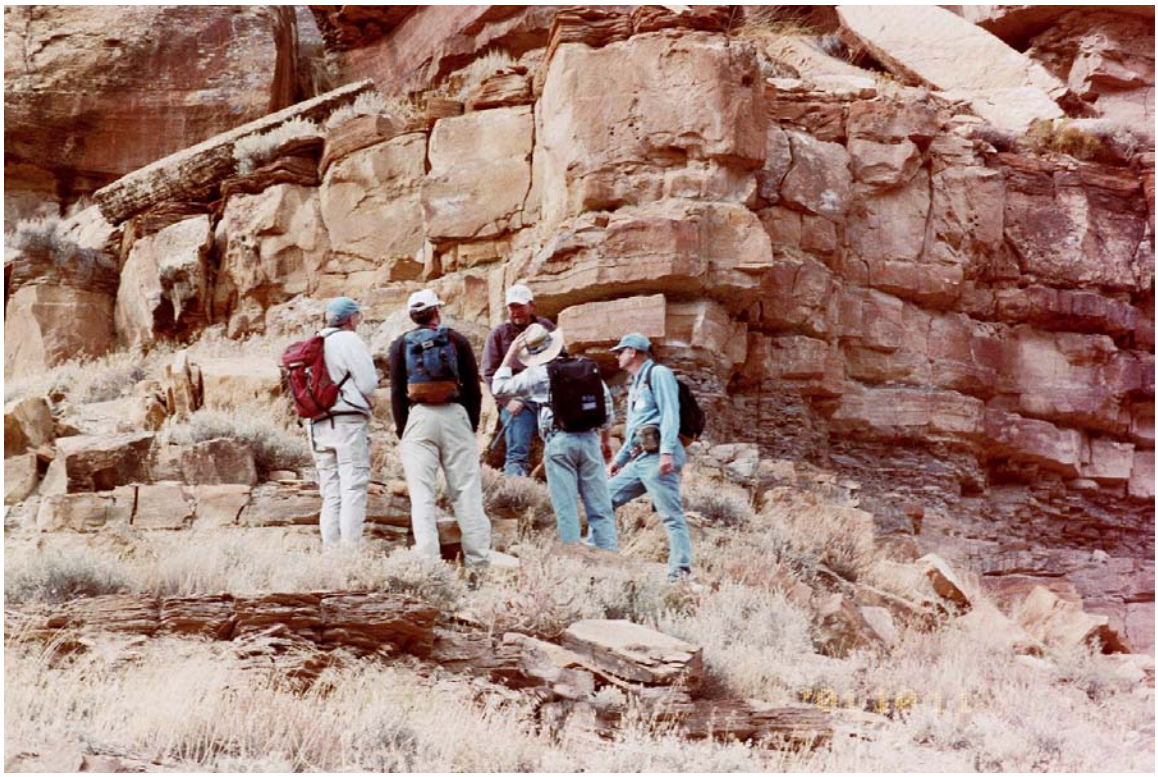
GEOLOGIC GUIDE AND ROAD LOGS OF THE WILLOW CREEK, INDIAN, SOLDIER CREEK, NINE MILE, GATE, AND DESOLATION CANYONS, UINTA BASIN, UTAH

by

Craig D. Morgan



OPEN-FILE REPORT 407 **March 2003**

UTAH GEOLOGICAL SURVEY

A division of

UTAH DEPARTMENT OF NATURAL RESOURCES

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Prepared under contract DE-AC26-98BC15103

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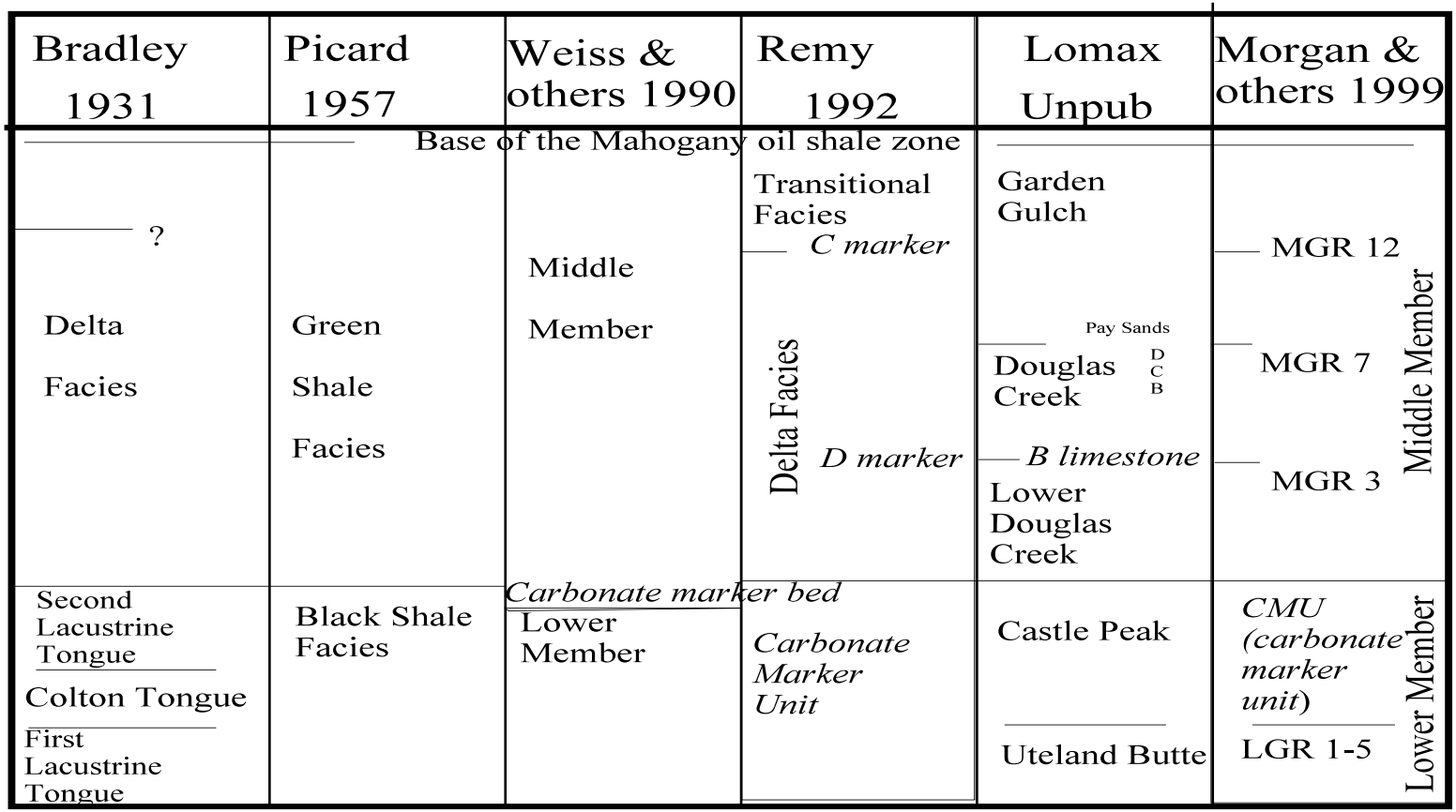
INTRODUCTION

The geologic guide and road logs of Willow Creek, Indian, Soldier Creek, Nine Mile, and Desolation Canyons was developed as part of an extensive study by the Utah Geological Survey (UGS) of the lower and middle members of the Green River Formation (Weiss and others, 1990). Figure 1 shows the Tertiary and Cretaceous stratigraphic nomenclature that has been used in this document. There are many other informal names for units within the Green River Formation that have been published but are not discussed here. This document is intended to be used as a self-guided tour of the canyons with emphasis on the Green River Formation, but also includes information on older Cretaceous rocks that are exposed. Also, information is given on oil, gas, and coal activity in the area, petroglyphs, and local history.

The objectives of the UGS study were to increase both primary and secondary hydrocarbon recovery through improved characterization (at the regional, unit, interwell, well, and microscopic scale) and numerical simulation modeling of fluvial-deltaic lacustrine reservoirs, thereby preventing premature abandonment of producing wells. The study will encourage exploration, and establishment of additional water-flood units throughout the south-central to southwest region of the Uinta Basin (figure 2), and other basins with production from fluvial-deltaic reservoirs.

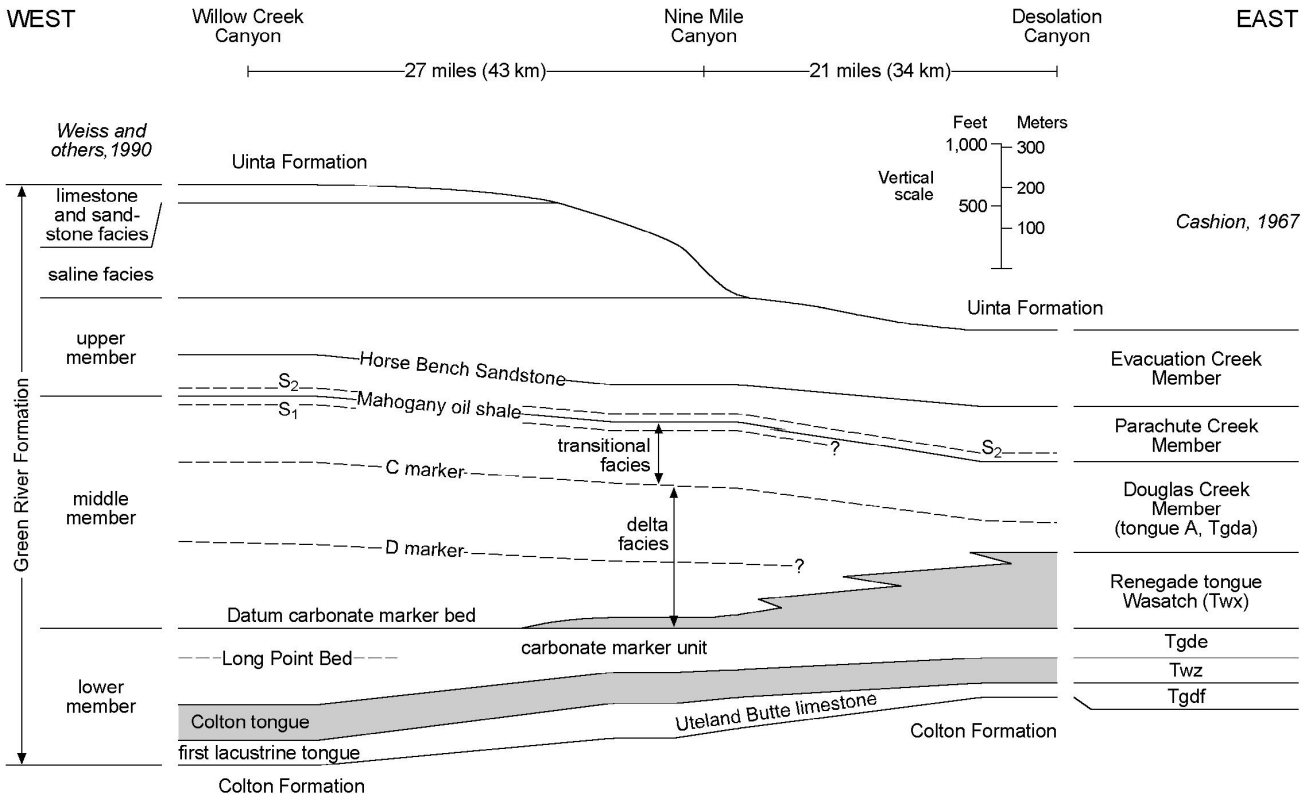
We established a log-based correlation scheme and nomenclature that reflect, as near as possible, time-correlative depositional cycles of the middle and lower members of the Green River Formation (figure 3). The cycles are at a scale that is easily recognizable on geophysical well logs and can be correlated throughout most of the south-central to southwest Uinta Basin. The correlation scheme is intended for log-based correlations but a few log markers can be correlated to surface exposures. Published measured sections by Remy (1992) were reviewed in the field, and additional sections were measured and described by the UGS in Willow Creek, Nine Mile, and Desolation Canyons. Gamma-ray (GR) data were gathered over several of the stratigraphic sections. Curves generated from the GR data were correlated with GR curves from wells in the area.

A detailed study site, Nutter's Ranch, was selected in Nine Mile Canyon, from Petes Canyon to Gate Canyon, both tributaries to Nine Mile Canyon (Morgan and others, 1999). The exposure is about 2,000 feet (600 m) in the east-to-west direction, and about 500 feet (150 m) in the north-to-south direction. The stratigraphic interval studied is slightly more than 100 feet (30 m) thick, and is bounded by carbonate beds. Six sections were measured and described, and GR data were gathered from five of the sections. To aid in the stratigraphic interpretation, the site was photographed from the canyon walls opposite the study site, and photomontages were compiled. The photomontages were used to map out individual beds and their relationships. Data from the study site provides an example of the reservoir heterogeneity that could be encountered in the interwell environment.



A

Figure 1. (A) Generalized nomenclature for the Green River Formation (below the Mahogany oil shale zone) for the south-central to southwest Uinta Basin, (B) time-stratigraphic cross section of the Green River Formation from Willow Creek Canyon to Desolation Canyon, and (C) time-stratigraphic cross section showing part of the Cretaceous and early Tertiary section in east-central Utah (modified from Franczyk and others, 1991).



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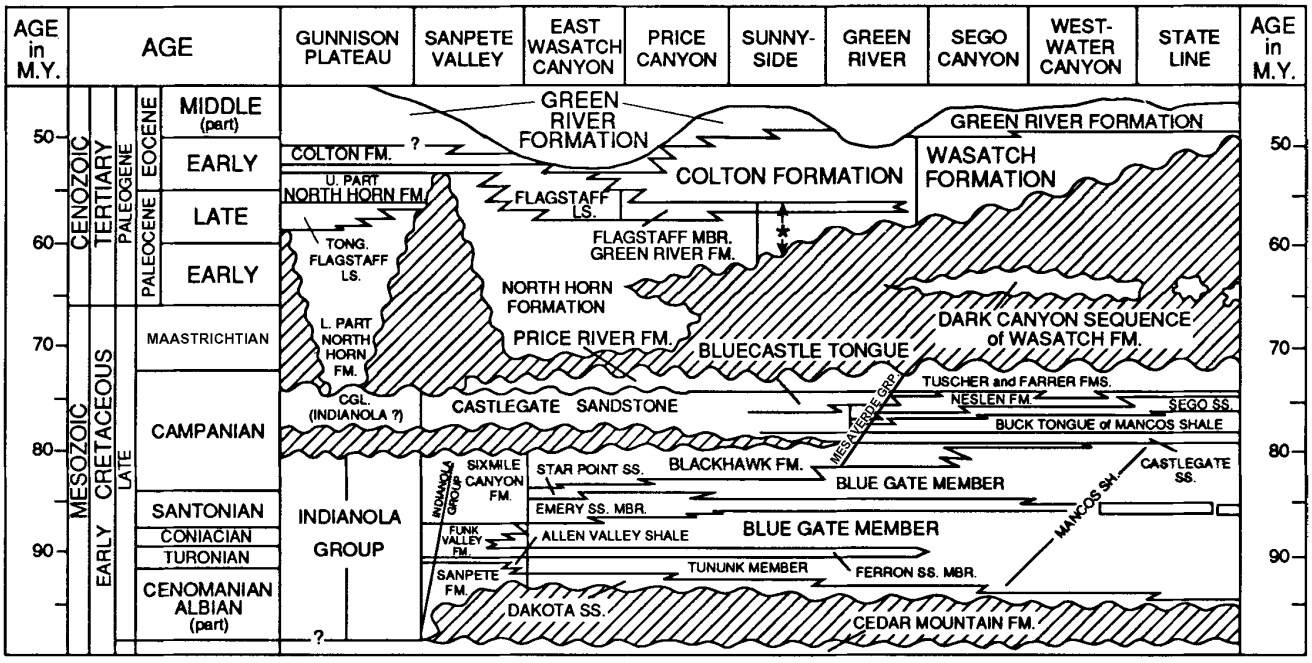

* Flagstaff Member and North Horn Formation undivided

C

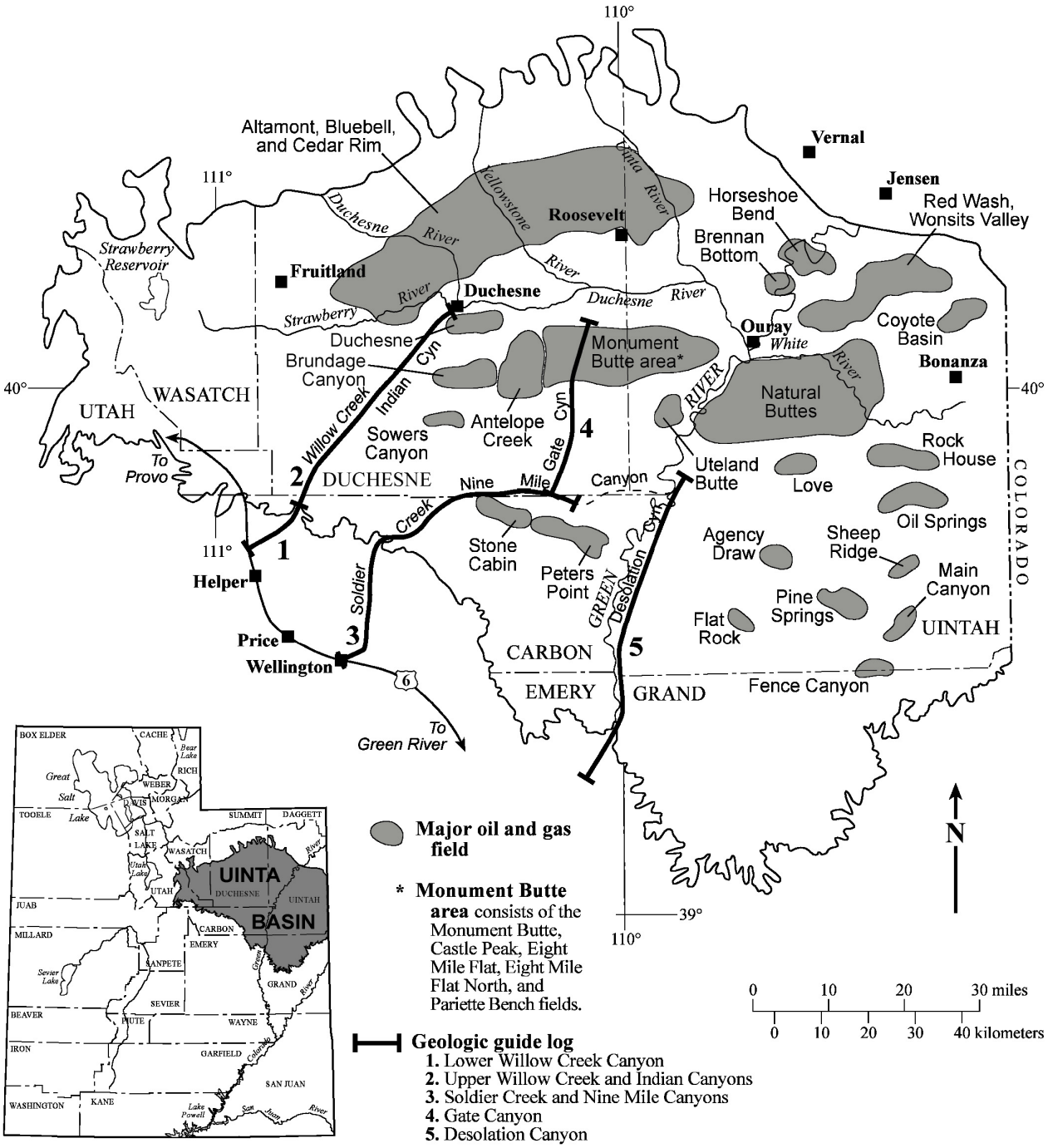

Figure 2. Index map of the Uinta Basin, Utah, showing location of geologic guides and major oil and gas fields.

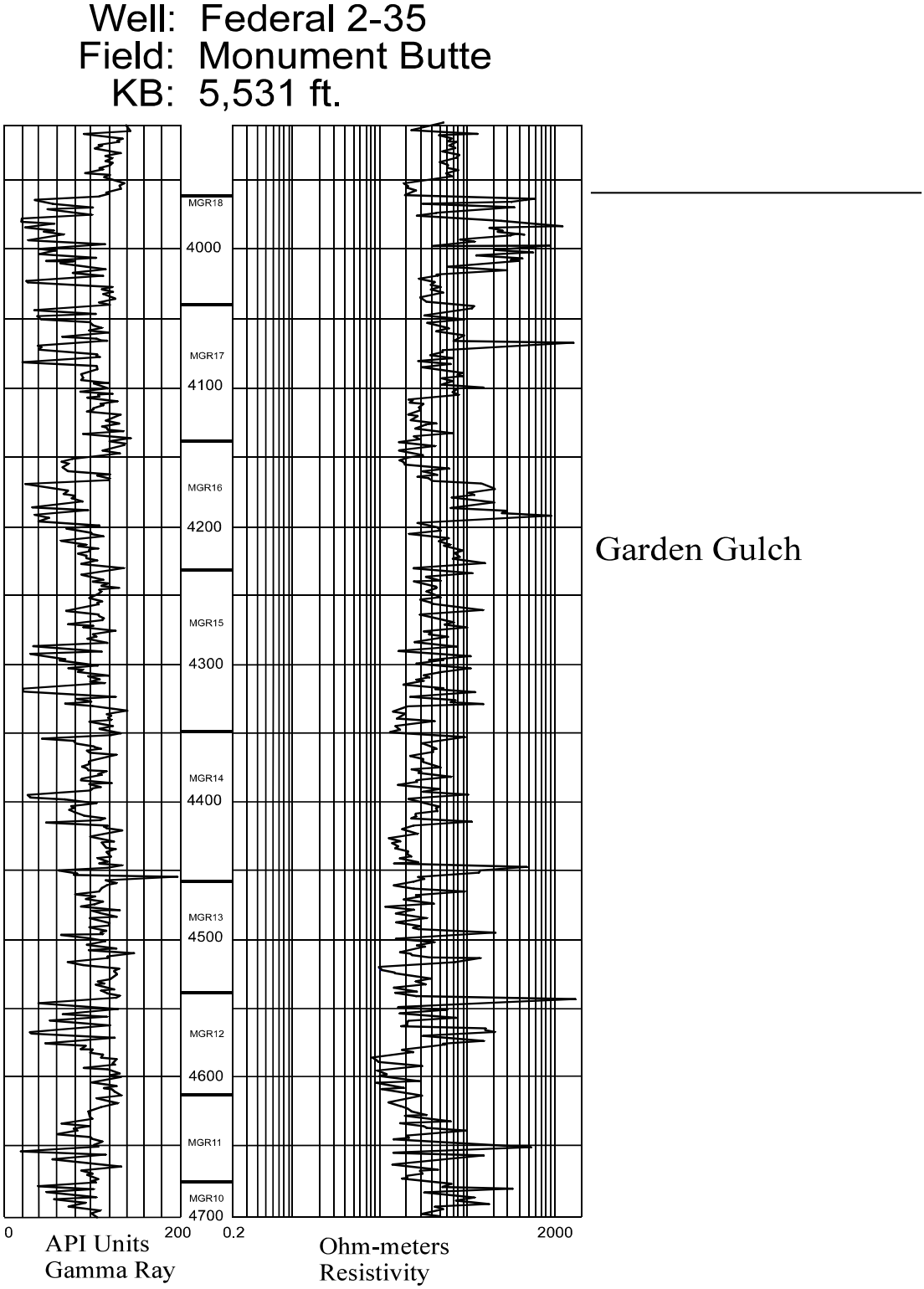

Figure 3. Type log showing the log cycles and oil reservoirs in the middle member (MGR) and lower member (LGR) of the Green River Formation. CMU is the carbonate marker unit of the lower member. Well location is NE1/4SE1/4 section 35, T. 8 S., R. 16 E., of the Salt Lake Base Line and Merdian.

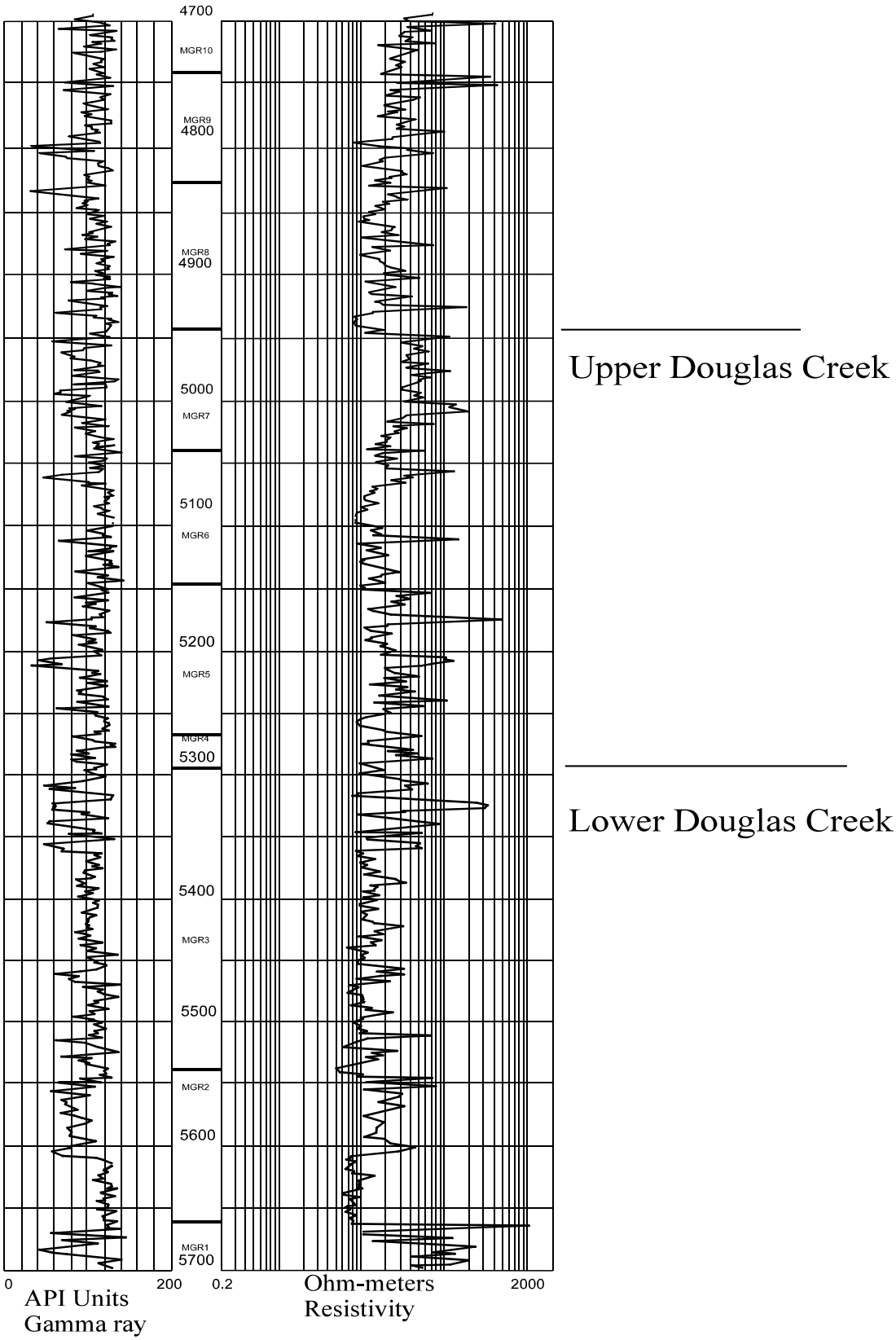

Figure 3 continued.

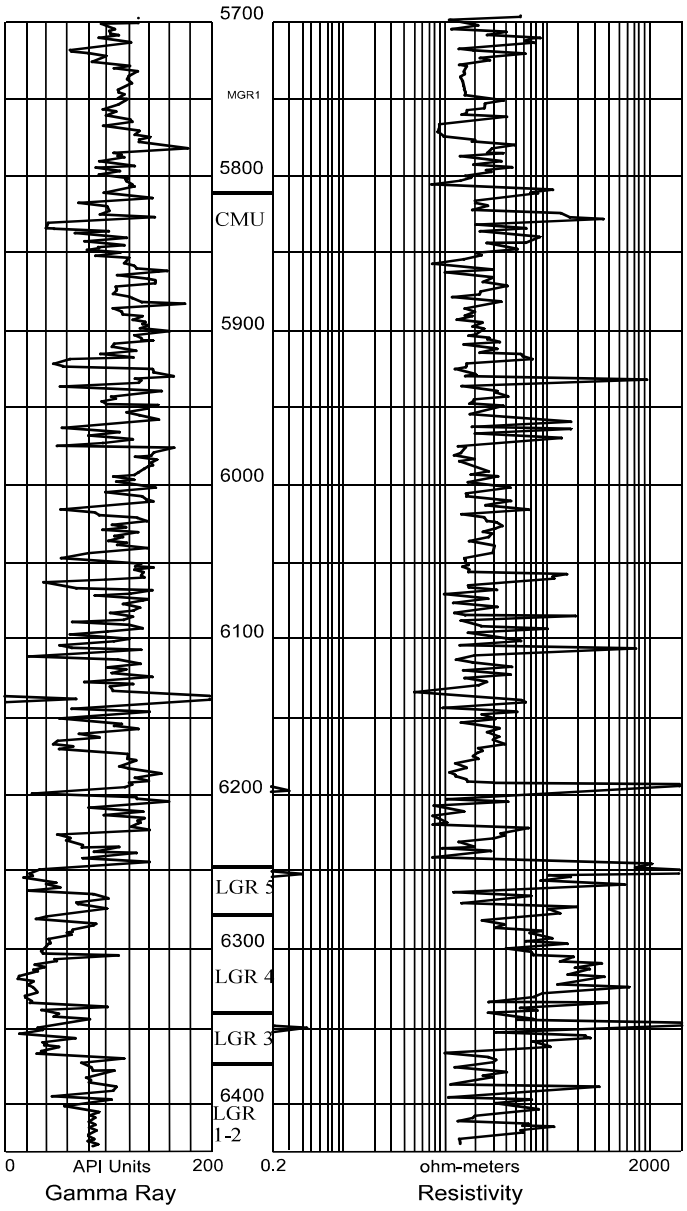
5700
MGR1
5800
CMU
5900
6000
6100
6200
LGR 5
6300
LGR 4
LGR 3
6400
LGR
I-2
0
API Units
200
Gamma Ray
0.2
ohm-meters
2000
Resistivity
Lower Douglas Creek
Castle Peak
Uteland Butte
Total Depth 6,440 ft.

Figure 3 end.

GEOLOGIC SUMMARY

The Uinta Basin is a topographic and structural trough encompassing an area of more than 9,300 square miles (14,900 km^2) in northeast Utah (figure 2). The basin is sharply asymmetrical, with a steep north flank bounded by the east-west-trending Uinta Mountains, and a gently dipping south flank.

The Uinta Basin formed in Maastrichtian (Late Cretaceous) time, creating a large area of internal drainage which was filled by ancestral Lake Uinta. Deposition in and around Lake Uinta consisted of open- to marginal-lacustrine sediments that make up the Green River Formation. Alluvial red-bed deposits that are laterally equivalent to, and intertongue with, the Green River make up the Colton Formation (Wasatch).

More than 450 million barrels of oil have been produced from the Green River and Colton Formations in the Uinta Basin. The Cedar Rim, Altamont, Bluebell, and Red Wash fields produce from the northern shoreline deposits of Lake Uinta, while the fields in the Monument Butte area produce from southern deltaic shoreline deposits in the middle and lower members of the Green River. The southern shore of Lake Uinta was very broad and flat, which allowed large transgressive and regressive shifts in the shoreline in response to climatic and tectonic-induced rise and fall of the lake. The cyclic nature of Green River deposition in the Monument Butte area resulted in numerous stacked deltaic deposits. Distributary channels are the primary producing sandstone reservoirs in the area.

The carbonate marker unit (CMU, figure 1) is considered by many to be the primary source for the oil in the Monument Butte area. The unit consists of interbedded black shale and carbonate with some sandstone. The sandstone beds, which are productive in some areas, are generally fine to medium grained, and were deposited as isolated channels. The top of the carbonate marker bed has typically been considered the top of the CMU or black shale facies, but Weiss and others (1990) used the base of the carbonate marker bed to define the top of the lower member or base of middle member of the Green River Formation. We have adopted the lower and middle member terminology, but use the top of the carbonate marker bed as the top of the lower member. The carbonate marker bed is easily identifiable on well logs throughout the region. Although the bed looks the same throughout the region on well logs, the lithology does vary a great deal. Where exposed, it is typically a grainstone and algal laminated argillaceous limestone; basinward it is an algal boundstone to limy mudstone.

The delta facies of the middle member of the Green River Formation (MGR 1 through12) in Willow Creek and Nine Mile Canyons is composed of green shale/siltstone with thin interbedded limestone (limy mudstone/marlstone, grainstone, and micrite) and sandstone. The sandstone consists of both individual and amalgamated channel-form beds. On outcrop, the entire delta facies appears to be lower delta plain, mudflat, swamp, shoreline to shallow lake deposits. Qualitatively, it appears that from Willow Creek to Nine Mile Canyon, and from west-to-east in Nine Mile Canyon, the delta facies becomes more sand rich, the channel sandstone beds become more amalgamated (thicker stacking), and individual channels appear to be more deeply incised. From Willow Creek to the west portion (Cottonwood Canyon) of Nine Mile Canyon, the facies changes from distal to the central portion of the delta.

In the Monument Butte area, the lower Douglas Creek (Lomax unpublished, oil field terminology) of the middle member of the Green River Formation (MGR 1 through 3) consists of black shale and turbidite deposits. Since there is no evidence of a relatively deeper lake on

outcrop, there must have been a hinge line where the slope changed between the outcrop and the Monument Butte area. The delta facies from the D marker (MGR 3) to the C marker (MGR 12), consists of lower delta plain deposits (except for two thin oil shale beds) in both Nine Mile Canyon and the Monument Butte area. Therefore, the rocks in Nine Mile Canyon are good examples of the type of reservoirs encountered in Monument Butte.

LOWER WILLOW CREEK CANYON ROAD LOG
From Castlegate to Emma Park

Cumulative Mileage (distance between)	
0.0	Turn off of U.S. Highway 6 onto U.S. Highway 191 to Duchesne. Proceed past the Carbon power plant and coal loadout facility. The plant burns 600,000 short tons of coal annually to produce about 1,300 gigawatt hours of electricity each year. The loadout was used to load coal from the Willow Creek mine onto trains bound for the Intermountain Power Plant in western Utah, and to the West Coast for export to Pacific Rim markets. Since the closure of the Willow Creek mine in 2000 the loadout is used to bring coal to the power plant.
1.0 (1.0)	Willow Creek coal mine north of the road. The mine was designed to extract 5 million tons per year from the Cretaceous Blackhawk Formation. The gassy mine caught fire in November 1998; everyone got out safely but the mine was closed down for nearly a year. In August 2000, a second fire and explosion took the life of two miners. Many of the miners killed in an explosion that occurred March 8, 1924 in the old Castle Gate mine, in this same area, are buried in the graveyard on the north side of the road. The explosion was so powerful that a mine car was shot out the main entry, like being shot from a cannon, and was found on the hill side on the south side of the road (a distance of over 1,000 feet [300 m]).
1.3 (0.3)	Reddish clinker beds in the Blackhawk Formation, due to coal burn, are exposed in the road cut. Hintze (1988) shows the Blackhawk to be 1,000 to 1,500 feet (304-457 m) thick in the Helper-Price-Wellington area (figure 4). The Blackhawk is overlain by the cliff-forming Cretaceous Castlegate Sandstone.
2.3 (1.0)	Contact between the Castlegate Sandstone and underlying Blackhawk Formation. Hintze (1988) shows the Castlegate to be 180 to 290 feet (54-88 m) thick in this area (figure 4).
2.7 (0.4)	Bridge over Willow Creek.
3.9 (1.2)	Contact between Castlegate Sandstone and Cretaceous Price River Formation.

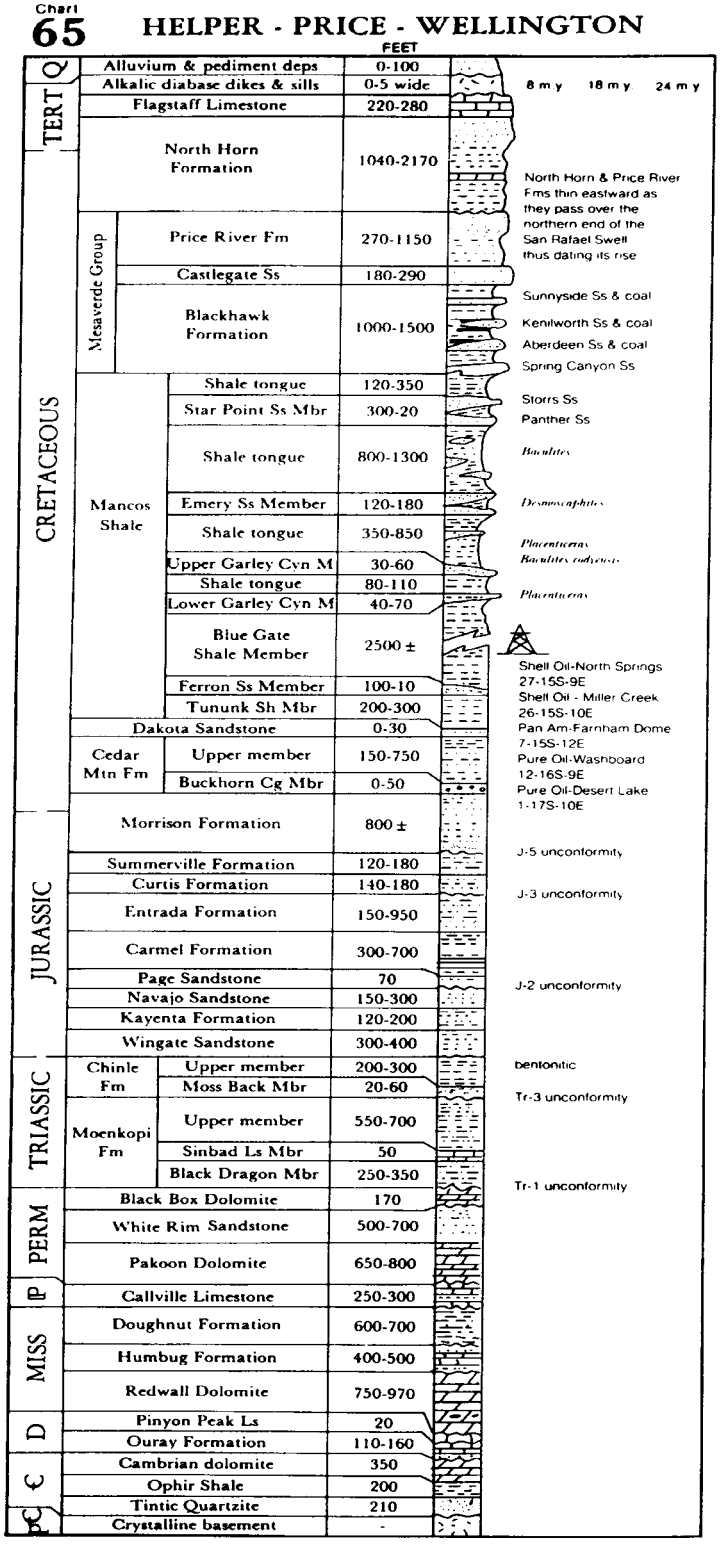

Figure 4. Stratigraphic section for the Helper-Price-Wellington area, Carbon County, Utah. From Hintze (1988).

5.9 (2.0) Approximate location of the contact between the Price River and Cretaceous/Tertiary North Horn Formations. The North Horn Formation in Willow Creek Canyon is nearly 1,000 feet (300 m) thick (Fouch and others, 1976).

7.7 (1.8) Intersection with Emma Park road to the west, at the site of the Bamberger Monument. The dip slope south of the Emma Park road is formed by beds in the basal portion of the Flagstaff Member of the Eocene Green River Formation. The road to the west continues through Emma Park, a strike valley in the Flagstaff Member and Colton Formation, and intersects U.S. Highway 6 at the top of Price Canyon. The Castlegate field is located on the dip slope to the southeast where coal-bed methane wells have produced about 3,210,000 thousand cubic feet of gas (MCFG) and 8,100,000 barrels of water (BW) (as of May 2001) from the Blackhawk Formation. The Flagstaff is 220 to 280 feet (67-85 m) thick in this area (figure 4). Fouch and others (1976) state that tongues of the Flagstaff are locally present below this horizon in the North Horn Formation, forming a gross thickness of nearly 800 feet (244 m).

8.0 (0.3) Approximate contact of the Flagstaff Member and overlying Paleocene/Eocene Colton Formation. The Colton is about 1,800 feet (550 m) thick in Willow Creek Canyon (Fouch and others, 1976). In Willow Creek Canyon, the Paleocene-Eocene boundary has been placed in the upper one-third of the Colton on the basis of palynomorph, ostracod, and charophyte assemblages (Ryder and others, 1976). The Colton thins and contains less sandstone to the west, and thickens and contains more stacked channel-form sandstone to the east.

8.3 (0.3) Bridge over Willow Creek.

8.4 (0.1) Graded road to the right (east) is the end of this road log, and the beginning of the Upper Willow Creek Canyon and Indian Canyon road log.

UPPER WILLOW CREEK CANYON AND INDIAN CANYON ROAD LOG
From Emma Park to the town of Duchesne

Cumulative
Mileage (distance between)

0.0 Graded road 0.1 mile (161 m) north of the bridge over Willow Creek. The road goes east to the coal-bed methane wells in the Castlegate field and farther east to Soldier Creek Canyon. Good view of Flagstaff Member of the Green River, Colton Formation, and lower member of the Green River Formation.

0.3 (0.3) Carbon and Duchesne County line.

1.8 (1.5) Sandstone in Colton Formation (figure 5) about 200 feet (60 m) below the carbonates in the lower member of the Green River Formation (also known as the first lacustrine tongue [Bradley, 1931], black shale facies [Picard, 1957], and Uteland Butte Limestone [Osmond 1992]). Thomas Morris, Brigham Young University, (verbal communication, 1994) believes this bed is more like a distributary channel than a typical Colton fluvial channel.

Figure 5. Distributary channel in the Colton Formation about 200 feet below the base of the Green River Formation. View is to the west (mile 1.8).

2.2 (0.4) Contact between the Colton and Green River Formations at mile post 168. The basal carbonates in the lower member of the Green River Formation were studied by Little (1988) who described them as a mix of siliciclastic and carbonate rocks deposited in margin, shallow, and offshore environments of the lake.

2.4 (0.2) Coal near the top of the basal carbonates (first lacustrine tongue) in Green River and base of Colton tongue.

2.8 (0.4) Bituminous sandstone (tar sand) is seen in exposures on the west side of road. The bed is about 45 feet (13.7 m) thick and saturated top to bottom (figure 6). The overlying sandstone bed is not saturated. An oyster bed, that is the base of the second lacustrine tongue of the Green River at this location, outcrops a short distance above the second sandstone bed.

Figure 6. Oil saturated sandstone in the Colton Formation (mile 2.8).

3.0 (0.2) Contact between the Colton tongue and second lacustrine tongue of the Green River Formation; oyster bed in the slope is the base of the second lacustrine tongue of the Green River.

3.3 (0.3) Pull out at top of first road cut; good exposure of the black shale facies in the lower member of the Green River Formation (figure 7). Interbedded black shale and carbonate grainstone, some containing gastropods, pelecypods, ostracods, and oolites. Road cut exposes the first 87 feet (0-26.5 m), units 1 through 11, on UGS measured section 1 (Appendix A, UGS 1 Willow Creek Canyon).

Figure 7. Long Point bed in the black shale facies of the lower member of the Green River Formation. Interbedded black shale, carbonate mudstone and grainstone; some contain gastropods, pelecypods, ostracods, and oolites. A thin coal bed (less than 1 inch thick) can be found near the base of the road cut (mile 3.3).

3.5 (0.2) Carbonate marker bed (figure 8) which divides the lower member (black shale facies) from the middle member (delta facies) of the Green River Formation. Weiss and others (1990) mapped the base of the carbonate marker bed as the top of the lower member. The top of the bed is more easily identified here and in Nine Mile Canyon. Also, the top of the carbonate marker bed has often been used to divide the two units. In my work, I have used the lower and middle member terminology, but define them using the top of the carbonate marker bed as the boundary. The top is at 339 feet (103.3 m), unit 45 on UGS measured section 1 (Appendix A, UGS 1 Willow Creek Canyon), described as interbedded oolitic grainstone, black shale, black to dark gray micritic limestone to limy shale. The top of the lower member is overlain by 1 foot (0.3 m) of green shale, which, in turn, is overlain by sandstone, light gray, fine grained, calcareous, intensely current rippled, with a flat base and gradational top.

Figure 8. Top of the carbonate marker unit and the base of the lower member of the Green River Formation. Interbedded oolitic grainstone, black shale to dark gray micritic limestone to limy mudstone, overlain by interbedded green shale and sandstone (mile 3.5).

3.9 (0.4) Interbedded red and green shale and thin sandstone and limestone (figure 9). Typical mudflat (green shale) to alluvial (red shale) environments with some shallow lake deposits (limestone). This stratigraphic interval is equivalent to MGR 1 through MGR 3 (lower Douglas Creek) which consists of black shale and thick clastic beds interpreted as turbidite deposits (Lutz and others, 1994) in the Monument Butte area.

Figure 9. Interbedded red and green shale, thin sandstone and limestone. This section is equivalent to the MGR 1 through MGR 3 interval which is the lower Douglas Creek reservoir in the Monument Butte area where it consists of black dolomitic shale and locally thick clastic turbidite sandstone deposited in incised cut-and-fill channels (mile 3.9).

4.2 (0.3) The marlstone (figure 10) in the lower portion of the road cut may be equivalent to the B limestone (top of MGR 3) in the subsurface, and the Remy D marker in Nine Mile Canyon, in the middle member of the Green River Formation. From here to the start of the S, turn the section correlates with subsurface units MGR 5, 6, and 7 (upper Douglas Creek reservoir), the primary pay section (B, C, and D, sands) in the Monument Butte area (figure 1).

Figure 10. Marlstone in the lower portion of the road cut may be equivalent to the B limestone (MGR 3) of the Green River Formation. The upper portion of the road cut has a thin oil shale. This interval is equivalent to the D marker and purple-black oil shale in Nine Mile Canyon (mile 4.2).

4.6 (0.4) End of road cut, beginning of S turn.

4.9 (0.3) Good location to see channel-form sandstone beds, and clay to mixed clay-sand filled channel forms (figure 11).

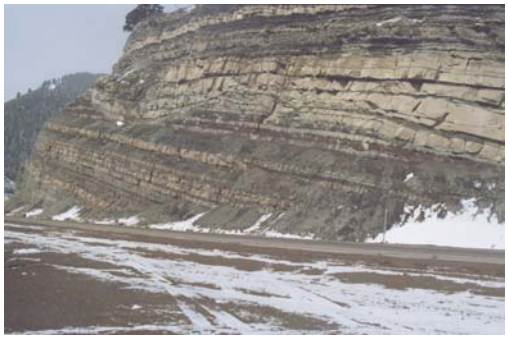

Figure 11. Channel-form sandstone beds and clay to mixed clay-sand filled channels (mile 4.9).

5.2 (0.3) Numerous limy mudstone to marlstone beds, tan, that weather to a light tan to orange (figure 12), which correlate to MGR 12, thickest marlstone bed at 1,747 to 1,754 feet (532.5-534.6 m); may be Remy C marker, a prominent algal boundstone to large algal stromatolite bed in Nine Mile Canyon. In Nine Mile Canyon, Remy uses the C marker to divide the delta facies from the overlying transitional facies. The MGR 12 log cycle containing the Remy C carbonate bed is easily correlated throughout most of the Monument Butte area. Fouch (1981) correlated the C marker with the middle marker (Ryder and others, 1976) (also known as the TGR3 and H marker by oil field operators) in the Altamont and Bluebell fields. Our correlations, using the lithostratigraphic descriptions and surface gamma-ray data of the measured sections in Willow Creek and Nine Mile Canyons, show the middle marker to be equivalent to the MGR 16 unit, with significant thickening between the MGR 12 (C marker) and the Mahogany oil shale zone, from outcrop to the Altamont and Bluebell fields.

Figure 12. Numerous limy mudstone beds. Interval correlates to MGR 12, thickest marlstone bed may be equivalent to the C marker in Nine Mile Canyon (mile 5.2).

5.7 (0.5) Pull off near the small shed, just past the Forest Service road to Avintaquin campground. Bituminous sandstone bed underlain by algal boundstone. Fouch and others (1976) correlate the bituminous sandstone bed to their S1 marker bed. The S1 marker is a sandstone bed below the Mahogany oil shale zone that is laterally extensive throughout most of the southwest Uinta Basin.

6.0 (0.3) Top of the next road cut. Mahogany oil shale zone is in the upper portion of the road cut (Garner and Morris, 1996).

6.2 (0.2) Fouch and others (1976) S2 marker bed. The S2 marker is a sandstone bed above the Mahogany oil shale zone that is laterally extensive throughout most of the southwest Uinta Basin.

6.3 (0.1) Wavy-bedded tuff.

6.4 (0.1) Junction with road east to Argyle Canyon.

6.5 (0.1) Low grade oil shales, end of measured section by Garner and Morris (1996).

7.0 (0.5) Road begins down Indian Canyon.

7.9 (0.9) Pull off area, first bench is the Horse Bench sandstone bed in the upper member of the Green River Formation (Weiss and others, 1990). The Horse Bench sandstone forms a prominent bench throughout most of the southwest Uinta Basin. In the subsurface, the Horse Bench sandstone bed is approximately equivalent to the upper marker of Fouch (1975).

13.9 (6.0) Horse Bench sandstone bed at road level.

18.4 (4.5) Wurtzillite mine high on the cliff face in the upper Green River Formation. Wurtzillite is a solid asphaltite hydrocarbon. There are four types of solid hydrocarbons in the Uinta Basin; ozocerite, albertite, gilsonite, and wurtzillite. Gilsonite is the only form that is commercially mined in the basin.

18.8 (0.4) U. S. Forest Service sign.

31.9 (13.1) Duchesne fault zone, recently studied by Groeger and Bruhn (2001). They describe the zone as a system of east-trending normal faults and joints several miles (tens of kilometers) long. The master fault dips steeply northward and accommodates about 650 feet (200 m) of slip and terminates downward at a depth of 4,500 feet (1,400 m), or flattens out at a depth of about 3,300 feet (1,000 m).

32.2 (0.3) Junction with road to the west going to Cottonwood Ridge and Sowers Canyon.

34.1 (1.9) Bridge over the Strawberry River.

34.5 (0.4) Junction of Utah Highway 33 (Indian Canyon) and U.S. Highway 40. End of road log.

SOLDIER CREEK AND NINE MILE CANYONS ROAD LOG
From Wellington to the Junction of Cottonwood and Nine Mile Canyons

Cumulative Mileage (between mileage)	
0.0	Turn north off of U.S. Highway 6 onto Nine Mile Canyon road (next to the Chevron truck stop). The road is on the Cretaceous Mancos Shale. Here the Mancos represents deposition of offshore muds in the Western Interior seaway about 82 to 95 million years ago.
1.0 (1.0)	Looking straight ahead (east), the low hills are the Farnham Dome formed by the Ferron Sandstone Member of the Mancos Shale. The Ferron Sandstone is a fluvial-deltaic deposit formed along the shores of the Western Interior seaway about 95 million years ago. The Farnham Dome field produced 4.76 billion cubic feet (BCF) of carbon dioxide (CO_2) from the Jurassic Navajo Sandstone and supplied a dry ice plant in Wellington from 1931 to about 1979. The Sinbad Limestone Member of the Triassic Moenkopi Formation tested 2,750 thousand cubic feet of CO_2 per day (MCFGPD), but was never produced (Morgan and Chidsey, 1991).
2.0 (1.0)	Pediment surfaces formed on the Mancos Shale; Book Cliffs in the background are formed by the Cretaceous Mesaverde Group.
5.7 (3.7)	Road to the east (right) leads to the Dugout Canyon mine which began producing coal from the Rock Canyon seam of the Blackhawk Formation (Mesaverde Group) in 1998. The mine is designed to produce 3 million tons of coal per year.
11.5 (5.8)	The sandstone-shale transition of the Mancos Shale and overlying Star Point Sandstone (Mesaverde Group) can be seen in the stream bed. At this location, the Star Point consists of thin sandstones deposited by storm waves in the Western Interior seaway, and represents a shallowing of the sea. Anderson (1983) measured a maximum thickness of 230 feet (70.1 m), and describes the Star Point as interbedded mudstone, siltstone, and sandstone. The Star Point is overlain by the Blackhawk Formation which is 910 to 1,215 feet (277.4-370.3 m) thick in the area (Anderson, 1983 [figure 13]). The Blackhawk represents continuing shallowing of the sea, with thicker sandstone deposits grading upward to nearshore and beach sandstone and to swamp deposits where peat and later coal was formed. Coal has been mined from the Blackhawk for over 100 years in this general area.

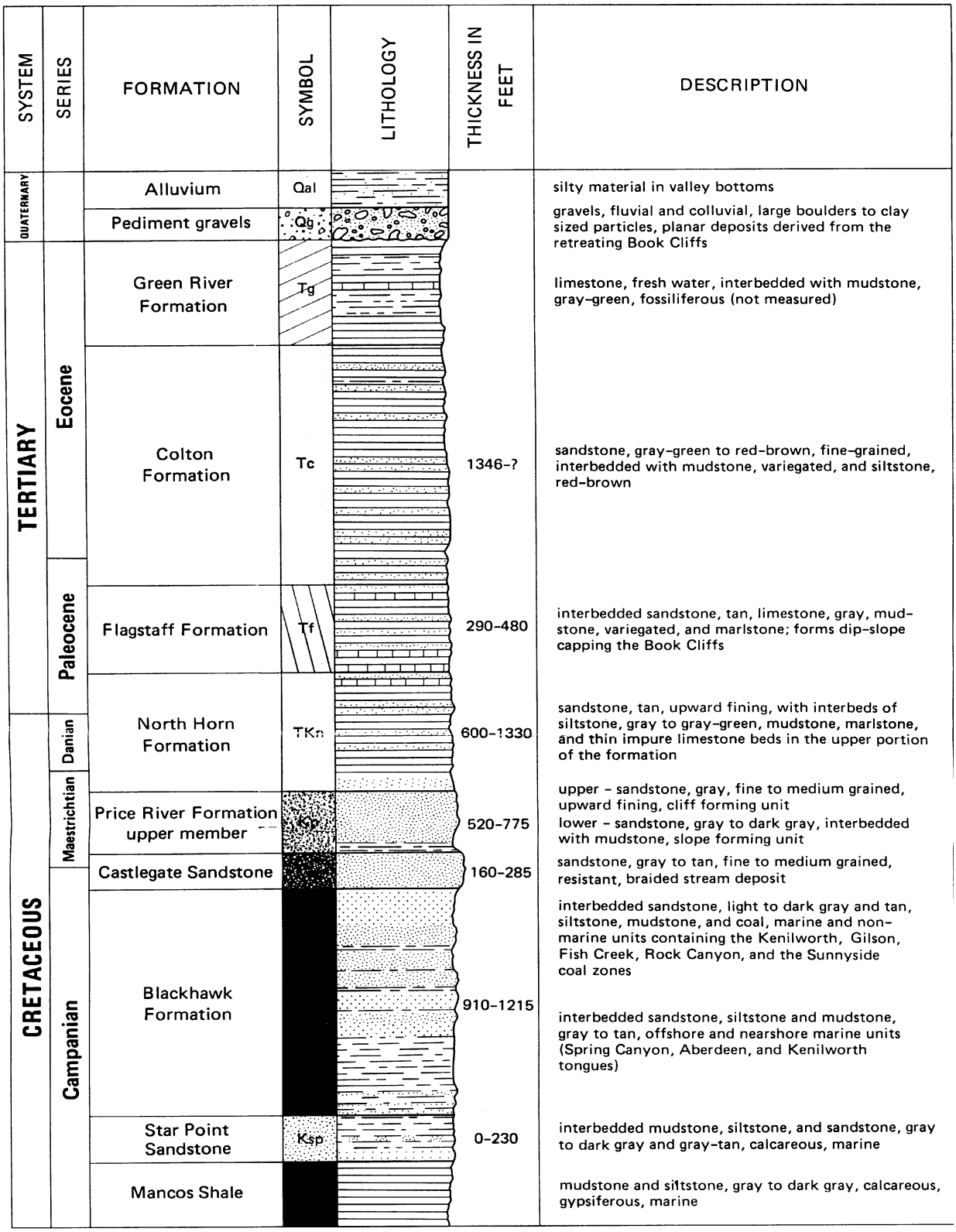

Figure 13.. Stratigraphic section for the Pine Canyon quadrangle, Carbon County, Utah, from Anderson (1983).

12.6 (1.1) Soldier Creek mine entrances are seen on both sides of the road. The mine produced more than 15 million tons of coal from several seams in the Blackhawk from 1970 through 1998, when the mine was closed.

12.7 (0.1) End of pavement.

14.1 (1.4) Contact between the Castlegate Sandstone and underlying Blackhawk Formation. Anderson (1983) describes the Castlegate as a fine to medium grained sandstone, deposited by braided streams, and 160 to 285 feet (48.8 - 86.9 m) thick. The braided streams were deposited about 78 million years ago in an upper coastal-plain environment, as the sea withdrew farther to the east.

14.5 (0.4) Approximate contact between the Price River Formation and underlying Castlegate Sandstone. Anderson (1983) shows 520 to 775 feet (48.8 - 86.9 m) of Price River, with a lower slope-forming sandstone interbedded with mudstone, and an upper cliff-forming, upward fining sandstone. The Price River and North Horn Formations are both fluvial and overbank deposits.

14.9 (0.4) The road to the west follows Whitmore Park, a strike valley formed in the top of the Flagstaff Member of the Green River Formation and basal Colton Formation. The road connects with Utah Highway 33 in Willow Creek Canyon. This location is also the approximate boundary between the North Horn Formation and underlying Price River Formation (figure 14). Anderson (1983) describes the North Horn Formation as 600 to 1,330 feet (182.9 - 405.4 m) thick, sandstone, upward fining, with interbeds of siltstone, gray to gray-green mudstone, marlstone, and thin impure limestone beds in the upper portion of the formation. The North Horn consists of fluvial channel and overbank deposits, as well as some small lake deposits. At that time the sea had completely withdrawn from the region ending the general west-to-east depositional pattern, and the interior drainage of the Uinta Basin now dominates with a general south-to-north depositional pattern beginning in the Late Cretaceous. The North Horn was deposited from 65 to 57 million years ago, straddling the Cretaceous-Tertiary boundary.

Figure 14. Boundary between the North Horn and underlying Price River Formation (mile 14.9).

15.9 (1.0) The dip slope and part of the valley are composed of the Flagstaff Member of the Green River Formation; some limestone can be found in the road cut. Anderson (1983) describes the Flagstaff as 290 to 480 feet (88.4 - 146.3 m) thick, interbedded sandstone, limestone, variegated mudstone, and marlstone; forms dip slope that caps the Book Cliffs. The valley floor is the Flagstaff and Colton Formation contact. The red cliffs to the north are made up of the Colton (figure 15). Anderson (1983) describes the Colton as 1,346 feet (410.3 m) thick or more, sandstone interbedded with variegated mudstone and red-brown siltstone. The Flagstaff is the first major lacustrine deposit of Lake Uinta (some thin lacustrine rocks are found in the North Horn), which occupied most of the present day Uinta Basin and the north-to-south area of the present day Gunnison and Wasatch Plateaus. The Flagstaff is the primary source and reservoir within the Altamont and Bluebell fields at a drill depth of about 14,000 to 16,000 feet (4,300 - 4,900 m). The entire Flagstaff is seldom penetrated, but it is about 3,000 feet (900 m) thick in the Altamont and Bluebell fields.

Figure 15. Whitmore Park. The Flagstaff and Colton Formation contact is in the valley floor. The Colton Formation is exposed in the red cliffs in the distance (mile 15.9).

17.8 (1.9) Cattle guard and divide between Soldier Creek and Nine Mile drainage.

18.9 (1.1) Cabin to the left is built on Colton Formation, the top of the cliff to the north (left) is the lower member of the Green River Formation.

21.2 (2.3) Road going up Minnie Maude Creek with good exposures of the lower member of the Green River Formation (Weiss and others, 1990). View to the north (figure 16) is of the first lacustrine tongue of the lower member (also known as the Uteland Butte Limestone or the basal limestone) of the Green River Formation and an intervening tongue of the reddish Colton, which is, in turn, overlain by the second lacustrine tongue of the Green River (terminology from Bradley, 1931). The top of the cliff may be sandstone of the Renegade Tongue (terminology from Cashion, 1967) of the middle member of the Green River (Weiss and others, 1990). The Green River carbonates were studied in the Minnie Maude Creek area by Little (1988). Much of the property is private. The red beds of the Colton

Formation are alluvial, deposited during a time when Lake Uinta was much smaller. Lake level fluctuations resulted in interbedding of red (alluvial) rocks with gray and green rocks of the Green River Formation. The Green River and Colton Formations were deposited from 55 to 45 million years ago.

Figure 16. Road going up Minnie Maude Creek. Red beds at the base of the cliff are Colton Formation, overlain by the first lacustrine tongue of the lower member of the Green River Formation. Mid-cliff is a tongue of the Colton overlain by the second lacustrine tongue of the Green River. The top of the cliff may be sandstone in the Renegade Tongue of the middle member of the Green River (mile 21.2).

21.4 (0.2) Bridge over Minnie Maude Creek.

22.9 (1.5) Cattle guard and entrance to Nine Mile Canyon.

23.0 (0.1) Tongue of the Colton Formation overlain by the second lacustrine tongue, or carbonate marker unit, of the lower member of the Green River Formation. Sandstone capping the cliff is probably the Renegade Tongue of the middle member of the Green River (figure 17).

Figure 17. Tongue of the Colton Formation beginning at road level, overlain by the second lacustrine tongue, or carbonate marker unit, of the lower member of the Green River Formation. Sandstone capping the cliff is probably the Renegade Tongue of the middle member of the Green River (mile 23.0).

23.6 (0.6) Mountain Fuel Supply's Keel Ranch 1 well to the north (left) was spudded 180 feet (55 m) above the base of the Colton Tongue (Fouch and others, 1976). The well was drilled to a total depth of 9,182 feet (2,798.7 m) in the Mancos Shale. Petroleum Information/Dwights® well data follows:

Completed 1964, total depth 9,182 feet (2,798.7 m) in Cretaceous Mancos Shale. Formation tops are; Colton (Wasatch) 515 feet (156.9 m), Price River 4,365 feet (1,330.5 m), Castlegate 5,330 feet (1,624.6 m), Blackhawk 5,635 feet (1,717.5 m), and Mancos 6,920 feet (2,109.2 m).
The following intervals were tested open-hole:
4,645 to 4,680 feet (1,415.8-1,424.4 m) (Price River) gas-to-surface (GTS) too small to measure (TSTM), shut-in pressure (SIP) 669 pounds per square inch (psi)
5,716 to 5,744 feet (1,742.2-1,750.8 m) (Mesaverde) mud
6,195 to 6,224 feet (1,888.2-1,897.1 m) (Mesaverde) mud
6,340 to 6,390 feet (1,932.4-1,947.7 m) (Mesaverde) 6 MCFGPD, 267 feet (81.4 m) slightly gas cut mud (GCM), SIP 1,230 psi
7,480 to 7,545 feet (2,279.9-2,299.8 m) (Mancos) mud
7,615 to 7,635 feet (2,321.1-2,327.1 m) (Mancos) 18 MCFGPD, 30 feet (9.1 m) GCM, SIP 265 psi
8,097 to 8,140 feet (2,467.9-2,481.1 m) (Mancos) 1,023-670 MCFGPD, 195 feet (59.4 m) mud, SIP 3,260 psi
8,945 to 8,965 feet (2,726.4-2,732.5 m) (Mancos) GTS TSTM, 180 feet (54.9 m) GCM, SIP 235 psi
The well was deepened to 12,646 feet (3,854.5 m) by Trigg Drilling in 1981. Reported formation tops are: Ferron 11,260 feet (3,432.0 m) and Dakota 12,000 feet (3,657.6 m). The Dakota was perforated from 12,196 to 12,590 feet (3,717.3-3,837.4 m) (gross) and tested a maximum of 2,300 MCFGPD. The Ferron was perforated from 11,374 to 11,420 feet (3,466.8-3,480.8 m), no results reported. Plugged back to 8,242 feet (2,512.2 m) and completed in the Mancos from 8,084 to 8,138 feet (2,464.0-2,480.5 m) for 444 MCFGPD. The well was plugged and abandoned in 1986 with a cumulative production of 94 barrels of oil (BO), 39,162 MCFG, and 38 barrels of water (BW).

23.8 (0.2) The Bed and Bunk.

24.4 (0.6) To the north (left) is the location of Remy's measured section 11 (Remy 1992) of the lower member of the Green River Formation; to the south is Cow Canyon.

25.1 (0.7) Good exposure of carbonate and sandstone beds in the carbonate marker unit (Castle Peak) of the lower member (figure 18).

Figure 18. Good exposure of carbonate and sandstone in the carbonate marker unit (also known as the Castle Peak) of the lower member of the Green River Formation (mile 25.1).

25.9 (0.8) The north (left) side of the road displays the easternmost exposure of the lower member of the Green River Formation, which is overlain by large channel-form sandstone beds of the Renegade Tongue (figure 19).

Figure 19. View to the west of the top of the carbonate bed at road level overlain by thick channel-form sandstone beds of the Renegade Tongue (mile 26.1).

26.1 (0.2) Location of UGS Argyle Ridge measured section (Appendix B, UGS 2 Argyle Ridge), and Remy's (1992) measured section 16. This is the best location to see the complete section of the delta facies (Picard [1957] green shale facies), from the base of the middle member to the C marker.

26.3 (0.2) Pull out (right side) to see petroglyphs on the north side of the road on channel sandstone of the Renegade Tongue.

27.3 (1.0) Cottonwood Glen picnic area and rest stop.

29.9 (2.6) Cottonwood tree on north side of road, view straight ahead of a nice depositional sequence consisting of carbonate - green shale - sandstone - green shale - carbonate (figure 20).

Figure 20. View of two depositional sequences from bottom up: carbonate-green shale-sandstone-green shale, then the cycle is repeated again (mile 29.9).

30.6 (0.7) Location of Remy's measured section 8 and Old Station. This site is part of the old town of Harper which once extended about a mile along the road. Mail deliveries and voting took place in these buildings. Originally homesteaded by Tom Tyler, the property was purchased by Ed Lee and became known as Lee Station, a stage stop. The steel poles seen in many parts of the canyon held the telegraph line which was installed by the U.S. Army around 1886. The telegraph line became the telephone line into the Uinta Basin from 1907 until 1917 (Utah Historical Society, 1993).

30.8 (0.2) Petroglyphs on sandstone north of road.

31.0 (0.2) Cottonwood tree on south (right) side of road, exposure of D marker and purple-black oil shale (figure 21), described by Fouch and others (1976) as:
"Light-gray carbonate mudstone capped by an oolite grainstone composed of coated ostracods. The unit is part bituminous. Overlying the grainstone is a 3.5-foot (1.1-m), gray-green claystone which, in turn, is overlain by algal stromatolitic boundstone up to 2.5 feet (0.8 m) thick. The stromatolitic boundstone is, in turn, overlain by a complex of composite channel-form sandstone beds. These beds are capped by a 2 inch (5 cm) thick bed of thinly laminated, organic-rich, mud-supported carbonate (oil shale)."

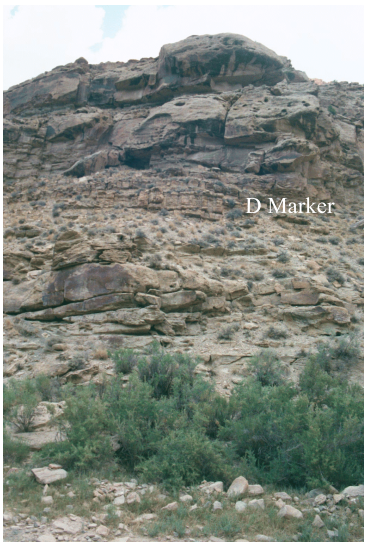

Figure 21. Exposure of D marker about mid-slope and oil shale above the D marker at the base of the sandstone (mile 31.0).

31.3 (0.3) View of Argyle junction; the flat-based sandstone bed located just about at road level (Argyle Canyon) is where the purple-black oil shale bed is found. Further up the slope, looking from east to west (right to left), you can see individual channel-form sandstone beds thicken and coalesce into a single sandstone bed greater than 60 feet (18 m) thick.

31.4 (0.1) Junction of Argyle and Nine Mile Canyons. The Argyle Canyon road continues west and intersects the Willow Creek Canyon road near the drainage divide between Willow Creek and Indian Canyons. A school house was built at the mouth of Argyle Canyon in 1895, but it was moved to Wellington in the 1930s (Utah Historical Society, 1993).

32.1 (0.7) Pig head balanced rock with some petroglyphs. Early freighters called it "the giant's chew of gum."

32.2 (0.1) Some excellent petroglyphs exposed on the north (left) side of the road.

32.7 (0.5) Carbon and Duchesne County line.

32.8 (0.1) Old abandoned ranch with numerous buildings. On the south (right) side of the road is the Harmon home. Ed Harmon was an early rancher and telegrapher in the area. On the north (left) side of the road was a one-room schoolhouse built about 1901, which was used as a community events center, hosting local hoe-downs (Utah Historical Society, 1993).

33.4 (0.6) Trail Canyon on the north (left) and Harmon Canyon on the south (right). Excellent petroglyphs on the sandstone at the northeast corner of Trail Canyon.

The Stone Cabin 3 well was drilled 0.7 miles (1.1 km) up Harmon Canyon. The well was completed in 1960, at a total depth of 4,500 feet (1,371.6 m). The top of the Colton (Wasatch) Formation was penetrated at 1,720 feet (524.3 m). The well was perforated in the Colton from 3,949 to 4,278 feet (1,203.7-1,303.9 m) and flow tested 1,500 MCFGPD. The well was plugged and abandoned in 1962, with a cumulative production of 369,997 MCFG and no oil or water.

The Badlands Cliff 2 well was drilled 3.25 miles (5.2 km) north, at the head of Trail Canyon, and was spudded in rocks just above the top of the Mahogany oil shale zone. The Badlands Cliff 2 well was completed in 1961, at a total depth of 7,773 feet (2,369.2 m) in the Cretaceous Mesaverde. The Colton (Wasatch) Formation was encountered at 3,350 feet (1,021.1 m) and Mesaverde at 7,746 feet (2,360.9 m). The following intervals were tested open-hole:
5,555 to 5,572 feet (1,693.2-1,698.3 m) (Colton) 89 MCFGPD, SIP 176 psi
5,814 to 5,856 feet (1,772.1-1,784.9 m) (Colton) 10 feet (3.0 m) mud
6,026 to 6,091 feet (1,836.7-1,856.5 m) (Colton) 170 feet (51.8 m) mud
6,231 to 6,239 feet (1,899.2-1,901.6 m) (Colton) 85 feet (25.9 m) slightly GCM
6,239 to 6,254 feet (1,901.6-1,906.2 m) (Colton) 1,256 feet (382.8 m) water cut mud (WCM) SIP 526 psi
7,048 to 7,069 feet (2,148.2-2,154.6 m) (Colton) 20 feet (6.1 m) GCM
7,253 to 7,273 feet (2,210.7-2,216.8 m) (Colton) 87 feet (26.5 m) GCM
The well was perforated in the Mesaverde from 7,239 to 7,375 feet (2,206.4-2,247.9 m), and in the Colton from 7,039 to 7,064 feet (2,145.5-2,153.1 m) and swabbed load water. The well was completed in the Colton from 5,565 to 5,581 feet (1,696.2-1,701.1 m) for 81 MCFGPD. The well was plugged and abandoned in 1961, with no reported production.

34.4 (1.0) Road marker 35, another good location to look at the D marker and purple-black oil shale.

35.0 (0.6) Active ranch house was the Egan Ranch and an early stagecoach stop (Utah Historical Society, 1993).

35.7 (0.7) Across the cattle guard and on the south (right) side of the road is a gas well which is usually not visible at road level due to vegetation. The north side (left) is Current Canyon; the UGS measured a section here beginning at the northeast corner of Current Canyon.

The well is the 33-36 Stone Cabin, completed in 1979, at a total depth of 6,383 feet (1,945.5 m) in the Castlegate Sandstone. Formation tops

from Dwights are: Colton (Wasatch) 1,480 feet (451.1 m); North Horn 3,688 feet (1,124.1 m); Price River 5,898 feet (1,797.7 m); and Castlegate 6,240 feet (1,901.9 m). The well is perforated in the North Horn from 3,865 to 4,460 feet (1,178.1-1,359.4 m). Cumulative production as of May 2001, is 22 BO, 189,022 MCFG, and no water. The average daily production for May was 36 MCFGPD; no oil or water.

36.7 (1.0) North (left) side of the road is a large block with ripples.

37.3 (0.6) Easternmost exposure of the D marker.

37.9 (0.6) Petes Canyon; this is the western corner of the UGS Nutter's Ranch study site.

38.0 (0.1) Nutter's Ranch house. The ranch was first homesteaded by a man named Brock. This was a stagecoach stop, and a common resting place for freighters, before heading up Gate Canyon to Myton and into the Uintah Basin. Pete Francis bought the place and developed it commercially. There was a fifteen-room hotel (destroyed by fire in the 1930s) and a saloon. Pete was allegedly shot to death in the saloon after which the ranch was sold to Preston Nutter in 1902 who closed the hotel and saloon, and used the ranch as headquarters for his cattle business. When Preston Nutter took control of the ranch the stagecoach stop was moved to the Egan Ranch and then to the Alger Ranch. Preston Nutter had about 25,000 head of cattle which grazed from here to the North Rim of the Grand Canyon. The Nutter family sold the ranch in 1977, and it is currently owned by the Hunt Oil Company (Utah Historical Society, 1993).

38.4 (0.4) Gate Canyon and Nine Mile Canyon junction; this is the eastern corner of the Nutter's Ranch study site. Figure 22 is a photomontage and a simplified interpretation of the lateral and vertical facies changes within the study site. The cliff to the northeast provides a good view of the C marker (figure 23), which divides the delta facies from the overlying transitional facies.

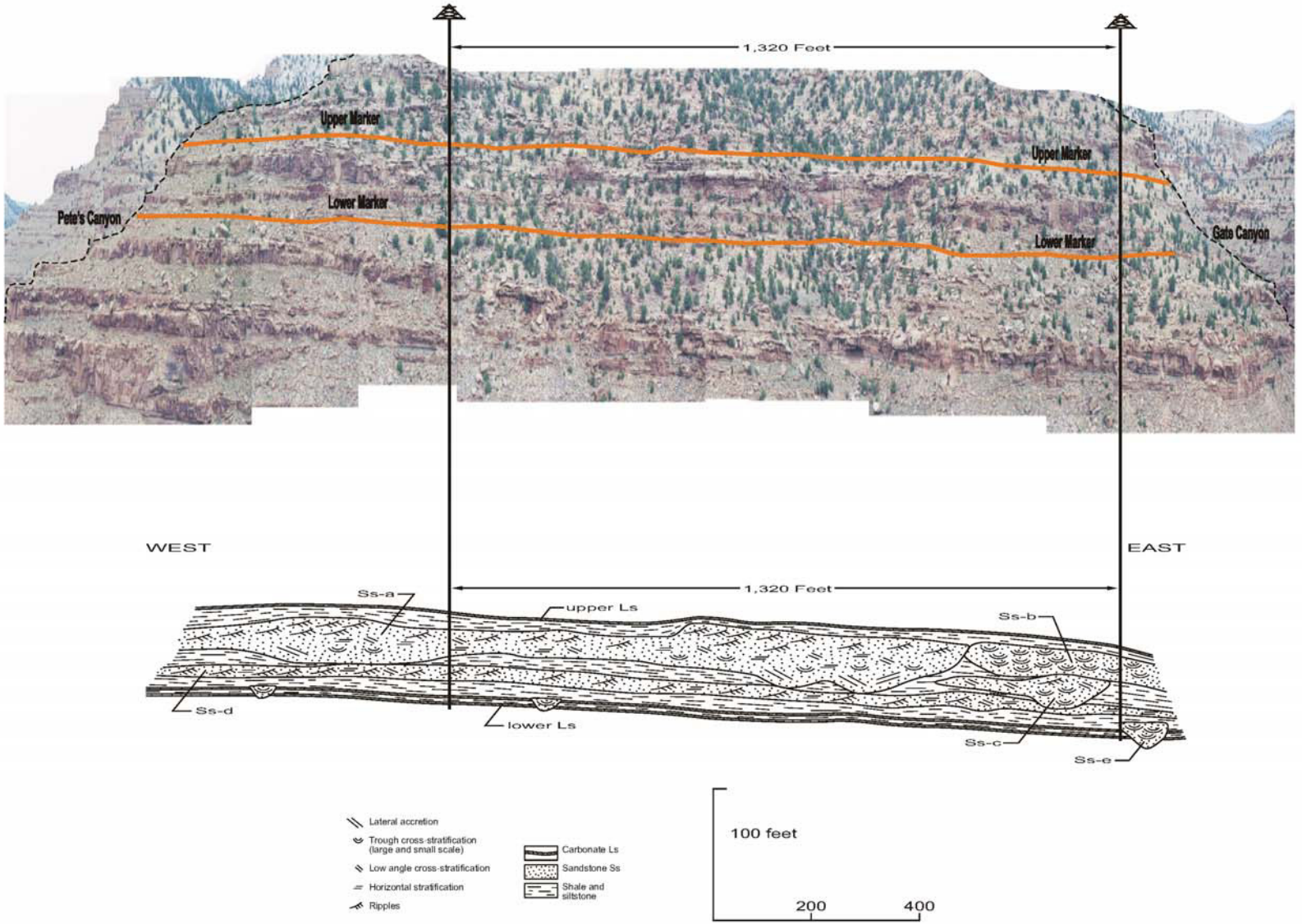

Figure 22. Photomontage and a simplified interpretation of the Nutter's Ranch study site. Two imaginary wells demonstrate the type of reservoir heterogeneity that can exist.

Figure 23. View of the C marker from the junction of Gate and Nine Mile Canyons (mile 38.4). The C marker is the prominent bleached white bed. At this location the bed is a stromatolitic algal boundstone.

39.2 (0.8) Pipeline compressor station where the gas line from Peters Point gas field joins the main gas line from the Uinta Basin to Salt Lake City. The Questar pipeline (JL 47) was built by Mountain Fuel Supply in 1972. The line is 12 inches (30 cm) in diameter with a capacity of more than 40 million cubic feet of gas per day, and delivers gas from the Uinta Basin to the Wasatch Front.

41.4 (2.2) Gas well on the south (right) side of the road. The well is the 1 Government Pickrell drilled to a total depth of 8,450 feet (2,575.6 m) in the Mancos Shale, and completed in 1962. Formation tops from Dwights are: Colton (Wasatch) 1,612 feet (491.3 m); Mesaverde 5,425 feet (1,653.5 m); and Mancos Shale 8,344 feet (2,543.3 m). The well is perforated in the Colton from 3,782 to 4,044 feet (1,157.8-1,232.6 m). Cumulative production as of May 2001, is 701,660 MCFG, and no oil or water. The average daily production for May 2001 was 59 MCFGPD. The initial potential for the well was 2,400 MCFGPD, with a shut-in tubing pressure of 2,702 psi (0.67 psi/feet).

41.6 (0.2) Road to the south (right) goes up Prickly Pear Canyon.

42.3 (0.7) Block with ripples on the north (left) side of the road.

43.5 (1.2) To the south (right) is a view of a rock tower called the Mummy.

43.8 (0.3) On the north (left) side of the road about 15 feet (4.6 m) above road level is a good exposure of a channel cut filled with green shale and siltstone.

44.0 (0.2) Daddy Canyon; rest rooms and lots of petroglyphs at this location

44.9 (0.9) Junction with Cottonwood Canyon and Nine Mile Canyon. The south (right) side of the road is the location of Remy's (1992) measured section 9 (figure 24). Remy (1992) describes the lower 328 feet (100 m) of the section as a delta front assemblage of the Sunnyside delta, consisting of "thick amalgamated sandbodies which are interpreted as stacked distributary mouth bars, and associated mudstone, thin sandstone, and limestone beds that accumulated in subaqueous to subaerial mudflat, crevasse-splay, overbank, and shallow-lacustrine sandsheet, and lake-

margin carbonate-flat environments."

Figure 24. Junction of Nine Mile Canyon and Cottonwood Canyon roads (mile 44.9). View is south of Remy's section 9.

45.

8 (0.9) Trail on south (right) side of road leads up the small rise and provides an excellent view of the cliffs on the north side of Nine Mile Canyon (figure 25).

Figure 25. Delta-front assemblage of stacked sandstone overlain by interbedded sandstone, shale, and limestone beds of the transitional facies. Looking north from trail at mile 45.8.

46.1 (0.3) Rock art panel near the mouth of Cottonwood Canyon (figure 26).

End of road log.

Figure 26. Rock art panel at the mouth of Cottonwood Canyon (mile 46.1).

GATE CANYON ROAD LOG
From Nine Mile Canyon to US 40 near the town of Myton

Cumulative Mileage (between mileage)	
0.0	Junction of Gate Canyon and Nine Mile Canyon.
0.9 (0.9)	"Outlaw Point," this is where several outlaws planned to rob the U.S. Army payroll and kill the 20 soldiers riding with it to the Uinta Basin. The Army was warned and doubled the guard. As a result, the robbers, who had been hiding on the ledges above, decided to call it off. Some people say Butch Cassidy tipped off the Army, to avoid blame for the murders and robbery (Utah Historical Society, 1993).
2.7 (1.8)	Bituminous sandstone bed crops out at road level.
3.4 (0.7)	The sandstone beds here are the Fouch S1 unit. Fouch and others (1976) state that "the S1 unit can be traced regionally along the south flank of the basin and is commonly oil-impregnated as it is in Willow Creek Canyon" (mile 5.7, Upper Willow Creek Canyon and Indian Canyon Road Log).
3.7 (0.3)	Mahogany oil shale zone.
4.0 (0.3)	Thin, flat-bedded sandstone and siltstone beds make up the S2 marker unit (Fouch and others 1976). Just to the east of the road, the sandstone is quarried for building stone on land leased from the Utah School and Institutional Trust Lands Administration.
4.1 (0.1)	Fouch and others (1976) place the wavy-bedded tuff (Cashion 1967) at this location.
4.8 (0.7)	Horse Bench sandstone bed of the upper member of the Green River Formation, forms a prominent bench throughout much of the southern Uinta Basin. Fouch (1975) calls this bed the upper marker in the subsurface.
5.0 (0.2)	Junction with road heading east to Sand Wash boat ramp. The road follows the top of the Horse Bench sandstone.
5.7 (0.7)	Base of the Eocene Uinta Formation.
6.9 (1.2)	Drainage divide between Gate Canyon and Wells Draw.

15.2 (8.3) "The Wells." Owen Smith dug a well here in 1891, and built an eight-room hotel, general store, hay house, blacksmith shop, and restaurant, to serve the stagecoach and freighters (Utah Historical Society, 1993).

For the next several miles you will see numerous oil wells that are in the western portion of the Monument Butte field. The wells are operated by Inland Resources and are producing from the middle and lower members of the Green River Formation at a depth from 5,500 to 6,500 feet (1,676 - 1,981 m).

Pavement begins at the boundary of the Uintah and Ouray Indian Reservation.

29.1 (13.9) Junction with Sand Wash road which leads to the Inland Resources field office (1.5 miles) and continues past abandoned gilsonite mines to Sand Wash boat ramp. Turn left (north) towards US Highway 40.

30.6 (1.5) End of road log, junction with US Highway 40.

DESOLATION CANYON AND GRAY CANYON RIVER LOG

River Miles (between mileage)

95.8 Sand Wash boat ramp. The Sand Wash boat ramp is an old ferry site that is now a boat ramp operated by the Bureau of Land Management (BLM). The ferry transported livestock and wagons across the river from the 1920s until 1952 (Canyonlands Natural History Association, 1993). This is the beginning of Desolation Canyon. The stratigraphy at the boat ramp ascending from river level, consists of the upper portion of the middle member and then the upper member of the Green River Formation. The lowermost cliff near the boat ramp is capped by the Mahogany oil shale which forms the base of the upper member. The Mahogany oil shale is a kerogen-rich marlstone that was mined in the 1950s and 1960s (Canyonlands Natural History Association, 1993) as evidenced by the numerous small adits visible in the cliff face. The prominent plateau above the Mahogany is formed by the Horse Bench sandstone bed of the upper member. Near the top of the highest cliffs to the north-northeast, a color change from the grays of the Green River shales to a more yellowish-orange sandstone color marks the contact between the Green River and overlying Uinta Formation.

A small landing strip was built on the Horse Bench sandstone just above the boat ramp. The landing strip is used for small planes that ferry boaters from the town of Green River to the Sand Wash boat ramp. The airstrip can be accessed by graded road or foot trail from the boat ramp. Standing at the edge of the plateau near the landing strip you can get an excellent view of the river and the general stratigraphy of the area. Large point bars above and below the boat ramp are visible from this location (figures 27 and 28).

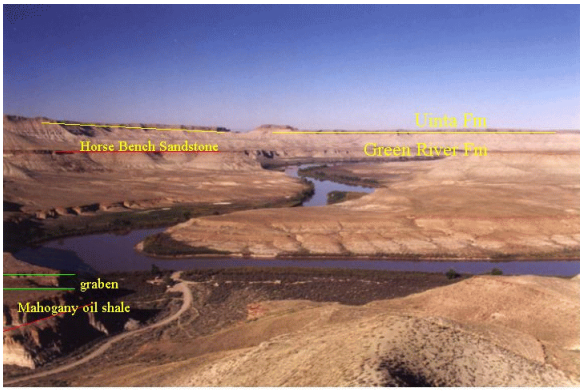

Figure 27. View north of the Sand Wash boat ramp from the landing strip on the Horse Bench sandstone.

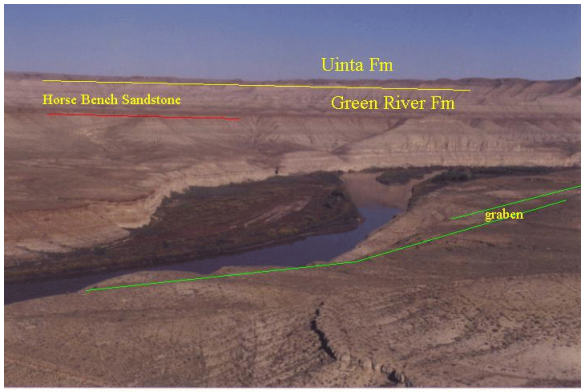

Figure 28. View south from the Sand Wash landing strip on the Horse Bench sandstone.

93.7 (2.1) River right, Nine Mile Canyon Creek enters the Green River.

92.4 (1.3) River left, a fault graben in the upper member of the Green River Formation in the cliff (figure 29). The graben can be traced for about 6 miles (10 km) from this location northwest through the Sand Wash boat ramp (figures 27 and 28). Numerous small faults sole out into a basal detachment. The conjugate fractures continue below the basal detachment. This may be the base of a fault graben similar to the Duchesne fault zone just south of the town of Duchesne. The Duchesne fault zone has several hundred feet of displacement at the surface but terminates within the Green River (Groeger and Bruhn, 2001).

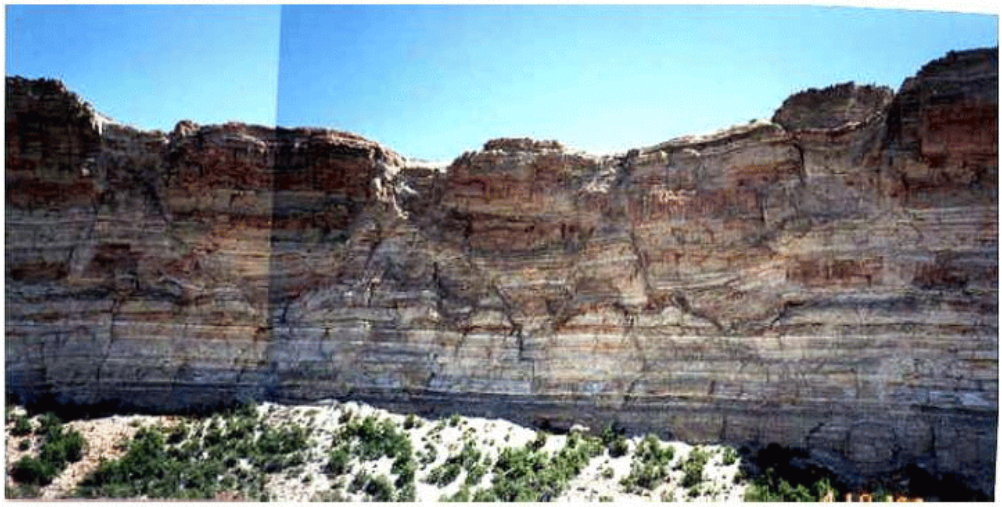

Figure 29. Fault graben in the upper member of the Green River Formation at mile 92.4, view is river left. Numerous small faults sole out into a basal detachment. Notice the displacement terminates at the basal detachment but the fracture pattern continues downward. Graben trends northwest for several miles, see figures 27 and 28.

91.0 (1.4) River left, Duches Hole, on the right is the Gothic Cathedral. The Gothic Cathedral consists of vertical alcoves separated by buttresses formed by differential erosion along vertical joints (Mutschler, 1969). This erosional style is common in the upper portion of Desolation Canyon where the Green River Formation is dominantly shale and siltstone (figure 30).

Figure 30. Gothic Cathedral, view is upriver from mile 89.5.

88.3 (2.7) River left, beginning of the Uintah and Ouray Indian Reservation on the left bank. From here to Coal Creek at mile 26.1, the river is the western boundary of the Uncompahgre Addition of the reservation.

87.8 (0.5) River right, fluvial sandstone beds in the upper portion of the middle member are exposed in the cliff.

86.7 (1.1) Tabyago Riffle caused by a small gravel bar formed at the mouth of Tabyago Canyon that enters from river left. All the riffles and rapids in the main channel of Desolation Canyon exist opposite side canyons where gravel and boulders have washed down during flood stages.

85.0 (1.7) Sumner's Amphitheater named by Major John Wesley Powell in 1869 for Jack Sumner (figure 31).

Figure 31. Sumner's Amphitheater, view is upriver from mile 84.0.

82.0 (3.0) River left, good exposure of the middle member with lenticular sandstone beds and interbedded, thin, laterally continuous carbonate beds (figure 32). The sequence is the typical deposition pattern of lower delta plain to shallow lacustrine environments. The carbonate beds were deposited during lake level rise and are often excellent correlation marker beds for many miles.

Figure 32. Middle member of the Green River Formation with lower delta-plain deposits of interbedded sandstone and laterally continuous carbonate beds, view is upriver from mile 82.5.

81.4 (0.6) River left is a small alluvial bank at the base of Renegade Tongue sandstone. At the foot of the cliff is an old iron-prowed flat-bottom boat. There are several patches of poison ivy at this location. Poison ivy is common along the banks of the Green River, but rarely found at the camp sites.

81.3 (0.1) River left is the beginning of the Gold Bar rincon. A rincon is a large abandoned meander. The section begins in the top of the Renegade Tongue of the Wasatch (Colton) Formation (Cashion, 1967). In Desolation Canyon, the Renegade Tongue ranges in thickness from 780 to 900 feet (238 - 274 m) and is dominantly a cliff-forming sandstone. The Renegade Tongue is equivalent to the lower portion of the middle member of the Green River Formation in Nine Mile Canyon. River right, faults in the Green River Formation (figure 33).

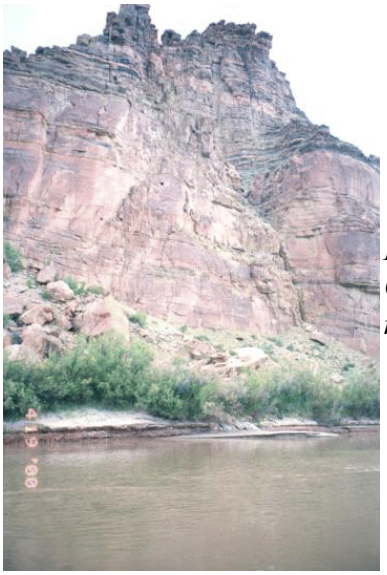

Figure 33. Faulting in the Green River Formation at mile 81.3, view is river right.

80.9 (0.4) Good view up river of the Gold Bar rincon.

80.0 (0.9) River right, Rock House Creek. The cliff that makes the Rock House is formed by sandstone of the Renegade Tongue (figure 34). The upper, more slope-forming area is the interbedded sandstone, shale, and limestone of the lower delta plain to shallow lacustrine deposits. The cliff at the entrance to Rock House Canyon is only a few feet thick (figure 35) and has some nice petroglyphs (figure 36). A 1.5 mile walk (2.5 km) (one way) up Rock House Canyon provides a good view of the Renegade Tongue and overlying lacustrine deposits (figures 37 and 38). Rock House rapid is caused by boulders washed out of Rock House Creek.

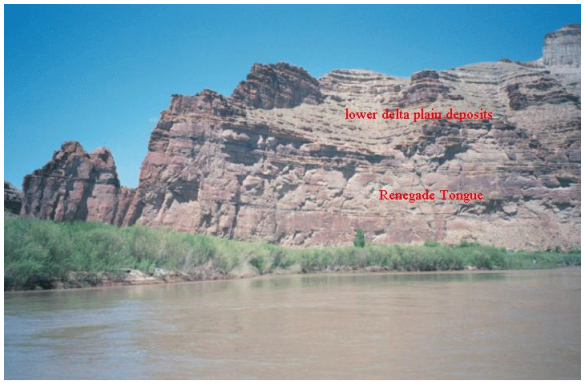

Figure 34. Rock House at mile 80.0, river right. Cliff-forming Renegade Tongue overlain by slope-forming lower delta-plain deposits.

Figure 35. Thin rock wall forming the entrance to Rock House Canyon.

Figure 36. Petroglyphs at the entrance to Rock House Canyon. Photograph by Judith Johnston.

Figure 37. Rock House Canyon. View is to the northwest up the canyon.

Figure 38. Rock House Canyon. View is to the east looking down the canyon towards the Green River and Desolation Canyon.

79.0 (1.0) Little Rock House Rapid.

77.5 (1.5) River left, boulder-capped demoiselles or hoodos (figure 39). These are remnants of an alluvial fan that developed when the river gradient was at a higher elevation. The soft, poorly consolidated sediments are protected from erosion by the boulders capping each pillar.

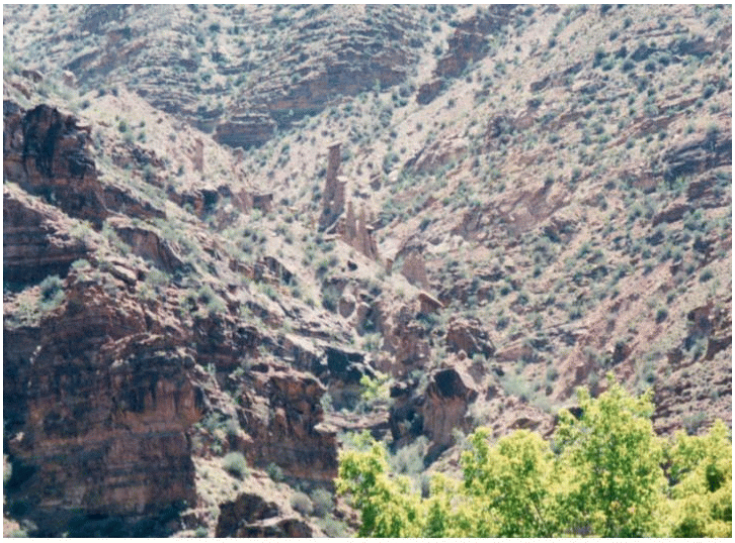

Figure 39. Boulder-capped demoiselles or hoodos at mile 77.5, river left.

77.0-72.0 (0.5) Peters Point is a large oxbow that provides many excellent views of the Green River Formation as you slowly float by (figure 40). The Peters Point gas field is 6 miles (9.7 km) to the west. The field produces from the Tertiary Wasatch, Flagstaff-North Horn undifferentiated, and Mesaverde Formations.

Figure 40. Peters Point looking upriver from mile 74.8.

74.0 (2.0) River right, this is where George Bradley saved Powell's life in 1869 (Mutschler, 1969). According to Bradley's journal, the one-armed Powell had become stranded on the cliffs above and Bradley had to climb above him, and using his long underwear as a rope, swung him to safety. Powell describes the location as Elephant Rock in Echo Park (Powell, 1895), a sheer rock wall.

72.7 (1.3) River right, the spire was named Lighthouse Rock by members of the 1871 Powell expedition (figure 41).

Figure 41. Lighthouse Rock. View down river from mile 73. Photograph by Judith Johnston.

70.5 (2.2) View up river of the Renegade Tongue, overlain by deltaic and transitional facies of the middle member of this Green River Formation, with the Mahogany oil shale and Horse Bench sandstone bed at or near the top of the cliff (figure 42).

Figure 42. Looking up river from mile 70.5, Renegade Tongue, delta facies, transitional facies, Horse Bench sandstone and Mahogany oil shale on top.

70.0 (0.5) Jack Creek Rapid caused by Jack Creek Canyon on river right. The high canyon walls of the lower part of the canyon are formed by the Renegade Tongue (figure 43). About 4 miles (6 km) up the canyon is the delta facies where the canyon walls are still very steep, but more slope forming (figure 44).

Figure 43. Jack Creek Canyon about 0.5 miles up from the Green River and Desolation Canyon, cliffs formed by the Renegade Tongue.

Figure 44. High on the wall of Jack Creek Canyon looking east towards Desolation Canyon.

67.0 (3.0) Big Canyon Rapid caused by Big Canyon on river left. Big Canyon is where Cashion (1967) measured and described his section A.

66.5 (0.5) River right, good view of jointing (figure 45).

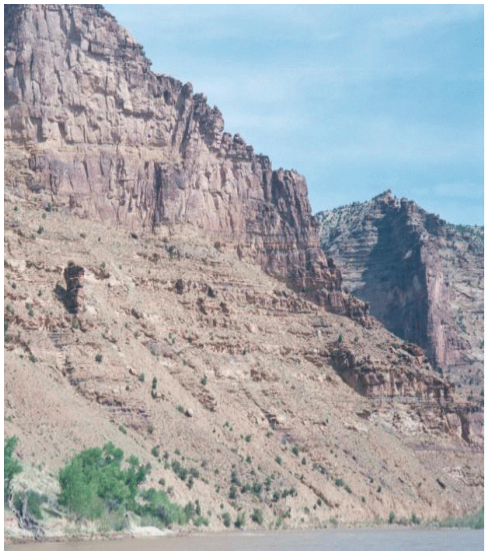

Figure 45. Jointing in the Green River Formation on river right, view is up river at mile 66.5.

65.8 (0.7) Firewater Rapid where Firewater Canyon enters on river left.

65.5 (0.3) River right is Cedar Ridge camp site. Carbonates at the top of the lower member of the Green River Formation (Cashion, 1967, Tongue E), exposed at the up-river side of the camp site, are down dropped by two normal faults (figure 46) that can also be seen on the opposite side of the river. The lower part of Cedar Ridge Canyon is formed by the Renegade Tongue with numerous east-west trending normal faults. Many of the faults from here to Rock Creek (mile 53.2) have only minor displacement (a few feet to a few tens of feet) but have relatively large deformation zones, possibly indicating that many of them had significant lateral movement (figure 47).

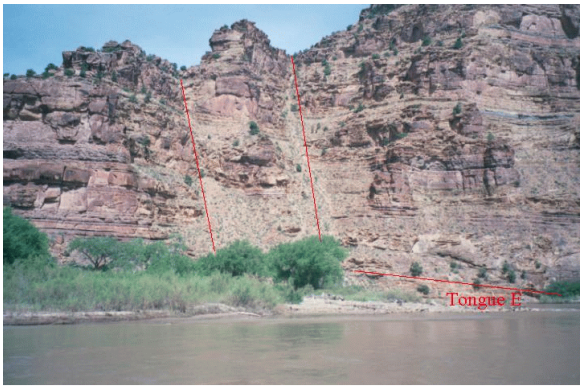

Figure 46. Cedar Ridge campsite, river right at mile 65.8. Top of lower member or Tongue E of Cashion at river level is faulted at the campsite.

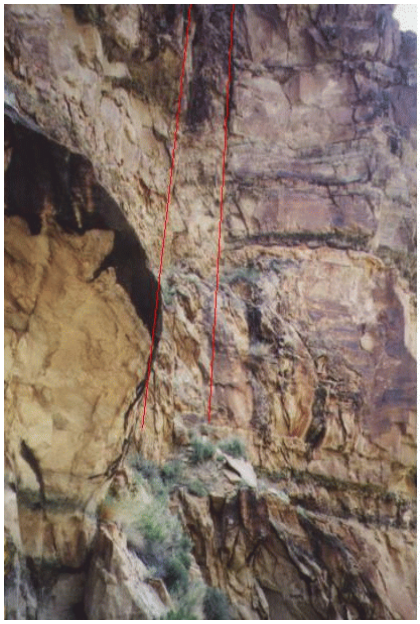

Figure 47. Fault zone about 2 feet wide. This exposure is about 0.4 mile up Cedar Ridge Canyon and is one of the faults exposed at the camp site.

65.4 (0.1) Cedar Ridge Rapid where Cedar Ridge Canyon enters river right.

64.4 (1.0) View down river of the lower member of the Green River Formation (Cashion, 1967, Tongue F) and overlying the Renegade Tongue. Notice the white alkali-stained sandstone beds (figure 48). The generally thicker, more porous sandstone beds in the Renegade Tongue seep ground water. As the water evaporates it leaves behind the white alkaline staining, or hard water deposit.

Figure 48. View down river from mile 64.4 of the lower member (Cashion Tongue F) and overlying Renegade Tongue of the middle member. White alkali deposits in the porous sandstone beds of the Renegade Tongue.

62.9 (1.5) Flat Canyon Rapid where Flat Canyon enters from river right.

62.0 (0.9) Unnamed rapid.

60.0 (2.0) Rapid formed down stream from the rincon on river left.

59.5 (0.5) Fretwater Rapid with camp site on river right. The view across the river from the camp site shows the main body of the Colton (Wasatch) Formation overlain by the lower member of the Green River Formation (Cashion, 1967, Tongue F), which is in turn overlain by an alluvial tongue of the Colton (Cashion, 1967, Wasatch Z) (figure 49).

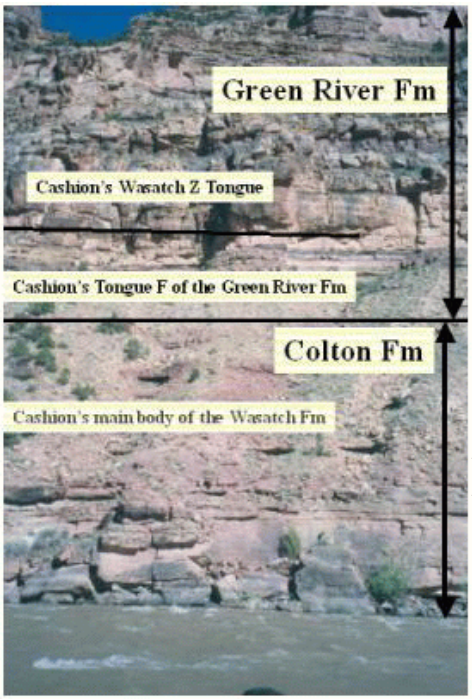

Figure 49. Fretwater Rapid at mile 59.5, river left. From river level up consisting of the Colton Formation overlain by the lower member of the Green River Formation, at this location consisting of a lacustrine facies (Tongue F) and an alluvial facies (Tongue Z).

59.0 (0.5) Rapid on both sides of a mid-channel bar.

58.4 (0.6) Wild Horse Rapid where Wild Horse Canyon enters from river left.

57.7 (0.7) Rapids.

57.6 (0.1) View down river with good exposure of Colton (Wasatch) Formation on river left (figure 50). Stacked channel sandstone beds may be similar to gas productive reservoir at Greater Natural Buttes field about 30 miles (48 km) to the northeast.

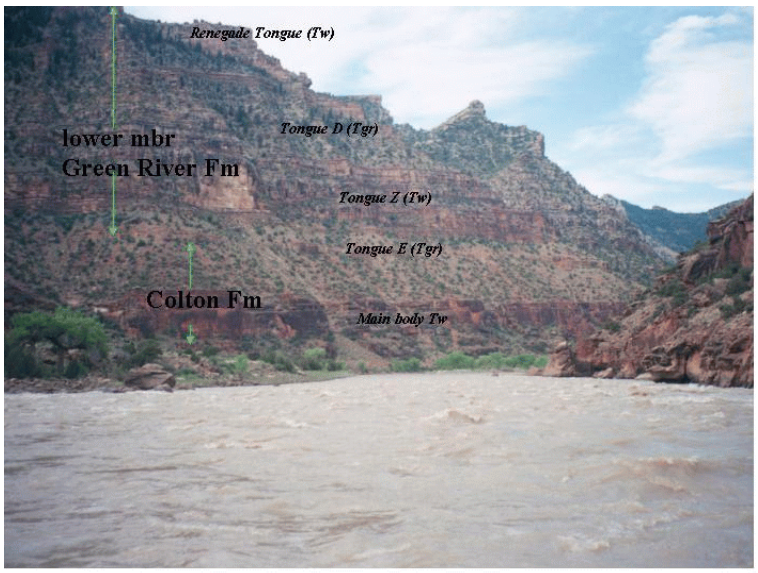

Figure 50. Mile 57.6 river right, view of Colton Formation and lower member of the Green River Formation. Contacts shown were not field checked and therefore are only approximations.

57.3 (0.3) Rapids on both sides of a mid-channel bar.

56.6 (0.7) Steer Ridge Rapid where Steer Ridge Canyon enters from river right. This may be where the Powell 1869 expedition capsized the boat *Emma Dean* (Mutschler, 1969).

53.9-53.2 (2.7) River right is Rock Creek, a perennial stream that is a popular place to cool off (figure 51). The red cliffs are interbedded sandstone and shale of the Colton (Wasatch) Formation (figure 52). The large fan deposited by Rock Creek was once irrigated and farmed. Several farm buildings of varying age still stand with numerous farm implements scattered about (figure 53). There are several fruit trees around the farm houses that often provide boaters with a nice snack when in season. Farming was abandoned in 1945. The property is still privately owned and although visitors are welcomed to look around, camping is forbidden.

Figure 51. Rock Creek near the confluence with the Green River at mile 53.9.

Figure 52. Rock Creek fan and red beds of the alluvial Colton Formation.

Figure 53. Historical buildings at the Rock Creek Ranch.

50.0 (3.2) River right, large rincon at Three Canyon (figures 54 and 55).

Figure 54. Large rincon at Three Canyon, mile 50.0 river right. River flowed around the large hill in the center of the photo.

Figure 55. Abandoned river channel in the Three Canyon rincon at mile 50.0. Photo by Judith Johnston.

39.4 (10.6) View up river of lower Colton (Wasatch) and old river terraces at the McPherson Ranch. The lower Colton is dominantly red shale with thin interbedded channel sandstone beds (figures 56 and 57).

Figure 56. Lower Colton consisting of slope-forming red shale and siltstone with thin interbedded sandstone overlain by cliff-forming stacked channel sandstone. Photo by Virginia Weyland.

Figure 57. Mile 39.4 looking up river at McPherson Ranch. Note old river terraces and shaley slope-forming lower Colton resulting in a widening of the canyon.

36.5 (2.9) View down river from above Wire Fence of the Flagstaff-North Horn undifferentiated and the Tusher and Farrer Formations of the Cretaceous Mesaverde Group (figure 58). This is the beginning of Gray Canyon.

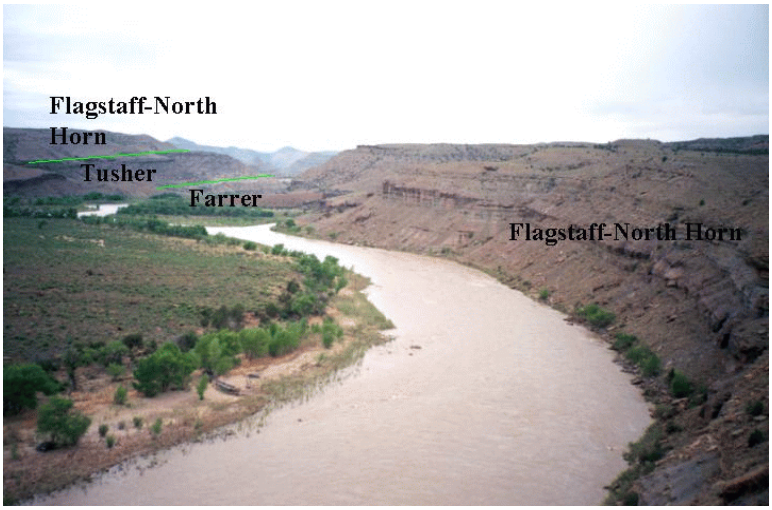

Figure 58. Above Three Fords Rapid at mile 36.5, looking down river at Flagstaff-North Horn Formations undifferentiated and Tusher and Farrer Formations of the Mesaverde Group in what is the beginning of Gray Canyon.

34.8 (1.7) River right, view of the top of the Tusher Formation.

33.8 (1.0) View up river of the Farrer and Tusher Formations with the tall cliffs of the Colton (Wasatch) Formation in the background (figure 59).

Figure 59. Looking up river from mile 33.8 at the Cretaceous Mesaverde Group. The Tertiary Colton Formation forms the red cliffs in the background.

30.3 (3.5) Top of the Price River Formation (figure 60).

Figure 60. Cliff-forming Bluecastle Sandstone of the Price River Formation of the Mesaverde Group at mile 30.3.

26.0 (4.3) River left is Coal Creek, the wall on river right is formed by the Castlegate Sandstone (figure 61). Large trenches were dug on both sides of the river in 1911 as part of a dam construction project that was never completed (figure 62). The old building on the left bank housed the workers (figure 63). A foot trail leads up Coal Creek Canyon where there are many excellent views of lower-shoreface to upper-shoreface deposits in the Price River Formation (figures 64 and 65).

Figure 61. Coal Creek camp site at mile 26.0. View down river of the Castlegate Sandstone overlain by the Buck Tongue and Bluecastle Sandstone.

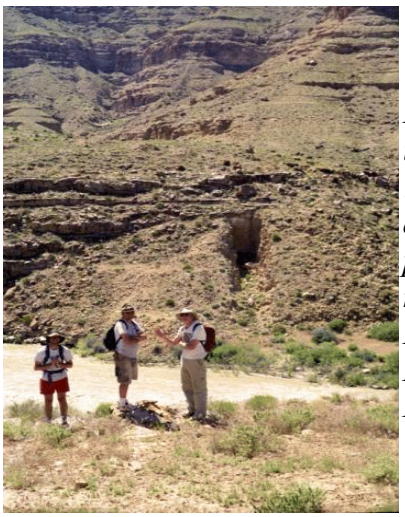

Figure 62. Large trench dug in 1911 as part of a dam-building project that was never completed. Photograph by Logan MacMillan.

Figure 63. Camp at Coal Creek mile 26.0. Old house was used by dam-building workers in 1911.

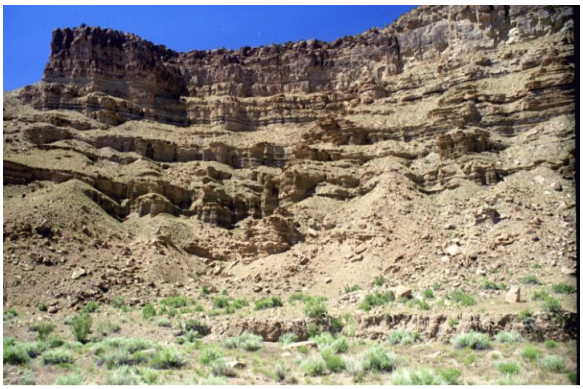

Figure 64. Price River Formation in Coal Creek Canyon. Photograph by Logan MacMillan.

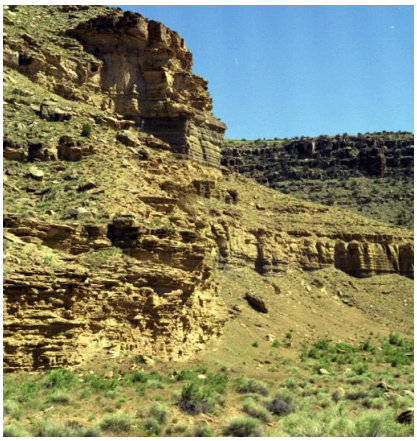

Figure 65. Price River Formation in Coal Creek Canyon. Photograph by Logan MacMillan.

22.0 (4.0) River right, coal in the Blackhawk Formation at Rattlesnake Rapid (figure 66).

20.1 (1.9) River right, rock pinnacle named after Queen Nefertiti (figure 67). The rock looks like a bust of Queen Nefertiti when viewed from this location, upriver from it, as well as when down river looking up.

Figure 66. View up river at Rattlesnake Rapids, mile 22.0. Coal bed near river level in the Blackhawk Formation of the Mesaverde Group.

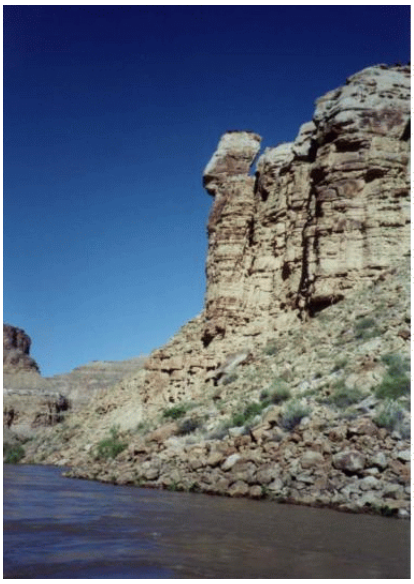

Figure 67. Rock pinnacle named Queen Nefertiti at mile 20.1, river right.

19.0 (1.1) View down river of the Mesaverde Group, consisting from river level up of the Blackhawk Formation, Castlegate Sandstone, Buck Tongue, and Bluecastle Member of the Price River Formation (figure 68).

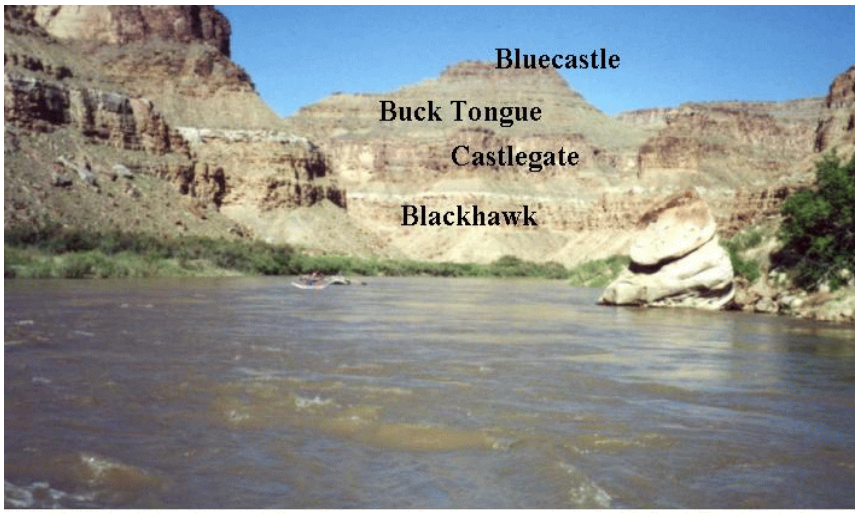

Figure 68. View down river at mile 19.0 of the Mesaverde Group from river level up; Blackhawk Formation, Castlegate Sandstone, Buck Tongue of the Mancos Shale, and Bluecastle Sandstone of the Price River Formation.

18.2 (0.8) River right, confluence with the Price river. The Price River can be difficult to see because the banks are heavily overgrown with tamarisk.

12.5 (5.7) View down river of Gunnison Butte on river right (figure 69). From river level up the butte consists of Mancos Shale, Blackhawk Formation, and is capped with Castlegate Sandstone.

Figure 69. View down river at mile 12.5 of Gunnison Butte on river right. From river level up; Mancos Shale, Blackhawk Formation and Castlegate Sandstone.

11.8 (0.7) River left, takeout at Swaseys boat ramp (figure 70).

Figure 70. Take out at Swaseys boat ramp at mile 11.8. Photograph by Roger Bon.

ACKNOWLEDGMENTS

The geologic guide to Willow Creek, Indian Creek, Soldier Creek, Nine Mile, and Desolation Canyons was prepared by the UGS as part of the U.S. Department of Energy's sponsored study of Green River Formation oil reservoirs. The study is entitled *Reservoir characterization of the lower Green River Formation southwest Uinta Basin, Utah* contract number DE-AC26-98BC15103, Virginia Weyland, Contract Manager, National Petroleum Technology Office, Tulsa, Oklahoma.

Members of the project's Technical Advisory Board and several representatives from the oil industry, joined the UGS-led field trip through these canyons and provided helpful suggestions. Thanks to the Price River Bureau of Land Management office for providing easy access to Desolation Canyon. A very special thanks to our volunteer boatmen (figure 71) without whom we would have been unable to study the rocks in Desolation Canyon.

Figure 71. The volunteer boatmen. Without them it would have been a long swim.

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APPENDIX A

UGS 1 Willow Creek Canyon
Measured Section

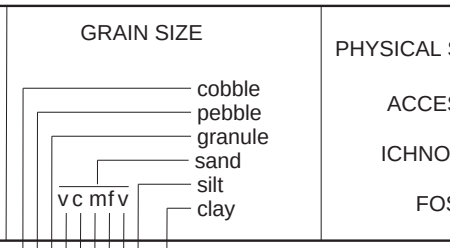
The section begins 3 miles north of the Carbon and Duchesne County line on U.S. Highway 191 in the NE1/4SE1/4 section 23, and ends 5.4 miles north of the County line following the highway in the NE1/4NW1/4 section 12, T. 11 S., R. 10 E., Salt Lake Base Line amd Meridian, Duchesne County, Utah.

Bed thicknesses were measured and described at road cuts along the highway.
The beds dip 3 to 5 degrees north.
Exposures are generally good but highly fractured resulting in a dangerous rock-fall hazard at many of the road cuts.

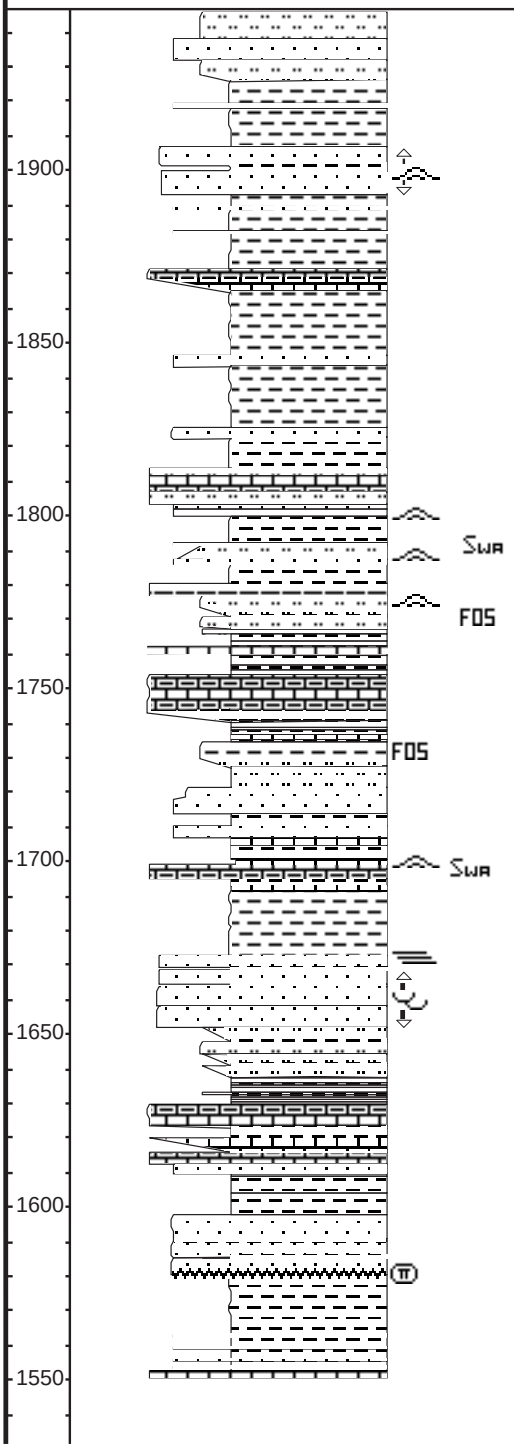
UGS 1

Willow Creek Canyon

The section begins 3 miles north of the Carbon and Duchesne County line on U.S. Highway 191 in the NE1/4SE1/4 section 23, and ends 5.4 miles north of the County line following the highway in the NE1/4NW1/4 section 12, T. 11 S., R. 10 E., of the Salt Lake Baseline, Duchesne County, Utah.



Unit number (measured section thickness [cumulative] in feet) - Lithologic description



205 — END OF ROAD CUT

204 — Unit 205 (1907-1946): Shale, siltstone, and some sandstone, shale and siltstone are green, sandstone beds are thin, (maximum 6 feet) overlain by green shale.

203 — Unit 204 (1893-1907): Sandstone and some shale, sandstone is light brown to light gray, medium grained, subangular, porous, conglomeratic base, sandstone beds thinning upward, many of the beds are wave rippled on top, interbedded green shale.

202 — Unit 203 (1878-1893): Shale and sandstone, shale is green with a few thin (2-6 inch) sandstone beds.

201 — Unit 202 (1814-1878): Shale, siltstone, and muddy limestone, shale is light gray, silty, some brown and green, thin sandstone and muddy limestone beds, muddy limestone beds thickening upward (maximum 6-feet thick).

200 — Unit 201 (1803.5-1814): Muddy limestone and some limy siltstone, muddy limestone is light tan, some large scale ripples and some internal channelling, siltstone, light gray.

199 — Unit 200 (1781-1803.5): Shale, siltstone, and sandstone, shale is green, sandstone beds are 0-2 feet, some are channel-form others are laterally continous, fine grained, light brown, calcareous, rounded, some swalely bedding and climbing ripples.

198 — Unit 199 (1777-1781): Limy mudstone, light tan weathers light tan to orange.

197 — Unit 198 (1766-1777): Siltstone and some shale, siltstone gray to dark gray, weather green, very to mildly calcareous, some wave ripple near top, trace of fossil fragments, laterally cut by a small channel with low angle accretion beds.

196 — Unit 197 (1754-1766): Shale and muddy limestone, shale green, limestone beds are 6-12 inches thick.

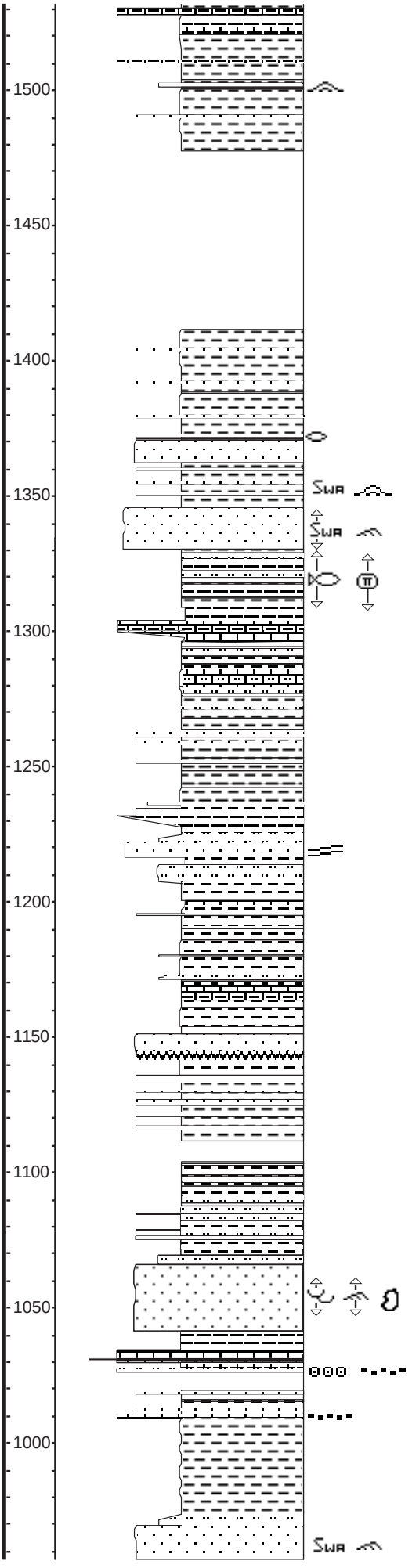
195 — Unit 196 (1747-1754): Muddy limestone.

194 — Unit 195 (1735-1747): Limy mudstone and green shale, limestone is light tan weathers to light tan to orange, near base of unit 1-foot limestone and 1-foot shale, gradually increasing upward in thickness of limestone and thinning of shale.

193 — Unit 194 (1722-1735): Shale to siltstone, green, a few layers of fossil fragments.

192 — Unit 193 (1714-1722): Sandstone, light gray, medium grained, friable, porous, non to slightly calcareous, grading upward to very fine grained, laterally discontinous, channel sandstone.

190 — 189 — 188 — 187 — 186 — 183 — 181 — 180 — 179 — 178 — 176



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Unit 192 (1701-1714): Shale and some silty limestone to silty mudstone, and limestone to limy mudstone, shale is green to gray and red, unit is capped with a 6 to 12 inch limestone to limy mudstone,orange.

Unit 191 (1698-1701): Limy siltstone to silty limestone, light gray to gray, some ripple and swaley bedding.

Unit 190 (1695-1698): Muddy limestone light gray, light tan, weathers light gray.

Unit 189 (1682-1695): Shale and limestone, red and purple shale with one limestone bed (1.5 feet) gray, silty.

Unit 188 (1673-1682): Shale, highly weathered slope. road cut discontinuous.

NEXT ROAD CUT

Unit 187 (1652-1673): Sandstone, base is light gray, conglomeritic, medium grained, porous, friable, highly trough cross bedded, channel-form bed, lateral accretion beds with red and green shale interbedded, becoming more planar towards top of unit, overlain by red and purple shale.

Unit 186 (1633-1652): Shale and siltstone, thin red shale mostly green shale and siltstone (gradational), siltstone beds thicken and increasing in number upward. Coarsening upward.

Unit 185 (1629-1633): Shale and muddy limestone, shale green.

Unit 184 (1627-1629): Muddy limestone light tan.

Unit 183 (1613-1627): Muddy limestone light tan, and green shale.

Unit 182 (1610-1613): Sandstone, major landslide block, project up roadcut past landslide.

Unit 181 (1598-1610): Shale, green and red, becoming more red towards top of unit, purple shale at top of unit.

Unit 180 (1581-1598): Sandstone, some siltstone and shale, channel-form sandstone with large lateral accretion beds with siltstone and shale between the accretion beds, unit is conglomertic at base, with some gar scales. Example of one accretion bed from channel to bank; sandstone-green siltstone-red shale.

Unit 179 (1564.5-1581): Shale, red and green, laterally (at upper bend of S-curve) this unit is deeply cut by a well expose channel-form bed composed of sandstone and interbedded shale.

Unit 178 (1553-1564.5): Shale and sandstone, shale green with interbedded red, some sandstone beds, increasing in number upward, about 1-foot thick, laterally continuous.

Unit 177 (1551-1553): Muddy limestone.

Unit 176 (1531-1551): Shale, green.

Unit 175 (1528-1531): Muddy limestone, light brown, weathers orange.

Unit 174 (1511.5-1528): Shale, green to gray, grading to limy mudstone.

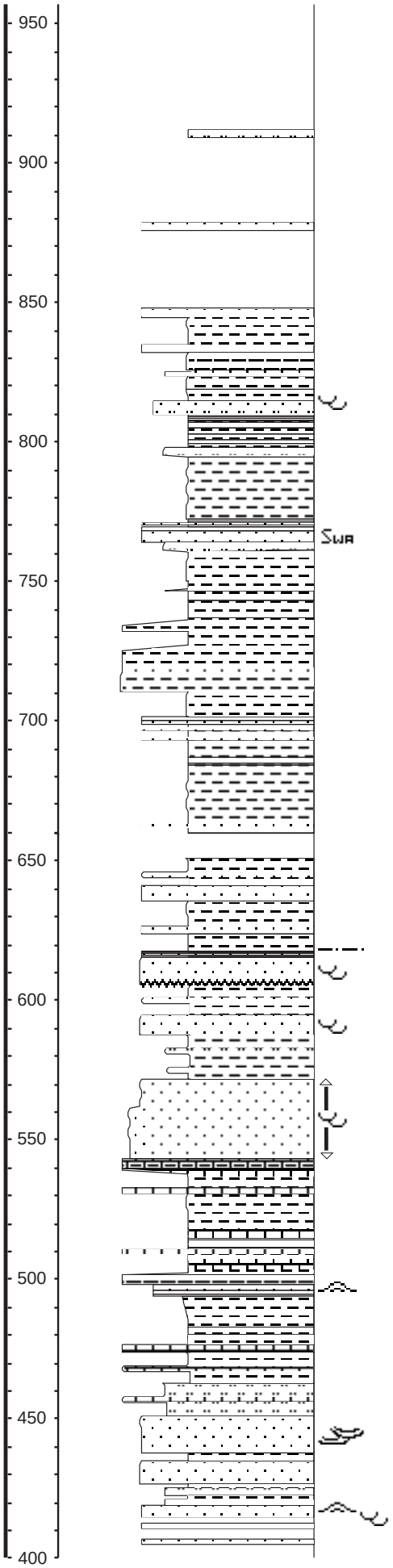
Unit 173 (1510.5-1511.5): Muddy limestone, light brown, weathers orange.

Unit 172 (1504-1510.5): Shale, green, some channel-forms filled with green shale.

Unit 171 (1501.5-1504): Siltstone and shale, siltstone beds (two) light gray to gray, slightly calcareous, wave rippled at base, interbedded with 2 inch green shale that grades upward to mudstone to siltstone.

Unit 170 (1478-1501.5): Shale, siltstone, and sandstone, shale is green, weathered, one 1-foot sandstone bed, very fine grained, light gray to light brown, discontinuous, finning upward to silty shale, interbedded red and green shale near top 6 inches of unit.

Unit 169 (1412-1478): Covered.



END OF ROAD CUT, BEGINNING OF S TURN

Unit 168 (1373-1412): Shale and sandstone, shale green, possibly some red, highly weathered slope, definite red shale bed at 1377 feet, some sandstone beds 2 to 6 inches thick.

Unit 167 (1370-1373): Sandstone and shale, lenticular sandstone beds becoming very discontinous near top of unit, interbedded thin fissile shale.

Unit 166 (1363-1370): Sandstone, channel-form bed.

Unit 165 (1346-1363): Shale and sandstone, shale is green, sandstone beds are 6-10 inch thick, swaley cross bedding with some ripples.

Unit 164 (1330.5-1346): Sandstone, light gray, medium to fine grained, climbing ripples with heavy minerals in troughs, some swaley beds, channel-form bed.

Unit 163 (1309-1330.5: Shale, siltstone, and limy mudstone, shale is green with a few thin (1-3 inch) red shale beds, thin (1-4 inch) siltstone beds, gray, calcareous, and some limy mudstone, light gray, weathers light tan, with traces of gar scales and possibly bone.

Unit 162 (1304-1309): Limy mudstone, green to brown.

Unit 161 (1286-1304): Shale, siltstone, limy mudstone, shale is green weathered, thin siltstone beds grading to silty limestone to brown muddy limestone.

Unit 160 (1264-1286): Shale, siltstone to silty limestone, shale is green, weathered, a few thin siltstone beds gradational to silty limestone.

BEND IN ROAD, ROAD CUT CONTINUOUS

Unit 159 (1248.5-1264): Shale, siltstone and sandstone, shale and siltstone beds green, upward increase in thin (4-6 inch) small discontinuous channel-form sandstone beds, very fine grained sandstone, laterally equivalent to larger channel-form sandstone bed (1237.5-1241).

Unit 158 (1238-1248.5): Shale, siltstone, and limestone, green shale and siltstone with thin orange limestone.

Unit 157 (1235-1238): Shale and sandstone, shale is green, sandstone is 8 inch thick, gray to light gray, very fine grained, calcareous.

Unit 156 (1232-1235): Sandstone, channel-form bed laterally thins and overlies another channel-form sandstone bed that is equivalent to the upper part of the underlying siltstone and shale unit 155.

Unit 155 (1222.5-1232): Siltstone and shale, green, some brown to orange, siltstone gradational to shale to mudstone.

Unit 154 (1217-1222.5): Sandstone and interbedded shale, numerous large channel-form sandstone beds, medium grained, low angle cross bedding, with thin interbedded green shale.

Unit 153 (1214-1217): Limy mudstone, light brown to light tan, weathers light tan to orange.

Unit 152 (1210-1214): Shale, and siltstone, shale is green, unit is highly weathered slope.

Unit 151 (1196-1201): Shale and interbedded sandstone, shale is green, sandstone light gray, very fine grained, calcareous, becoming silty limestone near top of unit, finning upward sequence.

Unit 150 (1184-1196): Sandstone, light gray, fine grained, channel-form bed, calcareous.

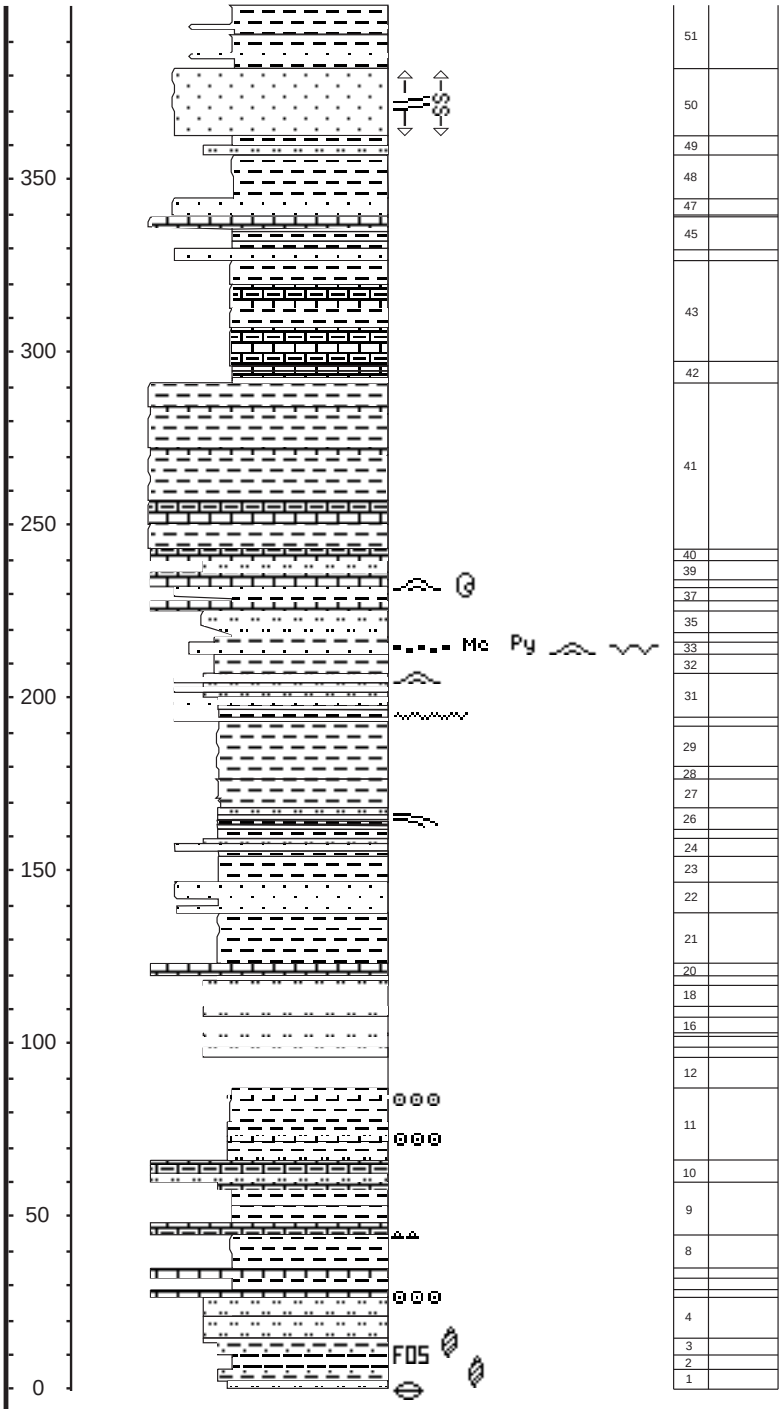
Unit 149 (1186-1184): Shale and interbedded sandstone, shale is green, sandstone beds thickening upward, coarsening upward sequence.

Unit 148 (1181-1186): Shale, green to gray.

END OF ROAD CUT

Unit 147 (1180-1181): Siltstone, grey to brown, weathers orange, calcareous.

Unit 146 (1172-1180): Siltstone and shale, green, weathered, calcareous, first two feet are siltstone, gradational to shale.



Unit 145 (1169-1172): Shale, brown, to possible oil shale, fissile, calcareous.

Unit 144 (1151.5-1169): Shale, green, silty, calcareous, grading upward to brown shale and muddy limestone very calcareous, capped with brown shale to possible oil shale, very slightly calcareous.

Unit 143 (1143-1151.5): Sandstone, fine grained, channel-form bed cutting down into green shale, lateral accretion beds with green shale interbedded, channel direction about N40°W.

Unit 142 (1112-1143): Shale, green, highly weathered, some thin sandstone beds (2-6 inches), light brown, very fine to fine grained, increasing in number of beds, towards the top. Coarsening upward sequence.

Unit 141 (1106-1112): Covered.

Unit 140 (1088-1106): Shale, green, with thin (1-4 inch) siltstone beds, siltstone beds becoming fewer and thinner towards top of unit.

END OF ROAD CUT

Unit 139 (1071-1088): Shale, siltstone and limy siltstone, some thin sandstone beds, green to gray green.

Unit 138 (1067.5-1071): Bottom 3 feet is siltstone, gray green, grading upward to brown shale. Top 0.5 feet is shale black, papery, dolomitic oil shale.

Unit 137 (1042.5-1067.5): Sandstone, very fine grain, calcareous, micaceous, some black (bitumen?) fragments, slight fining upward. Large lateral accretion beds, some small scale trough cross beds and climbing ripples. A few concretions about 1-foot diameter, very calcareous sandstone.

Unit 136 (1031-1042.5): Five feet muddy limestone, tan at base grading upward to dark brown on top and more calcareous. One inch chert bed 1.5 feet up from base of bed. Overlain by 6.5 feet mudstone, dolomitic, brown, shaley, becoming more resistant toward top of unit which grades upward to limy mudstone. Thin (1 inch) algal layer 2.5 feet above base of bed. Overlain by mudstone, dolomitic, gray to green gray, highly weathered.

Unit 135 (1028.5-1031): Limy mudstone, tan to gray green overlain by 1 foot dolomitic mudstone, tan to light brown, shaley top.

Unit 134 (1026-1028.5): Siltstone, weathered, green to gray green, calcareous, overlain by 0.5 feet limestone, dark gray, crystalline, some ooids and black (carboniferous) fragments.

Unit 133 (1020-1026): Covered.

END OF ROAD CUT.

Unit 132 (1011-1020): Shale, green, with interbedded thin (1-foot) siltstone and sandstone beds.

Unit 131 (1009-1011): Limestone to limy siltstone, orange, lots of specks and pieces of coaly organic material.

Unit 130 (978-1009): Shale, green, highly weathered, very poor exposure.

Unit 129 (972-978): Siltstone to shale, green, highly weathered.

Unit 128 (970-972): Siltstone, light gray to light green, thin bedded, badly broken up. Sandstone, channel form, swalely near top, badly broken up.

Unit 127 (957-970): Sandstone, channel form, swalely and climbing ripples, badly broken up unit.

Unit 126 (918-957): Covered.

Unit 125 (912-918): Mostly covered, some siltstone to very fine sandstone.

Unit 124 (909-912): Shale, green with interbedded siltstone, light gray to light green.

Unit 123 (906-909): Covered.

Unit 122 (894-906): Covered, dug. Weathered green shale and siltstone.

Unit 121 (891-894): Covered.

Unit 120 (879-891): Covered, dug a few inches found mostly green shale and thin interbedded siltstone to very fine grained sandstone.

Unit 119 (876-879): Sandstone, light gray, poorly exposed in gully between road cuts.

Unit 118 (848-876): Covered

Unit 117 (845-848): Sandstone, light gray to light brown, very fine grained, very calcareous.

Unit 116 (835-845): Mudstone, green, some light gray to light brown, color changes are gradual, very calcareous, shaley in places.

Unit 115 (832-835): Sandstone, light gray to light green, very fine grained, calcareous, hard, tight.

Unit 114 (826-832): Mudstone, green, silty, very calcareous.

Unit 113 (824-826): Siltstone to silty limestone.

Unit 112 (815-824): Shale to mudstone, green.

Unit 111 (813-815): Sandstone, very fine grained, trough cross bedded.

Unit 110 (810-813): Siltstone to sandstone, very fine grained, overlies channel that cuts underlying unit.

Unit 109 (807-810): Shale, interbedded red and green, laterally this unit is cut out by a channel-form sandstone that is laterally very limited.

Unit 108 (801-807): Shale to siltstone, light gray to green, siltstone bed 6 to 8 inch thick with interbedded 2 to 4 inch thick green shale to mudstone, slightly calcareous.

Unit 107 (798-801): Mudstone to shale, green to black.

Unit 106 (792-798): Shale to siltstone, green becoming light gray, limy thinly bedded siltstone near top or unit.

Unit 105 (774-792): Shale, green.

Unit 104 (768-774): Shale, green with interbedded calcareous siltstone and sandstone beds about 6 inches thick.

Unit 103 (764-768): Sandstone, light gray, friable, calcareous, some swalely cross bedding, fining upward.

Unit 102 (759-764): Shale to siltstone, green.

Unit 101 (753-759): Shale, red.

Unit 100 (750-753): Shale,

Unit 99 (747-750): Siltstone to silty shale, green.

Unit 98 (743-747): Shale, red to purple, and some green.

Unit 97 (732-743): Shale to silty shale, green, weathered.

Unit 96 (726-732): Shale, red and green.

Unit 95 (720-726): Shale, red, weathered.

Unit 94 (717-720): Shale, red, weathered, with thin (4-6 inch) discontinuous sandstone beds.

Unit 93 (711-717): Shale, red, weathered.

Unit 92 (702-711): Shale, green, weathered.

Unit 91 (699-702): Sandstone with interbedded thin (2-4 inch) green shale to siltstone beds.

Unit 90 (694-699): Shale, red to maroon, with very thin (1 inch) green shale and 1-foot sandstone beds.

Unit 89 (693-694): Sandstone.

Unit 88 (687-693): Shale, green, weathered.

Unit 87 (684-687): Shale, black, gradual change from green.

Unit 86 (663-684): Shale, green, highly weathered.

Unit 85 (662-663): Sandstone.

Unit 84 (660-662): Shale, green, weathered.

Unit 83 (651-660): Covered slope.
END OF ROAD CUT

Unit 82 (641-651): Shale, green with interbedded sandstone beds that are generally laterally discontinuous and about 6 inches thick.

Unit 81 (636-641): Sandstone, very limited laterally.

Unit 80 (627-636): Shale, green, highly weathered.

Unit 79 (624-627): Sandstone.

Unti 78 (621-624): Shale, green.

Unit 77 (617-621): Shale, black, silty, siliceous, highly weathered, with thin laterally limited flaggy sandstone beds.

Unit 76 (606-617): Sandstone, channel-form bed completely cuts out the underlying green shale unit in one location, large trough cross bedding with thin shale breaks near the top.

Unit 75 (595-606): Shale, green with interbedded sandstone beds 6 to 8 inches thick.

Unit 74 (588-595): Sandstone, cross bedded becoming flaggy at top.

Unit 73 (572-588): Shale, green with interbedded thin (6 inch) calcareous siltstone beds.

Unit 72 (543-572): Sandstone, slightly calcareous, friable, near base: fine to medium grained, rounded to semi-angular, near top: fine grained, semi-angular, large trough bedded and accretionary beds.

Unit 71 (540-543): Muddy limestone brown to black, very gradual change from shale below.

Unit 70 (537-540): Shale, green with interbedded limestone.

Unit 69 (533-537): Shale, green.

Unit 68 (531-533): Limestone.

Unit 67 (519-531): Shale, green.

Unit 66 (511-519): Shale, green with interbedded limestone beds thickening upward in the unit from 4 to 6 inches near base to 12 to 20 inches near the top of the unit.

Unit 65 (509-511): Limestone to limy siltstone.

Unit 64 (498-509): Mudstone to silty shale, green, with a few thin (4 to 6 inch) limestone beds.

Unit 63 (496-498): Sandstone, light gray, very fine grained, weathers tan, rippled on top.

Unit 62 (483-496): Shale, green, weathered, a few thin (4 inch) red shale beds, with thin 1-foot siltstone to very fine grained sandstone beds near top of the unit.

Unit 61 (480-483): Shale, red, weathered.

Unit 60 (477-480): Shale, green, weathered.

Unit 59 (474-477): Limestone.

Unit 58 (451-474): Shale to siltstone, green, with interbedded limestone beds 6 to 18 inches thick.

Unit 57 (438-451): Sandstone, cross bedded, rooted near top.

Unit 56 (435-438): Shale, green.

Unit 55 (427-435): Sandstone.

Unit 54 (419-427): Shale to siltstone, green, with interbedded thin siltstone and sandstone beds.

Unit 53 (415-419): Sandstone, trough cross bedded near base, wave rippled near top.

Unit 52 (400-415): Mostly covered. Some sandstone, very fine grained, 1- to 2-foot thick beds.
END OF ROAD CUT

Unit 51 (382-400): Shale, green with interbedded sandstone, very fine grained, 1 to 2 feet thick.

Unit 50 (363-382): Sandstone, irregular base, low angle cross-beds, some soft sediment contorted bedding

Unit 49 (357-363): Shale to siltstone, green with interbedded sandstone beds 1 to 3 feet thick.

Unit 48 (345-357): Shale, brown, highly weathered.

Unit 47 (340-345): Sandstone, light gray, fine grained, calcareous, rippled.

Unit 46 (339-340): Shale, green.

Unit 45 (330-339): Black shale, micritic limestone to limy shale, black, dark gray, limestone is dense and hard.

Unit 44 (327-330): Sandstone and interbedded black shale.

Unit 43 (297-327): Muddy limestone to shale, muddy limestone is light tan to brown, shale is black, siliceous, thin papery black shale at top of unit.

Unit 42 (291-297): Muddy limestone, light gray to white, with thin (2 inch) yellow to orange siltstones.

Unit 41 (243-291): Muddy limestone to shale brown to light tan to occasionally black, weathers gray to black, papery at base becoming more calcareous and dense towards top of unit.

Unit 40 (240-243): Shale, brown, not calcareous, weathers gray like oil shale.

Unit 39 (234-240): Muddy limestone to siltstone, muddy limestone brown, siltstone is light brown to tan, calcareous.

Unit 38 (232-234): Limestone, ostracodal, wave rippled on top.

Unit 37 (228-232): Sandstone and shale, coarsing upward.

Unit 36 (225-228): Muddy limestone, brown, highly weathered, overlain by thin papery brown shale.

Unit 35 (219-225): Siltstone, light brown to tan, calcareous.

Unit 34 (216-219): Shale to siltstone, green.

Unit 33 (213-216): Sandstone, light brown, very fine grained, slightly calcareous, some black organic material, mica and pyrite, rippled and mud cracks near top.

Unit 32 (207-213): Shale, green with interbedded thin (1 to 3 inches) sandstone.

Unit 31 (195-207): Shale to siltstone, brown, with interbedded sandstone beds 1 to 3 feet thick, lenticular, slightly scour base, wave rippled on top.

Unit 30 (192-195): Shale, brown with thin 1-foot sandstone.

Unit 29 (180-192): Shale, brown, highly weathered.

Unit 28 (177-180): Shale, silty, green to brown.

Unit 27 (168-177): Shale, silty, green.

Unit 26 (162-168): Shale to silty shale, green with thin interbedded siltstone to sandstone beds, calcareous.

Unit 25 (159-162): Shale, green.

Unit 24 (153-159): Shale to siltstone, green, with thin lenticular sandstone beds.

Unit 23 (147-153): Shale, green.

Unit 22 (138-147): Sandstone and interbedded mudstone, sandstone fine grain, brown to tan, calcareous; mudstone green.

Unit 21 (123-138): Shale, green, weathered slope.

Unit 20 (120-123): Limestone, silty, tan to brown, hard, dense.

Unit 19 (117-120): Siltstone to silty shale interbedded with thin shale, green, calcareous.

Unit 18 (111-117): Covered.

Unit 17 (108-111): Siltstone, poor exposure.

Beginning of second road cut

Unit 16 (103-108): Covered.

END OF ROAD CUT

Unit 15 (102-103): Siltstone and silty shale.

Unit 14 (99-102): Covered.

Unit 13 (96-99): Siltstone, gray, poor exposure.

Unit 12 (87-96): Covered.

Unit 11 (66-87): Silty shale and shale, dark brown to brown, calcareous, weathers gray to black, siltstone; black to dark brown calcareous thin papery shale, a few thin 8-10 inch oolitic limestones.

Unit 10 (60-66): Silty shale to muddy limestone, brown weathers gray to black, grading upward to limestone.

Unit 9 (45-60): Muddy limestone and shale, brown muddy limestone, black silty shale, near base small pebbles about 0.5 inches, oblong, chert center with siliceous growth around the chert.

Unit 8 (35-45): Shale, gray to black, thin limy, weathers gray.

Unit 7 (32.5-35): Limestone, light brown to tan, hard, dense.

Unit 6 (29-32.5): Shale, black to brown, weathers gray.

Unit 5 (27-29): Limestone, light gray to tan, oolitic at base.

Unit 4 (15-27): Interbedded brown siltstone, and black shale, siltstone 3-6 inches, black shale about 3 inches, coally layer at 21 feet less than 1 inch thick.

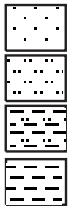
Unit 3 (9-15): Shale to silty shale to siltstone, gray to black, with abundant fossil hash (gastropods).

Unit 2 (6-9): Gray to black mudstone containing lots of fossil hash.

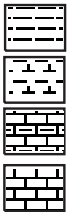
Unit 1 (0-6): Limy siltstone to silty shale, light brown, base contains large mollusk shells, top contains shell hash of smaller gastropods.

LEGEND

LITHOLOGY



Sandstone
Siltstone
Silty Shale
Shale



Shale and Mudstone
Limy Shale/Mudstone
Muddy Limestone
Limestone

Covered Slope
Coal
Oil Shale
Chert

CONTACTS

Scoured

PHYSICAL STRUCTURES

 - Trough Cross-Strat.

 - Ripples

 - Low Angle Tabular Bedding

 - Soft Sediment Deformation

 - Scour

 - Mud Cracks

 - Cross-Bedding

SWA - Swaley Cross-Strat.

 - Climbing Ripples

LITHOLOGIC ACCESSORIES

 - Cherty

Py - Pyrite

 Clasts

Mc - Micaceous

 - Oolitic

 - Silty

FOSSILS

 - Molluscs (undifferentiated)

 - Gastropods

 - Ostracodes

FOS - Fossils

APPENDIX B

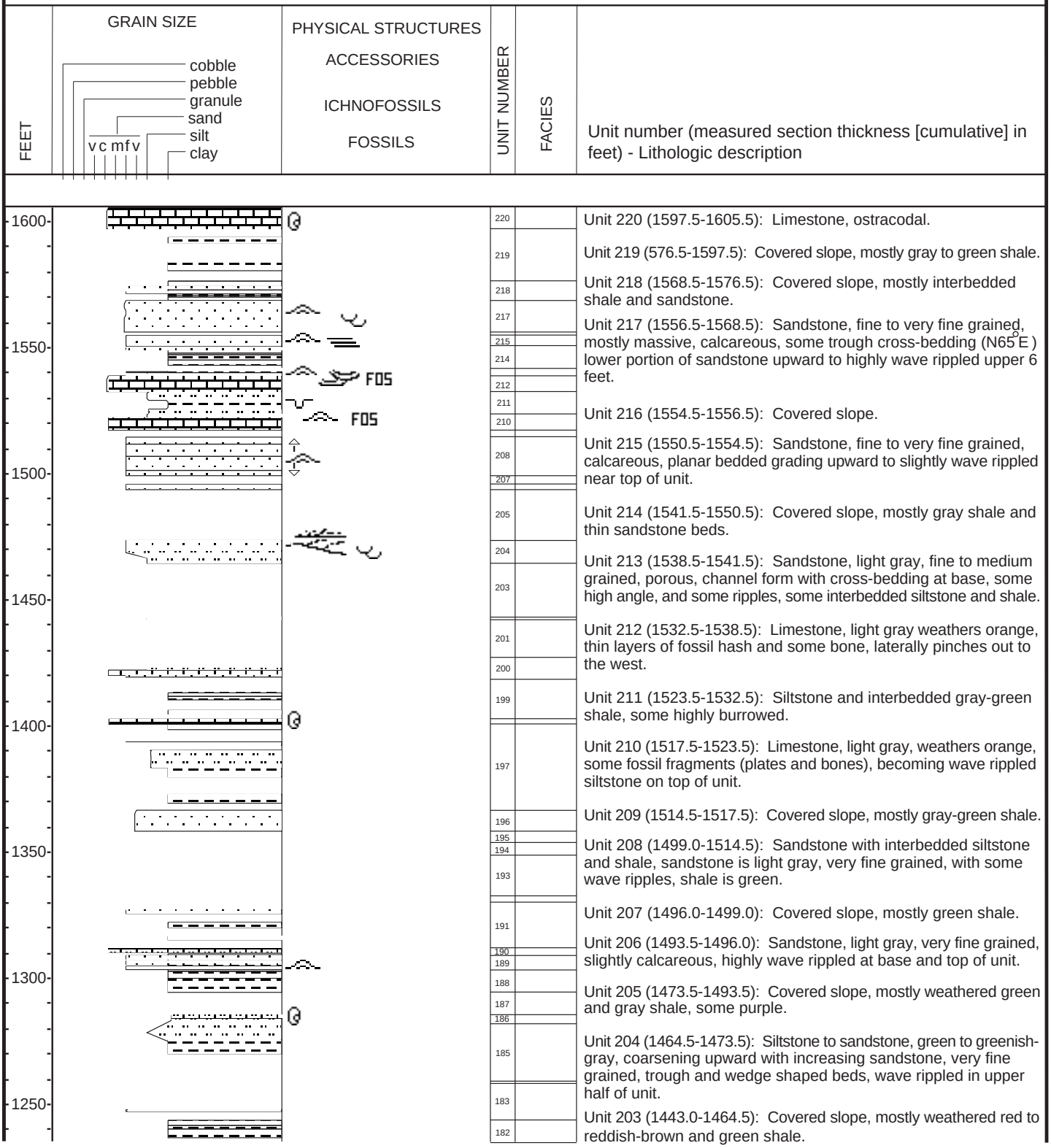
UGS 2 Argyle Ridge
Measured Section

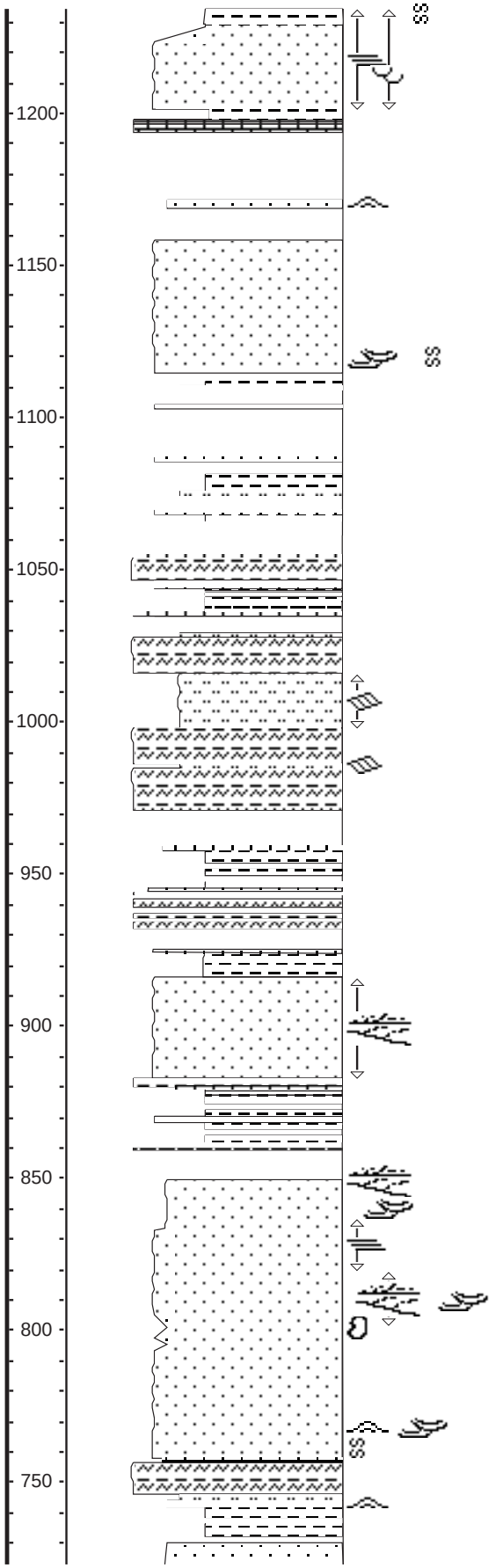
The section is in Nine Mile Canyon and begins at the canyon floor in the SE1/4SE1/4 section 11, and goes up the canyon wall ending near the top of Argyle Ridge in the NE1/4NW1/4 section 11, T. 12 S., R. 13 E., Salt Lake Base Line and Meridian, Carbon County, Utah.

The beds dip 3 to 5 degrees north.
Exposures are generally fair to good

UGS-2
Argyle Ridge

The section is in Nine Mile Canyon and begins at the canyon floor in the SE1/4SE1/4 section 11, and goes up the canyon wall ending near the top of Argyle Ridge in the NE1/4NW1/4 section 11 T. 12 S., R. 13 E, of the Salt Lake Baseline, Carbon County, Utah.





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Unit 202 (1442.5-1443.5): Siltstone, green, calcareous, laterally thickens from 6 inches to 3 feet, massive.

Unit 201 (1427.5-1442.5): Covered slope, mostly weathered red to reddish-brown and green shale.

Unit 200 (1418.5-1427.5): Covered slope, weathered limy mudstone, gray to gray-green, gradational change from silty siltstone.

Unit 199 (1403.5-1418.5): Covered slope, mostly weathered green shale, with some limy siltstone.

Unit 198 (1400.5-1403.5): Limestone, silty, light gray to white, weathers orange, dense, some ostracods, a few silty lenses.

Unit 197 (1366.5-1400.5): Covered slope, mostly weathered green shale with some red and purple, calcareous, occasionally grading to siltstone, one thin (6 inch) sandstone bed at 1396.5 feet.

Unit 196 (1358.5-1366.5): Sandstone, light brown, very fine grained, well sorted, subangular to subround.

Unit 195 (1354.5-1358.5): Covered slope, moslty weathered greenish-gray shale.

Unit 194 (1348.5-1354.5): Covered slope, mostly weathered red shale.

Unit 193 (1333.5-1348.5): Covered slope mostly weathered green shale.

Unit 192 (1330.5-1333.5): Covered slope, weathered red shale.

Unit 191 (1312.5-1330.5): Covered slope with some green shale, and gradational siltstone and mudstone, calcareous.

Unit 190 (1309.5-1312.5): Covered slope consisting of sandstone and silty limestone.

Unit 189 (1303.0-1309.5): Sandstone, (3 beds) light gray to light brown, slightly calcareous, slightly wave rippled, each bed coarsening upward, with interbedded shale, gray to greenish-gray.

Unit 188 (1294.5-1303.0): Shale, green-gray, grading upward to siltstone.

Unit 187 (1285.5-1294.5): Covered slope, weathered red reddish brown shale.

Unit 186 (1282.5-1285.5): Siltstone light brown to brown to orange, calcareous, becoming silty limestone, some ostracodes.

Unit 185 (1259.5-1282.5): Covered slope with weathered green shale grading into calcareous green siltstone.

Unit 184 (1258.5-1259.5): Covered slope, weathered red shale.

Unit 183 (1243.5-1258.5): Covered slope, weathered green shale with one thin sandstone bed.

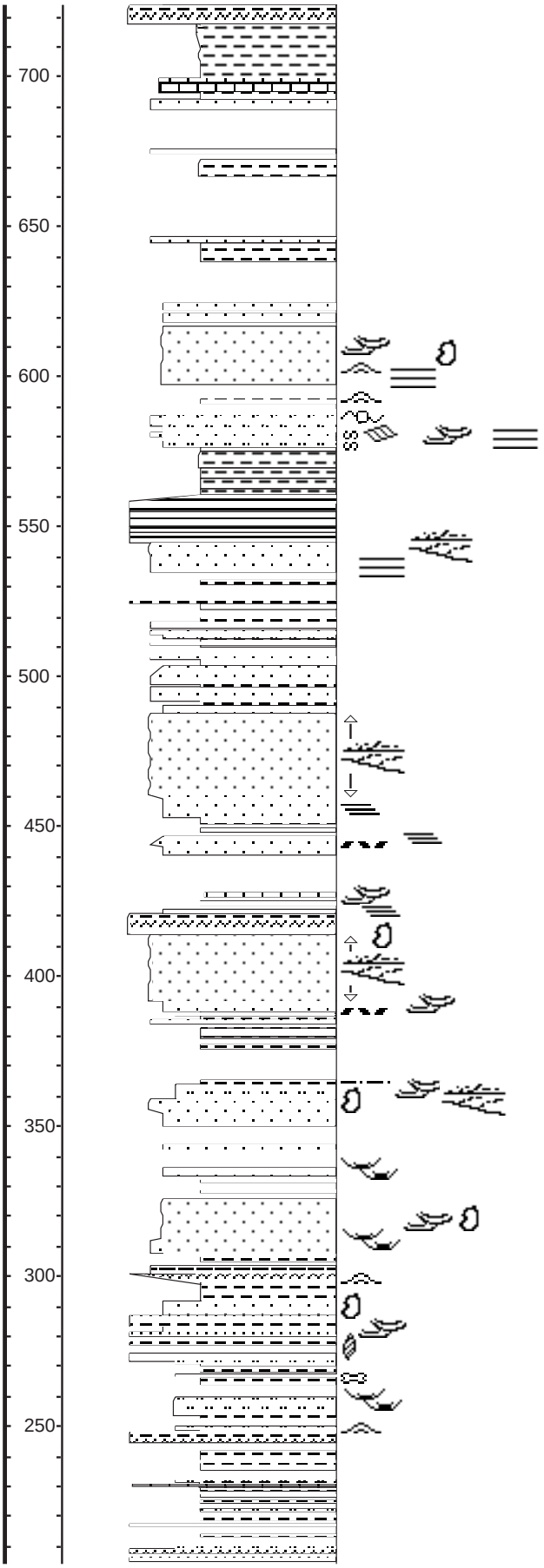
Unit 182 (1234.5-1243.5): Partially covered slope of green shale.

Unit 181 (1201.5-1234.5): Sandstone, light brown, fine grain to very fine grained, slightly calcareous, channel form with some channel lags near base consisting of intra-formational clasts of limy mudstone, some trough cross-bedding 16°N 55°E , and some planar bedding. Becoming flaggy (about 1219.5 feet) at top light brown, very fine grained, sub-round to sub-angular, very porous, grading upward into interbedded green shale and sandstone, some trough cross-bedding 8°N 2°E , some soft sediment deformation near top of unit.

Unit 180 (1193.5-1201.5): Ostracodal limestone (3 feet) overlain by partly covered limestone, micritic, to gray limy shale, grading upward to limy mudstone.

Unit 179 (1171.5-1193.5): Covered slope, weathered green shale.

Unit 178 (1168.5-1171.5): Sandstone, very fine grained, friable, porous, ripple laminated.



125 Unit 177 (1158.5-1168.5): Covered slope, probably interbedded sandstone and shale.

124 Unit 176 (1114.5-1158.5): Sandstone, light gray weathers light brown, fine grain, friable, porous, non-calcareous, channel-form bed with some cross-bedding at base, about 6 feet up from base abundant soft-sediment deformation, some thin shale breaks about 6 feet up from base, about 8 feet up from base a massive bed with cross-bedding overlain by large lateral accretion beds.

123 Unit 175 (1060.5-1114.5): Mostly covered slope of weathered green shale to calcareous siltstone, some red shale, some sandstone beds about 1-foot thick, light gray to light brown, fine to very fine grained, dense, siliceous, some beds calcareous, sub-round to angular.

121

120 Unit 174 (1055.0-1060.5): Covered slope, likely purple green shale/marlstone.

119

117

116 Unit 173 (1054.0-1055.0): Buff ostracode limestone (packstone), dense, very good effervescence.

115 Unit 172 (1046.5-1054.0): Gray green silty marlstone, moderately dense, fair effervescence, forms slope.

114 Unit 171 (1043.5-1046.5): Drab very fine sandstone with clay, moderately dense, fair effervescence.

113

111 Unit 170 (1039.5-1043.5): Gray green marlstone/shale, increasing sand towards top, weathers medium to thin shaly partings, fair to good effervescence, forms slope.

110

109

108

107 Unit 169 (1036.5-1039.5): Tan limy mudstone, dense, very good effervescence.

106 Unit 168 (1034.5-1036.5): Buff ostracode limestone (grainstone), dense, some very fine sandstone, fair effervescence.

105 Unit 167 (1029.5-1034.5): Covered slope.

104

103 Unit 166 (1028.0-1029.5): Buff siltstone with scattered ostracodes, dense, good effervescence.

100 Unit 165 (1016.0-1028.0): Gray green silty marlstone, weathers medium to thin shaly partings, fair effervescence, forms slope.

98

96

95 Unit 164 (998.0-1016.0): Buff fine siltstone, moderately dense, wispy bedding (climbing ripples?), no effervescence.

94 Unit 163 (986.0-998.0): Gray green marlstone, dense, weathers to medium shaly partings, no effervescence.

89

88 Unit 162 (984.5-986.0): Buff fine siltstone, wispy bedding (climbing ripples?), dense.

85

84

83

82 Unit 161 (971.0-984.5): Gray green marlstone, dense, weathers to medium to thin shaly partings, forms slope , no effervescence.

80

78 Unit 160 (959.0-971.0): Covered slope, likely gray green shale, weathers red.

77 Unit 159 (957.5-959.0): Buff ostracode limestone (grainstone), dense, good effervescence, forms small outcrop.

76

75

73 Unit 158 (945.0-957.5): Gray green shale, weathers medium to thin shaly partings, no effervescence, forms covered slope.

72

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69

67 Unit 157 (944.0-945.0): Buff very fine sandstone, dense, no effervescence.

65

63

62 Unit 156 (930.0-944.0): Gray green marlstone, slightly silty, forms covered slope, no effervescence.

61

58

57 Unit 155 (924.0-930.0): Covered slope.

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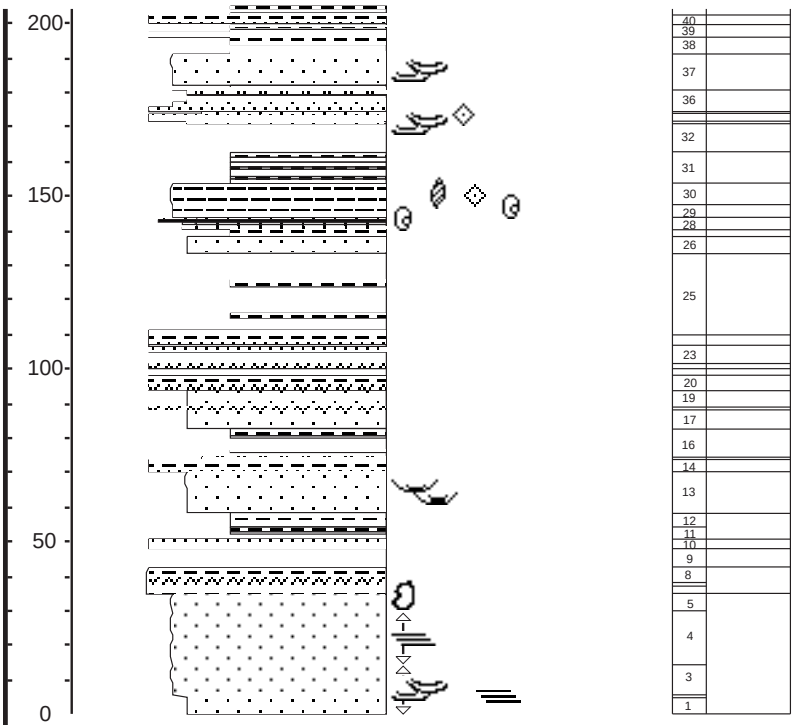
50

47 Unit 154 (923.5-924.0): Buff ostracode limestone (grainstone), dense, good effervescence, petroliferous odor upon HCl.

45

44



Unit 153 (916.0-923.5): Gray green shale, weathers to thin shaly partings.

Unit 152 (883.0-916.0): Buff fine sandstone, medium wedge crossbedding, probable channel.

Unit 151 (880.0-883.0): Tan gray marlstone, dense, no effervescence.

Unit 150 (879.0-880.0): Orange to tan ostracode limestone (packstone) w/ some small rounded clasts, dense, very good effervescence.

Unit 149 (870.0-879.0): Shale, covered, forms slope

Unit 148 (868.0-870.0): Buff fine sandstone, indistinct bedding, good effervescence.

Unit 147 (860.0-868.0): Shale, covered, forms slope.

Unit 146 (859.0-860.0): Light orange brown limy silty mudstone, dense, very good effervescence.

Unit 145 (849.0-859.0): Covered slope, likely shale.

Unit 144 (840.0-849.0): Buff fine to very fine sandstone, some medium wedge cross-bedding, fair effervescence.

Unit 143 (837.0-840.0): Buff very fine sandstone, small scale cross-bedding.

Unit 142 (831.0-837.0): Buff fine to very fine sandstone, possible laminar bedding, fair effervescence.

Unit 141 (819.5-831.0): Buff fine sandstone, possible laminar bedding.

Unit 140 (813.5-819.5): Buff fine sandstone, medium wedge cross-bedding, fair effervescence.

Unti 139 (805.5-813.5): Buff fine sandstone, medium cross-bedding, weathers medium to thin partings, fair effervescence.

Unit 138 (801.5-805.5): Buff fine sandstone with medium wedge cross-bedding, fair effervescence.

Unit 137 (795.5-801.5): Buff fine to very fine sandstone, abundant limonite concretions towards top, no effervescence, indistinct

Unit 136 (792.5-795.5): Buff fine to very fine sandstone, laminar bedding, weathers to thin to very thin partings, fair effervescence.

Unit 135 (789.5-792.5): Buff fine sandstone, planar bedding, no effervescence.

Unit 134 (777.5-789.5): Buff fine sandstone.

Unit 133 (771.5-777.5): Buff fine sandstone , laminar bedding, no effervescence.

Unit 132 (768.5-771.5): Buff fine sandstone, possible small scale cross-bedding, good effervescence.

Unit 131 (757.5-768.5): Tan to buff fine to very fine sandstone with soft sediment deformation to 765.5 feet. Small scale cross-bedding with ripples towards top terminated by planar bedding at very top of unit, no effervescence.

Unit 130 (756.5-757.5): Tan ostracodal grainstone/packstone.

Unit 129 (743.5-756.5): Tan siltstone (2 feet) at base, moderate effervescence, upper part gray marlstone with good effervescence.

Unit 128 (741.5-743.5): Tan very fine sandstone, massive at base, ripples towards top, good effervescence.

Unit 127 (729.5-741.5): Tan to grayish green shale, forms covered slope, no effervescence.

Unit 126 (723.5-729.5): Tan very fine sandstone with small limonite concretions, moderate to good effervescence, blocky appearance.

Unit 125 (699.5-723.5): Tan to light gray shale grades to thin bedded marlstone towards top. Occasional 1- to 2-feet. dense, limey marlstone beds in the vicinity of 717 feet with good effervescence, some petroliferous.

Unit 124 (694.5-699.5): Gray tan ostracodal (grainstone) limestone, strong effervescence, petroliferous, poorly exposed.

Unit 123 (625.5-694.5): Grayish green shale forming covered slope with occasional thin bedded very fine sandstone at 645 feet, 675 feet and 693 feet.

Unit 122 (624.5-625.5): Buff very fine sandstone, slight effervescence.

Unit 121 (615.5-624.5): Tan very fine sandstone (partially covered) thin bedded, slight effervescence.

Unit 120 (597.5-615.5): Tan to light gray very fine sandstone, planar bedding at base changing to ripples then cross-bedding (unidirectional troughs N46°W) possible channel base 3 feet up, slight to moderate effervescence, some limonite concretions.

Unit 119 (594.0-597.5): Siltstone?, covered.

Unit 118 (593.5-594.0): Buff very fine sandstone, ripples at base, moderate effervescence.

Unit 117 (587.5-593.5): Greenish gray shale, forms covered slope.

Unit 116 (576.5-587.5): Two sequences of very fine sandstone coarsening upwards to fine sandstone. First lower sequence-3 feet very fine to silty sandstone w/ horizontal bedding and soft sediment deformation coarsening to a 2 foot fine sandstone w/ small cross-beds, some climbing ripples. Second upper sequence-2 feet very fine to silty sandstone coarsening upwards to 3 feet fine sandstone w/ horizontal bedding, possible burrows, no effervescence.

Unit 115 (544.5-576.5): Greenish gray claystone to shale, thins upward in section, no effervescence, forms slope.

Unit 114 (534.5-544.5): Buff fine to very fine sandstone, planar bedding at base, high angle cross-beds (wedge?) at top, good effervescence.

Unit 113 (525.0-534.5): Greenish gray shale to marlstone, forms covered slope, good effervescence.

Unit 112 (524.5-525.0): Tan-gray marlstone, weathers orange, good effervescence.

Unit 111 (518.0-524.5): Greenish gray shale to mudstone, slight effervescence, forms covered slope.

Unit 110 (512.5-518.0): Buff to light gray very fine to fine sandstone, slight cross-bedding (poor expression), channel? wedge? slight to moderate effervescence, covered slope.

Unit 109 (503.33-512.5): Buff to light gray (with iron oxide streaks) siltstone to very fine sandstone, three 1 foot beds interbedded in a clay matrix, no distinct sedimentary structure, slightly effervescent.

Unit 108 (500.33-503.33): Light gray to buff very fine sandstone, non distinct cross-bedding, (wedge shaped?) possible ripples-channel?

Unit 107 (487.33-500.33): Gray 1- to 2-foot thick very fine to fine sandstone with interbedded gray shale forming covered slope, moderately strong effervescence.

Unit 106 (459.33-487.33): Buff, punky, fine to very fine sandstone, large scale wedge cross-bedding.

Unit 105 (452.33-459.33): Light tan very fine sandstone, laminar bedding, weathers to thin to very thin shaly partings.

Unit 104 (446.33-452.33): Gray silty shale, weathers to thin shaly partings, no effervescence, forms slope.

Unit 103 (444.33-446.33): Buff fine to very fine sandstone, moderately dense, planar bedding, fair effervescence.

Unit 102 (443.33-444.33): Buff very fine sandstone with abundant iron oxide stained ripup clasts.

Unit 101 (440.33-443.33): Buff fine to very fine sandstone, moderately dense, fair effervescence.

Unit 100 (427.33-440.33): Shale, covered slope.

Unit 99 (426.33-427.33): Buff silty limestone, dense, medium cross-bedding very good effervescence.

Unit 98 (422.33-426.33): Gray shale, weathers to thin shaly partings, poor effervescence, forms slope.

Unit 97 (420.5-422.33): Gray fine to very fine sandstone, moderately dense, laminar bedding, fair effervescence, weathers to medium partings.

Unit 96 (413.5-420.5): Gray silty marlstone, weathers medium to thin partings, fair effervescence.

Unit 95 (406.5-413.5): Buff fine sandstone, large wedge cross-bedding, scattered pebble size limonite concretions.

Unit 94 (391.8-406.5): Fine sandstone, small to medium wedge cross-bedding, no effervescence.

Unit 93 (391.5-391.8): Gray shale with iron oxide streaks, very thin shaly partings, no effervescence.

Unit 92 (388.25-391.5): Buff fine to very fine sandstone, lower 7 inches small rounded ripup clasts and detritus and wispy small scale cross-bedding towards top, no effervescence.

Unit 91 (387.5-388.25): Buff shale, friable.

Unit 90 (386.4-387.5): Limy siltstone, dense, very good effervescence.

Unit 89 (375.4-386.4): Gray shale, weathers to thin shaly partings, 18 inches very fine sandstone, dense, 1 foot below top, fair effervescence, forms slope.

Unit 88 (365.33-375.4): Light gray silty marlstone, moderately dense, weathers medium to thin shaly partings, fair effervescence, forms slope.

Unit 87 (364.8-365.33): Light tan silty limy marlstone, dense, good effervescence.

Unit 86 (363.8-364.8): Gray shale, weathers to thin shaly partings, no effervescence.

Unit 85 (358.8-363.8): Silty marlstone/siltstone, fair effervescence, small scale cross-bedding.

Unit 84 (354.67-358.8): Buff fine to very fine sandstone, large wedge cross-bedding, no effervescence, pebble size limonite concretions at top.

Unit 83 (349.67-354.67): Tan very fine sandstone, fair effervescence, horizon of platy noncalcareous features(pelecypod fragments).

Unit 82 (343.67-349.67): Gray marlstone, weathers to medium to thin shaly partings, forms slope.

Unit 81 (342.2-343.67): Buff very fine sandstone, dense, fair effervescence.

Unit 80 (336.1-342.2): Gray silty marlstone, moderately dense, fair effervescence, forms slope.

Unit 79 (333.33-336.1): Buff very fine sandstone, flaser bedding, fair to poor effervescence.

Unit 78 (325.33-333.33): Upper half red brown lower half gray shale, weathers to medium to thin shaly partings, no effervescence, forms slope.

Unit 77 (312.33-325.33): Buff very fine sandstone, some small scale cross bedding, fair effervescence, small scattered limonite

Unit 76 (307.33-312.33): Buff fine to very fine sandstone, flaser bedding, fair effervescence.

Unit 75 (303.33-307.33): Gray shale, weathers thin shaly partings, fair effervescence, forms slope.

Unit 74 (300.33-303.33): Silty mudstone/limestone, dense, weathers to medium shaly partings, good effervescence.

Unit 73 (291.33-300.33): Gray shale grading to buff silty marlstone, weathers to medium shaly partings, ripple bedding at top 6 inches, fair effervescence, dense.

Unit 72 (286.33-291.33): Buff fine to very fine sandstone, scattered round limonite concreations, fair effervescence.

Unit 71 (283.33-286.33): Buff silty marlstone, weathers medium to thin shaly partings.

Unit 70 (281.4-283.33): Buff fine to very fine sandstone, dense, small scale cross-bedding, good effervescence.

Unit 69 (276.67-281.4): Gray to light gray marlstone, weathers medium to thin shaly partings, fair effervescence, forms slope.

Unit 68 (275.4-276.67): Light gray limy marlstone grading into light brown limestone, dense, good to very good effervescence,

Unit 67 (271.4-275.4): Light gray marlstone, slightly silty, weathers medium to thin shaly partings, fair effervescence, forms slope.

Unit 66 (270.9-271.4): Light tan gray siltstone, dense, fair effervescence.

Unit 65 (267.0-270.9): Light gray shale/marlstone, thin to very thin shaly partings, fair effervescence, forms slope.

Unit 64 (265.5-267.0): Buff siltstone with trace of clay streaks, lower half gray silty marlstone with medium shaly partings, good effervescence, trace of vertabrate fragments.

Unit 63 (259.5-265.5): Red brown shale, poor effervescence, forms mostly covered slope.

Unit 62 (253.5-259.5): Buff siltstone, trace of clay streaks, flaser bedding, dense, fair effervescence, weathers medium to thin shaly partings towards top.

Unit 61 (249.5-253.5): Red brown shale, no effervescence, forms mostly covered slope.

Unit 60 (248.75-249.5): Buff siltstone, dense, small ripples, fair effervescence.

Unit 59 (247.4-248.75): Mottled purple gray shale weathers fine to very fine shaly partings, forms mostly covered slope.

Unit 58 (244.4-247.4): Light gray to tan marlstone, dense, weathers to medium partings, good effervescence, forms single outcrop.

Unit 57 (235.4-244.4): Gray to light gray shale, fair effervescence, forms covered slope.

Unit 56 (234.9-235.4): Buff silty marlstone, weathers medium to thin shaly partings, fair effervescence, forms small outcrop.

Unit 55 (232.6-234.9): Mottled purple gray shale, fair effervescence, weathers to thin shaly partings, forms covered slope.

Unit 54 (231.4-232.6): Tan siltstone with trace of mudstone, dense, fair effervescence, forms small outcrop on slope.

Unit 53 (230.75-231.4): Light gray nodular shale, good effervescence, froms small outcrop on slope.

Unit 52 (230.1-230.75): Light brown limestone, concoidal fracture, very dense; very good effervescence, froms small outcrop on slope.

Unit 51 (229.9-230.1): Light gray shale, weathers medium to thin shaly partings, good effervescence, forms mostly covered slope.

Unit 50 (226.9-229.9): Gray grading to light gray shale/mudstone, becoming silty towards top, weathers medium to thin shaly partings, good effervescence, forms mostly covered slope.

Unit 49 (223.9-226.9): Red brown shale/mudstone, no effervescence, forms slope.

Unit 48 (222.9-223.9): Buff fine to very fine siltstone, very dense, fair effervescence.

Unit 47 (218.9-222.9): Tan-gray shale/ mudstone, moderately dense, fair effervescence, forms slope.

Unit 46 (215.9-218.9): Red brown shale/ marlstone, moderately dense, weathers medium to thin shaly partings, forms slope, poor effervescence.

Unit 45 (212.9-215.9): Light gray shale/marlstone, moderately dense, weathers to medium shaly partings, forms slope.

Unit 44 (210.9-212.9): Light gray shale with fine well rounded detritus, weathers to fine shaly partings, very good effervescence, forms slope.

Unit 43 (207.9-210.9): Buff silty marlstone/siltstone, weathers to medium shaly partings, dense, fair effervescence, covered slope.

Unit 42 (204.9-207.9): Buff silty marlstone, dense, weathers to medium shaly partings, good effervescence, covered slope.

Unit 41 (201.9-204.9): Mottled purple-gray shale/marlstone, moderately dense, weathers to medium to very thin shaly partings, forms covered slope.

Unit 40 (198.9-201.9): Tan gray silty marlstone, dense, weathers to medium shaly partings, fair effervescence, partially covered slope.

Unit 39 (195.9-198.9): Gray silty marlstone/mudstone, dense, good effervescence, partially covered slope.

Unit 38 (190.9-195.9): Light gray shale, moderately dense, no effervescence, partially covered slope.

Unit 37 (180.25-190.9): Buff fine sandstone with some small scale cross-bedding, 6 inch light gray shale at bottom third.

Unit 36 (174.25-180.25): Silty marlstone, weathers to fissle-thin shaly partings, interbedded with fine to very fine sandstone beds.

Unit 35 (173.25-174.25): Buff silty to very fine sandstone, sharp transition to fine sandstone, dense, hiatus towards center, sparse fossil fragments.

Unit 34 (171.25-173.25): Gray limy marlstone, very fissle, faint petroliferous odor, good effervescence.

Unit 33 (170.75-171.25): Buff very fine sandstone, small scale cross-bedding/ flaser bedding? dense, hiatus/erosional surface at top.

Unit 32 (162.25-170.75): Covered slope, light gray shale, fair effervescence.

Unit 31 (153.33-162.25): Three (one-foot) tan gray marlstone beds with top bed (marlstone/limestone) interbedded with gray shale/marlstone beds, very good effervescence on top bed, no effervescence on other beds.

Unit 30 (147.33-153.33): Light gray mudstone/limestone, dense, good effervescence, grades to very thin shaly partings towards center back to medium shaly partings towards the top, fossil traces and fragments near center, gastropods in vicinity.

Unit 29 (143.33-147.33): Light to medium gray mudstone/limestone, with some sparse ostracods and small allochems, weathers to medium shaly partings, very good effervescence with a petroliferous odor.

Unit 28 (140.33-143.33): Four medium ostracodal grainstone to packstone limestone beds, dense, very good effervescence, interbedded with three light gray marlstone thin beds.

Unit 27 (137.8-140.33): Light gray shale, weathers to thin shaly partings.

Unit 26 (132.8-137.8): Buff very fine sandstone, dense.

Unit 25 (110.8-132.8): Covered slope, light gray to reddish brown shale.

Unit 24 (106.8-110.8): Medium to light gray silty marlstone, dense, weathers to some medium shaly partings, fair effervescence.

Unit 23 (102.8-106.8): Partially covered slope light gray marlstone, dense.

Unit 22(100.8-102.8): Partially covered slope, light gray silty marlstone, good effervescence.

Unit 21 (97.75-100.8): Partially Covered slope, light gray silty marlstone, good effervescence.

Unit 20 (93.75-97.75): Light gray silty marlstone, weathers to medium shaly partings, dense, fair effervescence.

Unit 19 (88.9-93.75): Buff fine to very fine sandstone,

Unit 18 (88.33-88.9): Light gray marlstone, dense, no

Unit 17 (82.67-88.33): Buff fine to very fine sandstone, nondistinct bedding.

Unit 16 (74.25-82.67): Covered slope, shale.

Unit 15 (73.25-74.25): Buff siltstone, dense, can't make bedding, no effervescence.

Unit 14 (70.25-73.25): Light greenish gray marlstone, faint effervescence.

Unit 13 (58.25-70.25): Buff fine to very fine sandstone, wispy or flaser bedding.

Unit 12 (54.25-58.25): Light gray shale, weathers medium to thin shaly partings.

Unit 11 (50.25-54.25): Covered slope, shale.

Unit 10 (48.0-50.25): Medium gray marlstone, dense, weathers to medium shaly partings, faint effervescence.

Unit 9 (42.0-48.0): Covered slope, greenish gray shale, weathers to medium to thin shaly partings, no effervescence.

Unit 8 (38.0-42.0): Light gray marlstone, dense, weathers to medium shaly partings, fair effervescence.

Unit 7 (37.0-38.0): Grayish tan marlstone, mostly medium gray, effervescence.

Unit 6 (34.5-37.0): Medium gray marlstone, dense, no effervescence.

Unit 5 (30.0-34.5): Buff fine sandstone, scattered limonite concretions.

Unit 4 (14.5-30.0): Buff fine sandstone, appears laminar bedding?, scattered limonite concretions upper 3 inches.

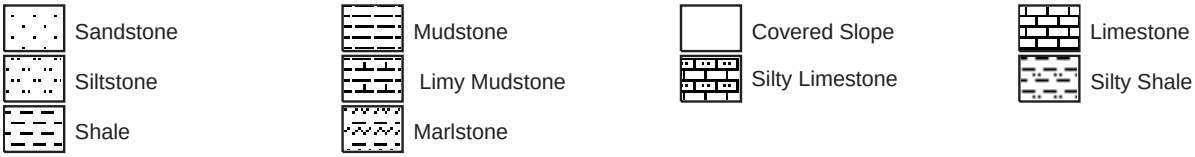
Unit 3 (6.0-14.5): Buff fine sandstone, medium cross-bedding.

Unit 2 (5.5-6.0): Buff fine sandstone, laminar bedding.

Unit 1 (0-5.5): Buff fine to very fine sandstone, medium cross-bedding.

LEGEND

LITHOLOGY



PHYSICAL STRUCTURES

LITHOLOGIC ACCESSORIES

FOSSILS