffs ahead (Fig. 2.17). **0.7**
71.7 Hermosa, Colorado. **0.2**
71.9 Cross Hermosa Creek. **0.3**
72.2 Cross tracks of Durango–Silverton narrow gauge railroad. **1.6**
73.8 Whispering Pines condominiums on left. **0.2**
74.0 Note excellent outcrops of Hermosa Formation (Group) and mass wasting on left. **0.6**
74.6 Mississippian limestones of Leadville Limestone crop out on left in roadcut. At 2:00, in Animas River valley, note Precambrian metavolcanic and metasedimentary rocks of the Irving Formation. **2.1**

PALEOZOIC STRATA OF THE ANIMAS VALLEY

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Paleozoic strata in the Animas Valley consist of the Late Cambrian Ignacio Quartzite, the Late Devonian Elbert Formation and overlying Ouray Limestone, the Early-Middle Mississippian Leadville Limestone, the Pennsylvanian Molas, Pinkerton Trail, Paradox and Honaker Trail formations, and redbeds of the Permian Cutler Formation (Baars, 1962, 1966; Baars and Ellingson, 1984; Wengerd and Strickland, 1954; Wengerd and Matheny, 1958; Wengerd and Szabo, 1968).

The spectacular Hermosa Cliffs expose Pennsylvanian and Permian strata. Along NM-550, mostly concealed by glacial sediments and slope wash, the basal Pennsylvanian Molas Formation, with its basal dark-reddish brown paleosol, overlies deeply weathered and karsted Mississippian Leadville Limestone. Above the basal paleosol, the Molas Formation includes fluvial sandstones overlain by marine shales bearing Atokan fusulinids. The Molas Formation is about 60 ft thick. The overlying Pinkerton Trail Formation is approximately 85 ft thick, consisting of marine argillaceous limestone and gray shale. These strata, exposed in road cuts near Tamarron, also bear Atokan fusulinids (Baars and Ellingson, 1984).

The 1200-ft thick Paradox Formation conformably overlies the Molas and is composed mainly of sandstones, thin dolomites, limestones and gray to black shales. The basal Paradox "San Luis facies" is about 800 ft thick and consists mostly of deltaic sandstones and gray shales which apparently pinch out westward. These strata were derived from the early Desmoinesian uplift of the Grenadier fault block to the north as suggested by Baars and Stevenson (1984). The overlying 400 ft of Paradox Formation consist of black shale, thinly bedded dolomites and limestones, and minor amounts of sandstone and gypsum. Gypsum beds, exposed mostly as gypsiferous soils, represent the easternmost extent of the Paradox Basin evaporite facies.

The upper 850 ft of Pennsylvanian strata, bearing Desmoinesian fusulinids, comprise the Honaker Trail Formation. At the type section of the Honaker Trail Formation in SE Utah, recent work has identified Missourian fossils. The Honaker Trail Formation consists of intertongued sandstone, limestone and shale (Baars and Ellingson, 1984). Lenticular arkosic sandstones dominate, and these form the thick "gritstone" ledges prominent halfway up the Hermosa Mountain exposures (Wengerd and Matheny, 1958). Included in the Honaker Trail Formation in this discussion are the interbedded limestones and sandstones of the transitional "Rico Formation."

Ridge-capping strata of the Cutler Formation are more than 2500 ft thick in the Animas Valley and are dominated by coarse-grained arkosic sandstones, interbedded with red shales, siltstones, and some thin argillaceous limestones. Baars and Ellingson (1984) reported the contact with the underlying Honaker Trail Formation is abrupt, occurring along a single bedding plane. To the N, they described a basal Cutler limestone-pebble bearing conglomerate, indicative of an erosional unconformity. Fossil data are sparse, but at other localities the Cutler is Early Permian in age.

The clastic Pennsylvanian strata described in the Hermosa Mountain measured section are especially critical to Pennsylvanian hydrocarbon exploration in the San Juan Basin. Pennsylvanian strata of the San Juan Basin are generally more clastic (sandier) towards the northeast, reflecting proximity to the Uncompaghre uplift of the Ancestral Rocky Mountains. Outcrop measured sections are of critical importance to Exploration efforts in the San Juan Basin, since fewer than seven wells encounter Pennsylvanian strata in the 3200-mi^2 "High-potential Fairway."

Fifty-five miles SSE from the Hermosa Mountain measured section of Wengerd and Matheny (1958), two of the deepest wells drilled in the San Juan Basin logged their most significant shows from sandstones in the Paradox Formation. El Paso Natural Gas-SJ 29-5 Unit #50 (SE¼ Sec. 7, T29N, R1E) was drilled to 14,423 ft in 1961. This well gauged flowing natural gas during a drill-stem test (DST) at a rate of 260 MCFD (thousand cubic feet per day). This test is especially significant because the gas flowed out of a sandstone reservoir without hydraulic stimulation. Four miles to the northwest, Phillips Petroleum-SJ 30-6 Unit #112Y (NE¼ Sec. 7, T29N, R6W) was drilled to 14,035 ft in 1984. This well, the most recent Pennsylvanian exploratory well in the San Juan Basin, flowed 280 MCFD after hydraulic stimulation.

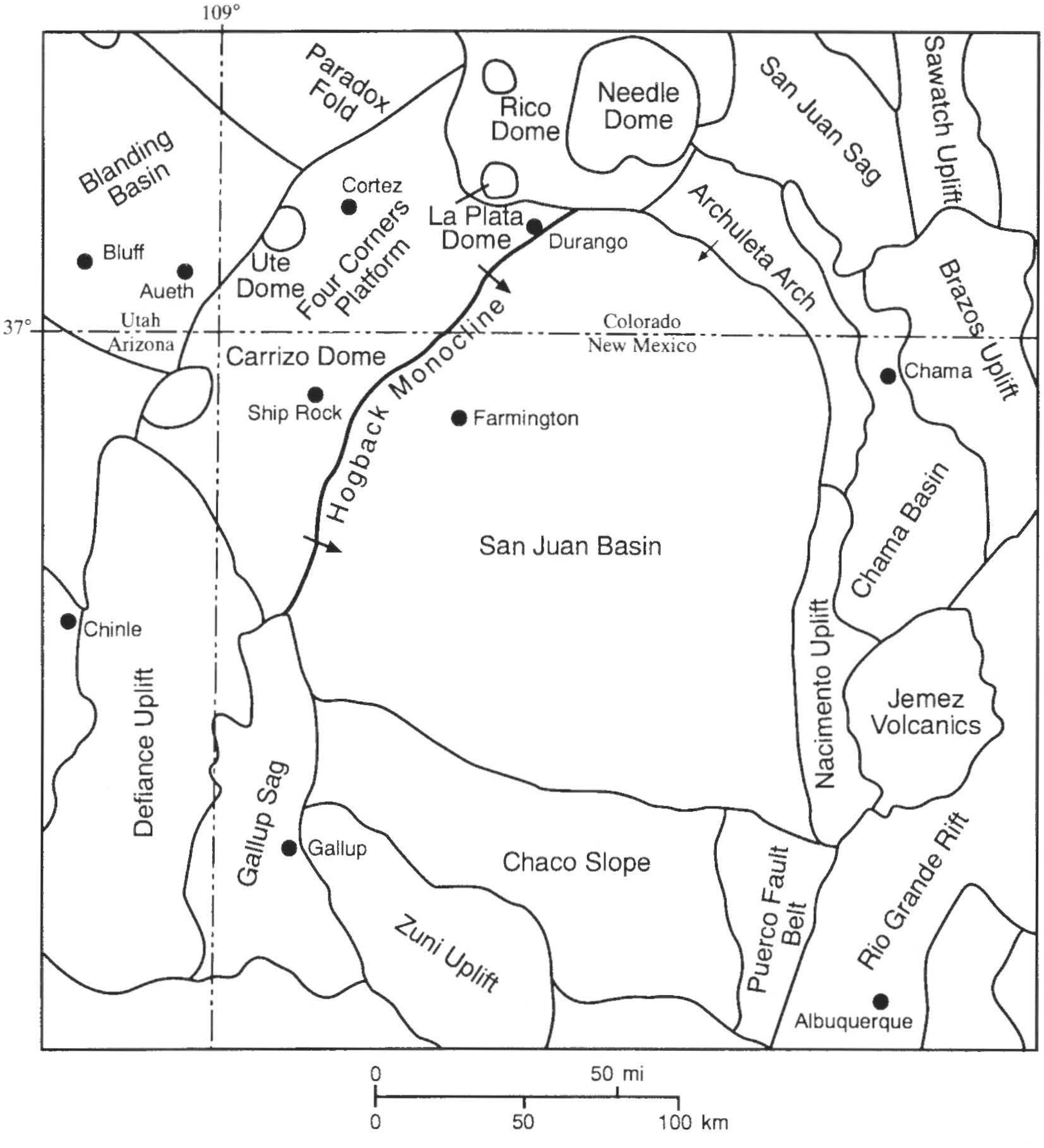
These two critical Pennsylvanian tests demonstrate that Pennsylvanian clastics, especially in the northeastern San Juan Basin, are highly prospective. Wireline and sample logs allow stratigraphic comparison from the Hermosa Mountain outcrops to the deep San Juan Basin. Honaker Trail strata in the subsurface, including the Rico interval, are only slightly thicker (900 ft vs. 850 ft) than correlative equivalents at the outcrop. Strata of the Paradox Formation are considerably thinner in the subsurface (900 ft vs. 1200 ft), reflecting greater distance from the source of coarse fan-deltaic clastics. Strata of the Molas and Pinkerton Trail formations are significantly thicker in the San Juan Basin than on Hermosa Mountain (135 ft vs. 60 ft and 125 ft vs. 85 ft), reflecting greater sediment accommodation space in the structurally lower San Juan Basin.

76.7 Enter San Juan National Forest. To right, note Shalom Lake and outcrops of Mississippian Leadville Limestone. Leadville is correlative westward with the Redwall Limestone, well exposed in Grand Canyon National Park, and correlative northward with the Madison Limestone. **0.4**

77.1 Rockwood to right. **0.8**

77.9 Pennsylvanian Hermosa Group crops out in cliff to left. In descending order the Hermosa consists of the Honaker Trail Limestone, the Paradox Formation and the Pinkerton Trail Limestone. Entrance to Tamarron resort.

End of Second-day road log.


109°
37°
Paradox Fold
Rico Dome
Needle Dome
San Juan Sag
Sawatch Uplift
Blanding Basin
Cortez
La Plata Dome
Durango
Archuleta Arch
Bluff
Aneth
Ute Dome
Four Corners Platform
Brazos Uplift
Utah
Arizona
Colorado
New Mexico
Carrizo Dome
Chama
Ship Rock
Farmington
Hogback Monocline
Chama Basin
San Juan Basin
Chinle
Nacimiento Uplift
Jemez Volcanics
Defiance Uplift
Gallup Sag
Gallup
Chaco Slope
Puerco Fault Belt
Rio Grande Rift
Zuni Uplift
Albuquerque
0
50 mi
0
50
100 km