RESERVOIR CHARACTERIZATION of the LOWER GREEN RIVER FORMATION, UINTA BASIN, UTAH

by
Craig D. Morgan, Thomas C. Chidsey Jr., Kevin P. McClure,
S. Robert Bereskin, and Milind D. Deo

OPEN-FILE REPORT 411 April 2003
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES

FOSSIL ENERGY

DOE/BC/15103-4
(OSTI ID: 805238)

RESERVOIR CHARACTERIZATION OF THE LOWER GREEN RIVER FORMATION, SOUTHWEST UINTA BASIN, UTAH

Final Report
October 1, 1998-September 30, 2002

By:
Craig D. Morgan, Utah Geological Survey
Thomas C. Chidsey, Jr., Utah Geological Survey
Kevin P. McClure, Utah Geological Survey
S. Robert Bereskin, Ph.D., Tesseract Inc.
Milind D. Deo, Ph.D., University of Utah

Date Published: December 2002

Work Performed Under Contract No. DE-AC26-98BC15103

Utah Geological Survey
Salt Lake City, Utah

National Energy Technology Laboratory
National Petroleum Technology Office
U.S. DEPARTMENT OF ENERGY
Tulsa, Oklahoma

DISCLAIMERS

Utah Geological Survey

This open-file report makes information available to the public which may not conform to Utah Geological Survey (UGS) policy, editorial, or technical standards. Therefore it may be premature for an individual or group to take actions based on its contents.

Utah Department of Natural Resources

Although this product represents the work of professional scientists, the Utah Department of Natural Resources, Utah Geological Survey, makes no warranty, expressed or implied, regarding its suitability for a particular use. The Utah Department of Natural Resources, Utah Geological Survey, shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to claims by users of this product.

United States Government

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DOE/BC/15103-4
Distribution Category UC-122

Reservoir Characterization of the Lower Green River Formation, Southwest Uinta Basin, Utah

By
Craig D. Morgan, Utah Geological Survey
Thomas C. Chidsey, Jr., Utah Geological Survey
Kevin P. McClure, Utah Geological Survey
S. Robert Bereskin, Ph.D., Tesseract Inc.
Milind D. Deo, Ph.D., University of Utah

December 2002

Work Performed Under DE-AC26-98BC15103

Prepared for
U.S. Department of Energy
Assistant Secretary for Fossil Energy

Virginia Weyland, Project Manager
National Energy Technology Laboratory
National Petroleum Technology Office
One West Third Street, Suite 1400
Tulsa, OK 74103

Prepared by
Utah Geological Survey
1594 West North Temple, Suite 3110
P.O. Box 146100
Salt Lake City, UT 84114-6100
(801) 537-3300

TABLE OF CONTENTS

ILLUSTRATIONS

TABLES

PLATES

ABSTRACT

The oil-productive lower and middle members of the Green River Formation in the southwest Uinta Basin are divided into five distinct reservoirs. The reservoirs in stratigraphically ascending order are: (1) Uteland Butte, (2) Castle Peak, (3) lower Douglas Creek, (4) upper Douglas Creek, and (5) Garden Gulch. The changing depositional environments of Lake Uinta controlled the characteristics of each of the reservoirs. The Uteland Butte consists of carbonate and rare, thin shallow-lacustrine sandstone bars deposited during the initial rise of the lake. The Castle Peak reservoir was deposited during a time of numerous and rapid lake-level falls and rises, which developed a simple drainage pattern across the exposed shallow and gentle shelf with each cycle. The lower Douglas Creek reservoir records a time of active tectonism which created a steeper slope and a pronounced shelf break where thick cut-and-fill valleys developed during lake-level falls and rises. The upper Douglas Creek reservoir represents a return to a very gentle shallow shelf where channel deposits became stacked in a lowstand delta plain and amalgamated into some of the best reservoir rock in the southwest Uinta Basin. The Garden Gulch reservoir represents a time of major lake expansion with fewer, less pronounced, lake-level falls, resulting in isolated single-storied channel- and shallow-bar sandstone deposits.

The rocks exposed in Nine Mile Canyon are a good analog to the oil reservoirs in the southwest Uinta Basin. Examination of the exposures of the middle member of the Green River Formation in Nine Mile Canyon revealed a high degree of heterogeneity in reservoir-quality sandstone beds. The heterogeneity identified on outcrop indicates that a significant amount of the oil is being left behind in the Green River Formation reservoirs in the southwest Uinta Basin, at the current well spacing.

Numerical simulation models were constructed for three fields, which produce from the Uteland Butte, Castle Peak, and upper Douglas Creek reservoirs. Modeling indicates that primary recovery from each of the reservoirs is less than 5 percent of the oil in place.

INTRODUCTION

The Utah Geological Survey led a four-year study of the lower and middle members of the Eocene Green River Formation in the southwest Uinta Basin, Utah (figure 1). The Green River is a highly oil-productive formation consisting of lacustrine- and marginal-lacustrine rocks deposited in and around Eocene-aged Lake Uinta. The objectives of the study were to increase both primary and secondary hydrocarbon recovery through improved characterization (at the regional, unit, interwell, well, and microscopic scale) 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 southwest region of the Uinta Basin, and other areas with production from fluvial-deltaic reservoirs.

A log-based correlation scheme and nomenclature that reflect, as near as possible, time-correlative depositional cycles of the lower and middle members of the Green River Formation were established. The cycles are at a scale that is easily recognizable on geophysical well logs and can be correlated throughout most of the southwest Uinta Basin. Logs from more than 1,300 wells were correlated, and data on cycle boundaries, total sandstone, and total feet of porosity, for each cycle, were entered into the well database and used for mapping.

Regional investigation of the surface exposures of the Green River Formation was conducted in Willow Creek, Nine Mile, and Desolation Canyons. Numerous stratigraphic sections in the Green River were measured and described. Photomontages of nearly 4 miles (6 km) of outcrop in Nine Mile Canyon where compiled and used for correlation of key marker beds. Spectral gamma-ray (GR) data were collected using an Exploranium® GR - 256 spectrometer with a GPX - 21 scintillation detector, over four stratigraphic sections; one in Willow Creek Canyon, and three in Nine Mile Canyon. Curves generated from the GR data were correlated with GR curves from wells in the area. Several carbonate marker beds are found in the middle member, which define large-scale (about 100-foot [30-m] thick) depositional cycles and are used to correlate the cycles for tens of miles along the outcrop and in the subsurface. Smaller scale depositional cycles have been identified on outcrop but are difficult to correlate regionally.

Five reservoirs were identified in the middle and lower members of the Green River Formation based on the regional chronostratigraphic correlations, investigation of well core, and examination of the surface exposures. The five reservoirs in stratigraphically ascending order are: (1) Uteland Butte, (2) Castle Peak, (3) lower Douglas Creek, (4) upper Douglas Creek, and (5) Garden Gulch. Each reservoir consists of one or more beds with similar paleodepositional history, petrology, and diagenesis that are unique to the reservoir.

A detailed study site was selected in Nine Mile Canyon, from Petes Canyon to Gate Canyon, both tributaries to Nine Mile. The exposure is about 2,000 feet (600 m) in the east-to-west direction and about 4,200 feet (1,280 m) in the north-to-south direction. The stratigraphic interval studied is slightly more than 100 feet (30 m) thick, bounded by carbonate beds. Eight sections were measured and described, and GR data gathered from five of the sections. To aid in the interpretation, the site was photographed from the canyon walls opposite the study site, and photomontages were compiled. Data from the study site serves as an important analog for the reservoir heterogeneity that can be expected in the interwell environment and at the scale of a typical Monument Butte area water-flood unit.

Geostatistial analyses were conducted and numerical simulation models were constructed for the Uteland Butte field (Uteland Butte reservoir), Brundage Canyon field (Castle Peak reservoir), and Monument Butte Northeast unit (upper Douglas Creek reservoir). The Uteland Butte and Brundage Canyon fields are in primary production while the Monument Butte Northeast is a secondary-recovery water-flood unit.

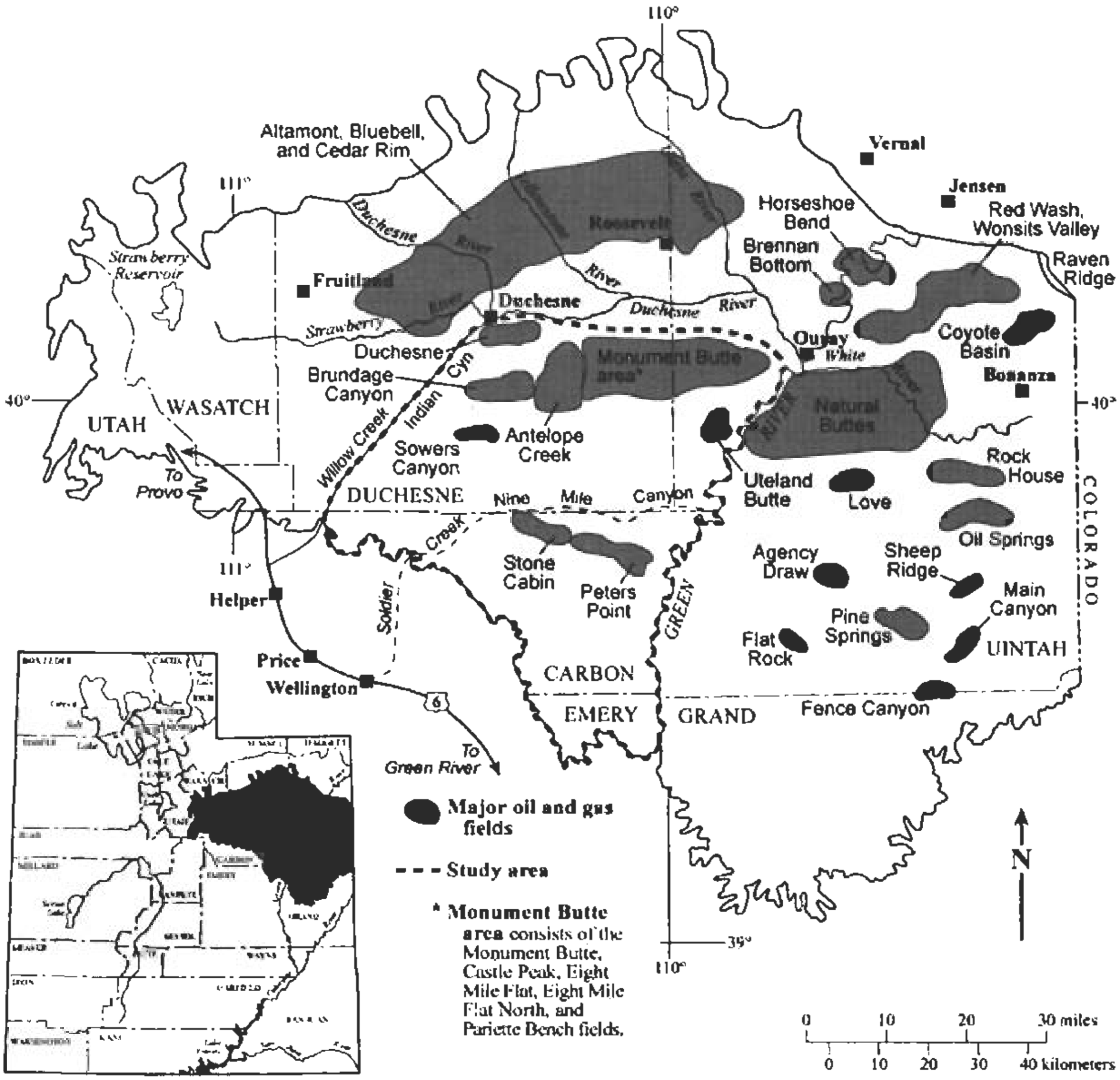


Figure 1. Location map of the Uinta Basin showing the southwest Uinta Basin study area.

Geophysical well log data were used to construct detailed the geostatistical models for the Monument Butte Northeast unit, that were upscaled to obtain reasonable number of grid blocks for reservoir simulation. Porosities, permeabilities, and water saturations required for reservoir simulation were generated from well log and core data. Comparison of the production results with the field data revealed that there was a phenomenogical deficiency in the model. This was addressed by incorporating hydraulic fractures into the models resulting in much better agreement between simulated production and actual field production data.

The Brundage Canyon and Uteland Butte fields were simulated in primary production. Only preliminary simulations were undertaken since a number of critical data elements could not be obtained from the operators. These studies revealed that the production performance of the Brundage Canyon field is much better than what can be predicted from simulations of a typical non-fractured, undersaturated reservoir, indicating that naturally occurring fractures are an important part of the Castle Peak reservoir. Uteland Butte field performance was that of a typical undersaturated reservoir.

GEOLOGIC SETTING

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 1). 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 Late Cretaceous Maastrichtian time, creating a large area of internal drainage, which was filled by ancestral Lake Uinta during the Paleocene and Eocene. 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 (Wasatch) Formation.

More than 450 million barrels of oil (MMBO) (72 million m^3) have been produced from the Green River and Colton Formations in the Uinta Basin. The Cedar Rim, Altamont, Bluebell, and Red Wash fields produce oil from the northern shoreline deposits of Lake Uinta, while the fields in the greater Monument Butte area (Duchesne, Brundage, Sowers, Antelope Creek, and Uteland Butte fields, and the Monument Butte area [figure 1]) produce from southern deltaic shoreline deposits as preserved in the middle and lower members of the Green River. The southern shore of Lake Uinta was often 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 southwest Uinta Basin resulted in numerous stacked deltaic deposits. Distributary-mouth bars, distributary channels, and nearshore bars are the primary producing sandstone reservoirs in the area.

PREVIOUS STUDIES AND STRATIGRAPHIC NOMENCLATURE

The stratigraphic nomenclature used to describe the Green River Formation in the Uinta Basin, Utah, is as diverse as the rocks themselves. The nomenclature is based on facies, which are often bounded by subtle and interfingering relationships that are difficult to carry with confidence any great distance within the basin. Regional facies studies such as Fouch (1975) and Ryder and others (1976), have greatly increased our knowledge of Lake Uinta as represented by the deposits of the Green River Formation, but rapid facies change with poorly defined boundaries has often lead to confusing stratigraphic relationships, and questionable and confusing use of terminology.

In the eastern Uinta Basin, Bradley (1931) named and described the Douglas Creek, Garden Gulch, Parachute Creek, and Evacuation Creek Members of the Green River Formation. In the western Uinta Basin, Bradley (1931) defined the basal lacustrine phase, tongue of the Wasatch, second lacustrine phase, delta facies, oil shale facies, barren and saline facies (figure 2). Picard (1955) introduced the term black shale facies for the western Uinta Basin area for the rocks equivalent to the first lacustrine phase and Wasatch tongue of Bradley (1931). Abbott (1957) expanded the use of black shale facies to include the second lacustrine phase of Bradley (1931) and showed the delta facies to be equivalent to the Douglas Creek Member. Picard (1957a, 1957b) introduced the term green shale facies, which is equivalent to most of the delta facies. In the subsurface the black shale facies thickens from south to north at the expense of the green shale facies (Picard 1957a). Ryder and others (1976) defined the carbonate marker unit equivalent to the black shale facies below the carbonate marker bed.

Several workers have described the fluvial-deltaic and interfingering alluvial deposits associated with the southern shoreline of Lake Uinta in the southwest Uinta Basin (Cashion, 1967; Picard and High, 1970; Fouch, 1975; Ryder and others, 1976; Pitman and others, 1982). Remy (1992) described the exposures and depositional environments of the delta facies of the Green River in Nine Mile Canyon and some of its tributaries. Remy (1992) defines the Sunnyside delta interval in Nine Mile Canyon from the top of the carbonate marker bed to the C marker (Jacob, 1969), and from the C marker to the top of the S1 sandstone, just below the base of the Mahogany oil shale, as the transitional facies.

There are a few laterally extensive marker beds, which have been identified on the surface and in the subsurface (Jacob, 1969; Weiss and others 1990). These marker beds have been used for time-stratigraphic correlations that can cross facies boundaries. Several marker beds have been identified on the surface and correlated to well-log signatures in the subsurface. The top of the carbonate marker unit of Ryder and others (1976) is placed at the top of the carbonate marker bed, which has an easily recognizable well-log response throughout most of the southwestern Uinta Basin. Jacob (1969) defines several carbonate marker beds in Nine Mile Canyon such as the D marker which is about 500 feet (150 m) above the carbonate marker bed and contains a pisolite bed which makes it easy to identify throughout most of the western portion of Nine Mile Canyon, before it dips below the canyon floor. Jacob's (1969) C marker consists of three ostracod grainstones that he designated from base to top as C3, C2, and C1. The C1 marker is equivalent to the stromatolite marker of Remy (1989) and the C marker of Remy (1992). The C marker is about 700 feet (200 m) above the D marker.

Bradley 1931	Picard 1957	Weiss & others 1990	Remy 1992	Lomax unpublished	Morgan & others 1999
		base of the Mahogany oil shale zone			
———? delta facies	green shale facies	middle member	transitional facies —— *C marker* delta facies *D marker*	Garden Gulch —— pay sands D C B A Douglas Creek —— *B limestone* lower Douglas Creek	—— MGR 12 —— MGR 7 —— MGR 3 middle member
carbonate	*marker bed (top)*	*(base)*			
second lacustrine tongue Colton Tongue first lacustrine tongue	black shale facies	lower member	CMU *(carbonate marker unit)*	Castle Peak Uteland Butte	*CMU (carbonate marker unit)* LGR 1-5 lower member

Figure 2. Generalized nomenclature for the Green River Formation (below the Mahogany oil shale zone) for the south-central to southwest Uinta Basin.

Weiss and others (1990) mapped a lower member, middle member, upper member, and saline member in the Nine Mile Canyon area. Weiss and others (1990) unlike previous workers, use the base of the carbonate marker bed instead of the top as a mapping horizon. To divide the lower member from the upper member we modified the lower member using the top of the carbonate marker bed as the top of the lower member - base of middle member. The modified lower member is equivalent to the black shale facies of Abbott (1957), the middle member from the top of the carbonate marker bed to the base of the Mahogany oil shale, is equivalent to all of the delta facies of Bradley (1931), Picard (1957), and the delta and transitional facies of Remy (1992). The upper member and saline member were not part of this study.

Recent workers have begun to use a sequence stratigraphic (chronostratigraphic instead of lithostratigraphic) approach to the Green River Formation. Crouch and others (2000) reported on their subsurface study of the Uteland Butte reservoir in Antelope Creek Field. Keighley and others (1999, 2001) studied the outcrops in Nine Mile Canyon while Borer and McPherson (1996), and Borer (1998), studied the outcrops at Raven Ridge and subsurface deposits at the neighboring Red Wash field. Our study uses chronostratigraphic correlations of surface outcrops and subsurface well logs to characterize the petroleum reservoirs in the lower and middle members of the Green River Formation in the southwest Uinta Basin.

STRATIGRAPHIC NOMENCLATURE AND CORRELATION MARKERS USED IN THIS REPORT

Members

Weiss and others (1990) divided the Green River Formation in the southwest Uinta Basin into informal members, in stratigraphically ascending order: (1) lower member, (2) middle member, (3) upper member, and (4) saline member. We studied only the lower and middle members. Weiss and others (1990) used the base of the carbonate marker bed to define the top of the lower member-base of middle member of the Green River Formation but previous workers used the top of the carbonate marker bed to define the top of the carbonate marker unit (Ryder and others, 1976; and Remy, 1992). The lower member includes the Uteland Butte reservoir also known as Bradley's (1931) first lacustrine phase, or the basal carbonate (Little, 1988) and the Castle Peak reservoir or carbonate marker unit (Ryder and others, 1976). 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 - base of middle member (figure 3). The carbonate marker bed is easily identifiable on well logs throughout the region. The middle member is defined as from the top of the carbonate marker bed to the base of the Mahogany oil shale. The middle member contains the lower and upper Douglas Creek reservoirs and Garden Gulch reservoir. The middle member also consists of the Douglas Creek Member and part of the Garden Gulch Member (Bradley, 1931) and Remy's (1992) delta and transitional facies.

Log Cycles

The +2,000-foot-thick (600-m), Tertiary-aged lacustrine deposits of the middle and lower members of the Green River Formation contain the primary oil-producing reservoirs in the southwest Uinta Basin, Utah. 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 (Morgan and others, 1999). The log-cycles are at a scale that is easily recognizable on geophysical well logs, typically range from 50 to 100 feet (15-30 m) thick, and can be correlated throughout most of the southwest Uinta Basin (figure 4).

The log cycles are numbered from the base of the member upward and were defined by gamma-ray and resistivity log patterns. Log patterns that may represent coarsening-upward sequences overlain by a flooding event or a rise-to-fall sequence were identified in key wells. The correlations were then made on regional east-to-west and north-to-south well-log cross sections (figure 5 and plates 1 through 4). Correlations that were difficult to make or appeared to have a limited extent were dropped. The correlations resulted in five cycles in the lower member of the Green River Formation (LGR) plus the carbonate marker unit, which was not divided because the log-cycle pattern was too small for reliable regional correlation. In the middle member (MGR), 18 cycles were identified although MGR 1 and MGR 2 proved to be unreliable correlations and were not picked in most well-log correlations.

The top of the uppermost cycle, MGR 18, correlates to the middle marker of Ryder and others (1976). This is the top of the stratigraphic sequence that we studied. There is about 500 to 600 feet (150-180 m) of middle Green River section from the top of the middle marker to the base of the Mahogany oil shale.

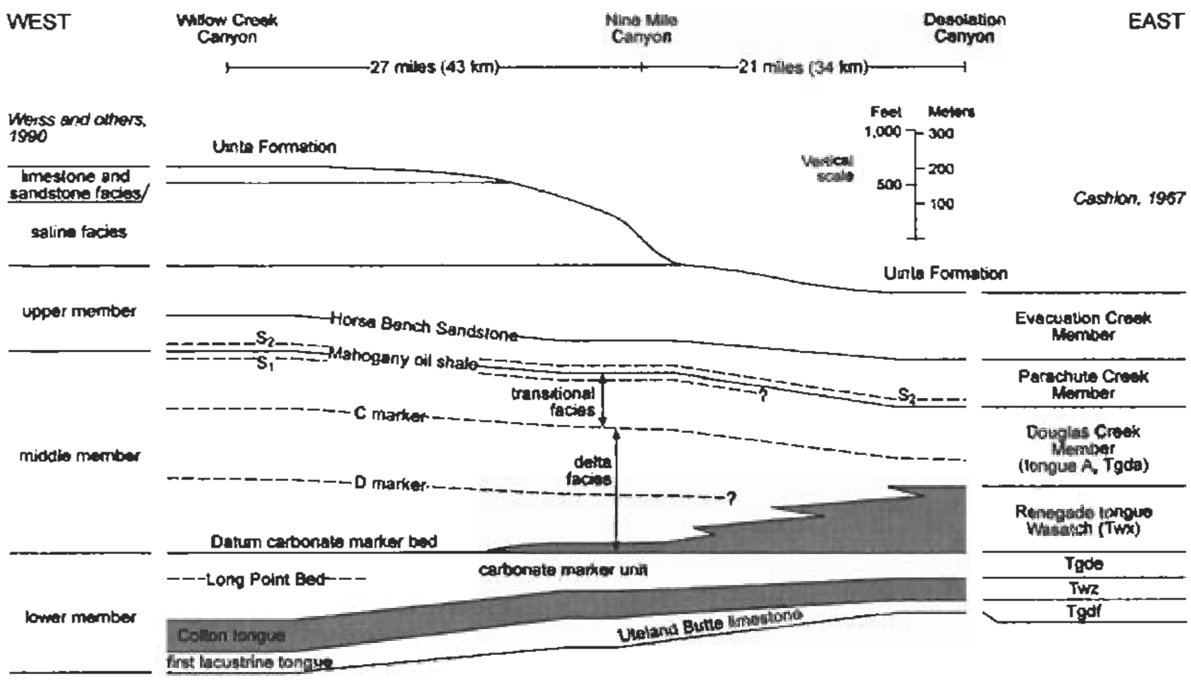


Figure 3. West to east stratigraphic cross section showing the stratigraphic nomenclature used in this report and some of the common stratigraphic names used by other workers.

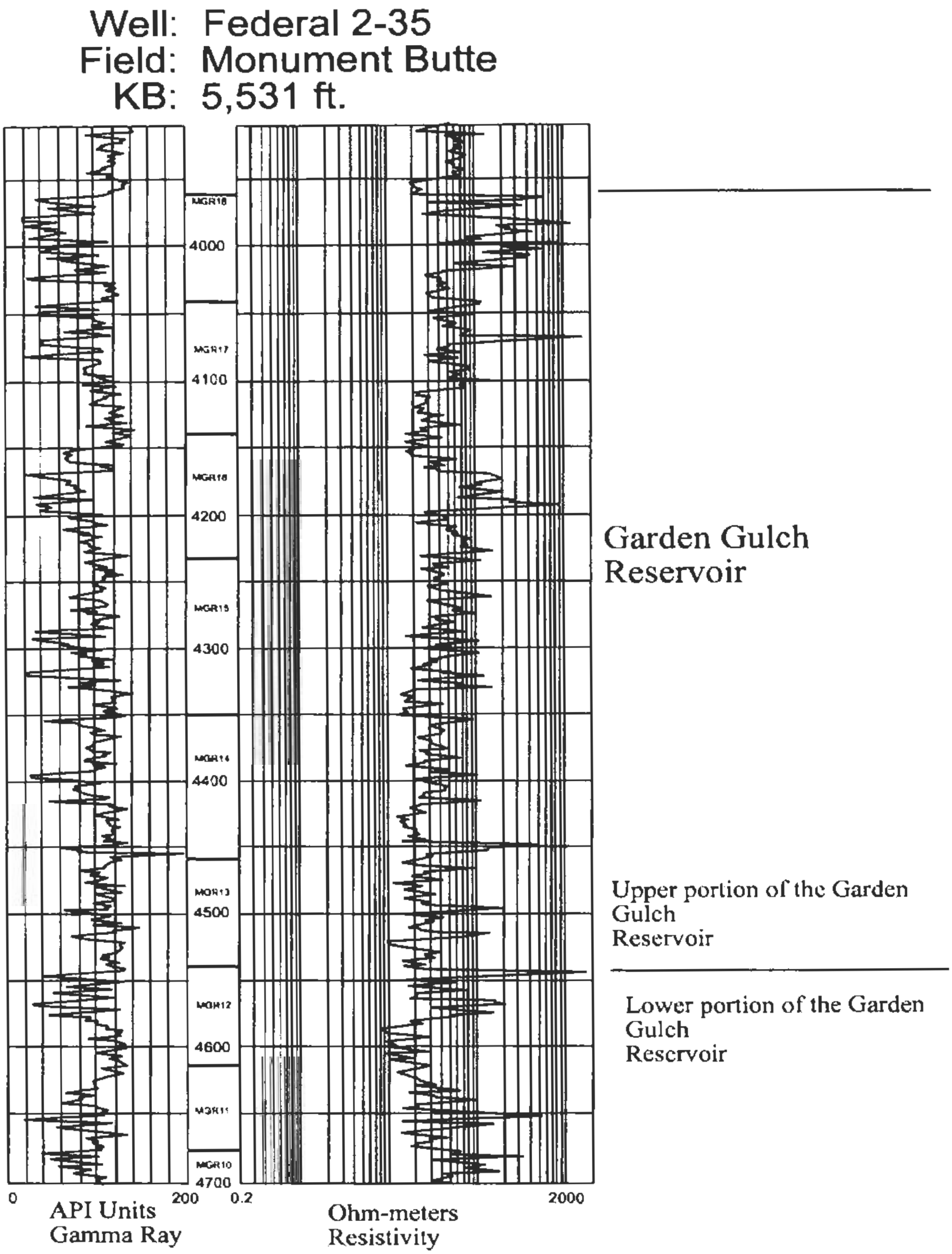


Figure 4. Type log showing the log cycles and oil reservoirs in the middle member (MGR) and lower member (LGR) of the Green River Formation. CMU is the carbonate marker unit of the lower member. Well location is NE1/4SE1/4 section 35, T. 8 S., R. 16 E., of the Salt Lake Base Line Salt Lake Base and Merdian.

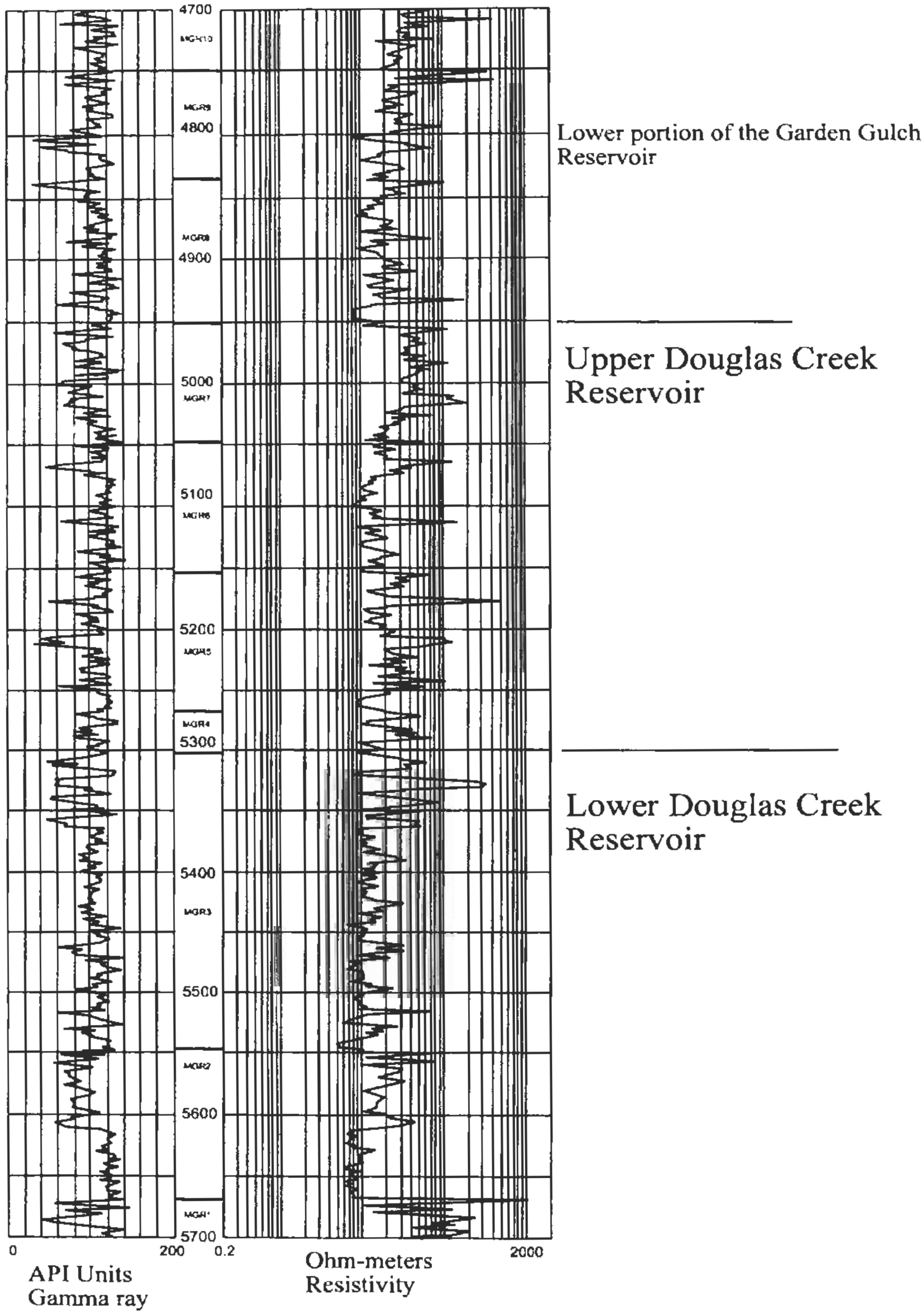


Figure 4 continued.

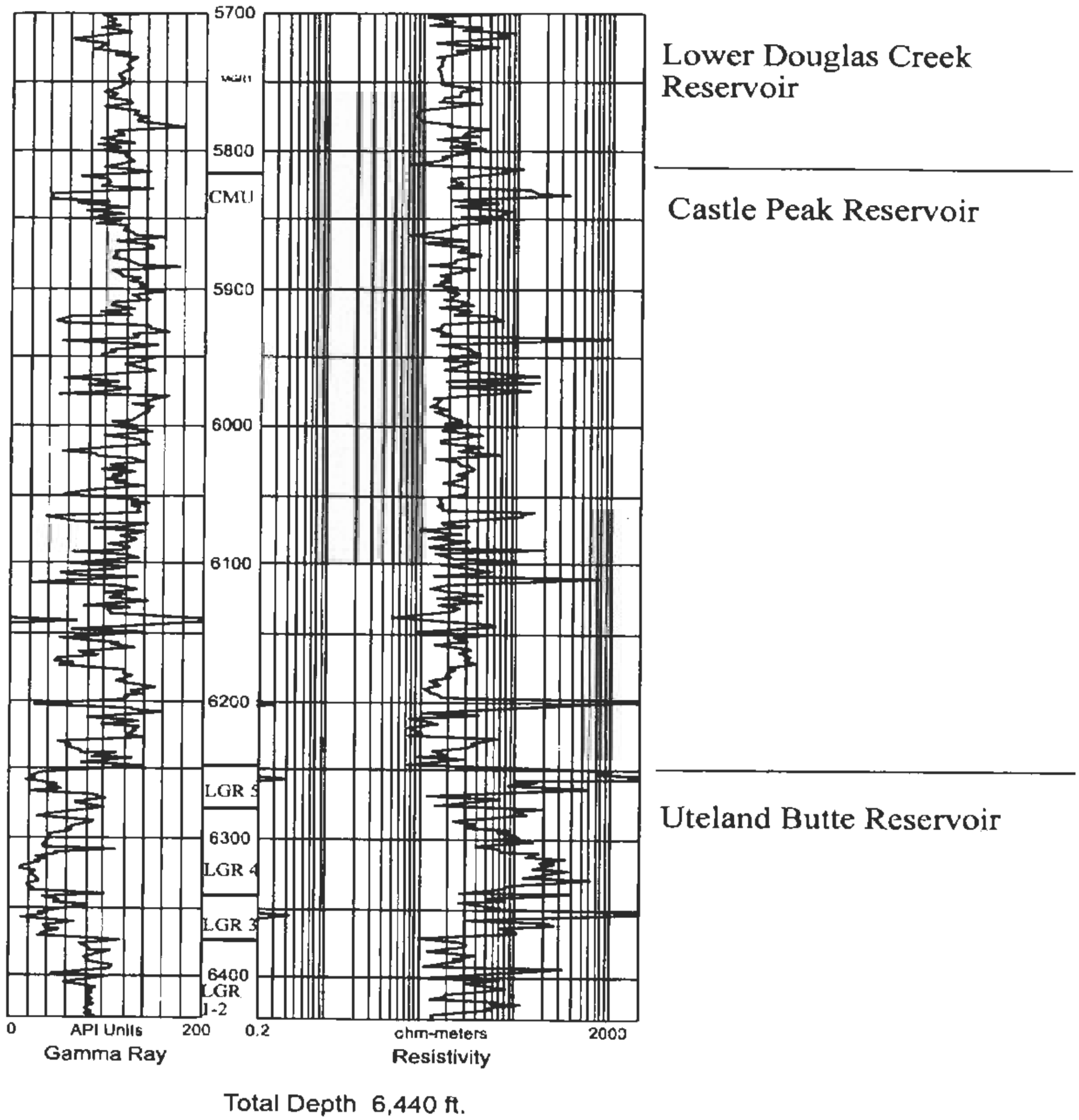

5700
5800
CMU
5900
6000
6100
6200
LGR 5
6300
LGR 4
LGR 3
6400
LGR 1-2
0
API Units
200
Gamma Ray
0.2
ohm-meters
2000
Resistivity
Total Depth 6,440 ft.
Lower Douglas Creek Reservoir
Castle Peak Reservoir
Uteland Butte Reservoir

Figure 4 end.

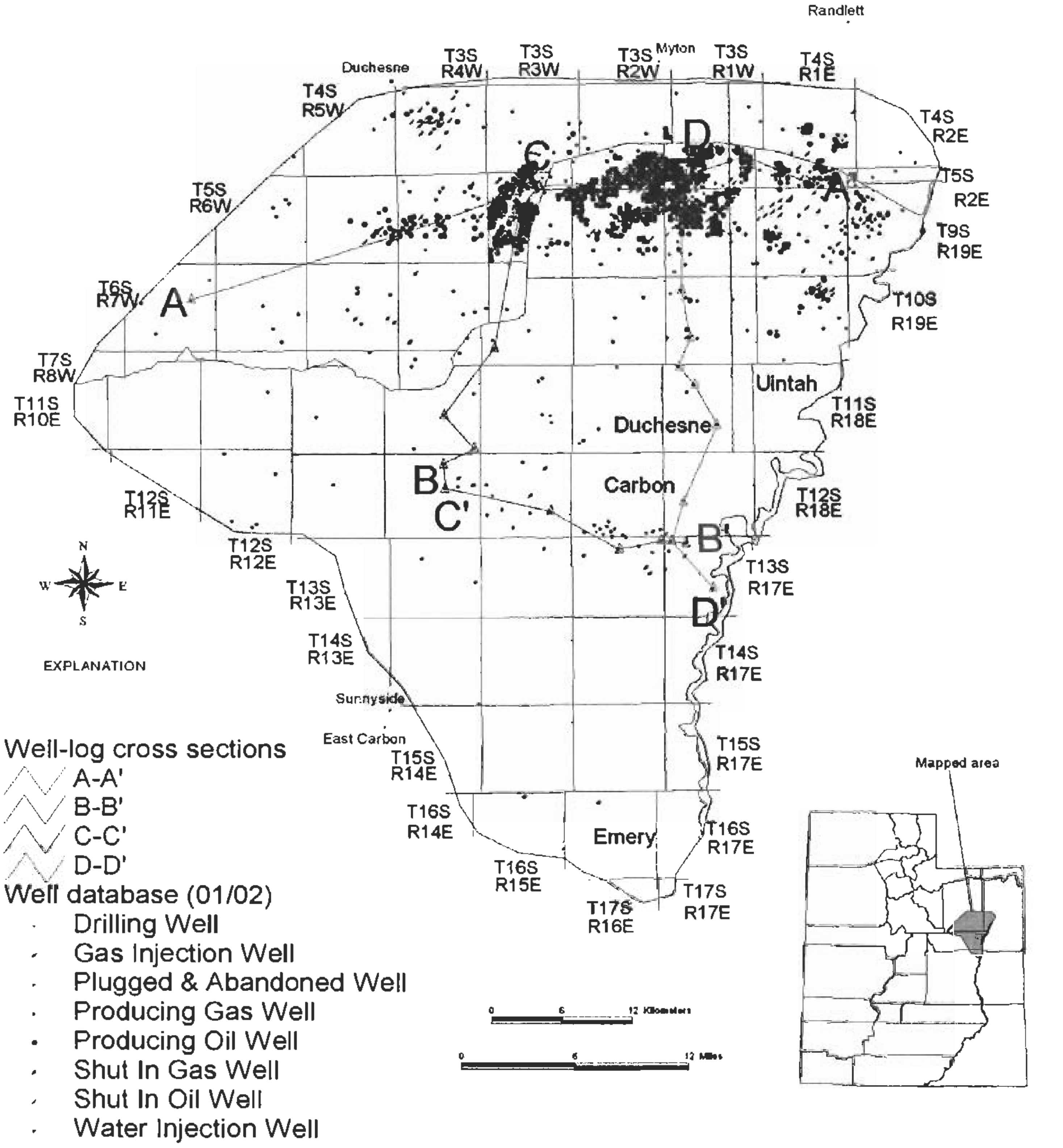


Figure 5. Map showing the location of regional well-log cross sections A – A' (plate 1), B – B' (plate 2), C – C' (plate 3), and D – D' (plate 4).

Log cycles LGR1 through LGR 5, are the Uteland Butte reservoir, also known as the basal Green River carbonate, or the first lacustrine tongue of Bradley (1931). The five divisions are based on the work of Little (1988) and can be correlated from surface outcrop to subsurface well logs. The carbonate marker unit or Castle Peak reservoir was not divided into log cycles because the patterns were too thin for regional correlations. Hackney and Crouch (2000) working in the Antelope Creek field (T. 5 S., R. 3 W., Uinta Base Line [UBL]) identified 17 different cycles in the Castle Peak reservoir. Some cycles in the MGR do not have the typical cyclic log pattern but are packages underlain and overlain by cyclic sequences. These packages could represent a period of stable lake level or a period of high cyclicity resulting in a series of sequences at a scale smaller than what we are studying. Regardless, these packages can be correlated and mapped regionally.

OUTCROP STUDIES

Exposures of the lower and middle members were studied to gain a better understanding of the regional paleodepositional history and stratal architecture of the stratigraphic sequence. The regional outcrop study when combined with the subsurface study, defined the trapping mechanism for the various reservoirs and is a useful tool for future exploration. A more limited exposure referred to as the Nutter's Ranch study site was investigated in more detail. The Nutter's Ranch study site consists of a stratigraphic sequence about 100 feet (30 m) thick with an extent of about 1 square mile (2.6 km^2). The Nutter's Ranch study site is a good analog for some of the reservoir beds in the greater Monument Butte area and provides insights into the potential reservoir heterogeneity that can exist in the interwell environment.

Exposures of the lower and middle member of the Green River Formation were studied in Willow Creek, Nine Mile, and Desolation Canyons and many of their tributaries. Eight stratigraphic sections (Appendix A) were measured and described totaling 8,813 feet (2,686.2 m). Gamma-ray data was gathered over four sections totaling 5,500 feet (1,680 m). Seven stratigraphic sections by Remy (1992) were field checked and graphically redrawn to match the style and scale of the UGS measured sections (Appendix B). Key marker beds were correlated between the stratigraphic sections relying in part on the correlations of Remy (1992) and Keighley and others (2002) (figure 6 and plates 5, 6, and 7). A 3.75 mile (6.0 km) portion of the north wall of Nine Mile Canyon was photographed, montages were constructed and used for correlation (Appendix C). The gamma-ray curves were used to help correlate between stratigraphic sections and to correlate from surface sections to subsurface well logs (figure 7 and plates 8 and 9).

Stratigraphic Correlation and Sequence Stratigraphy

During the latest Cretaceous through middle Eocene the Uinta Basin was an intermountain basin where Ancient Lake Uinta and associated fluvial deposition resulted in more than 3,000 feet (900 m) of siliciclastic and carbonate sediments. The sediments make up the Colton Formation and the Flagstaff Member, lower, middle, upper and saline members of the Green River Formation. The region was subtropical to semi-arid with strong seasonality and storm tracts generally from west to east, parallel to the long axis of Lake Uinta. Jacob (1969) interpreted the delta facies in the southwest Uinta Basin as being deposited on a shallow shelf, generally in water depths no more than a few tens of feet.

The Colton Formation and the lower and middle members of the Green River Formation are exposed in Willow Creek Canyon. The exposures in Willow Creek Canyon include Bradley's (1931) first and second lacustrine phase and overlying delta facies, which are correlative to Picard's (1957a and 1957b) black shale and green shale facies. The Mahogany oil shale is exposed near the top of Willow Creek Canyon.

The lower member of the Green River Formation is exposed in the western portion of Nine Mile Canyon. Most of the exposures in Nine Mile Canyon are the delta and transitional facies in the middle member. The Mahogany oil shale is at or near the top of the most of the cliffs in Nine Mile Canyon. The Colton Formation, and the lower and middle members of the Green River, are exposed in Desolation Canyon and many of its tributaries.

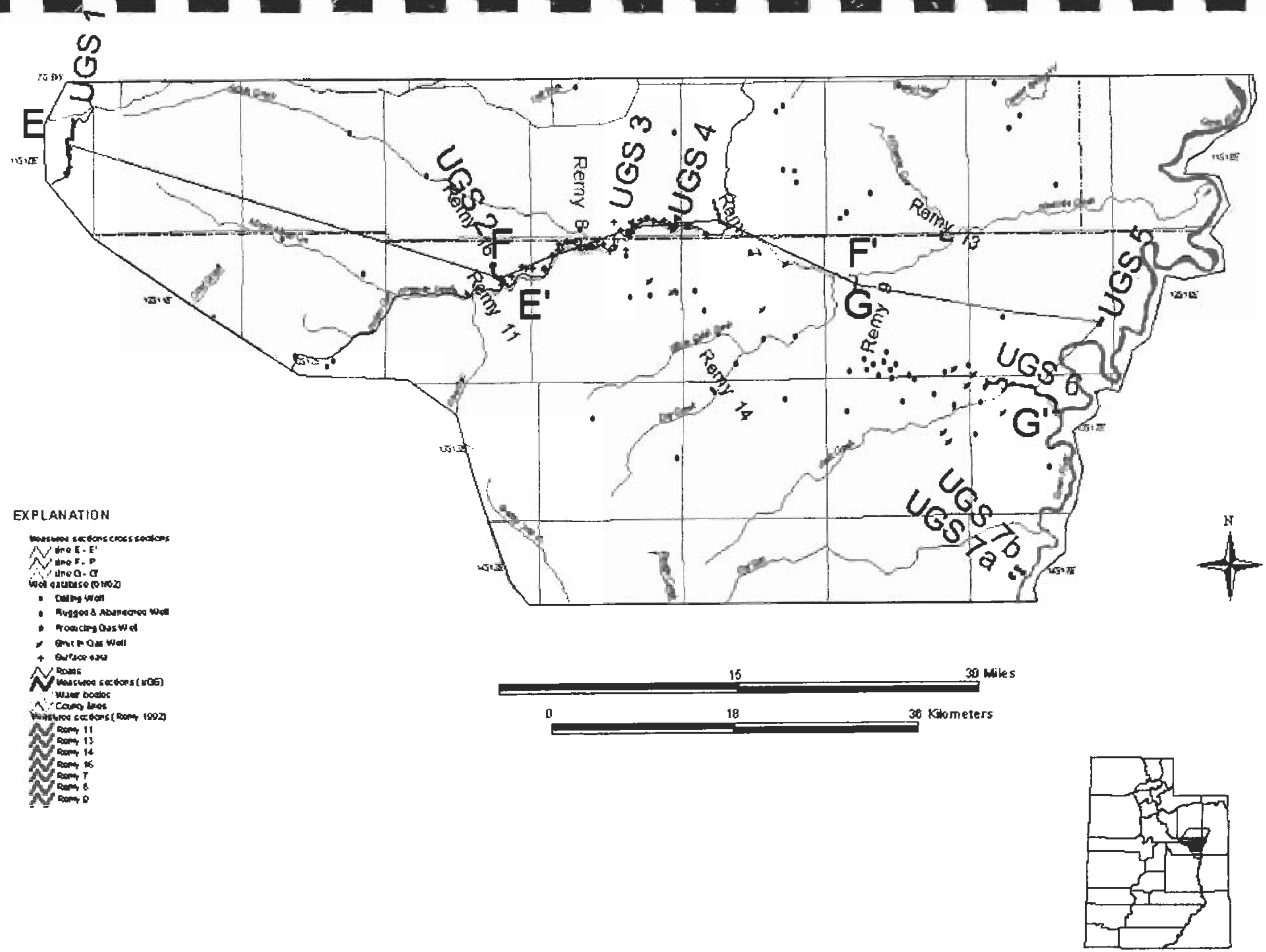


Figure 6. Map showing the location of the surface stratigraphic cross sections E – E' (plate 5), F – F' (plate 6), and G – G' (plate 7).

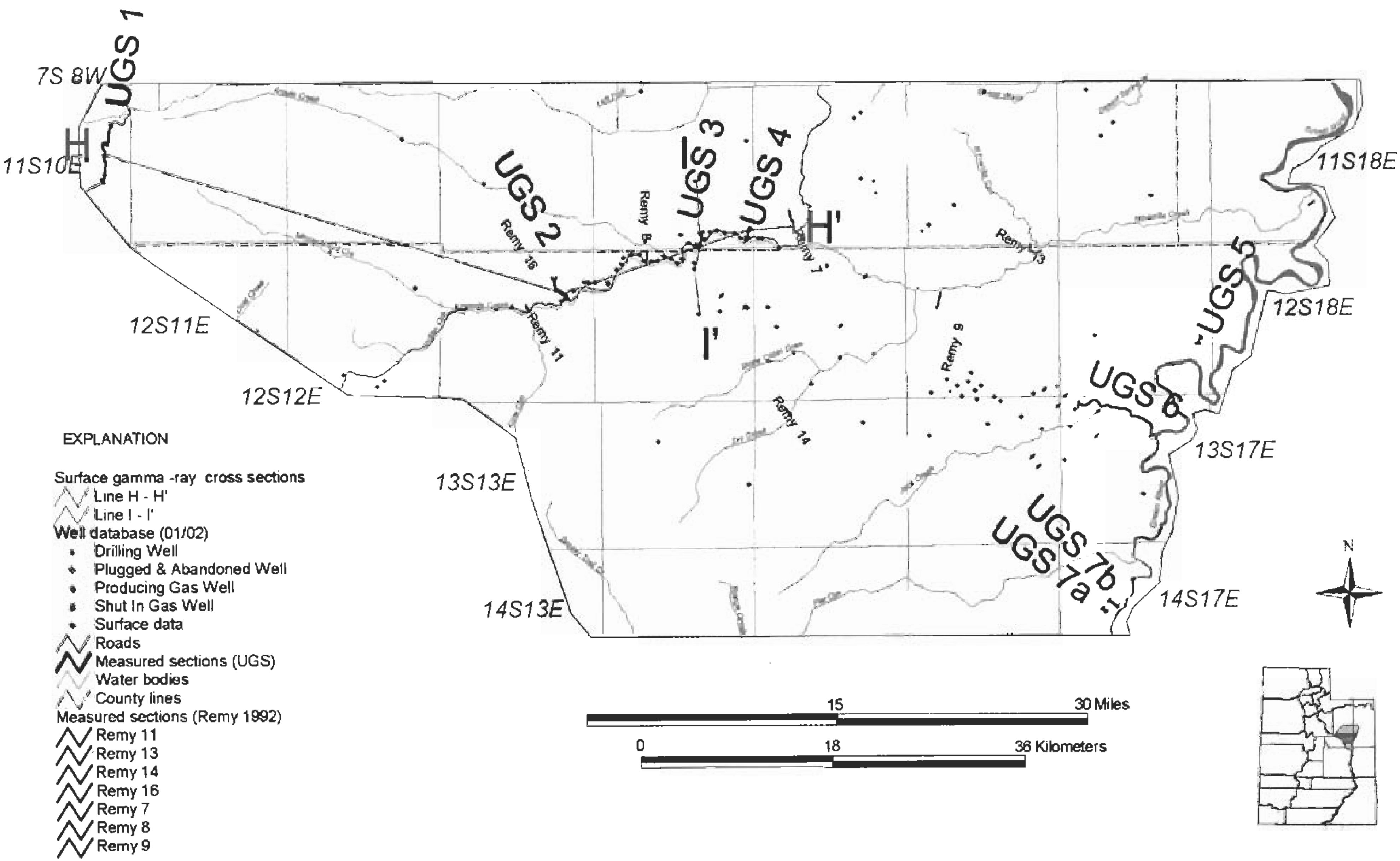


Figure 7. Map showing the location of the surface gamma-ray log cross sections H - H' (plate 8) and I - I' (plate 9).

Ryder and others (1976), and Fouch (1975), divided the Green River Formation into three major facies: (1) open lacustrine, (2) marginal lacustrine, and (3) alluvial. The three facies have been used to describe the paleodepositional history of the Colton and Green River Formations throughout the existence of Lake Uinta (Fouch, 1975; Ryder and others, 1976; Franczyk and others, 1992; and Remy, 1992). Chronostratigraphic interpretation of the paleodepositional environments of Lake Uinta have been based on key carbonate marker beds such as Jacob's (1969) C and D markers, and Ryder and others (1976) middle marker and carbonate marker beds. The Green River Formation, especially the middle member, is dominated by large scale (100 feet [30 m]) and smaller scale (30 feet [10 m]) depositional cycles caused by lake level fluctuations. Ryder and others (1976), Fouch and Pitman (1991, 1992), and Fouch and others (1992, 1994), and many others have described the cyclic nature of the Green River.

Borer (1998) and Borer and McPherson (1996), have presented high-resolution sequence stratigraphic interpretations for the Green River Formation at Raven Ridge and nearby Red Wash oil field. Keighley and others (2002, 2001, 1999) studied the sequence stratigraphy of the delta facies from the D marker to the C2 marker in Nine Mile Canyon.

Keighley and others (2002) identified 11 markers in Nine Mile Canyon, which they used to divide the sequence into depositional units or cycles 20 to 90 feet (6 - 30 m) thick. The markers are named in ascending stratigraphic order, M1, equivalent to the D marker, through M11, equivalent to the C2 marker. All of the markers are carbonate beds except M2, which is a thin (1 inch [3 cm]) oil shale. The markers are laterally extensive and can be traced for more than 10 miles (16 km). A marker bed will sometimes be locally absent when it is truncated by overlying fluvial sandstone. Keighley and others (2002) described the sequence as alternating 60-foot (20-m) thick floodplain-dominated intervals and 30-foot (10-m) thick lacustrine-dominated intervals.

Keighley and others (2002) defined two types of sequence boundaries in Nine Mile Canyon that represent significant basinward shifts in facies. Type A sequence boundaries are defined as offshore lacustrine facies that pass abruptly upward into floodplain-dominated intervals and/or where the lacustrine - floodplain transition is across a surface that is a mappable unconformity over the study area. Type B sequence boundaries are defined as lacustrine-dominated intervals that lack any distinct offshore facies and any unconformable contact with overlying floodplain-dominated strata. Type A sequences are more pronounced base-level falls while Type B sequences are higher frequency, lower magnitude lake-level falls.

We used Keighley and others (2002) correlation markers (M1 - M11) and sequence boundaries in Nine Mile Canyon. We designated the C1 marker of Jacob (1969) as M12 and identified additional sequence boundaries in the lower member of the Green River Formation, below the interval studied by Keighley and others (2002) (plates 5, 6, and 7).

Nutter's Ranch Study Site

To better understand the potential reservoir heterogeneity in the Green River Formation we selected a location for detailed study referred to as the Nutter's Ranch study site (figure 8), that contains a well-exposed, large-scale depositional cycle. The Nutter's Ranch study site lies within section 32, T. 11 S., R. 15 E. (Salt Lake Base Line [SLBL]), in Duchesne County. Wells in the Monument Butte area are drilled on 40 acre (16.2 ha) spacing resulting in about 1,320 feet (402 m) between wells. The typical water-flood unit in the Monument Butte area is a square mile (one section) or larger, with wells in the center of every 40 acre (16.2 ha) lot, or 16 wells per section. The wells are initially completed as oil wells, but after they have all been drilled, every other well is converted to a water injection well, resulting in eight producing and eight

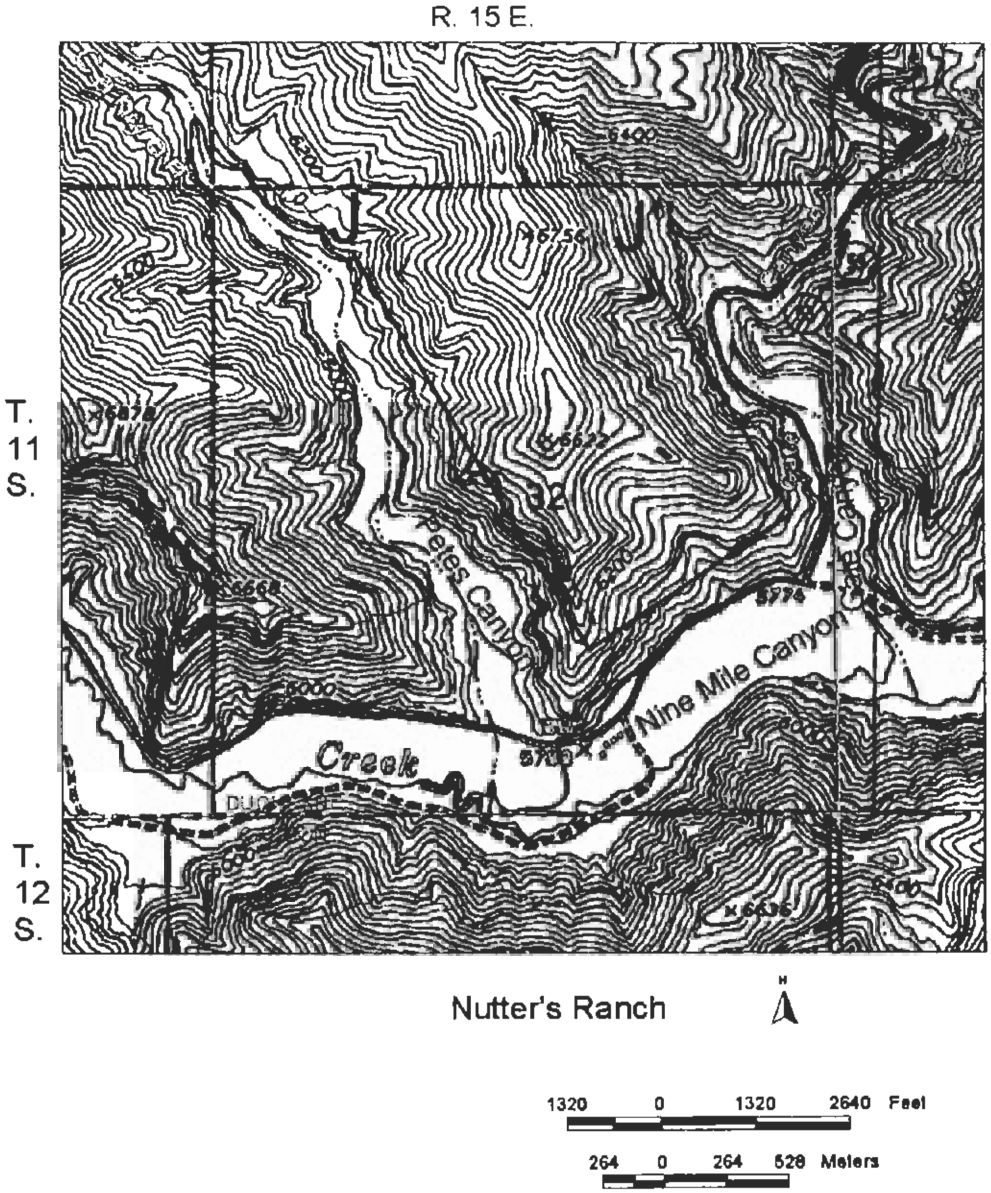


Figure 8. Map of Nutter's Ranch study site in Nine Mile Canyon, between Petes and Gate Canyons, showing the location of stratigraphic cross section J – J' (plate 10).

injection wells per section. Detailed examination of the outcrop helped us identify the potential heterogeneity that can exist between wells in two dimensions as well as over a square mile, as an analogy to a typical water-flood unit in the Monument Butte area.

The Nutter's Ranch study site includes portions of Petes Canyon and Gate Canyon, and the portion of Nine Mile Canyon between Petes and Gate Canyons. The exposure is about 2,000 feet (600 m) in the east-to-west direction in Nine Mile Canyon, and in the north-to-south direction in Gate Canyon, and about 4,200 feet (1,280 m) in the north-to-south direction in Petes Canyon. The stratigraphic interval studied is slightly more than 100 feet (30 m) thick, and is bounded by carbonate beds M8 at the base and M9 at the top (figure 9). Eight sections were measured and described, and GR data were gathered from five of the sections (plate 10). To aid in the stratigraphic interpretation, the site was photographed from the canyon walls opposite the study site, and photomontages were compiled (Appendix D). The photomontages were used to map out individual beds and their relationships. Data from the study site provide an example of the reservoir heterogeneity that could be encountered in a typical Monument Butte area water-flood unit and in the interwell environment.

The lithologies and depositional interpretations described in the Nutter's Ranch study site are shown in table 1.

Two-Dimensional Reservoir Model of the Nutter's Ranch Study Site

Two imaginary wells along the Nine Mile Canyon portion of the Nutter's Ranch study site are shown 1,320 feet (402 m) apart to illustrate the type of reservoir heterogeneity that could exist between two wells drilled on 40 acre (16.2 ha) spacing units. Both of the imaginary wells encounter a carbonate bed above (M9) and below (M8), and two reservoir-quality sandstone beds. Well logs would show excellent correlation of the carbonate and sandstone beds (figure 10). As a result, good lateral continuity of the sandstone beds would be expected. However, in this example, the upper sandstone in the two wells comprises two separate deposits (Ss-e and Ss-f) that would probably have very poor fluid flow between them (figure 11). Ss-e is an amalgamated channel deposit that has good reservoir potential but Ss-f is a crevasse splay deposit that has complex internal heterogeneity in the proximal channel facies and high clay content in the distal bar facies. The lower sandstone (Ss-c) is the same bed in both of the wells, but has been locally cut out by the overlying channel sandstone (Ss-d). In some places Ss-e has incised down to Ss-c, creating a potential for fluid-flow communication between the two sandstone beds. Ss-d nearly cuts out Ss-c and is a potential reservoir that is not penetrated by either of the imaginary wells. Ss-a is laterally continuous but thin and has poor porosity and permeability due to abundant clay. Ss-b is a very narrow bed that would rarely be penetrated by a well with 40 acre (16.2 ha) spacing and would probably not have sufficient storage capacity to be an economical oil reservoir.

Three-Dimensional Reservoir Model of the Nutter's Ranch Study Site

Thickness of the three potential reservoir sandstone beds (Ss-c, Ss-d, and Ss-e) were determined by direct measurement (plate 10) and by extrapolating between the measured sections using the photomontages (Appendix D). The sandstone thickness values and associated Universal Transverse Mercator (UTM) coordinates were entered into the Nutter's Ranch Arcview database. The section (section 32, T. 11 S., R. 15 E., SLBL) which contains the study site, was divided into 40 acre (16.2 ha) lots and the UTM coordinates for the center of each lot was determined and entered into the database as an oil well location with a well number (figure 12). Every other well was designated as a water injection well, the typical pattern for a water flood in the Monument Butte area. The imaginary wells in the two-dimensional model were

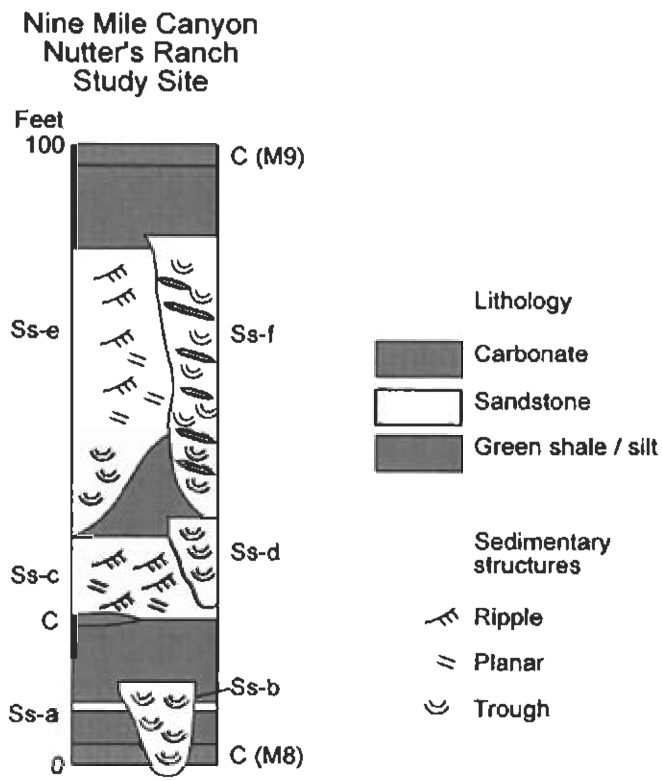


Figure 9. Composite vertical stratigraphic section of a 100-foot depositional cycle in the Nutter's Ranch study site in Nine Mile Canyon. Abbreviations (Ss-a, Ss-b, for example) refer to bed definitions in table 1.

Table 1. Lithology, description, and depositional interpretations from the Nutter's Ranch study site.

Lithology (bed designations)	Description	Depositional environment
Carbonate (C)	Oolitic/ostracodal grainstone and micrite, typically contains fossil hash. The beds weather orange.	Lagoonal, beach to shallow nearshore.
Sandstone (Ss-a)	Fine grain, rippled, tabular, thin (<3 feet), laterally continuous except where it is cut by channel sandstone body.	Flood-plain sheet flow.
Sandstone (Ss-b)	Fine grain, deeply incised channel-form bed, trough cross-beds, rip-up clasts and ooids common in lower portion, upper portion some ripples and soft-sediment deformation.	Nonsinuous streams on the upper delta plain.
Sandstone (Ss-c)	Fine grain, channel-form bed, laterally extensive amalgamated channels, planar base due to restrictive carbonate bed preventing downward cutting, promoting lateral migration. Fining upwards with upward decrease in scale of sedimentary structures from trough and low angle cross-beds to planar and rippled. Szantat (1990) Type I sandstone body.	High sinuosity, anatomizing channel deposit in the lower delta plain.
Sandstone (Sd-d)	Fine grain, channel-form bed, laterally limited, incised, individual channel deposit, concave upward lower bounding surface, fining upwards with upward decrease in scale of sedimentary features from lateral accretion beds, trough and low angle cross-bedding to planar and rippled.	Meandering distributary channel.
Sandstone (Ss-e)	Fine grain, channel-form bed, laterally extensive amalgamated channel deposits, concave upward lower bounding surface, fining upwards with upward decrease in scale of sedimentary features from lateral accretion beds, trough and low angle cross-bedding to planar and rippled. Szantat (1990) Type II sandstone body.	High sinuosity, anatomizing channel deposit in the lower delta plain.
Sandstone (Ss-f)	Fine grain, incised channel-form bed, laterally limited, typically inclined trough sets with shale drapes.	Proximal crevasse splay.
Sandstone (Ss-f)	Fine grain, coarsening upward with generally flat top, rippled, thin 1 to 3 feet thick, laterally extensive.	Distal crevasse splay.
Shale and siltstone	Green to gray-green shale and siltstone, typically thinly covered, highly weathered. Some thick covered slopes interpreted to be underlain by shale and siltstone.	Upper and lower delta plain, flood plain to mudflat, to swamp, possibly abandoned channel and overbank deposit.

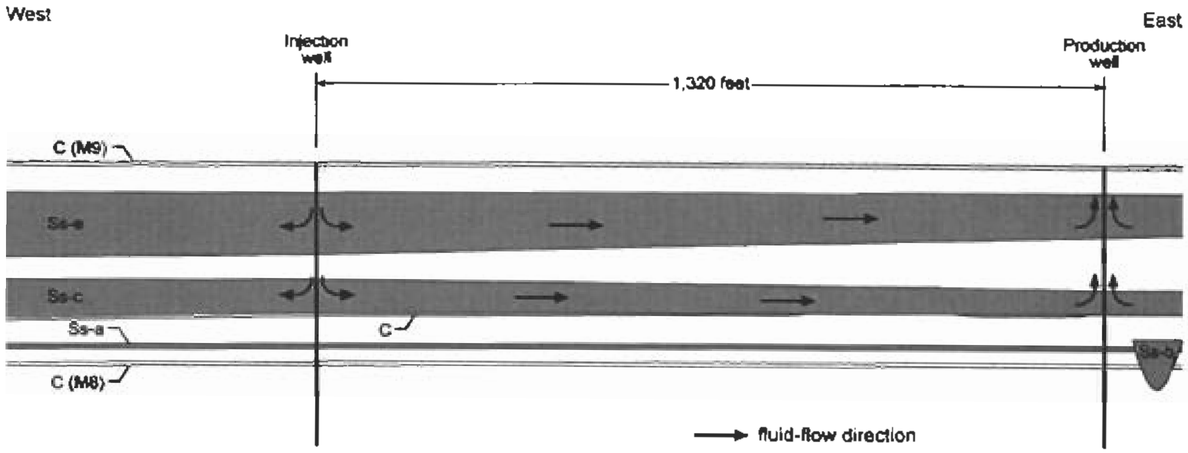


Figure 10. Hypothetical two-dimensional correlation and potential fluid-flow pattern between two imaginary wells "drilled" at the Nutter's Ranch study site. The correlations are based only on the data the "wells" penetrated and assume a continuous reservoir (Ss-e and Ss-c) between the two wells (see table 1 for lithologic unit descriptions).

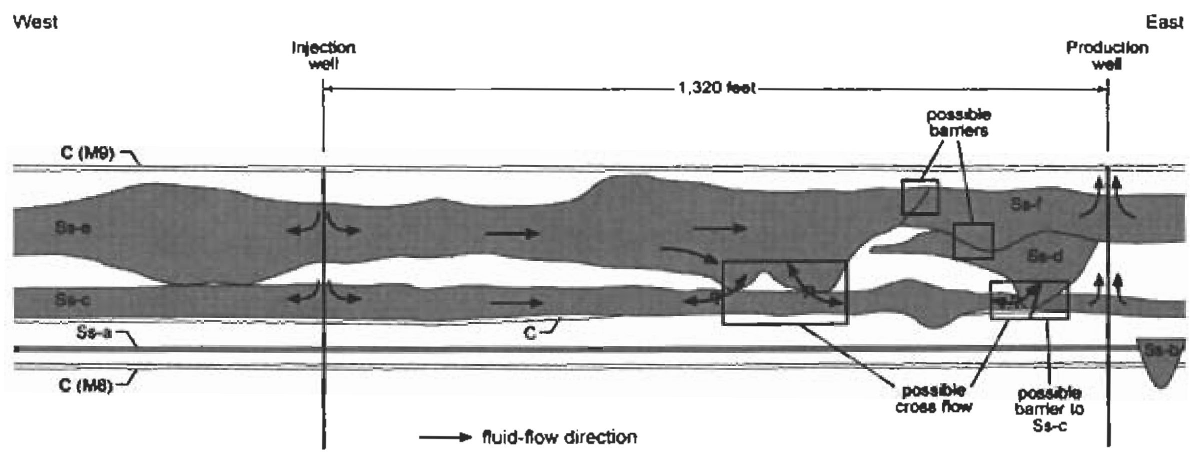


Figure 11. Actual two-dimensional correlation and potential fluid-flow pattern between the same two imaginary wells "drilled" at the Nutter's Ranch study site as in figure 10. The waterflood effectiveness and the "total oil produced" is much less than in the hypothetical model due to the reservoir heterogeneity. If a barrier exists between Ss-f and Ss-e, and a barrier exists between Ss-d and Ss-c, then oil in Ss-e and most of the oil in Ss-c will not be produced. Oil in Ss-d will also probably not be produced. The production "well" will only produce oil from Ss-f and a very limited amount of oil from Ss-c (see table 1 for lithologic unit descriptions).

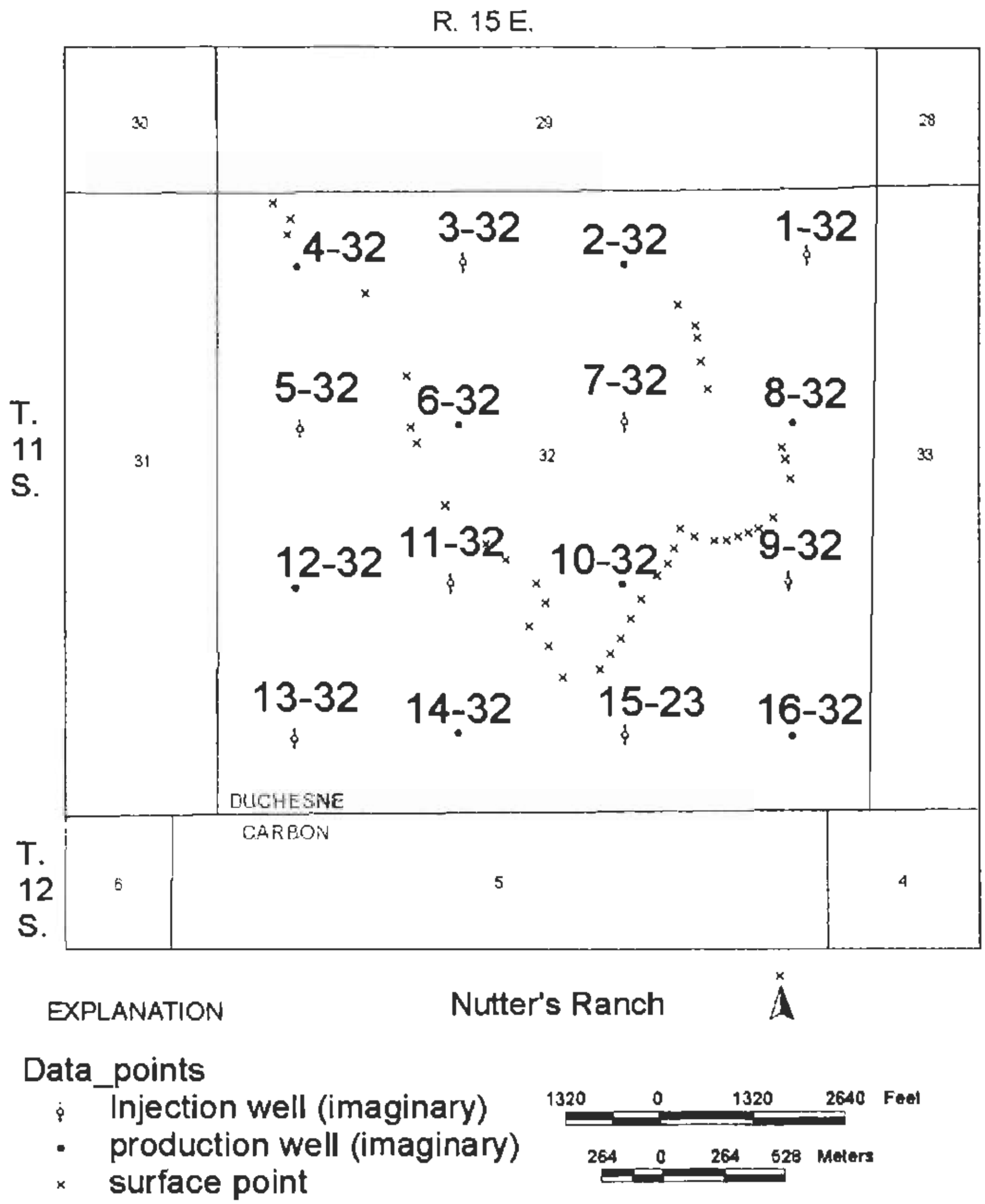


Figure 12. Map of Nutter's Ranch study site with imaginary well locations in the center of 40 acre lots.

located directly along the outcrop. The imaginary wells for the three-dimensional model are the centers of 40 acre (16.2 ha) lots and are not the same as the two-dimensional model imaginary well locations.

A draft of sandstone thickness maps based on the outcrop values, were constructed using Arcview Spatial Analyst® and by hand contouring. Sandstone thickness for each of the three beds were assigned to the imaginary wells based on the draft thickness maps and entered into the database. Final sandstone thickness maps for the three beds were generated using Arcview Spatial Analyst.

Ss-c (figure 13) is the most laterally extensive of the three potential reservoir beds. The bed is laterally extensive because it overlies a muddy limestone that it could not cut through, causing the channel to spread out. The alternating pattern of producer well and injector well would have some success in this bed. However, the thickest portion of this bed in the northwest quarter of the section is not penetrated and would be produced by wells on the flanks of the sandstone trend. Ss-d, which was shown in the two-dimensional model to nearly cut out Ss-c, isolates a portion of Ss-c in the center of the eastern most portion of the section.

Ss-d is narrow and has a very limited extent in the study area (figure 14) and would contain a very limited volume of oil. The 8-32 production well and 9-32 injection well penetrate the Ss-d but not along the axis of the sandstone bed. As a result, only a small portion of the limited oil volume of Ss-d would be produced.

Ss-e is moderately laterally extensive in the study site but is generally thicker, where present, than Ss-c (figure 15). The alternating pattern of production well and injection well appears to be moderately effective in Ss-e. Some of the thickest sandstone is between injection well 7-32 and production well 8-32. Production well 8-32 penetrated only 4 feet (1.2 m) of Ss-e, as a result, it would probably be a very poor producer and most of the oil contained in the thick sandstone between the two wells would remain in the ground.

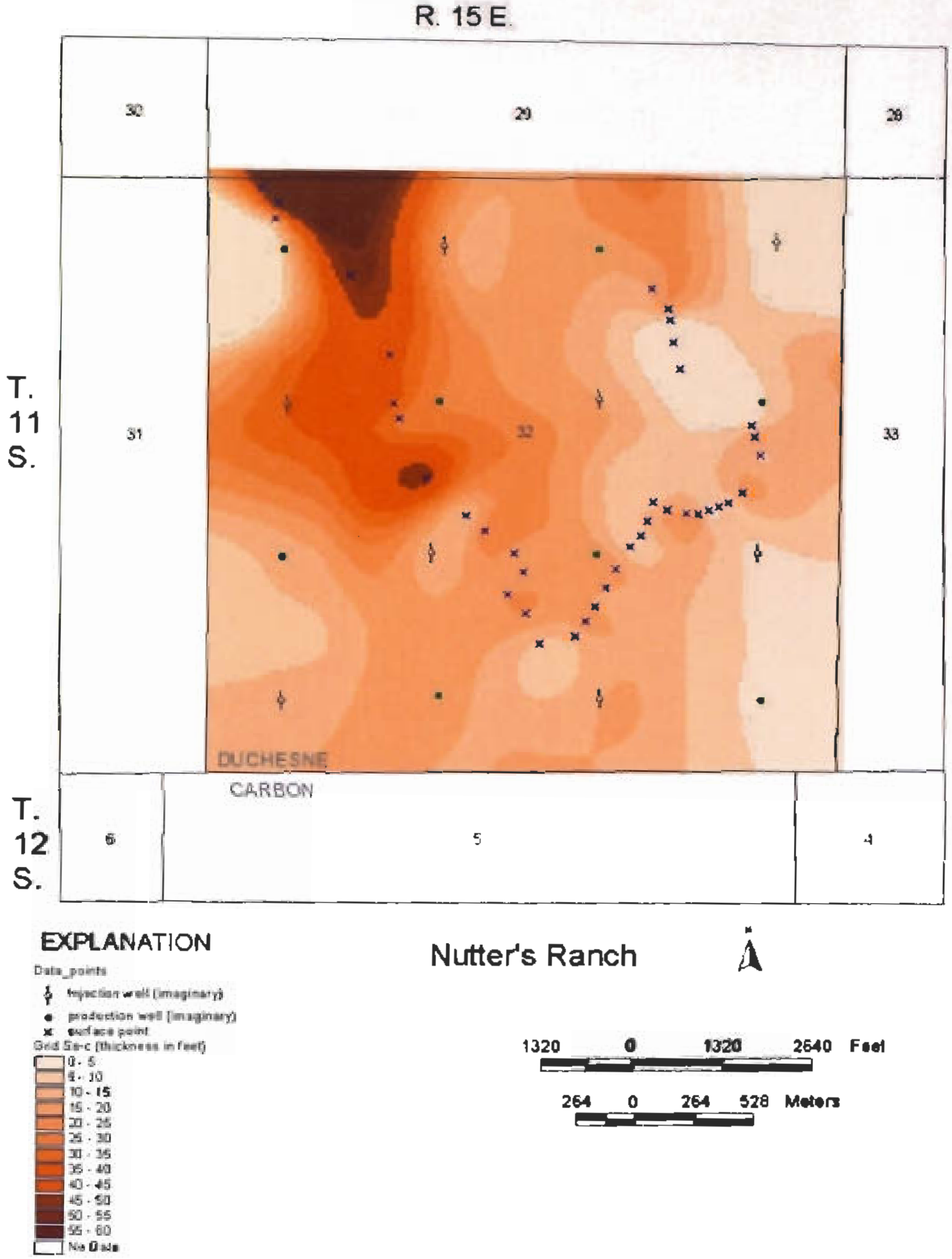


Figure 13. Map of Ss-c bed in the Nutter's Ranch study site. Grid interval is 5 feet.

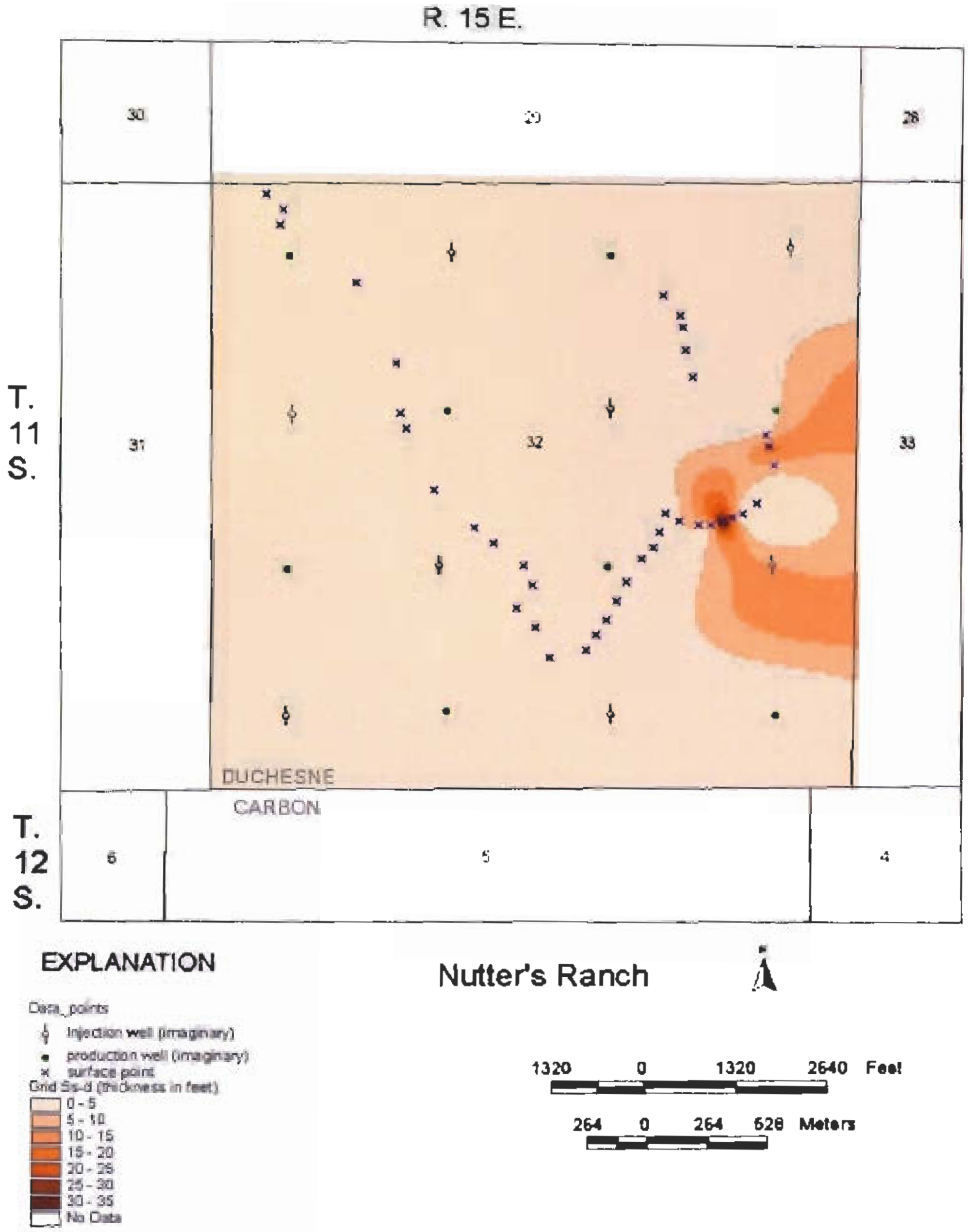


Figure 14. Map of Ss-d bed in the Nutter's Ranch study site. Grid interval is 5 feet.

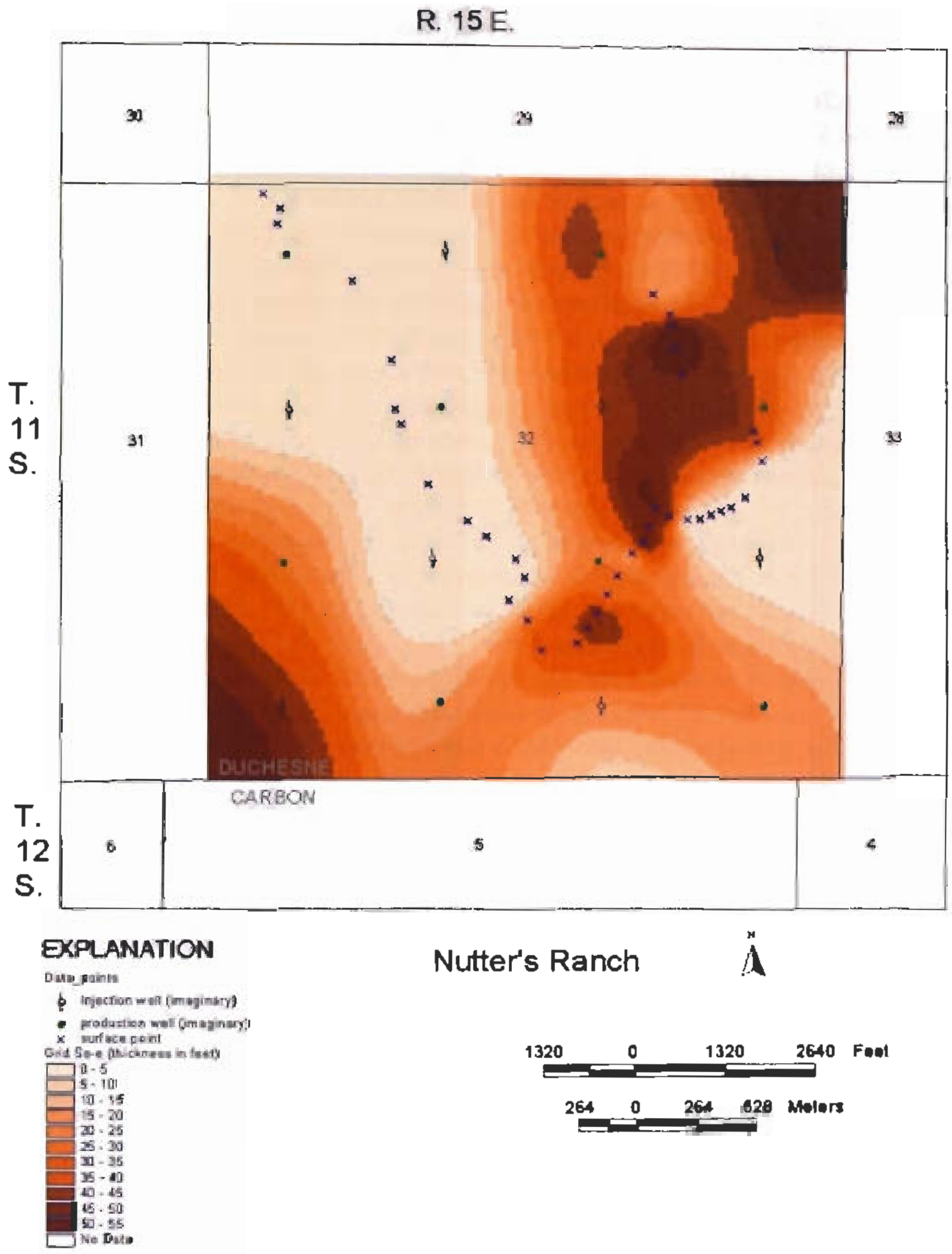


Figure 15. Map of Ss-e bed in the Nutter's Ranch study site. Grid interval is 5 feet.

HYDROCARBON RESERVOIRS IN THE LOWER AND MIDDLE MEMBERS OF THE GREEN RIVER FORMATION

Uteland Butte Reservoir

The Uteland Butte reservoir is the first major transgression of the lake after deposition of the alluvial Colton Formation. The Uteland Butte includes LGR 1 through LGR 5 log cycles (figure 4) and ranges in thickness from less than 60 feet (20 m) to more than 200 feet (60 m) in the southwest Uinta Basin. The Uteland Butte is equivalent to the first lacustrine phase of Bradley (1931), black shale facies of Picard (1955), lower black shale facies of Abbott (1957), basal limestone facies of Little (1988) and Colburn and others (1985), the Uteland Butte limestone of Osmond (1992), and the basal limestone member of Crouch and others (2000).

The Uteland Butte consists of limestone, dolostone, calcareous mudstone and siltstone, and rare sandstone. Most of the limestone beds are ostracodal grain-supported or mud-supported grainstone, packstone, or wackestone. Grainstone is more common near the shallow shoreline of the lake where as deeper distal deposits are commonly argillaceous limestone. A cryptocrystalline, dolomitized compacted wackestone with ostracods has been found near the top of the Uteland Butte in some core. The dolomite often has more than 20 percent porosity but is so finely crystalline that the permeability is low (single millidarcy or less).

Crouch and others (2000) working in Antelope Creek field (T. 5 S., R. 3 W., UBL) described the deposition of the Uteland Butte reservoir as a period of shoreline retrogradation and lake-level deepening. The lithology is described as micritic limestone, dolomicrite, and calcareous mudrocks. Little (1988), working in the Minnie Maud to Willow Creek Canyon area, described the deposition as shallow-water mud flats to offshore lacustrine. The lithology is dolomitized ostracodal and pellet grainstone and packstone, pelecypod-gastropod sandy grainstone interbedded with silty claystone or carbonate mudstone. Little (1988) describes 3- to 6-foot (1-2 m) thick beach- or bar-sandstone beds in the Minnie Maud area but absent in Willow Creek Canyon. Overall, siliciclastic rocks are rare in the Uteland Butte reservoir.

The Uteland Butte reservoir was deposited during a rapid and extensive lake-level rise. The Uteland Butte is distinctive in the abundance of carbonate and lack of sandstone which could have been caused by one or both of the following situations: (1) the rapid lake-level rise caused siliciclastic sediments to be deposited in the proximal alluvial channels, or (2) the main inflow into the lake was far from the southwest Uinta Basin area, perhaps flowing into the southern arm of the lake south and west of the San Rafael uplift.

The Uteland Butte reservoir is oil productive throughout most of the southwest Uinta Basin. The Uteland Butte is a secondary objective and usually perforated along with beds in the Castle Peak, lower Douglas Creek, and upper Douglas Creek reservoirs. The Uteland Butte is the primary producing reservoir in the Uteland Butte field (T. 10 S., R. 18 E., SLBL). Log cycles LGR 1 and LGR 2 are transitional with the underlying alluvial Colton Formation and are often not fully penetrated by wells in the southwest Uinta Basin. The interval LGR 3 through LGR 5 was mapped because it is typically fully penetrated and has a very distinctive log character that is easily recognized throughout the southwest Uinta Basin. The isopach of LGR 3 through LGR 5 (plate 11) is divided into three areas: (1) the proximal area which varies considerably in thickness due to interfingering of lacustrine and alluvial Colton deposits, (2) a northeast to southwest thin where shallow lacustrine beach- and bar-sandstone beds were deposited, and (3) the thick distal area.

The isopach thin extends from the Uteland Butte field in the northeast to the Minnie Maud area in the southwest. Sandstone is the most productive bed in the Uteland Butte field. Little (1988) described beach- and bar-sandstone deposits in the Minnie Maud area that are absent in Willow Creek Canyon to the west-northwest. The isopach thin defines the shallow lacustrine shelf where the sandstone beds were deposited and is the best area to explore for new oil deposits in the Uteland Butte reservoir.

The Uteland Butte reservoir is perforated in numerous wells in the distal area where the reservoir is almost entirely carbonate, having no sandstone. Crouch and others (2000) report that the carbonate in the Antelope Creek field has 0.4 to 0.01 md permeability resulting in very low oil recovery. As a result it is a secondary objective and not the primary target of drilling.

The cryptocrystalline dolomitic wackestone has not been extensively explored. This bed is potentially widely distributed throughout the southwest Uinta Basin. The dolomitized wackestone would be a low-volume oil producer similar to the carbonates in the Antelope Creek field because of the low permeability. As a result, many explorationists may have overlooked this objective. If areas of better developed permeability (sweet spots) can be found, the high porosity of the bed should yield significant oil potential.

Castle Peak Reservoir

The Castle Peak reservoir is defined as the stratigraphic interval from the top of the Uteland Butte (LGR 5) to the top of the carbonate marker bed of Ryder and others (1975) (figure 4). The Castle Peak is equivalent to the Wasatch (Colton) tongue and second lacustrine phase of Bradley (1931), the Colton tongue and carbonate marker unit of Ryder and others (1975), and is included in Picard's (1955) black shale facies. The alluvial Colton tongue is exposed in Willow Creek and Nine Mile Canyons but extends only a few miles north. Above the Colton tongue the Castle Peak consists of interbedded black shale, limestone, limy mudstone, with some sandstone and siltstone. The sandstone beds, which are productive in some areas, are generally fine to medium grained, and were deposited as isolated channels.

The Castle Peak sandstone is typically medium-grained (0.36 to 0.44 mm), poorly to moderately sorted, angular to very well rounded, mostly lithic arkose or feldspathic litharenite. Most of the other sandstone beds in the lower and middle members of the Green River Formation are very fine to fine grained.

Framework elements of the Castle Peak sandstone include monocrystalline and polycrystalline quartz, potassium feldspar (orthoclase and microcline), plagioclase, chert, sheared metaquartz, recrystallized metaquartz, hydrothermal quartz, intrusive rock fragments, dolomite, siltstone and mudstone clasts, carbonate ooids, isolated mica booklets (biotite, chlorite, and muscovite), some red-brown hematite staining, and assorted heavy minerals including zircon, epidote, tourmaline, sphene, and rare amphibole.

The Castle Peak sandstone are typically highly compacted with extensive quartz and feldspar cementation. Porosity and permeability in the sandstone is typically a result of dissolution of feldspars and some of the rock fragments. Trumbo (1993) reports an average porosity of 11 percent and 0.1 md permeability for the Castle Peak sandstone in Brundage Canyon and Sowers Canyon fields (T. 5 S., R. 4 W. to 5 W., UBL). Fractures in the sandstone most commonly develop at the base of the bed where the carbonate content is usually highest resulting in increased brittleness.

Hackney and Crouch (2000) working in the Antelope Creek field (T. 5 S., R. 3 W., UBL) defined 17 cycles of relative lake level rise and fall. They described the cycles as consisting of "progradational and retrogradational sandstone beds bounded above and below by transgressive limestone that onlap shoreward." In the Nine Mile Canyon area south of Antelope Creek field, the Castle Peak consists of a tongue of the Colton Formation overlain by multiple channel sandstone and floodplain deposits with a few interbedded limestone beds.

The Castle Peak stratigraphic interval thins from south to north (plate 12). An isopach map of the sandstone in the Castle Peak show a thick in the southern (highstand) and northern (lowstand) portions of the study area with an intervening thin (plate 13). The highstand deposits consist of alluvial sandstone (Colton tongue) and marginal lacustrine sandstone deposited during highstand lake levels. The lowstand consists of isolated marginal lacustrine channel sandstone encased in carbonate deposited during lake level fall and rise. The intervening zone of sediment bypass provides a regional updip trap for hydrocarbons in the Castle Peak. The sandstone beds in the Castle Peak are typically single, isolated channel deposits with limited lateral extent; channel stacking is rare. In the greater Monument Butte area, a drill hole will typically encounter a single channel (or none) in each depositional cycle. The lack of channel stacking is attributed to the short duration of the lake level rise and fall cycles. As a result, the drainage for each cycle never advanced beyond the initial stage. Schumn and Ethridge (1994) show that the initial drainage pattern on an exposed shelf is typically a series of parallel unconnected channels.

Lower Douglas Creek Reservoir

The lower Douglas Creek reservoir is defined as the stratigraphic interval from the top of the lower member of the Green River Formation (carbonate marker bed) to the base of the upper Douglas Creek (top of log-cycle MGR 3) (figure 4). The lower Douglas Creek is part of the middle member and ranges in thickness from 270 to 700 feet (80 to 200 m) in the southwest Uinta Basin (plate 14). The proximal lower Douglas Creek includes the alluvial deposits of the Renegade Tongue (Cashion, 1967) of the Colton Formation. The distal lower Douglas Creek is considered part of the black shale facies of Picard (1955) consisting of marginal-lacustrine and open-lacustrine deposits of interbedded sandstone and shale with some thin carbonate beds.

Throughout the region many of the sandstone beds in the lower Douglas Creek were deposited by channels and shallow bars, which locally contain oil. The primary reservoir in the lower Douglas Creek is turbidite and shallow lacustrine sandstone beds deposited in narrow cut-and-fill valleys along the shelf break during several lake level fall-and-rise cycles. Lutz and others (1994) described the lower Douglas Creek as moderate- to low-density turbidite channel deposits, debris flow and gravity flow deposits. Thickness of the sandstone in the cut-and-fill valleys can vary from more than 100 feet (30 m) in a well to zero in a neighboring well 1,320 feet (402.3 m) away. In areas where cut-and-fill did not occur less-productive marginal-lacustrine sandstone was deposited, as a result, a sandstone isopach does not accurately define the cut-and-fill reservoir area (plate 15). The 50-foot sandstone contour in the northern portion of the mapped area does crudely define a division of gradual thicks and thins from a more rapid change in thickness north of the contour. This may represent the approximate boundary of the shelf edge or it may just be a result of decreasing data points from north to south. The lower Douglas Creek is the only stratigraphic interval in the lower or middle members where there is evidence of a sharp shelf break in the southwest area. The shelf break may have developed in response to increased tectonic subsidence of the basin.

Two rock types comprise the majority of the sandstone beds in the lower Douglas Creek reservoir. Rock-type 1 is a very poorly sorted combination of silt and very fine grained sand that commonly contains detrital clay coating around many of the grains as well as large clasts of highly compacted dolomitic and illitic mudstone. Rock-type 1 typically has poor porosity and permeability due to tight grain packing, sporadic detrital clay coating, and pseudomatrix formation of mudstone clasts. Rock-type 2 is a laminated assemblage of very fine to fine grained sandstone that has the appearance of a chaotic breccia of haphazardly distributed carbonate mudstone clasts in a poorly sorted silt to very fine grained matrix with abundant soft-sediment deformation features. Rock-type 2 typically has low porosity and permeability due to tight grain packing, illite coating the grains, and a general lack of secondary intergranular pores. Fractures in the lower Douglas Creek sandstone are rare due to the clay content reducing the overall brittleness of the beds.

Upper Douglas Creek Reservoir

The upper Douglas Creek reservoir is defined as the stratigraphic interval from the top of the lower Douglas Creek (MGR 3) to the top of the Douglas Creek Member of the Green River Formation (MGR 7) of Bradley (1931) (figure 4). The upper Douglas Creek is part of the middle member and ranges in thickness from 250 feet (75 m) to less than 500 feet (150 m) in the southwest Uinta Basin (plate 16). The upper Douglas Creek is the primary reservoir in the greater Monument Butte area of the southwest Uinta Basin. The reservoir consists of amalgamated channel and distributary-mouth bar sandstone deposited on the distal lower delta plain of Lake Uinta. The upper Douglas Creek reservoir is a lowstand deposit with an area of sediment bypass forming the updip trap. A similar highstand deposit is mapped in the proximal position where the rocks are exposed in the Nine Mile and Desolation Canyons.

Two rock types comprise most of the sandstone beds in the upper Douglas Creek reservoir. Rock-type 1 is the most abundant and is typically very fine to fine grained (median 0.11 to 0.17 mm), moderately well sorted to well sorted, subangular to subround. The framework assemblage is similar in composition and abundance to the medium-grained sandstone in the Castle Peak sandstone except the very fine to fine grained sandstone has more biotite, chlorite, and muscovite, and the mudstone fragments are dolomitic, ankeritic, and carbonate allochems including ankeritic/dolomitic ooids, ankeritic/dolomitic rip-ups, ostracods, or interclasts.

Some of the sandstone show early cementation with iron-poor calcite, which greatly reduced the effects of compaction. Later dissolution of the iron-poor calcite resulted in some beds with permeabilities in the tens of md and porosity more than 20 percent. Some of the sandstone had a later stage of cementation with dolomite, ankerite, siderite, and iron-rich calcite, which greatly reduced the rock pore space. Partial dissolution of the late-stage cementation has resulted in 10 percent or more porosity with permeability rarely exceeding 20 md in some sandstone beds.

Rock-type 2 is a sandstone consisting of very fine grained sand and coarse silt with increased clay content. Rock-type 2 is a ripple drift lamination facies found at the upper portion of a fining upward sandstone sequence. The rock-type 2 sandstone is more poorly sorted, angular to subangular, has more of the grains are coated with illite, and contains more mica, especially muscovite, than the rock-type 1 sandstone. Examination of rock-type 2 sandstone shows that severe compaction occurred soon after deposition, which developed abundant microstylolites. Rarely is early iron-poor calcite cement found in rock-type 2. Dissolution of feldspars is minor, resulting in low porosity (less than 10 percent) and low permeability (0.1 md or less).

Garden Gulch Reservoir

The Garden Gulch reservoir is defined as the stratigraphic interval from the top of the Douglas Creek to the top of MGR 18 (figure 4). The Garden Gulch ranges from 550 feet (167.6 m) to more than 1,200 feet (365.8 m) thick in the southwest Uinta Basin. The Garden Gulch was divided into a lower portion (MGR 12 to MGR 7), which is equivalent to upper portion of the delta facies in Nine Mile Canyon (Remy, 1992) and an upper portion (MGR 18 to MGR 12), which is equivalent to most of the transitional facies (Remy, 1992). The thickness map of the lower portion of the Garden Gulch (plate 17) shows slight evidence of the delta shape. The thickness map of the upper portion of the Garden Gulch (plate 18) shows a strong west-to-east to slightly southwest-to-northeast trend, indicating a normal shoreline without the influence of a well-developed delta.

The Garden Gulch consists of interbedded sandstone, shale, and limestone. The Garden Gulch was deposited during a time of overall lake-level rise, transitional from the underlying delta facies in the Douglas Creek Member to the overlying deep-lake oil shale deposits of the upper member, resulting in less total sandstone and generally individual, isolated channel and bar deposits. The sandstone in the Garden Gulch reservoir is similar in composition to the upper Douglas Creek sandstone. There are fewer fining upward sequences and therefore less type-2 ripple drift laminated facies.

PALEODEPOSITIONAL HISTORY OF THE HYDROCARBON RESERVOIRS IN THE LOWER AND MIDDLE MEMBERS OF THE GREEN RIVER FORMATION

The deposits of the lower and middle members of the Green River Formation record a transitional lake history from passive carbonate shoreline to active delta building to major lake expansion and deepening.

The Uteland Butte interval was deposited over the alluvial sediments of the Colton Formation during a major lake expansion. Shoreline, and shallow open-lacustrine deposition was dominated by carbonate with very minor amounts of siliciclastic (figure 16). The lack of siliciclastic deposition is attributed to two causes: (1) the rise in base level where by most siliciclastic to deposition occurred in the fluvial channels before reaching the lake, and (2) the southwest Uinta Basin was not the site of the main in flow into the lake.

The Castle Peak interval was deposited during a period of numerous rapid lake level fall-and-rise cycles. A general parallel drainage pattern developed across the lower portion of the exposed, low-angle shelf during lake-level fall with an updip area of sediment bypass (figure 17). A rapid rise in the lake level resulted in isolated channels encased in lacustrine carbonate above and below, in the distal northern portion of the southwest Uinta Basin.

The top of the lower member-base of middle member marks a significant change in the structure of the southwest Uinta Basin. The top of the lower member is the carbonate marker bed, which was deposited during a lake highstand. The carbonate marker bed ranges from shallow lacustrine laminated algal limestone and grainstone in the proximal reaches (Nine Mile Canyon) to muddy limestone in the more distal open lacustrine reaches of the lake (Willow Creek Canyon and Antelope Creek-Monument Butte area). The lower member is overlain by lower Douglas Creek, which consists of alluvial deposits of the Renegade Tongue (Cashion, 1967) in Desolation and Nine Mile Canyons, and the green shale facies (Picard, 1957, 1955) in Willow Creek Canyon, a significant basinward shift of facies. But in the Antelope Creek-Monument Butte area, the lower Douglas Creek is composed of the black shale facies, an open-lacustrine deposit. The lake may have been reduced in size as evidenced by the basinward shift of the shoreline, but may have also deepened in the distal reaches, as evidenced by the deposition of black shale. Tectonic movement in the basin is needed to cause a regression of the shoreline with accompanying deepening of the lake. The lower Douglas Creek reservoir in the Antelope Creek-Monument Butte area consists of black shale with thick (100+ feet [m]) sandstone beds deposited in very narrow cut-and-fill valleys (figure 18) formed during lake-level falls, indicating a slope with a steep shelf break, which did not exist during deposition of the lower member.

The upper Douglas Creek of the middle member of the Green River Formation, represents deposition in an active lowstand delta built on a gentle slope, resulting in significant shifts in the shoreline during rise-and-fall cycles of the lake. The shallow shelf was the site of several depositional cycles that resulted in amalgamation and stacking of distributary channels and distributary mouth bars in both lowstand (greater Monument Butte area) and highstand (Nine Mile Canyon area) deltas (figures 19 and 20). The lowstand delta deposits are dominantly dolomitic black shale and marginal- to shallow-lacustrine distributary-channel and mouth-bar sandstone. The highstand delta deposits contain more marginal-lacustrine green shale, grainstone and micrite, and distributary- and fluvial-channel sandstone. A zone of sediment bypass separates the highstand and lowstand areas.

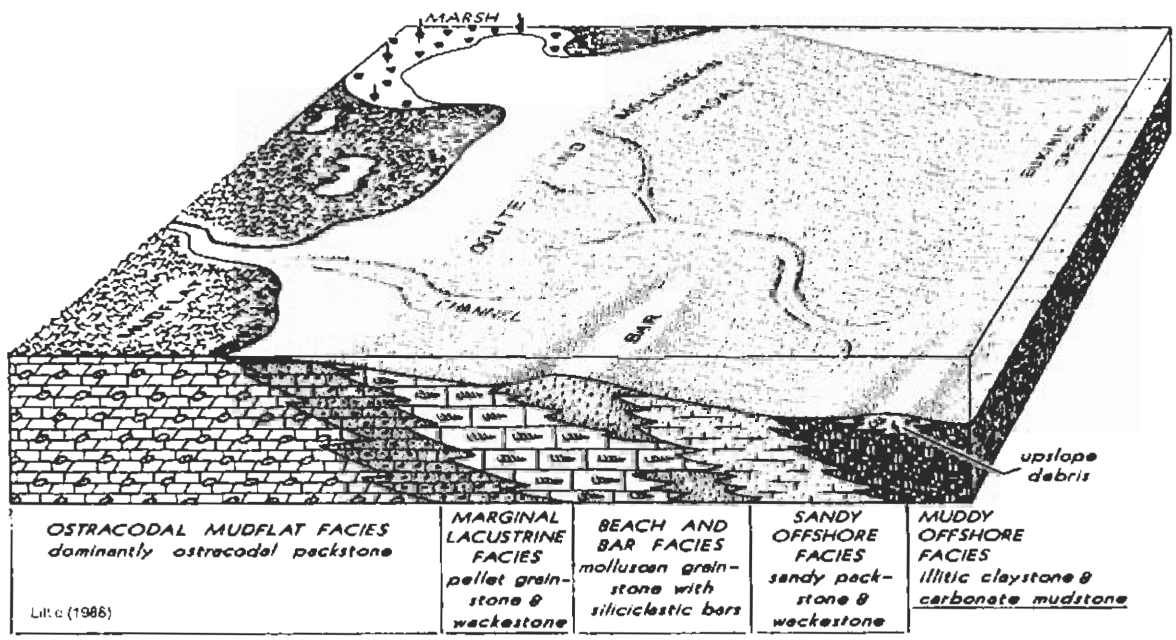


Figure 16. Conceptual three-dimensional diagram depicting the major facies of the Uteland Butte interval of the lower member of the Green River Formation (modified from Little, 1988).

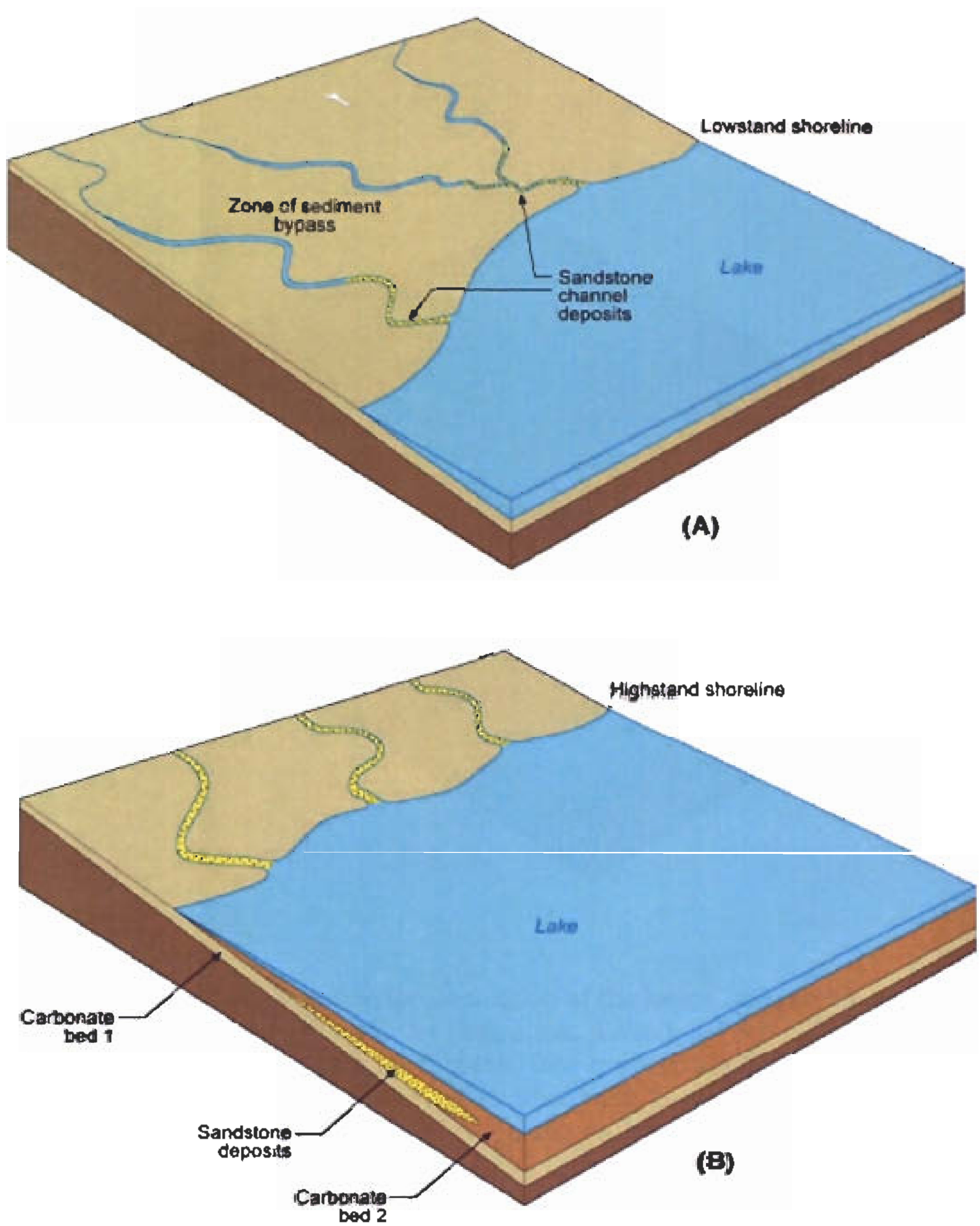


Figure 17. Diagrams depicting the deposition of the Castle Peak interval of the lower member of the Green River Formation. (A) Lake-level fall results in a lowstand shoreline and initial parallel drainage across a gently sloping shelf. (B) Lake-level rise results in a highstand shoreline. Sandstone is deposited in the lower reaches of the lowstand channels during initial lake-level rise, resulting in sandstone encased in carbonate.

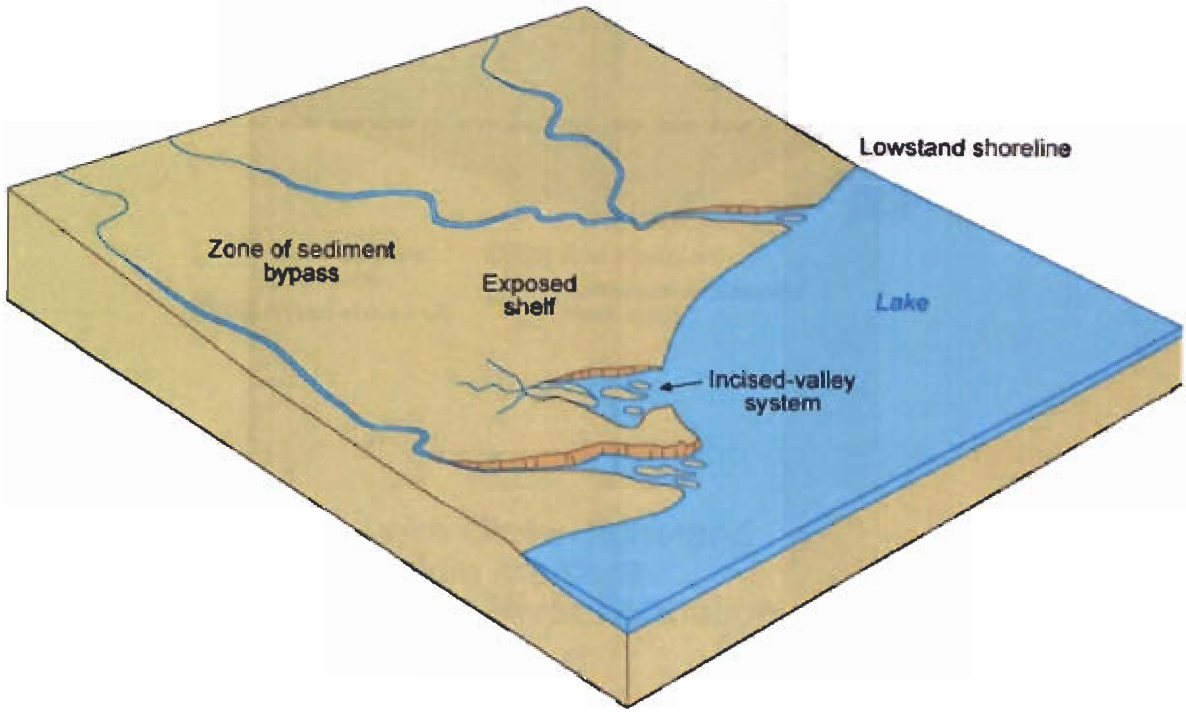
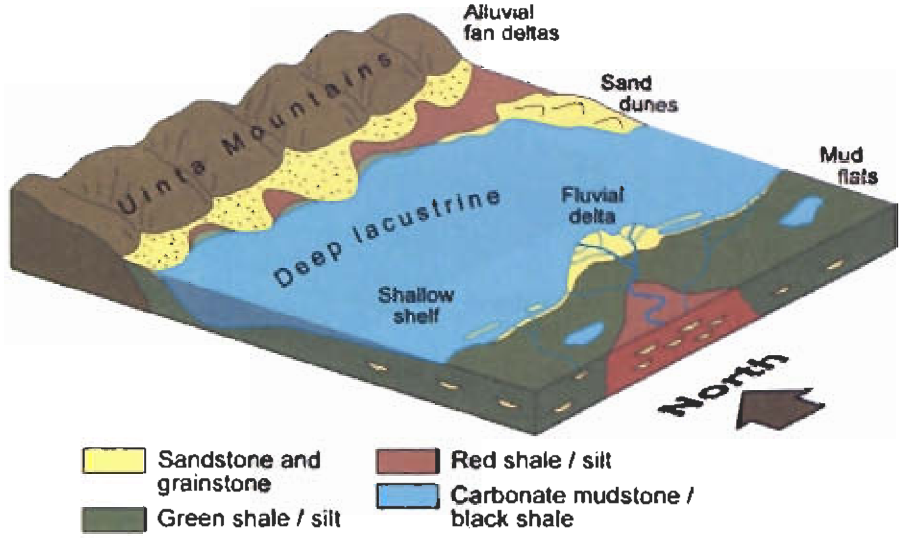


Figure 18. Diagram depicting the deposition of the lower Douglas Creek reservoir of the middle member of the Green River Formation. Lake-level fall results in deeply incised valleys cut along the exposed shelf break. The exposed shelf and lowstand shoreline are dominantly composed of open lacustrine black, silty, dolomitic shale. Lake-level rise results in the incised valleys filling with siliclastic shallow-lacustrine, gravity-flow and turbidity deposits.



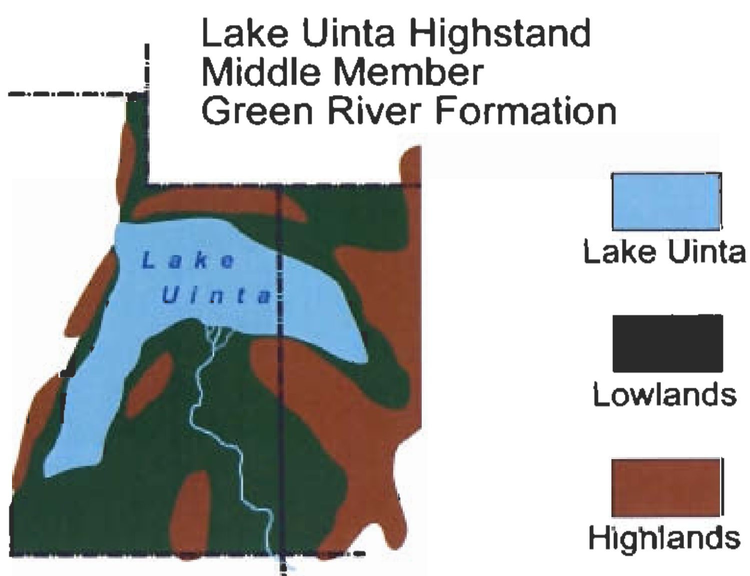
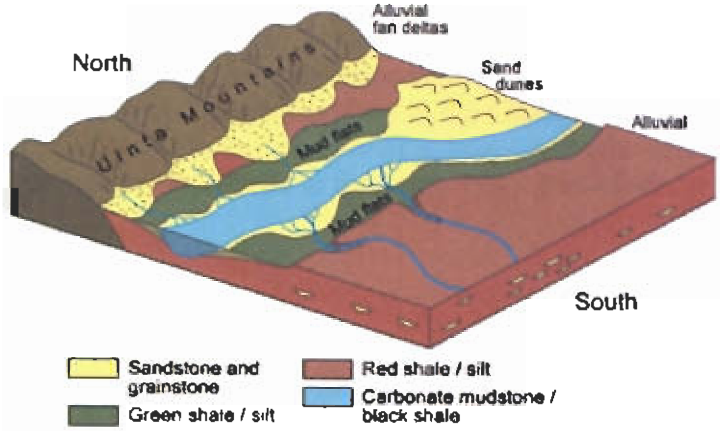
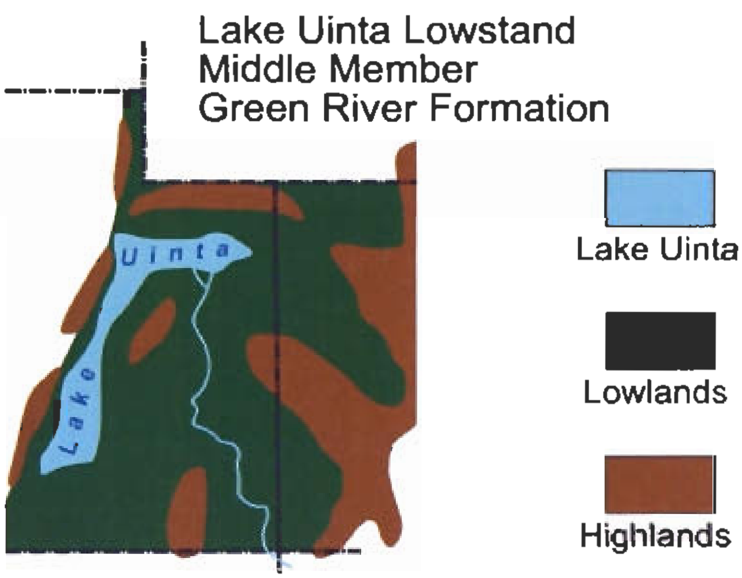


Figure 19. (A) Block diagram depicting a highstand delta deposited during the upper Douglas Creek interval of the middle member of the Green River Formation. (B) Paleogeography of Lake Uinta during highstand deposition of the upper Douglas Creek reservoir (modified from McDonald, 1972).



A



B

Figure 20. (A) Block diagram depicting a lowstand delta deposited during the upper Douglas Creek interval of the middle member of the Green River Formation. (B) Paleogrography of Lake Uinta during lowstand deposition of the upper Douglas Creek (modified from McDonald, 1972).

The Garden Gulch interval of the middle member of the Green River Formation, represents deposition during a period of significant expansion of the lake. The end of the Garden Gulch and middle member, is marked by the Mahogany oil shale in the upper member, which was deposited during the maximum expansion and maximum depth of the lake. Distributary-channel and shallow-lacustrine bars in the Garden Gulch were deposited during lake-level falls. But with the lake generally expanding, lake-level falls resulted in fewer, more isolated, individual channel deposits in the southwest Uinta Basin.

OIL FIELD EXAMPLES

Geological characterization, consisting of correlating and mapping all perforated beds, was carried out on portions of three oil fields: (1) Uteland Butte, (2) Brundage Canyon, and (3) Monument Butte Northeast (figure 21). The fields are examples of three different reservoir types found in the southwest Uinta Basin (figure 4). The Uteland Butte field produces oil from the Uteland Butte reservoir (units LGR 1 through LGR 5), also known as the basal Green River carbonate of the lower member. The Brundage Canyon field produces oil from sandstone beds in the Castle Peak reservoir, also known as the carbonate marker unit in the lower member. The Monument Butte Northeast water-flood unit produces from the upper Douglas Creek reservoir, units MGR 4 through MGR 7 (B, C, and D sands in operator terminology). Additionally, most wells are perforated in other beds throughout the lower and middle members of the Green River Formation.

Uteland Butte Field

The Uteland Butte oil field covers parts of sections 2, 3, 10, and 11, T. 10 S., R. 18 E., SLBL, Uintah County, Utah. The wells are perforated in the Uteland Butte reservoir (units LGR 5 through LGR 1), also known as the basal Green River carbonate in the lower member of the Green River Formation (figure 4). The reservoir is dominantly carbonate, varying from limestone to limy dolomite to dolomite, with rare thin sandstone beds in an area of regional north dip and no structural closure (figure 22). The field is in primary production. The wells are low volume, typically producing less than 100,000 barrels (16,000 m^3) of oil per well (figure 23). The field has a normal decline in monthly oil production (figure 24). Most of the gas production from the Uteland Butte field is from deeper Colton and Mesaverde beds. The monthly gas production is erratic due to seasonal demand for the natural gas.

Bed thickness defined with the gamma-ray curve, and porosity determined by the density and neutron logs, show only minor variation over the field area and do not define the reservoir and trap. Subtle permeability changes related to the gradual lithology variations probably provide the stratigraphic trap in the Uteland Butte field. The Uteland Butte reservoir is a secondary objective in most other fields in the southwest Uinta Basin because of the low volume of oil production.

Most of the perforated beds in the Uteland Butte field are carbonate except bed 1c, which is a sandstone. Bed 1c is perforated in all of the wells (plates 19 and 20) and is responsible for most of the production. Bed 1c ranges from 8 to 22 feet (2.4 to 6.7 m) thick in the Uteland Butte field (figure 25).

Brundage Canyon Field

The Brundage Canyon oil field covers most of T. 5 S., R. 4 W., and the eastern portion of T. 5 S., R. 5 W., UBL, Duchesne County, Utah. Our study focused on all of section 25 and part of section 24, T. 5 S., R. 5 W., UBL, and parts of sections 19 and 30, T. 5 S., R. 4 W., UBL (figure 26). There are 10 beds perforated in one or more wells in the portion of the Brundage Canyon field studied (plates 21 and 22).

The objective in Brundage Canyon field is sandstone beds in the Castle Peak reservoir, also known as the carbonate marker unit of the lower member of the Green River Formation. The field is in primary production. Sandstone distribution and porosity are important reservoir

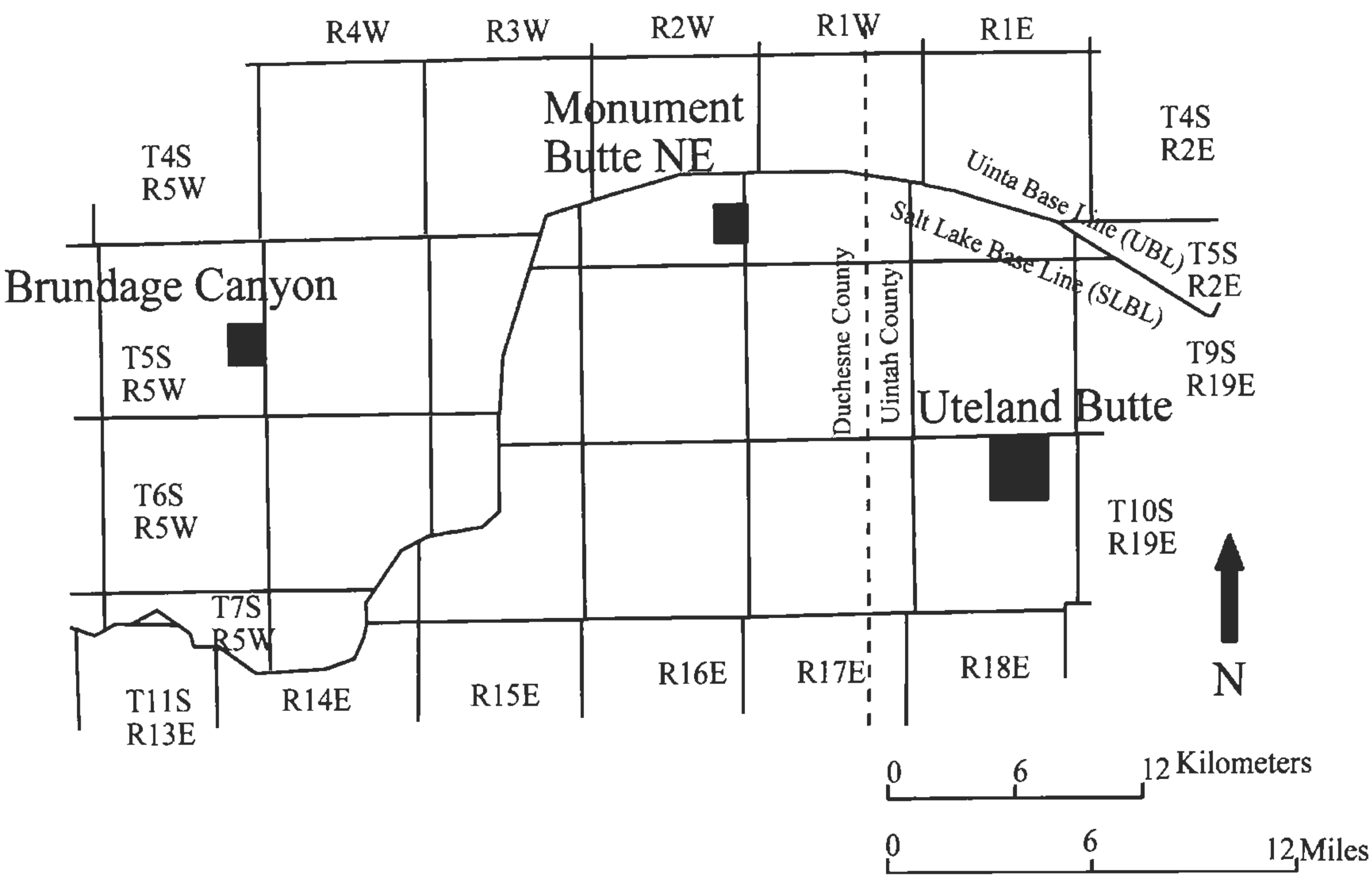


Figure 21. Map showing the location of the Uteland Butte and Brundage Canyon fields, and Monument Butte Northeast unit, that were studied in detail for this report.

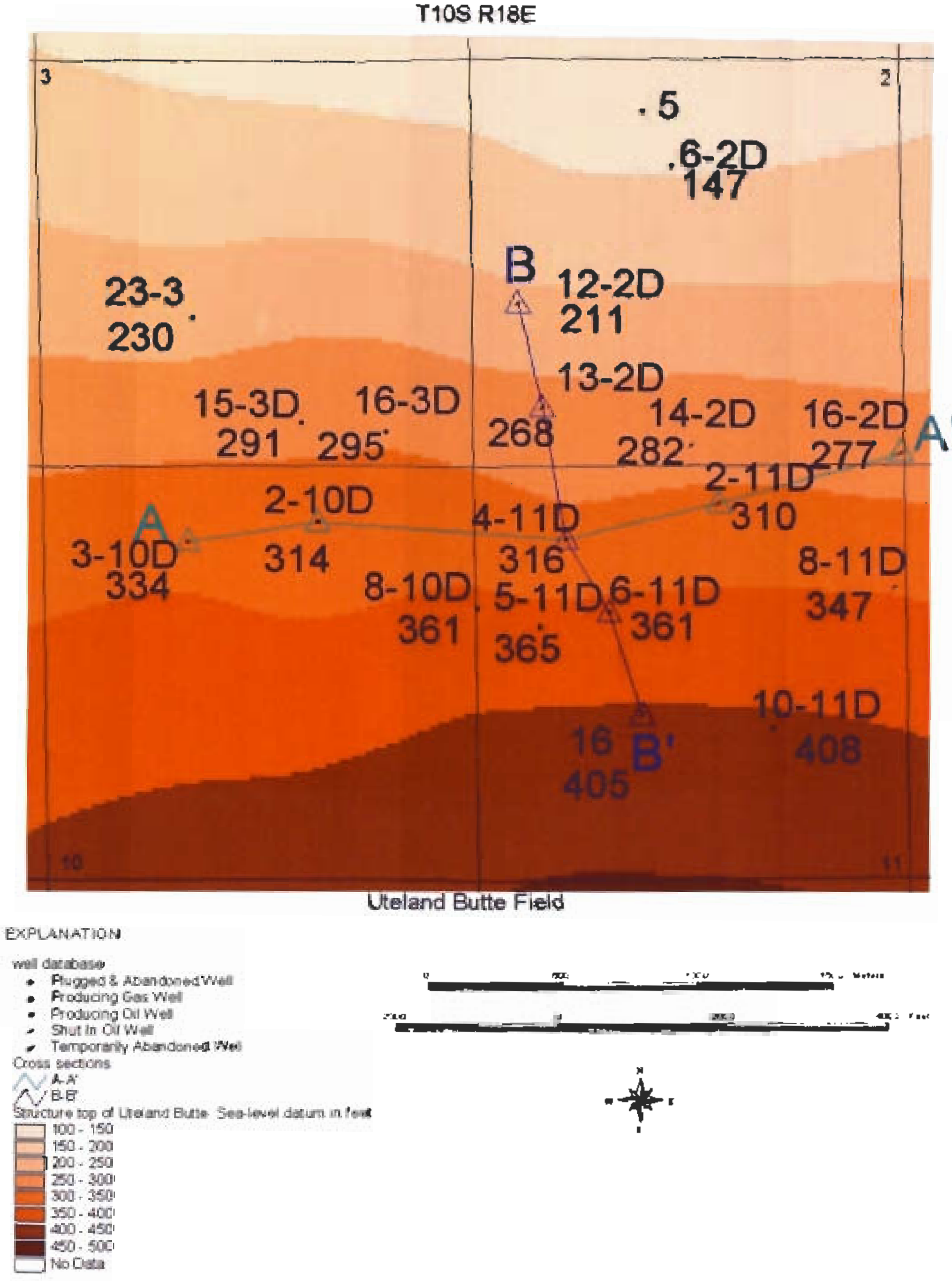


Figure 22. Map of Uteland Butte field showing wells, well numbers, cross section locations, and gridded structure of the top of the Uteland Butte reservoir. Grid interval is 50 feet, sea-level datum. Cross section A – A' is plate 19 and cross section B – B' is plate 20.

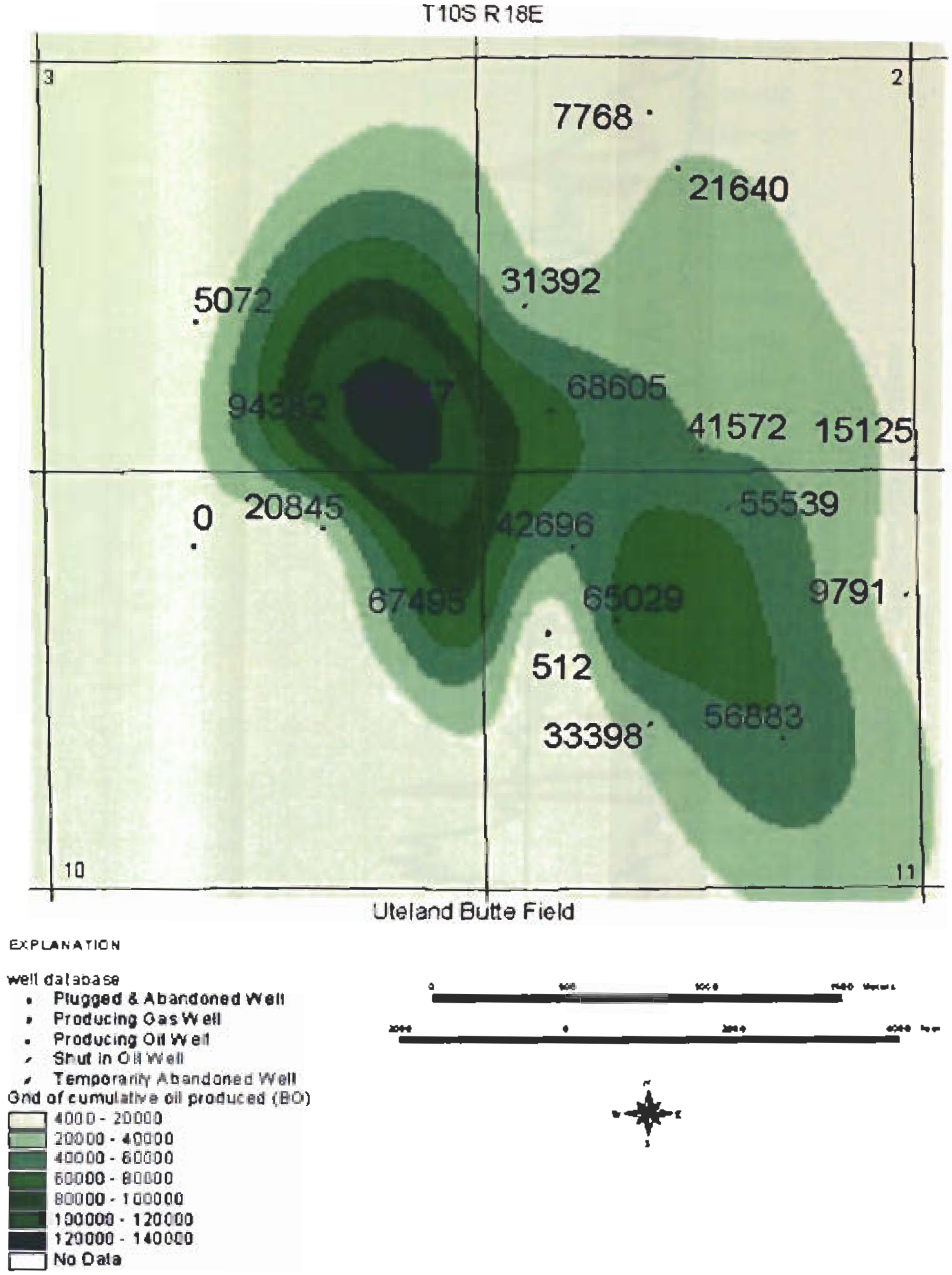


Figure 23. Gridded distribution of cumulative oil produced from each well in the Uteland Butte field, grid interval is 20,000 barrels of oil. Data source: Utah Division of Oil, Gas and Mining (February 28, 2001).

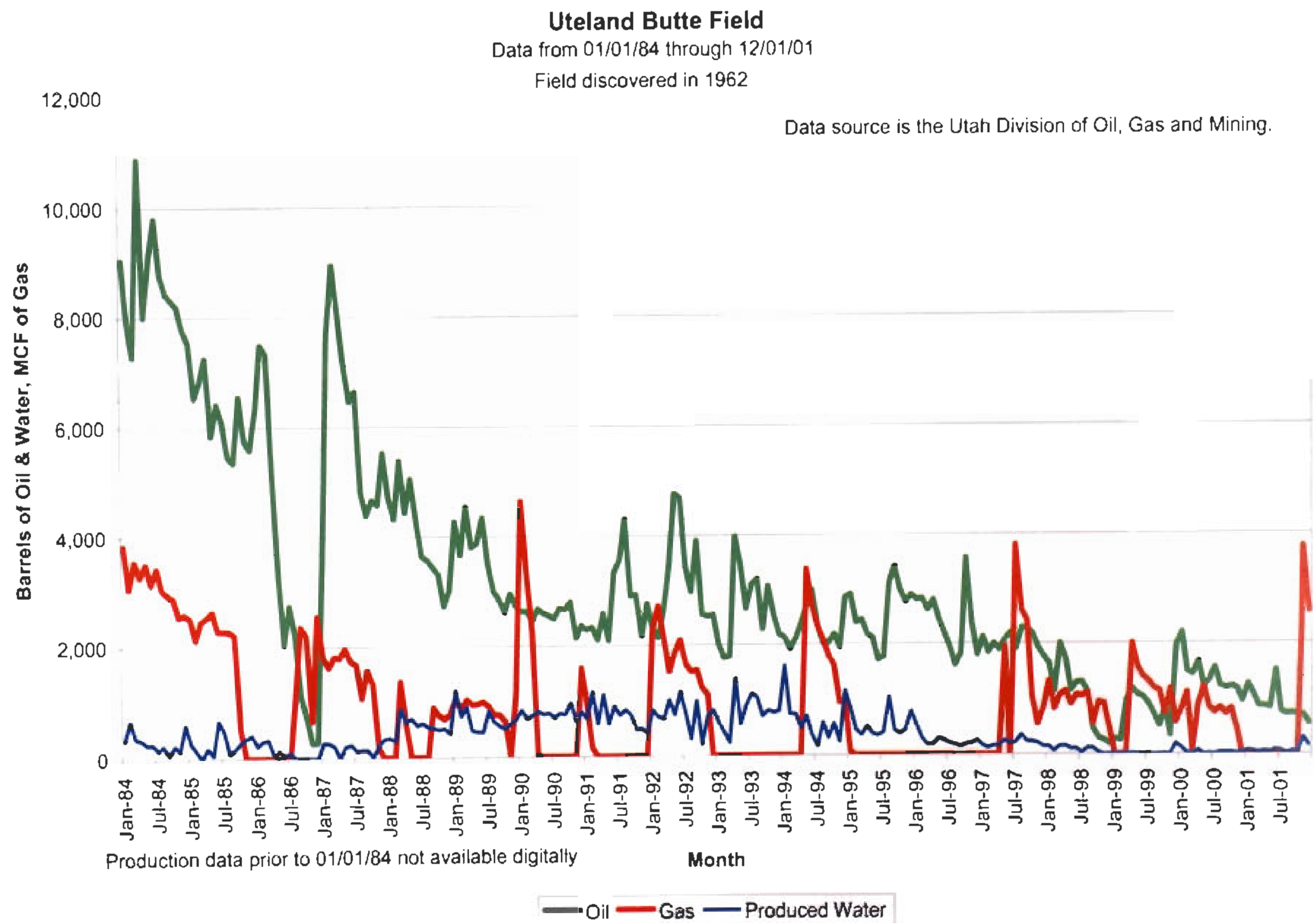


Figure 24. Monthly production of oil, gas, and water from the Uteland Butte field.

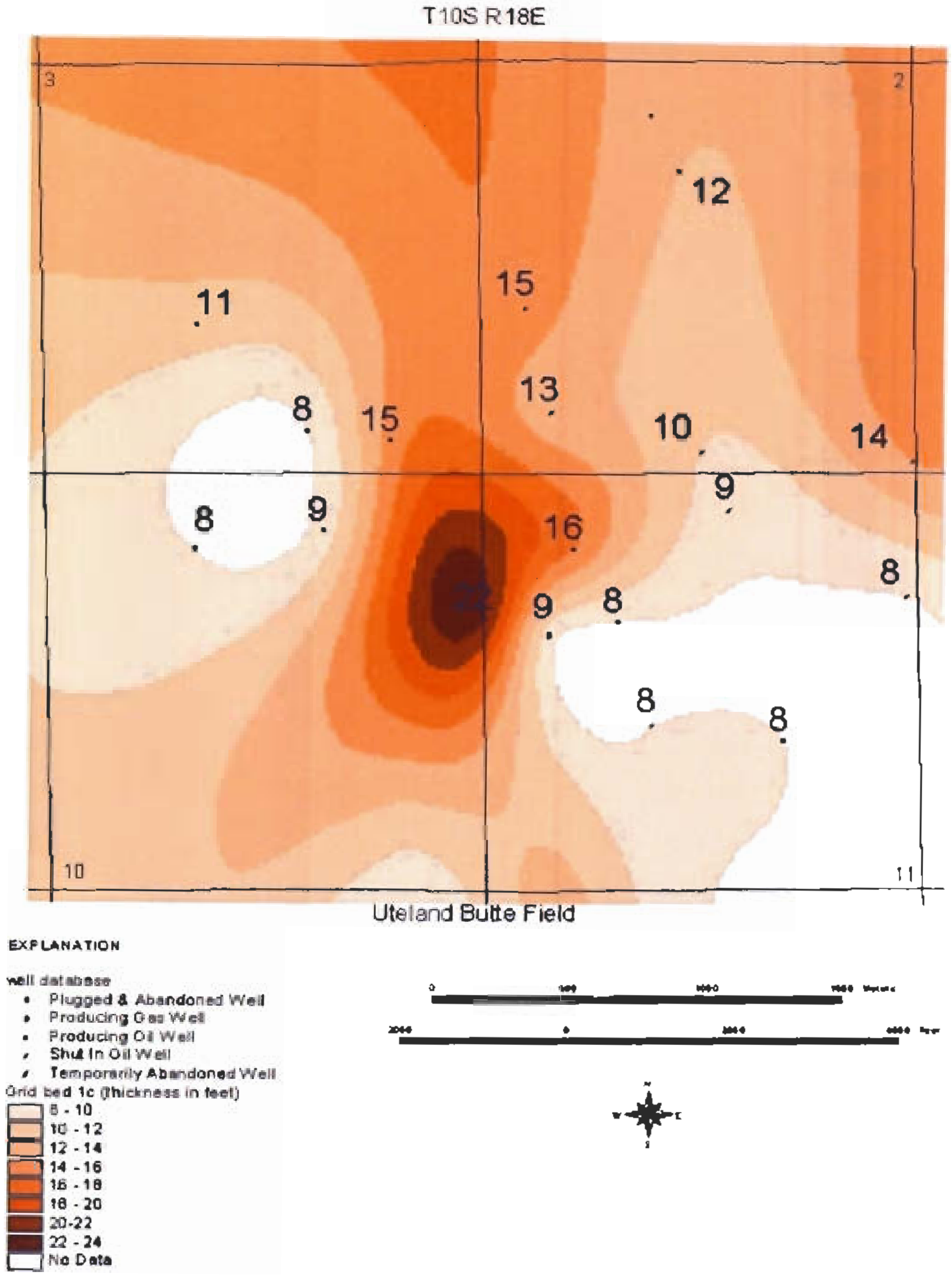


Figure 25. Gridded thickness map of the Uteland Butte 1c bed in the Uteland Butte field. Grid interval is 2 feet.

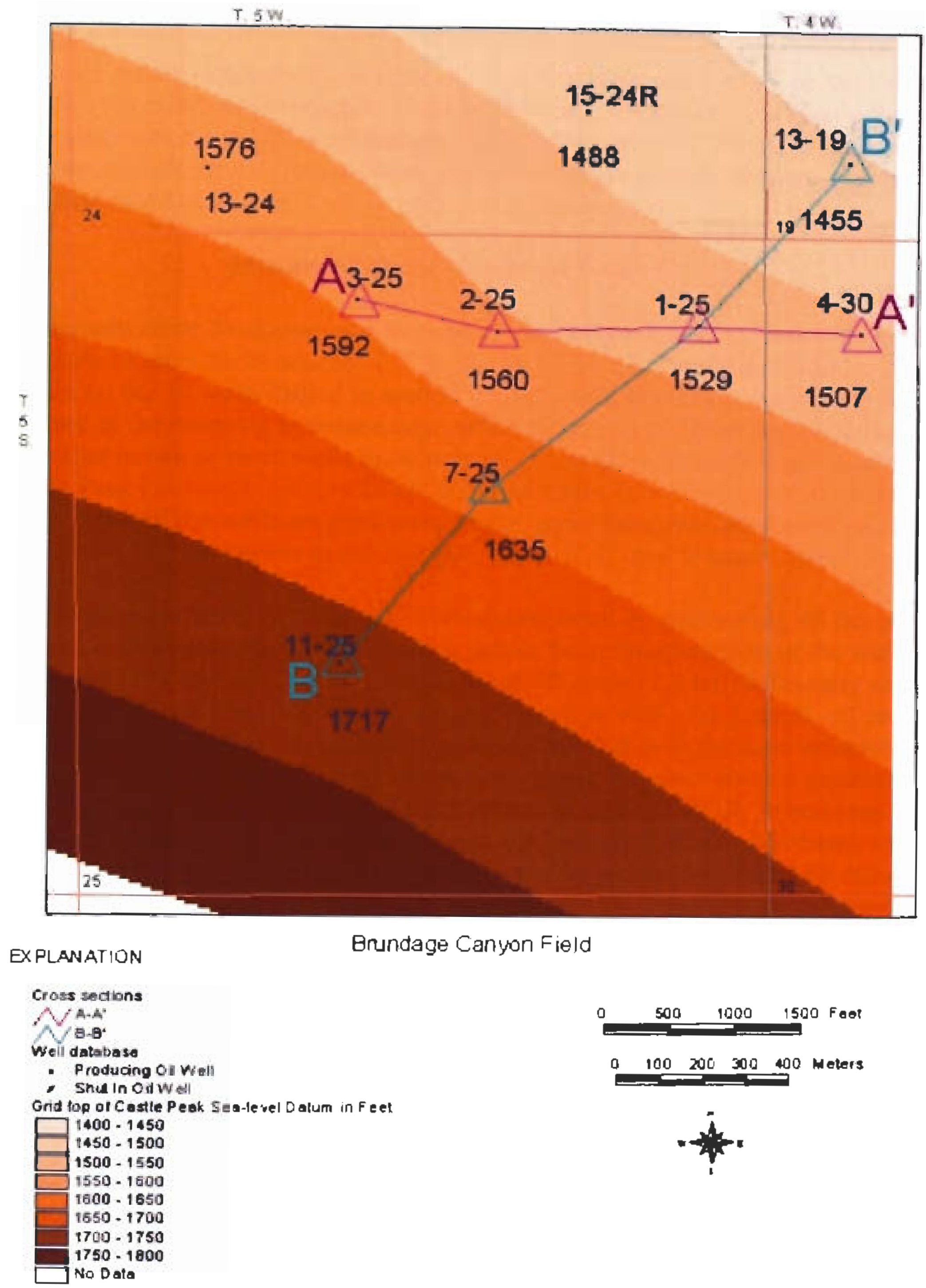


Figure 26. Map of the Brundage Canyon field showing wells, well numbers, cross section locations, and gridded structure of the top of the Castle Peak reservoir. Grid interval is 50 feet, sea-level datum. Cross section A – A' is plate 21 and cross section B - B' is plate 22.

parameters but reservoir quality is very dependent on natural fractures in the sandstone beds. As a result, individual well performance can vary widely (figure 27). Monthly production for the Brundage Canyon field has slowly increased over the years due to additional wells being drilled and produced (figure 28). Water production and the gas-to-oil (GOR) ratio has remained relatively constant.

Non-fracture density-log porosity is typically 2 to 4 percent and 8 to 12 percent when density and neutron porosities are averaged. The Castle Peak c (figure 29) and Castle Peak f (figure 30) sandstone beds are the thickest and generally most porous of the perforated beds in the Brundage Canyon study area. The sandstone thickness trends of both beds are oblique to the trend of the cumulative oil produced.

Monument Butte Northeast Unit

The Monument Butte Northeast unit (secondary recovery water-flood unit) covers all of section 25, and parts of sections 24 and 26, T. 8 S., R. 16 E., SLBL, Duchesne County, Utah. The study focused on the 16 wells drilled in section 25, but wells bordering the section were correlated and used in the mapping to reduce edge effect (figure 31). There are 27 beds, which have been perforated in one or more wells in section 25. Secondary objectives are sandstone beds in the Castle Peak (plates 23 and 24), lower Douglas Creek (plates 25 and 26), and Garden Gulch reservoirs. Most of the wells are perforated in the upper Douglas Creek reservoir (units MGR 4 through MGR 7), also known as the Douglas Creek B, C, and D sands, which are the primary objective (plates 27 and 28).

Wells in Monument Butte Northeast unit were completed by perforating all the beds that had a favorable show of hydrocarbon while drilling and/or from interpretation of the well logs. When section 25 was fully drilled (16 wells, one well per 40 acres [1.6 ha]) secondary recovery was begun. Every other well was converted to a water-injection well. As a result, oil production per well does not accurately reflect the contribution each well makes to the total production from the unit. However, the distribution of the oil production (figure 32) does show a pattern very similar to the MGR 7b sandstone trend (figure 33), indicating that the MGR 7b bed may be responsible for the majority of the oil production from the Monument Butte Northeast unit. The monthly production of oil, gas, and water, show a reduction in gas production and a reduction in the oil-production decline, after water injection began (figure 34). The monthly oil production has not increased but the decline is very slow.

Some of the best developed beds in the upper Douglas Creek reservoir are the MGR 7b (figure 33), MGR 6b (figure 35), and MGR 5b (figure 36). Each of these beds have lenticular thickness trends that are not optimally exploited by the current injection-production well pattern, but no single pattern would be optimal for all perforated beds. Many of the secondary objective beds are not being fully exploited during the secondary recovery phase of production because some are only perforated in injection wells while others are only perforated in producing wells. Sandstone thickness of the lower Douglas Creek reservoir trends west to east through the Monument Butte Northeast unit (figure 37). The trend is intersected by two injection wells in the western half of the trend and two production wells in the eastern half of the trend.

The producer-injector pattern does not always fully exploit the primary objectives. Many of the beds could be more effectively exploited with a pattern based on the sandstone trend. This could be accomplished by infill drilling along the sandstone trends or drilling short horizontal laterals from existing wells.

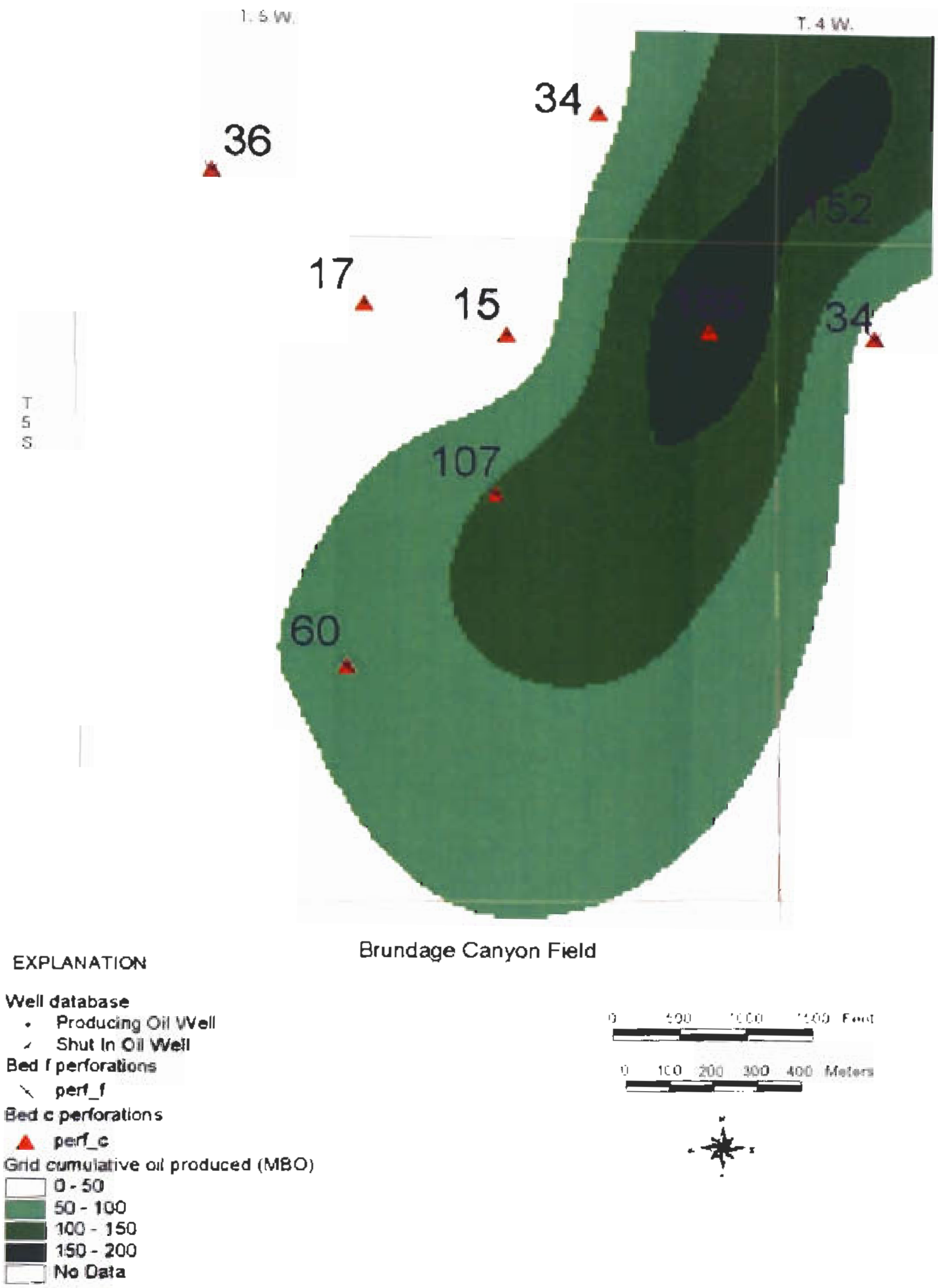


Figure 27. Gridded distribution of cumulative oil produced from each well in the Brundage Canyon field, grid interval is 50,000 barrels of oil. Data source: Utah Division of Oil, Gas and Mining (May 31, 2000).

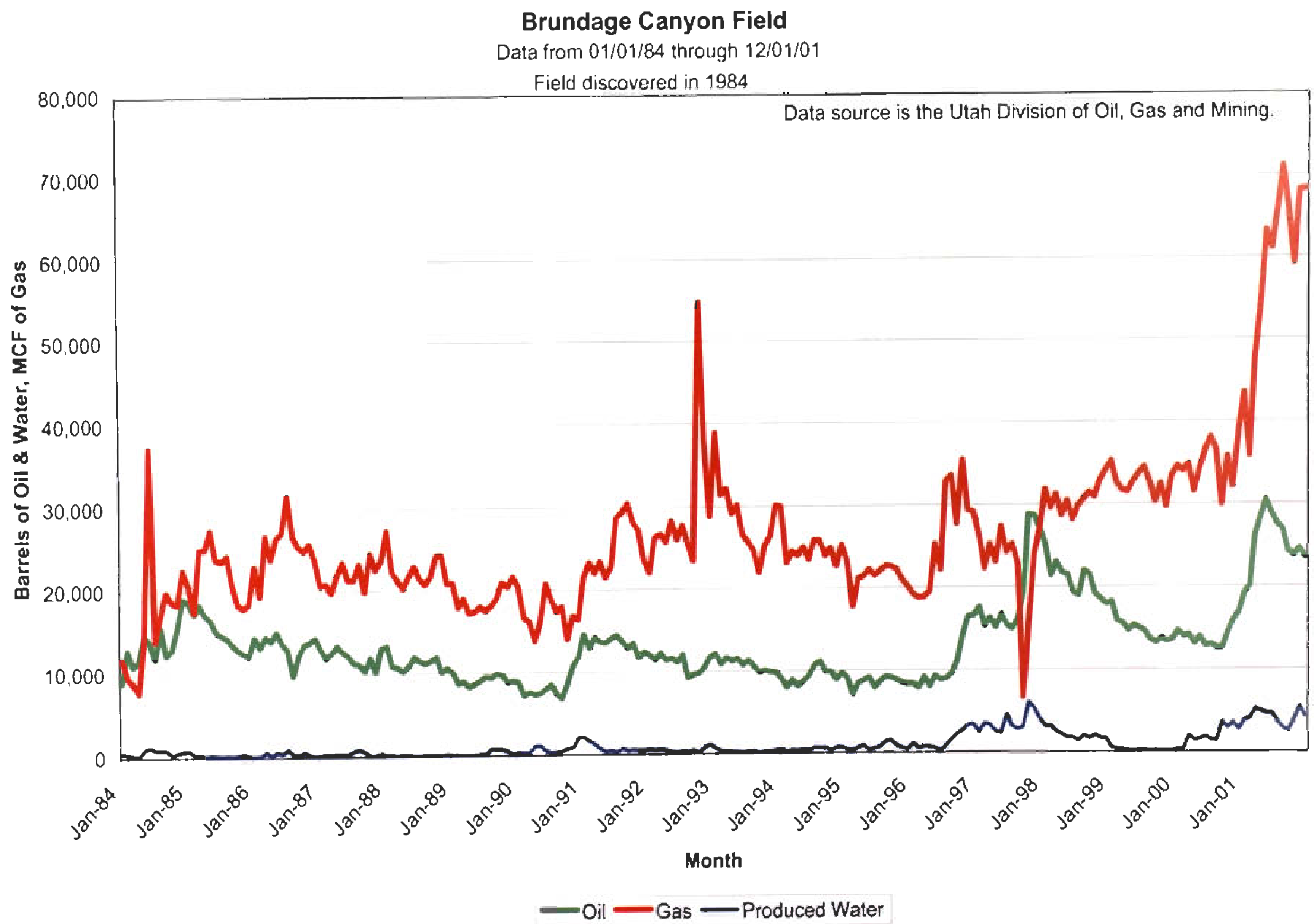


Figure 28. Monthly production of oil, gas, and water from the Brundage Canyon field.

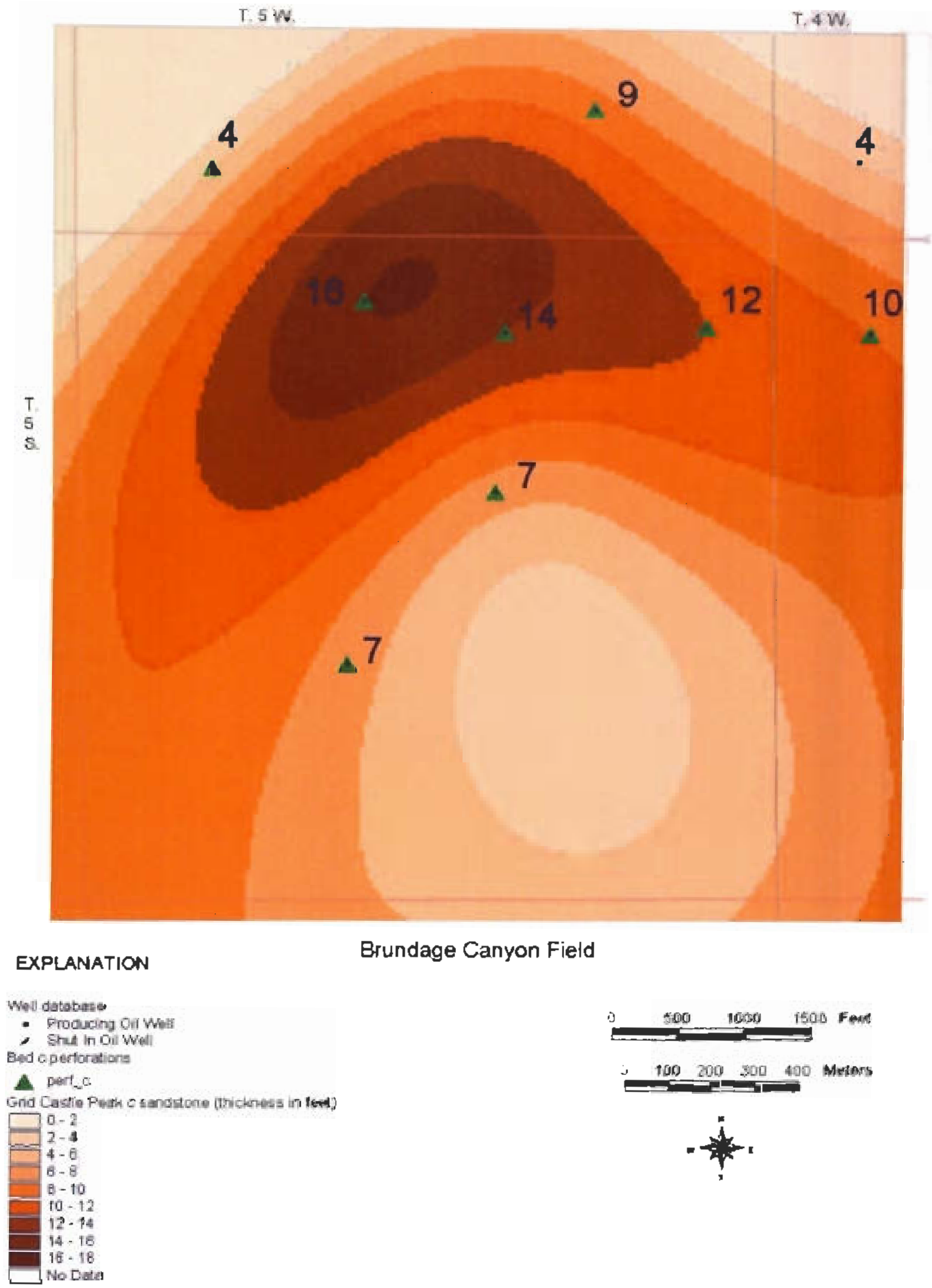


Figure 29. Gridded thickness map of the Castle Peak c sandstone in the Brundage Canyon field. Grid interval is 2 feet.

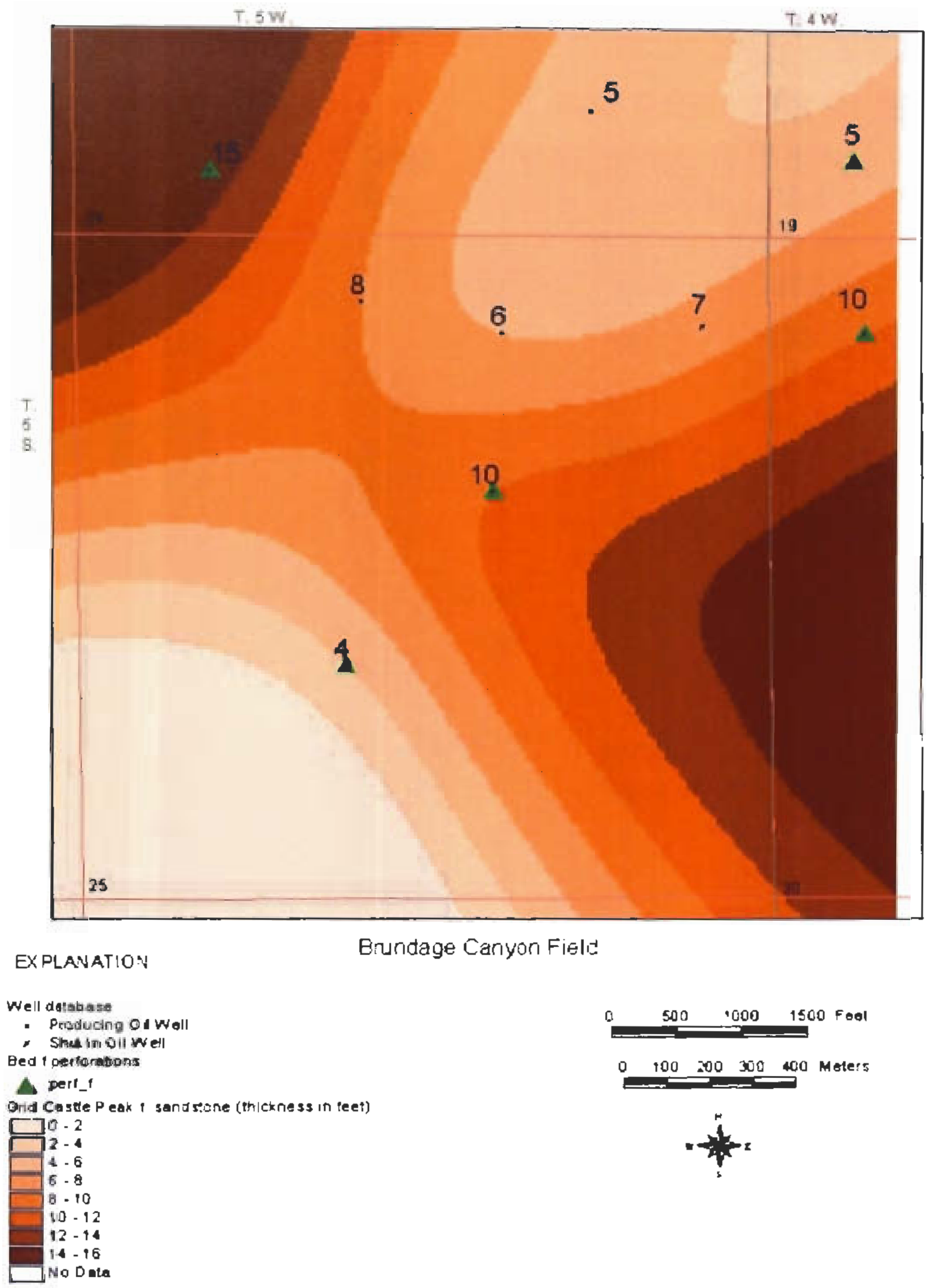


Figure 30. Gridded thickness map of the Castle Peak f sandstone in the Brundage Canyon field. Grid interval is 2 feet.

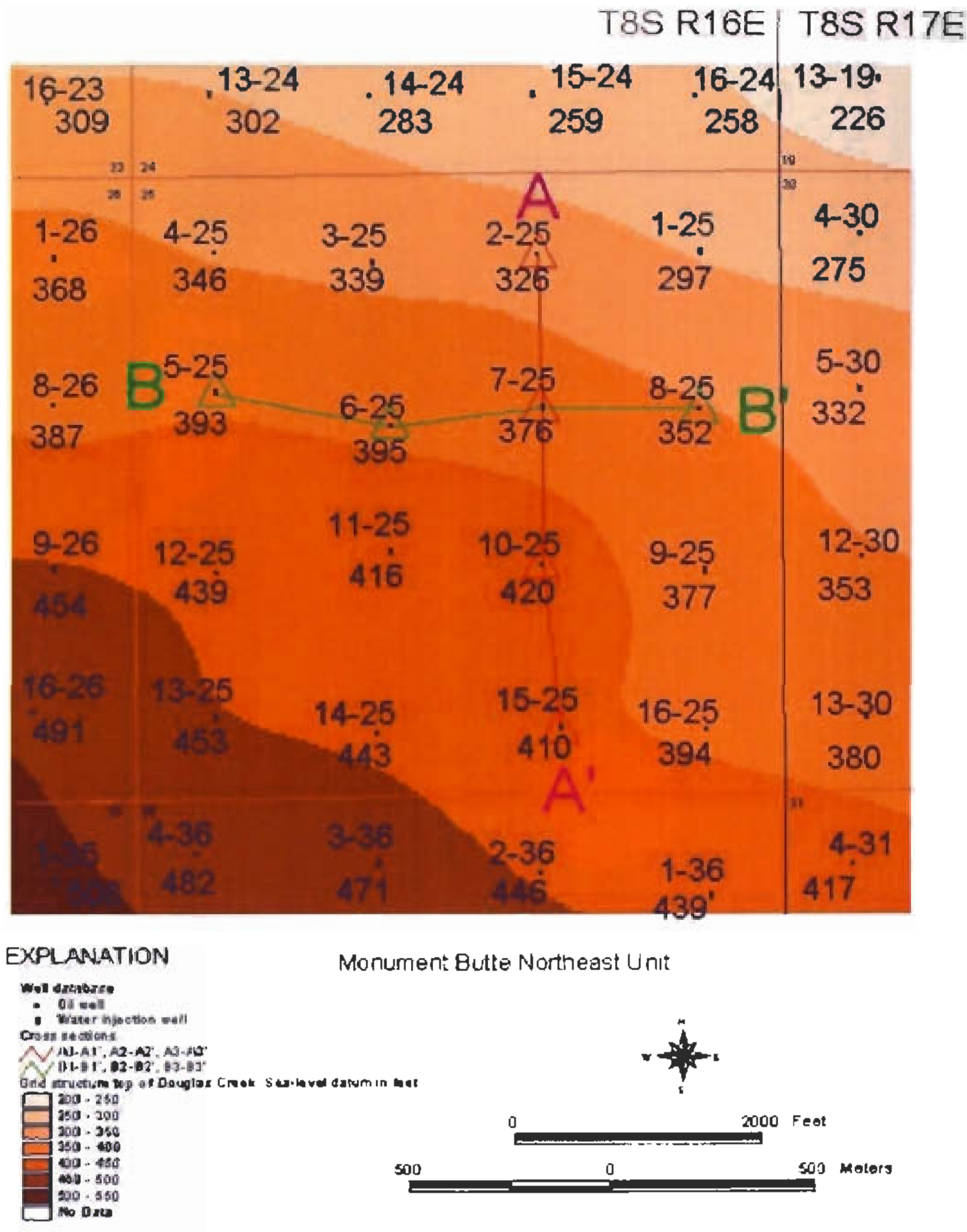


Figure 31. Map of the Monument Butte Northeast unit showing wells, well numbers, cross section locations, and gridded structure of the top of the Douglas Creek reservoir. Grid interval is 50 feet, sea-level datum. Cross sections A - A' and B - B', refer to A1 - A1' (plate 23), A2 - A2' (plate 25), A3 - A3' (plate 27), and B1 - B1' (plate 24), B2 - B2' (plate 26), B3 - B3' (plate 28), respectively. The number designation of the cross sections relate to the same wells but at different stratigraphic horizons and drill depths.

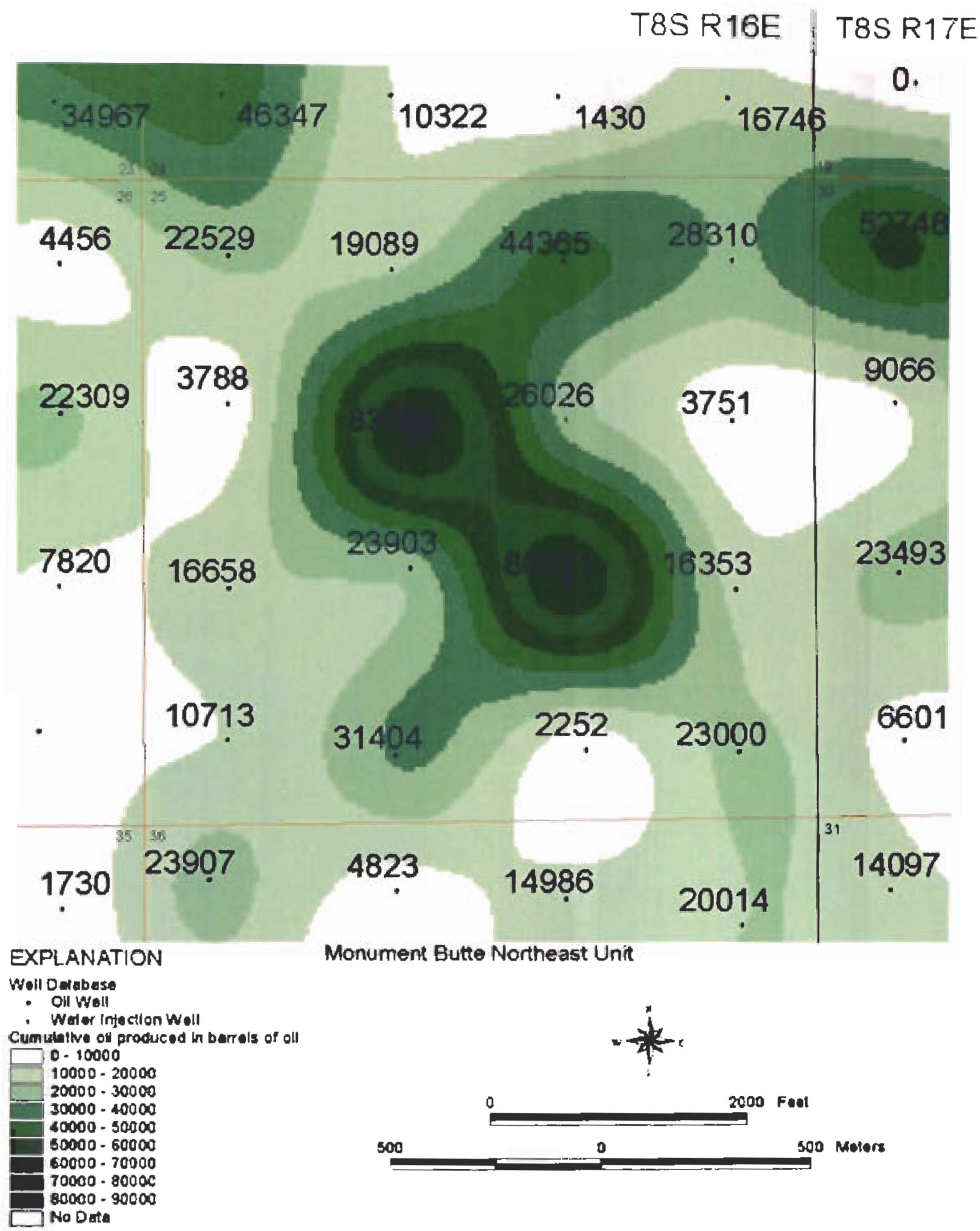


Figure 32. Gridded distribution of cumulative oil produced from each well in the Monument Butte Northeast unit, grid interval is 10,000 barrels of oil. The upper Douglas Creek is the primary oil-producing reservoir. Data source: Utah Division of Oil, Gas and Mining (October 31, 1999).

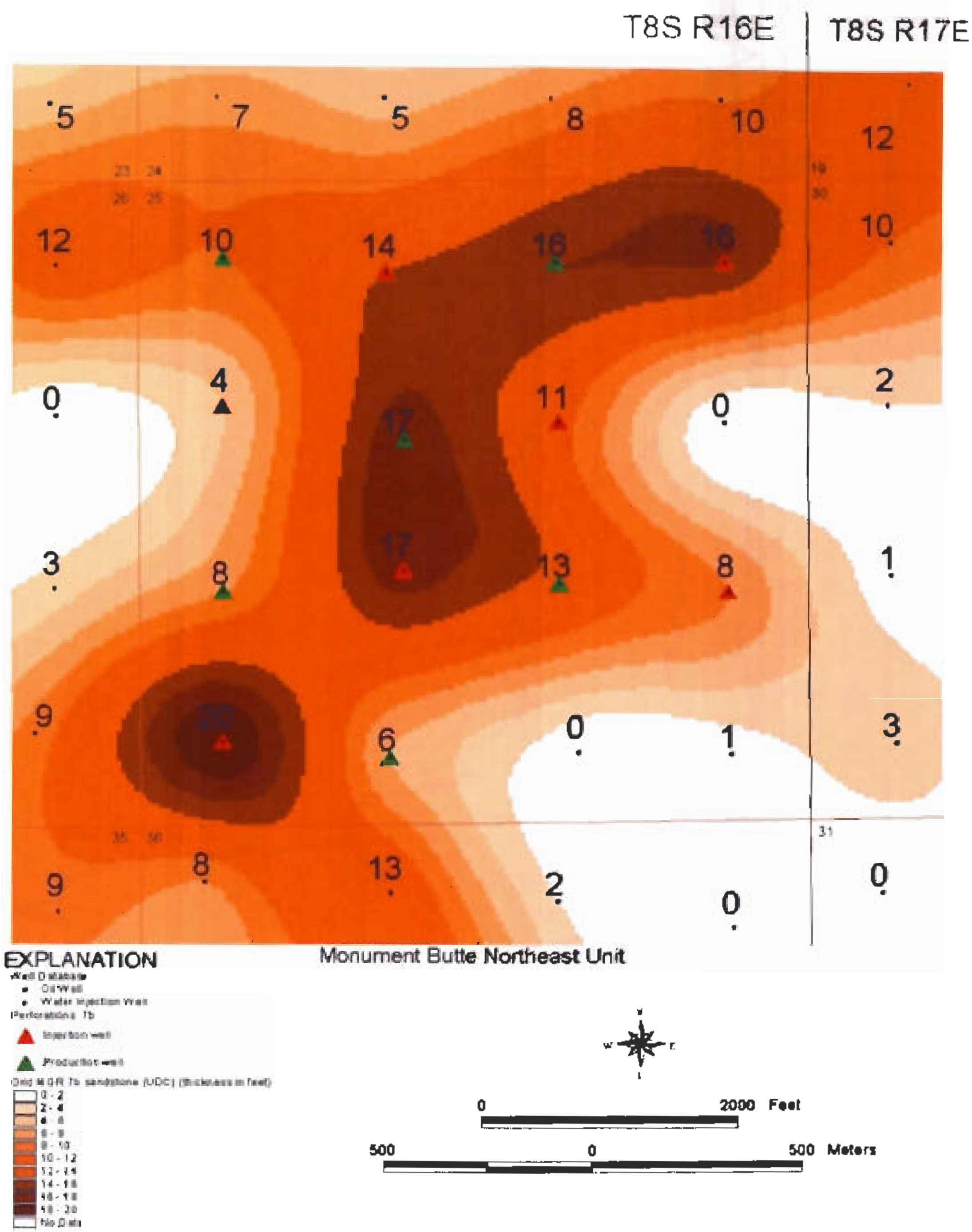


Figure 33. Gridded thickness map of the MGR 7b sandstone in the Monument Butte Northeast unit. Grid interval is 2 feet.

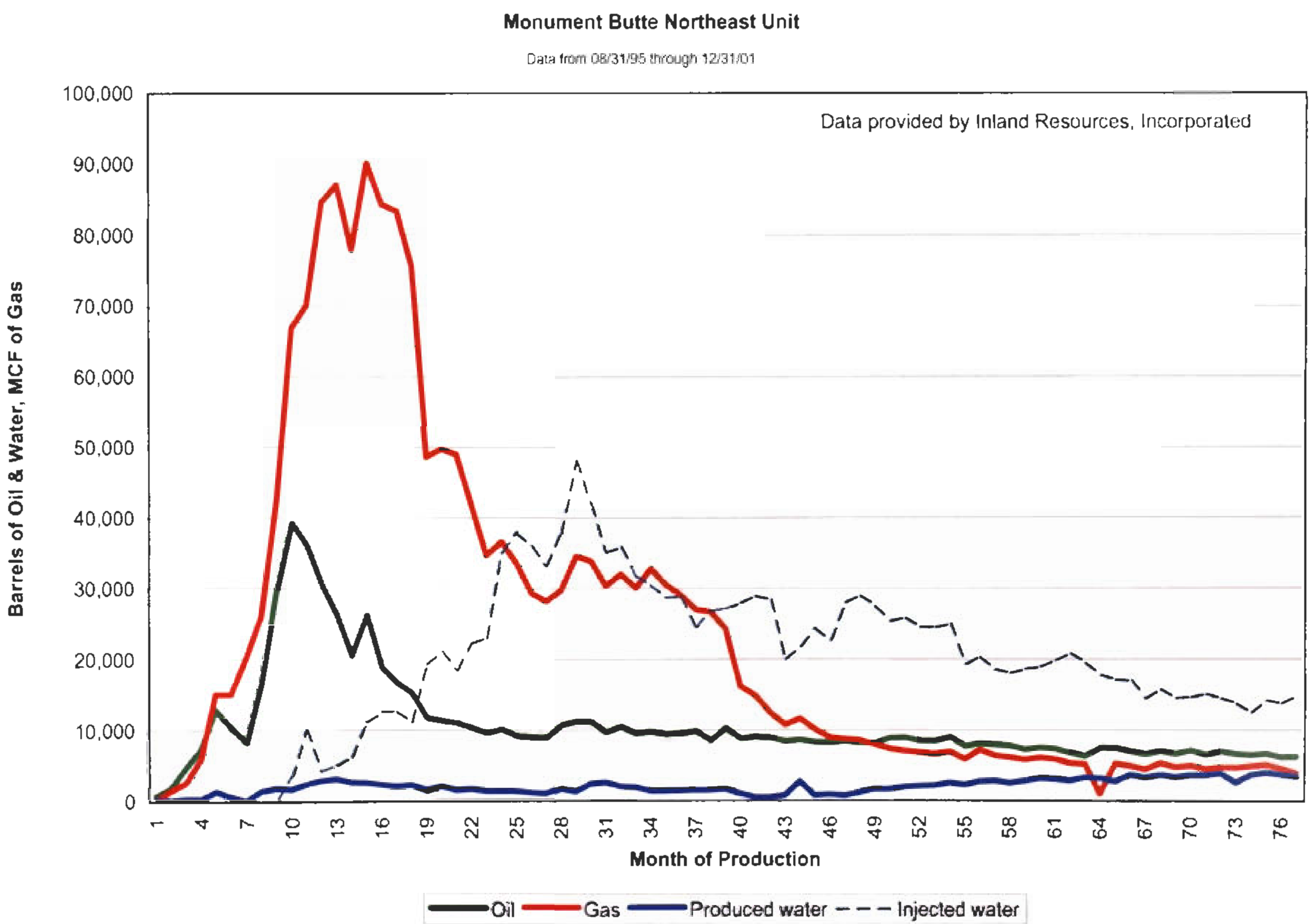


Figure 34. Monthly production of oil, gas, and water, and monthly volumes of water injected, in the Monument Butte Northeast unit. Water injection has reduced gas production and slowed the oil-production decline.

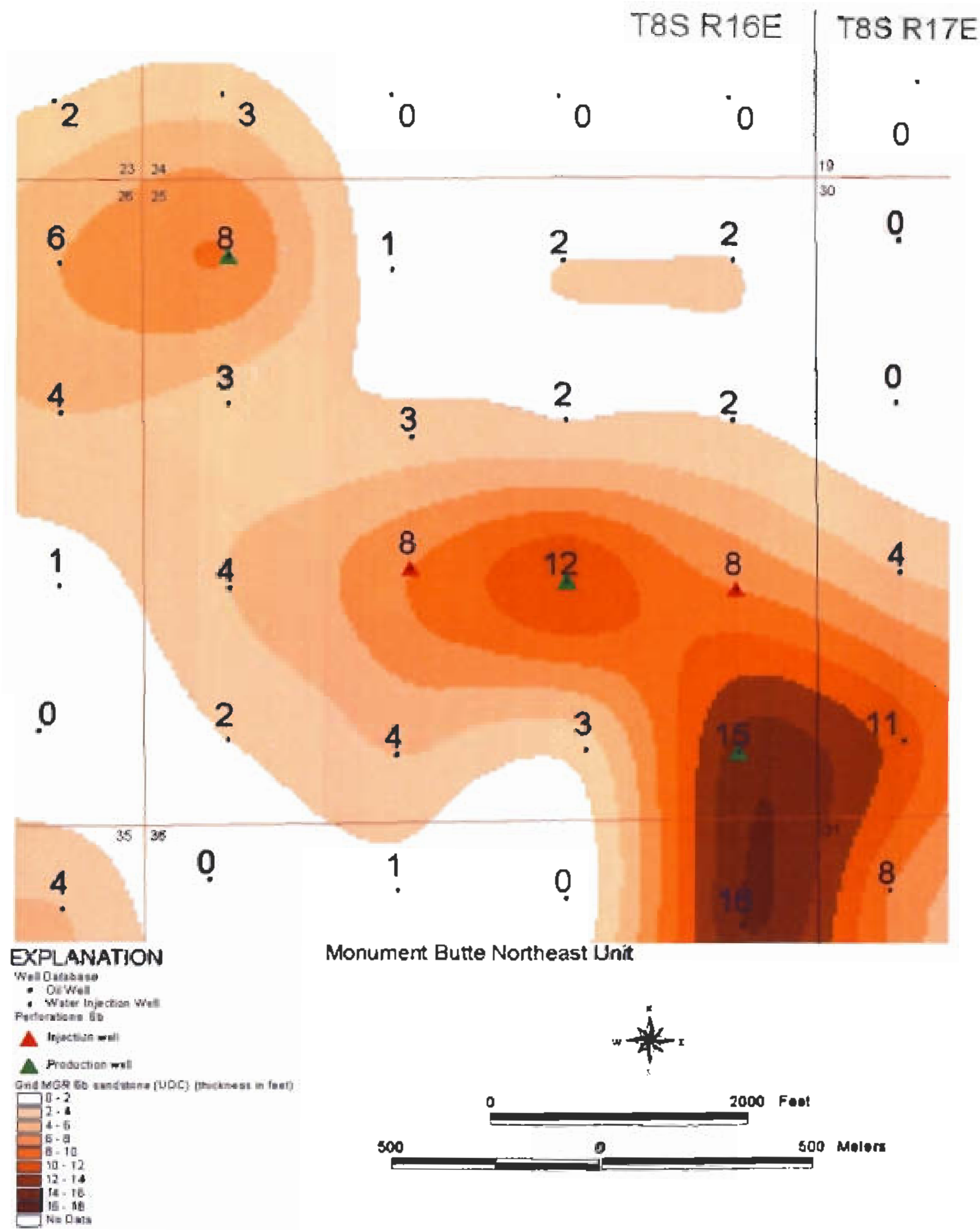


Figure 35. Gridded thickness map of the MGR 6b sandstone in the Monument Butte Northeast unit. Grid interval is 2 feet.

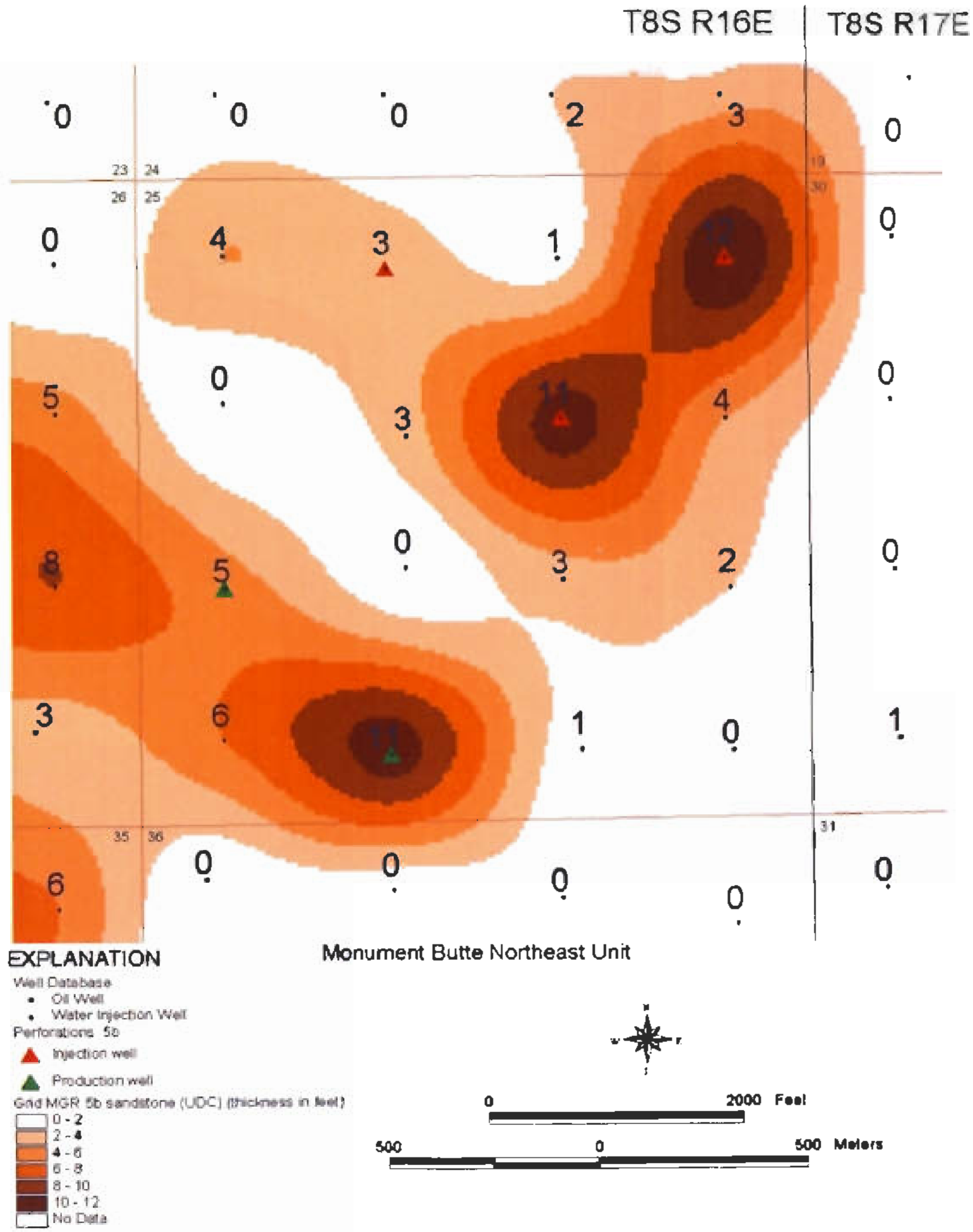


Figure 36. Gridded thickness map of the MGR 5b sandstone in the Monument Butte Northeast unit. Grid interval is 2 feet.

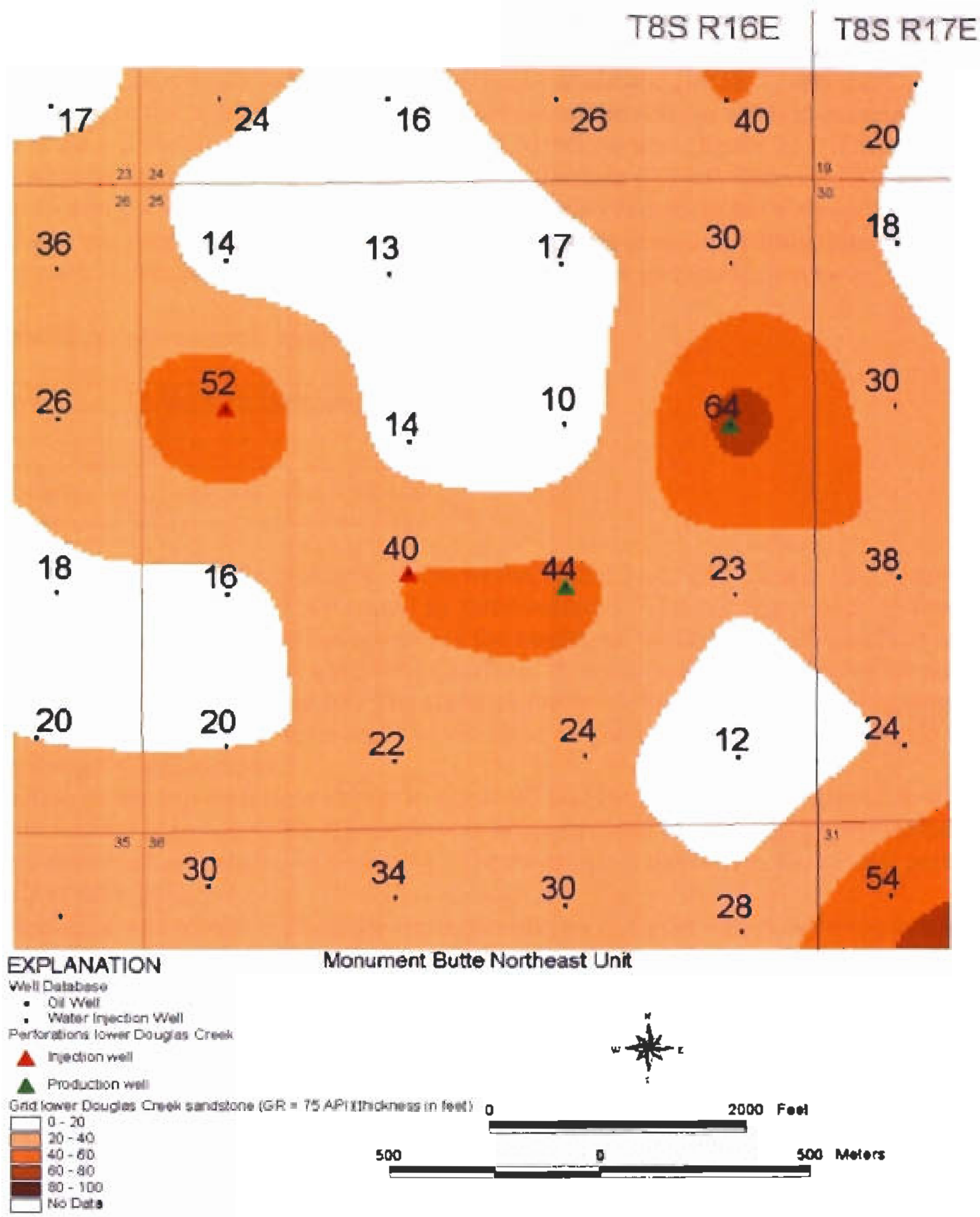


Figure 37. Gridded thickness map of the lower Douglas Creek sandstone using a 75 API unit gamma-ray cutoff, in the Monument Butte Northeast unit. Grid interval is 20 feet.

GENERATION OF GEOSTATISTICAL RESERVOIR MODELS

To create a geological model for the fluid flow simulations the spatial distributions of porosity, permeability and water saturation are required. The geological model for the MBNE unit was created using Heresim3D® (Heterogeneities of Reservoir Simulations), an integrated computer–aided reservoir description program by BEICIP-FRANLAB® Petroleum Consultants.

Petrophysical properties were generated for the D sandstone (MGR 7) and the C sandstone (MGR 6) in the upper Douglas Creek reservoir, in the sixteen wells in section 25, (T. 8 S., R. 16 E., SLBL), a portion of the Monument Butte Northeast unit (figure 21). The well log information included porosities and water saturations at 0.5-foot (0.1-m) intervals. Figure 38 shows the wells and the reference grid used, which was twenty blocks in the x-direction and twenty blocks in the y-direction. The block dimensions in both the x and y directions were 264 feet (80.5 m) each. Lithofacies were defined based on porosities and are shown table 2.

Table 2. Lithofacies assignments based on porosity.

Porosities in percent	Lithofacies Designation
0 to 12.5	10
12.5 to 15	20
15 to 17.5	30
17.5 to 20 +	40

The lithofacies designations in four of the wells (10-25, 11-25, 12-25 and 13-25) are shown in figure 39. The lithofacies are bound by three surfaces. The two upper and the lower surfaces are the upper and the lower boundaries of the sandstone while the middle surface was chosen at the middle of each sand as a reference surface. A northwest-to-southeast cross section through section 25 is shown in figure 40. The surfaces for the defined cross section are shown in figure 41. The entire D sandstone reservoir was modeled as one litho unit. A parallel grid was used in describing the stratigraphy.

Elevation of the top surface is shown in figure 42 and the corresponding elevation map for the bottom surface is in figure 43. The reservoir is constrained between these two surfaces. The thickness distribution is shown in figure 44. The reservoir is thickest in the central portion and tapers off at the edges.

Permeability was modeled using the cross plot shown in figure 45. A semi-logarithmic correlation between permeability and porosity was found to fit most measured porosity-permeability values across the field. The equation for the permeability-porosity cross-plot was:

$$\log(k) = 0.218\phi - 2.225$$

where, k was in millidarcies and ϕ was in percentage. The general statistics for the entire data set for permeability and porosity is shown in table 3.

Using the appropriate variogram parameters, lithotypes were simulated over the entire field. Litho unit distribution in the same cross section (as in figure 40) is shown in figure 46. Corresponding porosities and permeabilities are shown in figures 47 and 48.

We chose a resolution that was composed of about 250 half-foot layers (0.1-m), which would yield a total of 100,000 grid blocks. It is possible to build a reservoir model with these many blocks; however, the awkward aspect ratios of grid blocks would cause numerical instabilities. Therefore, the first series of reservoir models were built by upscaling the blocks vertically. A

Table 3. General permeability and porosity statistics for section 25, T. 8 S., R. 16 E. (SLBM), Monument Butte Northeast unit.

	Lithofacies 40		Lithofacies 30		Lithofacies 20		Lithofacies 10	
Attribute	ϕ (%)	K(md)	ϕ (%)	K(md)	ϕ (%)	K(md)	ϕ (%)	K(md)
Number of samples	86	86	114	114	121	117	91	80
Minimum	15.93	17.7	15.03	11.2	12.28	2.8	10.01	0.9
Maximum	20.3	158.7	17.49	38.7	16.34	21.8	12.51	3.2
Mean	18.6	74.02	16.2	21.1	13.9	6.992	11.5	2.085
Standard Deviation	0.854	33.24	0.71	7.7	0.79	2.78	0.71	0.63

ϕ = porosity in percent
K(md) = permeability in millidarcies

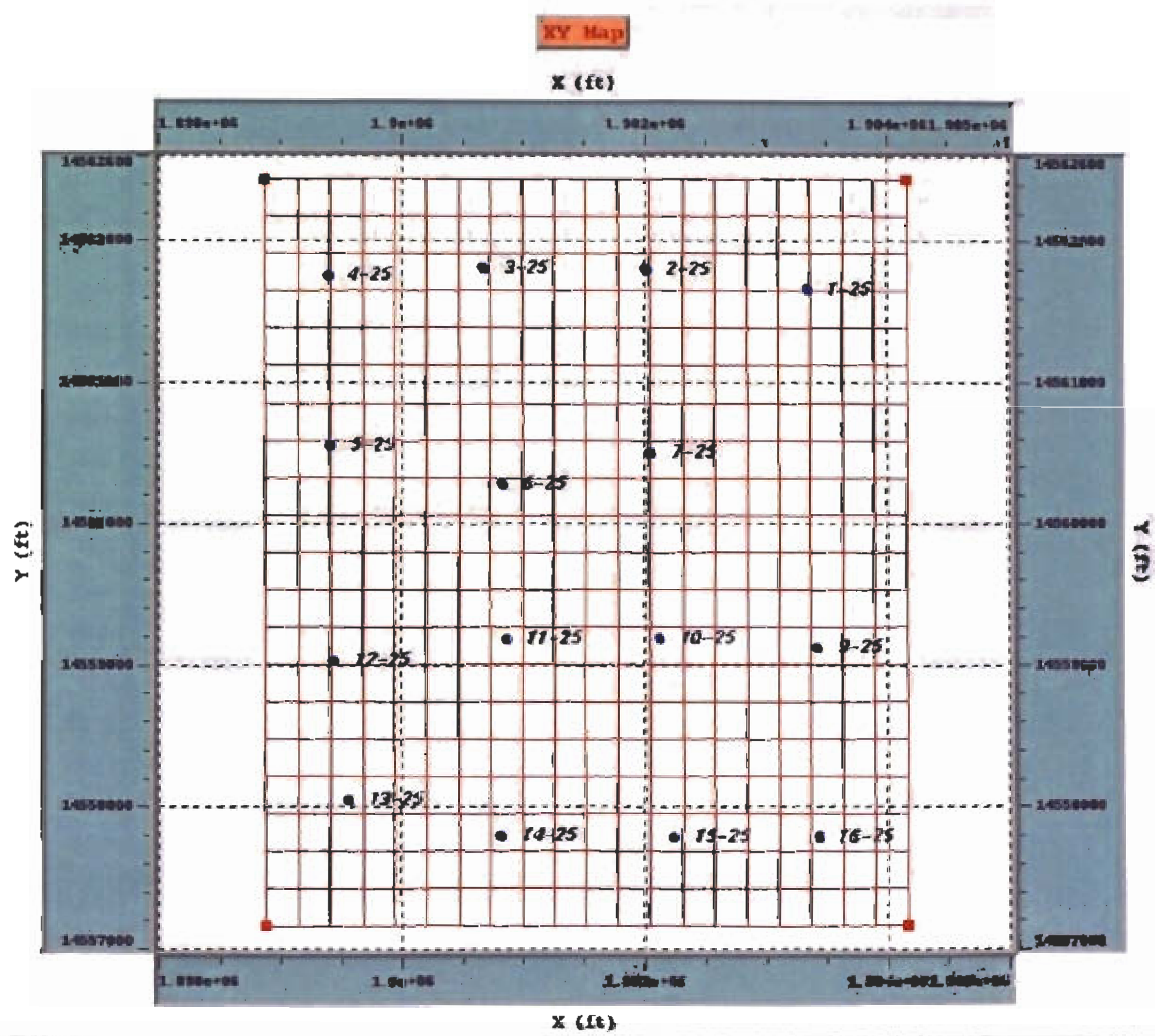


Figure 38. The map of section 25 showing the grid and all the wells.

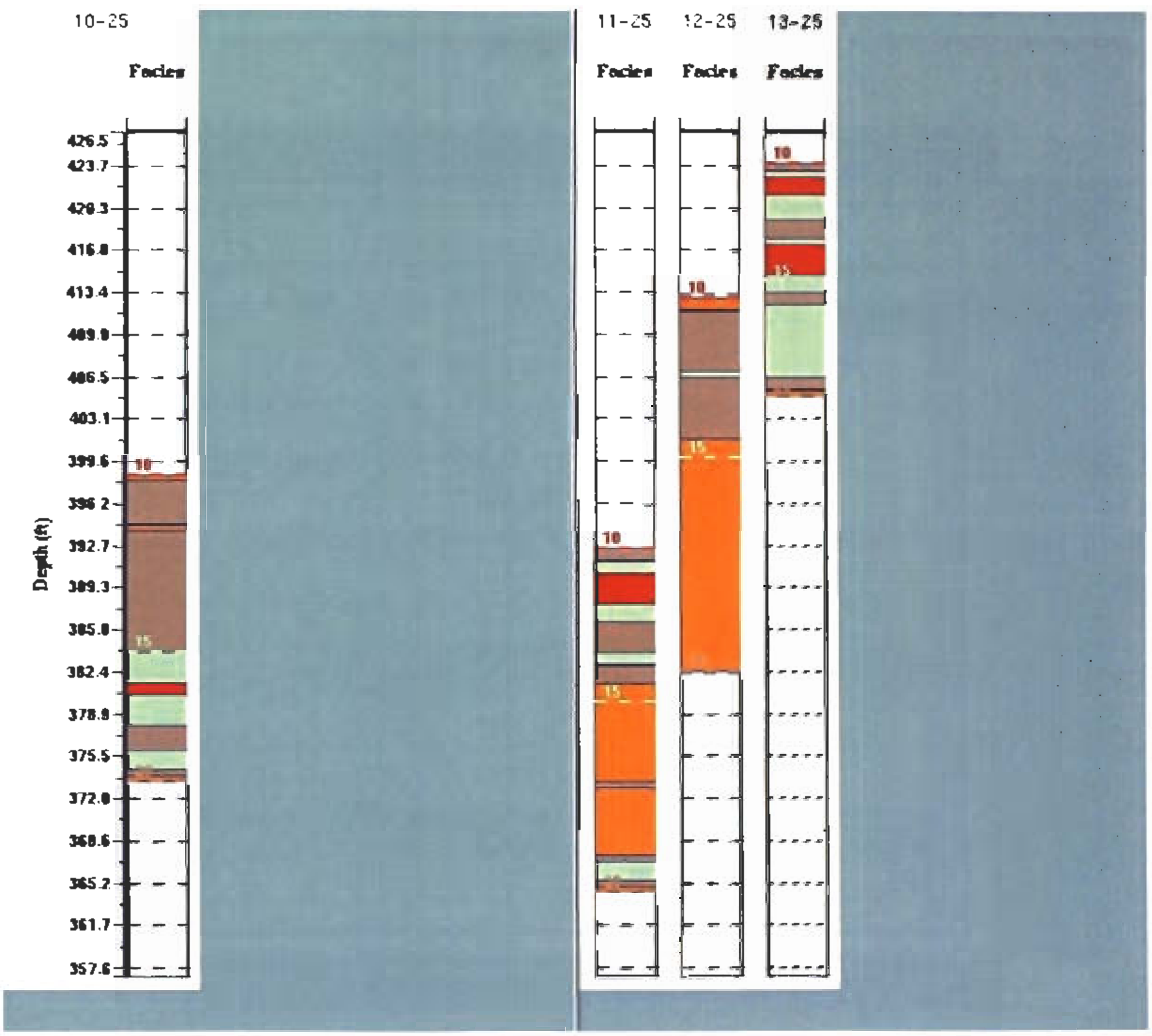


Figure 39. Lithofacies in some of the wells.

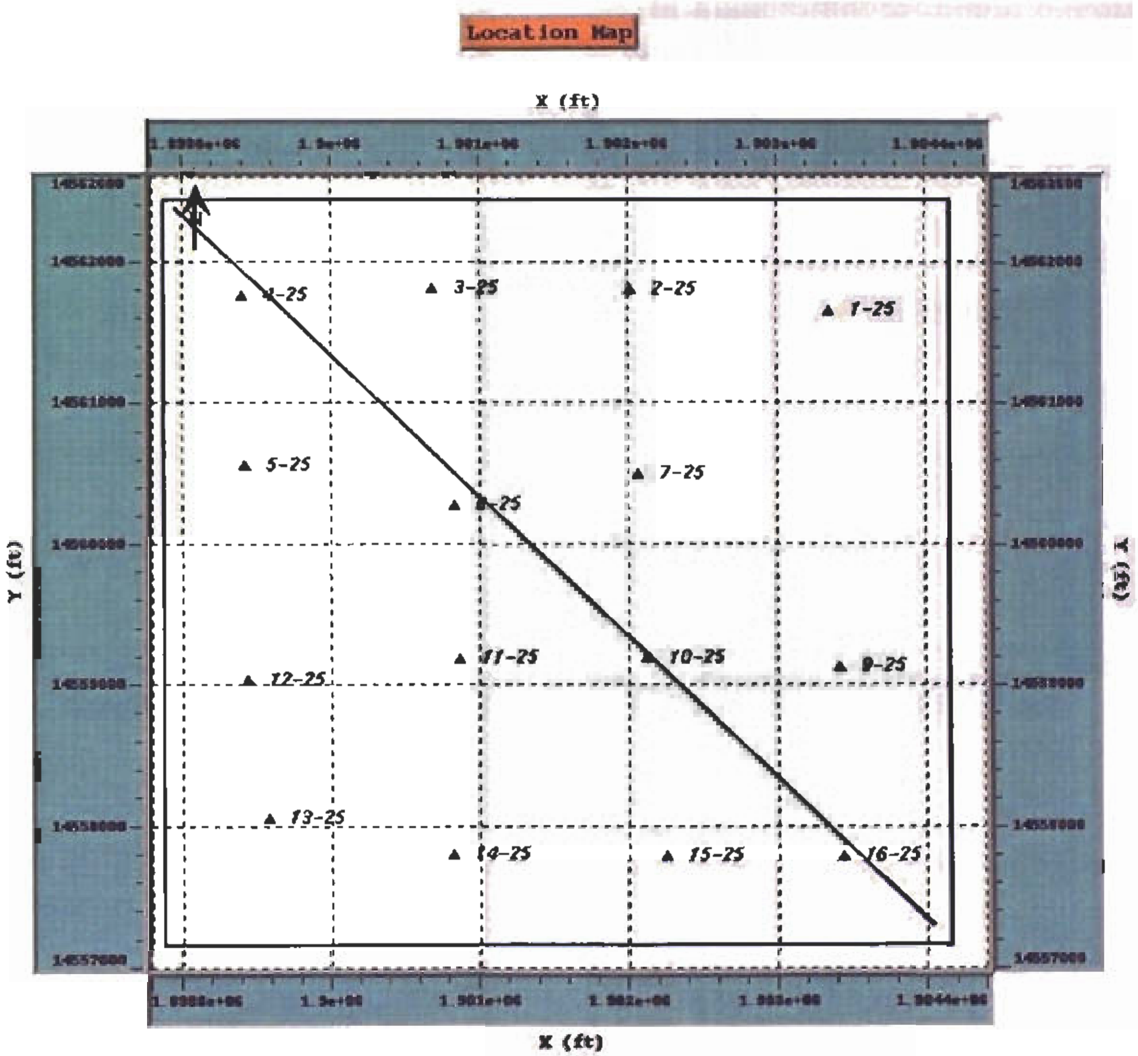


Figure 40. Location of the northwest-to-southeast cross section (figure 41) through section 25.

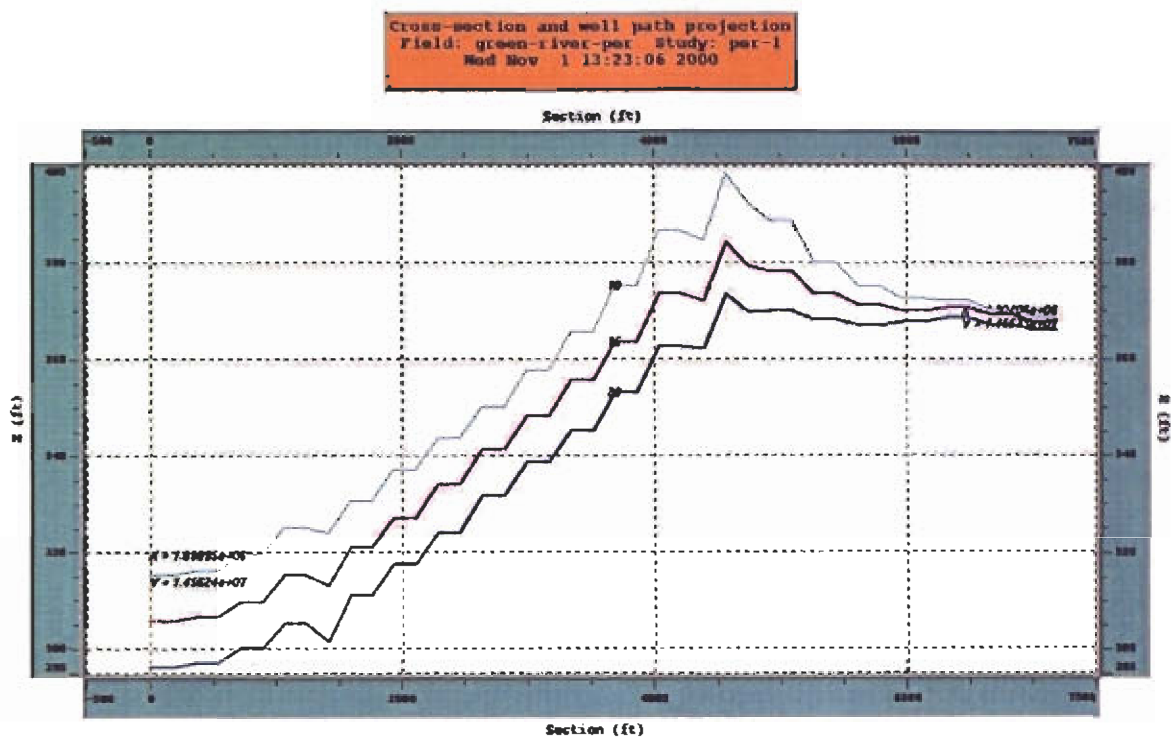


Figure 41. The three D sandstone surfaces along the cross section. See figure 40 for location of cross section.

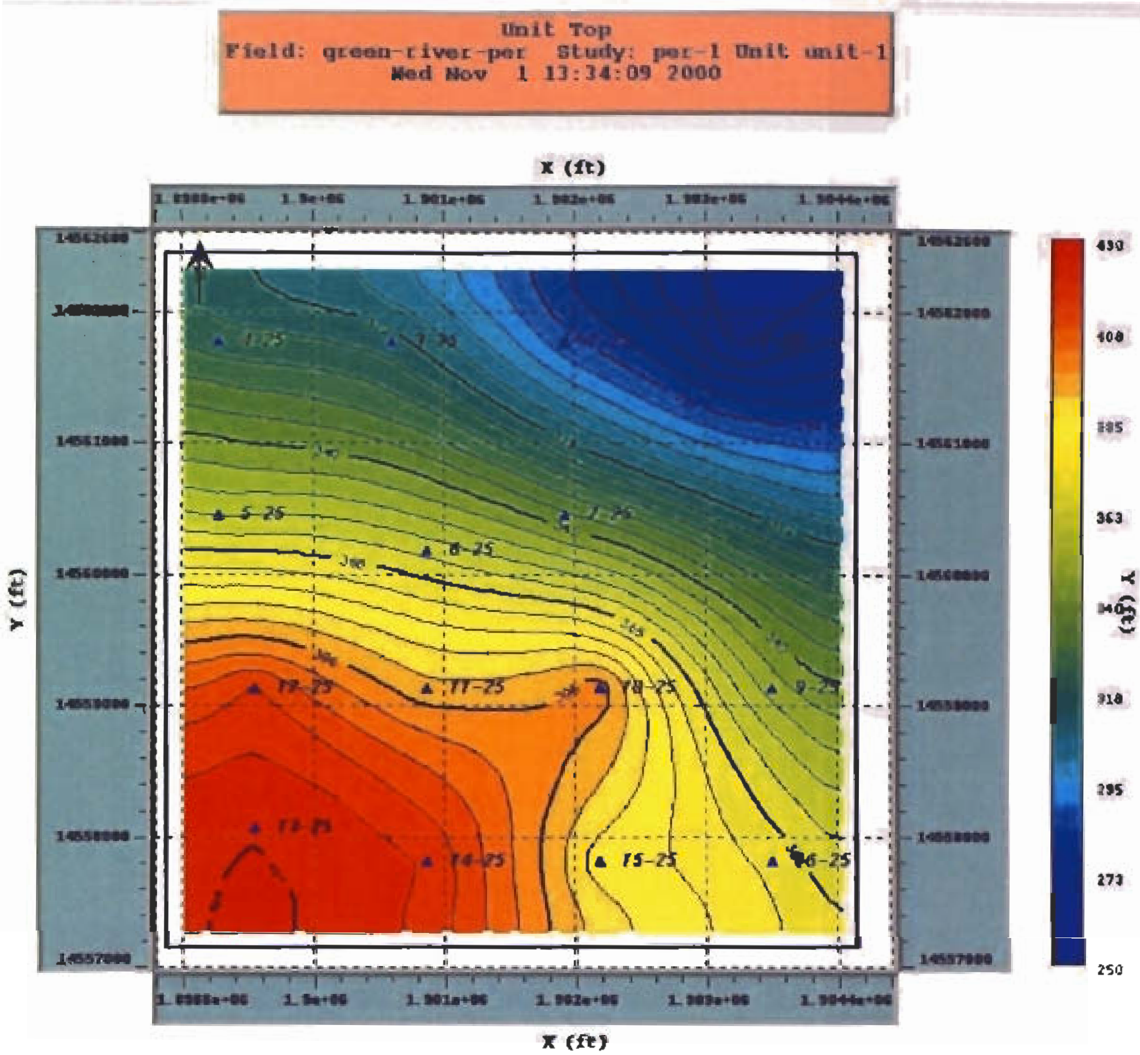


Figure 42. Contour map of the top surface of the D sandstone. Elevations are in feet, sea-level datum.

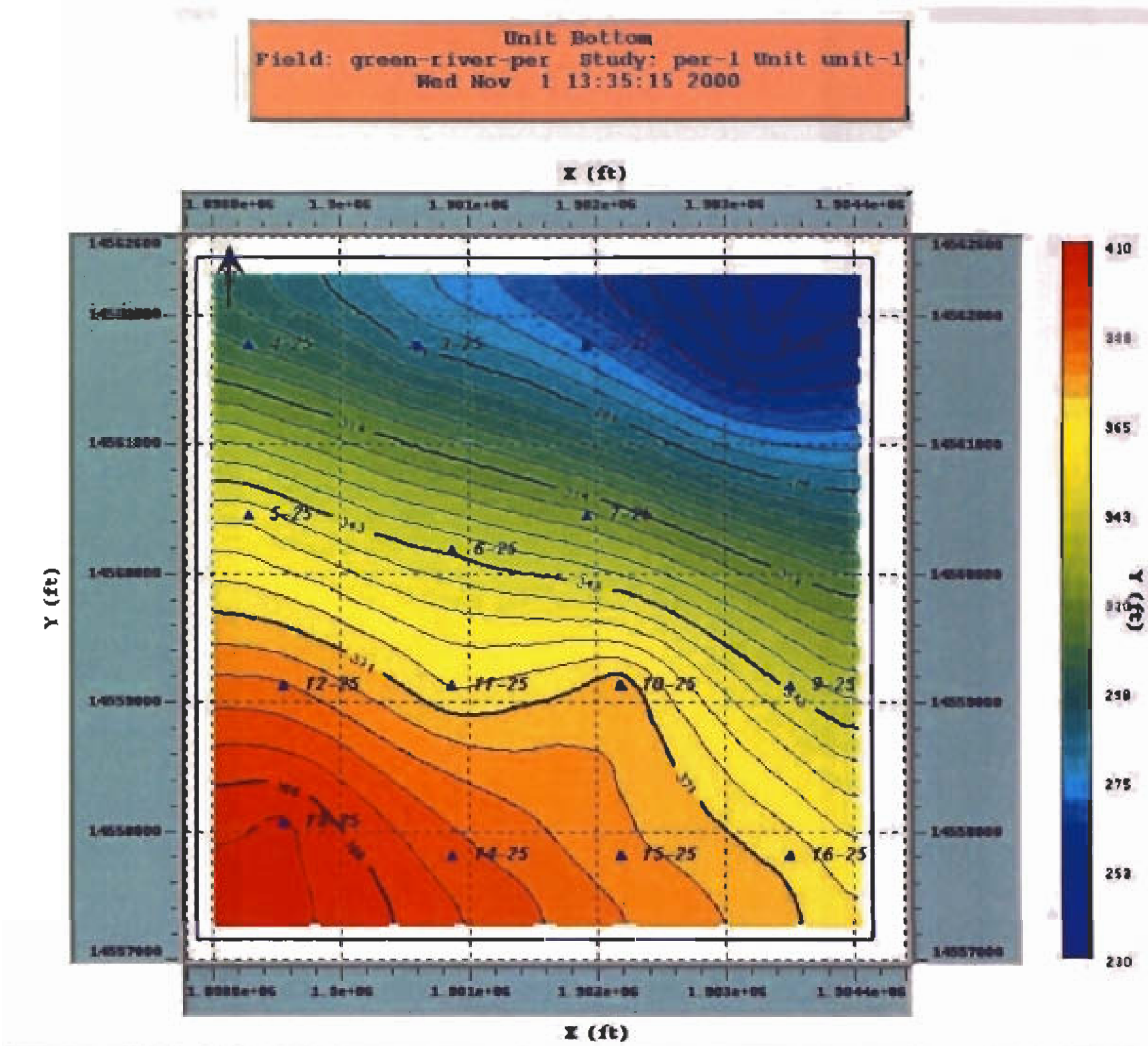


Figure 43. Contour map for the bottom of the D sandstone. Elevations are in feet, sea-level datum.

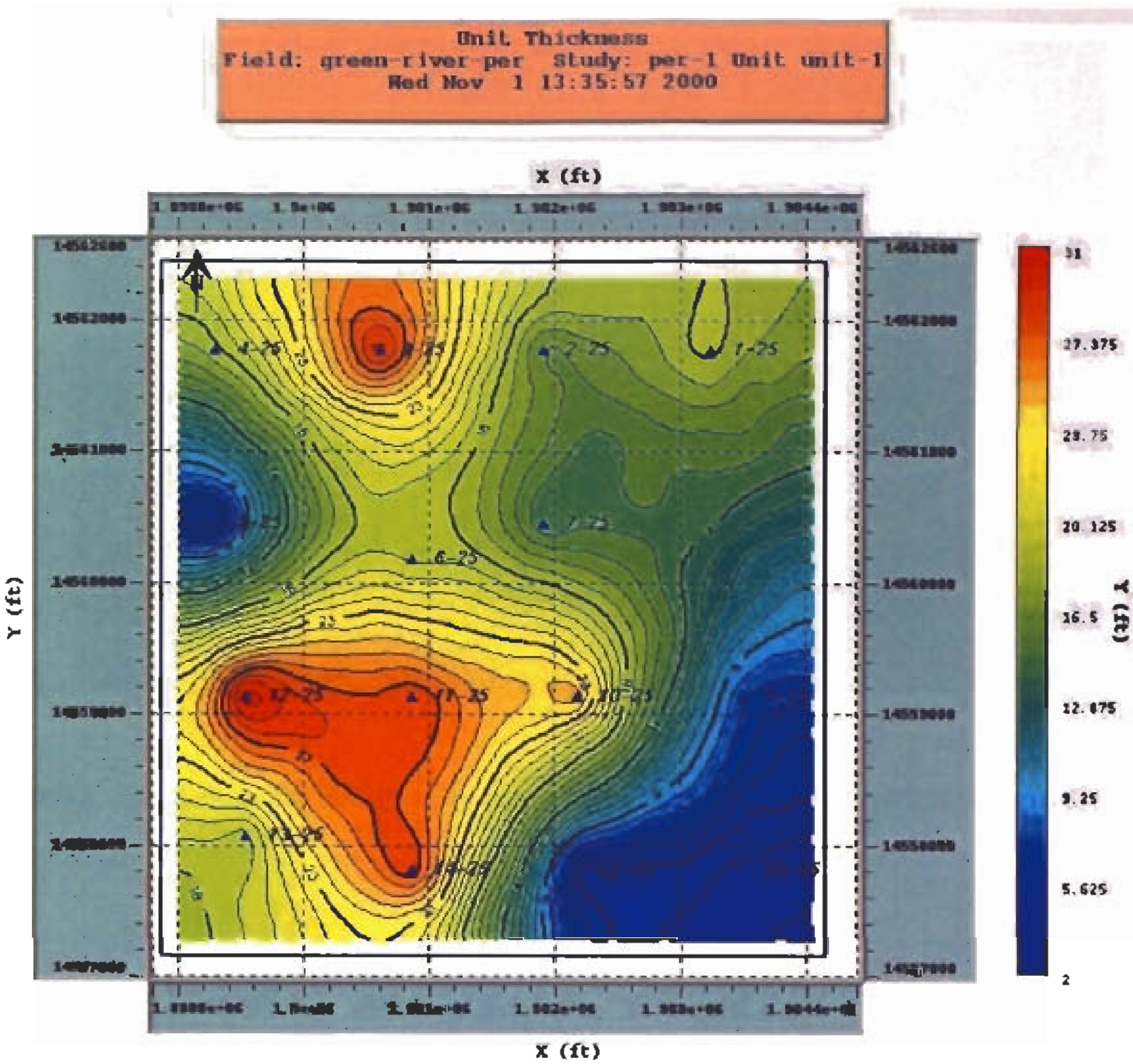


Figure 44. D sandstone thickness map in feet.

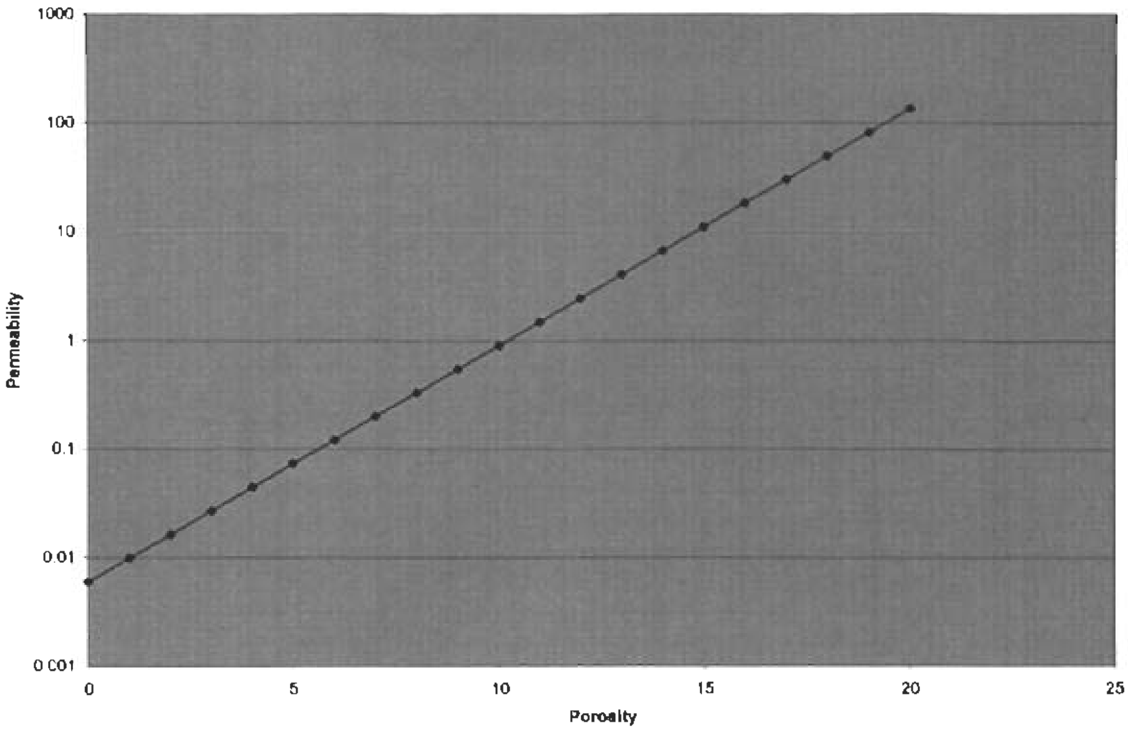


Figure 45. Porosity-permeability cross plot used in creating the petrophysical properties.

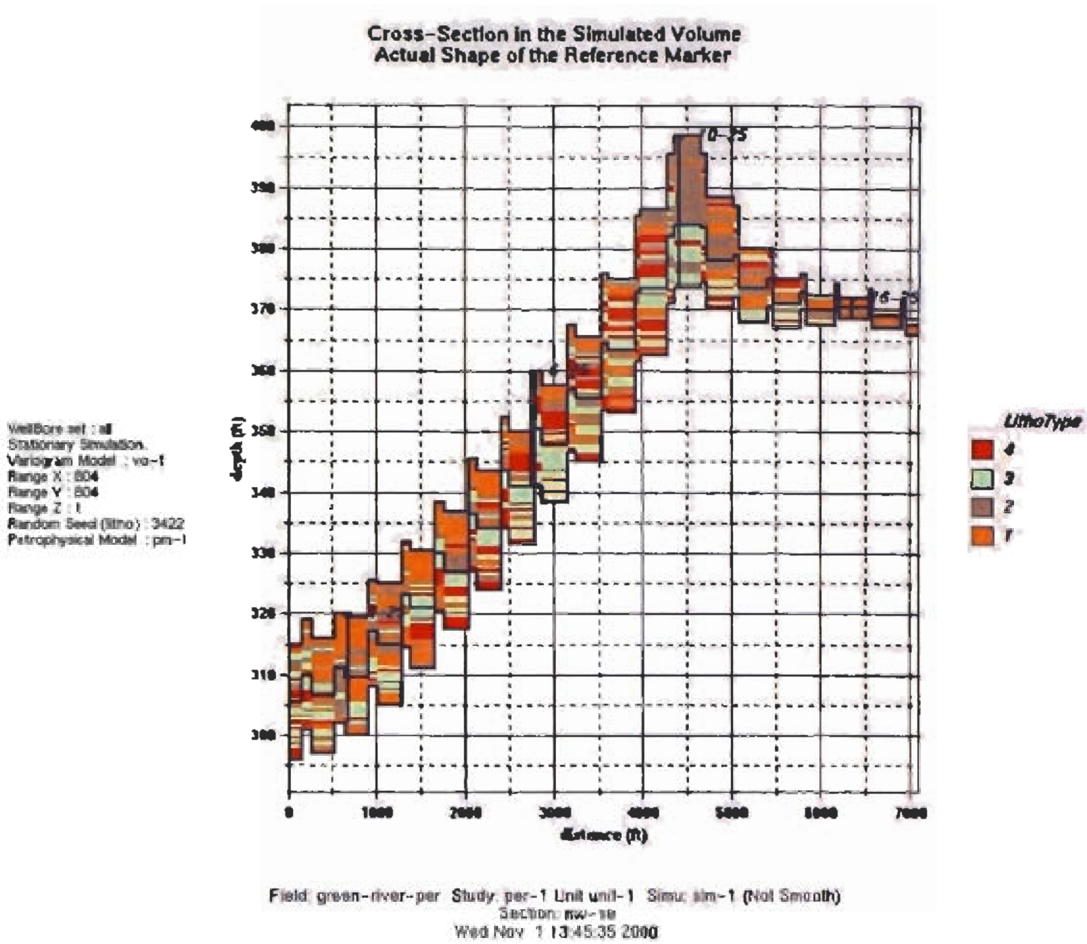


Figure 46. D sandstone lithotype distribution in the cross section shown in figure 40.

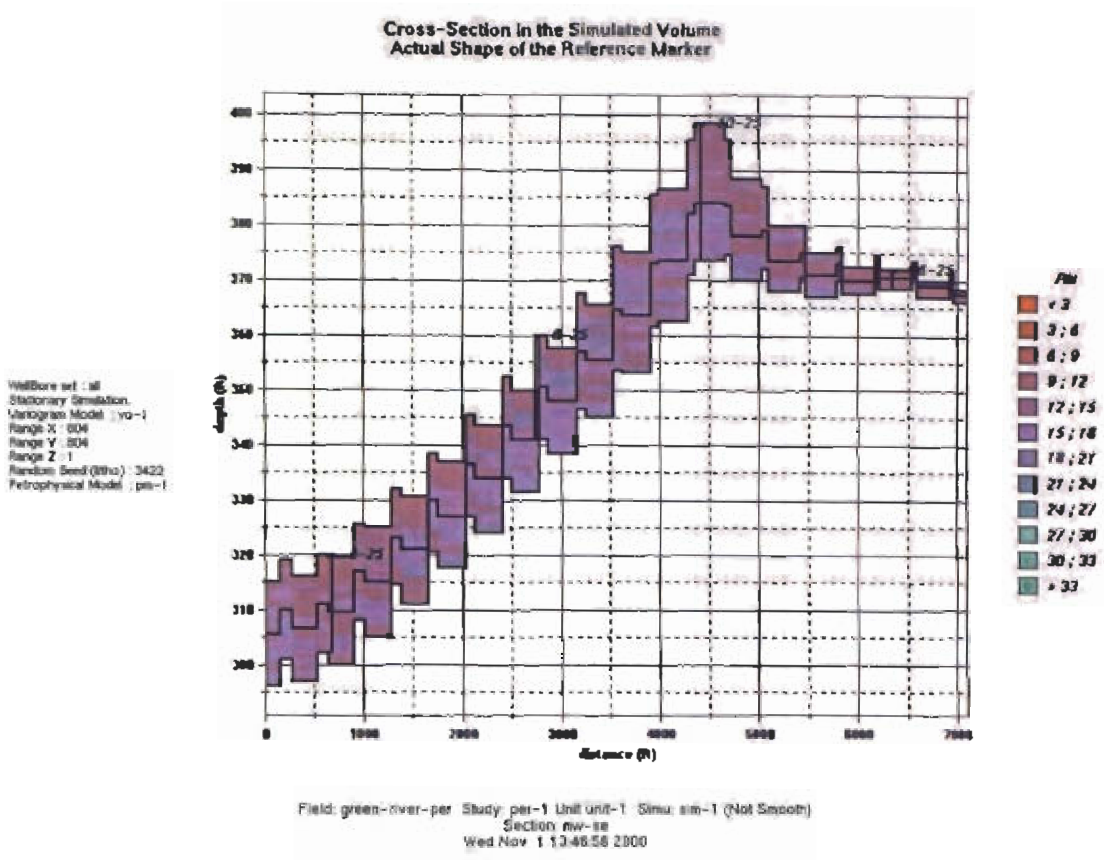


Figure 47. D sandstone porosity distribution in the cross section shown in figure 40.

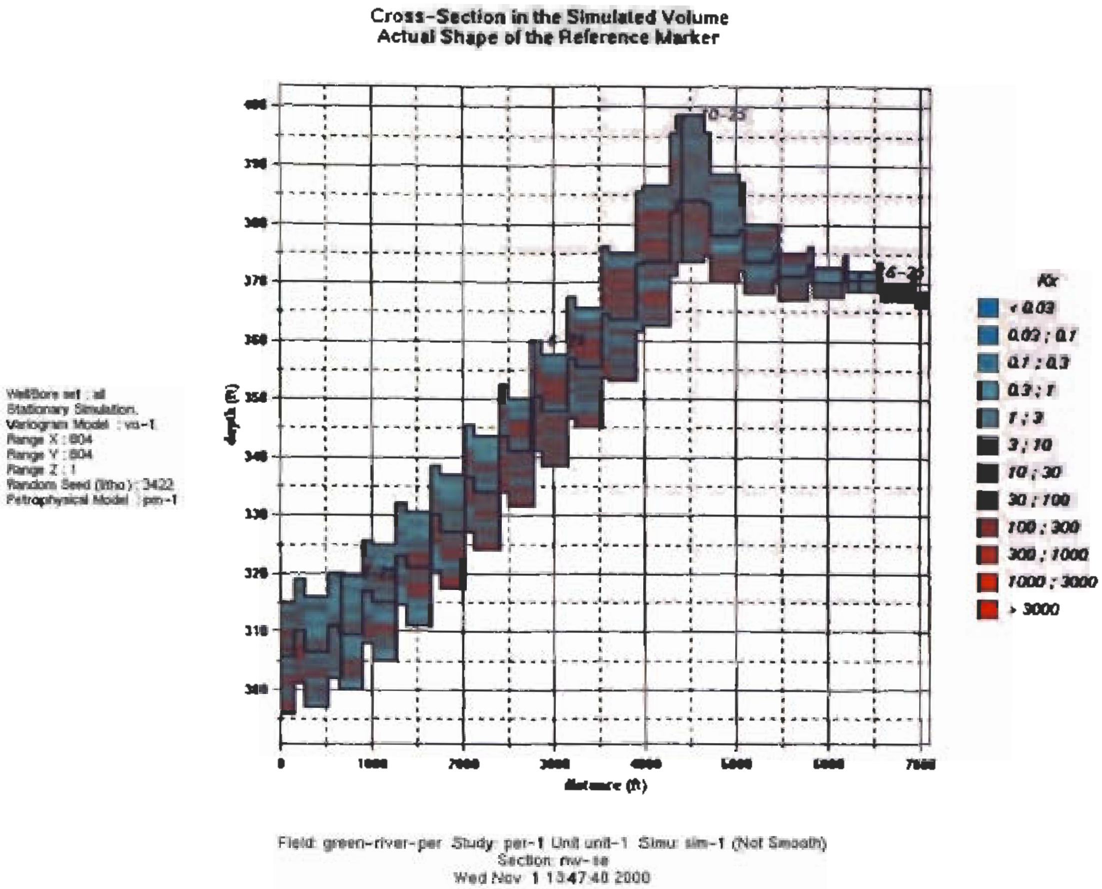


Figure 48. D sandstone permeability distribution in the cross section shown in figure 40.

total of 13 vertical blocks were created. The proportion of porosity as a function of elevation is shown in figure 49. This diagram is used to select locations of upscaled layers, which were selected at regular intervals. A reservoir model that was suitable for simulation was built using the upscaled information. The reservoir grid (plan view) is shown in figure 50.

The upscaled cross sections for section 25 (figure 40) are presented in figures 51 (porosity), figure 52 (permeability) and figure 53 (water saturation). The basic quality of petrophysical property distribution is preserved in the upscaling process. The upscaled models were later modified to accommodate the incorporation of hydraulic fractures.

The same methodology was used in generating petrophysical models for C sandstone. The thicknesses, porosities, permeabilities, and water saturations for the C sandstone are shown in figures 54-57. The thicknesses for the C sandstone are generally much lower than for D sandstone. The porosities, permeabilities and water saturations for the C sandstone and D sandstone, are comparable.

The conventional well-log data was effectively used to create detailed reservoir images based on geostatistics. The geostatistical models had be appropriately upscaled for use in reservoir simulation. The reservoir model was used to simulate production in section 25 and is discussed in the reservoir simulation chapter.

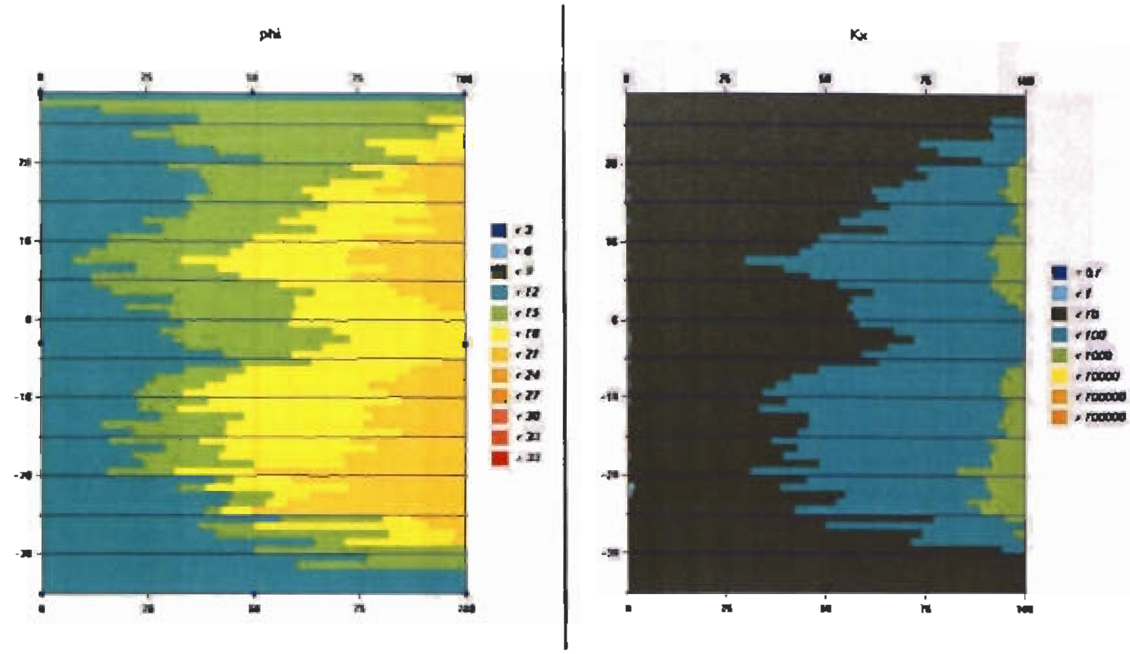


Figure 49. D sandstone porosity and permeability proportion curves and locations of upscaled layer boundaries.

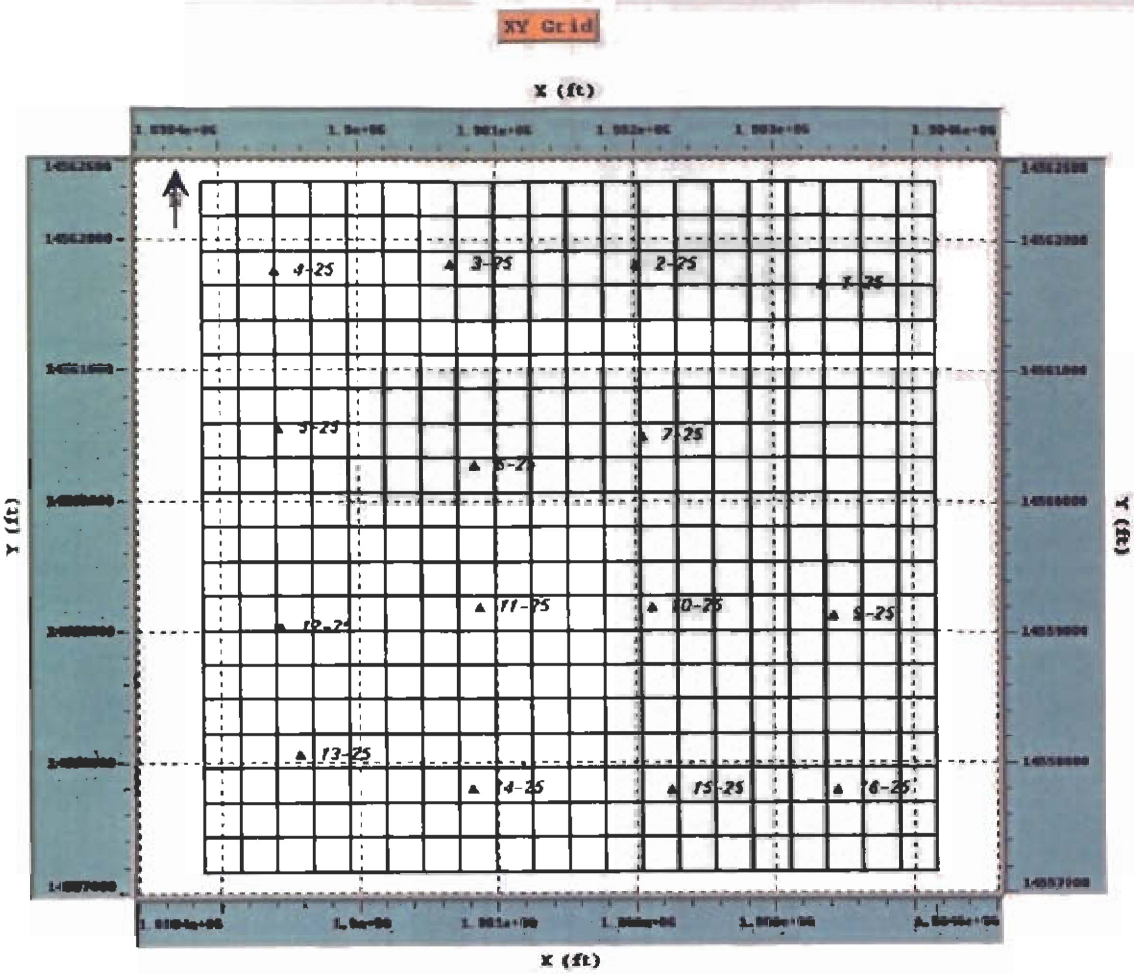


Figure 50. The plan view of the upscaled reservoir grid.

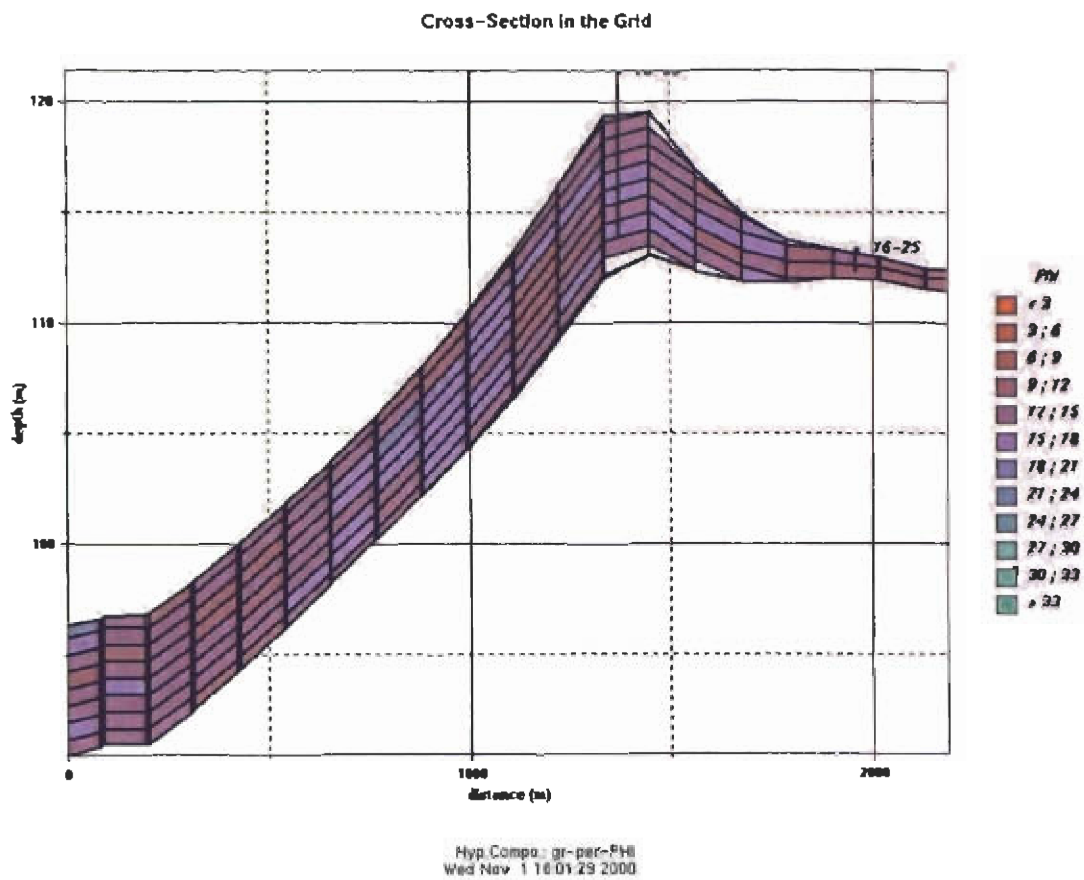


Figure 51. D sandstone porosity distribution in the cross section shown in figure 40 for the upscaled reservoir.

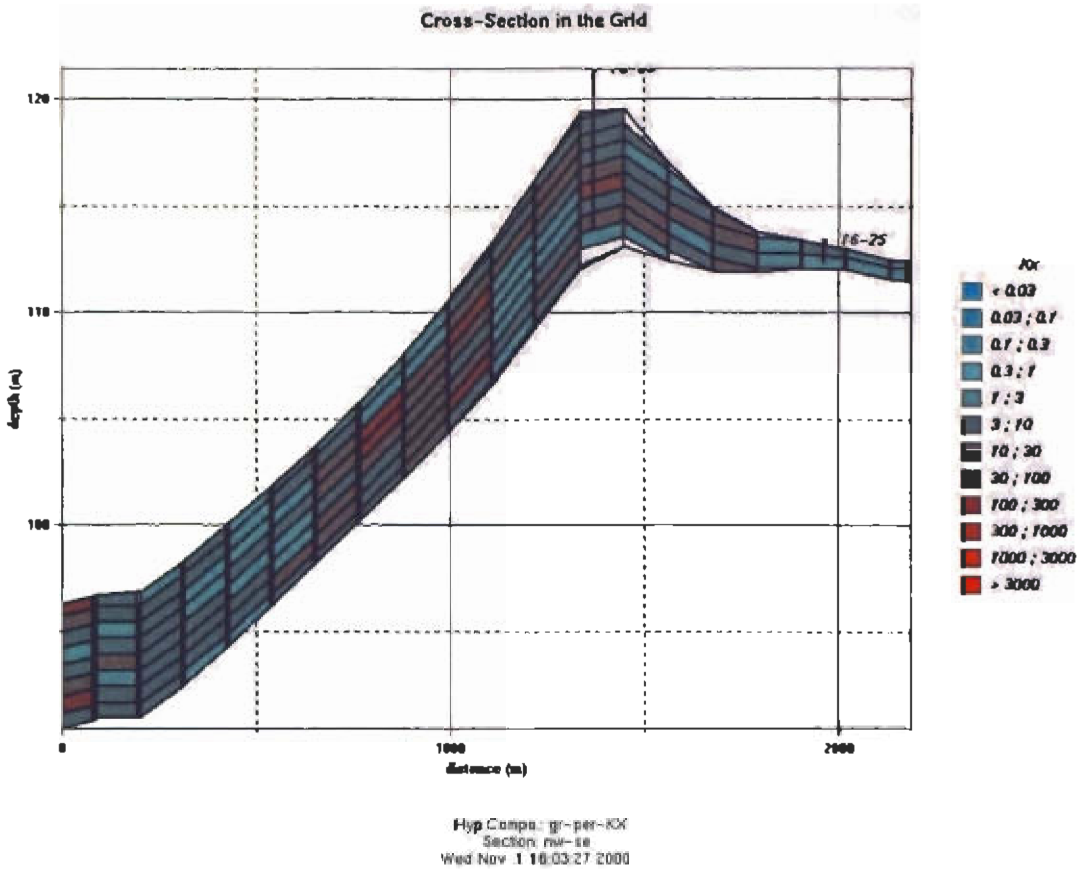


Figure 52. D sandstone permeability distribution in the upscaled reservoir for the cross section shown in figure 40.

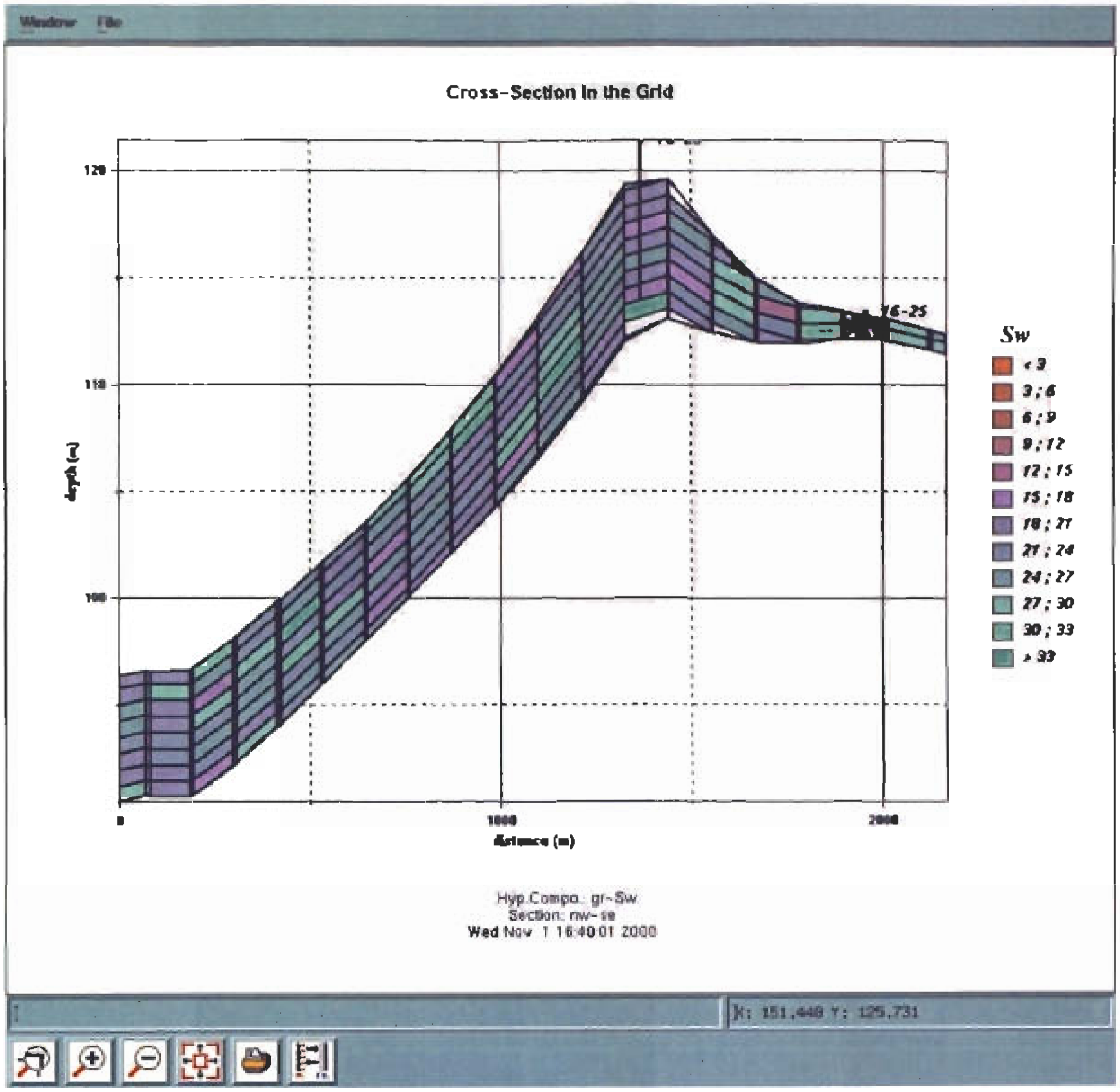


Figure 53. D sandstone water saturation distribution in the upscaled reservoir for the cross section shown in figure 40.

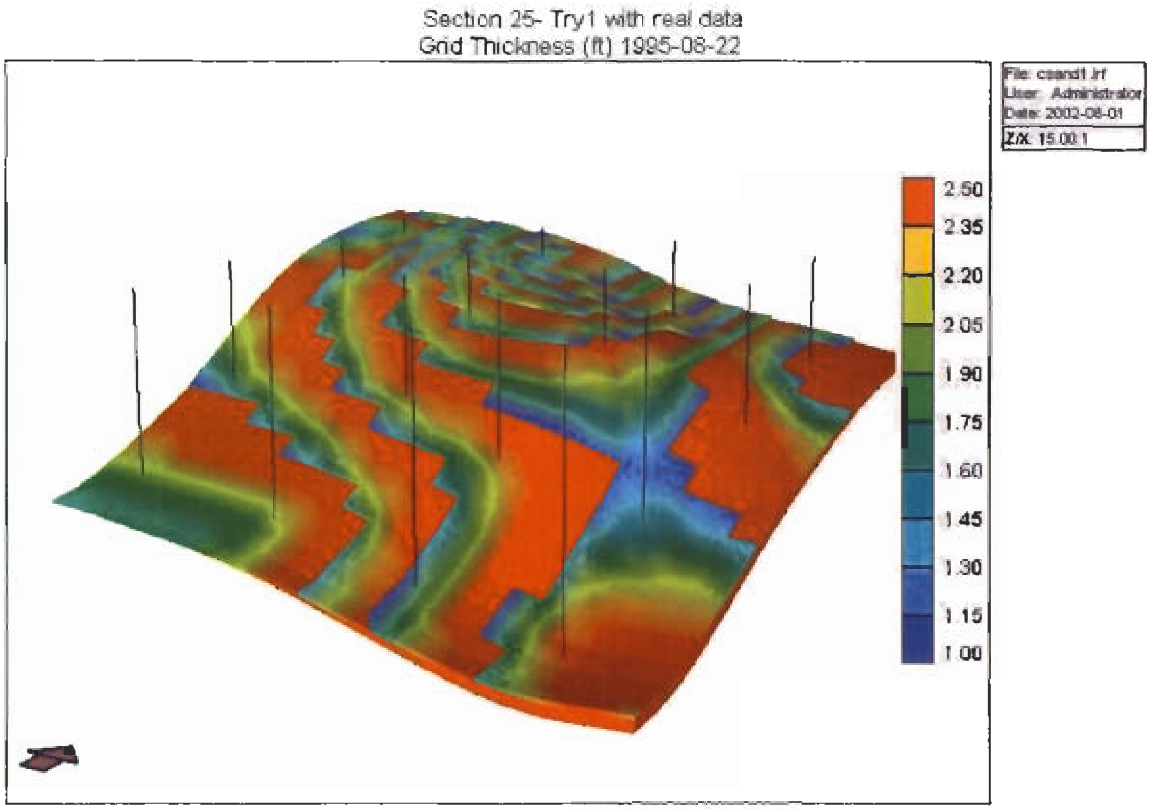


Figure 54. The C sandstone thickness map in feet.

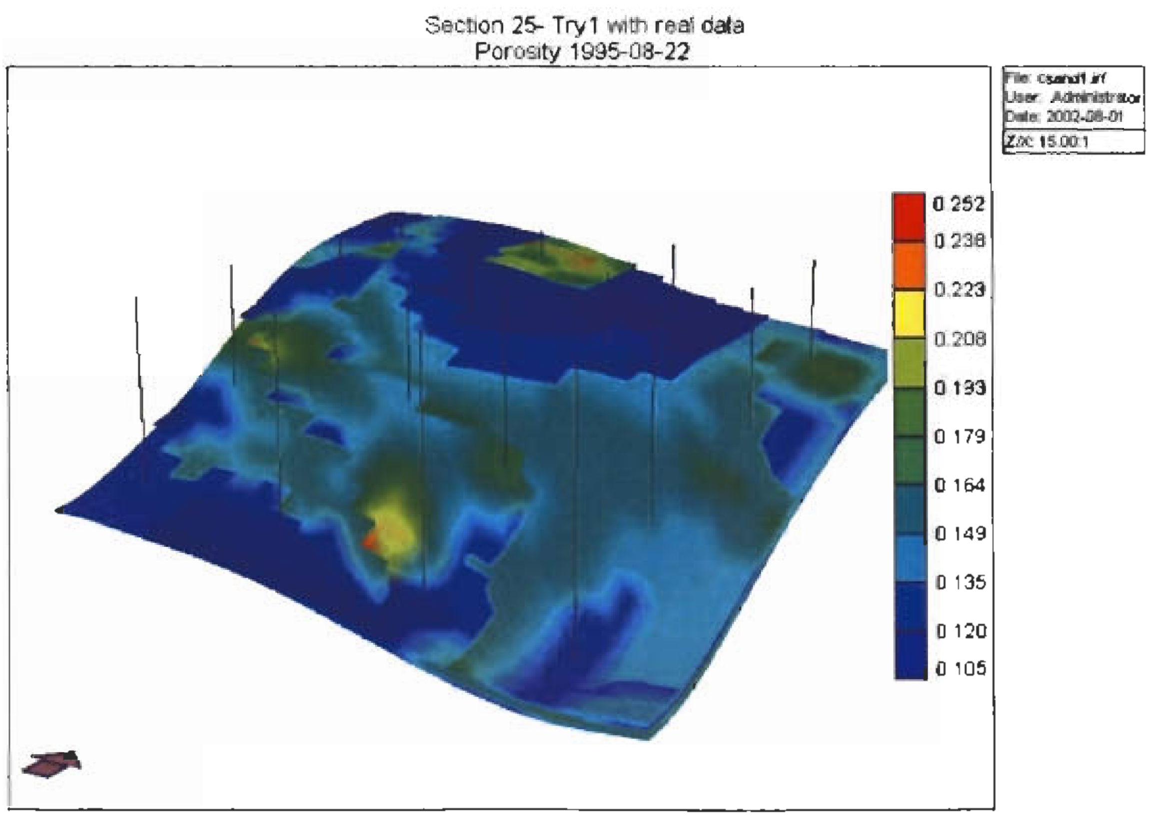


Figure 55. The C sandstone porosity map, dimensionless.

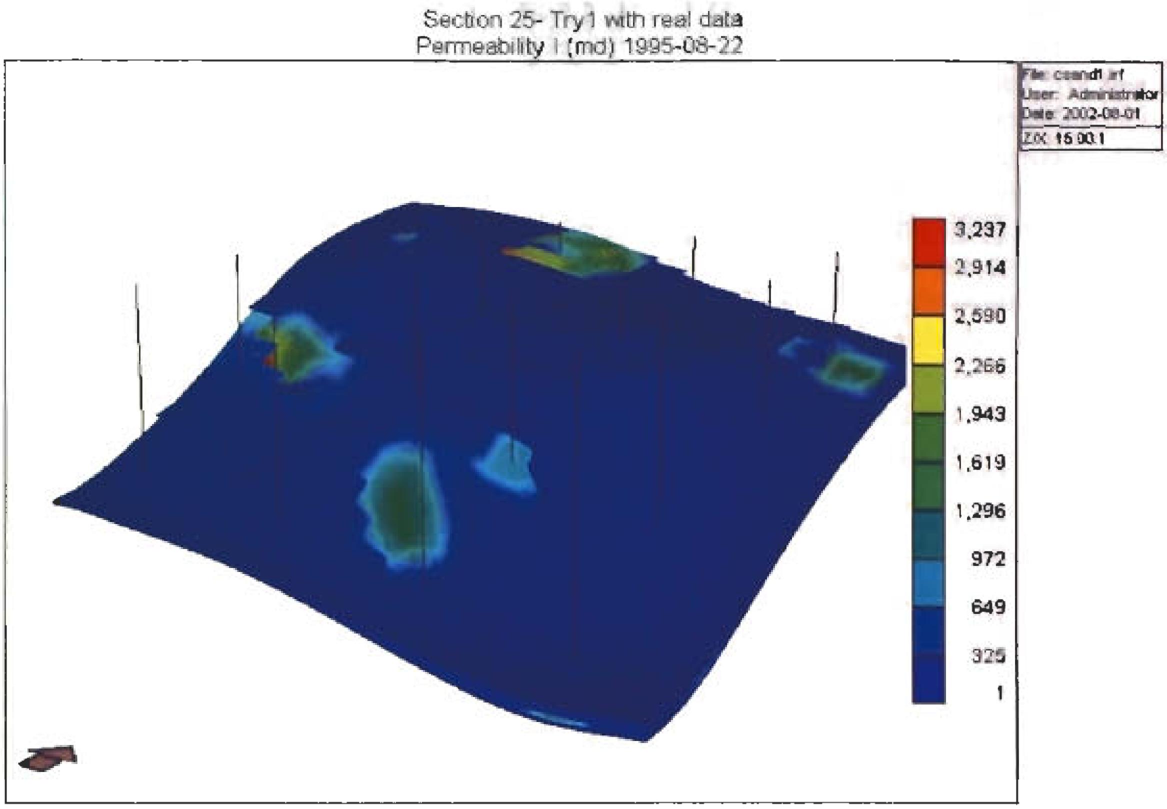


Figure 56. The C sandstone permeability values in millidarcies.

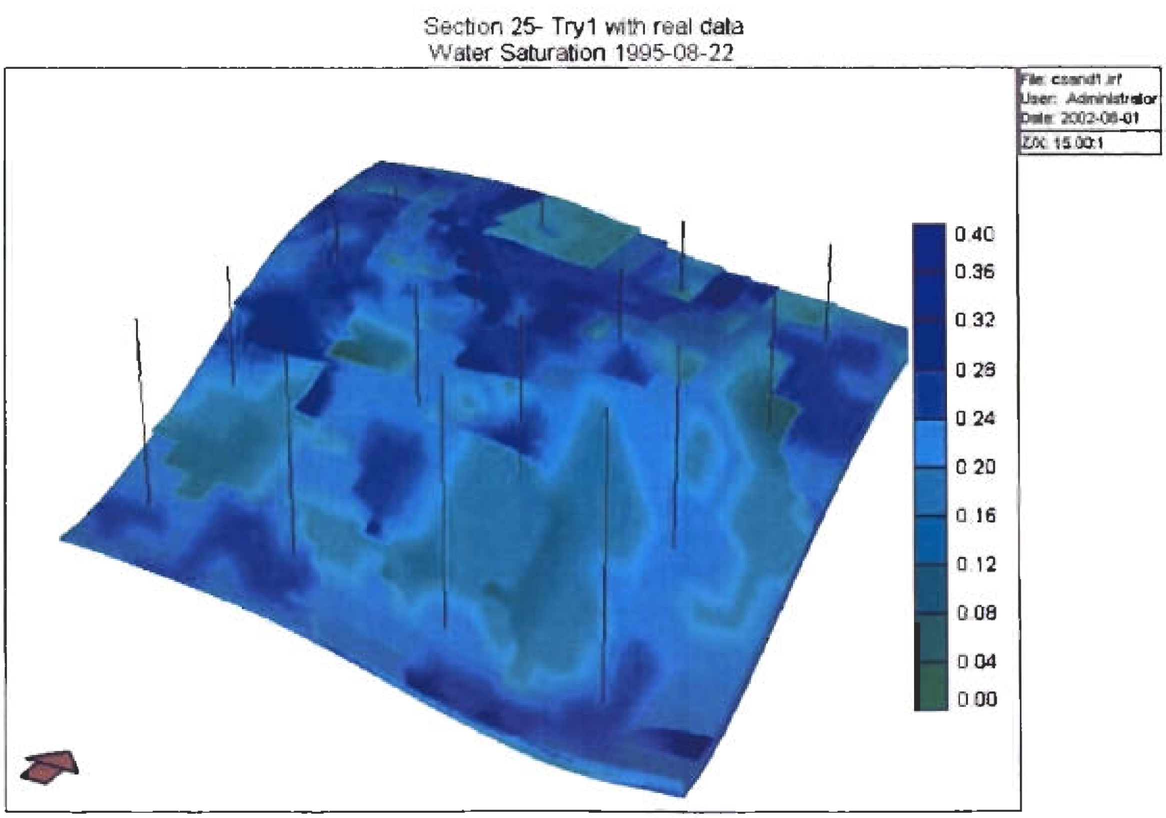


Figure 57. C sandstone water saturations, dimensionless.

NUMERICAL SIMULATION MODELS OF THE UPPER DOUGLAS CREEK, CASTLE PEAK, AND UTELAND BUTTE RESERVOIRS

Numerical simulation models were constructed for the Monument Butte Northeast unit (upper Douglas Creek reservoir), Brundage Canyon field (Castle Peak reservoir) and, Uteland Butte field (Uteland Butte reservoir). The Monument Butte Northeast is a secondary-recovery water-flood unit but the Brundage Canyon and Uteland Butte fields are in primary production. Porosity, permeability, and oil saturations were determined from geophysical well logs and core data. Geostatistical models of the porosity, permeability, and oil saturation for each of the fields were upscaled to obtain a reasonable number of grid blocks for reservoir simulation. All simulations were conducted using the Implicit-Explicit Black Oil Simulator® (IMEX), developed by the Computer Modeling Group Limited®.

Monument Butte Northeast Unit

The Monument Butte Northeast (MBNE) unit consists of 16 wells, eight injectors, and eight producers in section 25 (T. 8 S., R. 16 E., SLBL) (figure 21). The MBNE unit includes parts of the neighboring sections 24 and 26, but only section 25 was modeled. The MBNE unit produces from all of the reservoirs in the lower and middle members of the Green River Formation but the majority of the oil is produced from the upper Douglas Creek reservoir in the middle member. Section 25 has about 10 million stock-tank barrels (MMSTB) (1.6 MMm^3) of original oil in place (OOIP) in two major sandstone beds and several minor ones. The major oil-producing sandstone beds are the D (MGR 7) and the C (MGR 6) sandstone beds, of which the D sandstone has nearly 75 percent of the oil in place and was studied in the most detail.

A geological model, structure, and sandstone thickness was developed using geophysical well logs. The thickness of the sandstone beds were assigned based on the mapped thickness and the perforated interval data for each well. The composition of the oil from specific wells was analyzed by simulated distillation on a capillary gas chromatographic column. The reservoir fluid properties such as the viscosities and gravities, were measured in the laboratory. The bubble points and oil formation factors at different gas-to-oil ratios were also measured. The reservoir was modeled using a variable thickness, variable depth option with several layers present. The model resulted in an excellent match between the simulated production and actual field production.

Simulation Results

A Cartesian coordinate system was used to describe the Monument Butte unit with a multilayer, 20 by 20 grid to represent the reservoir. The total dimension of the field was 5,200 feet (1,584.9 m) by 5,200 feet (1,584.9 m). The reservoir was modeled using a variable thickness, variable depth option with 13 layers present. Porosity, permeability and water saturation computed in the geological model were used in constructing the model for flow simulations. Since there was no free gas present in the reservoir initially, the oil saturations are just the difference between total saturation 1.0 and the water saturation. With the aforesaid reservoir description, the D sandstone was determined to contain 7.52 MMSTB (1.20 MMm^3) of OOIP. Reservoir fluid properties were the same as those computed and used in the previous work. The properties are summarized in table 4. The initial pressure in the reservoir was estimated to be between 2,200 and 2,300 pounds per square inch (psi) (15,000 to 16,000 kPa).

Table 4. Thermodynamic properties of Monument Butte fluids.

p	rs	bo	eg	μ_o	μ_g
14.7	0	1.0018	4.73	14.1	0.0055
500	115.128	1.0625	168.8	12.248	0.0057
1000	230.256	1.125	350.803	7.245	0.0061
1200	276.307	1.15	426.603	6.21	0.0062
1500	345.383	1.1875	541.8	5.348	0.0065
2000	450.511	1.25	850.991	4.14	0.0071
2500	575.639	1.3125	950	3.45	0.0077
3000	690.767	1.375	1140	3.105	0.0842
4000	921.022	1.5	1500	2.415	0.0907
6000	1370	1.75	2200	1.5	0.092
9000	2025	2.1	3200	1	0.093

p = pressure in psi
rs = gas oil ratio in SCF/STB
bo = oil formation volume factor, reservoir barrel/stock tank barrel
eg = gas formation volume factor SCF/reservoir barrel
μ_o = oil viscosity in cp
μ_g = gas viscosity in cp

The bubble–point pressure of the reservoir crude at the initial GOR of about 450 to 500 standard cubic feet/stock-tank barrel (SCF/STB) (80 to 90 m^3/m^3) was around 2,200 psi (15,000 kPa), close to the reservoir pressure. As the first well was placed on production, the reservoir pressure began to drop, resulting in the formation of free gas in the reservoir. Gas being less viscous than oil, was preferentially produced and the production GOR increased. The average pressure had dropped to 2,140 psi (14,800 kPa). As water was injected into the reservoir, the reservoir was pressurized and the production GOR declined to the current value of 488 SCF/STB (86.9 m^3/m^3). The reservoir pressure was almost equal to the bubble–point pressure in most parts of the reservoir and well above the bubble point in the areas adjoining the injectors.

All the producer wells were operated at a bottom hole pressure of 650 psi (4,480 kPa). Since injecting as much water into the reservoir as possible is important for a successful water flood, water injection was started early in the MBNE unit. The important deviation from conventional water floods is the injection strategy. Some of the largest producers were converted to injectors. To ensure a five–spot pattern, alternate producers were converted to injectors.

The field cumulative oil production and that predicted by the simulator are shown in figure 58. The D sandstone contains nearly 76 percent of the OOIP and the remaining is in the C sandstone. To account for the production from D sandstone, simulations with different water injection rates were performed. Simulation runs with water injection rates of 60 percent and 40 percent of the original rates in each of the wells were performed. The cumulative oil production, as predicted by the simulations with 60 percent water injection (figure 59) rate did not match the field oil production well.

The run with 40 percent water injection rate (figure 60) matched approximately 82.8 percent of the total production from the field and the cumulative oil production profile matched the field results closely. This is approximately the production contribution expected from the D sandstone. The production match from individual wells was not matched well, though a satisfactory matched was obtained for some of the wells.

Figures 61 and 62 show the cumulative water and gas production profiles along with the corresponding field results. A pronounced variation between the field and simulation profiles was observed.

Figure 63 shows the water injection profile along with the field values. An excellent match was obtained between the simulation and the field results. However, the injection rate of 40 percent was lower than the amount that would have been injected into the D sandstone.

Inclusion of Hydraulic Fractures in the Reservoir Model

Introduction: All the wells in the field and most of the greater Monument Butte area are hydraulically fractured but the initial simulations did not include the effects of hydraulic fractures. Hydraulic proppant fracturing and gravel packing are common stimulation and stabilization treatments during completion, testing, and exploration of hydrocarbon reservoirs in the oil and gas exploration and production industry. Hydraulic fracturing is a method for increasing well productivity by fracturing the producing formation, and thus, increasing well drainage area. Thus, it can be defined as the process of creating a fracture or fracture system in a porous medium by injecting a fluid under pressure through a well bore in order to overcome the native stress and to cause material failure of the porous medium. Briefly, it is the creation and preservation of the fracture in a reservoir rock. Fluid is pumped down the well and injected into the formation, generating the energy needed to fracture the rock.

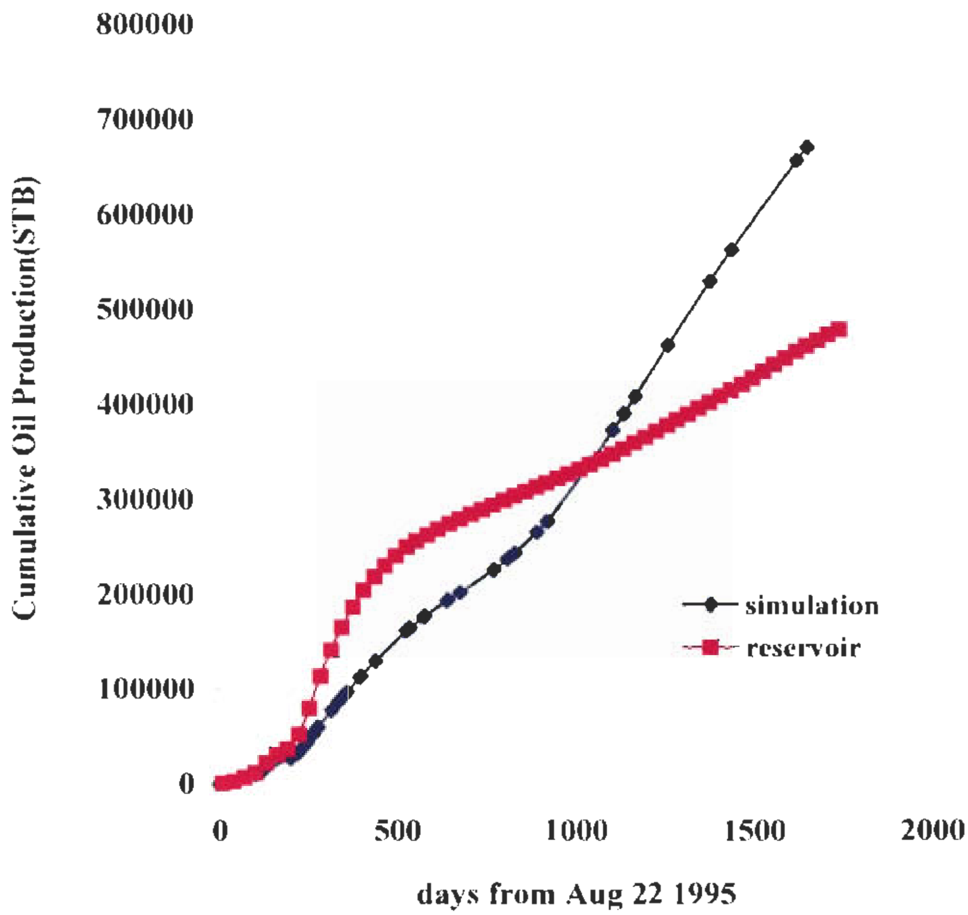


Figure 58. Comparison of cumulative oil production in the MBNE unit with total water injection into the D sandstone.

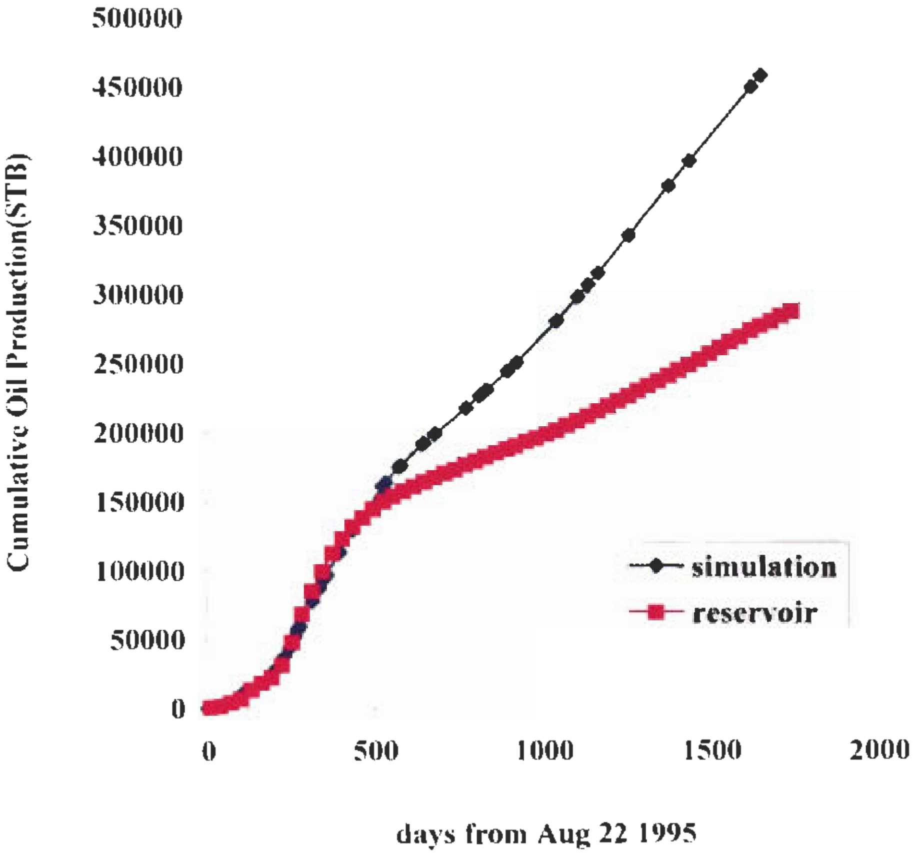


Figure 59. Comparison of cumulative oil production in the MBNE unit with 60 percent water injection into the D sandstone.

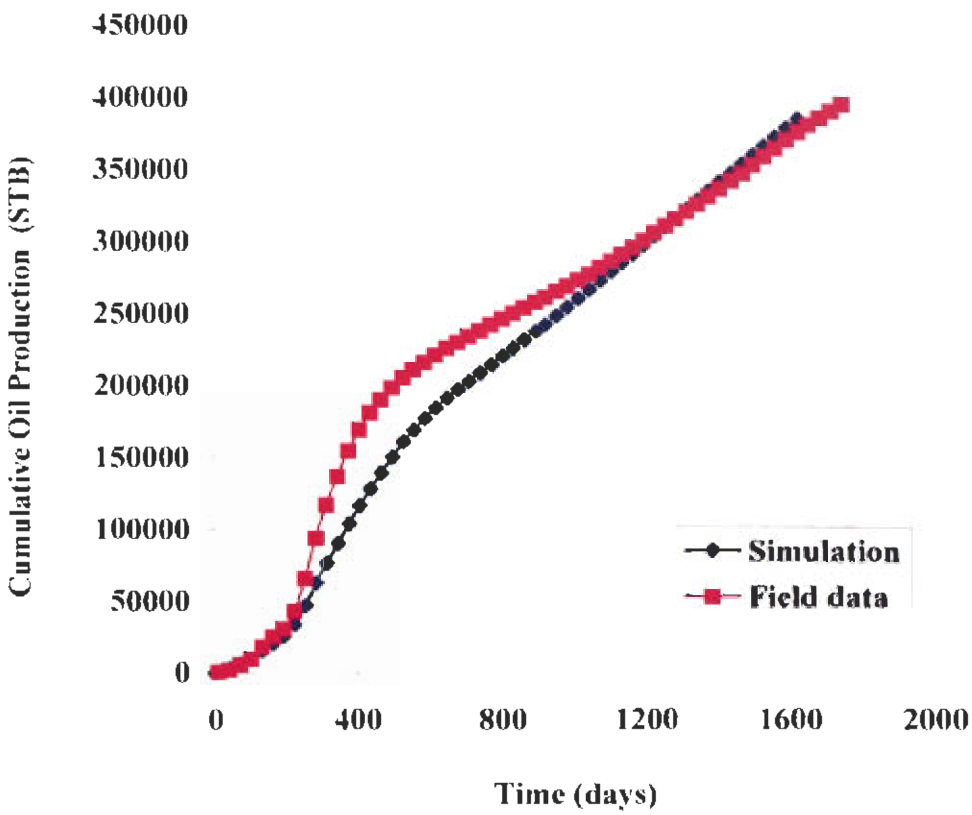


Figure 60. Comparison of cumulative oil production in the MBNE unit with 40 percent water injection into the D sandstone.

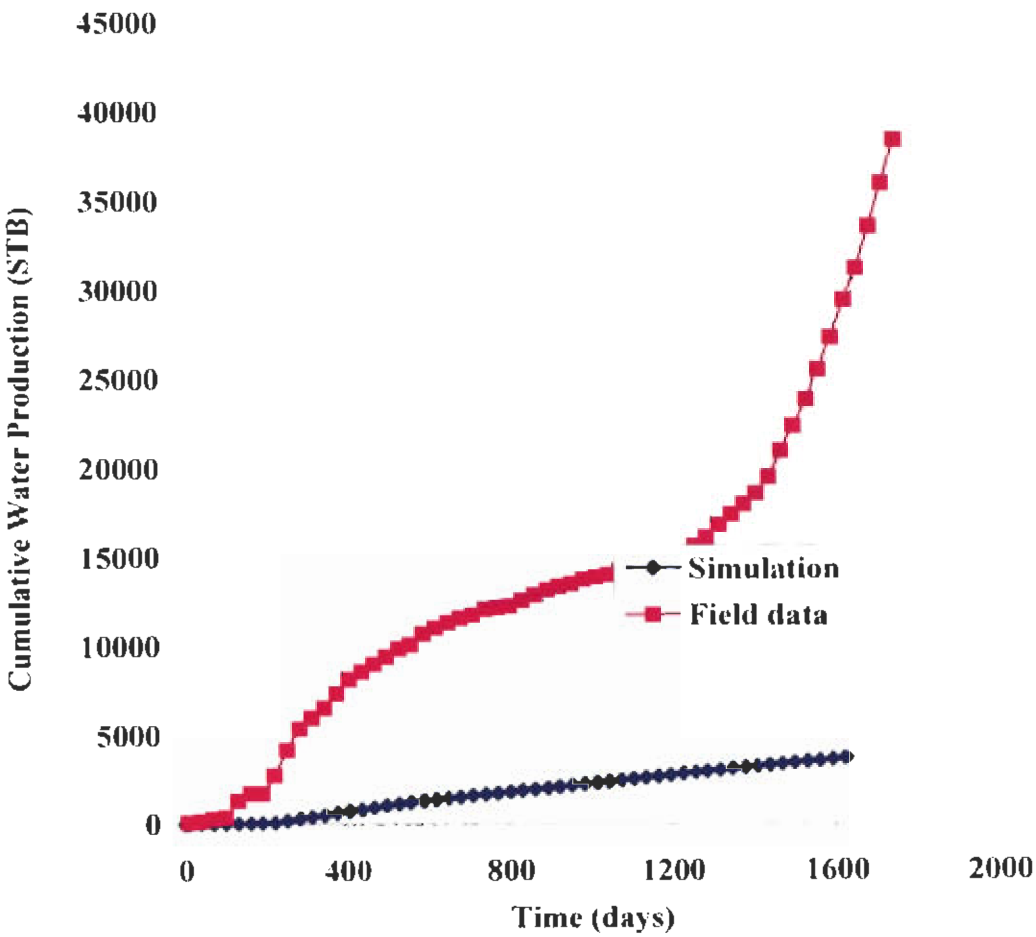


Figure 61. Comparison of cumulative water production in the MBNE unit with 40 percent water injection into the D sandstone.

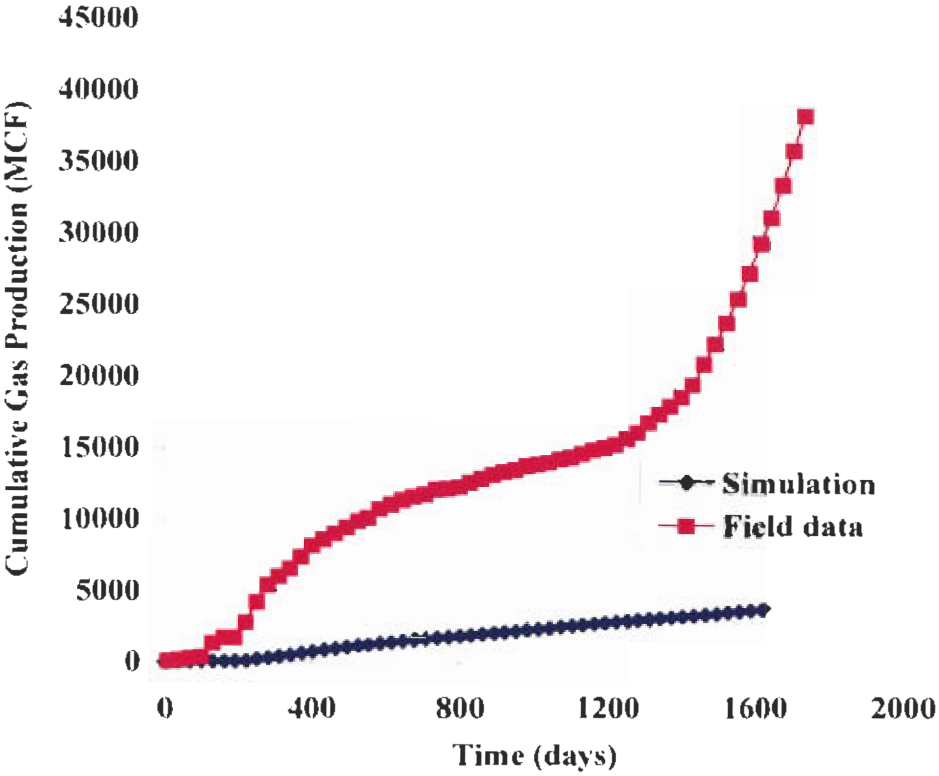


Figure 62. Comparison of cumulative gas production in the MBNE unit with 40 percent water injection into the D sandstone.

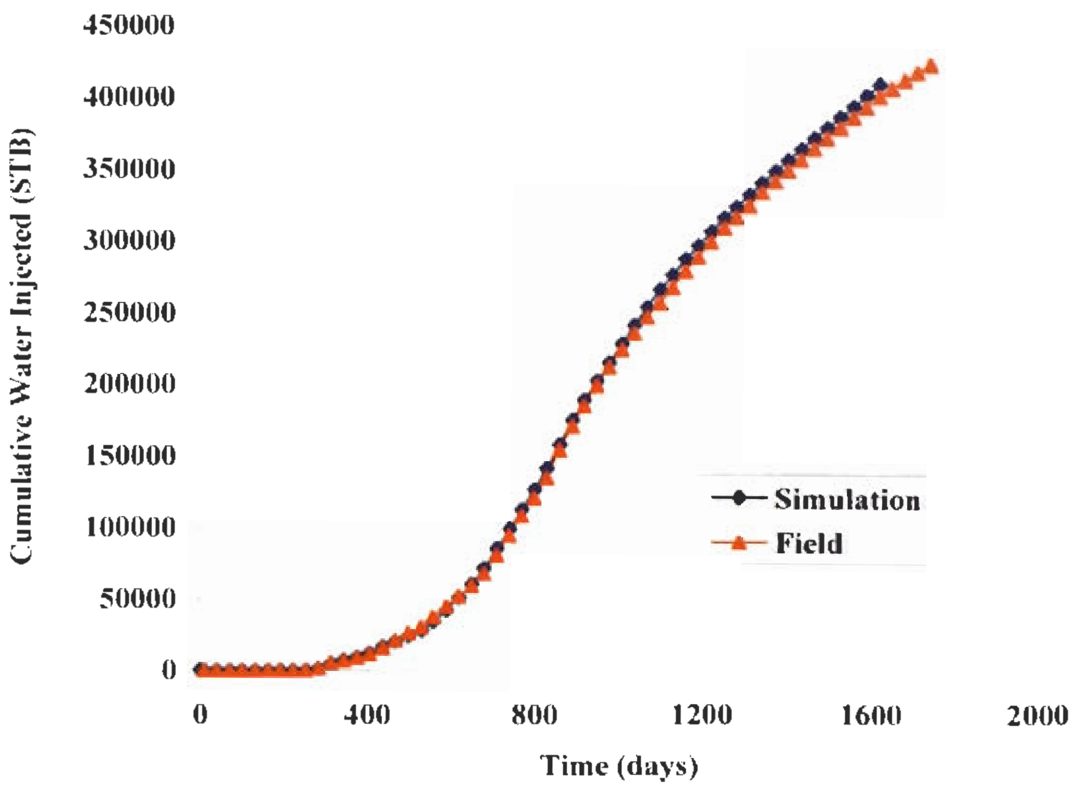


Figure 63. Comparison of cumulative water production in the MBNE with 40 percent water injection into the D sandstone.

The purpose of natural sand or synthetic proppants of different type and grain size in hydraulic fracturing is to support the crack in order to keep it open against the closure stress acting in pay zone depth and to maintain a highly conductive drainage path through the tight reservoir rock matrix for oil and gas flowing to the well bore, and in gravel packing to plug the perforation tunnels and to build a gravel mantle along the well bore wall in order to filter the hydrocarbons flowing into the well bore and prevent pay zone sand from moving. Hydraulic fracturing and gravel packing lead to enhanced oil and gas recovery from low permeability and weakly cemented to loose friable sandstones.

Incorporating Hydraulic Fractures: All wells in this field and in most of the greater Monument Butte belt are hydraulically fractured. The objective of this study was to examine the impact of the presence of hydraulic fractures in the reservoir. The hydraulic fractures were inserted in blocks containing the wells. It is known (from stimulation simulations and through rock-mechanics considerations) that the hydraulic fractures are vertical, circular shaped, and extend about 200 feet (60 m) beyond the well bore on either side and span the entire thickness of the reservoir.

The following procedure was used to incorporate hydraulic fractures in the reservoir model. The grid blocks containing the wells were refined by local grid refinement. The hydraulic fracture was approximately 158.5 feet (48.3 m) in length and its height spanned the perforated sand thickness. The fracture block was about 0.45 feet (0.137 m) in width. This was the finest refinement that the simulator would allow. The width of the hydraulic fracture cannot be set to a finite value and is based upon the local grid refinement of a grid block approximately 264 feet (80.5 m) in length and width. The block was refined into five blocks each in the x and y direction. The second, third, and the fourth blocks in the middle row in the j direction were further refined to five blocks in the i direction. The middle row of the resulting blocks was further refined and this procedure was carried out until the smallest refinement was slightly greater than the diameter of the well. With this refinement, there were a total of 12,900 grid blocks. A fracture spanning nearly 200 feet (60 m) on either side of the well bore would have represented a more realistic picture, but the total number of resulting blocks would exceed the limits of the simulator.

The smallest refinement thus obtained was nearly 0.45 feet (0.137 m) in width. All layers in which the wells were completed were refined to the dimensions stated above. We represented the fracture with the smallest refined block containing the well and one refined block on either side of the block containing the well. A high permeability zone represented the fracture and a permeability of 1,000 md was assigned to each of the refined blocks representing the fracture. It should be noted that the matrix permeability varied over a range of about 0.1 to 150 md. The porosity was the same as the original refined block. All other properties were identical to the original simulation.

Simulation Results

Comparison at the End of Primary Production: The initial pressure of 2,300 psi (15,900 kPa) dropped to around 2,100 psi (14,500 kPa) at the end of primary production. The presence of hydraulic fractures increased production in comparison to the model without fractures. The gas production rose significantly from 33.50 MMSCF (0.95 MMm^3) to 770.78 MMSCF (21.83 MMm^3). The average oil production rate increased to 533.46 STB/day (84.8 m^3/day) from 273.47 STB/day (43.5 m^3/day). The cumulative oil production increased to 77.09 MSTB (12,257 m^3) from 59.20 MSTB (9,413 m^3) in the model without the fractures. The gas saturation had increased to nearly 2 percent. The oil production rate increased to 641.88 STB/day from the previous value of 491.08 STB/day. The total water production had increased nearly tenfold from 0.266 MSTB to 2.99 MSTB, with the production rate increasing tenfold from 3.66 STB/day to 32.158 STB/day. Table 5 summarizes the primary production from the field and simulation models with and without fractures. In comparison to the field values, oil and gas production values were less than the corresponding field numbers. The water production matched quite well.

Table 5. Comparison of cumulative production at the end of primary.

Fluids	Field	Simulation	
		With fractures	Without fractures
Oil (MSTB)	99.97	77.093	59.209
Water(MSTB)	2.2926	2.9928	0.2668
Gas(MMSCF)	148.96	70.782	33.5

The difference in values of the oil and gas production may be due to relative permeability data used in the model. The values used are the ones experimentally determined in the laboratory and used in previous work on the Monument Butte field, as stated earlier. Different sections of the reservoir may have different relative permeabilities, which have not been accounted for in the model. Another plausible reason is the size of the hydraulic fractures. Hydraulic fractures usually extend to around 200 feet (60 m) on either side of the well bore, but the ones represented in the model is only 158.5 feet (48.3 m) in length. This was due to the limitation on the total number of blocks allowed by the simulator. To incorporate the required size, nearly 25,000 blocks would be necessary which is far more than that allowed by the simulator. The permeability of the fractures was assigned a value of 500 md. This value depends on the packing material and the packing pattern in the fracture.

Further Comparisons and Analysis: Water injection started on May 24, 1996. As water was injected into the reservoir, the reservoir pressure started to increase. The significant increase in gas production during primary production continued nearly at the same rate until about 600 days of production before more and more gas was driven into the solution, as only half of the injecting wells were opened by then. The production GOR reached a maximum of about 7,000 SCF/STB (1,200 m^3/m^3) before declining to the current value of around 600 SCF/STB (100 m^3/m^3) as the reservoir continued being pressurized. The gas saturation increased to nearly 5 percent before starting to decrease. The reason for this was some of the biggest producers had just been opened and some producers were opened after water injection had started in couple of wells. The gas saturation decreased to the current value of 1.33 percent at the end of simulation period. The average oil saturation at the end of the period decreased to about 70 percent. As expected, the reservoir shows a large variation in oil saturation, ranging from 25 percent in the vicinity of the injectors to 70 percent in regions farther from the injectors.

Figure 64 shows the comparison of the field cumulative oil production and that predicted by the reservoir simulator. When some the producers were switched to injectors, the production profile started to flatten out, but when all the injectors were functional, the water flood rejuvenated oil production. The production from D sandstone matched nearly 88 percent of the total production from the field. Hereafter, all comparisons are made between 88 percent of the field value and that from the simulator. The remaining is attributed to the C sandstone. The cumulative production at the end of the simulation period was 408,690 STB (64,981.7 m^3) and

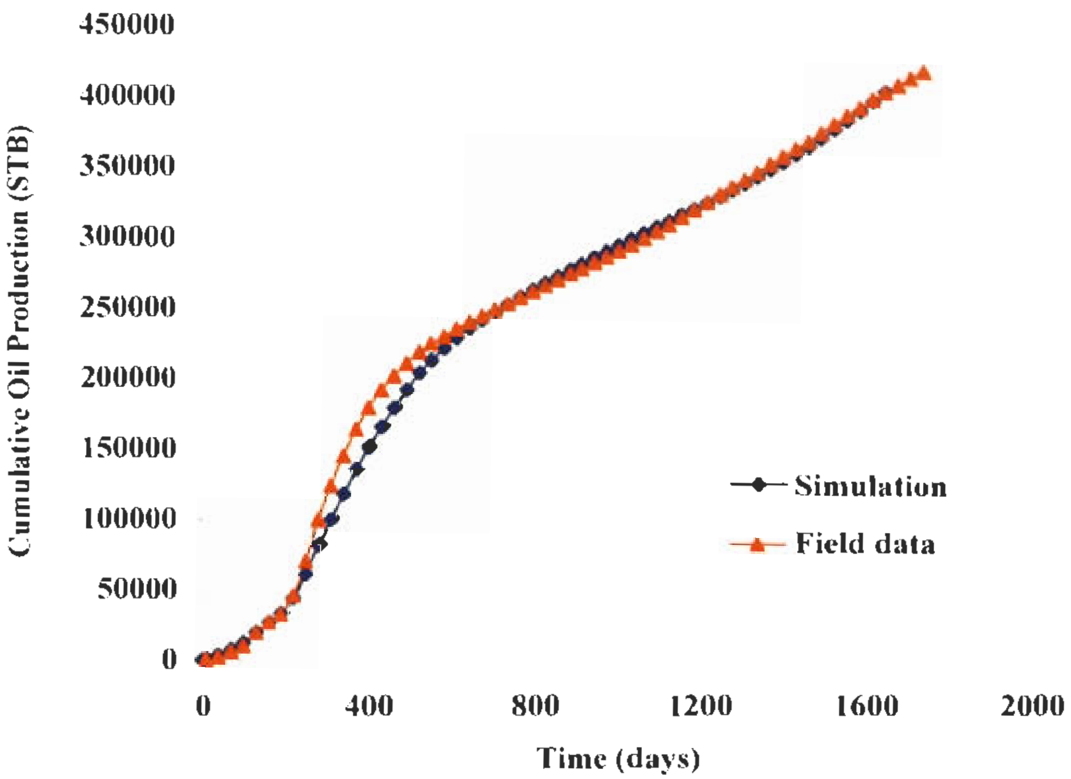


Figure 64. Comparison of actual cumulative oil production with simulated oil production in the MBNE unit.

nearly 7.5 percent of the mobile oil had been recovered. Figure 65 shows the comparison of the field average rate of oil production and that from the simulations. A close match is obtained. The simulator does not do a good job of predicting the quick response to water flood observed in the field without fractures, but the response is closer in the model with hydraulic fractures. Thus, the inclusion of hydraulic fractures in the wells is very important in matching history and cannot be neglected. The simulator matched the actual water injection profile well. Figure 66 shows the water injection for the MBNE field.

The mechanism of water flooding can be clearly understood by examining the instantaneous GOR as a function of time. The GOR is around 450 SCF/STB (80 m^3/m^3) at the beginning of primary production. The reservoir pressure falls below the bubble–point pressure and the instantaneous GOR increases rapidly. As more and more free gas is produced in the reservoir and this gas is preferentially produced, the production GOR continues to increase reaching a value of about 7,000 SCF/STB (1,200 m^3). When all the injectors are functional, the reservoir is slowly pressurized; gas is driven back in to the reservoir and the production GOR declines.

Figure 67 shows the field production GOR and those predicted by the simulations. The simulator lags behind the field response to water flood. It takes more time in the simulation for the GOR's to decline than in the field. This decline continues to the current value of around 600 SCF/STB (100 m^3) as stated earlier. Matching instantaneous GOR by reservoir simulation is complex since the value depends not only on the thermodynamics of oil and gas but also on the three–phase flow aspects of oil, water, and gas. Figure 68 shows the cumulative gas production is fairly tracked by the simulator. The simulator does a poor job matching the initial increase in gas production, as the reservoir initially declines below the bubble point. Once water flood was initiated, a close match in gas production is observed. As discussed earlier, a more realistic representation of the hydraulic fracture is bound to have a major effect on the amount of gas produced and an even closer match could be obtained.

The simulator does an excellent job of matching the cumulative water production. Figures 69 and 70 show the cumulative water production and the water cut as a percentage respectively. The water cut is much higher and closer to the field values in the model with hydraulic fractures. Figure 71 illustrates this point. There is a large variation in the water production and hence the water cut at the end of the simulation period. One reason may be due to existence of different regions with varying relative permeabilities. The relative permeability data used were the ones measured in the laboratory. The relative permeability data were altered to obtain a satisfactory match between the simulation and the field results. Another reason for variation in water production may be due to the use of bottom hole constraint to model the data rather than respecting the individual water injection rates. This had to be followed because the local grid refinement used to model the hydraulic fractures gave rise to backflow problems. The size of the grid block was too small to inject the given rate of water.

To obtain a realistic representation of hydraulic fractures, and to overcome the limitations of the simulator, the length of the grid blocks containing the wells was changed to nearly 392 feet (119.5 m), quite close to the actual size of the fractures. The simulator does not allow the representation of grid blocks with different lengths for a given position in any coordinate direction. To circumvent this problem, the position of some of the wells had to be shifted by one block, so that position in the x direction was the same. Simulations were performed with this representation. The relative permeabilities were adjusted and refined to match the total water production.

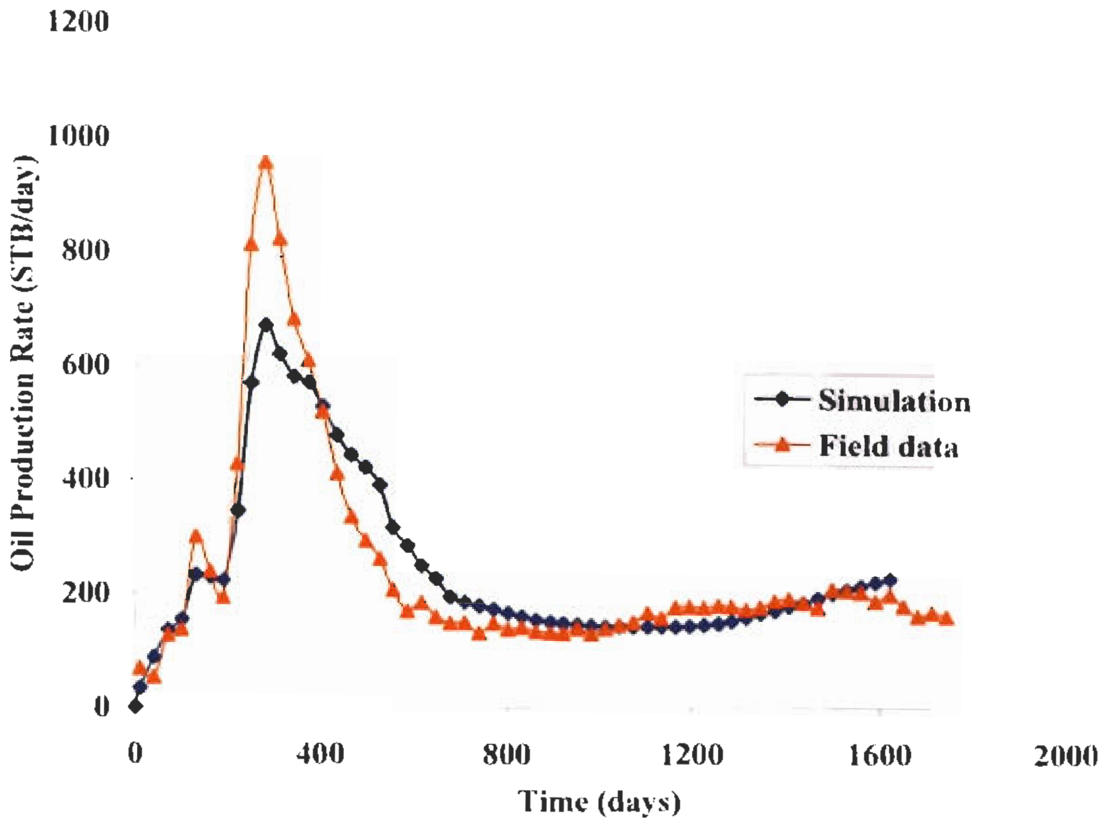


Figure 65. Comparison of actual average rate of oil production with simulated average rate of oil production in the MBNE unit.

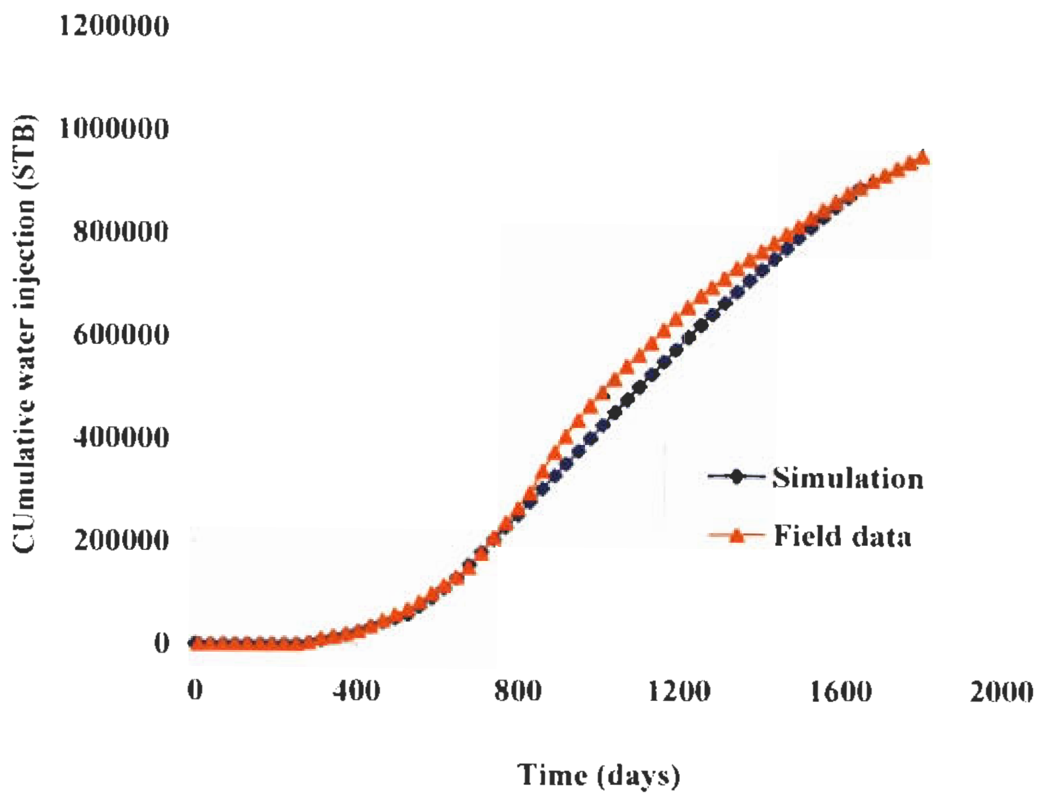


Figure 66. Comparison of actual cumulative water injection to simulated cumulative water injection in the MBNE unit.

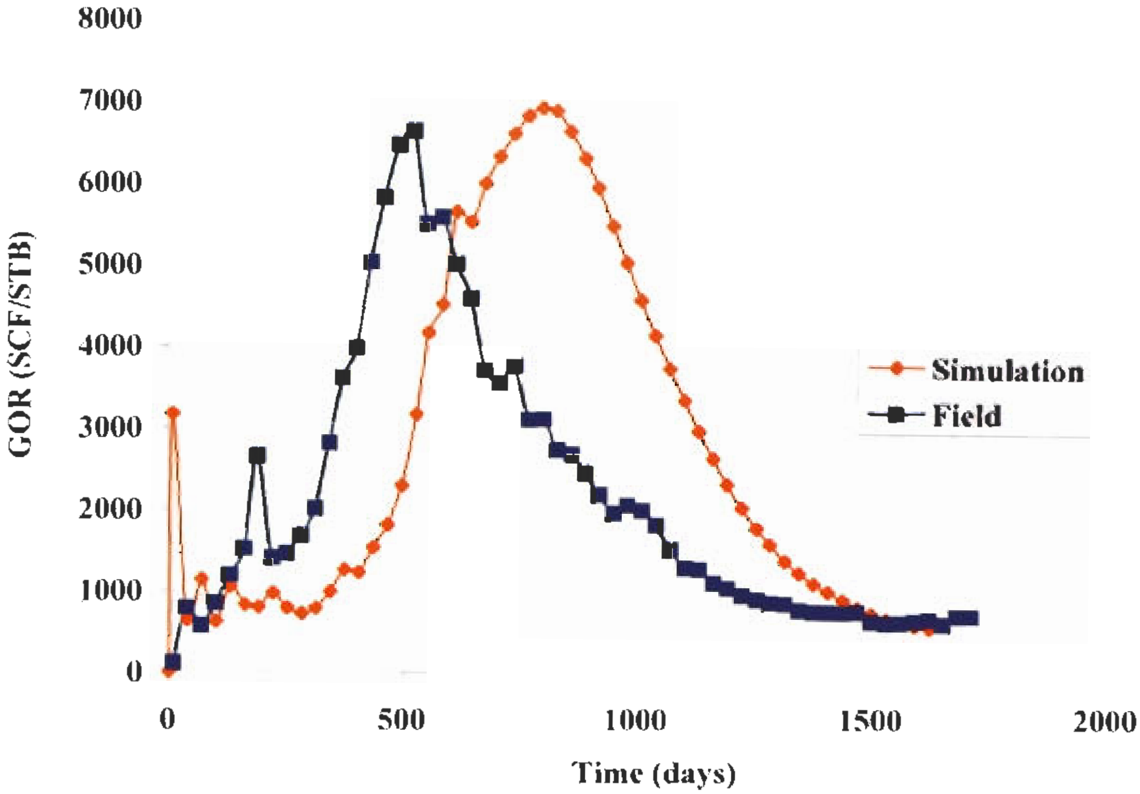


Figure 67. Comparison of producing gas-to-oil ratio to simulated gas-to-oil ratio in the MBNE unit.

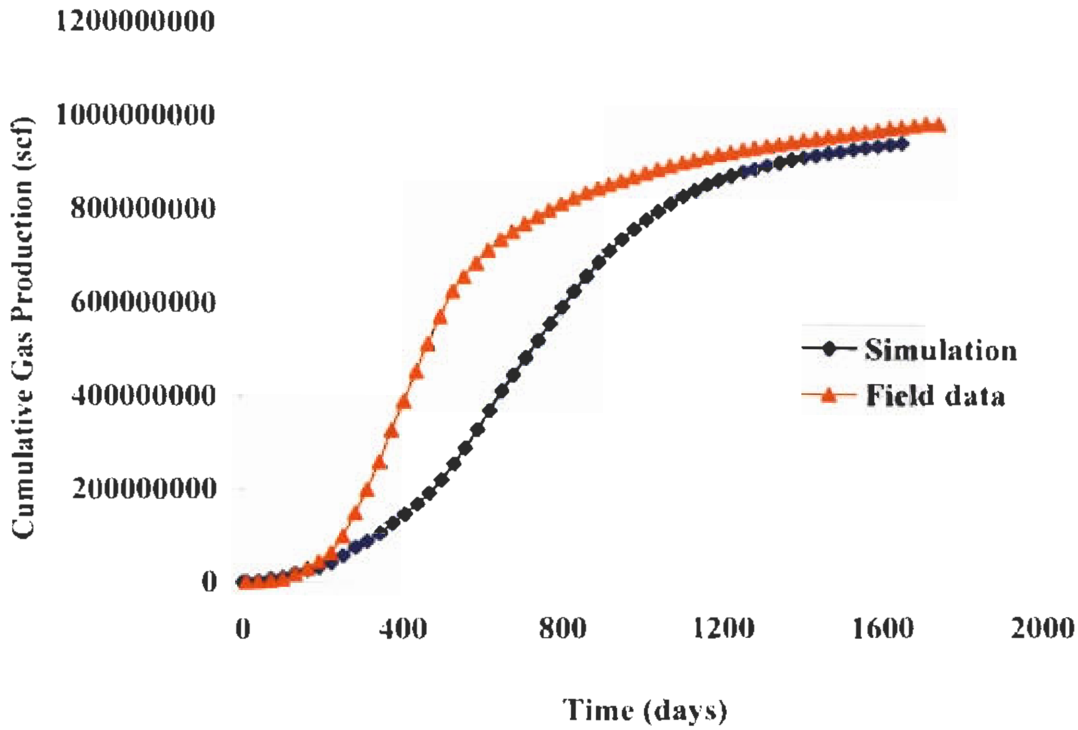


Figure 68. Comparison of actual cumulative gas production to simulated cumulative gas production in the MBNE unit.

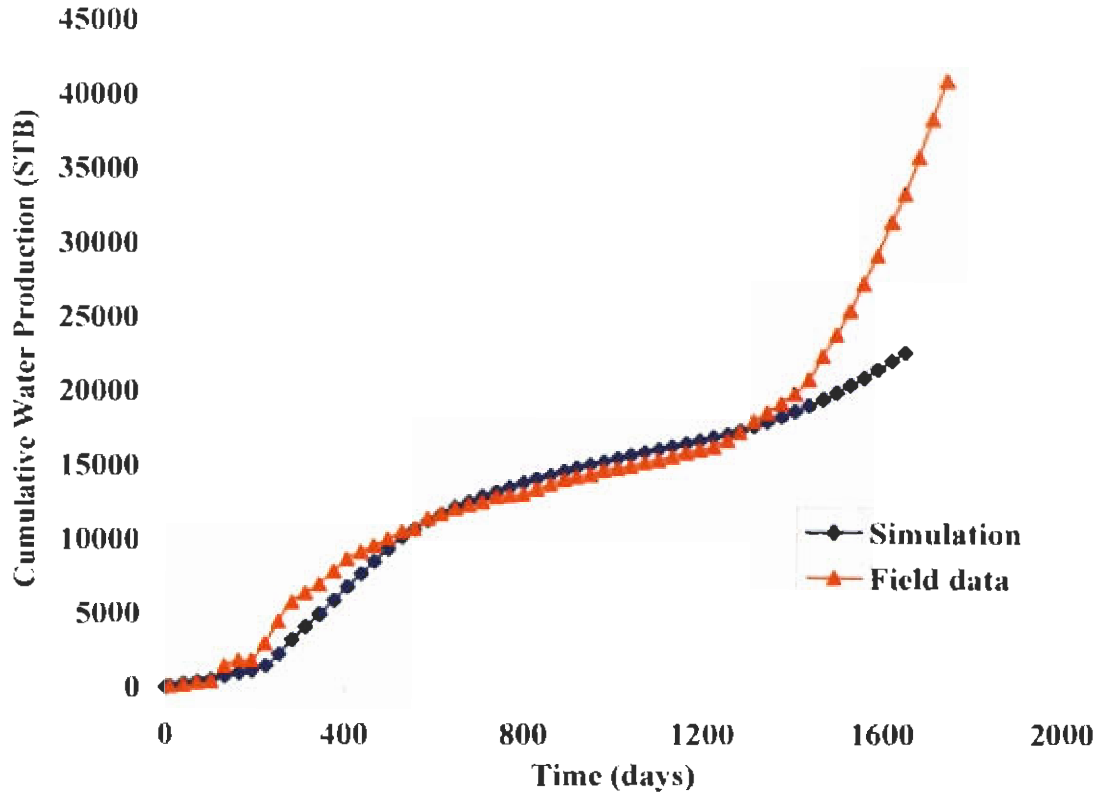


Figure 69. Comparison of actual cumulative water production to simulated cumulative water production in the MBNE unit.

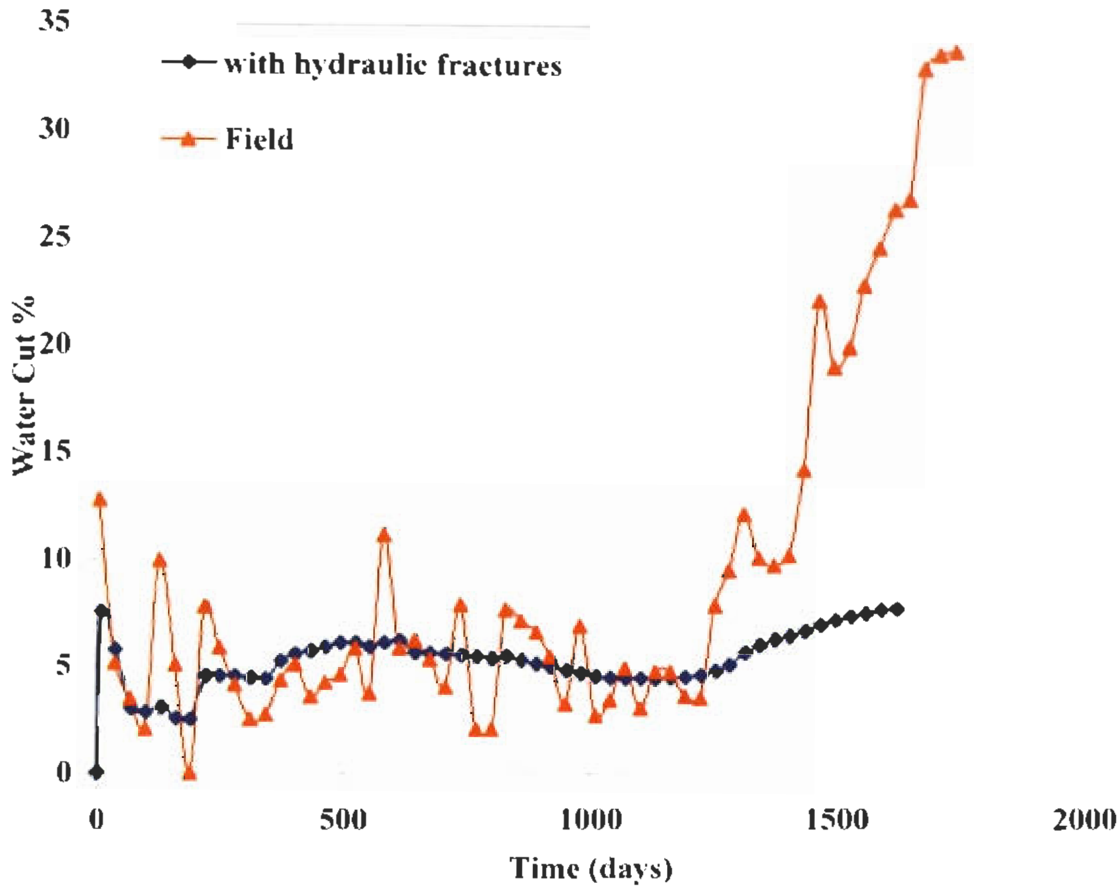


Figure 70. Comparison of actual water cut to simulated water cut in the MBNE unit.

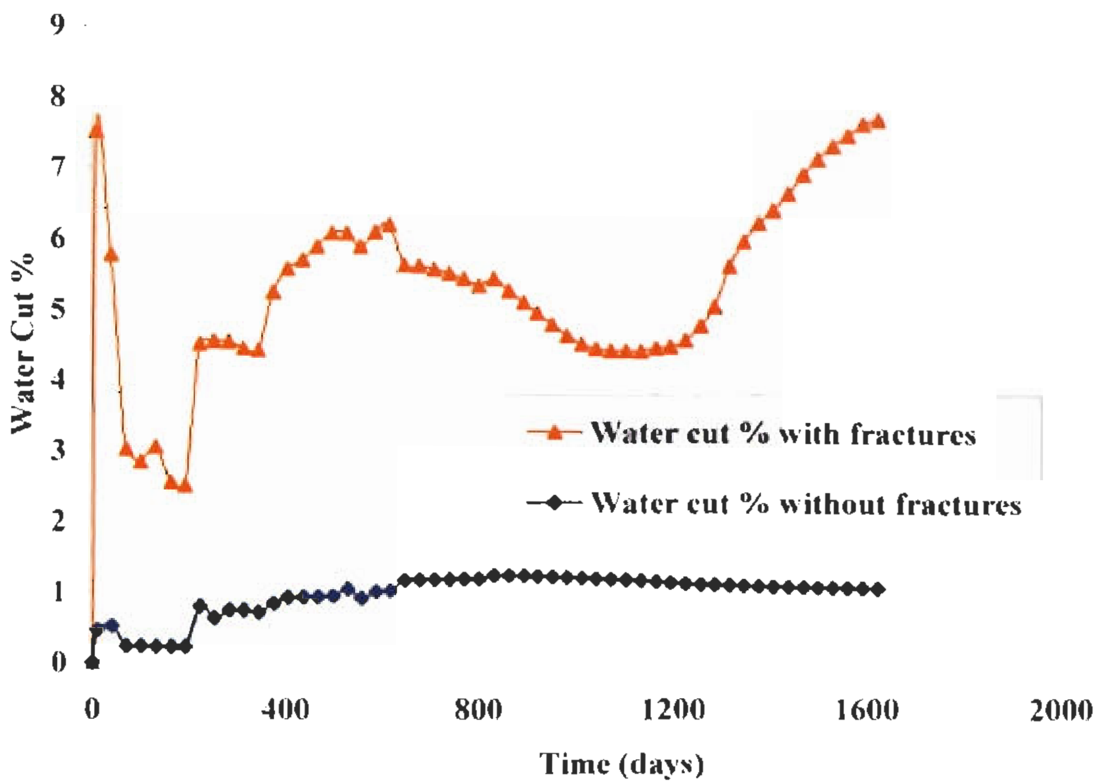


Figure 71. Comparison of simulated water cut with and without fractures, in the MBNE unit.

The cumulative oil production during primary production had increased to nearly 85 MSTB (14 Mm^3). Water and gas production had increased significantly to about 6 MSTB (950 m^3) and 100 MMSCF (2.8 MMm^3) respectively. At the end of the time period, roughly the same amount of oil as in the previous case had been produced, but the water and gas production had increased significantly. Nearly 43 MSTB (6.8 Mm^3) of water and 1,300 MMSCF (36.8 MMm^3) of gas had been produced and 1,110 MSTB (176.5 Mm^3) of water had been injected. The cumulative water production profile (figure 72) did not match the field results well, the total water produced at the end of simulation matching field data notwithstanding. The water cut profile is shown in figure 73.

Thus, the inclusion of hydraulic fractures increased oil production predominantly during primary production, but once water injection had started, there was not any pronounced influence on oil production. However, the water and gas production both increased phenomenally during primary production and at the end of the time period. The runs with more realistic representation of the fractures had decreased oil and water production while increasing gas production. The relative permeabilities had to be tuned to match oil and water production, but gas production and water injection increased slightly. Hence, the relative permeabilities play an influential role in obtaining a good history match.

While the simulator does an excellent job of matching the overall reservoir performance, it doesn't do so in matching individual well performance. Heterogeneities and local production constraints play larger roles in individual well performances. Most of the individual well productions were matched within about 40 percent margin.

The simulator does a good job in matching all the field quantities, but the overall contribution of 88 percent from the D sandstone appears to be higher than expected from that layer. Since the OOIP is nearly 75 percent of the total field and the D sandstone layer being the most productive one, a contribution of nearly 75 to 80 percent is reasonable. The primary reason for this being the fluvial reservoir modeled in this work is a subsystem that is a part of a much larger geologic system. The injected water may be leaving through the boundaries of the unit through sands channeling out of the unit. This is also the reason why the production rate predicted by the simulator is slightly higher than the ones observed in the field. Another reason is attributed to the paraffin deposition around the vicinity of injection and production wells, which is not accounted for in the model. Thus, even though the simulator in matching reservoir performance obtains a reasonably good match, it should be used with caution to predict future performance.

Extended Predictions

The simulations were extended to the year 2010 using the same reservoir representation. Results are tabulated in table 6. The simulations predict that 1.53 MMSTB (243 Mm^3) of oil would have been produced from the unit by the year 2010. This amounts to a recovery of 20 percent of the OOIP. The simulations project the water cut would have increased to 34 percent. With better representation of relative permeabilities, it is expected that the water cut would increase to around 60 to 70 percent and recover nearly 40 to 45 percent of the OOIP before the unit waters out. The model would have to be constantly monitored with field data and calibrated at a later time to ensure good prediction.

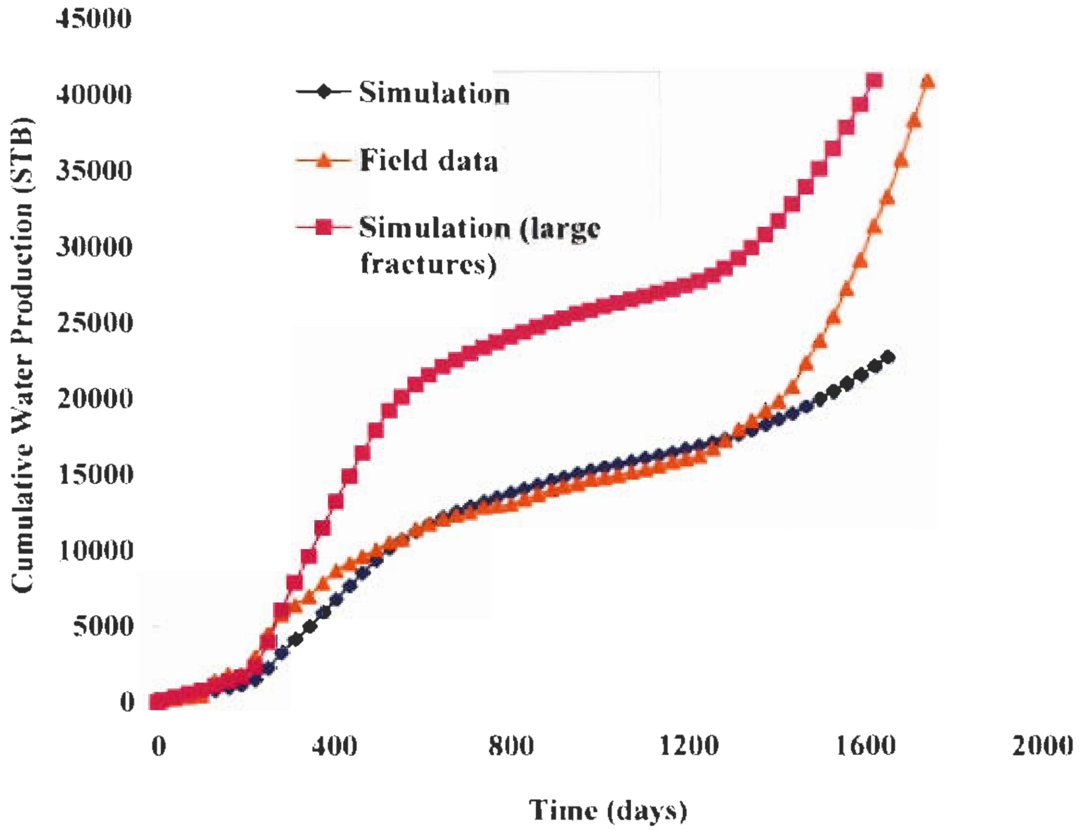


Figure 72. Comparison of actual cumulative water production to simulated cumulative water production without large fractures and without fractures, in the MBNE unit.

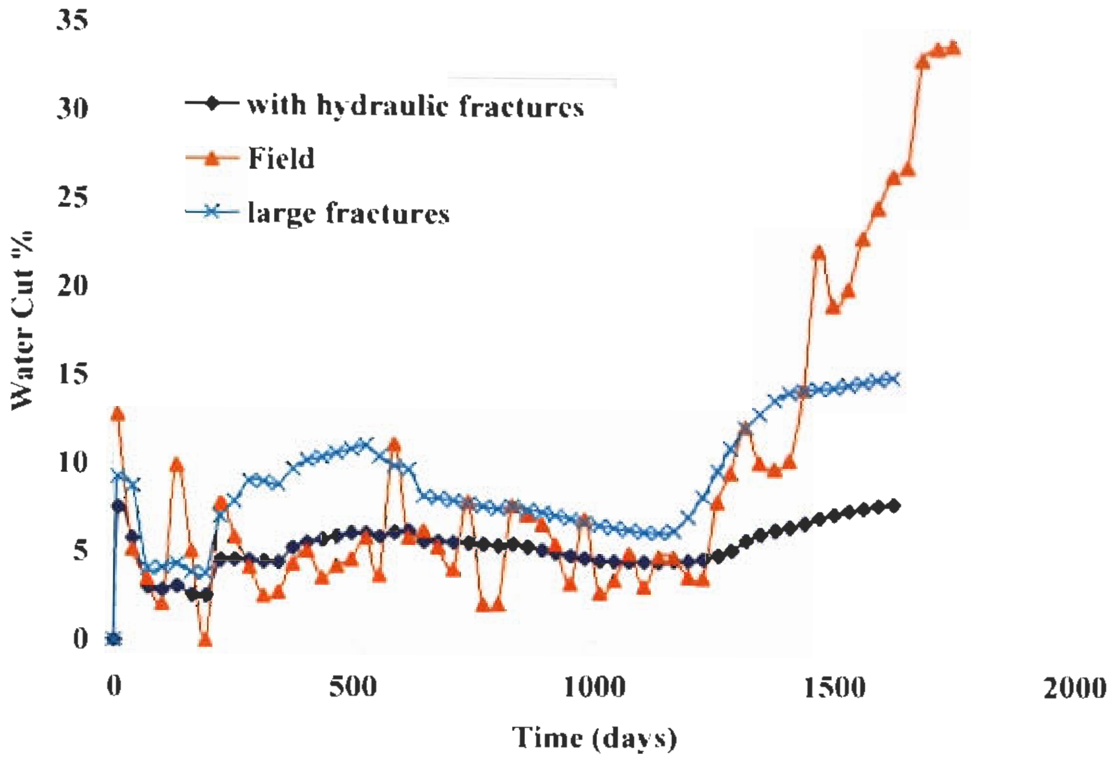


Figure 73. Comparison of actual water cut to simulated water cut with hydraulic fractures and with large fractures, in the MBNE unit.

Table 6. Extended simulation predictions.

Year (March of)	Cumulative Oil Production (MSTB)	Recovery % OOIP
2001	514	6.84
2002	626	8.32
2003	744	9.89
2004	864	11.49
2005	984	13.09
2006	1091	14.51
2007	1206	16.04
2008	1318	17.53
2009	1440	19.15
2010	1532	20.37

Simulations of the Uteland Butte Field

The purpose of this project was to make a baseline oil production prediction from the Uteland Butte oil field. The IMEX® program enabled us to break up the oil field into a grid system and assign values of porosity, permeability, and pressure for each individual block. The grid was simplified in the x and y plane into 15 x 15 matrix of equal size. Each of these blocks was approximately 225 feet (68.6 m) by 225 feet (68.6 m).

The next step was to determine the thickness of each block. In this instance, the case was greatly simplified. It was assumed that the grid had only one block in the z direction, and the thickness of the block was dependent upon how deep the wells were in the field. Most of the thickness values had to be estimated since there were only 19 wells with given thickness while 225 blocks needed to be assigned a thickness. If, for example, a well had a thickness of 10 feet (3 m), then the blocks around it that did not have wells would have thickness values close to that of 10 feet (3 m). To make reasonable estimations, some interpolation was done, and it was also assumed that the thickness at the edge of the grid eventually went to zero. After these calculations and estimations were performed, thickness values could be assigned. Figure 74 is the thickness grid generated by the simulator for the Uteland Butte field.

Now that the grid had been constructed, initial conditions had to be set. Several assumptions had to be made in this case, since it was not known at the time of this analysis what the initial conditions were. The assumptions that were made were a constant porosity of 13 percent for all of the blocks. The permeability was set to a constant of 5 md. The initial reservoir pressure was set to 3,000 psi (20,700 kPa), while the bubble point was set to 3,500 psi (24,100 kPa). The initial oil saturation was 78 percent, which meant that the initial water saturation was set to 22 percent for each of the blocks. Other values were assumed for well geometries and other important geometries and initial conditions.

The next part was to run simulations using the IMEX® program. In order for a baseline to be constructed, a simulation bad to be run for each well. In each case, only one well was opened and oil was collected for a time period from 1989 to 2005 (16 years). The amount of oil collected was different than for the other wells. The cumulative oil collected from each well is shown in figure 75.

This figure shows that the program does indeed work and obtains reasonable working values of oil collected. In comparison with the actual oil collected, some of the values are quite close, while there are some values that are not that close. These errors are expected however, since there was no time frame given when the wells were open and when they were closed. In conclusion, a reasonable baseline was obtained from the field.

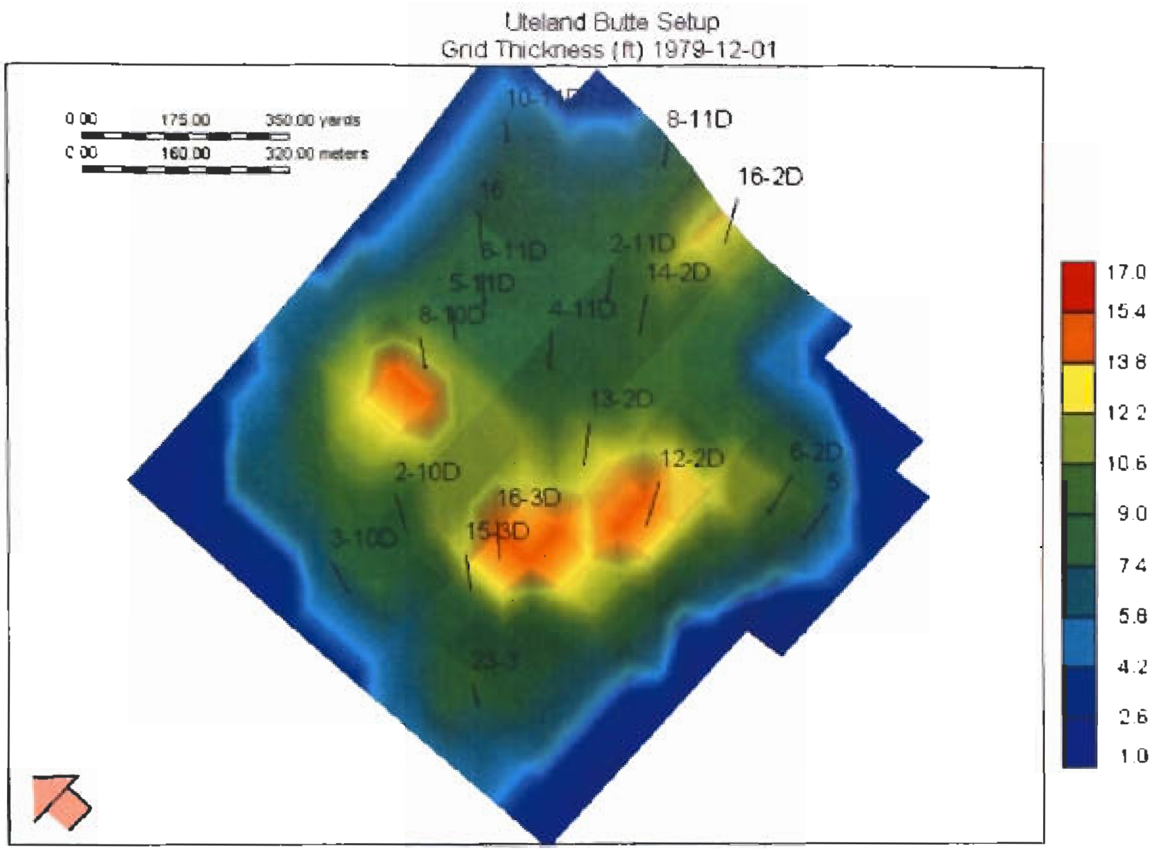


Figure 74. Sandstone thickness grid in feet, in the Uteland Butte field.

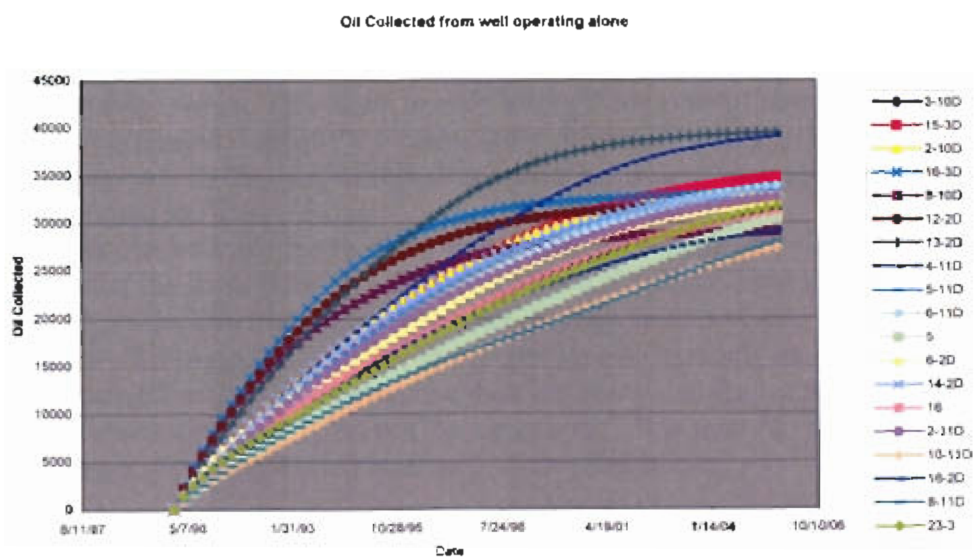


Figure 75. Cumulative oil production curves for all 16 wells in the Uteland Butte field.

Simulations of the Brundage Canyon Field

The purpose of this simulation was to compare the results of the computer simulation to the actual data that was collected from Brundage Canyon field. For purposes of simplification, the field was considered to be two layers on a 16 by 16 grid. Also from actual well data, porosity, and thickness were assigned to each block. The grid is shown in figure 76.

For this simulation, several simplifications needed to be made. One of these simplifications was that all of the blocks in the grid started with the same initial oil saturation. While this is not one hundred percent true, it is a fairly accurate assumption. The pressure versus temperature (PVT) table was also not altered for the experiment. Once again, for this simulation, only times were given when the wells were opened, but no data was supplied as to when the wells were shut in. This will lead to issues concerning well pressure, which will be discussed later.

The simulation was run with an initial oil pressure of 3,000 psi (20,700 kPa) and a bubble point of 2,300 psi (15,900 kPa). The initial oil concentration was constant throughout the whole grid and was at the value of 70 percent. When the simulation was run until the year 2006. The total oil collected is shown in figure 77.

A good deal of oil is collected from the well, with an extra push of oil collected in about 1998. This can be accounted for several new wells being opened during that time period. However, as time goes on, less oil is collected and eventually the oil production stops. This is due to the lack of pressure that is in the well, which is caused by the continuous operation of the wells. The pressure from the well reaches readings as low as 700 psi (4,800 kPa), which is a significant pressure drop compared to the initial pressure of 3,000 psi 20,700 kPa). Since there is not a considerable pressure gradient, no oil could be collected. One method to improve the computer simulation would be to have steam injected to the wells, or at least have the wells open and close when they actually did. Unfortunately, the data of when the wells were opened, not closed, was provided. If this information was given, the results could have been much more accurate.

Another major problem with the simulation was the initial conditions. It was not known what all of the initial conditions were. What were only known were the depths, porosity, and location of the wells. This leads to only a rough estimate of how much oil is collected. If proper data was given and correct PVT tables were provided, then a much better simulation could have been produced. In the case of this simulation, the output was not very close to the actual field data as shown in figure 78.

As can be seen, the shape of the curves are similar (oil production increases and decreases at the same time for both graphs), but the curve from the simulation shows a much lower oil production than the oil that was actually collected, and then at the end of the simulation, it slowly declines and the oil production virtually stops. This error is due to what has been discussed earlier. However, the data did show that the increase and decrease of oil rate was predicted reasonably well, but not the magnitude. It is possible that the field is fractured, allowing gas to segregate and maintain reservoir pressure.

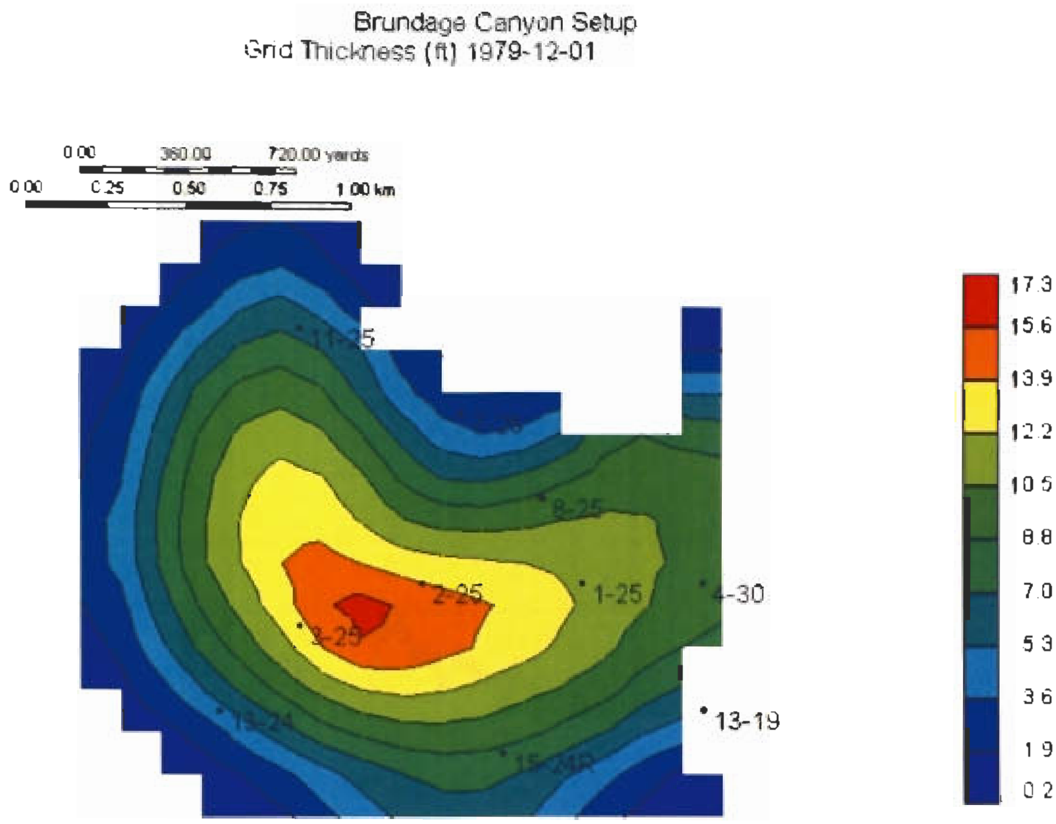


Figure 76. Sandstone thickness grid in feet, for the Brundage Canyon field.

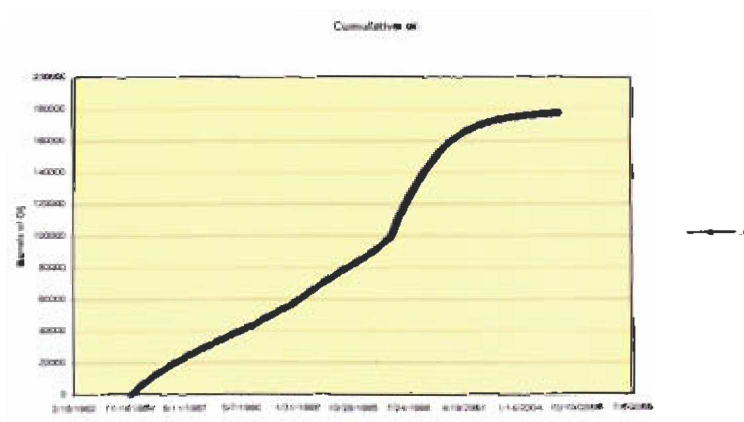


Figure 77. Cumulative oil produced from the Brundage Canyon field.

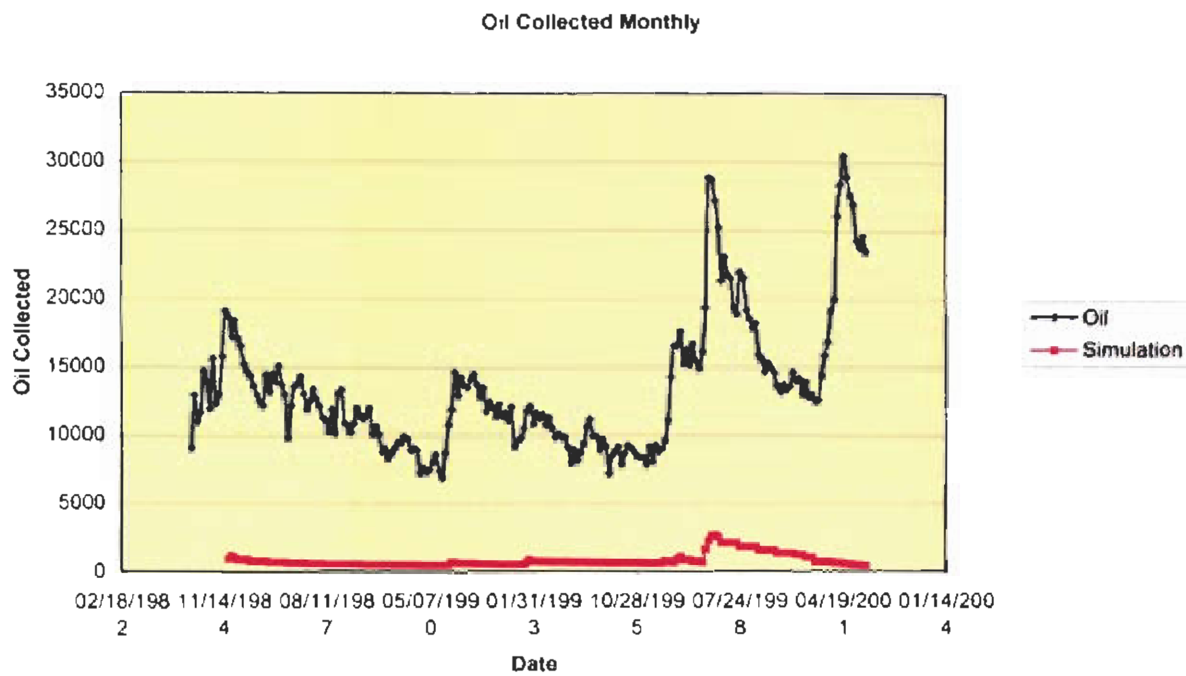


Figure 78. Comparison of actual oil produced to the simulated oil produced in the Brundage Canyon field.

TREND SURFACE ANALYSIS FOR VITRINITE REFLECTANCE DATA

Vitrinite reflectance data were analyzed using trend surfaces. Trend surfaces are created by multiple regression analysis where spatial coordinates are used as independent variables (Davis, 1984).

Data

The location of 211 samples selected for the trend surface analysis is shown in figure 79. The 211 data records (table 7) were selected from 246 published records (Nuccio and Johnson, 1986; Pitman and others, 1988; Anders and others, 1992; Rice and others, 1992; Schmoker and others, 1992; Johnson and Nuccio, 1993;). About 40 percent the selected records are for coal samples and the remainder are for kerogen, which was presumably obtained by acid digestion of whole rocks and cuttings. Reflectance values for five, newly collected samples (table 7) are used to verify results from the trend surface analysis.

Note that some published data are not included in the selected data. Four records are ignored where the reported vitrinite reflectance is considered doubtful. Thirty records are ignored where the reflectance assay is based on less than 30 measured readings or has a standard deviation greater than 0.1 percent. One data record is ignored where the reflectance is 2.4 percent. Although the reflectance value for this record is probably accurate, the value is more than four standard deviations from the median reflectance value of the selected data. Consequently, the record is not included in the regression analysis since it would have a disproportionately large influence on the result.

Method

Multiple regression analysis, where the spatial data are used to predict vitrinite reflectance, shows that a second-order trend surface gives the most satisfactory fit. Two independent variables in the second-order equation are omitted since they do not significantly improve the prediction. The resulting equation is shown below:

Eq. 1 $$Ro = -243.506 - 7.569E^{-7}\,UTME + 1.132E^{4}\,UTMN - 1.314E^{-11}(UTMN)^2 + \frac{1.960E^{4}}{(EL + 20{,}000)}$$

where, Ro is the percent vitrinite reflectance,
UTME is the NAD27 Universal Transverse Mercator easting coordinate,
UTMN is the NAD27 Universal Transverse Mercator northing coordinate and,
EL is elevation in feet relative to mean sea level.

The equation shows an adjusted R^2 equal to 0.70 and a standard error of 0.14 percent reflectance. This precision is reasonably good since the reproducibility of reflectance analysis of coal samples is about 0.06 percent reflectance (ASTM, 2001). Analytical precision for reflectance analysis of kerogen samples has not been established in national standards but is probably not as good as that for coal samples.

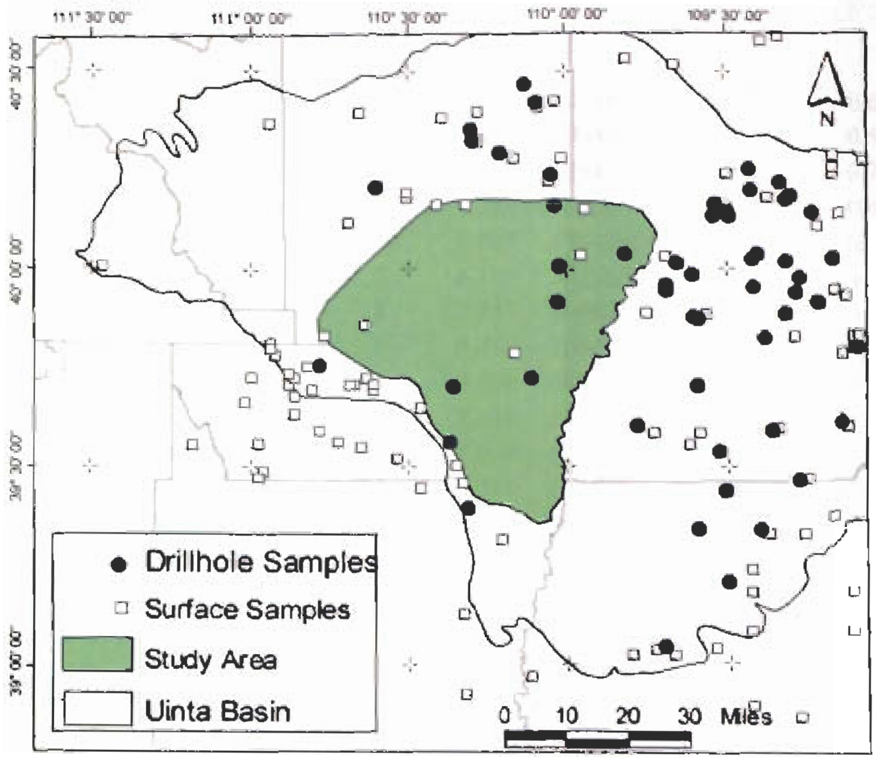


Figure 79. Location of 115 surface samples, and 96 subsurface samples from 52 drill holes, used to construct regional trends of vitrinite reflectance for the study area and surrounding Uinta Basin, Utah.

Table 7. Data used for trend surface analysis.

ID or Well Name	API Number	Depth (feet)	Elevation (feet)	UTME (meters)	UTMN (meters)	Ro (measured)	Ro** (calculated)
1 Bartles	4300710752	7,550	1,703	554889	4394753	0.68	0.72
1 Bitter Creek	4304710477	6,855	-963	638415	4409497	0.69	0.75
1 Govt-Dial (Carter Oil Govt.)	4300710480	1,665	5,761	518368	4400865	0.54	0.59
8 Peters Point	4300710481	8,505	-1,645	576109	4397424	1.03	0.87
not identified		0	5,919	571188	4404515	0.61	0.54
not identified		0	6,644	503199	4370780	0.68	0.64
not identified		0	6,801	501538	4378959	0.65	0.63
not identified		0	5,508	523305	4379215	0.68	0.65
not identified		0	6,001	511492	4392052	0.72	0.61
not identified		0	7,001	501540	4369148	0.68	0.64
not identified		0	7,775	555488	4372887	0.73	0.57
not identified		0	6,821	553835	4379368	0.73	0.58
not identified		0	7,188	498216	4390412	0.69	0.59
not identified		0	6,893	516462	4393692	0.72	0.58
not identified		0	8,176	499871	4396948	0.57	0.55
not identified		0	6,608	514795	4400237	0.49	0.57
not identified		0	7,995	532874	4395487	0.52	0.54
86-5I		0	5,600	539394	4374420	0.61	0.64
86-5J		0	5,607	529737	4377617	0.58	0.64
86-5K		0	5,600	518144	4382254	0.58	0.64
86-5L		0	5,896	511499	4387146	0.59	0.63
U86-KF-1RC		0	7,835	545737	4389060	0.52	0.54

UGMS 594		0	6,653	532881	4393867	0.63	0.57
86-5M		0	6,801	509824	4395323	0.55	0.58
UGMS 204		0	7,027	526462	4395462	0.70	0.57
UGMS 587		0	7,218	528065	4395468	0.61	0.56
86-5N		0	5,997	511484	4396957	0.61	0.60
UGMS 588		0	8,199	531265	4397101	0.59	0.53
86-5O		0	7,057	509820	4398597	0.49	0.57
86-5P		0	6,735	506499	4403499	0.54	0.57
U86-KF-1VR		0	7,798	504846	4405129	0.49	0.54
86-5Q		0	7,119	504845	4406761	0.49	0.55
1 Blanchard (1-3A2)	4301320316	10,456	-4,609	576971	4474891	0.85	0.81
1 Daniel Uresk	4301330113	5,035	211	581686	4445940	0.54	0.62
1 Daniel Uresk	4301330113	6,095	-849	581686	4445940	0.50	0.67
1 Daniel Uresk	4301330113	7,805	-2,559	581686	4445940	0.67	0.77
1 Daniel Uresk	4301330113	8,285	-3,039	581686	4445940	0.71	0.80
1 Daniel Uresk	4301330113	10,325	-5,079	581686	4445940	0.75	0.96
1 Daniel Uresk	4301330113	11,075	-5,829	581686	4445940	0.94	1.03
1 Dustin Etal	4301330122	8,695	-2,841	567075	4460313	0.77	0.75
1 Dustin Etal	4301330122	8,875	-3,021	567075	4460313	0.70	0.76
1 Dustin Etal	4301330122	10,525	-4,671	567075	4460313	0.74	0.88
1 Dustin Etal	4301330122	10,885	-5,031	567075	4460313	0.89	0.91
1 Dustin Etal	4301330122	11,005	-5,151	567075	4460313	0.84	0.92
1 Dustin Etal	4301330122	11,065	-5,211	567075	4460313	0.97	0.93
1 Dustin Etal	4301330122	11,665	-5,811	567075	4460313	0.92	0.99
1 Dustin Etal	4301330122	12,745	-6,891	567075	4460313	1.14	1.10
1 Dustin Etal	4301330122	13,285	-7,431	567075	4460313	1.26	1.16
1 Dustin Etal	4301330122	14,065	-8,211	567075	4460313	1.36	1.27
1 Miles	4301330029	12,195	-5,816	559401	4467053	1.10	0.96
1 Miles	4301330029	12,893	-6,514	559401	4467053	1.12	1.04
1 Miles	4301330029	12,918	-6,539	559401	4467053	1.15	1.04
1 Miles	4301330029	12,928	-6,549	559401	4467053	1.30	1.04
1 Senor Mortansen	4301311087	5,200	81	581107	4454393	0.50	0.59
1 Senor Mortansen	4301311087	6,300	-1,019	581107	4454393	0.61	0.65
1-11B4 Brotherson	4301330052	9,300	-3,121	559639	4463882	0.79	0.76
1-11B4 Brotherson	4301330052	10,700	-4,521	559639	4463882	0.94	0.86
1-11B4 Brotherson	4301330052	11,980	-5,801	559639	4463882	1.08	0.98
1-11B4 Brotherson	4301330052	13,180	-7,001	559639	4463882	1.23	1.10
1-11B4 Brotherson	4301330052	16,300	-10,121	559639	4463882	1.60	1.58
1-20Z2 Ute	4301330378	9,000	-2,624	573466	4479798	0.42	0.64
1-20Z2 Ute	4301330378	10,700	-4,324	573466	4479798	0.45	0.77
1-20Z2 Ute	4301330378	11,400	-5,024	573466	4479798	0.50	0.82
1-20Z2 Ute	4301330378	12,300	-5,924	573466	4479798	0.50	0.91
1-20Z2 Ute	4301330378	13,300	-6,924	573466	4479798	0.59	1.01
22-29 (1 Wilkin-RDG)	4301330327	12,185	-6,013	582770	4418763	1.60	1.14
22-29 (1 Wilkin-RDG)	4301330327	12,345	-6,173	582770	4418763	1.63	1.15
5 Book Cliffs	4301920065	1,515	4,479	629372	4340541	0.70	0.65
3 Cedar Rim	4301330040	8,202	-1,916	533790	4450601	0.68	0.75
85-73A		0	5,860	581583	4475085	0.45	0.29
85-74		0	5,138	580245	4452547	0.58	0.40

85-77		0	5,600	549826	4445847	0.48	0.44
85-97E		0	5,807	541787	4447408	0.47	0.43
85-97J		0	6,900	551144	4469998	0.45	0.30
U86-KF-2VR		0	7,995	519467	4408948	0.49	0.51
not identified		0	9,170	530759	4412137	0.50	0.47
not identified		0	8,973	504610	4468216	0.50	0.29
not identified		0	8,018	528651	4471477	0.45	0.29
not identified		0	6,801	525811	4440899	0.33	0.44
not identified		0	6,568	560749	4471668	0.30	0.30
not identified		0	6,096	560848	4463632	0.30	0.35
not identified		0	5,810	541761	4449017	0.36	0.43
not identified		0	5,807	576781	4473425	0.31	0.30
not identified		0	5,600	557857	4445904	0.30	0.43
not identified		0	5,600	570536	4458888	0.34	0.37
not identified		0	5,197	589973	4444608	0.30	0.42
not identified		0	5,194	583381	4459019	0.33	0.37
not identified		0	5,141	589065	4431887	0.55	0.47
U86-KF-3VR		0	7,401	557202	4367872	0.58	0.59
86-5H		0	5,367	545915	4366187	0.49	0.65
86-5D		0	4,600	557474	4330817	0.51	0.71
86-4Z		0	4,442	558095	4308704	0.53	0.72
not identified		0	9,035	484416	4378408	0.68	0.58
Forest 25-1 Arnold	4301510374	100	6,544	558895	4360787	0.56	0.62
not identified		0	6,174	567595	4352062	0.48	0.63
UB-86-KF-4VR		0	4,984	662667	4338588	0.65	0.61
2 EPR Sego Canyon	4301931232	656	5,184	612253	4322257	0.56	0.65
2 EPR Sego Canyon	4301931232	755	5,085	612253	4322257	0.57	0.66
1 Utah-Federal	4301915933	1,590	4,503	638082	4355486	0.69	0.63
1 Unit (PNGE 1 Segundo)	4301910805	5,490	2,851	620876	4355138	0.74	0.70
428-1 State	4301930169	5,140	2,173	628064	4366455	0.84	0.70
not identified		0	8,199	650236	4370138	0.52	0.49
not identified		0	6,998	657388	4359487	0.63	0.53
not identified		0	6,982	635061	4344524	0.64	0.57
not identified		0	6,630	649418	4354489	0.67	0.56
not identified		0	6,598	603067	4319795	0.63	0.62
not identified		0	6,099	614416	4319952	0.63	0.62
not identified		0	5,964	639738	4354309	0.63	0.58
not identified		0	5,197	635368	4326745	0.66	0.63
not identified		0	4,987	625731	4321745	0.57	0.65
not identified		0	4,268	662902	4327268	0.67	0.64
39-7		0	4,196	648618	4302738	0.60	0.66
39-15		0	4,396	635755	4305726	0.75	0.66
39-16		0	4,216	575862	4313693	0.57	0.71
UGMS 531		0	6,398	609529	4321503	0.59	0.62
UGMS 191		0	6,122	635173	4338065	0.70	0.60
86-5X		0	5,886	459780	4428186	0.40	0.56
84-56		0	5,600	663999	4459410	0.46	0.30
84-55A		0	5,600	663999	4459410	0.40	0.30
7 Southman Cyn	4304715882	5,971	-1,041	646839	4422379	0.7	0.71

4 Pariette Bench	4304715681	4,888	-141	600657	4432652	0.47	0.67
275 (31-26B) Red Wash	4304731077	5,413	138	645034	4449577	0.45	0.56
21 NBU	4304730255	4,495	355	634999	4423583	0.56	0.65
1-7 Federal Natural	4304730148	6,988	-1,454	619287	4415042	0.79	0.78
1-7 Federal Natural	4304730148	7,710	-2,176	619287	4415042	0.87	0.82
16 Chapita Wells	4304715061	5,512	-646	635934	4432812	0.58	0.67
128 Wonsits Valley	4304730798	5,315	-480	624203	4443257	0.48	0.63
117 Wonsits Valley	4304730238	5,545	-493	627835	4444537	0.49	0.62
11-17F River Bend UN	4304730584	8,300	-3,196	611878	4422267	0.83	0.87
1-1 Petes Flat-Federal	4304730558	8,202	-2,705	647758	4426263	0.91	0.80
Sunnyside		1,016	-1,016	553835	4379368	0.80	0.89
Oil Springs2		0	5,761	659989	4421545	0.26	0.43
Oil Springs1		0	6,004	662272	4407057	0.35	0.46
EX-1 Project Utah	4304700000	1,820	3,121	618624	4426866	0.37	0.53
EX-1 Project Utah	4304700000	2,340	2,601	618624	4426866	0.39	0.55
EX-1 Project Utah	4304700000	2,640	2,301	618624	4426866	0.40	0.56
EX-1 Project Utah	4304700000	2,800	2,141	618624	4426866	0.40	0.57
EX-1 Project Utah	4304700000	2,962	1,979	618624	4426866	0.40	0.58
Coyote Wash 1		2,674	2,416	643721	4431081	0.35	0.53
Coyote Wash 1		2,888	2,202	643721	4431081	0.45	0.53
Coyote Wash 1		3,423	1,667	643721	4431081	0.42	0.56
7 Southman Cyn Unit	4304715882	6,396	-1,466	646839	4422379	0.68	0.73
7 Southman Cyn Unit	4304715882	6,435	-1,505	646839	4422379	0.82	0.74
7 Southman Cyn Unit	4304715882	6,448	-1,518	646839	4422379	0.84	0.74
7 Southman Cyn Unit	4304715882	6,498	-1,568	646839	4422379	0.78	0.74
7 Southman Cyn Unit	4304731077	6,705	-1,323	652554	4419488	0.68	0.73
5 Chapita	4304715051	9,495	-4,550	634553	4431458	1.20	0.93
4 USA Pearl Broadhrs	4304715694	5,281	-101	642177	4453174	0.43	0.56
4 USA Pearl Broadhrs	4304715694	5,331	-151	642177	4453174	0.46	0.56
32 (32-22A) Red Wash	4304715159	10,003	-4,733	634197	4450791	0.74	0.87
32 (32-22A) Red Wash	4304715159	10,501	-5,231	634197	4450791	0.74	0.92
31-13 Federal	4304730097	3,445	4,815	648022	4369478	0.65	0.59
31-13 Federal	4304730097	5,200	3,060	648022	4369478	0.76	0.65
3 Pelilake	4304710876	5,782	-1,009	624755	4446926	0.42	0.64
3 Island Unit	4304715643	7,400	-2,440	611781	4423905	0.72	0.82
3 Island Unit	4304715643	10,875	-5,915	611781	4423905	1.12	1.09
288 (24-27B) Red Wash	4304731513	5,086	398	643462	4448388	0.45	0.55
2-8 Hope Unit	4304730189	9,195	-3,736	620299	4414474	0.94	0.93
23-2-1 Evacuation Cr	4304715675	3,575	2,211	663675	4407399	0.62	0.59
22-1 Conoco-Federal	4304730111	10,655	-5,822	614429	4430172	1.46	1.06
212 (41-8F) Red Wash	4304720014	8,705	-3,191	650721	4444909	0.67	0.77
212 (41-8F) Red Wash	4304720014	9,305	-3,791	650721	4444909	0.70	0.81
21 NBU	4304730255	7,402	-2,552	634999	4423583	0.72	0.81
21 NBU	4304730255	7,415	-2,565	634999	4423583	0.74	0.81
21 NBU	4304730255	7,459	-2,609	634999	4423583	0.77	0.81
21 NBU	4304730255	7,485	-2,635	634999	4423583	0.75	0.81
21 NBU	4304730255	7,491	-2,641	634999	4423583	0.76	0.81
21 NBU	4304730255	7,541	-2,691	634999	4423583	0.82	0.81
21 NBU	4304730255	8,449	-3,599	634999	4423583	0.89	0.88

21 NBU	4304730255	8,487	-3,637	634999	4423583	0.89	0.88
21 NBU	4304730255	8,496	-3,646	634999	4423583	0.90	0.88
21 NBU	4304730255	8,503	-3,653	634999	4423583	1.01	0.88
21 NBU	4304730255	8,563	-3,713	634999	4423583	1.00	0.89
108 Wonsits Valley	4304730026	5,552	-535	628237	4443400	0.52	0.63
I Unit (1 Rainbow)	4304720512	6,772	-1,222	643816	4416429	0.69	0.74
I Unit (Mid America)	4304710812	6,073	-620	656240	4432129	0.69	0.65
I Uintah Oil Assoc	4304711120	6,635	-690	620255	4395922	0.89	0.78
I Uintah Federal-219	4304711119	6,575	485	604520	4384316	0.77	0.76
I Two Waters Unit	4304710692	2,435	4,225	659357	4386194	0.62	0.57
I McLish Unit	4304710870	6,113	-996	633973	4456639	0.37	0.60
I Kralovec	4301310227	10,205	-4,725	583222	4428631	1.39	0.99
I Kralovec	4301310227	10,225	-4,745	583222	4428631	1.38	0.99
I Crooked Canyon	4304730271	4,477	2,530	640533	4383424	0.83	0.65
I Wolf Point Unit	4304730355	6,500	620	626467	4377301	0.76	0.75
not identified		0	5,699	646269	4409922	0.45	0.48
not identified		0	5,600	656573	4431335	0.39	0.41
not identified		0	5,469	656065	4455955	0.37	0.32
not identified		0	5,410	622281	4415873	0.58	0.49
not identified		0	5,200	651555	4441083	0.40	0.39
not identified		0	5,154	627402	4445568	0.30	0.39
not identified		0	4,800	611556	4432184	0.30	0.46
not identified		0	5,394	656031	4457598	0.30	0.32
not identified		0	5,236	656743	4423121	0.45	0.44
not identified		0	6,968	600395	4487004	0.59	0.19
not identified		0	6,772	613378	4485602	0.61	0.19
not identified		0	6,388	640771	4494019	0.52	0.14
not identified		0	5,600	635942	4492342	0.51	0.17
not identified		0	5,230	655963	4460883	0.48	0.31
not identified		0	7,559	661138	4384703	0.54	0.47
not identified		0	6,998	608430	4382195	0.52	0.53
not identified		0	6,801	618063	4379150	0.53	0.54
not identified		0	6,798	641964	4384326	0.54	0.51
not identified		0	6,398	621209	4382385	0.57	0.54
not identified		0	6,302	659111	4405392	0.50	0.46
not identified		0	6,197	663796	4410277	0.49	0.45
not identified		0	5,761	659989	4421545	0.28	0.43
not identified		0	5,577	662204	4410243	0.52	0.47
not identified		0	5,490	606149	4415986	0.35	0.50
not identified		0	5,469	638568	4449051	0.31	0.36
not identified		0	5,400	657904	4444499	0.35	0.37
not identified		0	5,000	627236	4455413	0.30	0.36
*Ute Tribal 2-25	4301331833	5,586	1,356	551758	4430251	0.74	0.64
*Grays Canyon		0	4,200	579570	4341343	0.50	0.70

* This study

**Calculated after equation 1

Results

Equation 1 can be used to estimate vitrinite reflectance at a given location and elevation within the Uinta Basin. For example, figure 80 shows the result from equation 1 for rocks at the surface, and figures 81, 82, 83, and 84 show predicted depths for buried sediments where reflectance is equal to 0.6, 0.8, 1.0, and 1.4 percent reflectance, respectively.

Projection of vitrinite reflectance gradients above the ground surface is sometimes used to estimate the thickness of eroded sediments (Dow, 1977). Although this approach is usually used with reflectance gradients observed in single wells, it is used here with equation 1 to examine the regional variation of sediments lost to erosion. Figure 85 shows the thickness of sediments eroded from the surface obtained by subtracting the current surface elevation from a hypothetical surface obtained by using reflectance value of 0.25 in equation 1 and solving for the elevation.

Equation 1 is perhaps most useful for estimating the maturity of buried source rocks where the depth of the source rock is known or can be estimated. For example, figure 86 shows the vitrinite reflectance for the top of the lower member of the Green River Formation in the study area. The figure shows that this potential source rock has not yet reached the onset of peak oil generation (0.8 percent Ro) suggested by Ruble and others (2001) for the type 1 kerogen found in the Green River Formation.

Limitation of the Trend Surface Analysis

The results presented here show a regional trend - local deviations from this trend are expected. Such deviations might be examined by constructing residual maps that show the difference between the predicted and measured vitrinite reflectance values. Although the selected data set (table 7) is reasonably comprehensive, an exhaustive literature search was not attempted and additional published data may be available. Clearly, additional data should improve confidence in the regression model. Finally, no attempt was made to correct the model for syn- and post-maturation structural deformation. Such corrections should improve the accuracy of the reflectance estimate, especially in areas with steeply dipping beds.

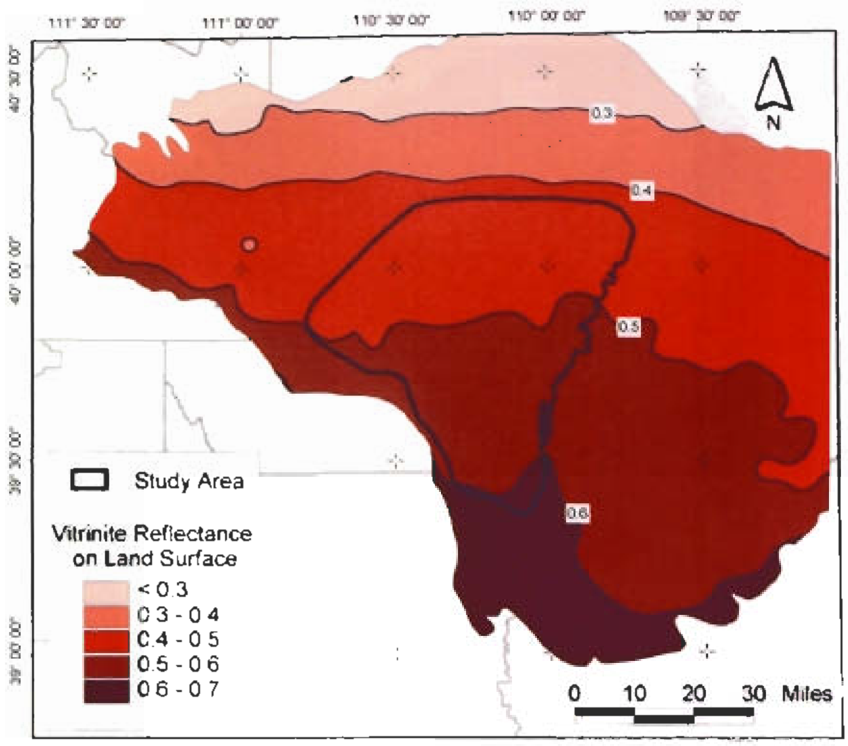


Figure 80. Regional trend of vitrinite reflectance on the land surface for the study area and surrounding Uinta Basin, Utah.

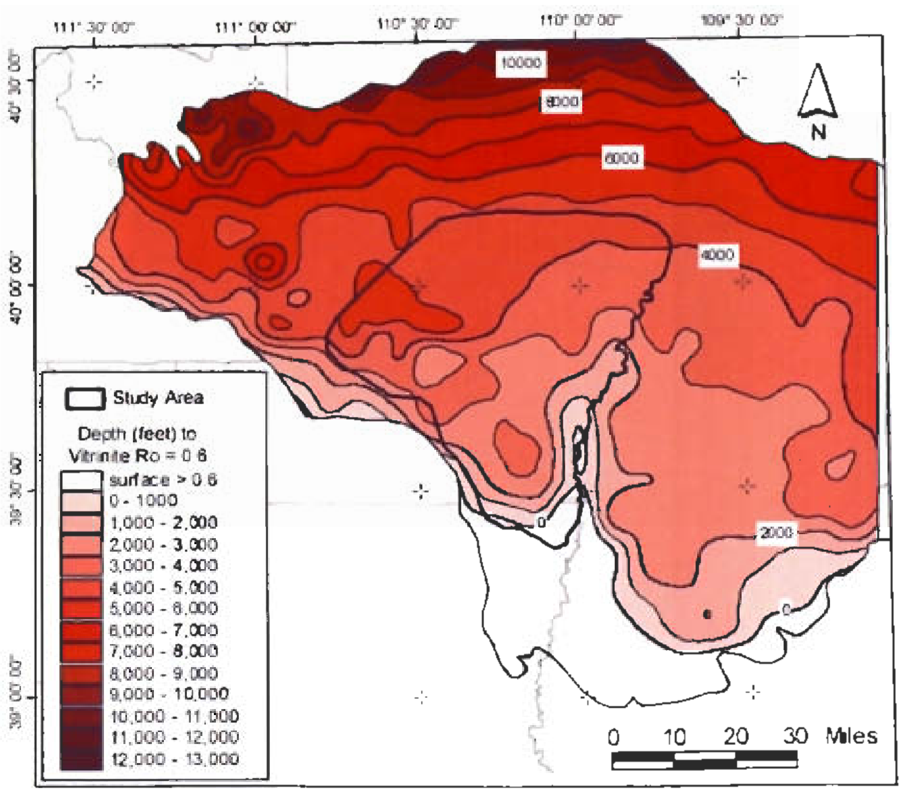


Figure 81. Estimated depth to sediments with a vitrinite reflectance equal to 0.60 (early oil window) in the study area and surrounding Uinta Basin, Utah.

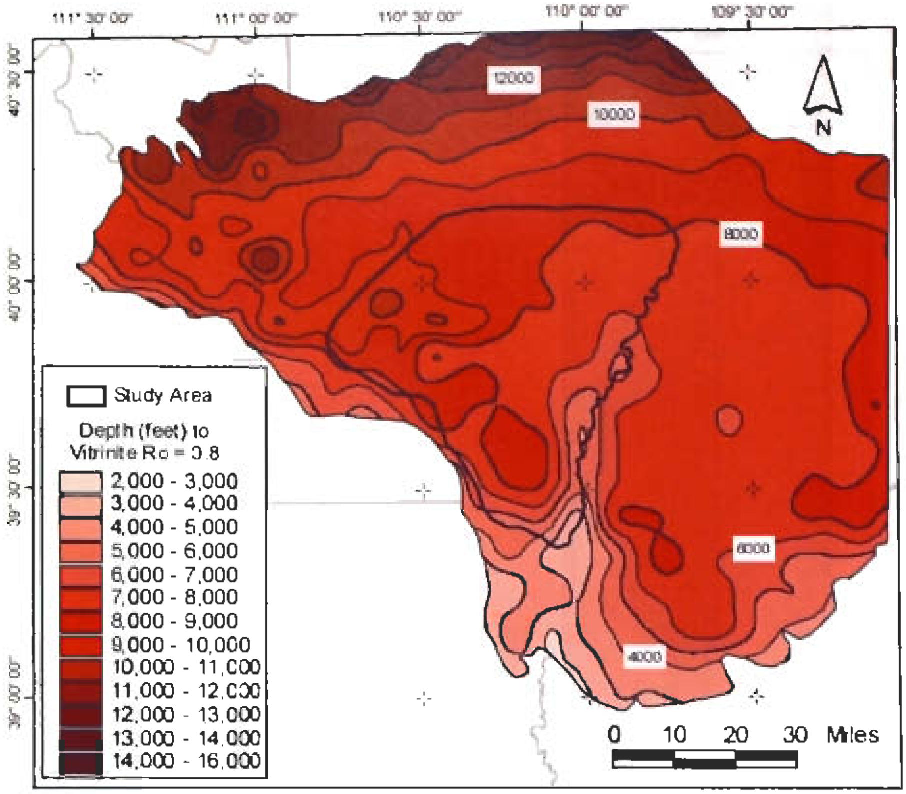


Figure 82. Estimated depth to sediments with a vitrinite reflectance equal to 0.80 in the study area and surrounding Uinta Basin, Utah. Ruble and others (2001) suggest that 0.80 percent reflectance marks the onset of peak oil generation from Green River kerogen.

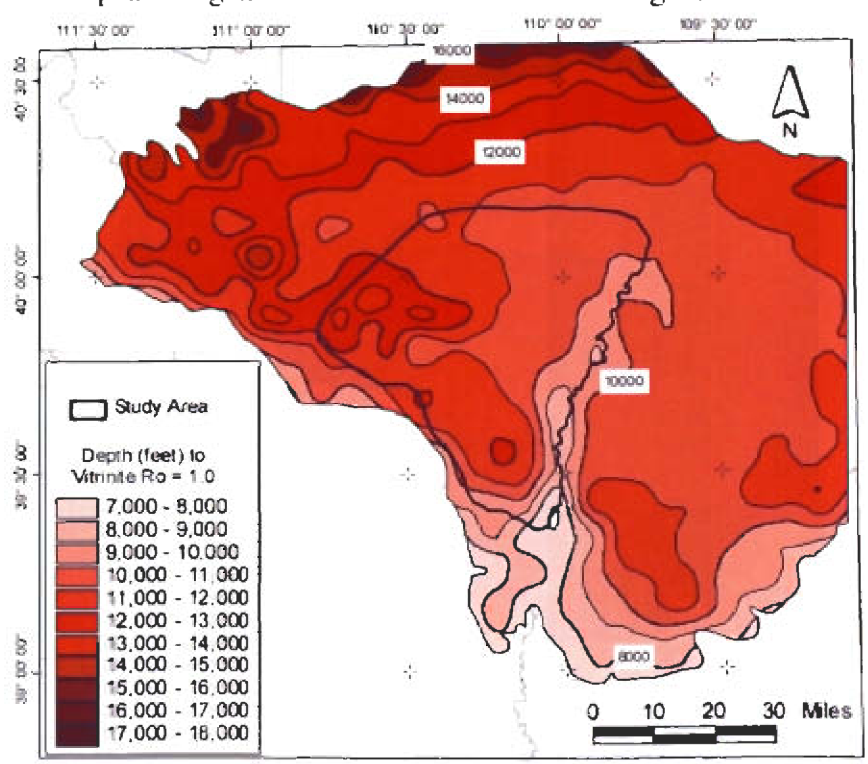


Figure 83. Estimated depth to sediments with a vitrinite reflectance equal to 1.0 in the study area and surrounding Uinta Basin, Utah. Ruble and others (2001) suggest 1.0 percent reflectance marks the end of peak oil generation from Green River kerogen.

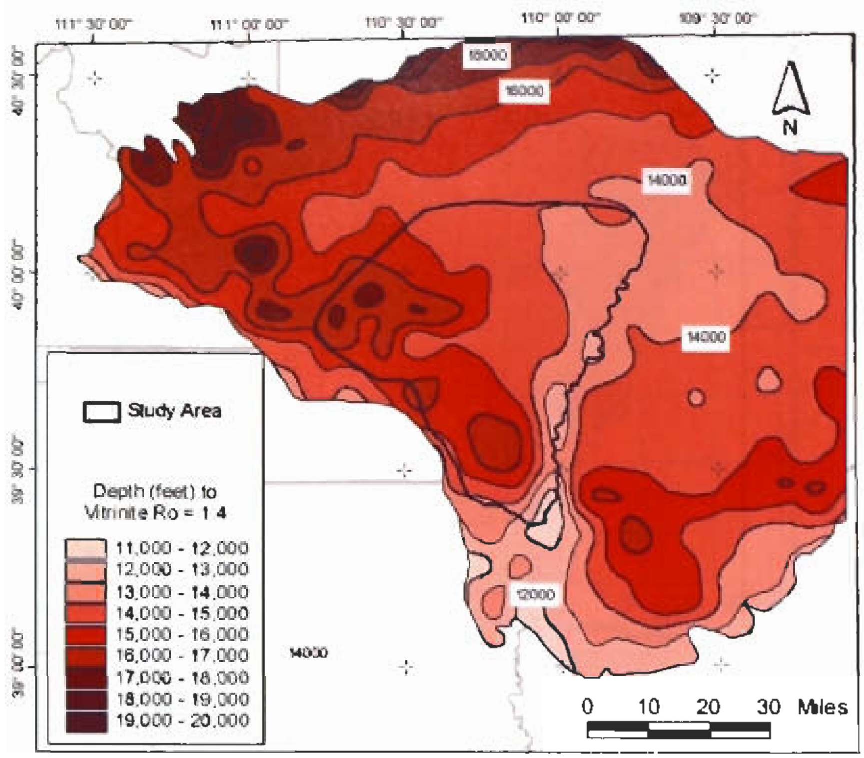


Figure 84. Estimated depth to sediments with a vitrinite reflectance equal to 1.4 (end of the oil window) in the study area and surrounding Uinta Basin, Utah.

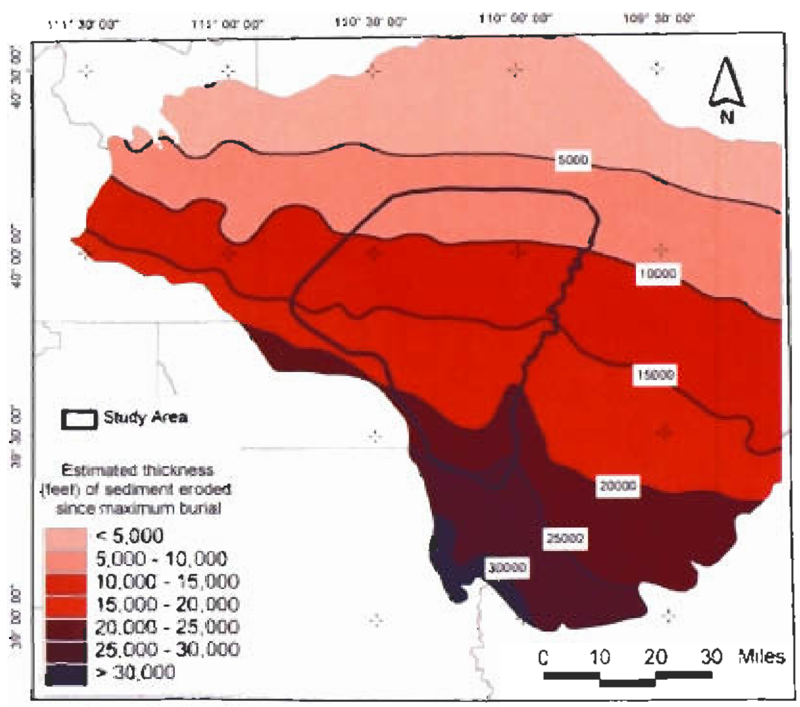


Figure 85. Estimated amount of eroded sediment corresponding to a paleo-surface vitrinite reflectance of 0.25 for the study area and surrounding Uinta Basin, Utah.

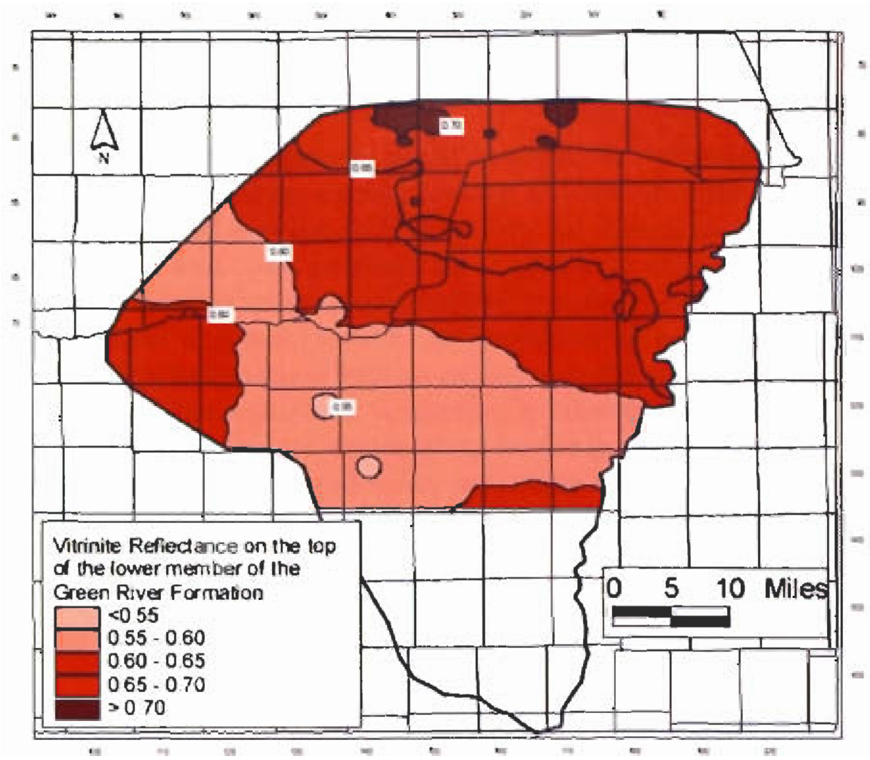


Figure 86. Estimated vitrinite reflectance at the top of the lower member of the Green River Formation in the study area.

FUTURE EXPLOITATION POTENTIAL

Development Potential

The middle and lower member reservoirs in the Green River Formation are currently drilled on 40 acre (16.2 ha) spacing. At the current spacing and rate of drilling, the area proven to be hydrocarbon productive should provide drilling activity for several more years. Drilling activity in the southwest Uinta Basin could continue for at least a decade, and probably much longer, as the proven oil field boundaries are expanded and hopefully, new wildcat discoveries are made. The production life of a typical Green River Formation oil well is several decades.

The work at the Nutter's Ranch study site, an analogue to the oil production in the greater Monument Butte area, indicates that significant volumes of oil could be left behind at a well spacing of 40 acres (16.2 ha). Reducing the well spacing for the greater Monument Butte area or allowing selective infill drilling along the trend of key sandstone beds, could result in a sizable drilling boom.

Exploration Potential

Hydrocarbon Shows

Hydrocarbon shows are very common while drilling the Green River Formation. No systematic attempt was made to study drilling shows because such shows are so common and drilling or mud logs are not available for most of the wells in the study area. Interesting log shows (unusually thick bed(s), abundant or unusually high porosity, for example) were noted while correlating the logs. This is by no means an extensive or all-inclusive study of log shows but a small sample of a few shows that were noted in sparsely drilled portions of the study area is shown on figure 87.

The Twelve Mile Creek 17-1 well (NW1/4SW1/4 section 17, T. 6 S., R. 7 W., SLBL) lies along the western boundary of the study area. The well was drilled at a kelly bushing (KB) elevation of 7,607 feet (2,318.6 m). Well logs show a 22-foot (6.7-m) thick sandstone with 12 feet (3.7 m) having 10 percent or more density-log porosity, in the MGR 5 (upper Douglas Creek reservoir) at a depth of 2,658 feet. The resistivity deep curve indicates 40 ohms with good separation between the shallow, medium, and deep resistivity curves. The spontaneous potential curve shows a strong deflection to the right indicating potential permeability. The MGR 5 was drilled with air and the operator reported oil in the pits while drilling through the interval. There are no reports of the MGR 5 being tested before the well was plugged and abandoned. The drilling show (oil in the pits) may under-represent the oil present in the MGR 5. Because of the shallow depth, the formation temperature may be near the pour-point temperature of the oil. Drilling could have further reduced the temperature in the near-well bore environment preventing the oil from flowing.

The Chokecherry 16-30 well (SE1/4SE1/4 section 30, T. 10 S., R. 15 E., SLBL) has a 52-foot (15.8-m) thick sandstone bed with 44 feet (13.4 m) having 10 percent or more density-log porosity, in the MGR 3 (lower Douglas Creek reservoir) at a depth of 3,835 feet (1,168.9 m). The well was drilled in 1983 from a KB elevation of 7,210 feet (2,197.6 m). There are no reports of the MGR 3 being tested before the well was plugged and abandoned.

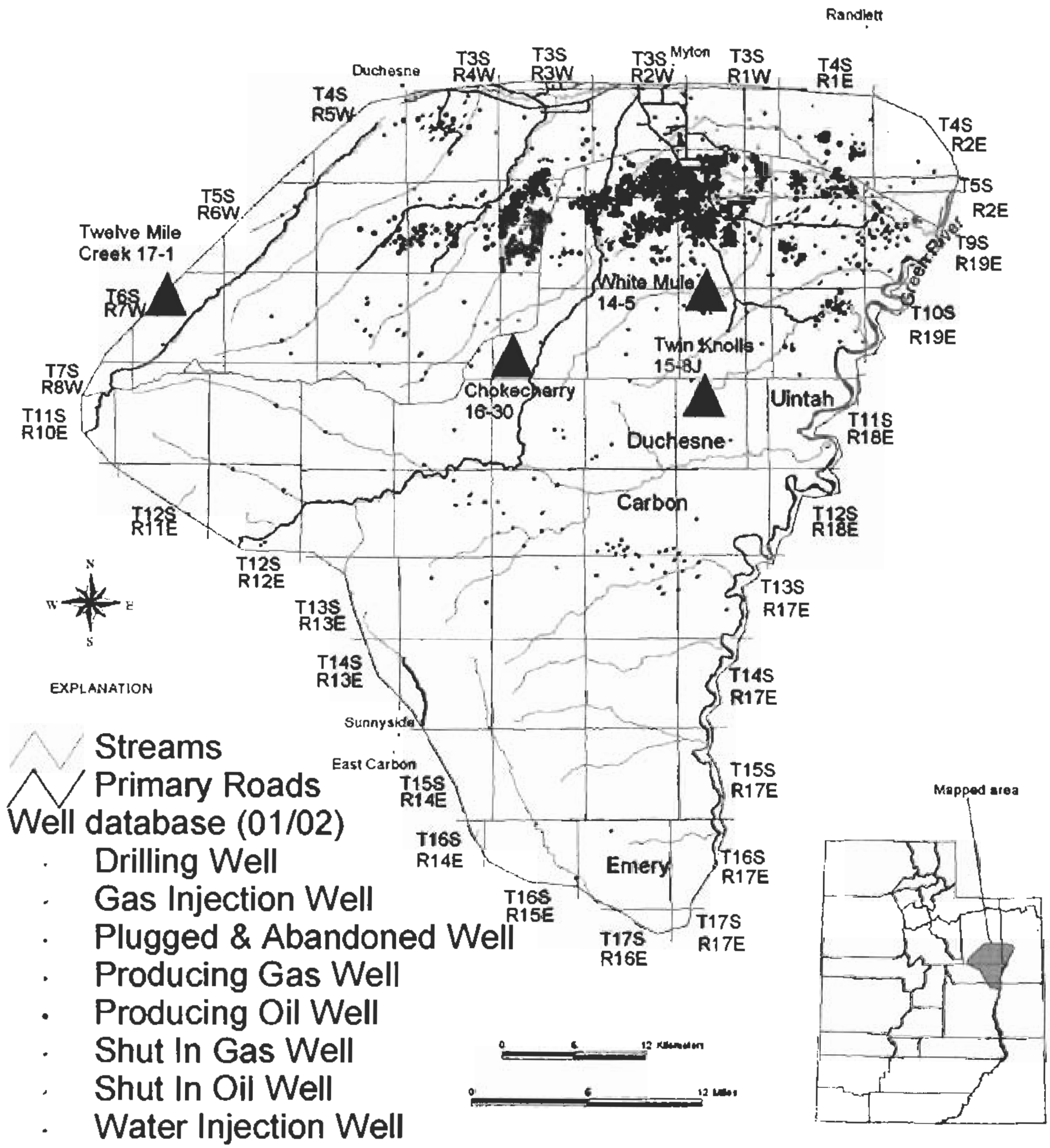


Figure 87. Map showing the location (triangles labeled with the well name and number) of some example wildcat wells with hydrocarbon shows, that are discussed in the report.

The White Mule 14-5 well (SW1/4SW1/4 section 5, T. 10 S., R. 17 E., SLBL) has a 20-foot (6.1-m) thick carbonate marker bed (top of the Castle Peak reservoir) with 10 percent or more density-log porosity at a depth of 4,815 feet (1,467.6 m). The well was drilled in 1983 from a KB elevation of 5,866 feet (1,787.9 m). The carbonate marker bed was perforated along with six other beds in the Castle Peak. The well was completed pumping 4 BO (0.6 m^3) per day but only produced 841 BO (133.7 m^3) before being abandoned. The White Mule 14-5 well was an offset to the Wells Draw 1 well (NW1/4SE1/4 section 8, T. 10 S., R. 17 E., SLBL) drilled in 1961, which encountered a thinner carbonate marker bed at a depth of 4,705 feet (1,434.1 m). An open-hole drill-stem test of the bed recovered 120 feet (36.6 m) of oil and 60 feet (18.3 m) of gas-cut mud in the drill pipe. The well was completed in the deeper Uteland Butte reservoir.

The porosity development in the carbonate marker bed in the White Mule well, could be a lead to a much larger algal-mound reservoir. Osmond (2000) describes a stromatolitic algal-boundstone reservoir (carbonate marker bed) in the West Willow Creek (T. 9 S., R. 19 E., SLBL) and Willow Creek (T. 10 S., R. 20 E., SLBL) fields, both fields are just east of the study area. The mound in the West Willow Creek field covers an area of roughly 1,240 acres (500 ha), reaches a maximum thickness of 100 feet (30.5 m), and has produced 827,912 BO (131,638 m^3) and 4.167 billion cubic feet of gas (118 million m^3) (through April 1999). The mound in the Willow Creek field covers 3,000 acres (1,200 ha), with a maximum thickness of 116 feet (35.4 m). The Willow Creek field produces from the deeper Wasatch Formation because the mound contains water.

The Twin Knolls 15-8J well (SW1/4SE1/4 section 8, T. 11 S., R. 17 E., SLBL) has a 58-foot (17.7-m) thick sandstone bed with 50 feet (15.2 m) having 10 percent or more density-log porosity in the MGR 4 (upper Douglas Creek reservoir) at a depth of 3,104 feet (946.1 m). The well was drilled in 1998 from a KB elevation of 6,515 feet (1,985.8 m). Porous sandstone beds are in the lower Douglas Creek and Castle Peak reservoirs as well. There are no reports of any tests in the Green River Formation before the well was plugged and abandoned.

Exploration Trends

Much of the southwest Uinta Basin has been extensively drilled but there is still room for exploration and discovery of new oil fields. The problem with a study like this with specific boundaries, is that most leads seem to be just developing within the study area and it's necessary to look beyond the boundaries to understand the leads. Never the less, several general exploration trends can be discussed within the limits of the study.

Most of the exploration trends in the middle and lower members of the Green River Formation follow shoreline or shelf-break trends of Lake Uinta. Most of the trends in the Monument Butte area are west to east and appear to shift southwest on the west side of the Monument Butte area into the Indian Canyon and Willow Creek Canyon area which we refer to as the Willow Creek embayment, and southeast on the east side of the Monument Butte area. This Monument Butte bulge crudely defines the Sunnyside delta (Remy, 1992), which dominated middle member depositional patterns in the southwest Uinta Basin. Unfortunately, less sandstone may be encountered as exploration follows the shoreline trends to the west and east side of the delta away from the primary area of sediment input. Long shore drift was from west to east, as a result, the east side of the delta may have good reservoir potential in shallow bar and shoreline deposits.

The Uteland Butte reservoir is a good exploration target with potential in the beach and bar sandstone deposits (figure 88). These sandstone beds typically are thin with low porosity and

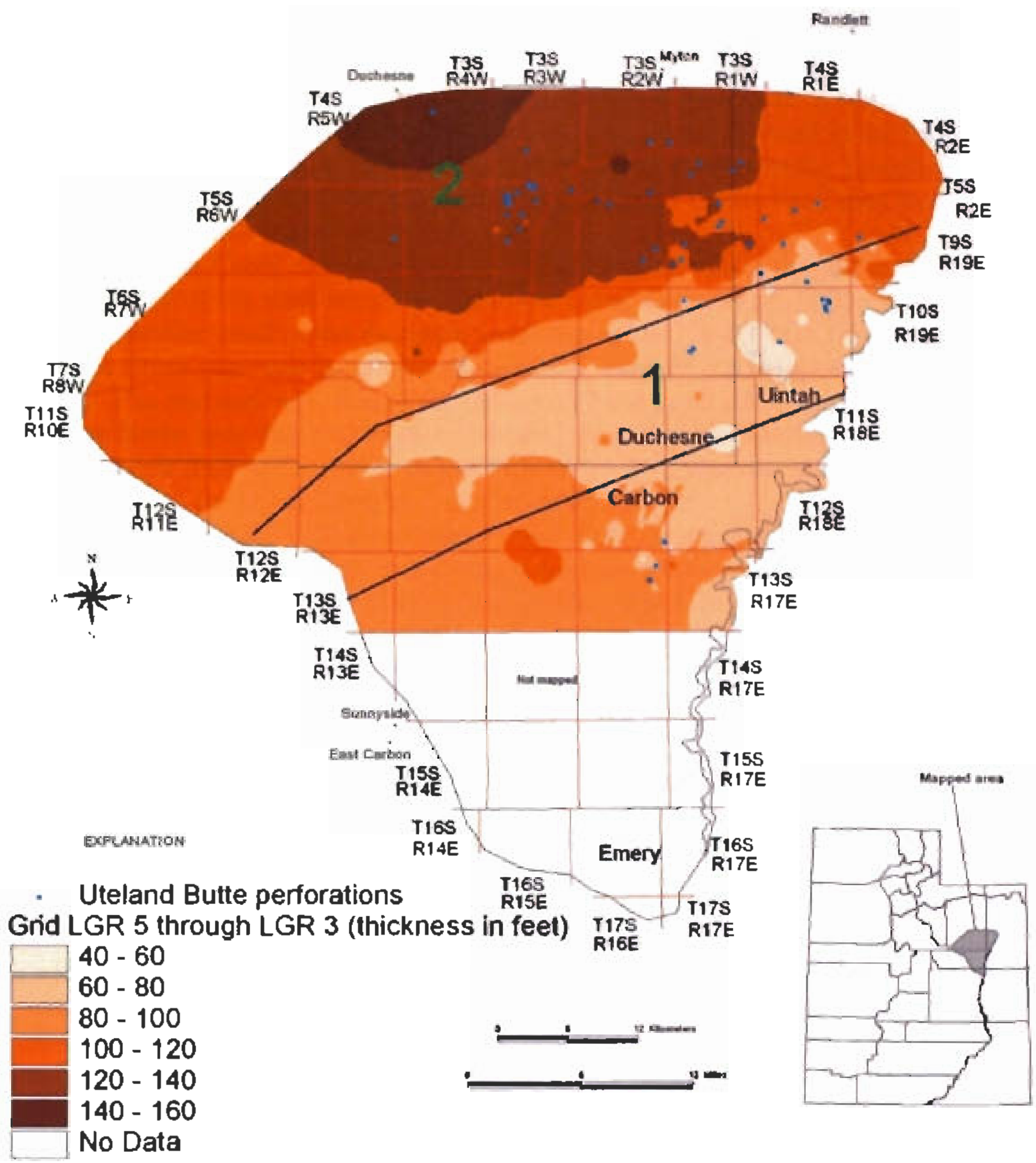


Figure 88. Trend of the Uteland Butte reservoir, lower member of the Green River Formation. Area 1 is the depositional trend of shallow beach and bar sandstone beds. Area 2 consists of distal open-lacustrine low-permeability carbonate beds that typically produce a low volume of oil and is a secondary drilling objective, but the area may also contain some high-permeability crystalline dolomite beds.

permeability but could be laterally extensive. The distal carbonates are a good low-volume secondary objective and have the potential for higher-volume discoveries in thin dolomitized beds. The dolomitized beds identified in core have high porosity but low permeability. Unfortunately, conventional well logs do not measure permeability so a high-porosity high-permeability dolomite can only be distinguished from a high-porosity low-permeability dolomite by testing.

The Castle Peak reservoir is limited in the updip direction by a zone of sediment bypass where well-developed channel sandstone beds pinch out. The shoreline trend in the Monument Butte area is about west to east, but in the western portion of the study area the shoreline turned sharply to the southwest. As a result, the exploration trend for the Castle Peak may trend southwest from the Monument Butte area (figure 89).

The lower Douglas Creek reservoir is a cut-and-fill deposit and is limited in the updip direction by the location of the shelf break during lower Douglas Creek time. The shelf break appears to follow a similar trend as the shoreline trend during the Castle Peak time (figure 90). The upper Douglas Creek reservoir is dominantly stacked, amalgamated channel deposits of the lower delta plain. The east and west side of the delta may have good quality reservoir rock but will probably have fewer beds that will be more isolated than stacked (figure 91). The overall thinning of the reservoir rock and isolation of the beds result in more expensive completions, and create economic limits to the upper Douglas Creek reservoir.

The Garden Gulch reservoir is a secondary target in the southwest Uinta Basin and has not been systematically explored. The Garden Gulch contains a few porous sandstone beds in the northern portion of the study area that have been produced in some wells. The Garden Gulch has not been proven to contain sufficient oil to produce by itself economically. However, because of the shallower drilling depths compared to the other reservoirs, the Garden Gulch could become a primary target in some areas.

Horizontal Drilling Potential

Horizontal drilling has rarely been tried in the middle and lower members of the Green River Formation anywhere in the Uinta Basin. A short lateral was drilled into the Castle Peak sandstone in Brundage Canyon many years ago. Very little is known about this horizontal well and production was not significantly improved. Chevron Oil Company drilled some short laterals into a carbonate bed in the Douglas Creek Member of the Green River Formation, in the Red Wash field to the northeast of the study area. The company did not feel that horizontal drilling increased their production relative to the increased cost, and the program was stopped.

The major deterrent to horizontal drilling in the Uinta Basin has been the number of beds typically perforated in a well. The majority of the wells in the Uinta Basin are marginally economic, therefore operators feel they must perforate and produce as many beds as they can in order to maintain an economical production rate. Horizontal drilling would require selecting a single bed for exploitation while abandoning any oil-productive beds below the horizontal leg.

The best candidate for horizontal drilling is the lower Douglas Creek reservoir. The lower Douglas Creek contains very thick (often > 100 feet [30 m]) sandstone beds that are oil saturated. But oil recovery is often very low because of the internal heterogeneity within the bed. High-porosity units within the lower Douglas Creek beds can be correlated in developed units with wells drilled on 40 acre (16.2 ha) centers. Many of the units in the greater Monument Butte area with thick lower Douglas Creek sandstone produce small quantities from the Castle Peak and Uteland Butte reservoirs below the lower Douglas Creek. The wells in these units may be good candidates for drilling short horizontal laterals from the existing well bores along the

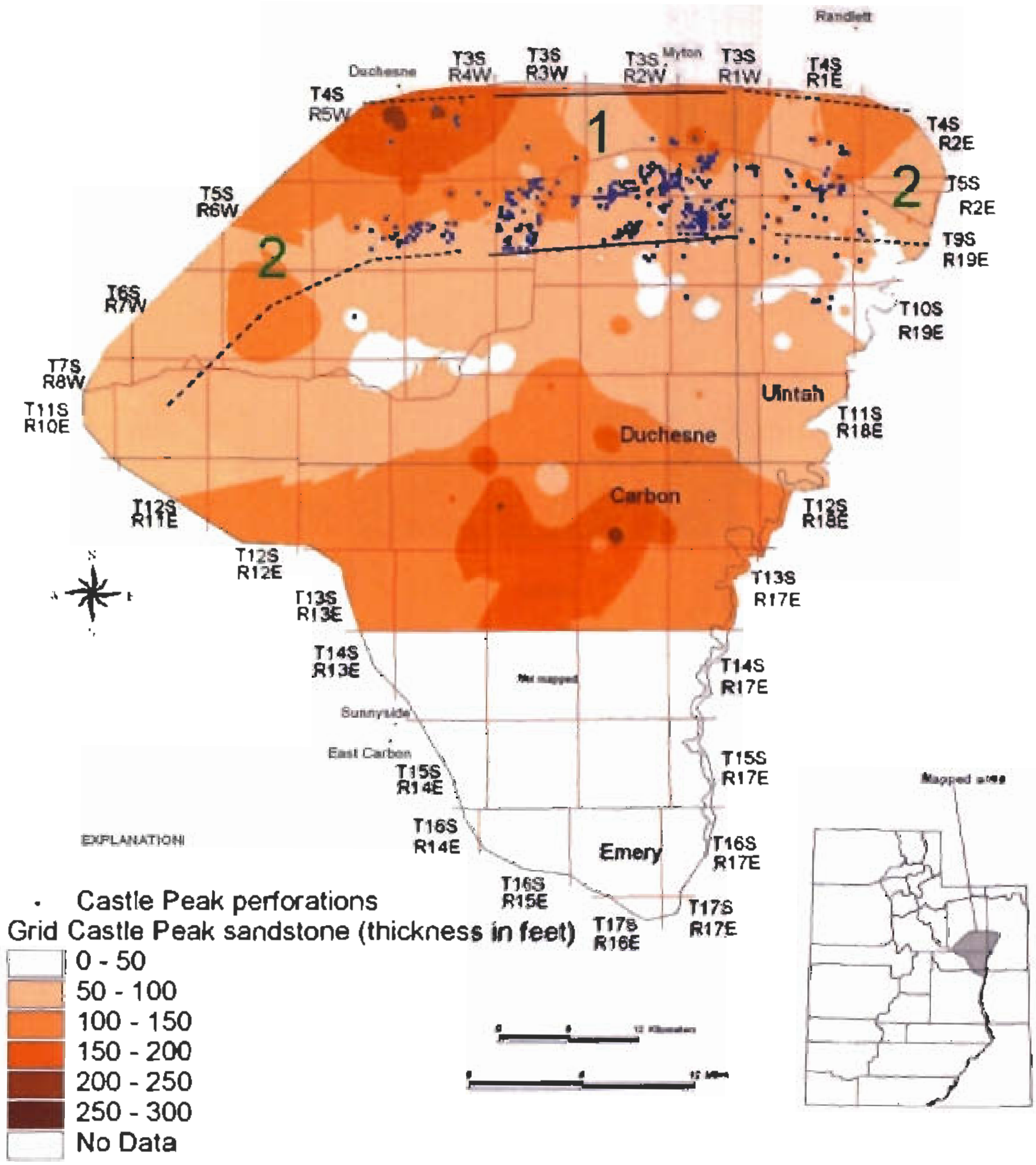


Figure 89. Trend of the Castle Peak reservoir, lower member of the Green River Formation. Area 1 consists of lake-level fall-to-rise cycles resulting in isolated channel and floodplain deposits bounded by carbonate beds. Area 2 may contain similar deposits but is less constrained by well data.

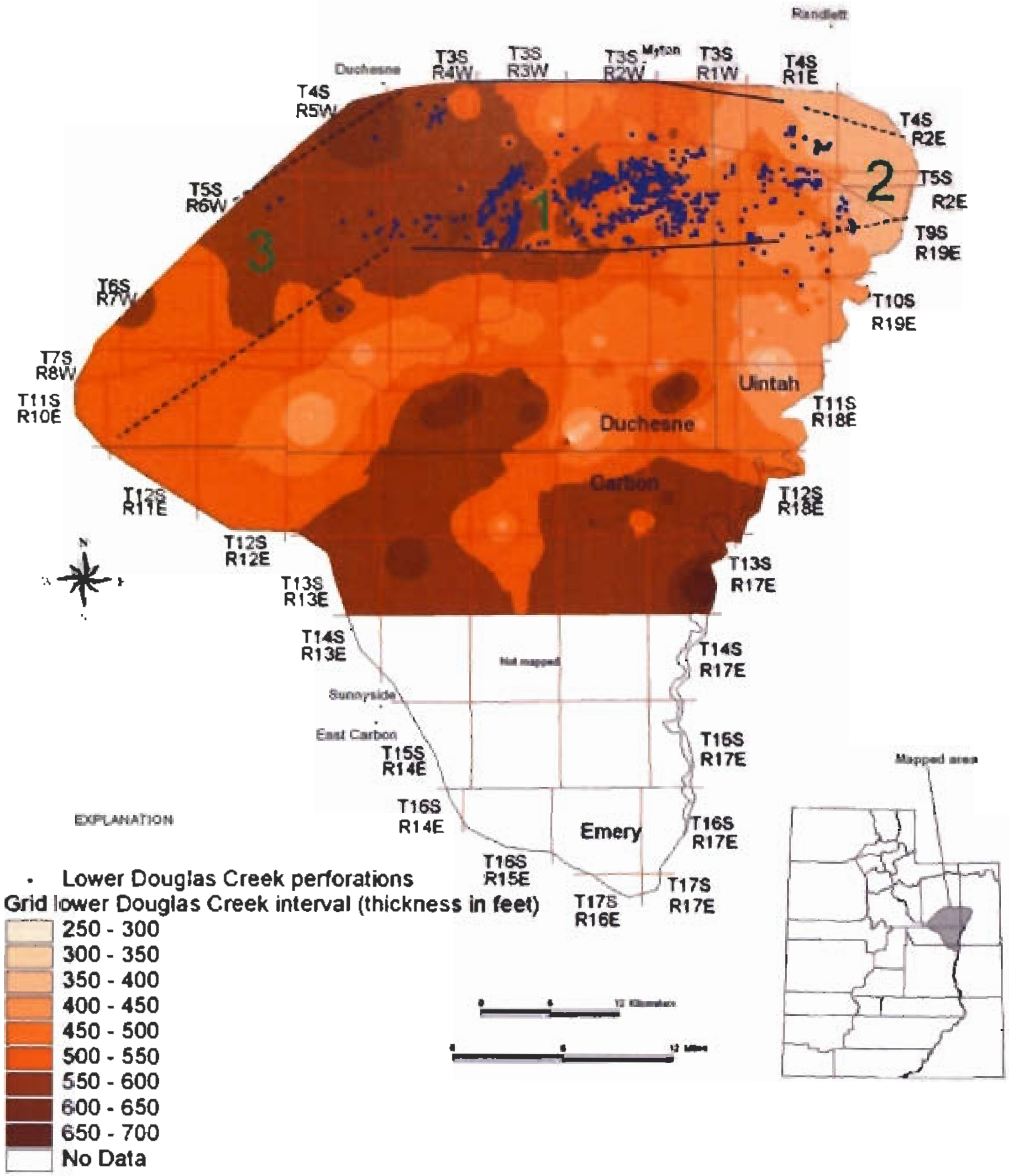


Figure 90. Trend of the lower Douglas Creek reservoir, middle member of the Green River Formation. Area 1 is dominantly thick cut-and-fill, incised valley-fill deposits and some thinner distributary-channel and mouth-bar deposits developed along a generalized shelf break during several lake-level falls. Area 2 consists of distributary-channel and mouth-bar deposits but the eastward extension of the shelf break is uncertain. Area 3 most likely consists of fewer distributary-channel and mouth-bar deposits and is unlikely to contain thick, incised valley-fill deposits.

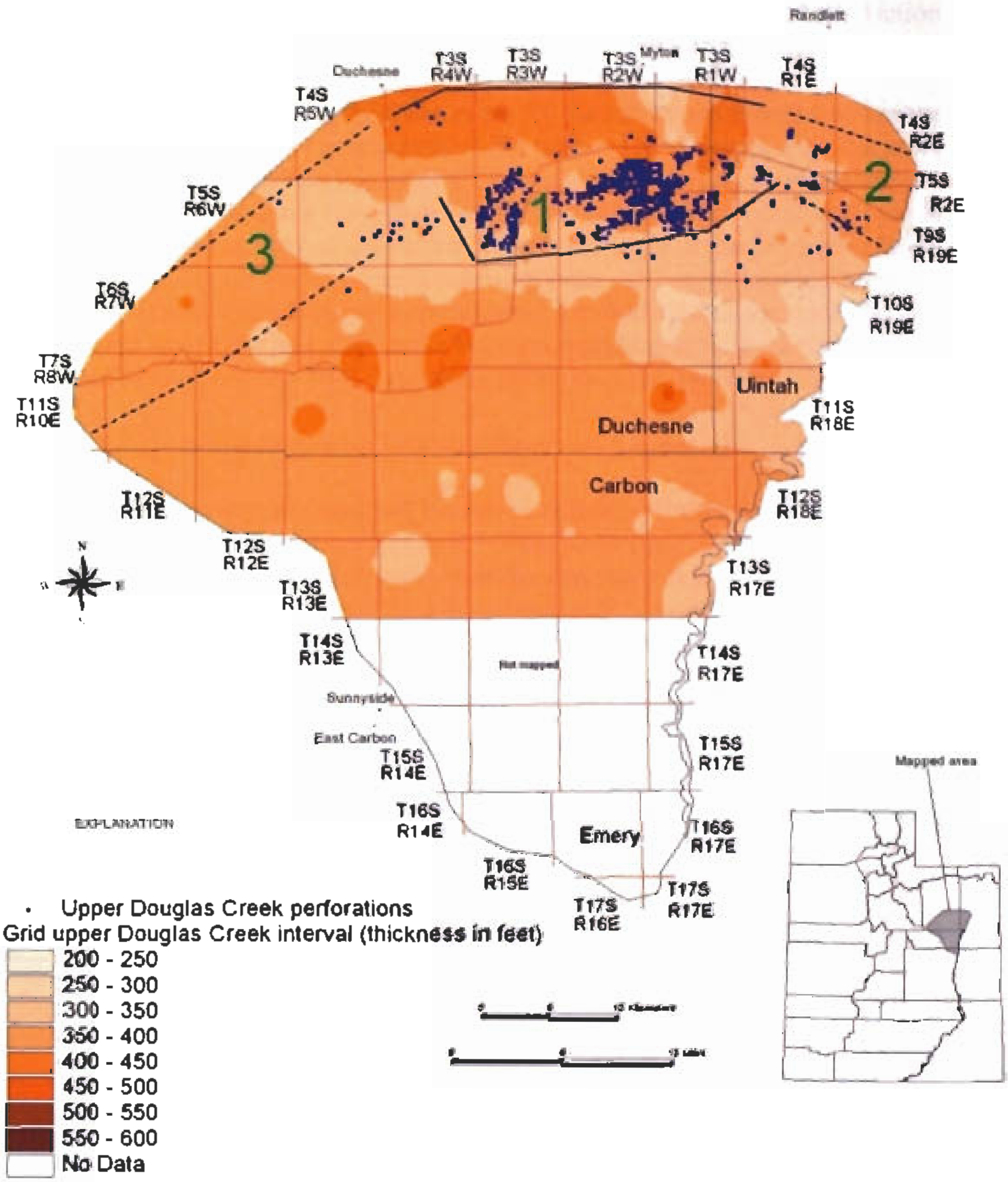


Figure 91. Trend of the upper Douglas Creek reservoir, middle member of the Green River Formation. Area 1 is dominantly amalgamated, stacked, distributary-channel and mouth-bar sandstone beds forming the main body of the lowstand deltas. Area 3 most likely consists of isolated distributary channels and poorly developed distributary mouth bars. Area 2 most likely consists of some distributary-channel and mouth-bar deposits but more wave-dominated shoreline and shallow-bar deposits.

strike of the lower Douglas Creek sandstone bed. Production potential from the deeper Castle Peak and Uteland Butte reservoirs may be insignificant in wells after an initial production period. The increased production from the lower Douglas Creek should more than off set any loss from abandoning the deeper reservoirs.

Horizontal drilling can be a good option in any of the reservoirs where fractures are known to play a dominant role in the production of the wells. This is especially true along the west-to-east trend of the Duchesne fault zone (DFZ). Only one horizontal well has been attempted along the DFZ. A shallow (less than 3,000 feet [900 m]) horizontal well was drilled in fractured shale of the upper member of the Green River Formation in the Duchesne field. Numerous fractures yielding oil were encountered but further drilling penetrated a water-bearing fracture zone. The operator was unable to stop the water production and the well was abandoned. Fractured sandstone and shale have been encountered in the middle and lower members in vertical wells along the DFZ indicating good potential for horizontal drilling.

Secondary and Tertiary Recovery Potential

The greater Monument Butte area has become a major oil producing region in the Uinta Basin since the U. S. Department of Energy Class I (Fluvial-Deltaic Reservoirs) demonstration program showed the economical feasibility of water flooding the middle and lower member reservoirs of the Green River Formation. The Class I study discovered that the reservoirs are near the bubble point and by starting a water flood soon after drilling the wells in a unit, the reservoir pressure is maintained above the bubble point, resulting in greatly increased oil recovery. It is now common practice in the Monument Butte area to develop a section on 40 acre (16.2 ha) spacing, produce all the wells initially for a few months, then convert every other well to a water injection well.

There are numerous tertiary recovery methods that have not been tested in the reservoirs of the Green River Formation. A pilot carbon dioxide (CO_2) flood was attempted in the Red Wash field in the 1980s, injecting CO_2 into four different wells that were producing from the Douglas Creek Member of the Green River Formation. Break through, CO_2 reaching neighboring wells, occurred almost instantly in two of the tests. As a result, the pilot program was abandoned. The greater Monument Butte area is an excellent candidate for tertiary recovery.

The water-flood program has been very successful because it maintains the reservoir pressure above the bubble point but it provides a poor sweep of the reservoir because of the low porosity and permeability. As a result, a large volume of oil is still being left behind that might be produced through tertiary methods. Tertiary methods that should be considered for oil production in the greater Monument Butte area are: (1) water alternating gas (WAG), (2) chemical flood such as a combination of alkalines, surfactant, and polymers (ASP), and (3) microbial.

ACKNOWLEDGMENTS

This report is the result of a study entitled *Reservoir characterization of the lower Green River Formation, southwest Uinta Basin, Utah*. The study was funded in part by the U. S. Department of Energy National Petroleum Technology Office (NPTO) in Tulsa, Oklahoma, under the Fundamental Geoscience for Reservoir Characterization program, contract number DE-AC26-98BC15103. U. S. Department of Energy contract manager is Virginia Weyland, NPTO, Tulsa, Oklahoma.

We appreciate the following company personnel and consultants who served as Technical Advisors to the study: Kevin Weller, Westport Company, Denver (formerly with Inland Resources, Inc.); Ben Crouch, Osage Oil, Hutchinson (formerly with Petroglyph Operating Company, Inc.); Terry Barrett and Jim Turner, formerly with Barrett Resources, Corp, Denver; Phil Moffitt, Questar E&P, Denver; Tom Yeager, Questar Gas Company, Salt Lake City; Logan MacMillan, Dick Castle, Roger Hively, and John Osmond, consultants, Denver; Mary McPherson, consultant, Grand Junction. We appreciate all the companies that have donated core to the Utah Geological Survey.

Many people at the Utah Geological Survey assisted with this study. Thomas Chidsey, Jr., Mark Milligan, and Bryce Tripp, assisted with the field work. Carolyn Olsen and Thomas Dempster prepared and photographed the much of the core. Sharon Wakefield was in charge of all of the GIS work done during the project. Barbara Marin with TerraTek, Salt Lake City, was responsible for all of the SEM work performed during the study. David Keighley, Halifax, completed his research for Shell Oil in Nine Mile Canyon just as our study was beginning. We appreciate Shell Oil allowing David to release the results of his work. David's correlations, sequence stratigraphic interpretation, and personnel advice, were very helpful to our study.

We would also like to thank all of the private ranchers in Nine Mile Canyon for allowing us access to their property. Dennis Willis with the Price office of the U.S. Bureau of Land Management was very helpful in providing us with access to the Desolation Canyon area. The work in Desolation Canyon would not have been possible without our volunteer boatmen; Tom Yeager, Salt Lake City; Jim Yeager, Corinne; Don Neff, Salt Lake City; Darrell and Kyle Buffington, Denver.

REFERENCES

Abbott, W.O., 1957, Tertiary of the Uinta Basin, *in* Seal, O.G., editor, Guidebook to the geology of the Uinta Basin: Intermountain Association of Petroleum Geologists Eighth Annual Field Conference, p. 102-109.

Anders, D.E., Palacas, J.G., and Johnson, R.C., 1992, Thermal maturity of rocks and hydrocarbon deposits, Uinta Basin, Utah, *in* Fouch, T.D., Nuccio, V.F., and Chidsey, T.C., Jr., editors, Hydrocarbon and Mineral Resources of the Uinta Basin, Utah and Colorado: Utah Geological Association Publication 20, p.53-76.

ASTM, 2001, method D 2798-99, Standard test method for microscopical determination of the reflectance of vitrinite in a polished specimen of coal: Annual Book of ASTM standards 2000 section five, volume 05.06. American Society for Testing and Materials, West Conshohocken, PA, p. 208-212.

Borer, J.M., 1998, High-resolution stratigraphy of the lower Green River Formation at Raven Ridge and Red Wash field, NE Uinta Basin - stratigraphic control on petroleum [abs.]: American Association of Petroleum Geologists Annual Convention Abstracts on CD-ROM.

Borer, J.M., and McPherson, M.L., 1996, High-resolution stratigraphy of the Green River Formation, NE Uinta Basin - implications for Red Wash reservoir compartmentalization [abs.]: American Association of Petroleum Geologists Annual Convention with Abstracts p. A18.

Bradley, W.H., 1931, Origin and microfossils of the oil shale of the Green River Formation of Colorado and Utah: U. S. Geological Survey Professional Paper 168, 56 p.

Cashion, W.B., 1967, Geology and fuel resources of the Green River Formation, southeastern Uinta Basin, Utah and Colorado: U. S. Geological Survey Professional Paper 548, 48 p.

Colburn, J.A., Bereskin, S.R., McGinley, D.C., and Schiller, D.M., 1985, Lower Green River Formation in the Pleasant Valley producing area, Duchesne and Uintah Counties, Utah, *in* Picard, M.D., editor, Geology and energy resources, Uinta Basin, Utah: Utah Geological Association Publication 12, p. 177-186.

Crouch, B.W., Hackney, M.L., and Johnson, B.J., 2000, Sequence stratigraphy and reservoir character of lacustrine carbonates in the basal limestone member - lower Green River Formation (Eocene), Duchesne and Antelope Creek fields, Duchesne Co., Utah [abs.]: American Association of Petroleum Geologists Annual Convention Program with Abstracts, p. A34.

Davis, J.C., 1984, Statistics and Data Analysis in Geology: John Wiley and Sons, New York, 550 pp.

Dow, W.G., 1977, Kerogen studies and geological interpretations: Journal of Geochemical Exploration, v. 7, p. 79-99.

Fouch, T.D., 1975, Lithofacies and related hydrocarbon accumulations in Tertiary strata of the western and central Uinta Basin, Utah, *in* Bolyard, D.W., editor, Symposium on deep drilling frontiers in the central Rocky Mountains: Rocky Mountain Association of Geologists, p. 163-173.

Fouch, T.D., Nuccio, V.F., Osmond, J.C., MacMillan, Logan, Cashion, W.B., and Wandrey, C.J., 1992, Oil and gas in uppermost Cretaceous and Tertiary rock, Uinta Basin, Utah, *in* Fouch, T.D., Nuccio, V.F., and Chidsey, T.C., Jr., editors, Hydrocarbon and mineral resources of the Uinta Basin, Utah and Colorado: Utah Geological Association Publication 20, p. 9-47.

Fouch, T.D., Nuccio, V.F., Anders, D.E., Rice D.D., Pitman, J.K., and Mast, R.F., 1994, Green River petroleum system, Uinta Basin, Utah, U.S.A., *in* Magoon, L.B., and Dow, W.G., editors, The petroleum system - from source to trap: American Association of Petroleum Geologist Memoir 60, p. 399-421.

Fouch, T.D., and Pitman, J.K., 1991, Tectonic and climate changes expressed as sedimentary cycles and stratigraphic sequences in the Paleogene Lake Uinta system, central Rocky Mountains, Utah and Colorado [abs.]: American Association of Petroleum Geologists Bulletin, v. 75, no. 3, p. 575.

---1992, Tectonic and climate changes expressed as sedimentary and geochemical cycles - Paleogene lake systems, Utah and Colorado - implications for petroleum source and reservoir rocks, *in* Carter, L.J., editor, U. S. Geological Research on Energy Resources, 1992 McKelvey Forum Program and Abstracts [abs.]: U. S. Geological Survey Circular 1074, p. 29-30.

Franczyk, K.J., Fouch, T.D., Johnson, R.C., Molenaar, C.M., and Cobban, W.A., 1992, Cretaceous and Tertiary paleogeographic reconstructions for the Uinta-Piceance Basin study area, Colorado and Utah: U. S. Geological Survey Bulletin 1787-Q, 37 p.

Hackney, M.L., and Crouch, B.W., 2000, The Castle Peak member of the lower Green River Formation, Antelope Creek field, Duchesne Co., Utah - an example of the effects of a migrating shoreline on the expression of an open-lacustrine carbonate facies [abs.]: American Association of Petroleum Geologists Annual Convention Program with Abstracts, p. A62.

Jacob, A.F., 1969, Delta facies of the Green River Formation (Eocene), Carbon and Duchesne Counties, Utah: Boulder, University of Colorado, Ph.D. dissertation, 97 p.

Johnson, R.C., and Nuccio, V.F., 1993, Surface vitrinite reflectance study of the Uinta and Piceance Basins and adjacent areas, eastern Utah and western Colorado Implications for development of Laramide basins and uplifts: U. S. Geological Survey Bulletin 1787DD, 38 p.

Keighley, David, Collins, Stephen, Flint, Stephen, and Howell, John, 1999, Reservoir-scale distribution of fluvial sandbodies in lacustrine closed basins, and some sequence-stratigraphic implications - Green River Formation, SW Uinta Basin, east-central Utah [abs.]: American Association of Petroleum Geologists Annual Convention Program with Abstracts, p. A71.

Keighley, David, Flint, Stephen, and Howell, John, 2001, High-resolution lacustrine sequence stratigraphy - an example from the Green River Formation, Uinta Basin, east-central Utah [abs.]: American Association of Petroleum Geologists Annual Convention Program with Abstracts, p. A102.

Keighley, David, Flint, Stephen, Howell, John, Anderson, Daniel, Collins, Stephen, Moscariello, Andrea, and Stone, Greg, 2002, Surface and subsurface correlation of the Green River Formation in central Nine Mile Canyon, SW Uinta Basin, Carbon and Duchesne Counties, east-central Utah: Utah Geological Survey Miscellaneous Publication 02-1, CD-ROM.

Little, T.M., 1988, Depositional environments, petrology, and diagenesis of the basal limestone facies, Green River Formation (Eocene), Uinta Basin, Utah: Salt Lake City, University of Utah, M.S. thesis, 154 p.

Lutz, S.J., Nielson, D.L., and Lomax, J.D., 1994, Lacustrine turbidite deposits in the lower portion of the Green River Formation, Monument Butte field, Uinta Basin, Utah [abs.]: American Association of Petroleum Geologists Annual Meeting Program with Abstracts, v. 3, p. 203.

McDonald, R.E., 1972, Eocene and Paleocene rocks of the southern and central basins, *in* Mallory, W.M., editor, Geologic atlas of the Rocky Mountain region: Rocky Mountain Association of Geologists, p. 243-256.

Morgan, C.D., Chidsey, T.C., Jr., Hanson, J.A., McClure, K.P., Weller, Kevin, Bereskin, S.R., Deo, M.D., and Yeager, Randy, 1999, Reservoir characterization of the lower Green River Formation, southwest Uinta Basin, Utah: Unpublished biannual technical progress report to the U. S. Department of Energy for the period 10/1/98 through 3/31/99, 11 p.

Nuccio, V.F., and Johnson, R.C., 1986, Thermal maturity map of the lower part of the upper Cretaceous Mesaverde Group, Uinta Basin, Utah: Miscellaneous Field Study Map MF-1842.

Osmond, J.C., 1992, Greater Natural Buttes gas field, Uintah County, Utah, *in* Fouch, T.D., Nuccio, V.F., and Chidsey, T.C., Jr., editors, Hydrocarbon and mineral resources of the Uinta Basin, Utah and Colorado: Utah Geological Association Publication 20, p. 143-163.

---2000, West Willow Creek field - first productive lacustrine stromatolite mound in the Eocene Green River Formation, Uinta Basin, Utah: Rocky Mountain Association of Geologists, The Mountain Geologist, v. 37, no. 3, p. 157-170.

Picard, M.D., 1955, Subsurface stratigraphy and lithology of the Green River Formation in Uinta Basin, Utah: American Association of Petroleum Geologists Bulletin, v. 39, no. 1, p. 75-102.

---1957a, Subsurface stratigraphy and lithology of Green River Formation in the Uinta Basin: American Association of Petroleum Geologists Bulletin, v. 39, p. 75-102.

---1957b, Green shale facies, lower Green River Formation, Utah: American Association of Petroleum Geologists Bulletin, v. 41, p. 2373-2376.

Picard, M.D., and High, L.R., 1970. Sedimentology of oil-impregnated, lacustrine and fluvial sandstone, P.R. Spring area, southeast Uinta Basin, Utah: Utah Geological and Mineral Survey Special Studies 33, 32 p.

Pitman, J.K., Fouch, T.D., and Goldaber, M.B., 1982, Depositional setting and diagenetic evolution of some Tertiary unconventional reservoir rocks, Uinta Basin, Utah: American Association of Petroleum Geologists Bulletin, v. 66, no. 10, p. 1581-1596.

Pitman, J.K., Franczyk, K.J., and Anders, D.E., 1988, Diagenesis and burial history of nonmarine upper Cretaceous rocks in the central Uinta Basin, Utah: U. S. Geological Survey Bulletin 1787D, 24 p.

Remy, R.R., 1989, Deltaic and lacustrine facies of the Green River Formation, southern Uinta Basin, Utah, *in* Nummedal, D., and Remy, R.R., editors, Cretaceous shelf sandstones and shelf depositional sequences, Western interior basin, Utah, Colorado, and New Mexico: Washington, D. C., American Geophysical Union, International Geological Congress, 28th Guidebook T-119, p. 1-11.

---1992, Stratigraphy of the Eocene part of the Green River Formation in the south-central part of the Uinta Basin, Utah: U. S. Geological Survey Bulletin 1787-BB, 79 p.

Rice, D.D., Fouch, T.D., and Johnson, R.C., 1992, Influence of source rock type, thermal maturity, and migration on composition and distribution of natural gases, Uinta Basin, Utah, *in* Fouch, T.D., Nuccio, V.F., and Chidsey, T.C., Jr., editors, Hydrocarbon and Mineral Resources of the Uinta Basin, Utah and Colorado: Utah Geological Association Publication 20, p. 95-109.

Ruble, T.E., Lewan, M.D., and Philp, R.P., 2001, New insights on the Green River petroleum system in the Uinta Basin from hydrous pyrolysis experiments: American Association of Petroleum Geologists Bulletin, v. 85, p.1333-1371.

Ryder, R.T., Fouch, T.D., and Elison, J.H., 1976, Early tertiary sedimentation in the western Uinta Basin, Utah: Geological Society of America Bulletin, v. 87, p. 496-512.

Schmoker, J.W., Nuccio, V.F., and Pitman, J.K., 1992, Porosity trends in predominately nonmarine sandstones of the upper Cretaceous Mesaverde Group, Uinta and Piceance Basins, Utah and Colorado, *in* Fouch, T.D., Nuccio, V.F., and Chidsey, T.C., Jr., editors, Hydrocarbon and Mineral Resources of the Uinta Basin, Utah and Colorado: Utah Geological Association Publication 20, p.111-121.

Schumn, S.A., and Ethridge, F.G., 1994, Origin, evolution and morphology of fluvial valleys, *in* Dalrymple, R.W., and Zaitlin, B.A., editors, Incised-valley systems - origin and sedimentary sequences: Society of Sedimentary Geology Special Publication no. 51, p. 11-27.

Szantat, A.W., 1990, Paleohydrology and paleomorphology of Early Eocene Green River channel sandstones, Uinta Basin, Utah: Fort Collins, Colorado State University, M.S. Thesis, 109 p.

Trumbo, D.B., 1993, Brundage Canyon/Sowers Canyon, *in* Hill, B.G., and Bereskin, S.R., editors, Oil and gas fields of Utah: Utah Geological Association Publication 22, unpaginated.

Weiss, M.P., Witkind, I.J., and Cashion, W.B., 1990, Geologic map of the Price 30'X60' Quadrangle, Carbon, Duchesne, Uintah, Utah, and Wasatch Counties, Utah: U. S. Geological Survey Miscellaneous Investigations Series map I-1981, 1 sheet.

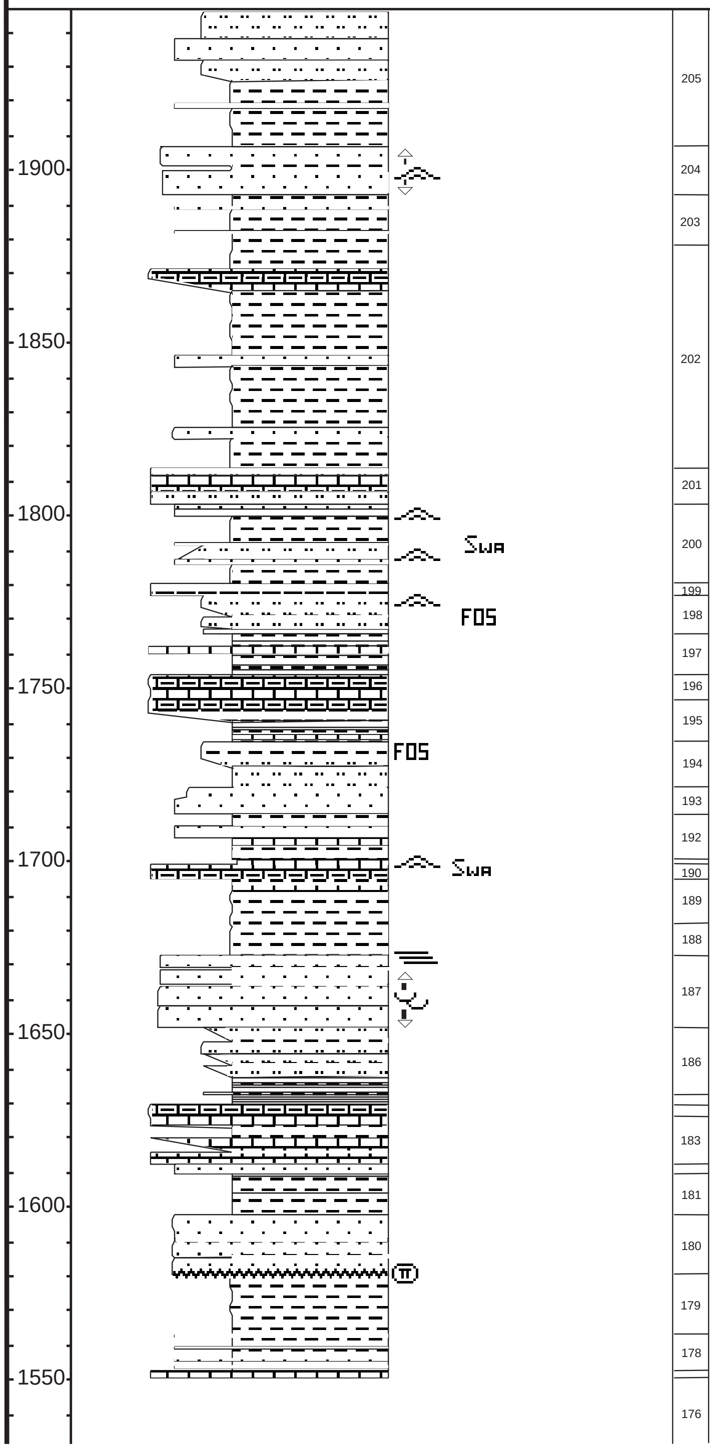
Back to Table of Contents Back to Report

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 Base line and Meridian, Duchesne County, Utah.

FEET	GRAIN SIZE: cobble, pebble, granule, sand (v c m f v), silt, clay	PHYSICAL STRUCTURES / ACCESSORIES / ICHNOFOSSILS / FOSSILS	UNIT NUMBER	Unit number (measured section thickness [cumulative] in feet) - Lithologic description



END OF ROAD CUT

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.

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.

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

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).

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.

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.

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

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

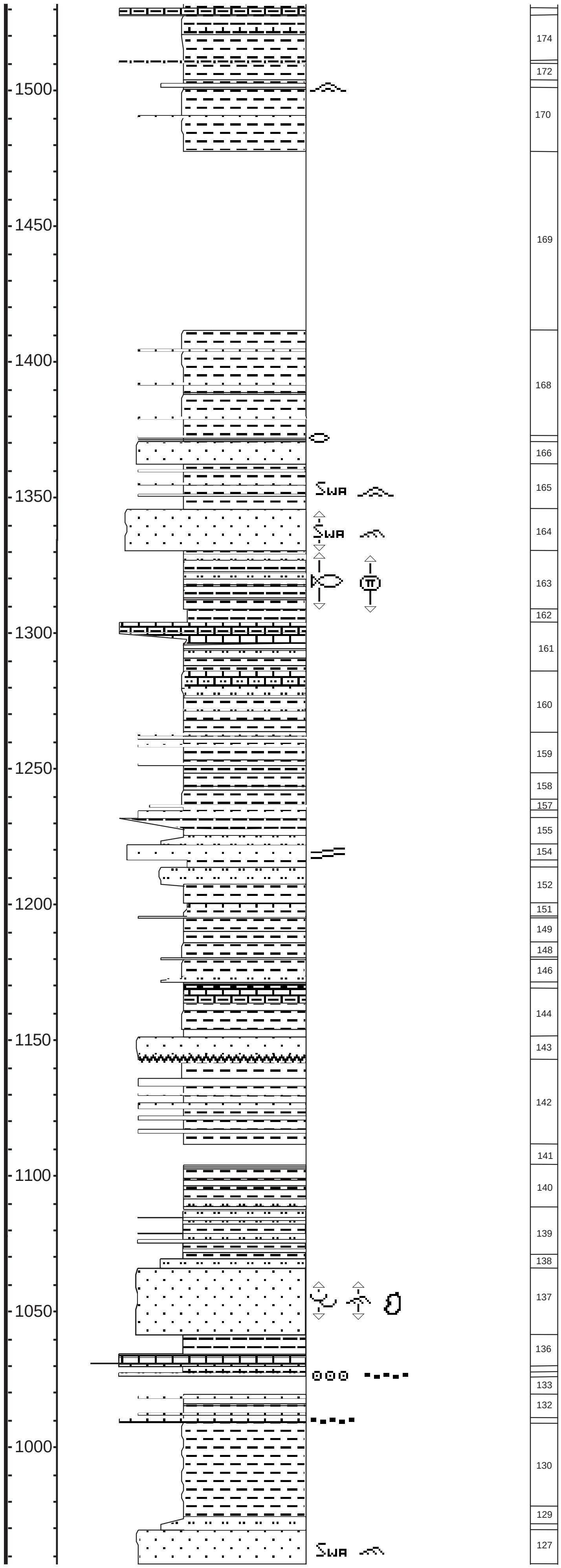
Unit 197 (1754-1766): Shale and muddy limestone, shale green, limestone beds are 6-12 inches thick.

Unit 196 (1747-1754): Muddy limestone.

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.

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

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.



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-thick 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.

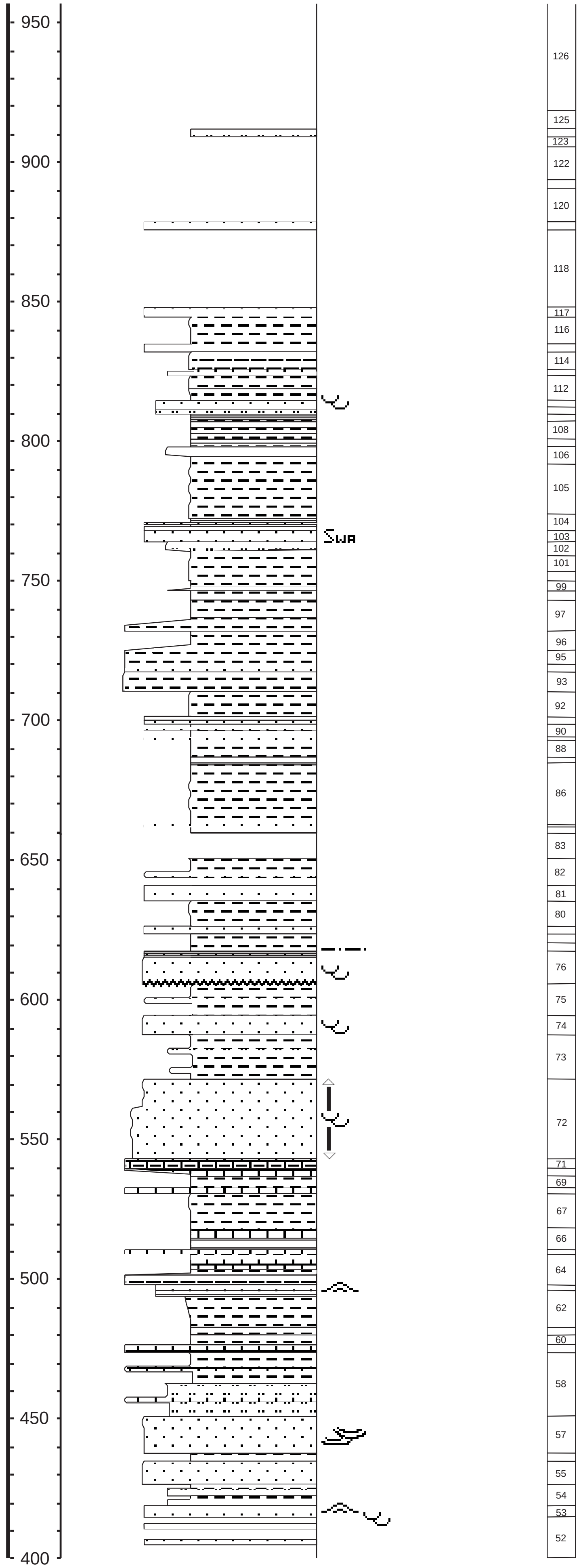
Unit 173 (1510.5-1511.5): Muddy limestone, light-brown, weathers orange.

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 1,377 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.

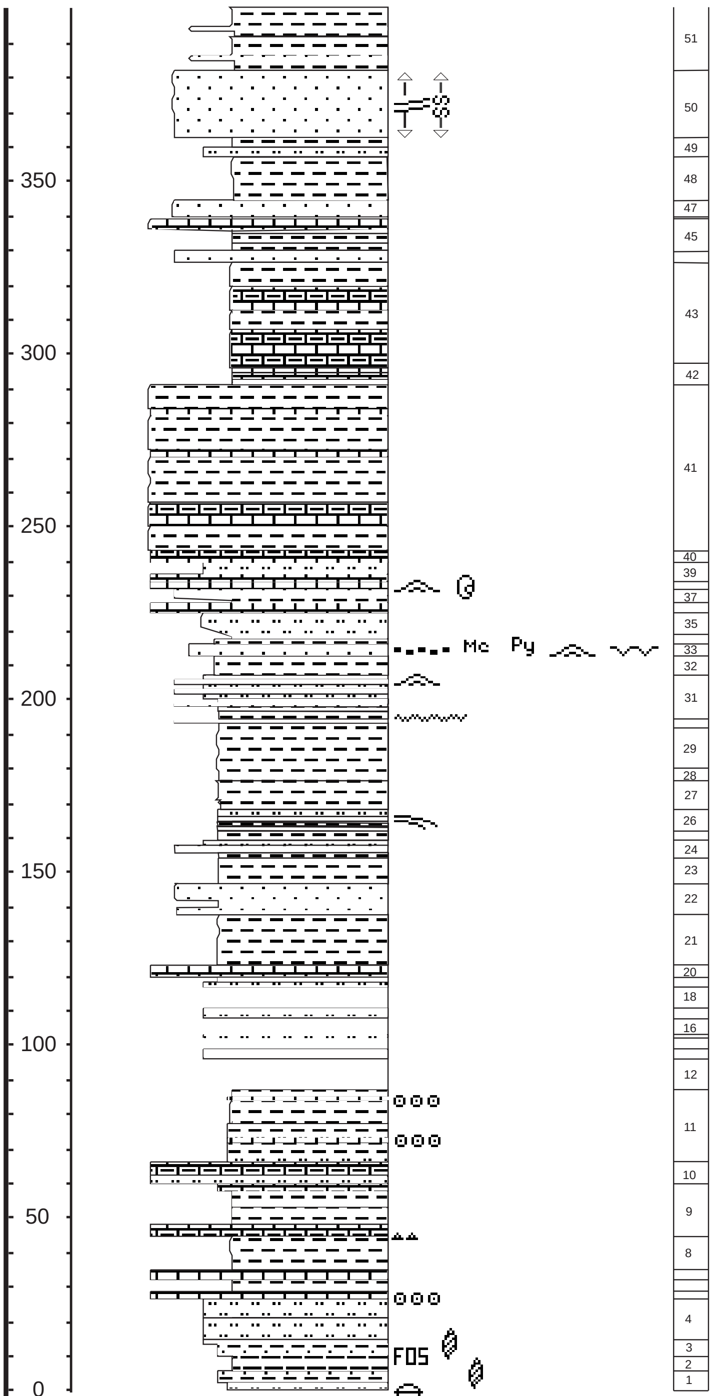
Unit 149 (1186-1184): Shale and interbedded sandstone, shale is green, sandstone beds thickening upward, coarsening upward sequence.

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

END OF ROAD CUT

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

Unit 146 (1172-1180): Siltstone and shale, green, weathered, calcareous, first 2 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 6-8-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 mudcracks 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 mollusc 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.
- Soft-Sediment Deformation
- Cross-Bedding
- Planar Lamination
- Ripples
- Scour
- Swaley Cross-Strat.
- Lenticular Bedding
- Low Angle Tabular Bedding
- Mud Cracks
- Climbing Ripples
- Concretions/Nodules

LITHOLOGIC ACCESSORIES

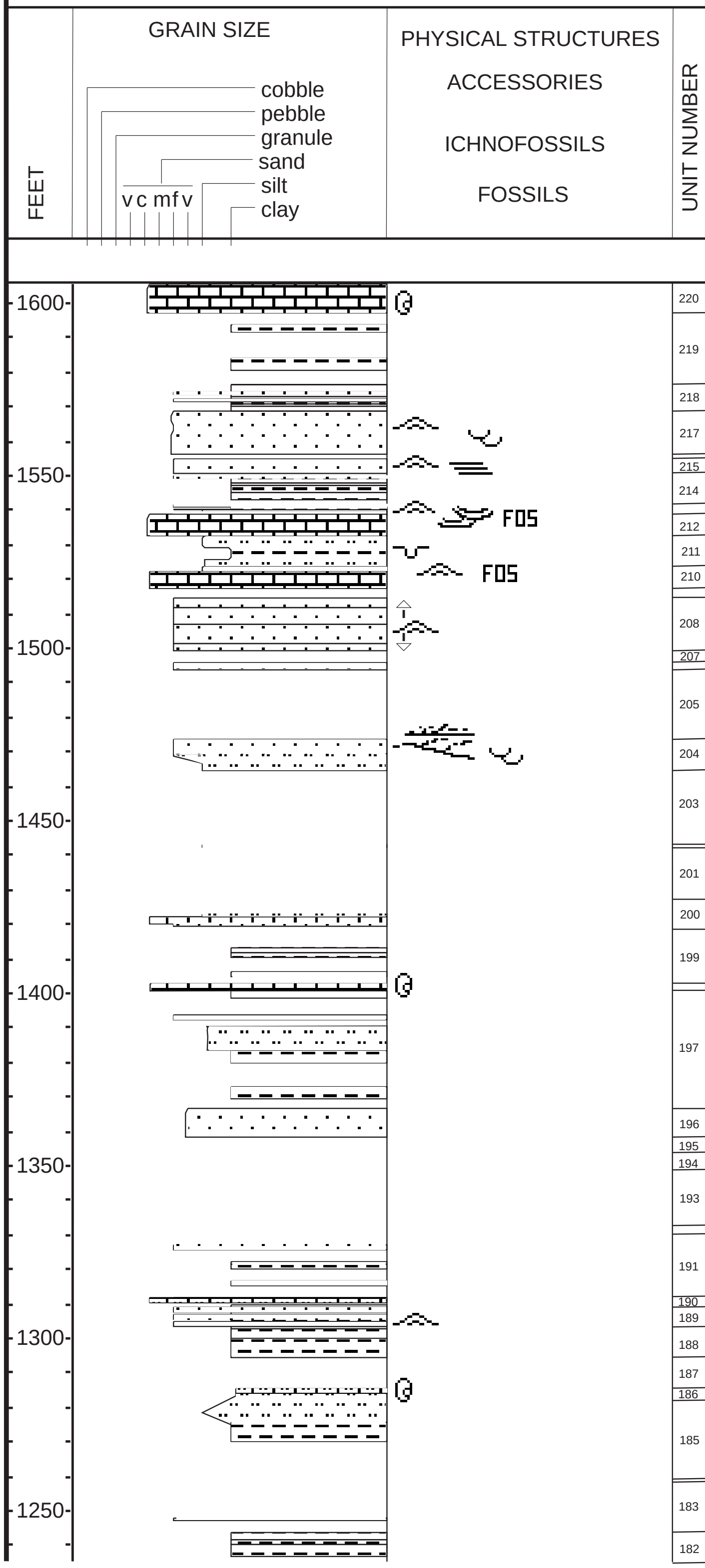
- Cherty
- Mc - Micaceous
- Py - Pyrite
- Oolites
- Clasts
- Silty

FOSSILS

- Molluscs (undifferentiated)
- Fish Scales
- Gastropods
- Fish Bone
- Ostracodes
- FOS - Fossils

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 Base line and Meridian, Carbon County, Utah.



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

Unit 220 (1597.5-1605.5): Limestone, ostracodal.

Unit 219 (576.5-1597.5): Covered slope, mostly gray to green shale.

Unit 218 (1568.5-1576.5): Covered slope, mostly interbedded shale and sandstone.

Unit 217 (1556.5-1568.5): Sandstone, fine-to very fine grained, mostly massive, calcareous, some trough cross-bedding (N65°E) lower portion of sandstone upward to highly wave rippled upper 6 feet.

Unit 216 (1554.5-1556.5): Covered slope.

Unit 215 (1550.5-1554.5): Sandstone, fine-to very fine grained, calcareous, planar bedded grading upward to slightly wave rippled near top of unit.

Unit 214 (1541.5-1550.5): Covered slope, mostly gray shale and thin sandstone beds.

Unit 213 (1538.5-1541.5): Sandstone, light-gray, fine-to medium grained, porous, channel form with cross-bedding at base, some high angle, and some ripples, some interbedded siltstone and shale.

Unit 212 (1532.5-1538.5): Limestone, light-gray weathers orange, thin layers of fossil hash and some bone, laterally pinches out to the west.

Unit 211 (1523.5-1532.5): Siltstone and interbedded gray-green shale, some highly burrowed.

Unit 210 (1517.5-1523.5): Limestone, light-gray, weathers orange, some fossil fragments (plates and bones), becoming wave rippled siltstone on top of unit.

Unit 209 (1514.5-1517.5): Covered slope, mostly gray-green shale.

Unit 208 (1499.0-1514.5): Sandstone with interbedded siltstone and shale, sandstone is light-gray, very fine grained, with some wave ripples, shale is green.

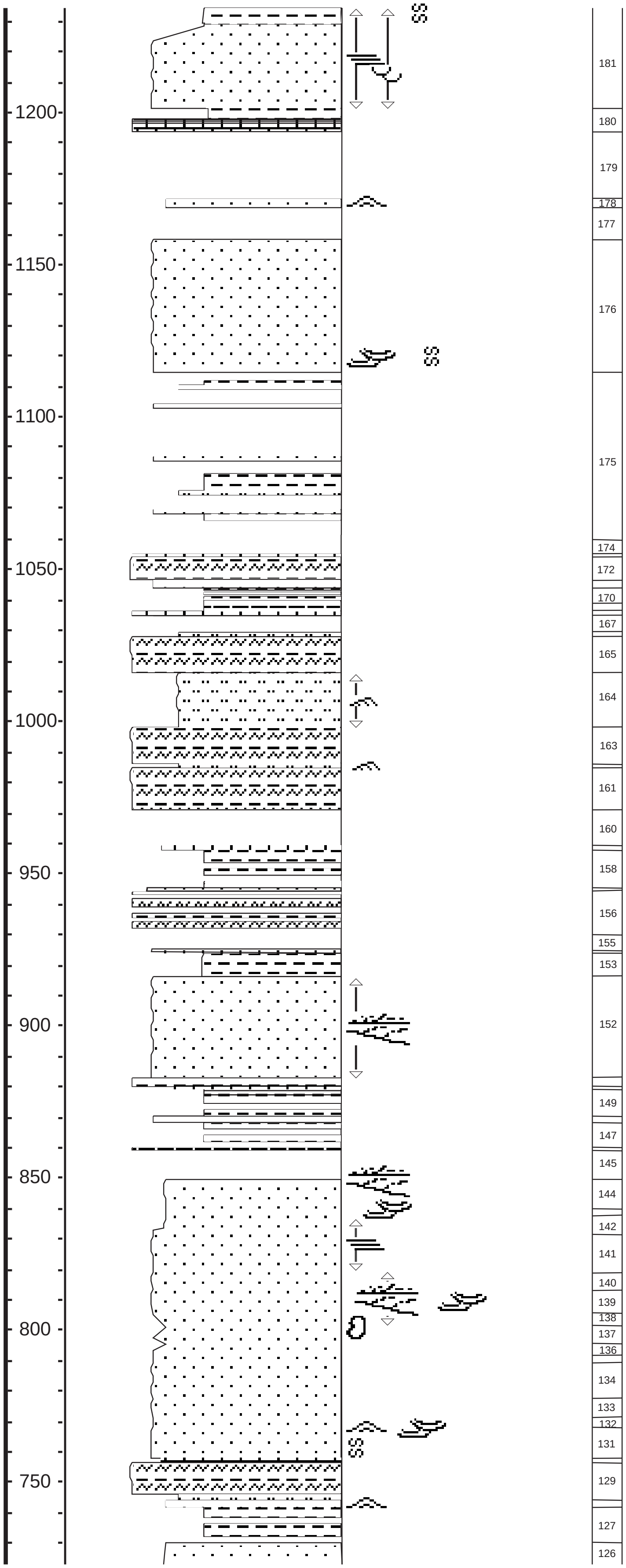
Unit 207 (1496.0-1499.0): Covered slope, mostly green shale.

Unit 206 (1493.5-1496.0): Sandstone, light-gray, very fine grained, slightly calcareous, highly wave rippled at base and top of unit.

Unit 205 (1473.5-1493.5): Covered slope, mostly weathered green and gray shale, some purple.

Unit 204 (1464.5-1473.5): Siltstone to sandstone, green to greenish-gray, coarsening upward with increasing sandstone, very fine grained, trough and wedge shaped beds, wave rippled in upper half of unit.

Unit 203 (1443.0-1464.5): Covered slope, mostly weathered red to reddish-brown and green shale.



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 ostracodes, 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 to 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.

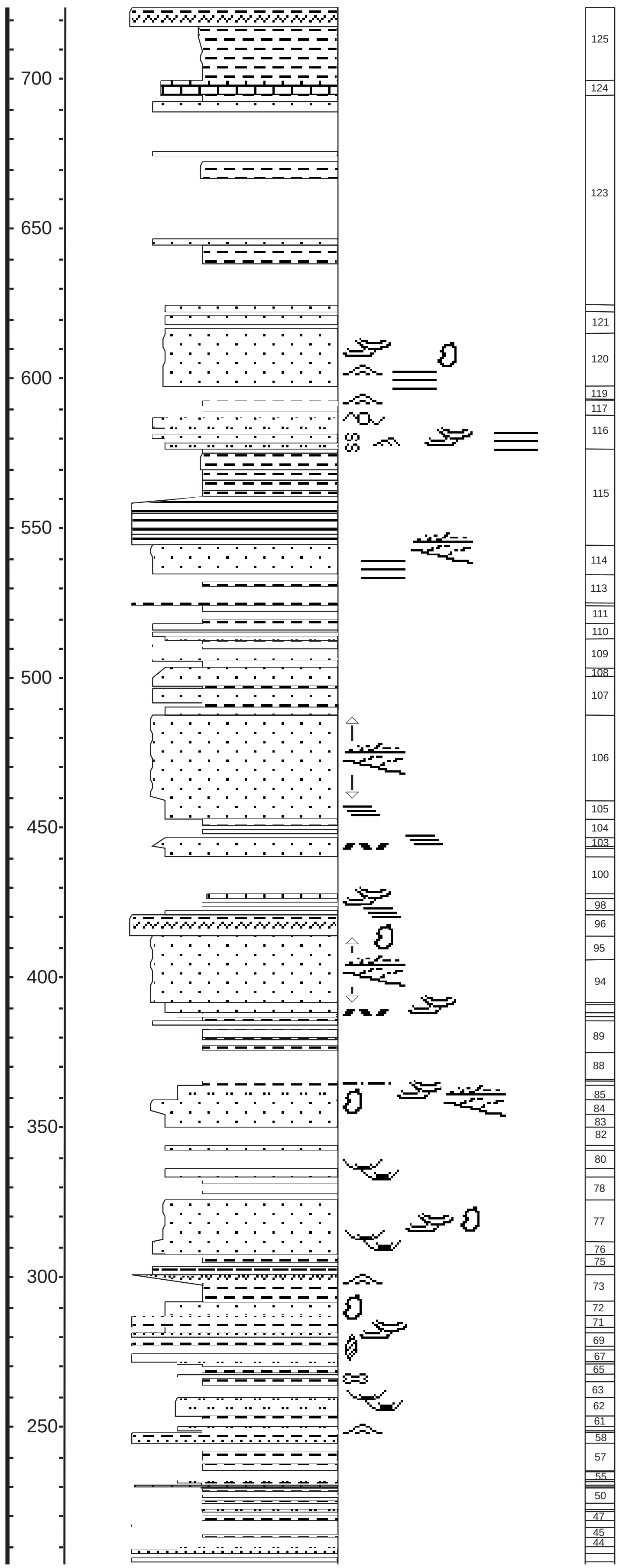
Unit 182 (1234.5-1243.5): Partially covered slope of green shale.

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 intraformational clasts of limy mudstone, some trough cross-bedding 16° N 55° E, and some planar bedding. Becoming flaggy (about 1,219.5 feet) at top light brown, very fine grained, subround to subangular, 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.



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

Unit 176 (1114.5-1158.5): Sandstone, light-gray weathers light-brown, fine-grained, 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.

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.

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

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

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

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

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.

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

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

Unit 167 (1029.5-1034.5): Covered slope.

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

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

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

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

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

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

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

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

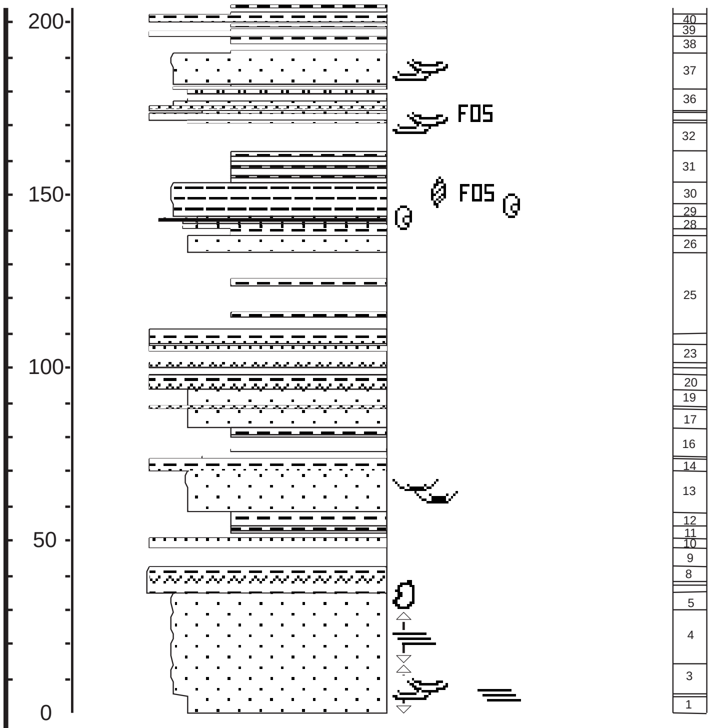
Unit 158 (945.0-957.5): Gray-green shale, weathers medium to thin shaly partings, no effervescence, forms covered slope.

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

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

Unit 155 (924.0-930.0): Covered slope.

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



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

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

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

Unit 150 (879.0-880.0): Orange to tan ostracodal 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-grained 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 grained sandstone, some medium wedge cross-bedding, fair effervescence.

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

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

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

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

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

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

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

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

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

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

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

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

Unit 131 (757.5-768.5): Tan to buff, fine-grained to very fine-grained 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 grained sandstone coarsening upwards to fine grained sandstone. First lower sequence-3 feet very fine-grained to silty sandstone w/ horizontal bedding and soft-sediment deformation coarsening to a 2-foot-thick fine-grained sandstone w/ small cross-beds, some climbing ripples. Second upper sequence-2 feet very fine grained to silty sandstone coarsening upwards to 3 feet fine-grained 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 grained 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-grained 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 grained sandstone, three 1-foot-thick beds interbedded in a clay matrix, no distinct sedimentary structure, slightly effervescent.

Unit 108 (500.33-503.33): Light-gray to buff, very fine grained 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-grained sandstone with interbedded gray shale forming covered slope, moderately strong effervescence.

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

Unit 105 (452.33-459.33): Light-tan very fine grained 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 grained sandstone, moderately dense, planar bedding, fair effervescence.

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

Unit 101 (440.33-443.33): Buff fine-to very fine grained 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 grained 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-grained sandstone, large wedge cross- bedding, scattered pebble size limonite concretions.

Unit 94 (391.8-406.5): Fine-grained 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 grained 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 grained 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 grained sandstone, large wedge cross-bedding, no effervescence, pebble size limonite concretions at top.

Unit 83 (349.67-354.67): Tan very fine grained sandstone, fair effervescence, horizon of platey 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 grained 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 grained sandstone, some small scale cross-bedding, fair effervescence, small scattered limonite concretions throughout.

Unit 76 (307.33-312.33): Buff fine-to very fine grained 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 grained 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 grained 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 vertebrate 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, forms small outcrop on slope.

Unit 52 (230.1-230.75): Light-brown limestone, concoidal fracture, very dense; very good effervescence, forms 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 grained 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 grained sandstone beds.

Unit 35 (173.25-174.25): Buff silty to very fine grained 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 grained 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 (1-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 grained 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-grained sandstone, dense.

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

Unit 17 (82.67-88.33): Buff fine-to very fine grained 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 grained 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, no effervescence.

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

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

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

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

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

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

LEGEND

LITHOLOGY

Sandstone

Siltstone

Shale

Mudstone

Limy Mudstone

Marlstone

Covered Slope

Silty Limestone

Limestone

Silty Shale

PHYSICAL STRUCTURES

- Ripples
- Wedge X-Bed
- Trough Cross-Strat.
- Concretion/Nodule
- Planar Lamination
- Cross-Bedding
- Climbing Ripples
- Flaser Bedding
- Horizontal Bedding
- Soft-Sediment Deformation

LITHOLOGIC ACCESSORIES

- Rip-Up Clasts
- Silty

ICHNIFOSSILS

- Vertical Burrows
- Suggested Burrows

FOSSILS

- Gastropods
- FOS - Fossils
- Ostracodes
- Vertebrates

UGS 3

Trail Canyon

The section begins on the east side of Trail Canyon in the SW1/4SE1/4 and ends in the SW1/4NE1/4 section 34, T. 11 S., R. 14 E., of the Salt Lake Base line and Meridian, Duchesne County, Utah.

FEET

GRAIN SIZE: cobble, pebble, granule, sand (v c m f v), silt, clay

PHYSICAL STRUCTURES

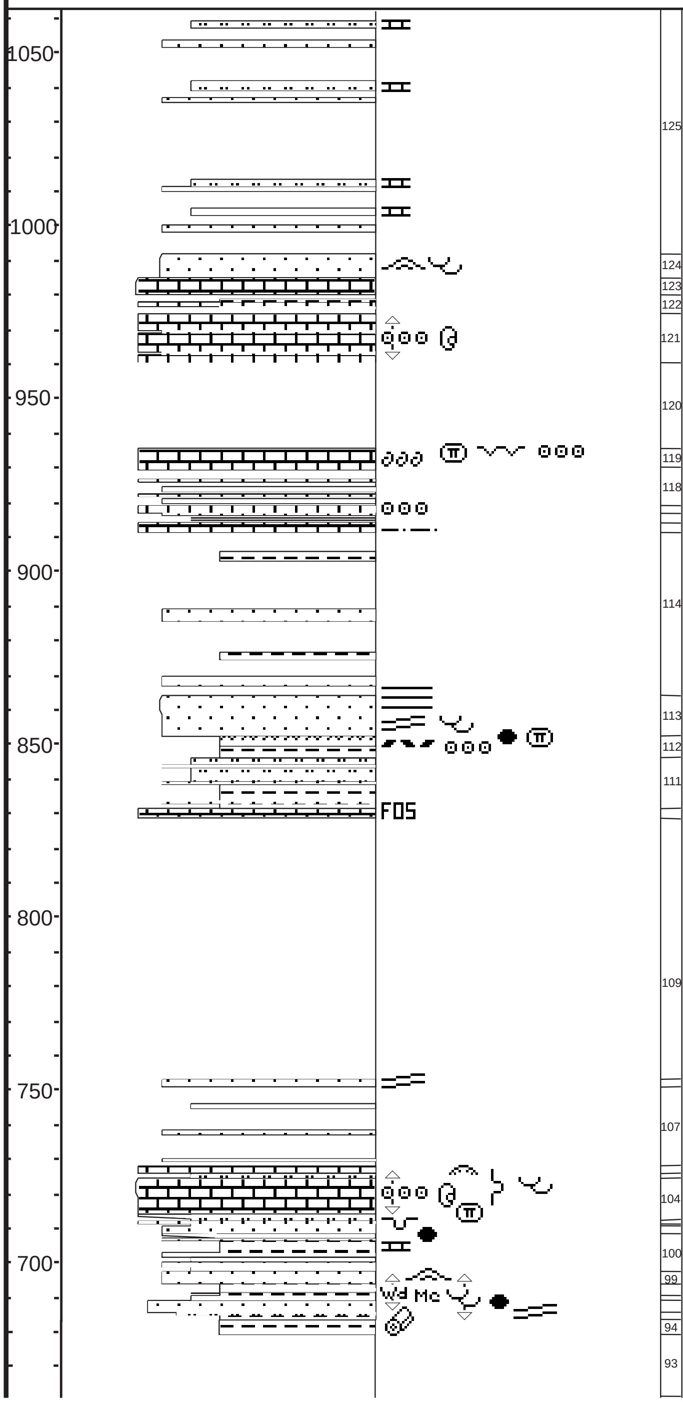
ACCESSORIES

ICHNOFOSSILS

FOSSILS

UNIT NUMBER

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



Unit 125 (992.5-1063): Covered slope, mostly weathered green to greenish-gray shale, some thin (0.5-foot thick) sandstone and calcareous to limy siltstone, weathers orange, coarsening upward.

Unit 124 (985.5-992.5): Sandstone, lower portion trough cross-bedding with some ripples and small scale trough cross-bedding, upper portion increasing ripples.

Unit 123 (980.5-985.5): Grainstone.

Unit 122 (975-980.5): Talus, some green shale and some thin (0.5-foot thick) interbedded grainstone.

Unit 121 (961-975): Grainstone, ostracodal and oolitic, some thin interbedded sandstone, very fine grained, top of unit is ostracodal grainstone.

Unit 120 (936-961): Covered slope.

Unit 119 (930-936): Grainstone, silty base, some shaley limestone in the middle of the unit, abundant fish scales and broken shells, upper portion of unit is oolitic grainstone with green shale mudcracks on top of unit.

Unit 118 (919-930): Covered slope, weathered green shale, some thin sandstone and limestone.

Unit 117 (917.5-919): Grainstone, oolitic, some algal laminations.

Unit 116 (914.5-917.5): Partially covered slope, siltstone, greenish-gray with interbedded thin sandstone.

Unit 115 (911.5-914.5): Limestone, silty, gray weathers orange.

Unit 114 (864.5-911.5): Talus, some interbedded sandstone and shale.

Unit 113 (852.5-864.5): Sandstone, channel form, base contains IFC and fish scales, some small scale trough and low angle parallel cross-bedding, horizontal parallel cross-bedding in upper portion of bed.

Unit 112 (846.5-852.5): Shale, limy, green, grading upward to marlstone/muddy limestone, light-tan, weathers orange, some ooids and thin layers of ripped up algal plates.

Unit 111 (832-846.5): Shale and siltstone, green, with interbedded thin sandstone.

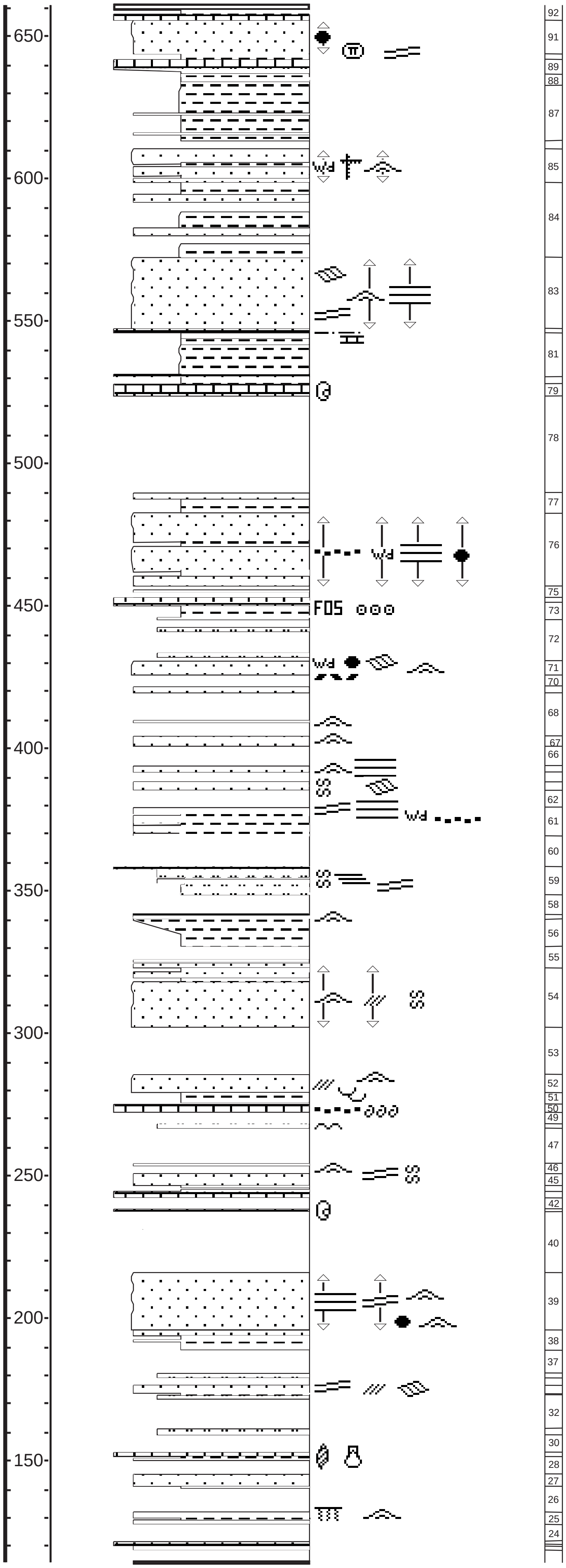
Unit 110 (829-832): Micrite limestone, gray weathers orange, contains fossil hash.

Unit 109 (753.5-829): Covered slope, dominantely weathered green to green-gray shale and siltstone.

Unit 108 (751-753.5): Sandstone, fine-grained, light-brown, subround, some parallel low angle cross-bedding.

Unit 107 (728-751.5): Covered slope, some thin (1-foot thick) sandstone and green siltstone beds.

Unit 106 (726-728): Stromatolitic algal boundstone, upper portion of bed oolitic and ostracodal grainstone.



Unit 105 (724.5-726): Siltstone, green.

Unit 104 (712.5-724.5): Grainstone, limy siltstone to silty limestone at base grading upward to oolitic grainstone with some ostracodes, and ostracodal grainstone with small scale trough cross-bedding in the upper most portion of the bed, fish scales in the lower portion of the bed, numerous thin layers of algal laminations in the middle portion of the bed, and horizontal burrows in the upper portion of the bed.

Unit 103 (711.5-712.5): Grainstone, vertical burrows.

Unit 102 (711-711.5): Siltstone, green.

Unit 101 (708.5-711): Sandstone, fine-grain, subangular to subround, some IFC and fish scales at base.

Unit 100 (698-708.5): Siltstone to shale, green, interbedded with thin sandstone (about 1-foot thick), slightly calcareous, generally sharp base and gradational upper contact.

Unit 99 (694.5-698): Sandstone, woody material, some small scale trough cross-bedding and ripples.

Unit 98 (691.5-694.5): Siltstone and thin green shale.

Unit 97 (689.5-691.5): Siltstone to silty shale, thinly bedded, black, micaceous.

Unit 96 (686.5-689.5): Sandstone, medium-grained, downcutting base, IFC and wood, large scale trough cross-bedding.

Unit 95 (683.5-686.5): Siltstone to very fine grained sandstone with interbedded green shale, small scale trough and low angle parallel cross-bedding, sharp base, top incised by overlying sandstone.

Unit 94 (679.5-683.5): Shale, green with log impressions, replaced with siltstone and grainstone, covered with encrusting algae, long direction of logs N67°E.

Unit 93 (661.5-679.5): Mostly covered weathered green shale.

Unit 92 (655.5-661.5): Grainstone limestone, oolitic, 1-foot thick green shale in middle of unit.

Unit 91 (644-655.5): Sandstone, low angle parallel cross-bedding at base with fish scales and some IFC.

Unit 90 (642-644): Shale, green.

Unit 89 (637-642): Siltstone grading upward to micrite capped with 0.5 feet grainstone.

Unit 88 (633-637): Interbedded gray shale and siltstone.

Unit 87 (613.5-633): Green shale and thin sandstone beds (1 foot).

Unit 86 (610.5-613.5): Covered slope, weathered green shale.

Unit 85 (598.5-610.5): Sandstone, thin bedded with interbedded green shale, some wood material in lower portion, highly rippled, fractures N25°W.

Unit 84 (572.5-598.5): Partially covered, interbedded sandstone and weathered green shale, some red shale.

Unit 83 (547.5-572.5): Sandstone, some low angle parallel-tangential in lower portion of bed, horizontal cross-bedding and ripples, some climbing ripples in upper portion of bed.

Unit 82 (546-547.5): Muddy limestone, silty.

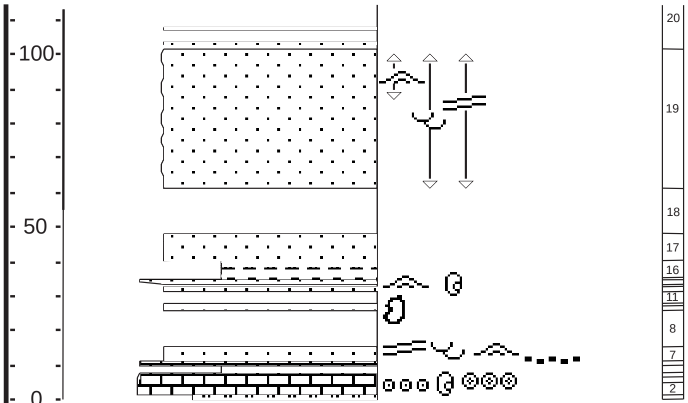
Unit 81 (531-546.5): Micrite limestone (0.5 feet), weathered green shale (11 feet), calcareous green shale grading to limy mudstone (4 feet).

Unit 80 (528-531): Weathered green shale.

Unit 79 (524-528): Grainstone limestone, oolitic, some ostracodes, grading upward to micrite limestone with ooids.

Unit 78 (490-524): Covered, mostly red soil at base and green shale upper portion of unit.

Unit 77 (482.5-490): Green shale (5 feet) and sandstone (2.5 feet).



Unit 76 (457-482.5): Sandstone, fine-grained, subrounded, abundant carbonate grains in lower portion of unit, base irregular with numerous IFC, some green shale clasts many 1 inch long, wood material, low angle parallel-tangential cross-bedding, some thin green shale interbeds dividing the lower unit into sandstone beds that wedge out into green shale northward. Flute casts at base of sandstone, current direction N28°E.

Unit 75 (452-457): Covered some thin sandsotne beds.

Unit 74 (450.5-452): Micrite limestone partially covered at base.

Unit 73 (445-450.5): Siltstone (1 foot) light-brown calcareous, green shale (0.5 feet), limestone and mudstone to the top, light-tan weathers orange, rare ooids, fossil hash on top.

Unit 72 (431-445): Covered weathered green to greenish-gray shale some thin siltstone beds.

Unit 71 (426-431): Sandstone, rippled, some climbing ripples, some carbonate rip up clasts at base of unit, some carbonate IFC and woody material upper portion of unit.

Unit 70 (421.5-426): Covered weathered green shale and thin sandstone beds.

Unit 69 (419.5-421.5): Sandstone, horizontal bedding, sharp upper contact.

Unit 68 (404-419.5): Covered, weathered green shale and some red shale with thin sandstone (0.5 feet thick) highly rippled.

Unit 67 (401-404): Sandstone, irregular lower contact sharp upper contact, intensley rippled.

Unit 66 (394-401): Covered, weathered green shale, possibly some red shale.

Unit 65 (391.5-394): Sandstone, gradational base and sharp upper contact, ripples and some small scale parallel tangential cross-bedding.

Unit 64 (388.5-391.5): Covered, weathered green shale.

Unit 63 (385.5-388.5): Sandstone, gradational base, some wedge shape, and sharp upper contact, some thin siltstone interbeds, climbing ripples and soft-sediment deformation structures in lower portion of unit.

Unit 62 (379.5-385.5): Covered, some thin sandstone beds possibly green shale.

Unit 61 (369.5-379.5): Sandstone, mostly sharp base, some down cutting, abundant wedge shaped beds with interbedded green shale and IFC lags, some with abundant wood material, some parallel-tangential cross-bedding becoming more low angle to horizontal cross-bedded in upper portion of unit.

Unit 60 (358.5-369.5): Covered.

Unit 59 (348.5-358.5): Siltstone to limy siltstone to limestone, lower portion of unit is thin accretary bed interbedded with green shale and siltstone, coarsening upward with grainstone limestone on top. Low angle parallel cross-bedding lower portion of unit horizontal algal laminations and soft-sediment deformation in middle portion of unit.

Unit 58 (342-348.5): Covered slope, weathered green shale possible some red.

Unit 57 (340.5-342): Sandstone, gradational base, sharp top, rippled.

Unit 56 (330.5-340.5): Weathered red shale, more maroon to green shale near top of unit.

Unit 55 (324.5-330.5): Covered, weathered green shale with thin sandstone beds.

Unit 54 (302.5-324.5): Sandstone, intensly rippled with some high angle parallel cross-bedding, middle portion of bed contains soft-sediment deformation structures, upper portion contains interbedded green shale.

Unit 53 (285.5-302.5): Talus, probably green shale and sandstone.

Unit 52 (279-285.5): Sandstone, irregular slightly gradational base, small scale trough cross-beds lower portion, and high angle parallel-tangential cross-bedding, upper 0.5 feet of bed ripples and some feeding traces.

Unit 51 (275-279): Shale, green, partially covered at base.

Unit 50 (272.5-275): Grainstone limestone, small limestone clasts minor fossil shell fragments upper portion of unit.

Unit 49 (268-272.5): Talus.

Unit 48 (267-268): Siltstone, light-brown, calcareous, wave rippled.

Unit 47 (254-267): Covered weathered green and some red shale.

Unit 46 (251-254): Partially covered thin bedded sandstone beds, highly rippled.

Unit 45 (246.5-251): Sandstone, down cutting base, flat top, abundant soft-sediment deformation structures, small scale low angle parallel cross-bedding and ripples upper portion fo bed.

Unit 44 (244.5-246.5): Partially covered base, shaley grading upward to micrite limestone, laterally this unit is cut out by overlying sandstone.

Unit 43 (242.5-244.5): Grainstone limestone.

Unit 42 (238.5-242.5): Talus.

Unit 41 (237.5-238.5): Grainstone limestone with ostracodes.

Unit 40 (216-237.5): Talus, possible weathered red shale.

Unit 39 (196-216): Sandstone, channel form, some thin green shale interbeds, some low angle parallel to horizontal cross-bedding, some ripples, intraformational conglomerate in lower portion of bed.

Unit 38 (189-196): Shale, green, with interbedded sandstone, increasing sandstone upward, sandstone is wedge shaped laterally equivalent to thick (6-foot) channel form bed.

Unit 37 (181-189): Talus.

Unit 36 (179.5-181): Siltstone, light-brown, very calcareous.

Unit 35 (176.5-179.5): Covered slope, weathered green and red shale.

Unit 34 (173.5-176.5): Sandstone, fine-grained, brown, angular to subangular, light-brown, some low angle parallel cross-bedding, occasional high angle parallel cross-bedding, climbing ripples in middle portion of bed. Overlain by 3 feet grading from sandstone to mostly oolitic and ostracodal grainstone. Middle of bed IFC lithoclasts composed of ooids, ostracods, some chert and limestone fragments. Top of bed horizontally laminated.

Unit 33 (173-173.5): Shale, green.

Unit 32 (161-173): Talus, some weathered green siltstone near top of unit.

Unit 31 (159.5-161): Siltstone, green to light-brown, calcareous.

Unit 30 (153-159.5): Covered slope, some weathered green shale.

Unit 29 (151.5-153): Grainstone limestone, some pelecypods and gastropods in lower portion, generally coarsening upward sequence.

Unit 28 (145-151.5): Covered slope, some thin sandstone beds and thin grayish-brown shale near top of unit.

Unit 27 (141-145): Sandstone, rippled.

Unit 26 (132-141): Covered slope, weathered green shale near top of unit.

Unit 25 (128-132): Sandstone, small coarsening upward sequence, interbedded shale and siltstone, rippled, synaeresis cracks.

Unit 24 (123.5-128): Covered.

Unit 23 (121-123.5): Grainstone limestone, oolitic to pisolitic, most coated grains 1.0 to 0.5 mm, some 2.0 mm; overlain by 1.5 feet of limy mudstone.

Unit 22 (120-121): Micrite limestone.

Unit 21 (119-120): Sandstone, very fine grained, very calcareous.

Unit 20 (101.3-119): Covered slope, weathered green shale with thin (1-foot thick) sandstone beds every 4 to 5 feet.

Unit 19 (61.3-101.3): Sandstone, fine-grained, irregular base, low angle parallel and small scale trough cross-bedding, large soft-sediment structures, dominately rippled upper portion.

Unit 18 (48.3-61.3): Covered slope, weathered green, purple to red shale.

Unit 17 (40.3-48.3): Sandstone, some thin green shale interbeds 1-2 inches, bed has flat base.

Unit 16 (35.3-40.3): Interbedded green shale and siltstone with some thin carbonate mudstone, overall coarsing upward sequence.

Unit 15 (35.1-35.3): Oil shale.

Unit 14 (33.6-35.1): Sandstone, ostracodes at base, highly rippled, grades up to grainstone on top.

Unit 13 (32.6-33.6): Covered slope.

Unit 12 (31.6-32.6): Sandstone.

Unit 11 (28.1-31.6): Covered slope.

Unit 10 (27.6-28.1): Sandstone, fine-grained, slightly calcareous.

Unit 9 (25.6-27.6): Sandstone, very fine grained to siltstone, some iron concretations in lower half of unit.

Unit 8 (15.6-25.6): Covered slope, probably weathered green shale.

Unit 7 (11.1-15.6): Sandstone, abundant carbonate material in basal 1 foot, low angle tabular-tangential and small scale trough cross-bedding with ripples on top.

Unit 6 (10-11.1): Limestone, algal stromatolite with 2-inch thick green shale on top.

Unit 5 (8-10): Covered slope, weathered green to gray shale at top of unit.

Unit 4 (7-8): Grainstone limestone, pisolitic.

Unit 3 (5-7): Micrite limestone.

Unit 2 (1.5-5): Grainstone limestone, ostracodal, oolitic.

Unit 1 (0-1.5): Siltstone, greenish-gray to tan, very calcareous.

LEGEND

LITHOLOGY

Sandstone
Mudstone
Covered Slope
Limestone
Siltstone
Shale
Marlstone

CONTACTS

Sharp

PHYSICAL STRUCTURES

- Climbing Ripples
- Trough Cross-Strat.
- Ripples
- Low Angle Tabular Bedding
- Planar Lamination
- High Angle Tabular Bedding
- Fractures
- Synaeresis Cracks
- Horizontal Bedded
- Intraformational Conglomerate (IFC)
- Soft-Sediment Deformation
- Wave Ripples
- Concretion/Nodule
- Mudcracks

LITHOLOGIC ACCESSORIES

- Calcareous
- Rip-Up Clasts
- Clasts
- Wood Fragments
- Shell Fragments
- Oolites
- Silty
- Pisolites
- Log Impressions

ICHNOFOSSILS

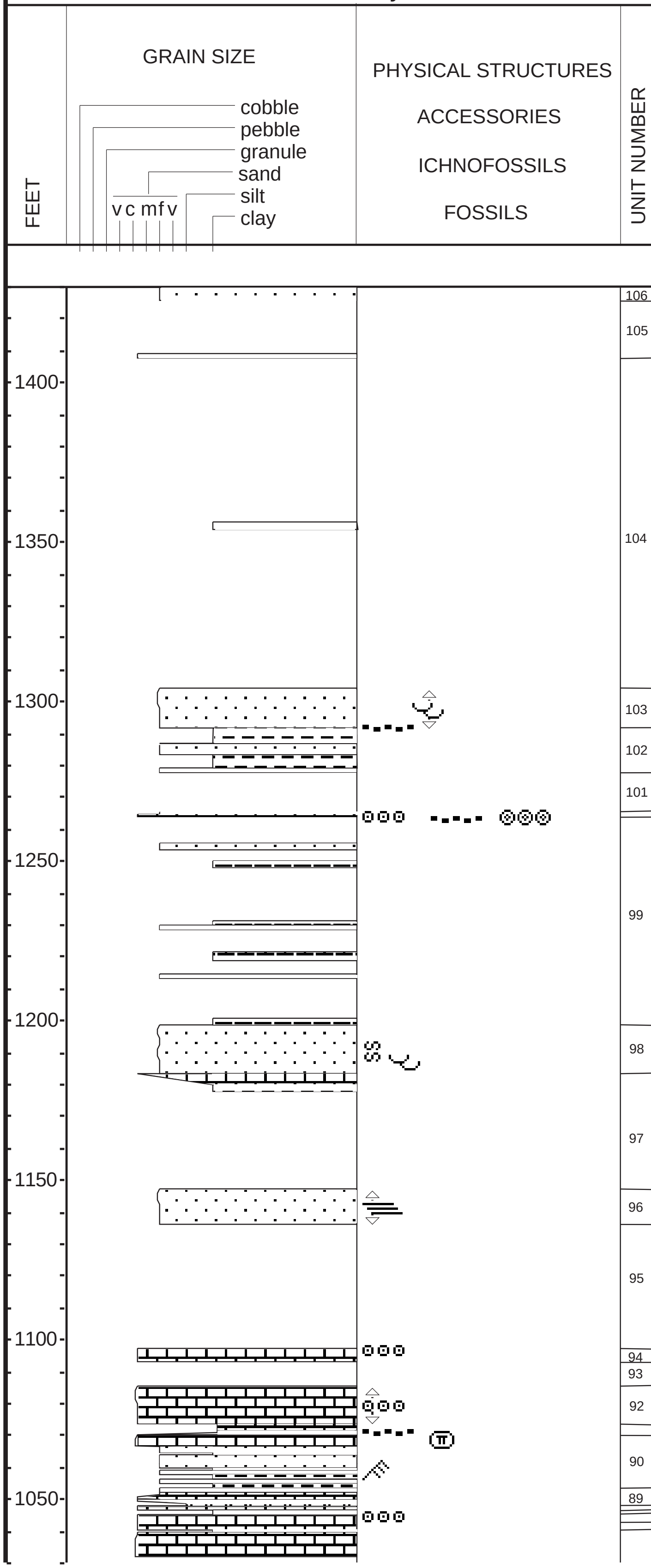
- Vertical Burrows
- Horizontal Burrows

FOSSILS

- Fish Scales
- Gastropods
- Pelecypods
- Ostracodes
- Fossils
- Algal Stromatolite

UGS 4
Currant Canyon

The section begins on the east side of Currant Canyon (start directly up from gas well) in the NW1/4SE1/4 and ends in the SW1/4NE1/4 section 36, T. 11 S., R. 14 E., of the Salt Lake Base line and Meridian, Duchesne County, Utah.



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

Unit 106 (1426-1430): Sandstone, trough cross-bedding, blocks from lower unit came from here. End of ridge. Unit is a bench former.

Unit 105 (1408-1426): Beginning of next ridge, basal foot is limy siltstone, light-gray, remainder of unit is covered slope. Five feet up from base rest some large sandstone blocks.

Unit 104 (1304-1408): Covered ridgeline. About middle of unit is the "Mahogany Oil Shale".

Unit 103 (1292-1304): Sandstone, abundant clay and limestone clasts in base, oil saturated, trough bedding, base highly oil impregnated.

Unit 102 (1278-1292): Interbedded green shale and thin sandstone.

Unit 101 (1265.5-1278): Covered slope, weathered green to gray siltstone.

Unit 100 (1264-1265.5): Bottom foot is oolitic to pisolitic grainstone with some large (0.5 to 1 inch) clasts, overlain by 6 inches of fine grained sandstone.

Unit 99 (1199-1264): Mostly covered slope, weathered green shale, some limy mudstone and thins sandstone beds.

Unit 98 (1183.5-1199): Sandstone, minor troughs in lower half, some soft-sediment deformation.

Unit 97 (1147.5-1183.5): Mostly covered slope, weathered green shale. Green shale grades up to muddy limestone in upper 5 feet.

Unit 96 (1136-1147.5): Sandstone, planar bedding.

Unit 95 (1097.5-1136): Covered slope.

Unit 94 (1093-1097.5): Oolitic limestone.

Unit 93 (1085.5-1093): Covered slope.

Unit 92 (1073.5-1085.5): Limestone, dense, partly oolitic.

Unit 91 (1070-1073.5): Calcareous siltstone with abundant clasts grading up to silty limestone, thinly laminated.

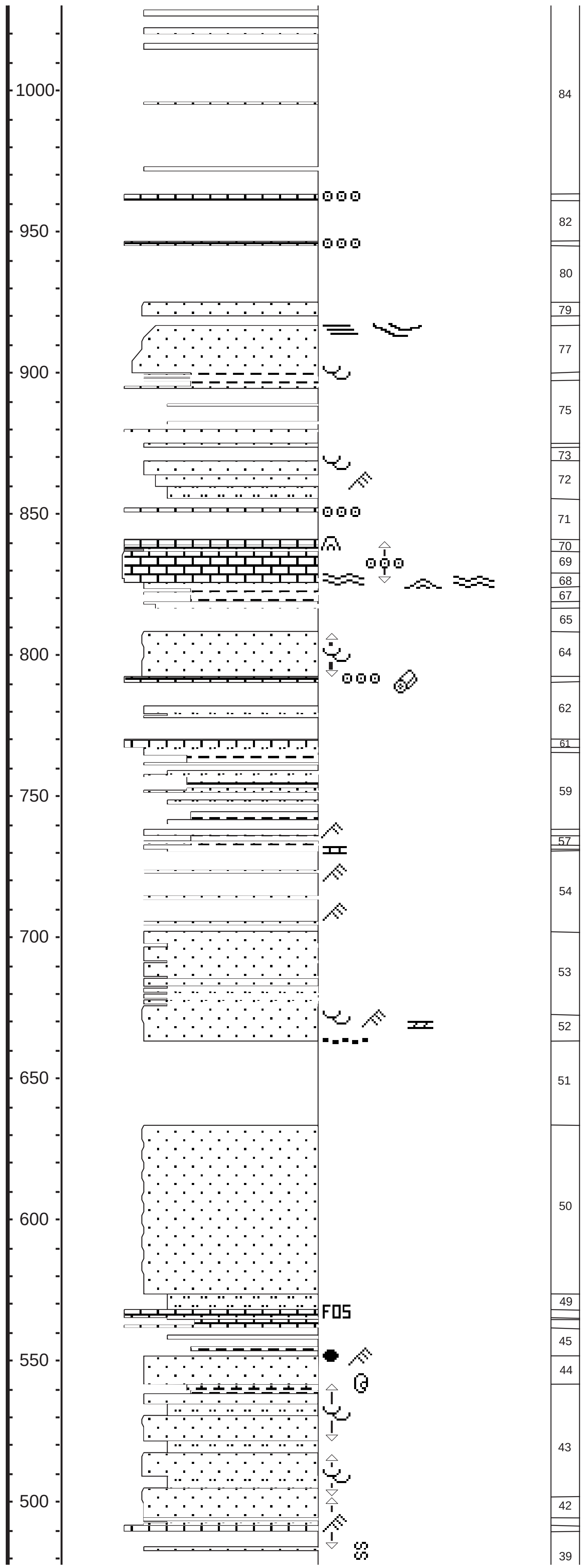
Unit 90 (1053-1070): Interbedded green shale and sandstone, sandstone beds thickening towards top, sandstone beds have flat bases, mildly current rippled towards top of beds. Top 3 feet micritic limestone, fossiliferous, fish scales and bone fragments.

Unit 89 (1048-1053): Green siltstone grading up to micritic limestone, fossiliferous. Unit capped with sandstone, calcareous, with ostracodes, highly trough bedded.

Unit 88 (1046.5-1048): Oolitic grainstone.

Unit 87 (1045.5-1046.5): Green shale.

Unit 86 (1043.5-1045.5): Oolitic limestone, grainstone.



Unit 85 (1040.5-1043.5): Limestone, pillar type algal boundstone.

Unit 84 (963.5-1040.5): Mostly covered slope, some green siltstone and shale, some thin 6-12 inch sandstone beds, number of sandstone beds increases towards top. Top 8.5 feet includes 6.5 feet of muddy limestone to limy mudstone, dark-gray to dark-green with thin green mudstone interbeds, weathers orange, which is overlain by 1 foot of micritic limestone with faint algal laminations at base overlain by 1 foot of green shale.

Unit 83 (961.5-963.5): Oolitic limestone, algal laminations on top.

Unit 82 (946.5-961.5): Covered slope, weathered green shale.

Unit 81 (945-946.5): Limestone, oolitic, oil stained, weathers orange.

Unit 80 (925-945): Covered slope, weathered gray to green shales.

Unit 79 (920-925): Sandstone.

Unit 78 (917-920): Covered slope.

Unit 77 (900-917): Sandstone, channel form, base medium-grained, some rip-up clasts, large scale troughs at base, unit fines upward to very fine grained at top, large low angle trough to planar bedding on top.

Unit 76 (897-900): Interbedded thin sandstone and green shale, unit cut by overlying massive sandstone.

Unit 75 (875-897): Mostly covered slope, some thin 6 inch lenses of gray siltstone, oolitic limestone to silty limestone. Top 2 feet is limy green shale underlain by 6 inches of micritic limestone, fossiliferous, weathers orange.

Unit 74 (874-875): Sandstone with orange carbonate grains.

Unti 73 (869-874): Covered slope.

Unit 72 (856-869): Sandstone, three beds coarsening up from siltstone to sandstone, current ripples throughout, some large low angle troughs in upper unit, oil saturated.

Unit 71 (841-856): Covered slope, 10 feet up from base 1 foot of oolitic limestone.

Unit 70 (837-841): Lower half flaggy sandstone grading up to oolitic grainstone. Upper half dense oolitic grainstone, some minor algal stromatolites.

Unit 69 (829-837): Massive oolitic grainstone, one block on top filled with bone fragments, prominant shelf former.

Unit 68 (824.5-829): Sandstone at base grading up to thin interbedded sandstone with lenses of oolitic grainstone, wavy to large ripples, grading up to oolitic grainstone.

Unit 67 (818.5-824.5): Thin interbedded sandstone and green shale.

Unit 66 (816.5-818.5): Sandstone, very fine grained, light-gray to light-brown, top 6 inches silty limestone to limy siltstone.

Unit 65 (808.5-816.5): Mostly covered, weathered green shale.

Unit 64 (792.5-808.5): Sandstone, gray to dark-gray, trough cross-bedding.

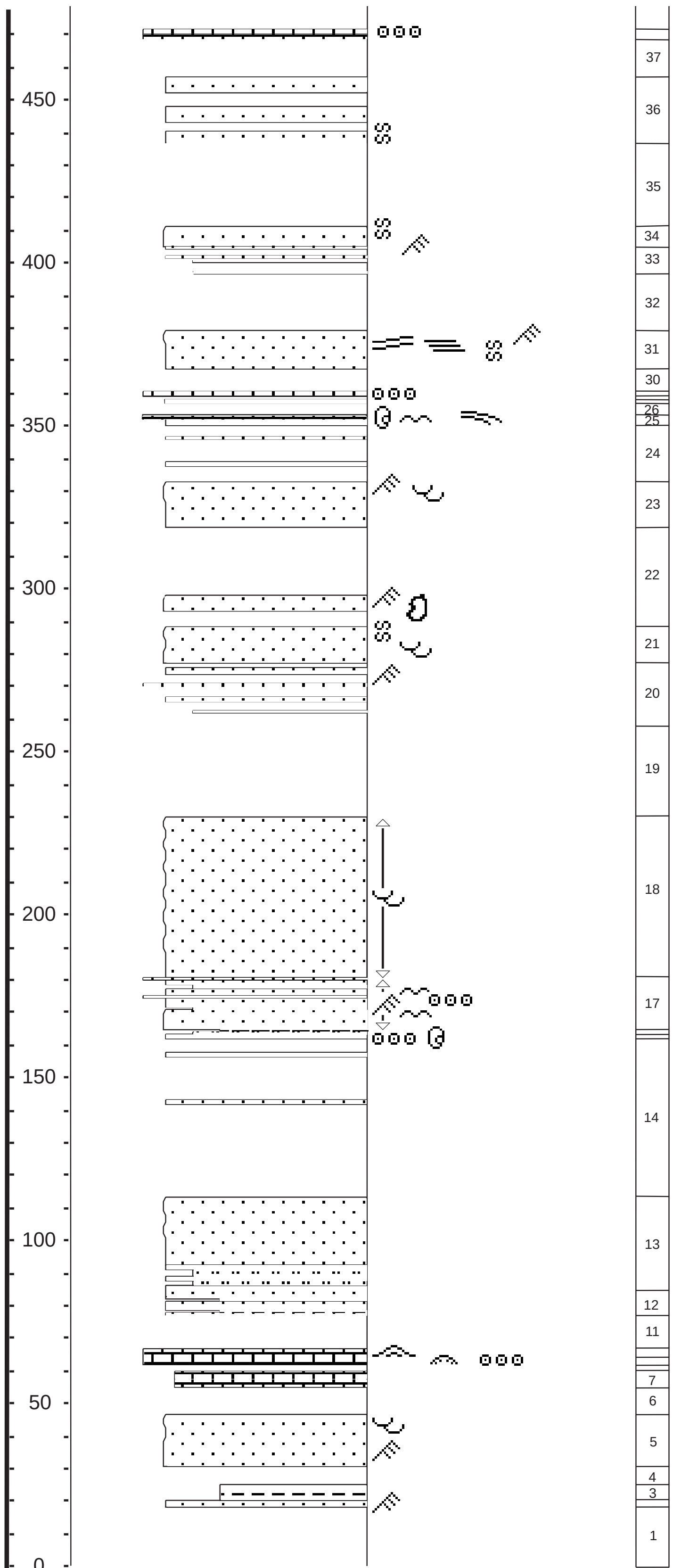
Unit 63 (790.5-792.5): Sandy carbonate, oolitic, several log impressions at base (3 feet in length and 1 foot in diameter) replaced with grainstone and siltstone encrusted with algae.

Unit 62 (770.5-790.5): Mostly covered, weathered green shale, 4 feet of sandstone in middle of unit, lensy with thin interbedded siltstone.

Unit 61 (767.5-770.5): Limestone, grainstone, ostracodes, weathers orange. Prominant marker.

Unit 60 (765-767.5): Sandstone, interbedded siltstone.

Unit 59 (738.5-765): Partially covered, interbedded green shale and thin sandstone and siltstone beds. Some thin (1-6 inch) oolitic limestone (grainstone) halfway up unit. One and a half feet above limestone is another limestone that is 1 foot thick.



Unit 58 (736.5-738.5): Sandstone, rippled.

Unit 57 (732.5-736.5): Weathered green shale, with thin 2-6 inch sandstone beds.

Unit 56 (731.5-732.5): Sandstone.

Unit 55 (730.5-731.5): Green siltstone, calcareous.

Unit 54 (702.5-730.5): Covered slope, weathered green shale, few thin sandstone beds (6-12 inches), current ripples.

Unit 53 (673.5-702.5): Interbedded sandstone and thin siltstone beds, sandstone thickening towards top of unit.

Unit 52 (663.5-673.5): Sandstone, irregular base, some clay conglomerate at base, trough cross-bedding and current ripples near top, several thin 1-inch dolomitic conglomerate lenses.

Unit 51 (633.5-663.5): Mostly covered slope, weathered green shale and thin sandstone.

Unit 50 (573.5-633.5): Massive sandstone bed. Mega ripples at base, dominately large trough cross-bedding, accretionary beds, some current ripples near top. Some interbedded green shale, some oil staining.

Unit 49 (568.5-573.5): Interbedded sandstone and siltstone.

Unit 48 (565.5-568.5): Limestone, micritic, gray to dark-gray, fossiliferous, 4-inch thick bed of limy shale in middle of unit.

Unit 47 (564.5-565.5): Green siltstone.

Unit 46 (562-564.5): Basal 4 inches ostracodal grainstone overlain by silty limestone, tan to light-gray, weathers orange.

Unit 45 (552-562): Covered slope, green shale and siltstone.

Unit 44 (542-552): Sandstone, some troughs at base, ostracodes in cross-beds at base, upper part current rippled, some intraformaional conglomerate lenses.

Unit 43 (502-542): Interbedded sandstone and green siltstone, large troughs, laterally equivalent to massive sandstone, top 3 feet interbedded limy siltstone to green shale, siltstone weathers yellow to yellowish brown.

Unit 42 (495-502): Sandstone, massive, abundant current ripples.

Unit 41 (492-495): Mostly sandstone, current ripples, some interbedded green siltstones.

Unit 40 (490-492): Limestone, micritic, weathers yellow, sharp upper contact in most places, slightly cutting in a few places.

Unit 39 (472-490): Mostly covered slope, 1-foot-thick sandstone bed at 483 feet, tool marks at base, current ripples, soft-sediment deformation at top.

Unit 38 (469-472): Basal foot is ostracodal grainstone with slight oil staining, overlain by 6 inches of covered slope, which is overlain by 1.5 feet of micritic limestone capped with thin ostracodal oolitic grainstone.

Unit 37 (457-469): Covered slope, probably green shale.

Unit 36 (437-457): Partially covered, mostly sandstone, large soft-sediment deformation in lower 3 feet.

Unit 35 (411.5-437: Covered slope, lower slope slightly red.

Unit 34 (404.5-411.5): Sandstone, lower 3 feet some thin green siltstone beds and current ripples, some soft-sediment deformation near top.

Unit 33 (396.5-404.5): Mostly covered slope, some thin green siltstone and sandstone beds. Laterally, unit almost entirely sandstone, highly current rippled.

Unit 32 (379.5-396.5): Covered slope.

Unit 31 (367.5-379.5): Sandstone, lower 3 feet abundant soft-sediment deformation, upper 7 feet planar to low angle bedding, abundant current rips and soft-sediment deformation.

Unit 30 (360.5-367.5): Covered slope.

Unit 29 (359.5-360.5): Oolitic ostracodal grainstone.

Unit 28 (359-359.5): Covered slope.

Unit 27 (358-359): Sandstone, capped with thin oolitic limestone.

Unit 26 (353-358): Covered slope.

Unit 25 (350-353): Sandstone, top is hummocky and wave rippled, cross-beds are filled with ostracodes, top 4 inches is ostracodal grainstone.

Unit 24 (333-350): Covered slope, a few thin sandstone beds that are ends of lateral accretions, about 50 feet to the east the sandstone beds thicken and form a continuous sandstone bed with unit below.

Unit 23 (319-333): Sandstone, base strongly down cutting, some accretionary at base, upper part highly trough bedded and current rippled.

Unit 22 (288-319): Mostly covered slope, at 293 feet there is a 5-foot-thick bed of sandstone, highly current rippled, at 294.5 feet there is a layer of large concretions (12-18 inches in diameter[long axis]), 5 feet or more apart.

Unit 21 (277-288): Sandstone, some troughs in lower half, soft-sediment deformation in lower half.

Unit 20 (257-277): Partially covered slope, interbedded sandstone and green siltstone, sandstone beds 1-2 feet thick, some current ripples, bioturbated, at 270 feet there is a 6-inch bed of oolitic limestone.

Unit 19 (230-257): Covered slope.

Unit 18 (180.5-230): Sandstone, large troughs throughout unit.

Unit 17 (164.5-180.5): Sandstone with some green siltstone beds, conglomerate layers at base of sandstone beds were they cut into the siltstone beds, 7 feet up there is a 3-foot-thick bed of oolitic sandstone to limy sandstone topped with micritic limestone, some thin limestone near top, round to oval clasts.

Unit 16 (163-164.5): Green siltstone and mudstone.

Unit 15 (162-163): Sandstone overlying green siltstone in unit below, top 2-4 inches is conglomeritic with some ooids and rare ostracodes.

Unit 14 (113-162): Mostly covered slope, float in lower half mostly red, float in upper half is gray, two thin (6-12 inches) sandstone beds in upper half.

Unit 13 (85-113): Bottom 5 feet mostly sandstone with some green siltstone beds, upper 15 feet massive sandstone.

Unit 12 (77-85): Sandstone, interbedded green shale and siltstone, mostly sandstone, overlain by large massive sandstone.

Unit 11 (67-77): Mostly covered, some thin sandstone and green siltstone beds.

Unit 10 (64-67): Micritic limestone, gray, weathers orange, rippled on top.

Unit 9 (62-64): Limestone, gray, capped with algal stromatolites, some ooids present.

Unit 8 (60-62): Covered slope.

Unit 7 (55-60): Mostly ostracodal grainstone with 1 foot of oolitic limestone, rippled, possible algal.

Unit 6 (47-55): Partially covered, interbedded green shale, siltstone, and sandstone.

Unit 5 (31-47): Sandstone, current ripples at base upward to large trough cross-beds.

Unit 4 (25-31): Covered slope.

Unit 3 (20-25): Weathered red and green shale.

Unit 2 (18-20): Sandstone, current ripples.

Unit 1 (0-18): Mostly covered slope, some thin siltstones and shales.

LEGEND

LITHOLOGY

Sandstone
Siltstone
Shale
Mudstone
Covered Slope
Limy Siltstone
Ostracodal Grainstone
Limestone
Silty Limestone
Limey Shale

PHYSICAL STRUCTURES

- Trough Cross-Strat.
- Low Angle Tabular Bedding
- Low Angle Trough Cross Sets
- Current Ripples
- Concretion/Nodule
- Ripples
- Wavy Laminations
- Soft Sediment Deformation
- Wave Ripples
- Planar Lamination
- Hummocky Cross-Strat.
- Algal Stromatolites
- Intraformational Conglomerate (IFC)

LITHOLOGIC ACCESSORIES

- Calcareous
- Oolites
- Dolomitic
- Pisolites
- Clasts
- Log Impressions

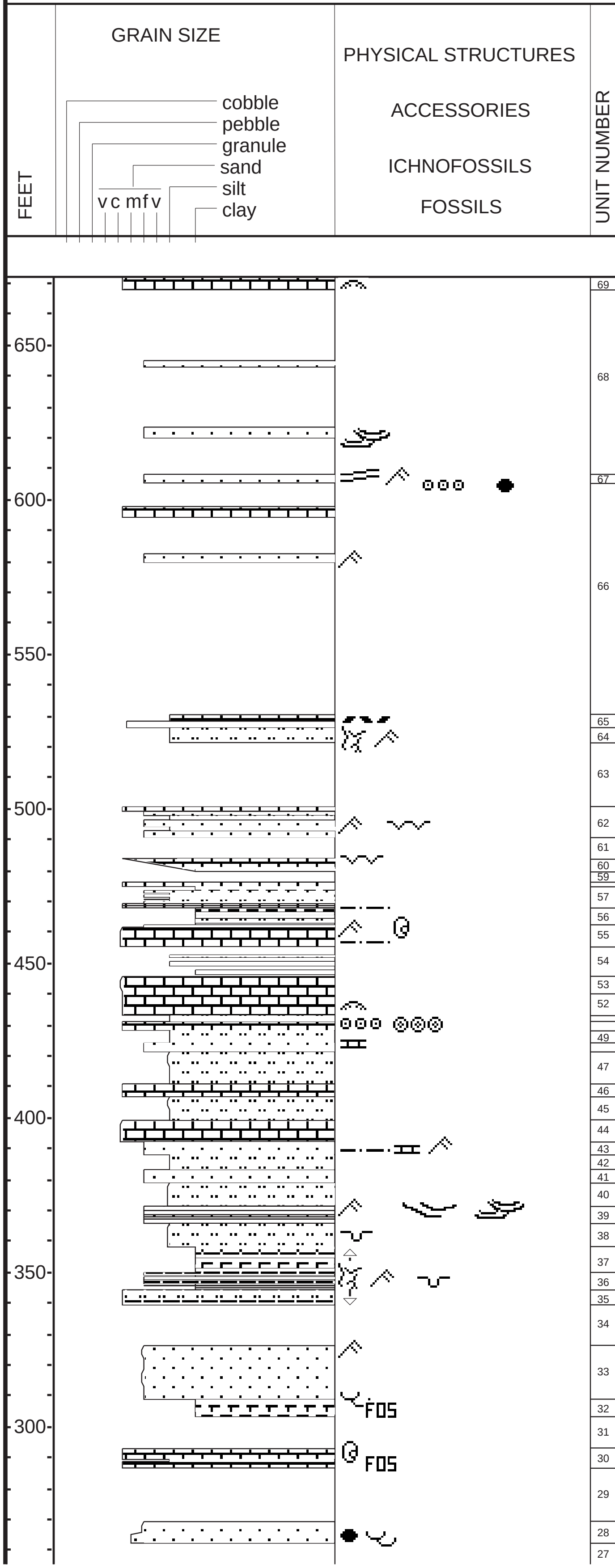
FOSSILS

- Algal Stromatolite
- FOS - Fossils
- Fish Scales
- Ostracodes

UGS 5

Rock House Canyon

The section begins and ends in the S1/2 section 24, T. 12 S., R. 17 E., of the Salt Lake Base line and Meridian, Duchesne County, Utah.



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

Unit 69 (668-672): Limestone, algal stromatolites.

Unit 68 (608-668): Mostly covered. At 12 feet above base 3 foot sandstone bed, cross-bedded, very fine grained; at 35 feet above base 1-foot thick sandstone beds.

Unit 67 (605-608): Sandstone, some IFC at base, coated oolites, mostly rippled, tabular cross beds.

Unit 66 (530-605): Covered slope. Fifty feet above base thin rippled sandstone; 65 feet above base thin bedded micrite.

Unit 65 (526-530): Lower half algal to fossil hash with rip-up clasts, upper half micrite.

Unit 64 (521-526): Light-green siltstone, bioturbated, coarsening toward top, some ripples.

Unit 63 (500.5-521): Covered slope.

Unit 62 (490.5-500.5): Interbedded green siltstone and sandstone, coarsening upward, ripples, some mudcracks, grading up to limy siltstone to limy sandstone, topped by micrite-silty muddy limestone.

Unit 61 (483.5-490.5): Partially covered slope, weathered green shale and siltstone.

Unit 60 (479.5-483.5): Shale to siltstone, coarsening upward, capped by 1.5 feet micrite, algal laminated, 2 feet grainstone with mudcracks on top, porous, possible bitumen filled pores in upper two thirds unit. (waypoint 10)

Unit 59 (476.5-479.5): Covered slope.

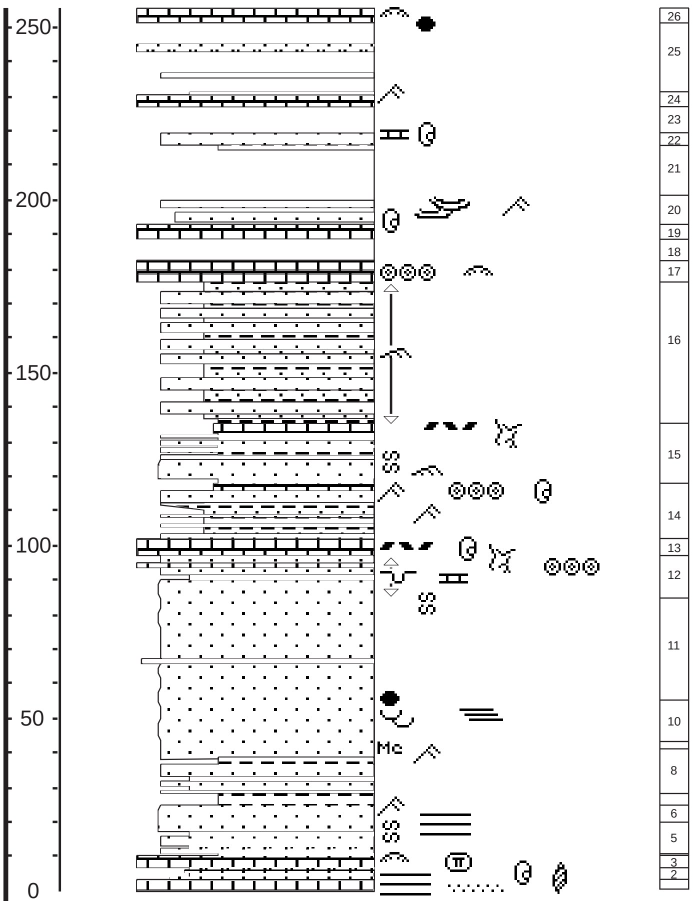
Unit 58 (474.5-476.5): Dense oolitic grainstone, weathers white, structureless.

Unit 57 (467.5-474.5): Thin interbedded mottled siltstone to sandstone, grading upward, at base mostly grainstone to silty grainstone, upper thin beds limy mudstone to coarse-grained siltstone.

Unit 56 (462.5-467.5): Green shale and siltstone.

Unit 55 (455.5-462.5): Grainstone, ostracodes, basal unit silty micrite to grainstone to silty grainstone to 1 foot of sandstone at top, some algal hash, some ripples.

Unit 54 (445.5-455.5): Mostly covered slope, weathered green shale and siltstone.



Unit 53 (440-445.5): Limestone.

Unit 52 (433-440): Limestone, algal heads.

Unit 51 (431-433): Siltstone.

Unit 50 (428-431): Limestone, oolitic pisolitic, packstone to grainstone.

Unit 49 (424-428): Siltstone.

Unit 48 (421-424): Sandstone, very fine grained, calcareous, hematite cement.

Unit 47 (411-421): Siltstone, gray-green, very fine lamination.

Unit 46 (407-411): Limestone.

Unit 45 (399-407): Siltstone, very fine laminated.

Unit 44 (392-399): Grainstone, stromatolitic.

Unit 43 (388-392): Sandstone, very fine grained, ripple laminated, silty, calcareous.

Unit 42 (383-388): Siltstone.

Unit 41 (379-383): Sandstone very fine grained.

Unit 40 (371-379): Siltstone.

Unit 39 (366-371): Sandstone, very fine grained, beds 1-2 feet, rippled, low-angle trough to cross-beds.

Unit 38 (358-366): Siltstone, light-gray to green, mottled, burrowed.

Unit 37 (349.5-358): Green to gray-green mudstone and shale, thin 1-2 inch grainstone beds, bioturbated. (waypoint 8)

Unit 36 (344.5-349.5): Thin interbedded sandstone, shale and siltstone, some vertical burrows, some thin algal laminataions, minor ripples, overall coarsening upward.

Unit 35 (339.5-344.5): Green (some red), silty, bioturbated.

Unit 34 (326.5-339.5): Covered slope.

Unit 33 (308.5-326.5): Sandstone, light-gray, fine-grained, subround, base large scale trough cross-bedding, ripples at top.

Unit 32 (303.5-308.5): Green shale, some highly fossiliferous limestone.

Unit 31 (292.5-303.5): Covered slope.

Unit 30 (286.5-292.5): Lower part fossiliferous micrite, 6 inches of siltstone, ostracodal grainstone, thin bedded toward top. (waypoint 7)

Unit 29 (269-286.5): Covered slope.

Unit 28 (262-269): Sandstone, trough cross-beds lower part, IFC channel lag, medium-to fine-grained, fining upward.

Unit 27 (255-262): Covered slope.

Unit 26 (251-255): Grainstone, abundant IFC at base, grading upward to micrite, top is algal stromatolite.

Unit 25 (231-251): Covered slope, some thin sandstone beds; 4 feet from base fine-grained sandstone, 12 feet from base a 1.5-foot thick flaggy limy siltstone with thin micrite at top.

Unit 24 (227-231): Ostracodal grainstone, overlain by algal, top with rippled siltstone algal laminations on ripples.

Unit 23 (219.5-227): Covered slope.

Unit 22 (215.5-219.5): Sandstone, very fine grain, calcareous, ostracodal at top.

Unit 21 (201.5-215.5): Covered slope, some green shale near top.

Unit 20 (192.5-201.5): Sandstone, partially covered slope, ostracodal, very well cemented, very fine grain, well sorted, subangular, few cross-beds, contorted, few ripples, coarsening upward.

Unit 19 (188.5-192.5): Ostracodal grainstone, some quartz grains, well cemented, algal mats.

Unit 18 (182.5-188.5): Covered slope.

Unit 17 (176.5-182.5): Limestone, pisolitic, topped with algae, some fine-grained sandstone layers, coated grains, stromatolitic algal heads.

Unit 16 (135.5-176.5): One foot green shale at base, thin interbeded green silty shale and very fine grain sandstone, climbing ripples (possible overbank to crevasse splays) up to 2-foot thick sandstone beds, up to 1-foot thick shale beds, occasional channel form beds about 10 feet wide.

Unit 15 117.5-135.5): 1.5 feet shale overlain by sandstone, abundant climbing ripples, top of sandstone abundant soft-sediment deformation (possible seismic), overlain by green shale, thin channel sandstone, interbedded continuious sandstone beds (6 inches) increasing upward, mudstone highly bioturbated. 8 feet of interbeddded sandstone and green mudstone, 3 feet of grainstone, algal rip-ups at top.

Unit 14 (103-117.5): (Flooding Surface) Silty shale, coarsening upward, some thin (1 inch) sandstone beds, some hummocks, some ripples, coarsening upward to very fine grained sandstone intensly rippled, top 1.5 feet coated ostracodal grainstone with a few pisolites.

Unit 13 (97-103): Grainstone with quartz to ostracodal sandstone on top, abundant rip-ups and algae.

Unit 12 (85-97): Sandstone, upper 2 feet highly bioturbated, vertical burrows, overlying beds graded calcareous siltstone with ostracodes to ostracodal limestone, grading upward to grainstone, top of unit algal, some pisolites, coarse grains, thin encrusting algae.

Unit 11 (55-85): Multi-story channel complex, sandstone, numerous IFC at channel base. One thin lense of abundant gar scales, bone, algal fragments, possible transgressive lag?, discontinuious, cut out by overlying channels. Upper 5 feet abundant dewatering fractures and some mudstone concretion.

Unit 10 (43-55): Sandstone, fine-grained black rock fragments, upward-dipping lateral sets, becoming planar upward, some troughs, abundant gar scales.

Unit 9 (41-43): Sandstone very fine grained, micaceous, light-gray, subround, well sorted, swaley bottom, erosional base cutting units underlying muddy siltstone.

Unit 8 (28-41): Sandstone, base is lenticular, 1-2 foot thick interbedded paper shale and siltstone, gray to orange, some ripples in siltstone.

Unit 7 (25-28): Gray to maroon shale.

Unit 6 (20-25): Sandstone, fine-grained, some ripples at very top of unit, thin bedded in upper portion.

Unit 5 (11-20): Sandstone, channel form very fine to fine-grained, interbedded with 1-2 foot thick siltstone units, some soft-sediment deformation, horizontal bedding near top.

Unit 4 (10-11): Gray to green shale.

Unit 3 (7-10): Micrite with algal stromatolites interbedded, prominent at top of unit, orange to tan, some gar fish scales.

Unit 2 (3-7): Gray to greenish gray siltstone with small interbeds (0.4-0.5 ft) of packstone to grainstone with ostracodes and a few gastropods.

Unit 1 (0-3): Base covered, ostracodal grainstone with quartz sand (fine-grained) stringers, weathers tan to orange to gray, thin horizontal beds.

LEGEND

LITHOLOGY

Sandstone
Silty Shale
Silty Mudstone
Limestone
Siltstone
Mudstone
Calcareous Siltstone
Fossil Hash
Shale
Covered Slope

PHYSICAL STRUCTURES

- Ripple Drift Lamination/ Climbing Ripples
- Trough Cross-Strat.
- Planar Lamination
- Mud-cracks
- Low Angle Trough Cross Sets
- Low Angle Tabular Bedding
- Cross-Bedding
- Soft-Sediment Deformation
- Horizontal Bedded
- Intraformational Conglomerate (IFC)
- Ripples

LITHOLOGIC ACCESSORIES

- Sand Lamina
- Calcareous
- Rip-Up Clasts
- Micaceous
- Oolites
- Pisolites
- Silty

ICHNOFOSSILS

- Unidentified Bioturbation
- Vertical Burrows

FOSSILS

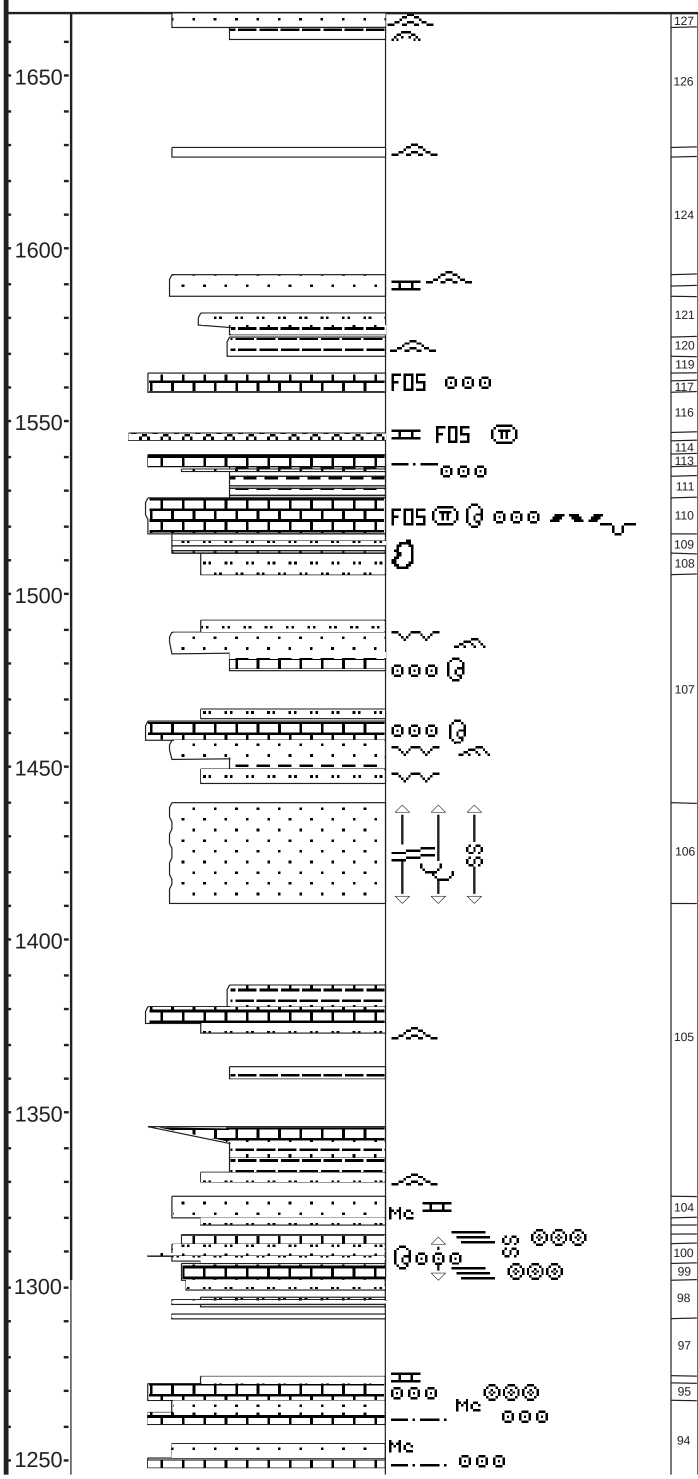
- Algal Stromatolite
- Fish Scales
- Gastropods
- Ostracodes
- Fossils

UGS 6

Jacks Creek Canyon

The section begins in the S1/2 section 10, T. 13 S., R. 17 E., and ends in the W1/2 section 6, T. 13 S., R. 17 E., of the Salt Lake Base line and Meridian, Carbon County, Utah.

FEET | GRAIN SIZE: cobble, pebble, granule, sand (v c m f v), silt, clay | PHYSICAL STRUCTURES, ACCESSORIES, ICHNOFOSSILS, FOSSILS | UNIT NUMBER | Unit number (measured section thickness [cumulative] in feet - Lithologic description



Unit 127 (1664.5-1668.5): Sandstone, very fine grained, light-gray, current ripples.

Unit 126 (1629.5-1664.5): Covered slope, top few feet mudstone, green with well developed layer of algal stromatolites, 6-12 inch diameter.

Unit 125 (1626.5-1629.5): Sandstone, very fine grained, light-gray, current ripples.

Unit 124 (1592.5-1626.5): Covered slope.

Unit 123 (1589.5-1592.5): Sandstone, very fine grained, very calcareous, flaggy, large ripples.

Unit 122 (1586.5-1589.5): Sandstone, very fine grained, light-gray, calcareous, subround to subangular.

Unit 121 (1574.5-1586.5): Covered slope, interbedded light-gray to white limy mudstone gradational with siltstone.

Unit 120 (1569.5-1574.5): Mudstone, light-gray to light-green, limy, gradational with underlying green shale, top is very thin ripple bedded.

Unit 119 (1564.5-1569.5): Covered slope, weathered shale, green to gray-green.

Unit 118 (1562.5-1564.5): Limestone, oolitic, white to light-gray, weathers white, some bone fragments.

Unit 117 (1559-1562.5): Limestone, oolitic grainstone, interbedded with shale, green, and mudstone, limy, light-gray to light-green, thinly bedded.

Unit 116 (1547-1559): Covered slope, weathered green shale.

Unit 115 (1545-1547): Conglomerate, quartzitic, very fine grained, very calcareous, micritic limestone clasts, fossil fragments, including bone fragments and gar scales.

Unit 114 (1541-1545): Covered slope, probably weathered green shale.

Unit 113 (1537.5-1541): Limestone, light-gray to light-green, slightly silty.

Unit 112 (1534-1537.5): Shale, green and interbedded oolitic grainstone.

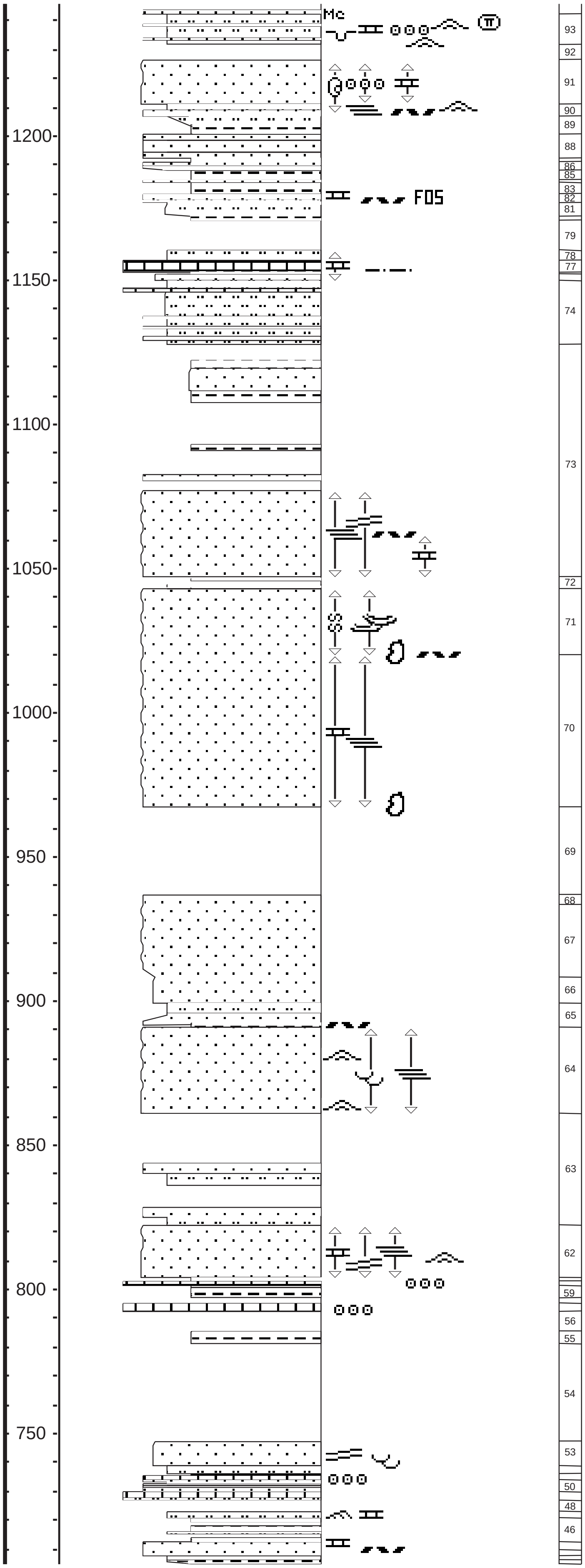
Unit 111 (1528-1534): Shale, green, some thin siltstone.

Unit 110 (1518-1528): Limestone, grainstone, medium-to coarse-grained, ostracodal and oolitic, fish scales, fossil hash, 2-inch-thick lag, rare burrowed surfaces.

Unit 109 (1512-1518): Sandstone, buff to light-orange, fine-grained, interbedded siltstone, green to buff.

Unit 108 (1506-1512): Siltstone, gray-green, small clay concretions.

Unit 107 (1440-1506): Covered slope, some sandstone, fine-grained with interbedded siltstone, gray to green shale, some mudcracks, feeding trace fossils, grainstone, light-tan weathers orange, ostracodal and oolitic up to 6-feet thick, sandstone, fine-grained, climbing ripples.



Unit 106 (1411-1440): Sandstone, fine-grained, light-brown, trough cross-bedded, low angle bedding, soft-sediment deformation, slightly flaggy near top.

Unit 105 (1326-1411): Covered slope, some mudstone, gray to green, some siltstone with ripples, oolitic grainstone, tan to gray limy mudstone, ripples.

Unit 104 (1320-1326): Sandstone, fine-grained, gray, micaceous, highly calcareous, thin bedded.

Unit 103 (1318-1320): Siltstone, tan to green, micaceous.

Unit 102 (1315-1318): Covered slope.

Unit 101 (1312-1315): Limestone, grainstone, light-tan, oolitic to pisolitic and ostracodal, planar laminations.

Unit 100 (1307-1312): Siltstone, interbedded with sandstone, fine-grained, light-gray to green, soft-sediment deformation, 1-inch thick oolitic limestone.

Unit 99 (1302-1307): Limestone, grainstone, light-tan, oolitic to pisolitic and ostracodal, planar laminations.

Unit 98 (1290-1302): Partially covered, interbedded sandstone and green siltstone, grading to sandstone, very fine grained near top.

Unit 97 (1274-1290): Covered, possible weathered shale, red and green.

Unit 96 (1272-1274): Siltstone, light-tan to brown, very calcareous.

Unit 95 (1267-1272): Limestone, oolitic to pisolitic grainstone, poorly sorted, abundant coarse quartz grains.

Unit 94 (1242-1267): Sandstone, fine-grained, tan, micaceous, interbedded with limestone, silty, oolitic, mostly covered.

Unit 93 (1232-1242): Siltstone, tan, interbedded with sandstone, oolitic, calcareous, with feeding burrows, some rippled surfaces, gar scales.

Unit 92 (1226-1232): Covered slope, calcareous siltstone at top.

Unit 91 (1212-1226): Sandstone, fine-grained, calcareous, ostracodes and ooids.

Unit 90 (1207-1212): Sandstone, fine-grained, tan to buff, massive at base, planar laminations, some ripples, 10-inch thick ostracodal-rich sandstone, 2 feet gray to buff siltstone, 10 inches thick ostracodal sandstone, limy siltstones, lag with micrite debris.

Unit 89 (1200.5-1207): Shale, green, grading up to siltstone, light-green to light-gray, gradational with overlying massive sandstone.

Unit 88 (1192.5-1200.5): Sandstone, some thin green siltstone stringers.

Unit 87 (1191-1192.5): Shale to mudstone, green.

Unit 86 (1188-1191): Siltstone, light-tan, very calcareous, grading upward to sandstone, very fine grained.

Unit 85 (1184.5-1188): Shale, green.

Unit 84 (1184-1184.5): Sandstone, very fine grained, light-gray to tan.

Unit 83 (1180-1184): Shale, green.

Unit 82 (1176-1180): Sandstone, light-gray to light-tan, very fine grained, very calcareous, rip-ups, fossil debris interbedded with siltstone light-gray to light-green, some red.

Unit 81 (1173-1176): Siltstone, red.

Unit 80 (1171-1173): Shale, green and reddish-purple, grading into siltstone, light-green.

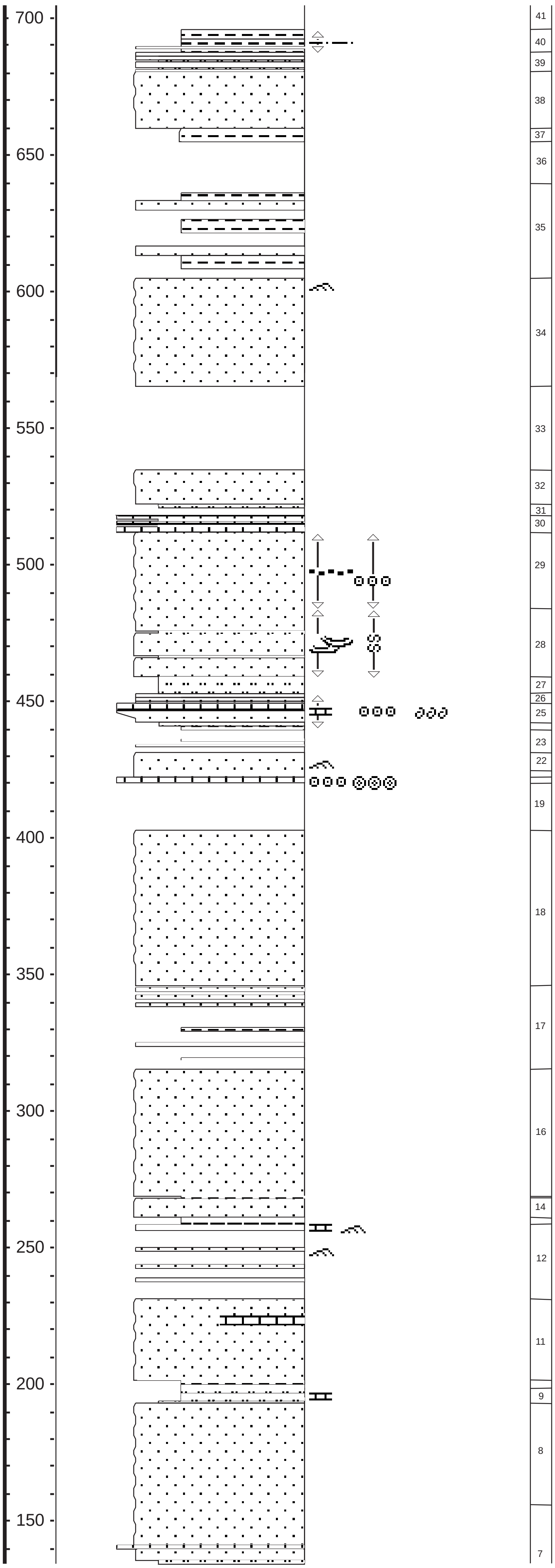
Unit 79 (1160-1171): Covered slope, probably red and green siltstone.

Unit 78 (1157-1160): Siltstone, light-tan, calcareous.

Unit 77 (1153-1157): Limestone, micrite, light-gray, occasionally silty.

Unit 76 (1152-1153): Siltstone and shale, green.

Unit 75 (1150-1152): Sandstone, very fine grained, light-tan, very calcareous.



Unit 74 (1128-1150): Siltstone, green to light-gray, mudcracks, interbedded with fine-grained sandstone, 2 feet interbedded mudstone/siltstone, maroon, load casts and trace fossils at base of overlying sandstone, 2.5 feet of carbonate (interbedded micrite and algal with some siltstone/mudstone) at 1,146 feet .

Unit 73 (1077-1128): Mostly covered, some thin sandstone, some green and red shale, top 21 feet mostly red shale and siltstone.
1,047-1,077: Sandstone, fine-grained, channel lag at the base, gray weathering, low angle to horizontal laminations, bottom half calcareous, top half non-calcareous, 1 inch of lag at base of top half (6 feet in length).

Unit 72 (1043-1047): Mostly covered, thin siltstone and shale.

Unit 71 (1020-1043): Sandstone, fine-grained, buff, tabular cross-beds, concretionary zone, channel lag with rip-ups, soft-sediment deformation, cliff former.
USGS corner marker T.12S., R. 17E. section 31.

Unit 70 (967-1020): Sandstone, fine grained, buff, massive, concretionary zone near base, calcareous, parallel laminations.

Unit 69 (937-967): Covered slope, weathered green and maroon siltstone.

Unit 68 (934-937): Sandstone, fine-grained, ledge former.

Unit 67 (909-934): Sandstone, buff to light-brown, laminated, some interbedded green siltstone.

Unit 66 (899-909): Sandstone, very-fine grained.

Unit 65 (891-899): Sandstone, fine grained to siltstone, base is 1-foot thick green shale, channel form with lag contains rip-up clasts of micrite.

Unit 64 (861-891): Sandstone, fine-grained, planar laminated, troughs, some ripples.

Unit 63 (822-861): Covered slope, some buff to light-brown sandstone interbedded with brown to maroon and green siltstone, sandstone is flaggy bedded.

Unit 62 (804-822): Sandstone, fine-grained, light-brown, friable, horizontal to low angle laminations, calcareous, some ripples, weathers to a very vuggy to cavernous surface.

Unit 61 (803-804): Shale, green to reddish purple.

Unit 60 (801-803): Limestone, micrite, light-gray, some ooids.

Unit 59 (797-801): Partially covered, interbedded siltstone and green shale.

Unit 58 (795-797): Covered slope, weathered green shale.

Unit 57 (792-795): Limestone, oolitic grainstone.

Unit 56 (792-785): Covered slope.

Unit 55 (781-785): Shale, green.

Unit 54 (747-781): Covered, across the wash, mostly sandstone with some green shale.

Unit 53 (738.5-747): Sandstone, light-gray to light-tan, very fine grained, flat base, low angle cross-bedding, minor troughs.

Unit 52 (736-738.5): Siltstone, light-gray to green.

Unit 51 (735-736): Limestone, oolitic grainstone with large clasts of micrite, 6 inches of black shale in middle of unit.

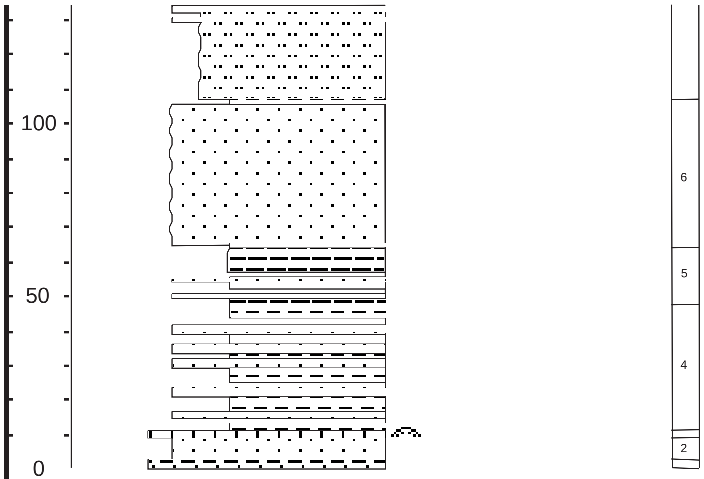
Unit 50 (730-735): Sandstone, light-gray to light-tan, very fine grained, thin bedded, interbedded with light-gray siltstone.

Unit 49 (727-730): Limestone, gray, micrite, some algal laminations, bottom 6 inches limy siltstone grading upward to limestone.

Unit 48 (722.5-727): Covered slope, weathered green shale.

Unit 47 (720.5-722.5): Siltstone, light-orange to tan, base very calcareous, top slightly calcareous, some current ripples at top.

Unit 46 (712-720.5): Partially covered, red shale, some interbedded siltstone.



Unit 45 (710-712.5): Sandstone, light-gray, very fine grained, calcareous.

Unit 44 (707.5-710): Sandstone, very fine grained, slightly calcareous, abundant rip-up clasts.

Unit 43 (706-707.5): Siltstone, light-gray, calcareous, gradational with underlying unit.

Unit 42 (705-706): Shale, red to reddish-purple.

Unit 41 (696-705): Covered slope, probably red shale.

Unit 40 (687.5-696): Shale, red, silty, some thin interbedded very fine grained sandstone.

Unit 39 (680.5-687.5): Sandstone and siltstone interbedded thin beds, sandstone very fine grained and green siltstone.

Unit 38 (659.5-680.5): Sandstone.

Unit 37 (655-659.5): Shale, green to purple.

Unit 36 (640-655): Covered, weathered red shale.

Unit 35 (605-640): Partially covered, sandstone and shale.

Unit 34 (565-605): Sandstone, abundant current ripples toward top of unit.

Unit 33 (535-565): Covered slope.

Unit 32 (522-535): Sandstone.

Unit 31 (518-522): Partially covered, purple to green siltstone at top of unit.

Unit 30 (512-518): Limestone, silty, orange with interbedded green siltstone.

Unit 29 (484-512): Sandstone (similar to unit 28) but with some ooids and some sand-sized micrite clasts, cliff former.

Unit 28 (459-484): Sandstone, fine-grained, calcareous, orange, tabular cross-bedding, large scale (several feet) soft-sediment deformation, silty interbeds.

Unit 27 (453-459): Siltstone, dark purple.

Unit 26 (449-453): Sandstone, fine-grained, calcareous, some shale.

Unit 25 (442-449): Sandstone, very fine grained, calcareous, grading to oolitic grainstone, orange-brown, rare shell fragments, ooids, and skeletal hash at base.

Unit 24 (440-442): Siltstone to mudstone, blue-green, slightly calcareous.

Unit 23 (431-440): Covered slope, one thin sandstone and one thin mudstone unit, each about 1-foot thick.

Unit 22 (424-431): Sandstone, thick bedded, light-gray on fresh surface, dark-gray on weathered surface, minor ripples.

Unit 21 (422-424): Sandstone, thin bedded, very fine grained, orange-brown on fresh surface.

Unit 20 (420-422): Limestone, oolitic to pisolitic, orange-gray, micrite clasts.

Unit 19 (403-420): Covered slope.

Unit 18 (346-403): Sandstone, cliff former.

Unit 17 (315-346): Mostly covered, some thin sandstone, some red to green shale, increasing sandstone towards top of unit.

Unit 16 (269-315): Sandstone.

Unit 15 (268-269): Shale, green, grading up to purple mudstone.

Unit 14 (261-268): Sandstone, very fine grained, green-gray to medium-brown, mostly yellow-tan.

Unit 13 (258-261): Mudstone, mostly green, some purple, slightly limy.

Unit 12 (231.5-258): Mostly covered slope, sandstone beds, thin orange-brown weathered surface, some ripple lamination, top 20 inches sandstone bed very limy.

Unit 11 (201.5-231.5): Sandstone, channel form, irregular cutting base, (carbonate bed at 222 feet, but cut out here).

Unit 10 (198.5-201.5): Green shale and thin siltstone.

Unit 9 (193-198.5): Siltstone to shale thin (6-inch), green, thin very calcareous siltstone, hard, dense, thin interbedded green siltstone to silty shale, almost a silty limestone.

Unit 8 (156-193): Sandstone, massive channel form, base variable, down cutting, so thickness varies laterally.

Unit 7 (107-156): Siltstone, green at base, grading up to light brown to reddish-purple, mostly reddish-purple, grading upward to very fine grained sandstone with thin interbeds of reddish-purple and some green siltstone, some bottom feeding structures in the green siltstone, some rare thin (1-2 inches) limestone, ostracodal, brecciated. Thin channel form sandstone beds near top of unit.

Unit 6 (64-107): Sandstone, channel form, red shale above and below, cross-bedded, fine-grained to very fine grained.

Unit 5 (48-64): Purple mudstone and medium-brown sandstone, some covered slope, purple mudstone with minor green mudstone at top of bed.

Unit 4 (11-48): Interbedded sandstone (40%) and shale (60%), sandstone thin bedded, some covered slope.

Unit 3 (9-11): Algal stromatolites.

Unit 2 (3-9): Fine-grained sandstone.

Unit 1 (0-3): Limy shale, orange-gray, shaly partings.

LEGEND

LITHOLOGY

- Sandstone
- Siltstone
- Organic -Rich Shale
- Shale
- Mudstone
- Limy Shale
- Conglomerate
- Limy Mudstone
- Covered Slope
- Limestone

PHYSICAL STRUCTURES

- Ripple Drift Lamination/ Climbing Ripples
- Planar Lamination
- Soft-Sediment Deformation
- Trough Cross-Strat.
- Low Angle Tabular Bedding
- Cross-Bedding
- Ripples
- Mudcracks
- Concretion/Nodule

LITHOLOGIC ACCESSORIES

- Calcareous
- Oolites
- Shell Fragments
- Rip-Up Clasts
- Silty
- Clasts
- Mc - Micaceous
- Pisolites

ICHNOFOSSILS

- Vertical Burrows

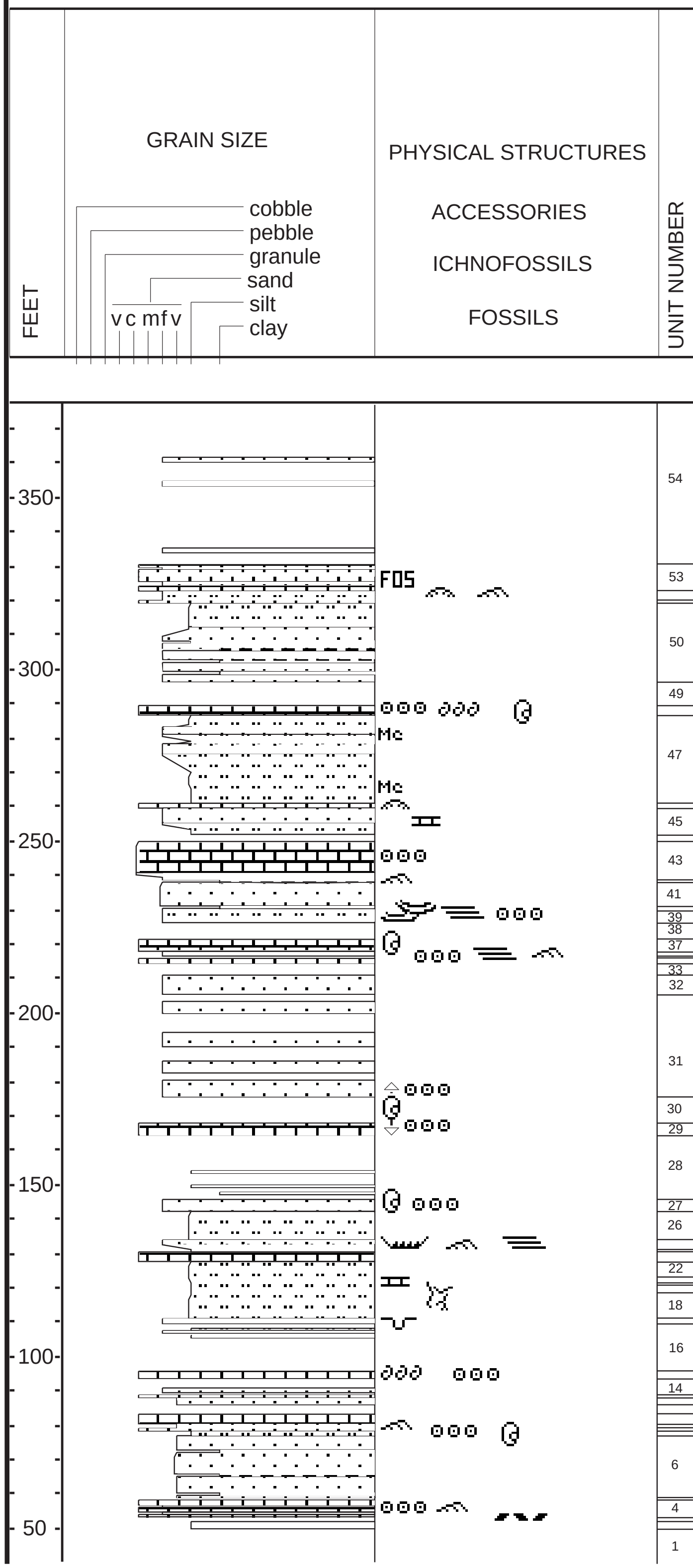
FOSSILS

- Algal Stromatolite
- FOS - Fossils
- Fish Scales
- Ostracodes

UGS 7a

Fret Rapids Tongue E

The section is located near Fret Water Rapids in Desolation Canyon and begins in the SW1/4NW1/4 section 16, and ends in the NE1/4NE1/4 section 17, T. 14 S., R.17 E., of the Salt Lake Base line and Meridian, Carbon County, Utah.



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

Unit 54 (330.5-377.5): Covered slope, some thin beds of fine-grained sandstone. End of section, cliff blocking progress.

Unit 53 (322.5-330.5): Limestone, micritic, light-gray, interbedded with sandstone up to 2 feet thick, middle of unit 6 inch layer of fossil hash with micrite clasts. At base of unit, algal stromatolites up to 8 inches in diameter.

Unit 52 (320-322.5): Sandstone, fine-grained, medium-gray, ripples, with interbedded siltstone, platy weathering.

Unit 51 (319.5-320): Algal stromatolite, probably dolomitized.

Unit 50 (296.5-319.5): Sandstone fine-grained, with small interbeds of gray siltstone to shale, fining upward to siltstone, light-gray.

Unit 49 (289.5-296.5): Covered slope.

Unit 48 (286.5-289.5): Grainstone, oolitic, some ostracodes, some shell fragments.

Unit 47 (260.5-286.5): Siltstone, light-gray, grading upward to green siltstone, and sandstone, fine-grained, slightly micaceous, platty weathering.

Unit 46 (259.5-260.5): Algal stromatolite with pillar type algal on top.

Unit 45 (251.5-259.5): Siltstone grading up to sandstone, fine-grained, calcareous.

Unit 44 (249.5-251.5): Covered slope.

Unit 43 (238.5-249.5): Sandstone (2 feet), fine-grained, grading upward to oolitic grainstone, dessication cracks, some ripples.

Unit 42 (238-238.5): Shale and siltstone, green.

Unit 41 (231-238): Sandstone, fine-grained.

Unit 40 (230-231): Siltstone to shale, green.

Unit 39 (226-230): Sandstone, fine-grained, locally abundant ostracodes and ooids, planar laminations and cross-bedding.

Unit 38 (221-226): Covered slope, some green to gray shale.

Unit 37 (218-221): Ostracodal grainstone, some ooids.

Unit 36 (216.5-218): Sandstone, fine-grained, ripple and planar lamination.

Unit 35 (215.5-216.5): Covered slope.

Unit 34 (214.5-215.5): Grainstone, ostracodes and ooids.

Unit 33 (210.5-214.5): Covered slope.

Unit 32 (205.5-210.5): Sandstone, fine-grained.

Unit 31 (175.5-205.5): Sandstone, fine-grained, bottom 4 feet contains ostracodes and ooids, mostly covered slope, some thin beds.

Unit 30 (167.5-175.5): Covered slope.

Unit 29 (164-167.5): Grainstone, ostracodes and ooids.

Unit 28 (145.5-164): Covered slope, some maroon siltstone and green shale.

Unit 27 (142-145.5): Sandstone, pale-orange, abundant ostracodes, some ooids.

Unit 26 (133.5-142): Siltstone, green to gray and purple, lag layer near base.

Unit 25 (131.5-133.5): Siltstone grading upward to sandstone, very fine grained, planar laminations, ripples.

Unit 24 (130.5-131.5): Siltstone, green to gray, shaly laminations.

Unit 23 (127.5-130.5): Ostracodal grainstone.

Unit 22 (124-127.5): Siltstone, gray to green, pale-orange on top.

Unit 21 (122-124): Siltstone, red grading to green.

Unit 20 (121-122): Siltstone, very calcareous, buff.

Unit 19 (118-121): Siltstone, purple grading upward to dark-green.

Unit 18 (111-118): Siltstone, maroon to light-green at base, bioturbated.

Unit 17 (109.5-111): Sandstone, fine-grained, pale-orange, some burrowing, ledge former.

Unit 16 (95.5-109.5): Covered slope, with dark gray siltstone some thin sandstone beds towards the top of the unit.

Unit 15 (93.5-95.5): Ostracodal limestone, sandy, some ooids, shell fragments near top of unit.

Unit 14 (88.5-93.5): Covered slope, probable green shale with 1 foot of sandstone.

Unit 13 (88-88.5): Ostracodal grainstone.

Unit 12 (86-88): Sandstone, very fine grained, grading up to siltstone.

Unit 11 (83-86): Covered slope.

Unit 10 (80-83): Ostracodal grainstone, some trace fossils.

Unit 9 (79-80): Sandstone, very fine grained, light-gray, highly rippled.

Unit 8 (78-79): Oolitic grainstone, with some ostracodes, micrite clasts up to 2 inches in diameter.

Unit 7(77-78): Siltstone, green.

Unit 6 (58-77): Sandstone, very fine grained to fine-grained, thin bedded to platy, yellowish-tan to buff, some gray shale, top has some ripples.

Unit 5 (57-58): Covered Slope.

Unit 4 (53-57): Ostracodal grainstone, ripple marks, lag about 1 foot from base, some ooids, some sandstone.

Unit 3 (51.5-53): Covered Slope.

Unit 2 (50-51.5): Siltstone, gray-green.

Unit 1 (0-50): Covered slope.

LEGEND

LITHOLOGY

Sandstone | Shale | Limestone | Coquina

Siltstone | Covered Slope

PHYSICAL STRUCTURES

- Ripple Drift Lamination/ Climbing Ripples
- Planar Lamination
- Rip-Up Lag
- Cross-Bedding

LITHOLOGIC ACCESSORIES

- Calcareous
- Rip-Up Clasts
- Shell Fragments
- Mc - Micaceous
- Oolites

ICHNOFOSSILS

- Unidentified Bioturbation
- Vertical Burrows

FOSSILS

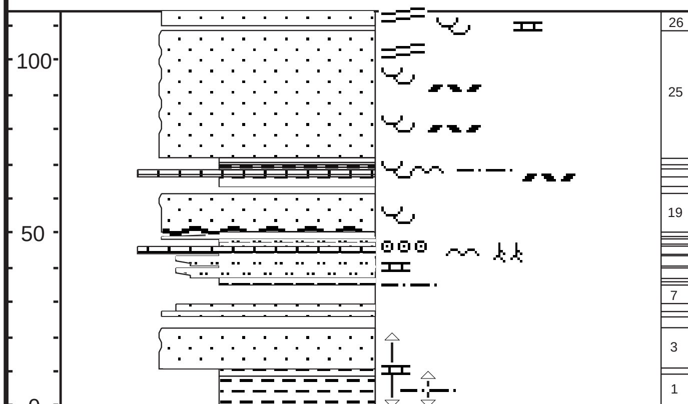
- Algal Stromatolite
- Ostracodes
- FOS - Fossils

UGS 7b

Fret Water Rapids Tongue F

The section is located near Fret Water Rapids in Desolation Canyon and begins and ends in the SW1/4NE1/4 section 17, T. 14 S., R. 17 E., of the Salt Lake Base line and Meridian, Carbon County, Utah.

FEET	GRAIN SIZE (cobble, pebble, granule, sand [v c m f v], silt, clay)	PHYSICAL STRUCTURES / ACCESSORIES / ICHNOFOSSILS / FOSSILS	UNIT NUMBER	Unit Number (measured section thickness [cumulative] in feet) - Lithologic description



Unit 26 (109-114.5): Sandstone, partially covered base, light-tan, very fine grained, slightly calcareous, some low angle and trough cross-beds. Overlain by thick unit of red shale.

Unit 25 (72-109): Sandstone, fine-grained, light-tan, massive, some low angle and trough cross-beds, some lag rip-up clasts of calcareous siltstone and silty limestone.

Unit 24 (70-72): Shale, light-gray to light-green, some dark-gray, one limy mudstone unit (6 inches thick) in lower half of unit.

Unit 23 (68.5-70): Oolitic grainstone with interbedded shale in the lower half of the unit. Shale light-gray to light-green, silty some wave ripples, occasional small trough cross-beds, generally coarsening upward unit except capped with light-gray to light-green limy mudstone, which is transitional with overyling unit.

Unit 22 (66.5-68.5): Limestone to limy mudstone, light-gray to light-green at base, rare ooids, grading upward to coarse oolitic grainstone, light-yellow, unit weathers red. Grainstone unit has wave ripples and trough cross-bedding near the top, base of upper half of the unit has numerous clasts of green shale to limestone, rare chert.

Unit 21 (63.5-66.5): Shale, light-gray to light-green.

Unit 20 (61.5-63.5): Covered slope.

Unit 19 (50.5-61.5): Sandstone, very fine grained to fine-grained, rare medium-grained, weathers red, limonitic, subround to subangular, frosted grains, some clear, trough cross-beds.

Unit 18 (48.5-50.5): Siltstone grading to very fine grained sandstone, calcareous light-gray to green, base sharp, top undulatory due to loading from overlying unit. Fining upward to 1-2 inch shale at top, light-gray to light-green.

Unit 17 (48-48.5): Shale, light-gray to light-green.

Unit 16 (47-48): Oolitic grainstone, black at base to brownish-orange at top, coarsening upward.

Unit 15 (46.5-47): Shale, light-gray to light-green, some black, near the top of the unit 1 inch oolitic grainstone.

Unit 14 (44.5-46.5): Limestone, argillaceous, some ooids, grading upward to oolitic grainstone, light-gray to light-brown, top 1-inch dark-gray to black micrite limestone with some ooids. Base flat, top generally sharp, some wave ripples some root traces, spreading laterally but not very deep.

Unit 13 (44-44.5): Shale to mudstone, non-calcareous.

Unit 12 (41-44): Siltstone to very fine grained sandstone, green, calcareous.

Unit 11 (40.5-41): Limy mudstone, weathered surface often stained red.

Unit 10 (37.5-40.5): Siltstone, grading upward to very fine grained sandstone, green, limonitic, rare muscovite, calcareous.

Unit 9 (36-37.5): Limy mudstone, green.

Unit 8 (35.5-36): Weathered limy mudstone, silty, green, resistive.

Unit 7 (30-35.5): Covered slope.

Unit 6 (27.5-30): Sandstone, light-gray, very fine grained, subround, limonitic, flat base and top, some flat parallel and low to moderate angle crossbeds.

Unit 5 (26-27.5): Interbedded very fine grain sandstone and light gray to light-green shale.

Unit 4 (22.5-26): Covered slope.

Unit 3 (11-22.5): Sandstone, fine-grained, subround, frosted and some clear grains, calcareous.

Unit 2 (9-11): Shale, green, silty, calcareous, transitional with underlying red shale. Bottom of Green River Formation.

Unit 1 (0-9): Shale, red, calcareous, silty, hard, dense. Top of Colton Formation.

LEGEND

LITHOLOGY

Sandstone	Shale	Limy Mudstone	Limestone
Siltstone	Mudstone	Covered Slope	

CONTACTS

Undulating

PHYSICAL STRUCTURES

- Trough Cross-Strat.
- Low Angle Tabular Bedding
- Wave Ripples

LITHOLOGIC ACCESSORIES

- Calcareous
- Rip-Up Clasts
- Oolites
- Silty

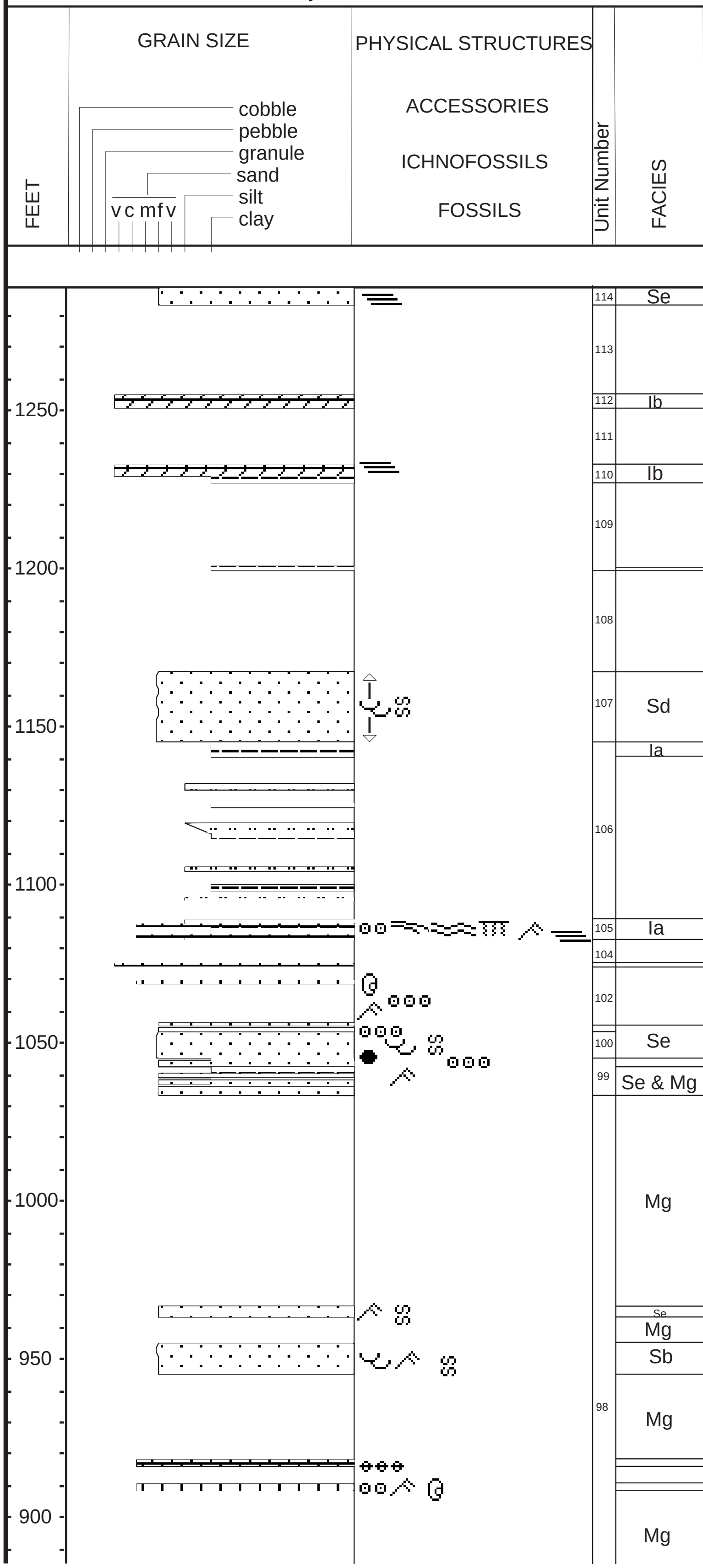
ICHNOFOSSILS

- Rootlets

Back to Table of Contents Back to Report

Remy 7

The section is located at the junction of Nine Mile and Gate Canyons, beginning in the NE1/4SE1/4 section 32 and ending in the NE1/4SW1/4 section 29, T. 11 S., R. 15 E., of the Salt Lake Base line and Meridian, Duchesne County, Utah.



Unit Number - Lithologic description

Unit 114: Sandstone, fines upward (280-170 microns). Planar laminations with parting lineations.

Unit 113: Covered.

Unit 112: Dolostone. Laminated and kerogenous (oil shale), upper half weathers to paper shale.

Unit 111: Covered.

Unit 110: Mudstone and dolostone. Basal 23.6 in. is yellowish-brown mudstone; 23.6-51.2 in. is laminated, kerogenous dolostone (oil shale); 51.2 in. to top is laminated dolostone. All three subunits contain streaks of yellow silty rock (tuff?).

Unit 109: Mainly covered: 9.8 in. thick bed of light brown calcareous mudstone grading into kerogenous dolostone (oil shale) at base.

Unit 108: Covered interval.

Unit 107: Sandstone, 175-300 microns. Base sharp and scours 7.9 in. into underlying mudstone; well exposed large-scale trough cross-beds, some are oversteepened.

Unit 106: Mainly covered. Light-gray soil, few thin outcrops of calcareous, coarse-grained siltstone and medium-brown calcareous mudstone; brown laminated mudstone crops out beneath unit 107.

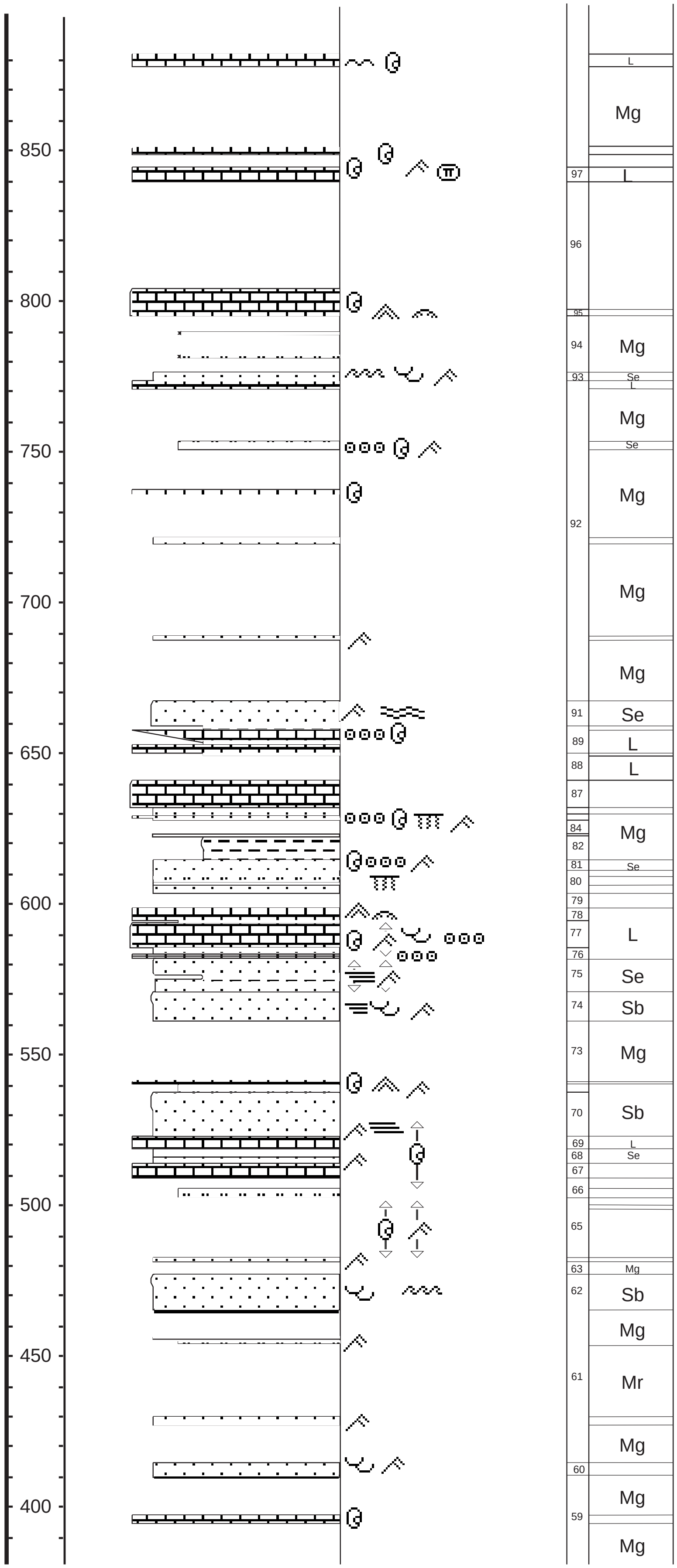
Unit 105: Interbedded siltstone, mudstone, limestone and sandstone. Basal 6.3 in. is coarse-grained siltstone; 6.3-10.6 in. is covered; 10.6-40.6 in. is light gray-olive is massive calcareous mudstone grading up to silty mudstone;40.6-51.2 in. is calcareous coarse-grained siltstone; 51.2 in. to top is sandy limestone.

Unit 104: Covered slope.

Unit 103: Dolostone. Laminated and kerogenous (oil shale), light bluish-gray weathered color, very dark-gray fresh color, slight oily smell.

Unit 102: Mainly covered. Three thin outcrops: Base consists of thin lenticular sandstone, rippled, 125 microns; middle 90 micron sandstone containing minor ooids and ostracodes; top is ostracodal grainstone with coated carbonate grains.

Unit 101: Sandstone, seperated into three beds by covered slope. Basal bed 5.9 in. thick, ooids; middle bed 7.9 in. thick; top bed 3.1in. thick. All beds have poorly exposed ripples.



Unit 100: Sandstone, fines upward. Base is sharp and dips 5 degrees to N.30E. Truncates unit 99, usually lacks lag deposits, but locally can contain large (11.8 by 5.9 by 5.9 in.) limestone blocks. Mudstone interbeds near top.

Unit 99: Interbedded green mudstone, sandstone, siltstone, and limestone. Bed thickness less than 31.5 in. siltstone coarse and rippled, in places top 13.8 in. is a bed of ooid grainstone.

Unit 98: Poorly exposed interval. 3.6 feet above base is ostracodal grainstone. At 877.7 feet there is a 4.9 foot bed of silty micrite which contains green mudstone partings and thin interbeds. At 908.9 and 915.4 feet there are two thin beds of rippled ostracodal limestone and a bed of limestone containing coated carbonate grains, respectively. Two small sandstone beds between 944.9 feet and 967.9 feet.

Unit 97: Limestone. Base is very light-gray micrite; middle is rippled ostracodal grainstone containing minor intraclasts and fish scales; top is ostracodal grainstone.

Unit 96: Mainly covered. Slope covered with soil and talus; few thin outcrops of ostracodal limestone near base.

Unit 95: Limestone.

Unit 94: Mostly covered. Scattered fragments of green mudstone and a few very thin outcrops of siltstone.

Unit 93: Sandstone, fines upward (140 to 125 microns).

Unit 92: Mainly covered. Abundant fragments of green mudstone. Some beds of limestone, siltstone and sandstone.

Unit 91: Sandstone, 110-135 microns. Base sharp and flat, well-exposed ripples throughout.

Unit 89: Limestone, mudstone and sandstone.

Unit 88: Mainly covered. Green mudstone crops out beneath unit 89.

Unit 87: Limestone (?). Silty micrite (?), fine-grained to moderately silty, very calcareous.

Unit 86: Sandstone, 140 microns. Structureless.

Unit 85: Lower two-thirds is 140 micron sandstone, bed thickness less than 0.8 in. Upper one-third limestone.

Unit 84: Mainly covered. Abundant green mudstone fragments and green mudstone beneath unit 85.

Unit 83: Sandstone, 100 microns.

Unit 82: Mudstone. Greenish gray, poorly exposed.

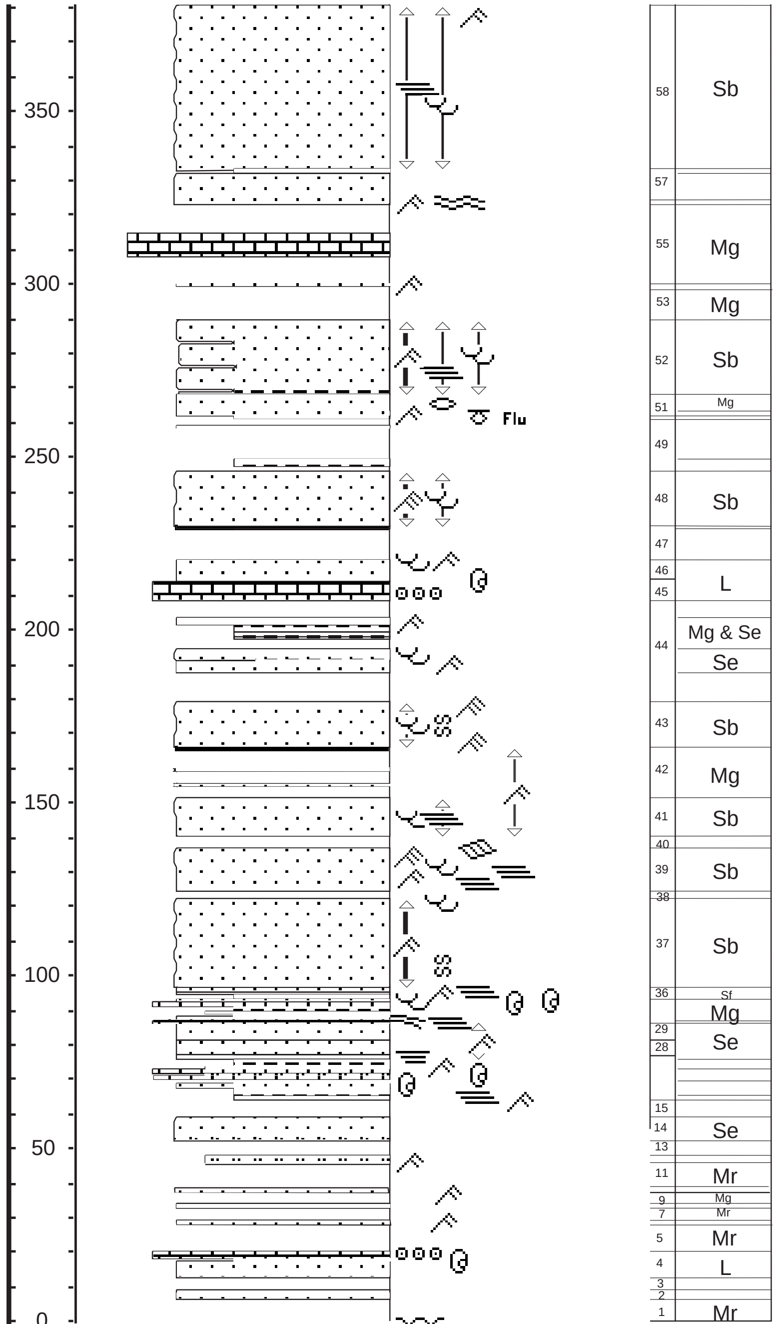
Unit 81: Sandstone, mainly 150 microns, top 7.9 in. is 80 microns. Mostly structureless, except ripples(?) in top 7.9 in.

Unit 80: Interbedded sandstone (< 100 microns), siltstone and green mudstone

Unit 79: Covered.

Unit 78: Limestone. Lower half consists of large (up to 23.6 in.) domal stromatolites; upper half consists of pillar-type stromatolites.

Unit 77: Limestone. Mainly ostracodal grainstone. Top 11.8 in. is siltstone containing ostracodes.



Unit 76: Limestone, siltstone and sandstone. Overall unit coarsens upward.

Unit75: Interbedded sandstone (<100 microns) and green mudstone.

Unit 74: Sandstone, 90-125 microns. Base dips 15 degrees WNW; ripples and planar laminations with low-angle truncations and minor trough cross-beds.

Unit 73: Covered. Abundant green mudstone fragments and green mudstone beneath unit 74.

Unit 72: Limestone. Ostracodal grainstone, small pillar-type stromatolites at base.

Unit 71: Siltstone, coarse-grained. Poorly exposed.

Unit 70: Sandstone, fines upward (160-110 microns). Scours all of unit 69 and part of unit 68 in places. Consists of two subunits: (1) basal lag deposit 0 to few feet thick, small to large angular framents of limestone from unit 69, IFC as multiple lenses, matrix of well-sorted 160 micron sand, planar laminations with low-angle truncations and ripples; (2) upper zone of 120-110- micron sandstone, 6.6 to 13.1 feet thick, lateral-accretion bedding cuts through subunit 1 and into unit 68 downdip, multiple internal scours and ripples (wave?), thin green mudstone interbed and thin IFC lens at top.

Unit 69: Limestone. Basal 3.3 feet is ostracodal grainstone; top 15.9 in. is silty micrite (?) containing ostracodes.

Unit 68: Sandstone and Siltstone. Basal 23.6 in is rippled sandstone (100-130 microns); Top 3.3 feet is interbedded sandstone and siltstone.

Unit 67: Mainly covered. Similar to unit 65.

Unit 66: Upper half mainly ostracode grainstone and lower half mainly thin bedded siltstone.

Unit 65: Mainly covered. Numerous thin outcrops of rippled siltstone and ostracodal limestone.

Unit 64: Sandstone, 90 microns. Sparse to abundant clasts in upper half.

Unit 63: Covered. Abundant green mudstone fragments.

Unit 62: Sandstone, fines upward (190-125 microns). 19.7 in. of basal scour; some troughs have oversteepened cross-beds. Sedimentary structures are not well exposed.

Unit 61: Mainly covered. Thick soil and abundant float. A few beds sandstone, siltstone and mudstone.

Unit 60: Sandstone, 125-155 microns.

Unit 59: Mainly covered. Thick soil and abundant talus; two beds of ostracodal limestone and micrite; friable very fine grained sandstone at top.

Unit 58: Sandstone, most of unit is 120-150 microns, upper 6.6 feet is 110 microns. Probably composite amalgamated sandbody containing scattered internal IFC zones and mulitple internal scoured sandstone-sandstone and sandstone-mudstone contacts. Most of unit contains planar laminations with low-angle truncations, few log impressions; basal 9.8 feet exhibit lateral accreation bedding, beds dip northeast.

Unit 57: Mainly covered. Top 19.7 in. is interbedded sandstone, siltstone, and mudstone.

Unit 56: Sandstone, 70-150 microns.

Unit 55: Covered. Green soil and green mudstone chips suggests unit is green mudstone.

Unit 54: Sandstone, 100 microns.

Unit 53: Covered. Green soil and green mudstone fragments suggests unit consists of greenish-gray mudstone.

Unit 52: Sandstone, 100-110 microns. Few thin mudstone interbeds. Numerous stacked and mutually truncating lenticular 32.8-49.2 foot sandbodies.

Unit 51: Interbedded Sandstone (65 microns) and mudstone. Bed thickness 7.9 in. or less.

Unit 50: Sandstone, 100 microns. Base contains sole marks, load structures, and tool marks or flute casts.

Unit 49: Mainly covered. A couple mudstone beds and a thin bed of fine-grained sandstone.

Unit 48: Sandstone, coarsens upward (65 to 110 microns).

Unit 47: Mainly covered. One 7.9 in thick bed of 90 micron sandstone and mudstone.

Unit 46: Sandstone, 100-120 microns. Complex interlensing of sandstone and lesser ostracodal limestone and limestone with limestone intraclasts. Individual beds are discontinuous. Unit thickens to the east.

Unit 45: Limestone. Basal 7.9 in. is sandy ostrocodal grainstone, most of unit is a dark-yellowish-orange micrite.

Unit 44: Partly exposed interval of sandstone, mudstone, and siltstone. Interval is 60 percent covered.

Unit 43: Sandstone, 120-130 microns. Unit contains large scale trough cross-beds and soft-sediment deformation.

Unit 42: Mostly covered. Four to five thin outcrops of fine-grained rippled sandstone.

Unit 41: Sandstone, 120-130 microns.

Unit 40: Covered. Greenish-gray mudstone and fissile medium-grained siltstone beneath the soil.

Unit 39: Sandstone 110-150 microns. Basal 31.5 in. contains planar laminations that have parting lineations; 31.5 in. to 5.7 ft. contains trough cross-beds, ripples, and some planar lamination; upper 6.39 ft. contains trough cross-beds, 3-D current ripples and some climbing ripples.

Unit 38: Mainly covered. Unit forms bench between ledges formed by units 37 and 39.

Unit 37: Sandstone, 100-160 microns. Base sharp, tool marks and load structures; massive except one distinct 7.9 in. bed about 6.6 feet above base that contains soft-sediment deformation and one distinct 9.8 in bed at top that contains ripples and few cross-beds.

Unit 36: Interbedded mudstone, sandstone, and ostracodal limestone. Beds are lenticular and contain local concentrations of carbonized wood or small clasts of sandstone and limestone.

Unit 35: Limestone and sandstone. Sandy limestone grades upward to 65 micron sandstone; trough cross-beds or scours throughout; linguoid ripples at top of unit. Unit grades laterally into interval consisting of complex mix of sand and ostracodes having no vertical trends.

Unit 34: Mudstone. Greenish-gray, ostracodes in places, weathers into small angular fragments.

Unit 33: Siltstone, coarse-grained. Structureless.

Unit 32: Mudstone, Green.

Unit 31: Sandstone, 110 microns. Sharp base, poorly exposed.

Unit 30: Limestone. Mainly ostracodal grainstone, base sharp, 3.9 in. basal scour; contains ripples, planar laminations, and hummocky cross-stratification; limestone is sandy, amount of sand increases upward; upper third of unit consists of interbedded sandstone (<130 microns) and limestone.

Unit 29: Sandstone, 115 microns. Base sharp, 1.9-2.4 in. of basal scour, top sharp, rippled (type unknown).

Unit 28: Sandstone. Four beds (base to top). (1) 3.9 in., structureless, 110 microns, (2) 1.9 in., structureless, 110 microns, (3) 21.7 in., 100 micron sandstone that grades through siltstone to 1.9 in. of green mudstone, structureless, (4) 15.7 in., 150 micron sandstone at base, most is 70 micron, rippled at top.

Unit 27: Mudstone, fine-grained. Greenish-gray, slightly calcareous.

Unit 26: Sandstone, fines upward (130 to 70 microns). Unknown ripples and unknown planar laminations, top sharp.

Unit 25: Interbedded mudstone and siltstone.

Unit 24: Siltstone. Relatively sharp base and top.

Unit 23: Limestone. Dark-gray micrite containing ostracodes.

Unit 22: Siltstone. Gradational with unit 21, sharp top, contains ostracodes.

Unit 21: Limestone. Ostracodal grainstone.

Unit 20: Mudstone. Green, poorly exposed.

Unit 19: Sandstone, 100 microns. Sharp base, unknown wave ripples.

Unit 18: Mudstone, greenish-gray.

Unit 17: Limestone. Mainly ostracodal grainstone, base sharp and slightly scoured, top sharp; 3.9-13.8 in. above base thin siltstone interbeds; 7.9-13.8 in. above base horizontally laminated; top 5.9 in. mainly structureless, faint ripples in places.

Unit 15: Mostly covered. Beneath unit 16 is green mudstone overlain by 5.9-inch-thick bed of silty limestone or very calcarous siltstone.

Unit 14: Sandstone, 90 microns. Wave ripples, burrows on some bedding planes.

Unit 13: Mainly covered, top 13.8 in. is friable 65 micron sandstone that grades into unit 14. Sandstone is massive and structureless.

Unit 12: Siltstone, coarse-grained. Base gradational over 3.9 in. with underlying red mudstone, rippled (?).

Unit 11: Covered. Red mudstone crops out beneath unit 12.

Unit 10: Base and top sharp and irregular (0-1.9 in of relief), faint ripples. 100 mircons.

Unit 9: Covered. Green mudstone crops out beneath unit 10.

Unit 8: Well-exposed wave ripples (wave ripples have chevrons, bidirectional cross-laminations, bundled upbuilding, and irregular and undulatory ripple-set boundaries). 90 microns.

Unit 7: Covered. Red soil suggests red mudstone.

Unit 6: Rippled, base fairly sharp, breaks into thin wavy plates. 65 microns.

Unit 5: Deep soil, red mudstone cropping out beneath unit 6 and red color of soil suggest unit is red mudstone.

Unit 4: Interbedded limestone, sandstone and mudstone.

Unit 3: Covered. Some green mudstone fragments on surface.

Unit 2: Base grades upward to finer grained sandstone. 100 microns.

Unit 1: Covered. Fragments of mudcracked red mudstone at base.

LEGEND

LITHOLOGY

Sandstone
Siltstone
Mudstone
Limestone
Covered Slope
Shale
Dolostone

CONTACTS

Sharp

PHYSICAL STRUCTURES

- Trough Cross-Strat.
- Wavy Laminations
- Convolute Bedding
- Load Casts
- Ripples
- Wave Ripples
- Algal Stromatolite
- Climbing Ripples
- Lenticular Bedding
- Mudcracks
Flu - Flute Casts
- Current Ripples
- Pillar-Type Stromatolite
- Planar Lamination
- Hummocky Cross-Strat.
- Synaeresis Cracks
- Soft-Sediment Deformation
- Intraformational Conglomerate (IFC)

LITHOLOGIC ACCESSORIES

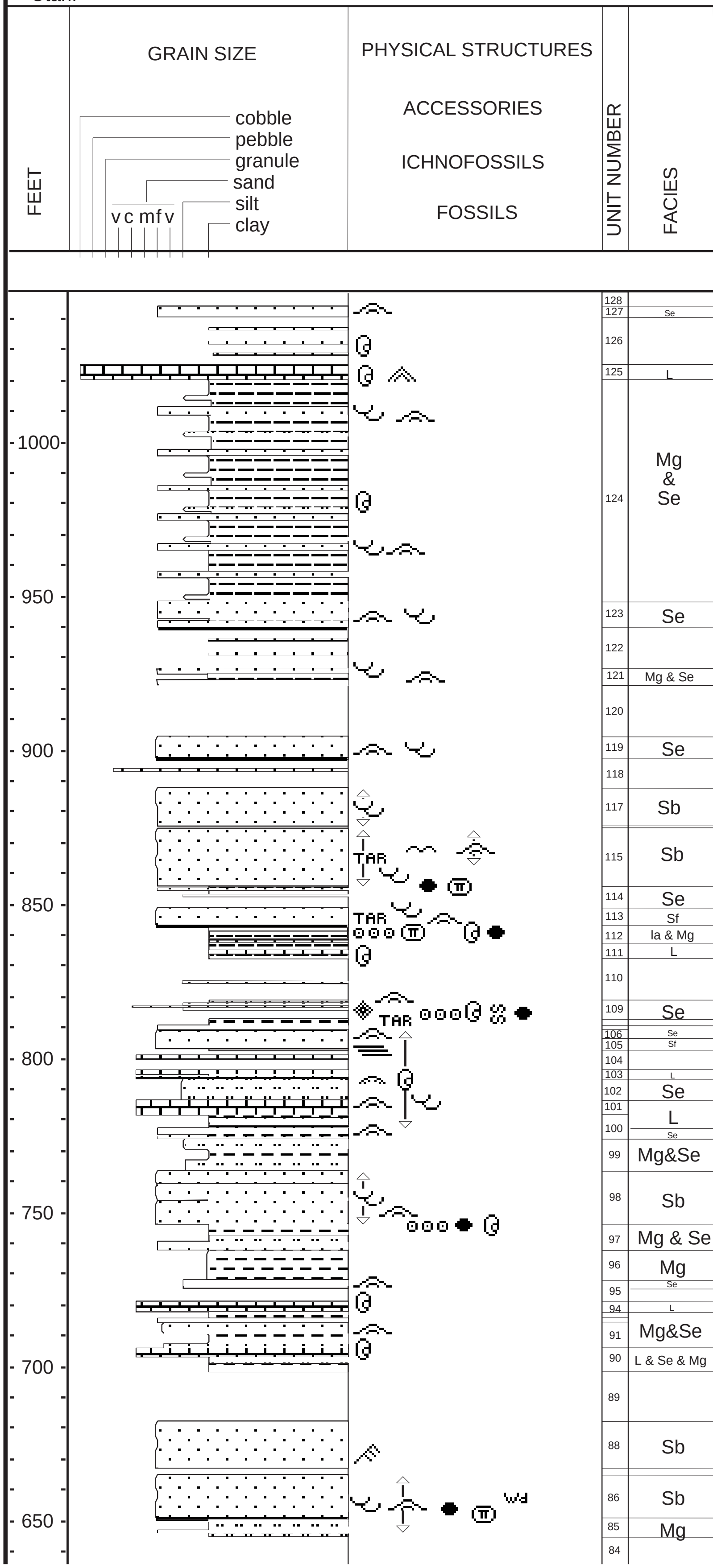
- Oolites
- Coated Grains

FOSSILS

- Fish Scales
- Ostracodes

Remy 8

The section is located in Nine Mile Canyon, beginning in the SW1/4NW1/4 and ending in the NW1/4NW1/4 section 4, T. 12 S., R. 14 E., of the Salt Lake Base line and Meridain, Duchesne County, Utah.



Unit Number - Lithologic description

Unit 128: Covered.

Unit 127: Sandstone, 130 microns. Base not exposed.

Unit 126: Mainly covered. Few thin outcrops of silty limestone or calcareous mudstone, some contain ostracodes.

Unit 125: Limestone. Lower two-thirds consists of pillar-type stromatolites; upper third is hard, light-gray to yellow micrite containing ostracodes.

Unit 124: Interbedded mudstone and siltstone (70-80 percent) and sandstone (20-30 percent). Sandstone is 80-120 microns.

Unit 123: Sandstone, most is 100-150 microns, basal bed 220 microns. Bed thickness 3.9-23.6 inches.

Unit 122: Mainly covered. Scattered outcrops of silty micrite.

Unit 121: Interbedded 90-125 micron sandstone and mudstone. Mudstone is green and is present as thin discontinuous interbeds in sandstone and as one 19.7-inch-thick bed.

Unit 120: Mainly covered.

Unit 119: Sandstone, 100-125 microns. Sandstone beds are amalgamated (?).

Unit 118: Mainly covered. Thin bed of silty micrite in center; greenish-gray mudstone containing few-inch-thick tuff(?) crops out near top.

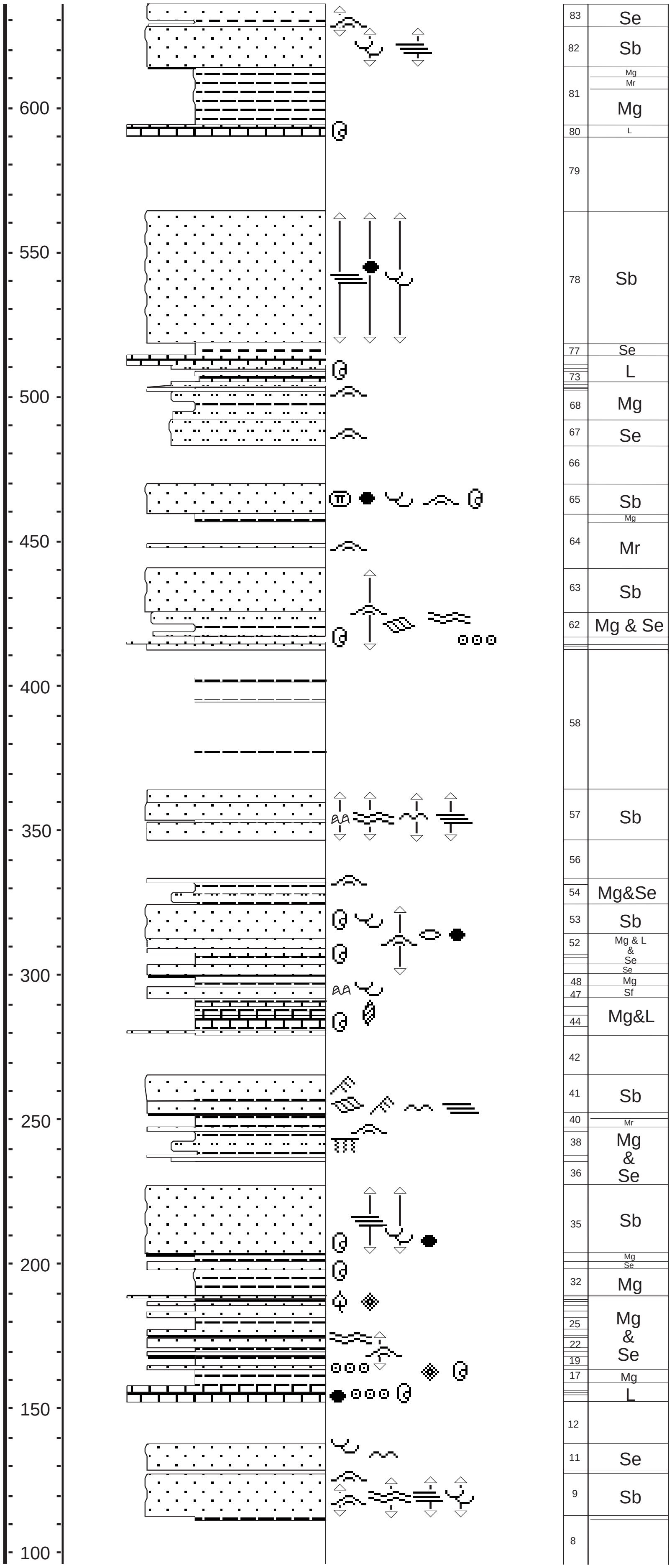
Unit 17: Sandstone, 125-135 microns. Base covered.

Unit 116: Covered. Probably greenish-gray mudstone.

Unit 115: Sandstone, 110-275 microns. Basal 3.9-11.8 inches consists of 275 micron sandstone containing laminated yellow mudstone clasts and fish scales overlain by 220 micron sandstone that scours into basal bed; upper 18 feet fines upward (275-110 microns).

Unit 114: Interbedded mudstone, siltstone and sandstone. Lower half is covered; mudstone is green.

Unit 113: Sandstone, 124-150 microns. 11.8-15.7 in. of basal scour in places; unit thickens to the west; tar saturated.



Unit 112: Interbedded mudstone, siltstone, and limestone. Lower half of unit is interbedded greenish-gray mudstone and light-gray siltstone; upper half is interbedded-interlaminated light-brown mudstone, siltstone, and thin carbonate beds consisting of carbonate intraclasts, ooids, ostracodes, and fish scales; contacts between beds are sharp to gradational.

Unit 111: Interbedded mudstone and limestone. Basal 11.8 in. is mudstone with minor ostracodes; 11.8-19.7 in. is ostracodal limestone; 19.7-31.5 in. is green mudstone; 31.5 in. to top is ostracodal limestone; top 1.2-1.6 in. is micrite.

Unit 110: Mainly covered. One bed of sandstone.

Unit 109: Interbedded sandstone, siltstone and limestone. Basal 19.7 in. is 130 micron sandstone containing 5-10 percent carbonate grains; 19.7-21.7 in. is yellow, sandy, ostracodal limestone; 21.7-31.5 in. is poorly sorted 100 micron sandstone, base is 160 microns; 31.5-39.4 in. above base is siltstone; 39.4 in. to top is 100 micron sandstone.

Unit 108: Mainly covered. Some green mudstone in places.

Unit 107: Sandstone, 150 microns. Yellow carbonate grains near base; upper half of unit is tar saturated; sedimentary structures indistinct, probably ripples.

Unit 106: Sandstone, 70-130 microns. Forms series of sandstone ledges and soil-covered slopes. Bed thickness less than 7.9

Unit 105: Sandstone, coarsens upward (70 to 85 microns).

Unit 104: Mainly covered. One 11.8-inch-thick bed of dark-gray limestone containing ostracodes and fossils; a 9.8-inch-thick bed medium-greenish-gray, fissile, calcareous shale; one thin bed of siltstone.

Unit 103: Interbedded limestone, mudstone, and siltstone. Basal 8.5 in. is domal algal stromatolite, domes about 19.7 in. width; 8.5-13.4 in. above base is greenish-gray mudstone and siltstone; 13.4-18.1 in. is algal laminated limestone; 18.1 in. to top is ostracodal grainstone.

Unit 102: Siltstone. Contains ostracodes, poorly exposed.

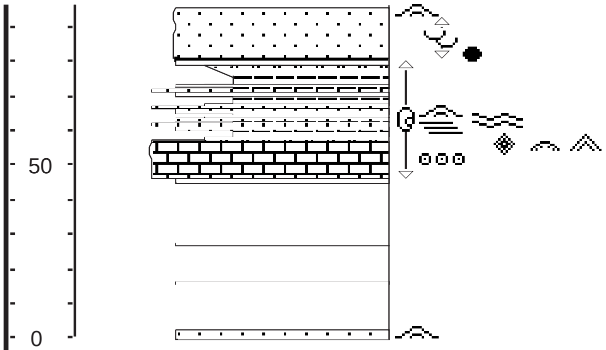
Unit 101: Limestone. Ostracodal grainstone.

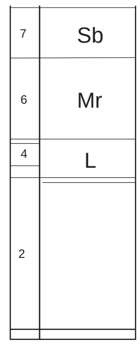
Unit 100: Sandstone, siltstone, mudstone, and limestone. Basal 3.6 feet is mainly sandstone and a few thin mudstone beds; upper 3.9 feet of unit consists of interbedded-interlaminated ostracodal grainstone and lesser greenish-gray mudstone and siltstone, bed thickness few millimeters to 7.9 inches.

Unit 99: Interbedded mudstone and siltstone. Poorly exposed; mudstone is green.

Unit 98: Sandstone, fines upward (140 to 110 microns). Base is sharp and scoured, in places base of unit contains IFC (clast-supported in places) composed of carbonate, siltstone, and mudstone clasts, base also contains scattered bone fragments; weakly tar saturated.

Unit 97: Interbedded sandstone, siltstone, and mudstone. Contacts between rock types are gradational. Mudstone is green.





Unit 96: Mudstone. Greenish-gray. Silty, amount of silt increases upward.

Unit 95: Siltstone. Lower two-thirds poorly exposed; upper third rippled.

Unit 94: Limestone. Yellow ostracodal grainstone; unit thins toward east.

Unit 93: Mudstone and siltstone. Greenish-gray mudstone grades upward to siltstone.

Unit 92: Sandstone, 70 microns.

Unit 91: Interbedded sandstone-siltstone and mudstone. Mean bed thickness 7.9 in.; most sandstone beds are structureless, mudstone is greenish-gray; contacts between beds are sharp.

Unit 90: Mudstone, siltstone, and limestone. Basal greenish-gray mudstone grades upward to very coarse grained siltstone through silty ostracodal limestone to silty micrite(?).

Unit 89: Covered.

Unit 88: Sandstone, 80-100 microns. Unit forms a series of sandstone ledges and soil-covered slopes.

Unit 87: Covered.

Unit 86: Sandstone, 90-140 microns. 19.7 in. of basal scour, basal 19.7 in. contains scattered mudstone intraclasts; lenticular zones of mudstone clasts above base, internal scours, one zone contains abundant wood impressions; basal 9.5 feet consists of 110-140 micron sandstone ; top 4.9 feet consists of 90 micron sandstone.

Unit 85: Greenish-gray mudstone and lesser siltstone and sandstone. Sandstone and siltstone are rippled.

Unit 84: Covered. Probably greenish-gray mudstone.

Unit 83: Interbedded sandstone (very fine grained) and mudstone. Sandstone beds are 15.7-19.7 in. thick; mudstone is greenish-gray.

Unit 82: Sandstone, mainly 130-175 microns, some 95 micron.

Unit 81: Mudstone. Mainly greenish-gray, poorly exposed; top 6.5 feet consists of purple mudstone that grades upward to gray mudstone that grades upward to greenish-gray mudstone.

Unit 80: Limestone. Silty micrite(?).

Unit 79: Covered.

Unit 78: Sandstone (100-135 microns) and minor mudstone. Complex sand body: (1) upper two-thirds fines upward overall, probably contains multiple smaller scale fining upward sequences, (2) lower one-third consists of thick sandstone beds separated by lenticular greenish-gray mudstone,whereas upper two-thirds consists of multiple lenticular amalgamated sandstone beds, (3) lateral-accretion bedding, (4) multiple channel-like scours within unit, (5) some planar laminations and trough cross-beds, altogether sedimentary structures are generally not well exposed.

Unit 77: Mudstone. Greenish-gray.

Unit 76: Limestone. Olive-gray micrite(?) containing minor ostracodes(?).

Unit 75: Siltstone.

Unit 74: Covered.

Unit 73: Limestone and mudstone. Silty micrite and one 5.9-inch-thick bed of mudstone.

Unit 71: Sandstone. Base slightly irregular.

Unit 70: Mudstone. Greenish-gray.

Unit 69: Sandtone. Base irregular.

Unit 68: Siltstone and mudstone, greenish-gray, poorly exposed.

Unit 67: Siltstone.

Unit 66: Covered.

Unit 65: Sandstone, 125-145 microns. Base coverd. Numerous irregular intervals containing IFC; sandstone beds are 11.8-19.7 in. thick, amalgamated in places, and separated by lenticular, thin, green mudstone interbeds; numerous internal truncations; log impressions, trough cross-beds, ripples, HCS(?), and intervals containing 10-15 percent ostracodes.

Unit 64: Mainly covered. Red mudstone under thin soil cover; 15.7-inch-thick bed of 70 micron sandstone; top 3 feet is mudstone.

Unit 63: Sandstone, 100 micron. 7.9-11.8 in. of basal scour; bed thins toward the east where it contains several thin mudstone interrbeds and is partially truncated by sandstone beds with lateral-accretion bedding.

Unit 62: Interbedded mudstone (40 percent) and sandstone-siltstone (60 percent). Sandstone-siltstone bed range in size from coarse grained siltstone to 120 micron sandstone. Mudstone is greenish-gray.

Unit 61: Limestone and mudstone. Mainly ostracodal grainstone that grades upward to green mudstone, and grades downward to silty micrite.

Unit 60: Mudstone, greenish-gray.

Unit 59: Sandstone, 130 microns.

Unit 58: Mainly covered. Several thin beds of siltstone; green and red soil suggests unit is mainly green and red mudstone.

Unit 57: Sandstone, 80-90 microns. At base of unit sandstone beds dip 13° N. 60° E. Suggests lateral-accretion bedding.

Unit 56: Covered. Greenish-gray soil and fragments of greenish-gray and red mudstone suggests unit consists of mudstone.

Unit 55: Sandstone, 60-70 microns. Greenish.

Unit 54: Interbedded greenish-gray mudstone and siltstone.

Unit 53: Sandstone, generally 90-100 microns, some zones of 150 microns. Base irregular, lenticular beds of mudstone and IFC at base; 90-100 micron sandstone is rippled; 150 micron sandstone is trough cross-bedded.

Unit 52: Interbedded sandstone(60-70 microns), and lesser siltstone, mudstone, and limestone. Sandstones contain small channels in places.

Unit 51: Limestone. Ostracodal grainstone, contact gradational with unit 50 from greenish-gray mudstone to yellowish ostracode-rich mudstone to ostracodal grainstone. Parts of unit 51 truncated by channels filled with mudstone.

Unit 50: Mudstone. Greenish-gray.

Unit 49: Sandstone, 100 micron. Top is scour filled with green mudstone, faint dipping laminations.

Unit 48: Interbedded mudstone and sandstone-siltstone. Greenish-gray mudstone contains several thin sandstone and siltstone beds.

Unit 47: Sandstone, 90-110 microns.

Unit 46: Interbedded mudstone and limestone. Basal 15.7 in. is greenish-gray mudstone; 15.7-31.5 in. is hard gray micrite; 31.5 in. to top is siltstone or mudstone.

Unit 45: Interbedded limestone and mudstone. Slightly scoures unit 43. Unit consists of ostracodal grainstone.

Unit 44: Interbedded mudstone and sandstone (70 micron). Sandstone beds structureless.

Unit 43: Limestone. Mainly ostracodal grainstone; 3.1-inch-thick bed of mudstone 7.9 in. above base; 1.9-inch-thick of interlaminated green mudstone and limestone 11.8 in. above base.

Unit 42: Covered. Minor green mudstone crops out beneath unit 43.

Unit 41: Sandstone, coarsens upward lightly (95 to 105 microns). 3.9-5.9 in. of scour, carbonate grains at base. One 7.9 in. bed of mudstone.

Unit 40: Mudstone. Lower half green and purple; upper half fissile green mudstone to shale.

Unit 39: Sandstone, 70 micron.

Unit 38: Interbedded greenish-gray mudstone and siltstone. Syneresis cracks(?) in mudstone.

Unit 37: Sandstone and siltstone. Medium-grained siltstone grades upward to 90 micron structureless sandstone.

Unit 36: Mainly covered.

Unit 35: Sandstone, 110-140 microns. Scours unit 33 and 32 and part of 31, basal scour irregular and contains IFC, ostracodes(up to 50 percent).

Unit 34: Mudstone. Greenish-gray.

Unit 33: Sandstone, 70-80 microns. Transitional with unit 32.

Unit 32: Mudstone. Greenish-gray.

Unit 31: Limestone. Ostracodal grainstone.

Unit 30: Mudstone. Greenish-gray.

Unit 29: Sandstone, siltstone, and shale. Basal 0.8 in. is 100 micron sandstone that grades upward to siltstone to light-gray paper shale that contains leaf impressions and carbonized twigs.

Unit 28: Sandstone. Grades upward from unit 26 through brownish siltstone to brown 90 microns sandstone.

Unit 27: Mudstone. Greenish-gray.

Unit 26: Interbedded sandstone (up to 100 microns) and siltstone seperated by a thin bed of mudstone.

Unit 25: Mudstone. Greenish-gray.

Unit 24: Sandstone, 70-80 microns.

Unit 23: Mudstone. Green.

Unit 22: Sandstone, 80 microns.

Unit 21: Mudstone, greenish-gray.

Unit 20: Sandstone, 160 microns. Thin greenish-gray mudstone beds in places.

Unit 19: Interbedded mudstone and siltstone. Mudstone is greenish-gray.

Unit 18: Sandstone, 125 microns.

Unit 17: Mudstone and siltstone. Top 7.9 in. is siltstone containing carbonaceous debris and yellowish grains.

Unit 16: Limestone. Two beds of gray micrite or fine-grained mudstone seperated by 2.95 in. bed of dark-brown, fissle, calcarous shale.

Unit 15: Limestone. Type uncertain, may contain recrystallized carbonate grains.

Unit 14: Dolostone. Dark-gray, some zones kerogenous (oil shale).

Unit 13: Limestone. Silty micrite(?), contains ostracodes, ooids, and limestone intraclasts; top 1.9-3.9 in. is ostracodal grainstone.

Unit 12: Covered.

Unit 11: Sandstone, 80-100 microns.

Unit 10: Covered.

Unit 9: Sandstone, 95-110 microns.

Unit 8: Mainly covered. Green mudstone crops out beneath unit 9.

Unit 7: Sandstone, 80-105 microns. 3 feet of scour, sedimentary structures poorly exposed, probably trough cross-beds or small channels.

Unit 6: Interbedded mudstone, siltstone, sandstone, and minor limestone. Mudstone is green, gray, and purple and exhibits lateral and vertical color transitions; sandstone has sharp and flat to scoured bases and is structureless, less than 125 microns; siltstone beds have irregular and gradational bases and tops; few thin ostracodal limestone beds are wavy planar laminated and rippled.

Unit 5: Limestone. Carbonate clasts and ostracodes; grades upward into silty micrite; top 3.9 in. is domal-and pillar type stromatolites.

Unit 4: Limestone. Micrite, medium-brownish-gray to dark-gray, poorly exposed, small carbonized twigs in places.

Unit 3: Limestone. Basal 27.5 in. is ostracode grainstone; 27.5-61 in. is silty micrite; 61 in. to top is ooid grainstone.

Unit 2: Mainly covered. Several thin sandstone beds crop out, greenish-gray soil suggests interval is green mudstone.

Unit 1: Sandstone. Coarsens upward.

LEGEND

LITHOLOGY

Sandstone
Siltstone
Shale
Mudstone
Covered Slope
Limestone
Dolomite

CONTACTS

Sharp

PHYSICAL STRUCTURES

- Trough Cross-Strat.
- Lenticular Bedding
- Soft-Sediment Deformation
- Combined-Flow Ripples
- Algal Stromatolites
- Climbing Ripples
- Synaeresis Cracks
- Wavy Laminations
- Wave Ripples
- Pillar-Type Algal Stromatolites
- Planar Lamination
- Ripples
- Intraformational Conglomerate (IFC)
- Current Ripples

LITHOLOGIC ACCESSORIES

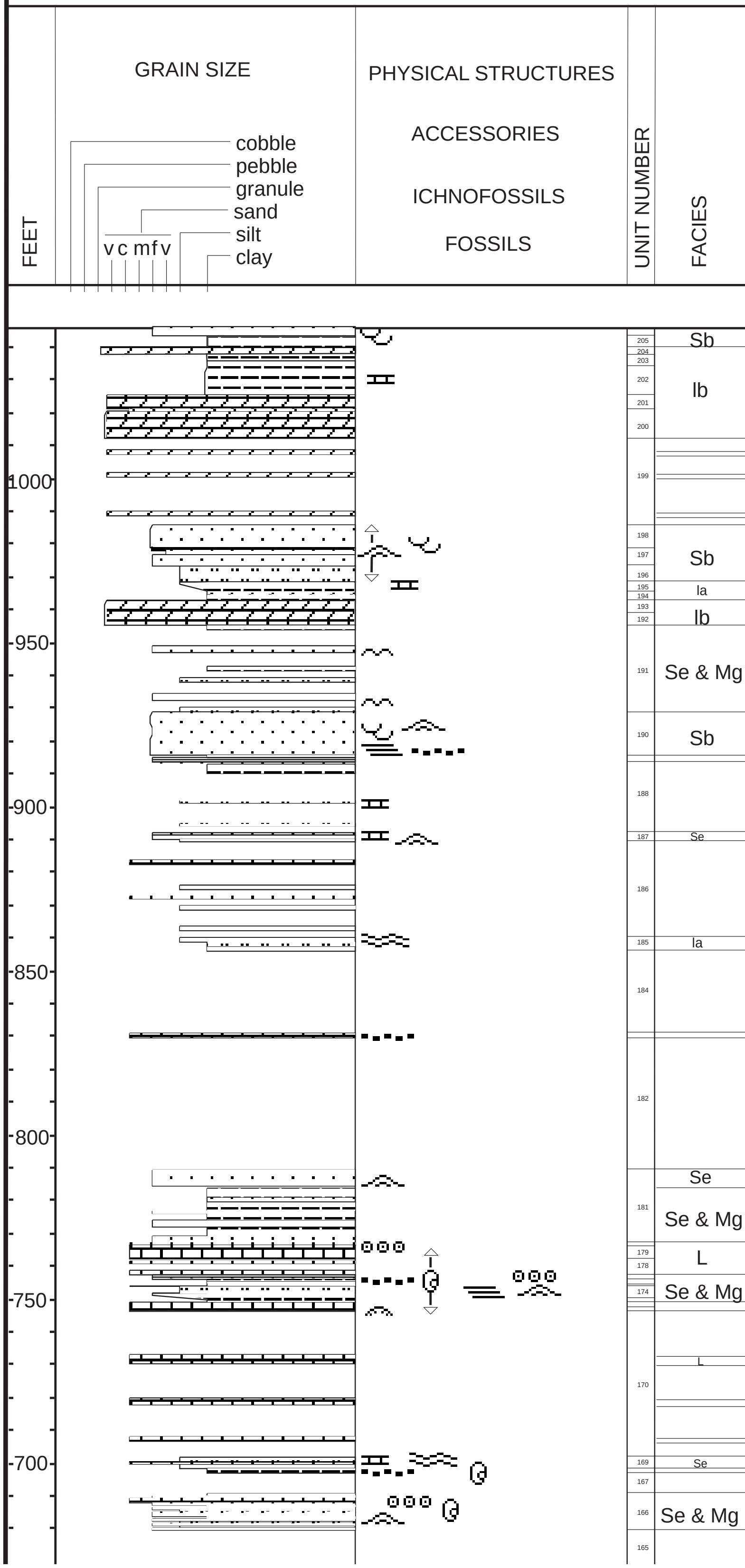
- Oolities
TAR - Tar
Wd - Wood Fragments

FOSSILS

- Plant Remains
- Carbonized Fossils (undifferentiated)
- Gastropods
- Fish Scales
- Ostracodes

Remy 9

The section is located in Nine Mile Canyon, beginning in the SE1/4SW1/4 section 8 and ending in the NW1/4SW1/4 section17, T. 12 S., R. 16 E., of the Salt Lake Base line and Meridian, Duchesne County, Utah.



Unit Number - Lithologic description

Unit 206: Sandstone, fines upward. Base sharp and flat, faint trough cross-beds.

Unit 205: Mudstone. Olive-brown, silty, laminated.

Unit 204: Dolostone. Very dark-gray, laminated on weathered surfaces.

Unit 203: Mudstone and dolostone. Medium brownish-gray, moderately calcareous mudstone grades upward to very dark-gray dolostone.

Unit 202: Mudstone. Light to medium brownish-gray, moderately calcareous, fine-grained to moderately silty, weathers very light-gray, some zones are laminated on weathered surfaces.

Unit 201: Dolostone. Laminated, very kerogenous (oil shale), weathers to paper shale in places.

Unit 200: Dolostone. Laminated and moderately kerogenous (oil shale), weathers to paper shale in places; 0.75 in. thick tuff near top.

Unit 199: Mainly covered. Few thin outcrops of brown dolostone.

Unit 198: Sandstone. Base sharp and scours underlying sandstone; most structureless, well exposed ripples in places and trough cross-beds in lower half.

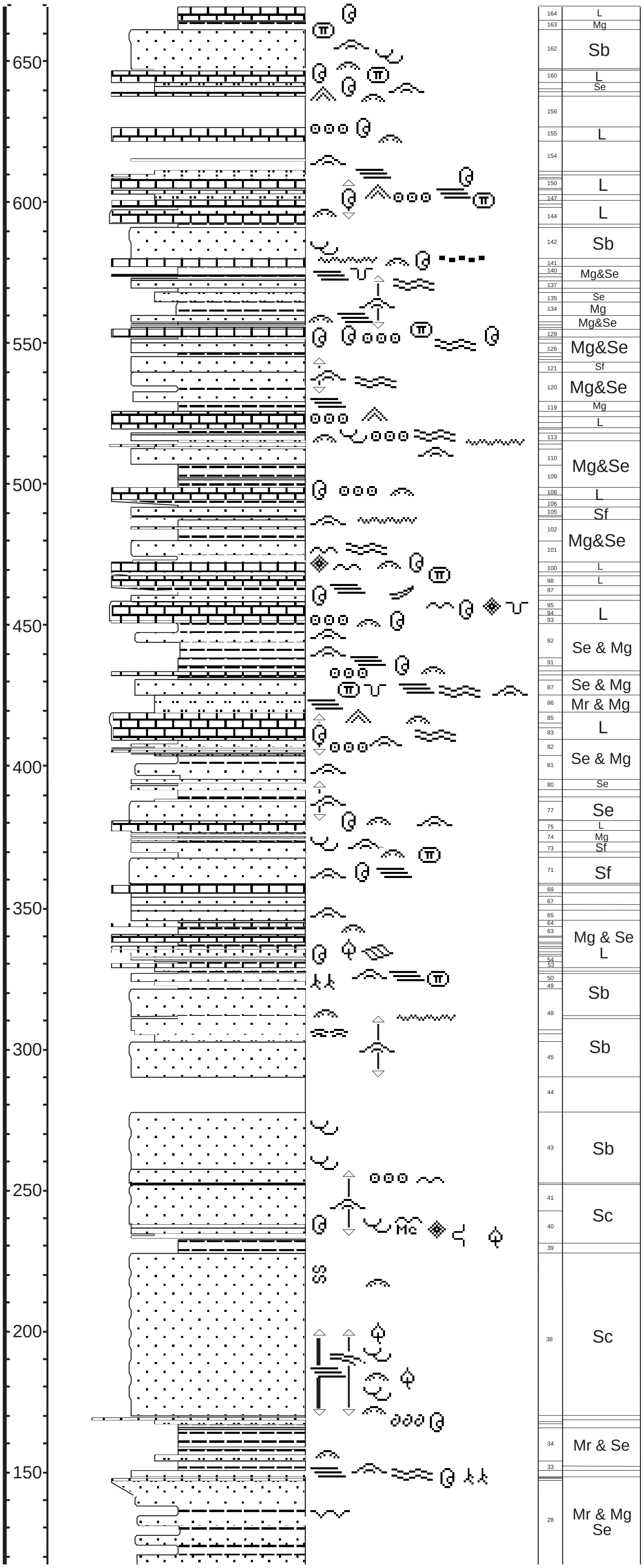
Unit 197: Sandstone. Basal two-thirds is rippled; upper third forms recess.

Unit 196: Siltstone, medium to coarse-grained. Base gradational over 5.9 inches with underlying mudstone, rippled in places.

Unit 195: Mudstone. Sharp base, light brownish-gray, moderately calcareous, mudstone grades upward to very light-gray mudstone; unit weathers white and is laminated in places.

Unit 194: Mudstone. Olive-gray, laminated, gradational contact with underlying dolostone; near top 3.1 in. bed of orange-red rock (tuff ?).

Unit 193: Dolostone. Basal 7.9 in. moderately kerogenous.



Unit 192: Dolostone. Laminated and very kerogenous (oil shale), weathers to paper shale in places.

Unit 191: Siltstone, sandstone, and mudstone. Much of unit covered; abundant siltstone and wave-rippled sandstone, and olive-gray mudstone in places.

Unit 190: Sandstone, fines upward. Base sharp, less than 11.8 in. of scour; 0-15.7-inch-thick zone containing mudstone clasts at base, minor trough cross-beds, ripples and planar laminations; mostly structureless.

Unit 189: Sandstone-siltstone and mudstone. Three beds of sandstone overlain by 7.9 in. thick bed of green mudstone and siltstone.

Unit 188: Mainly covered. Several outcrops of laminated to thinly bedded, light-gray calcareous siltstone; thin bed of mudstone crops out beneath unit 189.

Unit 187: Siltstone and sandstone. Basal 9.8 in. is calcareous siltstone; 9.8-19.7 in. is sandstone; 19.7 in. to top is structureless sandstone.

Unit 186: Mainly covered. Minor outcrops of light-gray laminated siltstone and light-gray carbonate rock.

Unit 185: Mudstone and siltstone. Laminated dark yellowish-brown mudstone grades upward to laminated, light-gray, fine-grained siltstone that grades upward to coarse-grained siltstone containing wavy planar laminations.

Unit 184: Covered. Abundant float of tar-saturated limestone, some ooids.

Unit 183: Limestone. Mainly of fine carbonate grains and larger grains and zones of brecciated laminated limestone.

Unit 182: Covered.

Unit 181: Sandstone and mudstone. Unit covered along section but lower 21.6 feet of interval exposed in nearby cliff where it consists of basal 6.6 feet interbedded green mudstone and fine-grained sandstone; 6.6-16.4 feet green mudstone and several sandstone-siltstone interbeds; 16.4-17.4 feet unidentified bed; 17.4-21.6 feet rippled sandstone.

Unit 180: Limestone. Grain supported ooids and ostracodes, base sharp and irregular.

Unit 179: Limestone. Micrite, white, very fine grained, laminated in few places, minor carbonate grains in places.

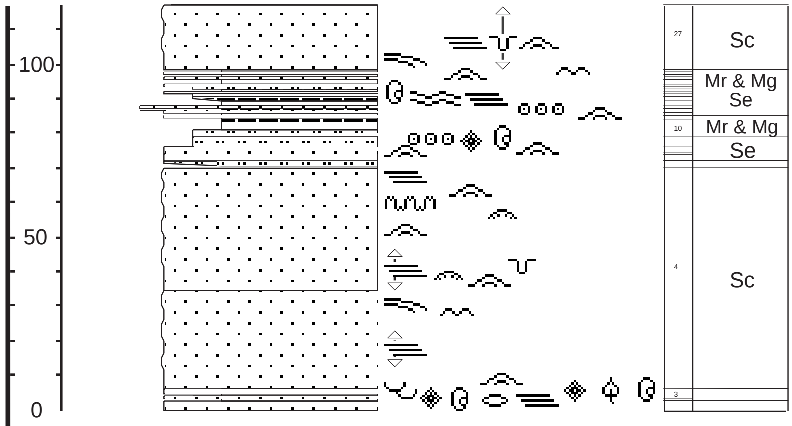
Unit 178: Mainly covered. One bed of ostracodal and ooid grainstone containg limestone clasts and one 5.9-inch-thick bed of brownish-gray micrite.

Unit 177: Sandstone and mudstone. Rippled sandstone breaks in slabs 0.8-3.1 in. thick; 5.9 -inch-thick bed of fissile green mudstone 3.9 in. from top.

Unit 176: Mudstone and siltstone. Basal 7.9 in. is fissile green mudstone; upper 11.8 in. is interbedded mudstone and siltstone.

Unit 175: Limestone. Base sharp; composed of ostracodes, small round carbonate grains and larger more angular limestone clasts.

Unit 174: Siltstone and sandstone. Base grades upward from mudstone to sandstone; top grades upward to coarse-grained siltstone; contains planar laminations and ripples.



Unit 173: Mudstone, greenish-gray.

Unit 172: Limestone. Basal 7.9 in. is lightyellowish-gray, composed of silt to very fine sand-sized carbonate grains and less than 10 percent ostracodes; upper 7.9 in. is interbedded limestone composed of ostracodes and other carbonate grains and limestone similar to basal 7.9 inches.

Unit 171: Limestone. Oncolites, angular fragments of laminated limestone, and small domal stromatolites in matrix of fine-grained limestone containing ostracodes.

Unit 170: Mainly covered. Few outcrops of thin bedded to laminated limestone, abundant green mudstone float on surface.

Unit 169: Siltstone and limestone. Siltstone is light-gray and moderately calcareous, contains wavy planar laminations, breaks into slabs .008-.04 in. thick, one 0-5.9-inch-thick bed of laminated limestone disrupts siltstone bed.

Unit 168: Mudstone and limestone. Basal 7.9 in. is green mudstone containing limestone clasts and thin limestone interbeds; basal mudstone grades upward to limestone composed of ostracodes and small spherical to oval limestone clasts.

Unit 167: Covered.

Unit 166: Interbedded sandstone, siltstone, mudstone, and limestone. Bed thickness 2-11.8 in.; sandstone and siltstone are rippled; mudstone is green; limestone is one 9.8 in. thick bed of silty micrite containing ooids and ostracodes.

Unit 165: Covered.

Unit 164: Limestone, ostracodal grainstone.

Unit 163: Mudstone. Green, poorly exposed.

Unit 162: Sandstone, fines upward (160 to 85 microns). Basal 19.7 in. contains abundant, small, well-rounded limestone clasts in matrix of 140-160 micron sand; IFC overlain by 29.5-39.4 in. interval of trough cross-beds overlain by ripples; top of unit contains abundant chert pebbles and fish scales.

Unit 161: Siltstone, medium-grained. Medium-gray, fissile.

Unit 160: Limestone. Silty micrite containing two intervals of ostracodes, two intervals of fish scales, relatively large bone fragments in center.

Unit 159: Siltstone. Laminated, on 3.5-inch-thick bed of rippled ostracodal grainstone near middle.

Unit 158: Siltstone. Light-gray, medium-grained, weathers like mudstone.

Unit 157: Limestone. Pillar-type algal stromatolites and small domal stromatolites at base, pillars generally 0.02 in. wide and 1.2-2.4 in. long and subparallel.

Unit 156: Covered.

Unit 155: Limestone. Basal 15.7 in. is silty micrite; 15.7-23.6 in. above base are grain-supported, small ,well-rounded limestone clasts; 23.6 in. to top is ostracodal grainstone containing some ooids and small zones with laminated limestone.

Unit 154: Mainly covered. Unit has one 9.1-inch-thick bed of 125 micron sandstone.

Unit 153: Siltstone and sandstone (160 microns). Thin-bedded siltstone, one sandstone bed in top 2 inches.

Unit 152: Limestone. Pillar-type algal stromatolites, pillars less than 0.02 in. in diameter.

Unit 151: Sandstone, 90 microns.

Unit 150: Limestone. Ooid grainstone in lower half grades upwards to ostracode grainstone.

Unit 149: Covered.

Unit 148: Limestone. Pillar-type stromatolites having ostracodes between pillars; some intervals ostracodal grainstone planar laminated.

Unit 147: Siltstone. Medium-gray, calcareous, rock breaks into thin slabs less than 0.6 in. thick.

Unit 146: Limestone. Silty micrite containing ostracodes, ooids and scattered fish scales; top 3.9 in. composed of limestone intraclasts.

Unit 145: Limestone. Composed of small domal algal stromatolites, pillar-type stromatolites and some subhorizontal laminations; top 2.8-3.9 in. is ostracodal grainstone.

Unit 144: Limestone. Mainly silty micrite (?). Base gradational over few inches; 23.6-35.4 in. contains ostracodes and some limestone clasts; 3.9-7.9 in. below top is micrite containing ooids and larger round grains as wide as 0.01 in.; top 3.9 in. is green mudstone.

Unit 143: Mudstone. Pale-green.

Unit 142: Sandstone, fines upward (200 to 150 microns). 3.9-5.9 in. of scour and contains scattered small limestone clasts; sedimentary structures poorly exposed; upper half of unit contains lateral accretion bedding that dips 14°N. 70°E.

Unit 141: Limestone. Ostracodal grainstone grades upward to silty micrite, in transition zone the limestone is laminated.

Unit 140: Mudstone. Green; top 5.9 in. contains scattered ostracodes, few patches with abundant ostracodes, and ostracode-filled burrows; top 3.9 in. is gradational with unit 141.

Unit 139: Sandstone (110 micron) and limestone. Sandstone containing ostracodes grades upward to ostracodal grainstone.

Unit 138: Interbedded sandstone (110 micron) and mudstone. Thin beds of rippled sandstone are separated by thinner green mudstone beds, mudstone beds are truncated by sandstone in places; top 5.9 in. is green mudstone.

Unit 137: Sandstone, fines upward (110-70 microns).

Unit 136: Mudstone. Greenish, unit thins to 3.9-5.9 in. 16.4 feet to the west.

Unit 135: Siltstone. Greenish-gray; green mudstone beds near top.

Unit 134: Mudstone, light olive-gray to brownish-gray.

Unit 133: Sandstone, 125 microns.

Unit 132: Sandstone, 125-135 microns. 2 in. of scour, and contains 20-25 percent small clasts of fine-grained limestone.

Unit 131: Mudstone. Grayish-olive, contains one thin bed of lenticular 125 micron sandstone.

Unit 130: Sandstone, 75 microns. Contains a few mudstone beds.

Unit 129: Limestone. Base sharp, 2.8-3.1 in. of basal 5.9 in. is sandy ostracodal and ooid grainstone; 5.9-17.7 in. is light-gray silty micrite truncated by troughs or channels filled with ostracodal grainstone; 17.7 in. to top is silty micrite containing lenses of fish scales near base.

Unit 128: Mudstone. Green, silty, minor ostracodes.

Unit 127: Sandstone, 100-115 microns. 4.7-9.1 in. above base contains 30 percent ooids and ostracodes; wavy planar laminations in lower 9.1 in.; upper 6.7 in. structureless.

Unit 126: Sandstone, coarsens upward slightly (80 to 95 microns). Sedimentary structures obscured by weathering, small orange concretions near top.

Unit 125: Mudstone. Pale-olive.

Unit 123: Sandstone, 90 microns.

Unit 122: Sandstone, 65-70 microns.

Unit 121: Sandstone, coarsens upward (70 to 130 microns).

Unit 120: Interbedded 65-130 micron sandstone (65 percent) and mudstone (35 percent). Sandstone beds are 0.8-9.8-inch-thick, some beds are structureless, some contain ripples and wavy planar laminations, one bed contains ball-and-pillow structure; mudstone is olive-gray.

Unit 119: Mudstone. Light olive-gray, laminated in places, abundant fractures filled with gypsum.

Unit 118: Limestone. Algally laminated, mainly pillar-type stromatolites, some horizontal laminations, top of bed has irregular mounds.

Unit 117: Limestone. Micrite (?), laminated, white; upper half contains small lenses of ooids, proportion of ooids increases upward.

Unit 116: Limestone. Micrite (?), very light-gray, weathers yellow to orange, silty.

Unit 115: Limestone. Composed of well-rounded limestone intraclasts (sand sized to 0.02 in. diameter), clasts fine upward.

Unit 114: Mudstone. Green; one 2-inch-thick bed of limestone composed of well-rounded limestone intraclasts (similar to unit 115).

Unit 113: Sandstone, 80-175 microns. 11.8 in. of scour; basal 21.7 in. coarsens upward (80-100 microns) and has 3.9 in. of ripples overlain by wavy planar laminations; 21.7 in. to top fines upward (175-130 microns), sharp contact with underlying finer sandstone, abundant ooids and algally laminated limestone in lower 3.1 in. of upper part.

Unit 112: Mudstone and siltstone. Unit consists of green mudstone overlain by greenish siltstone.

Unit 111: Siltstone and limestone. Basal 5.9 in. is calcareous siltstone (?); upper 13.8 in. is limestone composed of ooids and small well-rounded limestone clasts.

Unit 110: Interbedded sandstone (60 percent) and mudstone (40 percent). Mudstone is green and is present as three 7.9-11.8-inch-thick beds; two lowest sandstone beds are about 11.8 in. thick and contain ripples, upper sandstone beds are finer (70-80 microns), thinner, and structureless.

Unit 109: Interbedded mudstone (60 percent), sandstone-siltstone (30 percent), and limestone (10 percent). Mudstone is green, one bed near base contains purple mottles, contacts with mudstone beds sharp to gradational; limestone is one 7.9-inch-thick bed of ooid grainstone; sandstone-siltstone beds are 3.9-9.8-inch-thick, grain size medium-grained silt to very fine grained sand.

Unit 108: Limestone. Basal 3.9 in. contains abundant ostracodes, coated ostracodes, and limestone clasts; 3.9-13.8 in. is ooid grainstone; 13.8-23.6 in. is algal laminated (subhorizontal); 23.6-29.5 in. consists of grain-supported small limestone clasts ; 29.5 in. top is transitional to green mudstone.

Unit 107: Limestone (?). Contains ooids (?). Light-gray, weathers yellow.

Unit 106: Mudstone, green.

Unit 105: Sandstone, fines upward (160-125 microns). Base truncates unit 104 in places; top 3.9 in. grades into green mudstone.

Unit 104: Mudstone. Green, with intervals of abundant 150-175 micron sand.

Unit 103: Sandstone, 150 microns. Scours as much as 23.6 in. of unit 102.

Unit 102: Interbedded mudstone (70 percent) and sandstone-siltstone (30 percent). Most sandstone-siltstone beds are less than 5.9 in. thick; mudstone is green.

Unit 101: Interbedded 80-125 micron sandstone (80 percent) and mudstone (20 percent). Mudstone is green and thin bedded; sandstone beds are up to 11.8 in. thick; contains well expose wave ripples and wavy planar laminations.

Unit 100: Limestone. Composed of ostracodes, limestone intraclasts, and 10-20 percent sand (100-150 microns). Near base is in-place and ripped-up algal laminated limestone; top 3.9 in. is algal laminated limestone (subhorzontal and tube type).

Unit 99: Sandstone, 200-220 microns. 0.4-3.9-inch-basal interval of bone fragments, fish teeth, and limestone clasts; several vertical to oblique burrows filled with limestone.

Unit 98: Limestone. Micrite (?), light-to-medium-gray, fine-grained, one algal laminated zone, weathers yellow to orange-yellow.

Unit 97: Mudstone. Green, laminated in places, 4.7-inch-thick zone in center is medium-gray and calcareous.

Unit 96: Sandstone, 165-180 microns. Basal 13.8 in. contains 5-10 percent ostracodes and is structureless; upper 13.8 in. is wave rippled; contains green mudstone flasers and a few vertical burrows; top 3.9 in. contains abundant yellow ostracodes and limestone clasts and thin laminae of finer grained rock.

Unit 95: Limestone (?). Silty micrite (?), base gradational, laminated, carbonaceous debris along some bedding planes.

Unit 94: Limestone (?). Light to medium brownish-gray, very calcareous, fine-grained, laminated in places; a thin interval containg carbonaceous debris along bedding plane is near base.

Unit 93: Limestone: Basal 9.8 in. is mainly ooid grainstone; 9.8-13.8 in. is light-green siltstone; 13.8-14.6 in. is ostracodal grainstone containing small carbonate clasts, erosively truncates underlying siltstone; 14.6-23.2 in. is laminated ooid limestone containing minor ostracodes and limestone clasts; 23.2-24.4 in. is medium-gray micrite; 24.4 in. to top is light-gray to light-brown silty micrite.

Unit 92: Interbedded mudstone (50 percent) and sandstone-siltstone (50 percent). Bed thickness 7.9-23.6 in.; mudstone pale-green; sedimentary structures poorly exposed, ripples in places.

Unit 91: Interbedded mudstone (70 percent) and sandstone-siltstone (30 percent). Mudstone is light olive-gray and laminated (?).

Unit 90: Interbedded siltstone and mudstone. Contacts indistinct, siltstone contains sparse ostracodes.

Unit 89: Limestone. Most consists of micrite that contains ooids, ostracodes, fragments of laminated limestone (sand sized to 3.9 in. in diameter), and a few bone fragments; 10-20 percent laminated limestone (horizontal laminations, small asymmetric domes, and oncolites(?)).

Unit 88: Mudstone. Green, three thin siltstone beds.

Unit 87: Interbedded sandstone-siltstone (80 percent) and mudstone (20 percent). Sandstone-siltstone consists of coarse-grained siltstone to 125 micron sandstone, some sandstone beds fine up (125 to 80 microns).

Unit 86: Mudstone and siltstone. Mainly laminated mottled green, brown and reddish-purple mudstone, minor siltstone, mudstone fills irregularities in top of unit 85.

Unit 85: Limestone. Algal laminated, basal 15.7 in. consists of large domal stromatolites; ostracodes, oncolites, and tube-type stromatolites are present between the domes; upper 23.6 in. consists of tube-type stromatolites, tubes concentrically laminated.

Unit 84: Limestone. Micrite (?), very light-gray, very fine.

Unit 83: Limestone. Ostracodal grainstone; 1.2-inch-thick zone of small intraclasts 23.6 in. above base.

Unit 82: Interbedded and interlaminated limestone, siltstone, sandstone, and mudstone. Basal 7.9 in. is light-greenish-gray siltstone ; 7.9-45.3 in. is interlaminated to thinly interbedded siltstone, sandstone, and ostracodal and ooid grainstone; 45.3 in. to top is poorly exposed mudstone.

Unit 81: Interbedded green mudstone (40 percent) and very fine grained sandstone-siltstone (60 percent).

Unit 80: Sandstone, 70-95 microns. One thin bed of green mudstone near center.

Unit 79: Mudstone. Light-olive, middle 13.8 in. is mottled light olive-gray and purple.

Unit 78: Siltstone and mudstone.

Unit 77: Sandstone, 62-130 microns.

Unit 76: Mudstone. Green.

Unit 75: Limestone. Composed of ostracodes and 15-20 percent carbonate intraclasts (as long as 1.2 in.) composed of very fine grained, partly laminated limestone, clasts are mainly 7.9-23.6 in. above base, few bone fragments.

Unit 74: Interbedded mudstone, siltstone, and sandstone. Contacts between rock types is gradational, bed thickness 2.8-11.8 inches.

Unit 73: Sandstone, coarsens upward slightly (90 to 110 microns). 2-2.8 in. of basal lag with fish scales and small noncalcareous clasts; top 2-3.9 in. grades upwards to greenish-gray mudstone.

Unit 72: Mudstone. Greenish-gray, moderately silty, moderately calcareous, siltier at top.

Unit 71: Sandstone, two fining-upward sequences (145-85 microns and 125-70 microns). Most of unit is structureless.

Unit 70: Mudstone, greenish-gray.

Unit 69: Limestone. Ostracodal grainstone, yellow.

Unit 68: Sandstone, 70-105 microns. Sparse ostracodes and ostracodal limestone clasts near top.

Unit 67: Sandstone, 70 microns.

Unit 66: Interbedded sandstone (70-110 microns) and mudstone. Consists of several structureless sandstone beds separated by 2-3.1-inch-thick beds of greenish-gray mudstone.

Unit 65: Limestone and sandstone (65-125 microns).

Unit 64: Mudstone, limestone, and siltstone. Basal medium-brownish gray, calcareous mudstone grades upward to intraclast limestone that grades upward to a bed of mudstone containing a 3.9-inch-thick siltstone bed.

Unit 63: Mudstone and limestone. Mainly very pale-orange, calcareous mudstone; basal 3.1 in. is limestone consisting of small calcareous plates and round carbonate grains.

Unit 62: Siltstone, medium-grained. Medium-gray, laminated, fine-grained carbonaceous debris.

Unit 61: Limestone. Ostracodal grainstone, few bone fragments.

Unit 60: Siltstone.

Unit 59: Mudstone and siltstone, laminated.

Unit 58: Limestone. Ostracodal grainstone.

Unit 57: Siltstone. Plant debris on bedding planes.

Unit 56: Mudstone. Light olive-gray, moderately calcareous, slightly silty.

Unit 55: Interbedded sandstone, siltstone, mudstone, and limestone. Basal 3.9 in. and top 3.5-5.1 in. is limestone; middle of unit is thinly interbedded mudstone, siltstone, and sandstone.

Unit 54: Interbedded sandstone, mudstone, and siltstone. Bed thickness 1.6-3.1 in., beds have sharp tops and bases; sandstone contains as much as 20 percent ostracodes.

Unit 53: Interbedded limestone mudstone and siltstone. Basal 13.8 in. is interbedded siltstone and mudstone, contains ostracodes; 13.8-29.5 in. above base is limestone containing ostracodes; top 13.8 in. is greenish-gray mudstone, faintly to moderately laminated, slightly calcareous, slightly silty.

Unit 52: Dolostone. Laminated (laminations somewhat wavy and disturbed), olive-gray.

Unit 51: Mudstone and siltstone. Very pale-orange, slightly calcareous siltstone grades upward to light-greenish-gray, moderately calcareous, siltier mudstone that grades upward to yellowish-orange, very calcareous, silty mudstone or siltstone.

Unit 50: Sandstone (62-130 microns) and siltstone (very coarse grained). Slightly to very calcareous.

Unit 49: Siltstone to very coarse grained mudstone. Very silty, structureless, slightly calcareous, tiny irregular tubes (rootlets?).

Unit 48: Sandstone, 70-120 microns. Upper 9.2 feet sedimentary structures obscured by desert varnish.

Unit 47: Siltstone-sandstone and mudstone. Unit consists of very coarse grained siltstone and very fine grained sandstone containing greenish-gray mudstone flasers and several thin greenish-gray mudstone beds.

Unit 46: Siltstone, very coarse grained.

Unit 45: Sandstone, 110 microns.

Unit 44: Covered.

Unit 43: Sandstone, 60-150 microns. Basal 5.2 feet is 60-70 microns; 5.2 feet to top is 125-150 microns with scoured base.

Unit 42: Mudstone, greenish-gray.

Unit 41: Covered along measured section. Few feet north this interval is continuation of unit 40F (very fine grained rippled sandstone).

Unit 40: Sandstone and siltstone. Unit scours interval of interbedded sandstone and red and green mudstone. Divided into six subunits: (A) coarsens upward from red to green mudstone to siltstone to very fine grained sandstone; (B) 130-140 micron sandstone; (C) mainly medium-to coarse-grained laminated siltstone; (D) 130-140 micron sandstone with mica along bedding planes; (E) ostracode rich sandstone 130-180 microns; (F) 110 micron sandstone.

Unit 39: Mudstone, red.

Unit 38: Sandstone, 85-160 microns. Upper third of unit fines upward from 100 to 85 microns; lower half of unit has several scour surfaces with intraclasts; above base are several lenticular zones of sandstone, siltstone, and mudstone clasts (1.6 in. or less); upper 24.9 feet sedimentary structures are poorly exposed; lateral-accreation bedding dips to northeast.

Unit 37: Interbedded limestone, siltstone, mudstone and sandstone. Basal 2 in. is dark-brown, carbonaceous, calcareous siltstone; 2-3.1 in. above base is limestone containing coated ostracodes; 3.1-4.7 in. is very fine grained sandstone; 4.7-9.8 in. above base is calcareous siltstone or mudstone; 9.8-11.0 in. is limestone containing small shell fragments; 11.0-15.4 in. is limestone; 15.4-22.4 in. is laminated dolostone; 22.4 in. to top is mudstone.

Unit 36: Mudstone. Greenish-gray, 2-10 percent ostracodes.

Unit 35: Interbedded mudstone and siltstone (coarse grained). Siltstone is light-gray and calcareous; mudstone is very silty, and is present as two beds (3.9-5.9 in.) in the siltstone.

Unit 34: Interbedded siltstone and mudstone. Basal 29.5 in. is siltstone; 29.5-49.2 in. is red mudstone contains small mudstone clasts and one thin siltstone bed; 49.2-59.1 in. is light-greenish-gray siltstone; 59.1 in. to top is reddish-purple and purple mudstone.

Unit 33: Mudstone. Colors (base to top): greenish gray, red with light-green interbeds and mottling, grayish-red, purple with green mottles; contacts between different colors irregular and gradational.

Unit 32: Sandstone, 65-70 microns. Base is sharp and has 11.8 in. of scour. Top grades into overlying mudstone.

Unit 31: Mudstone. Greenish-gray overlain by red.

Unit 30: Sandstone, fines upward (95 to 65 microns). Base has 3.9 in. of scour.

Unit 29: Limestone. Light-gray, hard, contains mud- to grain-supported ostracodes.

Unit 28: Interbedded sandstone-siltstone (50 percent), red mudstone (30 percent), and greenish-gray mudstone (20 percent). Basal 10.8 feet is mainly green mudstone; 10.8-28.5 feet is red mudstone containing green mottles, and subordinate green mudstone containing abundant rippled sandstone and siltstone; top 11.8 in. is sandstone.

Unit 27: Sandstone, 70-115 microns.

Unit 26: Mudstone. Basal 9.8 in. red; top 2 in. green.

Unit 25: Sandstone, 70-80 microns.

Unit 24: Mudstone. Consists of 0.4-inch-thick bed of greenish-gray mudstone overlain by 3.5-inch-thick bed of red mudstone.

Unit 23: Sandstone, 70-80 microns.

Unit 22: Mudstone. Red and lesser green, mottles of greenish-gray mudstone in the red mudstone.

Unit 21: Siltstone (very coarse grained) and sandstone (100 microns). Sedimentary structures obscured by weathering.

Unit 20: Mudstone, greenish-gray.

Unit 19: Siltstone and sandstone. Top 3.9 in. of unit is very fine grained sandstone containing 10 percent ostracodes, in places top 3.9 in. of unit is ostracode and ooid grainstone containing some bone fragments, fish scales and teeth.

Unit 18: Siltstone. Very coarse-grained. Light gray.

Unit 17: Mudstone and siltstone. Greenish-gray mudstone grades upward to coarse-grained siltstone.

Unit 16: Mudstone, greenish-gray, concretions in places.

Unit 15: Limestone. Consists of grain-supported ostracodes and ooids(?) and 40 percent sand.

Unit 14: Mudstone, greenish-gray.

Unit 13: Sandstone,70-80 microns. Contains ostracodes and ooids that are disseminated, occur in discrete laminae, upward increase in proportion of ostracodes and ooids; top few inches of unit is silty ostracodes and ooid grainstone, most of unit obscured by desert varnish.

Unit 12: Mudstone, greenish-gray.

Unit 11: Sandstone, 70-115 microns. Unit consists of 4.7-inch-thick bed of 70 micron sandstone overlain by a 11.0-inch-thick bed of 115 microns sandstone.

Unit 10: Interbedded mudstone and siltstone. Basal 19.7 in. is interbedded red and greenish-gray mudstone and siltstone; top 3.6 feet is grayish-red and subordinate greenish-gray mudstone, both mottled.

Unit 9: Interbedded siltstone and mudstone. Mainly light-greenish coarse-grained siltstone containing light-colored mudstone interbeds.

Unit 8: Sandstone, 65-80 microns. Greenish-gray mudstone near base in places.

Unit 7: Mudstone, greenish-gray.

Unit 6: Sandstone, 100-200 microns. Sandstone contains back-filled burrows, unit has lenticular geometry.

Unit 5: Interbedded mudstone and siltstone. Basal 7.9 in. is covered. Mudstone is greenish-gray, siltstone is very coarse grained.

Unit 4: Sandstone. Unit divided into two subunits: (1) basal 28.5 feet is 70 microns at base, 110-150 microns above base; (2) 28.5 feet to top, base of subunit is a scoured surface having 15.7-19.7 in. of relief and a basal lag of clasts of greenish-gray mudstone, siltstone and sandstone in matrix of 110-120 micron sandstone.

Unit 3: Interbedded limestone, mudstone, siltstone, and sandstone. Basal 9.8 in. is 225 micron sandstone, grades upward to siltstone, scours units 1 and 2 in places, contains lenticular 0.008-0.06 in. lenses of ostracodes, few feet to south entire unit contsists of ostracodal grainstone; 9.8-19.7 in. above base is green mudstone; 19.7-35.4 in. is 125 micron sandstone, half trough cross-beds, half structureless; 35.4 in. to top is green mudstone.

Unit 2: Mudstone. Red and green, basal tool marks oriented east-west.

Unit 1: Interbedded mudstone and sandstone (90 microns). Base of unit indistinct; mudstone green and red.

LEGEND

LITHOLOGY

Sandstone
Siltstone
Covered Slope
Dolomite
Silty Sand
Mudstone
Limestone

CONTACTS

Sharp

PHYSICAL STRUCTURES

- Trough Cross-Strat.
- Climbing Ripples
- Planar Lamination
- Lenticular Bedding
- Hummocky Cross-Strat.
- Scour
- Mudcracks
- Double Mud Drapes
- Stylolites
- Flaser Bedding
- Ripples
- Wave Ripples
- Wavy Planar Laminations
- Soft-Sediment Deformation
- Domal-Type Algal Stromatolites
- Pillar-Type Algal Stromatolites

LITHOLOGIC ACCESSORIES

- Shell Fragments
- Micaceous
- Oolites
- Clasts
- Calcareous

ICHNOFOSSILS

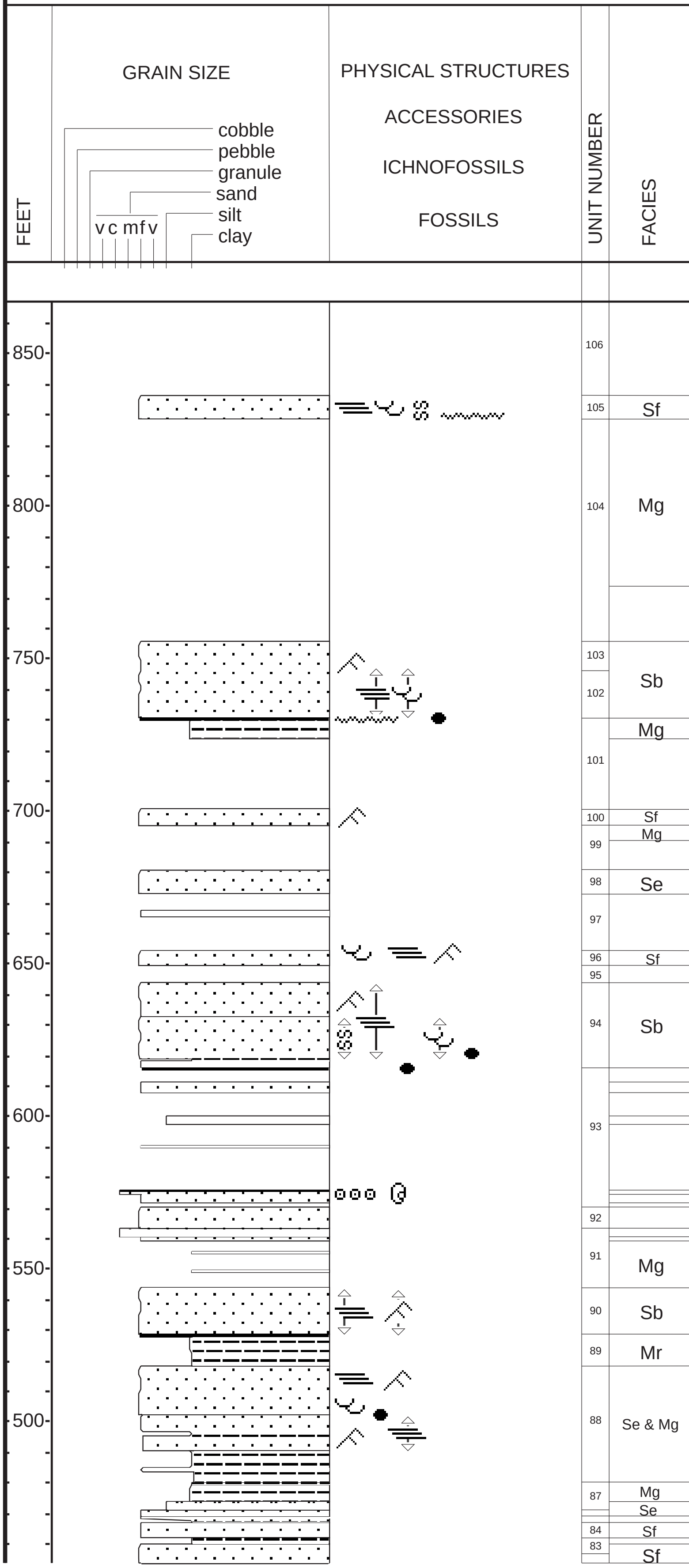
- Rootlets
- Horizontal Burrows
- Vertical Burrows

FOSSILS

- Fish Scales
- Ostracodes
- Plant Remains
- Carbonized Fossils (undifferentiated)

Remy 11

The section is located in Nine Mile Canyon and begins and ends in the SE1/4NW1/4 section15, T. 12 S., R. 13 E., of the Salt Lake Base line and Meridian, Duchesne County, Utah.



Unit Number - Lithologic description

Unit 106: Covered. Top of unit 106 is top of ridge.

Unit 105: Sandstone, coarsens upward (110 to 140 microns). Base sharp and scoured, sandstone contains trough crossbeds and planar laminations that are, in places, disrupted by soft-sediment deformation.

Unit 104: Covered. Green mudstone fragments in upper 55.8 feet; green mudstone crops out beneath unit 105.

Unit 103: Sandstone, 105 microns. Poorly exposed, rippled (50 percent) and structureless (50 percent).

Unit 102: Sandstone, 105 microns. Base sharp, several feet of scour; base of unit is composed of several lenticular sandstones; basal 29.5 inches has several zones of generally well rounded siltstone and mudstone clasts as long as 3.1 inches; trough crossbeds and planar laminations that dip (due to lateral-accretion bedding) are throughout unit; upper 6 feet contains abundant ripples; abundant scour and fill within unit; mudstone interbeds in lower half only.

Unit 101: Mainly covered. Silty light-gray mudstone 6 feet thick crops out beneath unit 102.

Unit 100: Sandstone, 80-110 microns. Base sharp, scoured, dips northeast; most of unit is structureless, ripples in basal 15.7 inches.

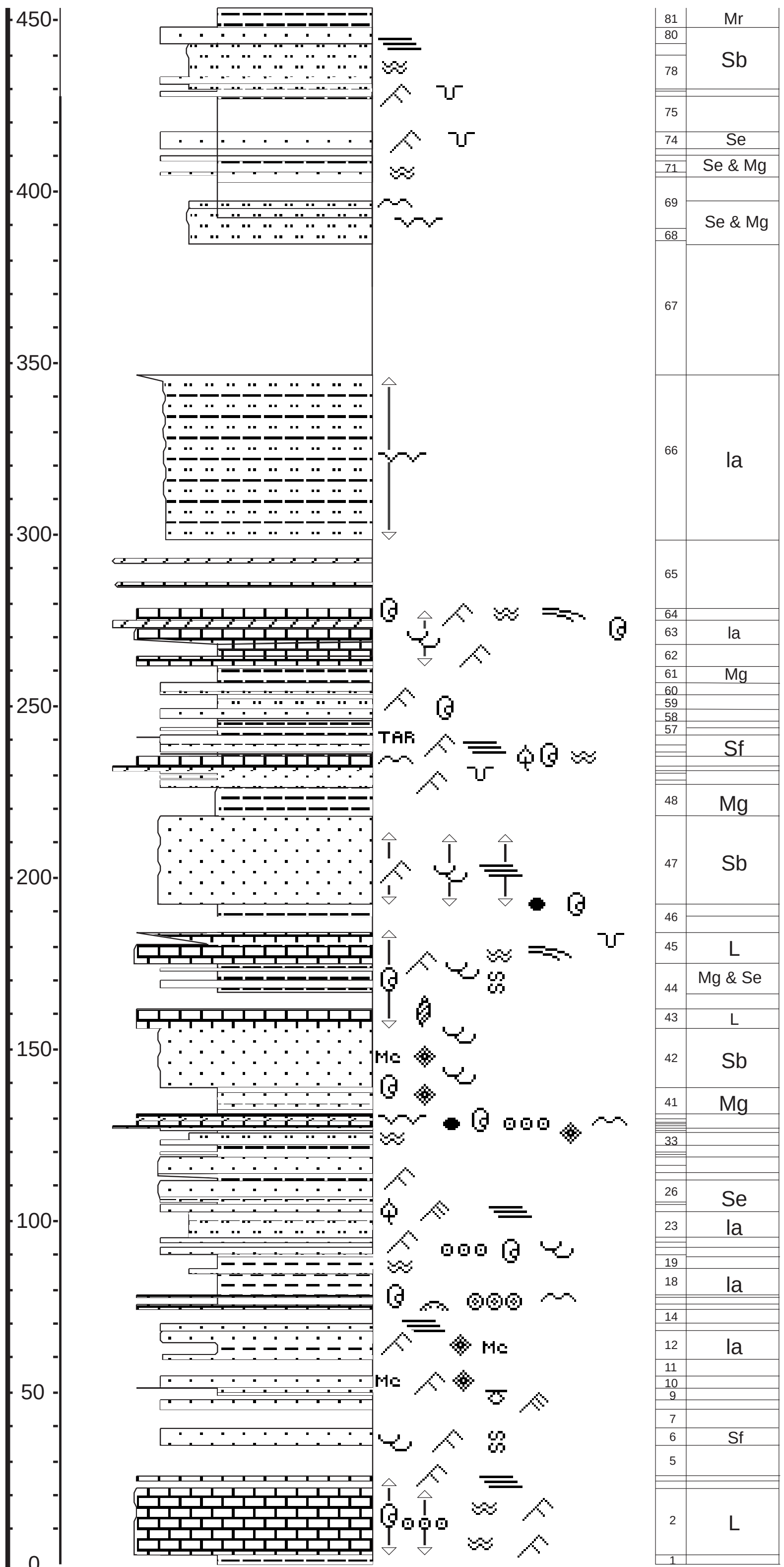
Unit 99: Mainly covered. Lower 5.2 feet is covered by thick soil; upper 9.2 feet has abundant fragments of green mudstone on surface.

Unit 98: Sandstone, 56-80 microns. Base is covered, structureless.

Unit 97: Mainly covered. Unit has one poorly exposed 90 micron sandstone bed.

Unit 96: Sandstone, 125 microns. Base and top of unit dip 15° northewest (i.e. lateral-accretion bedding); unit thins toward northwest.

Unit 95: Mainly covered. Friable, very fine grained sandstone crops out beneath unit 96.



Unit 94: Sandstone, 100-140 micron. 19.7-23.6 inches of scour (truncates siltstone and mudstone); basal 19.7-23.6 inches is 140 micron sandstone containing mudstone clasts; 23.6-31.5 inches above base is mudstone; 2.6-16.7 feet is sandstone which has basal siltstone clasts as long as 3.9 inches; 16.7 feet to top. Beds of unit are hoizontal along measured section but 164-246 feet west same unit contains lateral-accretion beds that dip to northeast(sandstone beds are 6-9 feet thick and thin downdip, mudstone interbeds thicken downdip).

Unit 93: Covered (65 percent), minor sandstone, siltstone, and limestone.

Unit 92: Sandstone, coarsens upward (70 to 115 microns). Base sharp and flat, bed thickness 19.7-23.6 inches, small sand filled channel cuts top of unit, structureless.

Unit 91: Mainly covered. Several outcrops of green mudstone; 19.7-inch-thick be of 70 micron sandstone; toward west unit is all sandstone.

Unit 90: Sandstone, 100-125 microns. Base is sharp and scoured; 80 percent structureless, 10 percent planar laminated, and 10 percent rippled; lenticular geometry, sandstone beds within unit dip 20° north 5° east (lateral accretion bedding).

Unit 89: Mudstone. Red, mainly covered.

Unit 88: Sandstone and mudstone. Complex sandstone body composed of three subunits: (1) Basal 9.8 feet is interbedded red and green mudstone (80 percent) and very fine grained sandstone (20 percent), bed thickness less than 9.8 inches, sandstones have sharp bases and tops, base of subunit flat; (2) 9.8 to 22 feet above base is interbedded sandstone (80 percent) and mudstone (20 percent), beds dip 35 degrees northeast (lateral accretion bedding), sandstone beds merge updip and truncate mudstones, sandstone are 80-110 microns, 50 percent structureless, 30 percent rippled, 20 percent planar laminations; (3) 22 feet to top is sandstone, fines upward (140 to 100 microns), mudstone clasts at base.

Unit 87: Siltstone and mudstone. Basal 2.3 feet is silstone; upper 6.6 feet is red mudstone overlain by 11.8-inch-thick bed of green mudstone.

Unit 86: Sandstone, 100 micron. Structureless.

Unit 85: Mudstone. Green, poorly exposed.

Unit 84: Sandstone, coarsens upward (65 to 90 microns).

Unit 83: Sandstone (67-70 microns). and green mudstone. Poorly exposed; lower half sandstone; upper half green mudstone.

Unit 82: Sandstone, coarsens upward (65 to 100 microns). Structureless.

Unit 81: Mudstone. Poorly exposed; light to medium grayish purple in lower 3.9 feet; green in upper 2 feet.

Unit 80: Sandstone, 65-70 microns. Structureless except for laminations at base, breaks into thin slabs.

Unit 79: Siltstone. Medium brownish gray, slightly calcareous, poorly exposed.

Unit 78: Siltstone and sandstone (80 microns). Basal 3.3 feet grades from siltstone to sandstone; upper 7.2 feet is siltstone, breaks into curving plates.

Unit 77: Mudstone. Green.

Unit 76: Sandstone. Base gradational from green mudstone through siltstone to 70-80 micron sandstone; 60 percent of unit is structureless, 40 percent ripples; vertical burrows, laterally persistent.

Unit 75: Covered. Green mudstone 7.9 inches thick at top.

Unit 74: Sandstone, fines upward (105 to 65 microns). Base gradational from very coarse grained siltstone to sandstone; 85-90 percent of unit structureless, 10-15 percent rippled; upper third of unit contains small concretions or burrows.

Unit 73: Covered. Green mudstone under soil.

Unit 72: Sandstone, 65-70 microns. Structureless, moderately calcareous.

Unit 71: Mudstone. Green, silty, poorly exposed.

Unit 70: Sandstone and siltstone. Base transitional from silty mudstone to siltstone to 95 micron sandstone; top of unit grades into siltstone that breaks to wavy plates.

Unit 69: Siltstone and mudstone, 50 percent covered. Base is medium-grained calcareous brownish-gray siltstone, large mudcracks; 6.6-8.5 feet is calcareous medium-gray siltstone, breaks into thin plates, some of which exhibit symmetrical undulations (wave ripples?); 8.5-14.8 feet is covered; 14.8 feet to top is silty greenish-gray mudstone.

Unit 68: Siltstone, very coarse grained. Calcareous, forms resistant ledge.

Unit 67: Mainly covered. Top of unit is 7.9-inch-thick bed of coarse grained siltstone.

Note: At contact between units 66 and 67 there is a regional change in the weathered color of the rocks from light gray below to brown above.

Unit 66: Mudstone-siltstone. Moderately fissile, slightly to moderately calcareous silty mudstone-siltstone, variable colors; basal 10.2 ft is medium brown; 10.2-13.4 feet is light medium gray; 13.4-42.6 feet is medium brownish gray; 42.6 feet to top is light gray; mudcracks in places; 5.9-inch-thick bed of 135 micron sandstone 4.9 feet above base.

Unit 65: Dolostone. Poorly exposed, laminated, medium to dark brown, weathers into paper shale.

Unit 64: Limestone. Ostracodal grainstone, most structureless, minor ripples and trough crossbeds in places, unit breaks into thin wavy slabs suggesting wavy planar laminations or HCS.

Unit 63: Dolostone and limestone. Basal 2 inches of unit is white limestone interbedded with ostracode grainstone; most of unit is laminated and kerogenous (oil shale), calcareous, medium brown, some ostracodes.

Unit 62: Limestone. Ostracodal grainstone, bed thickness 3.9-15.7 inches, few thin greenish-gray mudstone and brown fissile shale interbeds; 70-80 percent structureless; 20-30 percent has trough crossbeds and ripples; one bed in center of unit contains coated ostracodes in top 2-3.9 inches.

Unit 61: Mudstone and siltstone. Greenish-gray to light-gray mudstone containing beds of light-gray medium-grained siltstone; upper 11.8 inches is all greenish gray mudstone.

Unit 60: Sandstone, 70-80 microns. Base sharp, rippled, few thin green mudstone interbeds near base.

Unit 59: Mudstone and siltstone. Mudstone-siltstone contacts are gradational.

Unit 58: Sandstone. Basal 25.6 inches grades upward from mudstone through siltstone to very fine grained sandstone; upper 17.7 inches fines upward (130 to100 micron), 0-10 percent ostracodes.

Unit 57: Mudstone, green.

Unit 56: Mudstone, siltstone, and sandstone. Grades upward from green mudstone through siltstone to 70-80 micron sandstone.

Unit 55: Sandstone, 80-100 microns, coarsens upward. Basal 25.6 inches contains planar laminations and ostracode limestone laminae (20 percent of interval); upper 3.1 feet contains a few ostracode limestone laminae and is rippled and tar saturated in places.

Unit 54: Interbedded siltstone, mudstone, and sandstone. Basal 1.2 inches is laminated siltstone; 1.2-4.3 inches is light-to-medium-gray calcareous mudstone; 4.3-5.9 inches is 65 microns sandstone; 5.9 inches to top is live gray to greenish gray mudstone.

Unit 53: Limestone. Basal 11.8 inches is ostracode grainstone that contains wavy planar laminations and few thin interbeds of grayish-brown, fissile dolostone, limestone bed thickness less than 3.9 inches, some beds have symmetrical undulatory bases; middle 11.8 inches is ostracode grainstone; top 7.9 inches consists of well-rounded carbonate grains, minor ostracodes.

Unit 52: Dolostone. Laminated and kerogenous (oil shale), grayish brown (5YR 3/2).

Unit 51: Sandstone, 65-70 microns.

Unit 50: Mudstone and sandstone. Poorly exposed green mudstone containing one 3.9-inch-thick bed of very fine grained sandstone in center.

Unit 49: Sandstone, 65-70 microns. Basal 5.9 inches sturctureless; upper 9.8 inches rippled, few vertical burrows.

Unit 48: Mudstone and siltstone. Mudstone dusky yellow green, poorly exposed; 7.9-inch-thick bed of very coarse grained siltstone crops out beneath unit 49.

Unit 47: Sandstone, fines upward (160-90 microns). Basal 3.9 inches consists of matrix of 160 micron sand and angular mudsonte clasts as long as 3.9 inches, hematite-stained plant debris, muscovite, small yellow limestone fragments, and ostracodes; top 15.7 inches contains laminations that dip as much as 20° toward 310° (lateral accretion bedding?); unit is laterally persistent for at least 246 feet but appears to thicken and thin.

Unit 46: Interbedded green mudstone (65 percent) and sandstone-siltstone (35 percent). Lower half covered; sandstone is very fine grained; sandstone and siltstone beds have sharp bases and tops and are less than 3.9 inches thick; mudstone is moderatley to very silty and calcareous.

Unit 45: Limestone. Ostracode grainstone; basal 3.3 feet contains wavy planar laminations that have low-angle truncations, trough crossbeds, and minor ripples; upper 6.9 feet is mainly structureless and contains few ripple foresets or wavy surfaces, burrows, and thin mudstone interbeds.

Unit 44: Mudstone and sandstone. Basal third covered; upper two-thirds green mudstone containing one 7.9-inch-thick bed of rippled very fine grained sandstone and one 23.6-inch-thick bed of 175 micron trough crossbedded sandstone containing ostracodes in places and some soft-sediment deformation.

Unit 43: Limestone. Ostracode grainstone, relatively abundant gastropods.

Unit 42: Sandstone, fines upward (175 to 135 microns) Base sharp and flat except one zone with 11.8-15.7 inches of scour; base contains 15-20 percent ostracodes; top 6.6 feet possible trough cross beds.

Unit 41: Interbedded mudstone (60 percent) and sandstone(40 percent). Basal 19.7 inches and upper 15.7 inches are mainly green mudstone; middle is interbedded green mudstone and very fine grained sandstone containing abundant fine-grained carbonaceous debris along some bedding planes, bed thickeness 3.9-5.9 inches.

Unit 40: Limestone. Ostracodal grainstone.

Unit 39: Dolostone and limestone. Brown, kerogenous, laminated dolostone (oil shale) with very large mudcracks filled with ostracodal grainstone.

Unit 38: Limestone. Clast-supported mix of ooids, ostracodes, and 0.004-0.6 inches long micrite intraclasts.

Unit 37: Limestone. Several beds of ostracode grainstone.

Unit 36: Dolostone. Medium brownish gray, structureless, very fine grained, weathers light green, abundant mudcracks filled with ostracodes.

Unit 35: Sandstone, 110 microns. Lower few inches contains carbonaceous debris in places; thickens and thins.

Unit 34: Mudstone. Greenish gray, top conains carbonaceous debris.

Unit 33: Sandstone and siltstone. Lower half coarsens upward from 65 to 85 micron sandstone; upper half is fine to very coarse grained siltstone, lower 25.6 inches contains wavy planar laminations and wave ripples.

Unit 32: Mudstone. Greenish gray, similar to unit 30.

Unit 31: Sandstone, 125 microns.

Unit 30: Mudstone. Greenish gray, moderately silty, moderately calcareous, typical mudstone weathering.

Unit 29: Sandstone, fines upward (150-125 microns). Unit thickens to west, contains scattered small hematite concretions.

Unit 28: Sandstone, less than 90 microns.

Unit 27: Shale. Medium gray, slope forming, slightly silty, slightly calcareous.

Unit 26: Sandstone, variable grain size (70-140 microns).

Unit 25: Mudstone. Light olive gray, carbonized plant impressions and few very thin coal seams.

Unit 24: Sandstone, 100 microns. Basal 3.9 inches contains planar laminations and plant debris; upper 19.7 inches current ripples; few hematite concretions in upper 7.9 inches.

Unit 23: Shale and siltstone. Dark-gray, slightly calcareous shale, forms slope; upper 5.9 inches of unit is siltstone.

Unit 22: Sandstone, 70-80 microns. Truncates unit 21 and most of unit 20 northwest of measured section; unit 22 appears to dip to northwest (lateral accretion bedding).

Unit 21: Covered.

Unit 20: Sandstone, 70-150 microns. Basal 7.9 inches is one bed of 70 micron sandstone containing wavy planar laminations; upper 11.8 inches is 150-125 micron sandstone that fines upward, contains 15-20 percent ostracodes and ooids, scours 3.9 inches into underlying sandstone bed.

Unit 19: Shale and siltstone. Basal 3.3 feet is poorly exposed light-olive-gray, slightly calcareous shale; upper 15.7 inches is light-gray, medium-to-coarse-grained siltstone.

Unit 18: Shale and siltstone. Light-to medium-brownish-gray shale containing siltstone, coarsens upward; top 19.7 inches is thin bedded gray siltstone that contains wavy planar laminations.

Unit 17: Limestone. Yellow silty micrite, sparse to abundant ostracodes and ooids; upper 2 inches is wave rippled sandy ostracode and ooid grainstone.

Unit 16: Shale. Medium greenish gray, breaks into slabs a few millimeters thick.

Unit 15: Limestone. Basal 11.8 inches is medium-brownish-yellow limestone, contains some algal laminations; top 3.9 inches consists of small domal stromatolites.

Unit 14: Covered.

Unit 13: Sandstone, 80-135 microns. Indistinct planar laminations and ripples, organic matter in center of unit.

Unit 12: Interbedded shale and sandstone. Partly exposed unit consists of interbedded dark-gray, silty, fissile shale and rippled 90 micron sandstone; several sandstone beds contain hematite concretions.

Unit 11: Covered.

Unit 10: Sandstone, 75-110 microns. Basal 13.8 inches is 75 micron sandstone; 13.8-29.5 inches is 110 micron sandstone, abundant mica and organic matter along ripple -bedding planes; 29.5 inches to top is 110 micron sandstone, minor amounts of mica and organic matter.

Unit 9: Mainly covered. Dark-gray, silty mudstone and thin-bedded 65 micron sandstone that has sole marks, crop out beneath unit 10.

Unit 8: Sandstone, 115-125 microns. Partly exposed, base dips 26° north and 60° east.

Unit 7: Covered.

Unit 6: Sandstone, coarsens upwards (95 to 120 microns).

Unit 5: Mainly covered. Dark-gray siltstone crops out beneath unit 6; 23-26 feet west of measured section interval consists of lenticular sandstone.

Unit 4: Limestone. Mainly medium-grayish-brown micrite containing a few ostracodes; top 3.9 inches of unit is ostracodal grainstone.

Unit 3: Covered.

Unit 2: Limestone. Composed of grain-supported ostracodes (80-90 percent) and ooids (10-20 percent); one bed contains minor chert nodules.

Unit 1: Mudstone, shale, ostracodal grainstone, and sandstone.

LEGEND

LITHOLOGY

- Sandstone
- Siltstone
- Sandy Silt
- Shale
- Mudstone
- Coal
- Mudstone-Siltstone
- Covered
- Limestone
- Dolostone

CONTACTS

- Sharp

PHYSICAL STRUCTURES

- Trough Cross-Strat.
- Mud Cracks
- Ripples, Unknown
- Wavy Planar Laminations
- Stromatolite, Domal
- Planar Lamination
- Load Casts
- Wave Ripples
- Intraformational Conglomerate (IFC)
- Hummocky Cross-Strat.
- Soft Sediment Deformation
- Current Ripples
- Scour

LITHOLOGIC ACCESSORIES

- Mc - Micaceous
- TAR - Tar
- Oolitic
- Pisolites

ICHNOFOSSILS

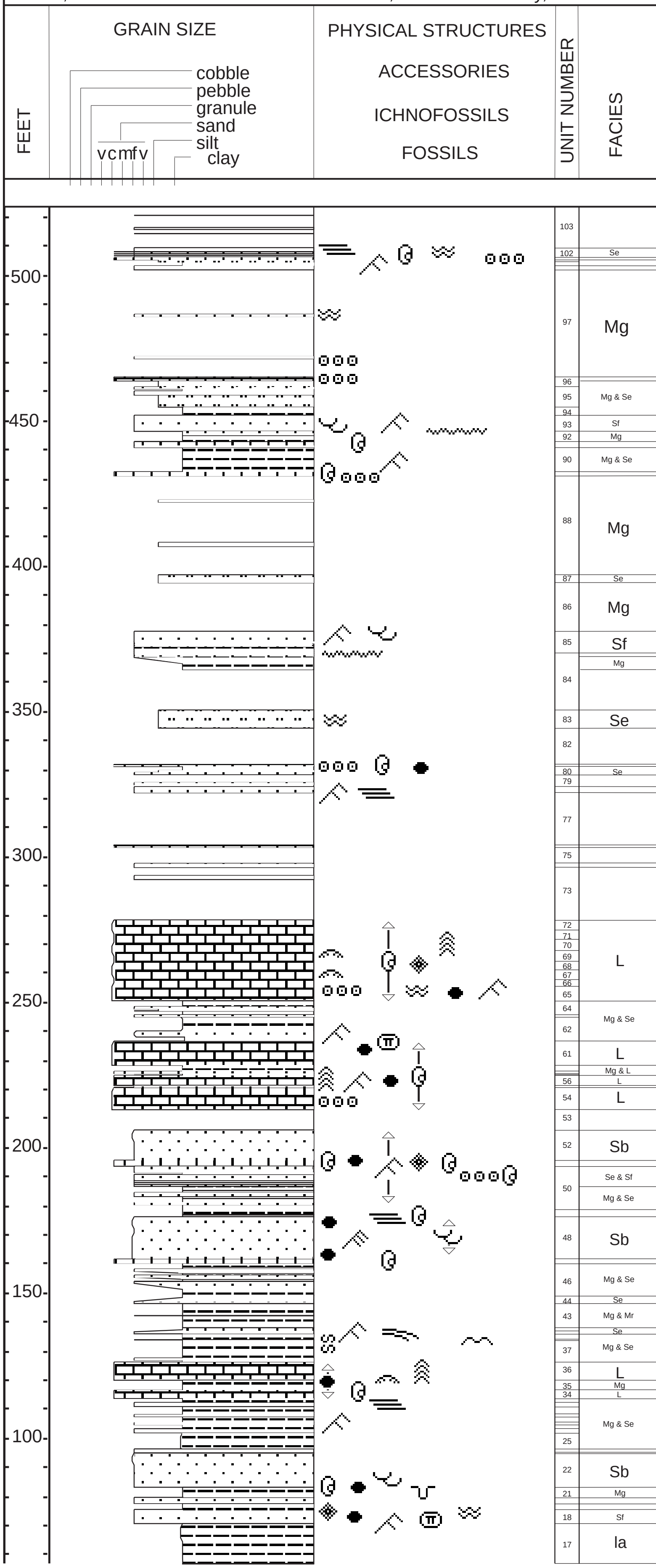
- Vertical Burrows

FOSSILS

- Carbonate Debris
- Plant Remains
- Gastropods
- Ostracodes

Remy 13

The section is located at the junction of Nine Mile and North Franks Canyons, beginning in the NW1/4NW1/4 section 1, T. 12 S., R.16 E. and ending in the SE1/4SE1/4 section 35, T. 11 S., R. 16 E., of the Salt Lake Base line and Meridian, Duchesne County, Utah.



Unit Number - Lithologic description

Unit 103: Mainly covered. Unit has 4-5 thin (3.9-5.9 inches) beds of laterally persistent very fine-sandstone.

Unit 102: Sandstone, 65-70 microns. Planar laminations, some beds wavy, and minor ripples; few thin ostracodal limestone interbeds; several mudcracked zones; forms regionally prominent ledge.

Unit 101: Limestone. Basal 7.9 inches is algally laminated; upper 7.9 inches is grain-supported ooids without obvious nuclei.

Unit 100: Siltstone, medium grained. Very calcareous, white.

Unit 99: Mudstone. Green, poorly exposed.

Unit 98: Sandstone, coarsens upward slightly (90 to 110 microns). Rippled.

Unit 97: Mainly covered. Unit probably mainly green mudstone; 5.9 feet above base is 7.9-inch-thick bed of 135 micron sandstone containing ooids; 20.3 feet above base is laterally persistant 7.9-inch-thick bed of 75-80 micron sandstone that contains wavy planar laminations.

Unit 96: Sandstone, siltstone, and limestone. Basal 7.9 inches is sandstone, calcareous, contains ooids; 7.9-33.5 inches is siltstone, medium to coarse grained; 33.5 inches to top is limestone composed of ooids with sand nuclei, sand coarsens upward (90 to 120 microns).

Unit 95: Interbedded siltstone (50 percent), green mudstone (30 percent), and sandstone (20 percent). Siltstone is calcareous and thin bedded; sandstone is one 9.8-inch-thick bed 4.3 feet above base; top 11.8 inches is green mudstone.

Unit 94: Mudstone. Green.

Unit 93: Sandstone, 115-135 microns. Base sharp, 7.9-11.8 inches of scour; basal 3.3 feet contains trough crossbeds; upper 3 feet is 90 percent covered by desert varnish and 10 percent rippled.

Unit 92: Mudstone and siltstone. Basal 19.7 inches is green mudstone; upper 11.8 inches is silty green mudstone and siltstone.

Unit 91: Sandstone, 62-110 microns (coarsens up from mudstone). Base gradational and top sharp, top 5.1 inches is limestone containing ostracodes.

Unit 90: Interbedded green mudstone (60 percent) and sandstone (40 percent). Sandstone beds are rippled in places and are 0.8-5.9 inches thick.

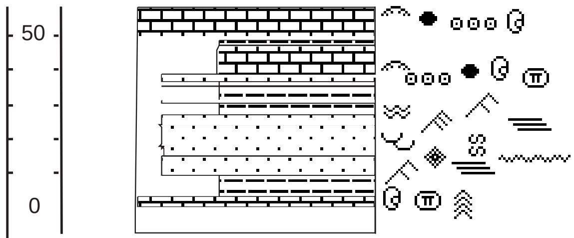
Unit 89: Limestone. Composed of ostracodes and ooids, and minor laminated algal limestone clasts.

Unit 88: Covered. Greenish-gray mudstone fragments common, few thin siltstone beds.

Unit 87: Siltstone, medium-to coarse-grained (coarsens upward). Structureless.

Unit 86: Covered. Abundant greenish-gray mudstone fragments.

Unit 85: Sandstone, fines upward (150 to 105 microns). 7.9 inches of basal scour; basal 4.3 feet consists of seven 2.4-11.8-inch-thick beds separated by thin green mudstone beds; upper 3.6 feet is one bed containing ripples (15 percent) and trough crossbeds (5 percent), but most is obscured by weathering (80 percent).



Unit 84: Mainly covered. Upper 5.9 feet of unit is green mudstone that grades upward to 65 micron sandstone.

Unit 83: Interbedded siltstone (80 percent) and 80 micron sandstone (20 percent). Siltstone is laminated; sandstone contains wavy planar laminations, most sandstone is in zone 7.9-27.6 inches above base.

Unit 82: Covered.

Unit 81: Limestone (?). Ooid grainstone (?), contains abundant 135 micron sand with carbonate coating and carbonate intraclasts and ostracodes.

Unit 80: Mudstone, sandstone and siltstone.

Unit 79: Mainly covered. One 5.9-in-thick bed of 105 micron sandstone in lower third.

Unit 78: Sandstone, 110 microns. Partly exposed; basal 7.9 inches is planar laminated; upper 9.8 inches is rippled.

Unit 77: Covered.

Unit 76: Limestone. Ostracodal grainstone.

Unit 75: Covered.

Unit 74: Sandstone, coarsens upward slightly (80 to 110 microns). Structureless.

Unit 73: Mainly covered. One 7.9-inch-thick bed of ledge-forming sandstone 14.4 feet above base.

Unit 72: Limestone. Ostracode grainstone, very sandy in places, weathers into slabs.

Unit 71: Limestone. Ostracode grainstone.

Unit 70: Limestone. Pillar-type stromatolites, pillars 0.08-1.0 inches wide and as long as 3.9 inches.

Unit 69: Limestone. Composed of abundant ostracodes and large domal stromatolites; top 3.9 inches contains small domal stromatolites.

Unit 68: Limestone. Consists of grain-supported ostracodes and carbonate grains (well rounded); top 5.9 inches contains small domal stromatolites.

Unit 67: Limestone. Subhorizontal algal laminations and subordinate large domal stromatolites as wide as 23.6 inches, abundant ostracodes, forms ledge.

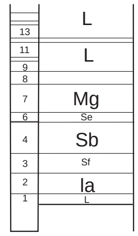
Unit 66: Limestone. Basal 11.8 inches similar to unit 65; 11.8 inches to top is light-medium-brownish-gray, fine-grained limestone.

Unit 65: Limestone. Consists of grain-supported ostracodes and lesser ooids and carbonate intraclasts, wavy planar laminations and ripples.

Unit 64: Interbedded green mudstone, siltstone, and sandstone. Contacts between beds are indistinct; top 2.3 ft is mudstone.

Unit 63: Sandstone, 65 microns. Well-exposed large ripples throughout, forms resistant ledge.

Unit 62: Interbedded mudstone (70 percent) and 70-125 micron sandstone (30 percent). Green mudstone contains thin sandstone beds; sandstone beds contain starved ripples in places, pinch and swell bedding, and sharp bases and tops.



Unit 61: Limestone. Basal 7.1 feet is white ostracode grainstone containing abundant sand; 7.1 feet to top consists of well-rounded carbonate intraclasts, ostracodes, and fish scales, rippled.

Unit 60: Mudstone. Green, several thin siltstones.

Unit 59: Limestone. Pillar-type stromatolites, pillars have spongy interior texture, tip and base of unit very irregular, green mudstone between pillars in places.

Unit 58: Mudstone, sandstone, and siltstone. Unit consists of green mudstone containing several thin beds of sandstone and siltstone.

Unit 57: Sandstone, 80-90 microns. Rippled.

Unit 56: Limestone. Silty micrite, yellow, top few inches contains abundant carbonate intraclasts and some ostracodes.

Unit 55: Interbedded mudstone, limestone, and 80 micron sandstone. Mudstone is green; limestone is ostracode grainstone; sandstone is one 2.4-inch-thick bed containing low-amplitude ripples.

Unit 54: Limestone. Basal 5.9 feet is white micrite containing sparse to abundant ostracodes and ooids; 5.9-6.6 feet consists of subhorizontal algal laminations; 6.6 feet to top contains pillar-type stromatolites and algal limestone intraclasts and ostracodes.

Unit 53: Covered.

Unit 52: Sandstone, 90-115 microns. Base sharp and flat over distance of 98.4 feet and contains a few small limestone clasts; 80 percent of unit structureless, 20 percent rippled; upper half poorly exposed.

Unit 51: Limestone. Micrite, sparse to abundant ostracodes; top 7.9 inches contains ostrcodes and well-rounded carbonate clasts as wide as 0.6 inches; forms locally prominent yellow band.

Unit 50: Interbedded mudstone, siltstone, sandstone, and minor limestone. Unit coarsens upward; basal 6.6 feet is silty green mudstone and rippled sandstone and siltstone; 6.6-8.9 feet consists of several 7.9-inch-thick beds of rippled 70-80 micron sandstone; 8.9 feet to top is mainly sandstone and siltstone, one 2-inch-thick bed ostracode and ooid grainstone is 10.8 feet above base of unit.

Unit 49: Mudstone. Greenish gray (5GY 6/1), several 0.8-in-thick beds of ostracode grainstone in basal 9.8 inches.

Unit 48: Sandstone, 100-115 microns. Base sharp and slightly scoured; basal 3.1 inches has IFC consisting of small limestone clasts; basal 12.5 feet contains well-exposed current ripples (85 percent), tabular tangential or trough crossbeds (5 percent), 10 percent is covered; 12.5 feet to top is planar laminated (50 percent) and structureless (50 percent); 7.9-inch-thick lens of IFC 11.8 inches below top of unit.

Unit 47: Limestone. Silty micrite; base irregular, top sharp; minor ostracodes; top 7.9 inches contains abundant oval to round 0.8-2.4-inch-wide patches spongy texture.

Unit 46: Interbedded mudstone and sandstone. Green moderately to very silty mudstone containing three 7.9-15.7 inches thick beds of very fine grained sandstone with gradational boundaries in upper half of unit.

Unit 44: Sandstone, 105 microns. Base irregular and sharp, grades upward to mudstone, structureless.

Unit 43: Mudstone and sandstone. Mudstone is green and purple, mottled in places; one bed of rippled sandstone 3.9-4.4 feet above base.

Unit 42: Sandstone. Continuation of unit 40, fines upward to mudstone, 40 percent rippled and 60 percent structureless or poorly exposed.

Unit 40: Sandstone, 110 microns. Rippled.

Unit 39: Mudstone, and sandstone. Green, very silty mudstone and several thin sandstone beds, sandstone contains wave ripples and HCS.

Unit 38: Sandstone, 75 microns. Base and top sharp and flat, structureless.

Unit 37: Mudstone. Greenish gray, silty, laminated, small zone of soft-sediment deformation; 7.9-19.7 inches above base is very fine grained sandstone.

Unit 36: Limestone. Basal 7.9 inches is stromatolite, subhorizontal laminations and small domes, sparse to abundant algal limestone clasts; 7.9-39.4 inches is white micrite; 39.4-53.1 inches is stromatolite, pillar-type and subhorizontal; 53.1 inches to top is algaly laminated limestone, mottled texture and algal limestone clasts; top of unit irregular, has 7.9 inches of relief.

Unit 35: Mudstone. Pale green, silty, calcareous.

Unit 34: Limestone. Composed of ostracodes, carbonate intraclasts, and thin algally laminated zones, very silty in places, unit ranges from silty grainstone to calcareous siltstone.

Unit 33: Mudstone. Very pale green, very silty, very calcareous.

Unit 32: Sandstone, 115 microns. Base sharp and flat, top gradational, ripples and planar laminations.

Unit 31 Mudstone. Green, very silty, calcareous; 2-2.6 feet above base mudstone is laminated and has thin siltstone interbeds.

Unit 30: Sandstone, 75 microns. Base sharp and flat, top gradational.

Unit 29: Mudstone. Green, fissile.

Unit 28: Sandstone, 110 microns. Sharp and flat base, rippled.

Unit 27: Mudstone. Green, laminated and fissile, calcareous, moderately silty to very silty.

Unit 26: Sandstone, 100 microns. Base and top sharp and flat, rippled.

Unit 25: Mudstone. Pale green very silty, noncalcareous, fills scour cut into unit 24.

Unit 24: Sandstone, 90 microns. Base indistinct, top truncated.

Unit 23: Mudstone. Green.

Unit 22: Sandstone, fines upward (175 to 65 microns). Base sharp and flat, scattered zones of ostracodes and algal limestone intraclasts near base, most of unit covered by desert varnish, some trough crossbeds in basal 6.6 feet.

Unit 21: Mudstone. Pale green, slightly silty, moderately calcareous, vertical burrows 0.4 inches wide by 1.4-2 inches long.

Unit 20: Sandstone, fines upward (170 to 80 microns) Base sharp and slightly irregular, sedimentary structures covered by weathering and lichen.

Unit 19: Mudstone. Yellow calcareous mudstone (70 percent) and green silty mudstone (30 percent).

Unit 18: Sandstone, coarsens upward (80 to 150 microns). 25 percent unit rippled, 5 percent contains wavy planar laminations, and 75 percent is obscured by weathering; 0-25 percent carbonate grains, one zone contains carbonate intraclasts and fish scales; unit thickens to east.

Unit 17: Mudstone. Light to medium gray and brown, moderately to very calcareous, silty, laminated.

Unit 16: Limestone. Micrite and algal laminated limestone (mainly subhorizontal, few small domes).

Unit 15: Limestone. Subhorizontal to domal stromatolites, most domes 3.9-11.8 inches wide, in places limestone contains algal limestone intraclasts.

Unit 14: Limestone. Composed of grain-supported ostracodes and ooids, very sandy.

Unit 13: Limestone. 80 percent silty micrite and 20 percent algaly laminated limestone (subhorizontal and very small domes).

Unit 12: Mudstone. Light greenish gray, very calcareous.

Unit 11: Limestone. Micrite containing 10 percent algal laminations (mainly subhorizontal with few very small domes).

Unit 10: Limestone. Domal stromatolites 7.9 inches high and 11.8 inches wide.

Unit 9: Limestone. Composed of grain-supported ostracodes, ooids, and lesser carbonate intraclasts; size of ostracodes increases upward to 0.004 inches long due to carbonate coating on ostracodes.

Unit 8: Interbedded sandstone, mudstone, and limestone. Basal 2 inches is sandstone; 2-4.7 inches is green mudstone; 4.7-15.7 inches is sandy ooid limestone; 15.7-39.4 inches is sandstone containing fish scales (10 percent), bone fragments, fragments of algaly laminated limestone; 39.4 inches to top is calcareous sandstone.

Unit 7: Mudstone. Light olive gray, silty, noncalcareous to slightly calcareous; basal 9.8 inches laminated; 4.7-inch-thick bed of sandstone 3.6 feet above base; 4.6-5.2 feet above base is silty mudstone containing ripples and wavy planar laminations.

Unit 6: Sandstone (65-80 microns) and siltstone. Basal 19.7 inches contains current ripples, top 5.9 inches planar and wavy planar laminations and one small water-escape structure.

Unit 5: Mudstone. Green.

Unit 4: Sandstone, fines upward (160 to140 microns). Base has 5.2 feet of scour, abundant yellow carbonate grains near base, trough crossbeds, 20 percent of troughs distorted by soft-sediment deformation.

Unit 3: Sandstone, 65-150 microns. Unit composed of thin sandstone beds, some separated by thin green mudstone interbeds, beds thicken upward and coarsen upward, bases of sandstones sharp, tops sharp to gradational.

Unit 2: Mudstone. Laminated, slightly to moderately calcareous, medium brown to olive green, silt content increases upward.

Unit 1: Limestone. Basal 9.8 inches is algally laminated limestone (80 percent has horizontal to subhorizontal laminations and 20 percent has domes) containing ostracodes and coated carbonate grains; middle 11.8 inches contains pillar-type stromatolites and ostracodes; upper 13.8 inches is ostracode grainstone containing a few fish scales.

LEGEND

LITHOLOGY

- Sandstone
- Mudstone
- Covered
- Limestone
- Siltstone

CONTACTS

- Sharp

PHYSICAL STRUCTURES

- Trough Cross-Strat.
- Scour
- Ripples, Unknown
- Wavy Planar Laminations
- Stromatolite, Domal
- Planar Lamination
- Wave Ripples
- Intraformational Conglomerate (IFC)
- Stromatolite, Small Pillars
- Hummocky Cross-Strat.
- Soft Sediment Deformation
- Current Ripples

LITHOLOGIC ACCESSORIES

- Oolites

ICHNOFOSSILS

- Vertical Burrows

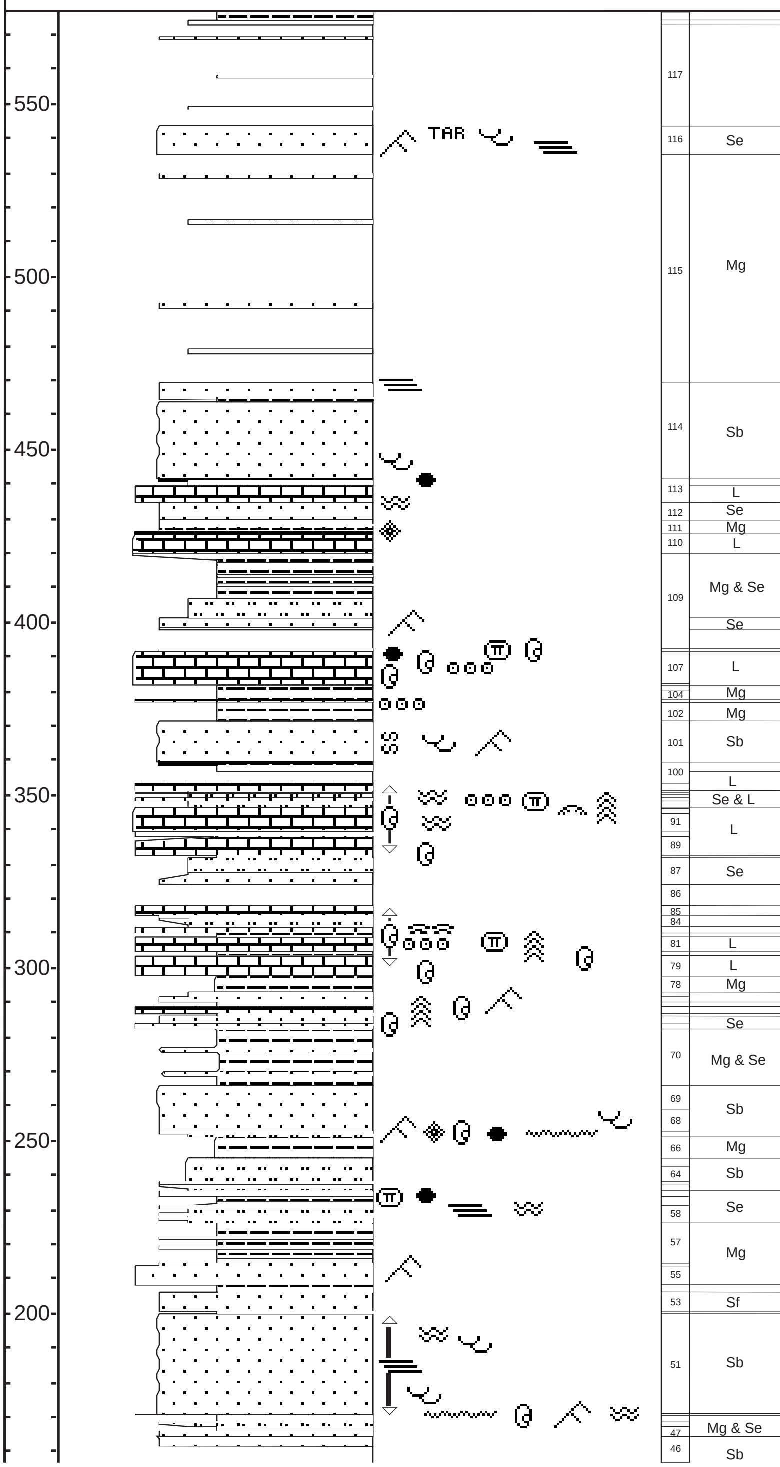
FOSSILS

- Carbonate Debris
- Fish Scales
- Ostracodes

Remy 14

The section is located in Dry Canyon and begins and ends in the SW1/4 section 5, T.13 S., R. 15 E., of the Salt Lake Base line and Meridian, Duchesne County, Utah.

FEET	GRAIN SIZE (cobble, pebble, granule, sand: v c m f v, silt, clay)	PHYSICAL STRUCTURES / ACCESSORIES / ICHNOFOSSILS / FOSSILS	UNIT NUMBER	FACIES	Unit Number - Lithologic description



Unit 119: Mudstone. Green, poorly exposed.

Unit 118: Siltstone. Forms resistant ledge.

Unit 117: Mainly covered. Minor outcrops of green mudstone, siltstone, and sandstone.

Unit 116: Sandstone, 65-150 microns. Basal 4.9 feet is planar laminated, rippled, and trough crossbedded; 4.9 feet to top is rippled; very weakly tar stained in places.

Unit 115: Mainly covered. Abundant green mudstone float suggest unit is mainly green mudstone, 4-5 thin sandstone and siltstone beds.

Unit 114: Sandstone (fines upward (160 to 100 microns)) and minor mudstone. Base sharp, scours unit 113; basal 7.9 inches has lag consisting of smalll limestone clasts; 4.6 feet below top is bed of green mudstone scoured by overlying sandstone; basal 9.8 feet of unit is trough crossbedded; upper 4.6 feet planar laminated.

Unit 113: Limestone and siltstone (medium to coarse grained). Basal 4.3 feet is light-gray micrite; 4.3 feet to top is light-gray siltstone.

Unit 112: Sandstone, 70-80 microns. Wavy planar laminations.

Unit 111: Interbedded green mudstone and sandstone. Upward increase in bed thickness and amount of sandstone; 15.7 inches above base 2.8-inch-thick bed of sandstone containing 20 percent carbonate clasts.

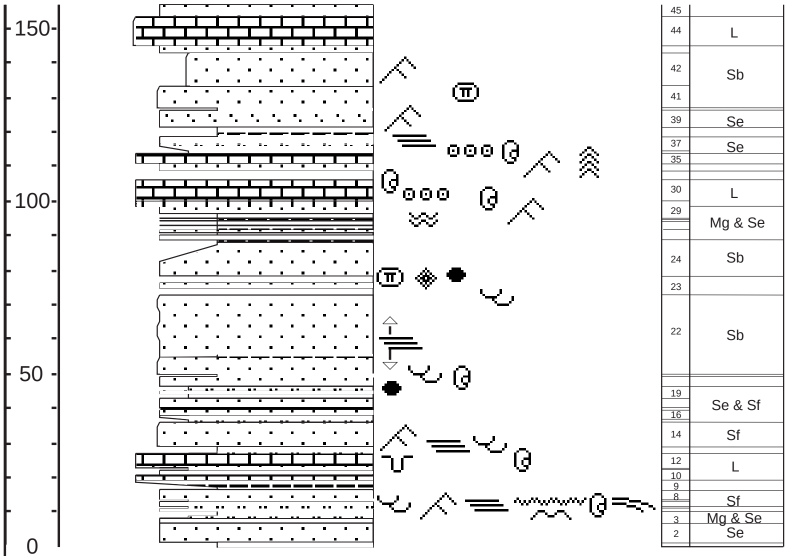
Unit 110: Limestone. Micrite or very calcareous mudstone, light-gray, weathers yellow, fine-grained, base gradational over 0.4-7.9 inches with underlying mudstone, top sharp.

Unit 109: Sandstone (80-115 microns), siltstone, and mudstone. Basal 5.9 feet is covered; 5.9-6.6 feet above base is rippled 115 micron sandstone; 6.6-9.2 feet is rippled 80 micron sandstone; 9.2-14.4 feet is very coarse grained structureless siltstone; 14.4 feet to top is silty green mudstone containing three 13.8-19.7 inch thick beds of structureless siltstone.

Unit 108: Sandstone, fines upward (125 to 65 microns). Contains as much as 10 percent fish scales, carbonate clasts and ostracodes.

Unit 107: Limestone. Silty micrite, abundant ostracodes 19.7-29.5 inches above base, other thin zones of ostracodes and ooids throughout unit.

Unit 106: Limestone. Ostracodal grainstone.



Unit 105: Mudstone. Consists of 3.9-inch-thick bed of medium gray calcareous mudstone that weathers orange overlain by 7.9-inch-thick bed of light-gray moderately calcareous mudstone.

Unit 104: Mudstone. Green, calcareous, silty, typical mudstone weathering.

Unit 103: Limestone. Mainly silty micrite; basal 0.8 inches is ooid grainstone.

Unit 102: Mudstone. Green, poorly exposed.

Unit 101: Sandstone, fines upward (150 to 75 microns). Base is sharp and flat; basal 4.3 feet contains trough crossbeds and large-scale soft sediment deformation; 4.3 feet to top contains ripples, trough crossbeds, and minor small-scale soft sediment deformation.

Unit 100: Mainly covered. Lower half is probably ostracode grainstone; olive-gray, fine-grained mudstone crops out beneath unit 101.

Unit 99: Limestone. Ostracodal grainstone.

Unit 98: Siltstone. Very calcareous, laminated.

Unit 97: Limestone. Ostracodal grainstone, wavy planar laminations.

Unit 96: Siltstone, coarse-grained. Light gray, calcareous, massive.

Unit 95: Limestone. Lower half is ostracode and ooid grainstone containing fish scales; upper half is ooid grainstone.

Unit 94: Siltstone. Laminated, calcareous.

Unit 93: Limestone. Consists of small domal and pillar-type stromatolites, and ostracodes.

Unit 92: Limestone. Silty micrite containing ostracodes.

Unit 91: Limestone. Ostracodal grainstone, wavy planar laminations; 15.7 inches above base is 3.9-inch-thick bed of siltstone.

Unit 90: Limestone. Unit consists of ostracodal grainstone that grades upward to light-gray silty limestone containing 10 percent ostacodes; top 0.8 inches is dark-gray laminated chert.

Unit 89: Limestone. Basal 9.8 inches is micrite containing minor ostracodes; upper 4.3 feet is ostracode grainstone.

Unit 88: Mudstone. Green; lower half typical mudstone weathering; upper half spheroidal weathering and hematite stains.

Unit 87: Sandstone (62-100 micron) and siltstone (coarse grained). Lower half is 100 micron structureless sandstone; upper half grades upward to siltstone.

Unit 86: Covered.

Unit 85: Limestone. Ostacodal grainstone; top 1 inch of unit is sandy; weathers orange yellow.

Unit 84: Siltstone (medium to coarse grained) and sandstone (65-70 micron). Unit coarsens upward from siltstone to laminated sandstone.

Unit 83: Limestone. Ostacodal grainstone; upper half contains thin (0.2-0.8 inches) beds of ostracode grainstone separated by thin mudcracked green mudstone drapes.

Unit 82: Interbedded green mudstone and siltstone. Unit fines upward; top 2.4 inches contains 50 percent ostracodes.

Unit 81: Limestone. Basal 9.8-23.6 inches consists of pillar-type algal stromatolites, top of lower zone is very irregular, overlain by silty micrite containing 20 percent ostracodes and ooids; upper 7.9 inches contains abundant fish scales.

Unit 80: Mudstone. Light green, silty, calcareous.

Unit 79: Limestone. Silty micrite, basal 5.2 feet has upward increase in proportion of ostrcodes from none to 25 percent; upper 11.8 inches contains minor ostracodes; structureless.

Unit 78: Mudstone. Grayish green (5G 5/2) to pale green (10G 6/2), some spheroidal weathering but most has typical mudstone weathering.

Unit 77: Interbedded siltstone (coarse grained) and sandstone (very fine grained). Bedding and contacts between beds indistinct.

Unit 76: Sandstone, 80-100 microns. Unit consists of rippled sandstone beds separated by 0.4-1.6-inch-thick beds of green mudstone.

Unit 75: Mudstone. Green, typical mudstone weathering.

Unit 74: Limestone. Silty micrite, 5-10 percent ostracodes; upper 3.9 inches contains pillar-type algal stromatolites.

Unit 73: Mudstone. Green.

Unit 72: Sandstone, 100-115 microns. Basal 3.9 inches consists of 2-3 beds of 100 microns sandstone containing 5-10 percent ostracodes; upper 15.7 inches is structureless 115 micron sandstone.

Unit 71: Sandstone (65 microns) and limestone. Sandstone containing minor ostracodes that grades upward to sandy ostracodal limestone, ostracodes look abraided.

Unit 70: Mudstone and sandstone (65-80 microns). Green mudstone containing 4-5 7.9-13.8 inches thick beds of sandstone.

Unit 69: Sandstone, 70-90 microns. Friable, structureless.

Unit 68: Sandstone, fines upward (125 to 105 microns). Base sharp and has 7.9 inches of scour, in places 2.8-inch-thick basal lag consists of carbonate clasts, carbonaceous debris, and ostracodes in matrix of 160 micron sand; unit mainly rippled, minor trough cross beds in lower half.

Unit 67: Siltstone (coarse grained) and sandstone (65-70 microns). Basal 3.9 inches is sandstone; upper 9.4 inches is calcareous siltstone.

Unit 66: Mudstone. Green, spheroidal weathering in places, most weathers like typical mudstone.

Unit 65: Siltstone (very coarse grained) and sandstone (62-110 microns). Siltstone that coarsens upward to 110 micron sandstone, numerous small bone and turtle shell fragments on top of unit.

Unit 64: Siltstone, very coarse-grained. Poorly exposed, green.

Unit 62: Sandstone, 70 microns. Base gradational with unit 61, bed thickness 0.4-3.1 inches.

Unit 61: Siltstone, green.

Unit 60: Sandstone, 70 microns. Fish scales and IFC in basal 3.1 inches.

Unit 59: Poorly exposed. Lower half continuation of unit 58; upper half green mudstone.

Unit 58: Siltstone (very coarse grained) and sandstone (very fine grained). Planar and wavy planar laminations.

Unit 57: Mudstone. Green, few thin beds of sandstone.

Unit 56: Sandstone, 65 microns. Rippled.

Unit 55: Mudstone-siltstone and sandstone. Interbedded very silty green mudstone or siltstone (60 percent) and sandstone (40 percent); ripples in upper sandstone.

Unit 54: Mudstone, green.

Unit 53: Sandstone, coarsens upward (95 to 120 microns). Structureless, numerous hematite concretions.

Unit 52: Mudstone. Green.

Unit 51: Sandstone, fines upward (135 to 70 microns). Base sharp and in places scours units 50 and 49; mainly planar laminations, some trough crossbeds (20 percent), wavy planar laminations with low-angle truncations, and minor tabular-tangential crossbeds.

Unit 50: Limestone. Very fine grained carbonate grains and some ostracodes, sandy, wavy planar laminations and ripples.

Unit 49: Mudstone. Light gray, very silty, noncalcareous, typical mudstone weathering.

Unit 48: Siltstone (coarse grained) and sandstone (70-80 micron). Coarsens upward from siltstone to sandstone at top, structureless.

Unit47: Sandstone (90-140 microns) and mudstone. Basal 15.7 inches consists of sandstone that fines upward (140 to 90 microns), ostracodes, obscure sedimentary structures; upper 19.7 inches green mudstone.

Unit 46: Sandstone. Partly exposed.

Unit 45: Sandstone, 135 microns. Base covered.

Unit 44: Limestone. Algal, blotchy porous texture, partly exposed.

Unit 43: Sandstone, very fine grained. Structureless.

Unit 42: Siltstone. Rippled.

Unit 41: Sandstone, 80-100 micron. Few fish scales and bone fragments.

Unit 40: Mudstone. Green, some intervals fissile.

Unit 39: Interbedded sandstone (90-105 microns) and siltstone (very coarse grained). Four or five 0.8-5.9-inch-thick beds of sandstone separated by siltstone, sandstone beds pinch-and-swell, sandstone coarsens upward from 90 to 105 microns and is rippled in places.

Unit 38: Mudstone and shale. Basal 15.7 inches is dark-brown, silty, fissile shale; upper 19.7 inches is silty, green, calcareous mudstone, some fissile zones.

Unit 37: Siltstone (medium to coarse grained) and sandstone (110 microns). Unit coarsens upward from siltstone to sandstone; calcareous and planar laminated.

Unit 36: Siltstone, coarse-grained. Rippled, sparse to 20 percent ostracodes and ooids.

Unit 35: Limestone. Ostracodal grainstone, pillar-type algal stromatolites in lower 7.9 inches.

Unit 34: Sandstone, fines upward slightly (115 to 95 microns).

Unit 31: Covered.

Unit 30: Limestone Basal 2 feet is ostracodal grainstone that grades upward to ooid grainstone consisting of carbonate-coated ostracodes, overall coarsening upward due to carbonate coatings on ostracodes; upper 3.6 feet is ostacode grainstone.

Unit 29: Sandstone (very fine grained), siltstone, and limestone. Basal 27.6 inches is indistinctly bedded sandstone and siltstone; upper 21.7 inches is mainly rippled ostracode grainstone containing sand stringers.

Unit 28: Mudstone. Pale olive (10Y 6/2); 2 inches above base is 0.4-inch-thick band fo orange ostracode grainstone, above this bed are a few less distinct bands of ostracodal grainstone.

Unit 27: Sandstone, 65-70 microns. Base sharp, ripples or wavy planar laminations.

Unit 26: Mudstone. Green, silty; 4.7-inch-thick 90 micron sandstone bed in center and 2-inch-thick sandstone bed about 3.9 inches from top.

Unit 25: Sandstone, 60-70 microns. Gradational base and top; friable, structureless; 3.9-5.9-inch-thick bed of green mudstone in center of bed.

Unit 24: Sandstone, fines upward (150 to 90 microns). Base poorly exposed; basal few inches contains carbonaceous debris, IFC, few bone fragments and fish scales; wedge shaped geometry, wedge thins toward southeast, sandstone beds dip 11° SSW; top 11.8 inches grades to green mudstone.

Unit 23: Mainly covered. One 15.7-inch-thick 125 micron sandstone bed in center.

Unit 22: Sandstone, 125-135 micron. Base sharp and flat; 3.9-inch-thick bed of green mudstone 4.9 feet above base; trough crossbeds in upper 4.9 feet and basal 19.9 inches; middle contains planar laminations with parting lineations and low-angle truncations.

Unit 21: Mudstone, green.

Unit 20: Sandstone, 150-130 microns. Base sharp, 5.9 inches of scour; wedge-shaped geometry, unit composed of 3-4 sandstone beds that dip about 15° ESE; trough crossbeds; basal few inches composed of 50 percent ostracodes, 35 percent 150 micron sand, and 15 percent IFC, rest of unit consists of about 20 percent ostracodes.

Unit 19: Interbedded siltstone (very coarse grained) and sandstone (100 micron). Siltstone (70 percent) and one bed of sandstone (30 percent).

Unit 18: Sandstone, 115 microns. Base is sharp and truncates unit 17; unit wedge shaped, thickens toward east-southeast and merges with unit 16; along line of section unit is sandstone, 4.9 feet to west unit is composed of ostracodal grainstone.

Unit 17: Siltstone, medium- to coarse-grained. Green, unit truncated east-southeast of section by unit 18 and by rise of unit 16.

Unit 16: Siltstone (very coarse grained) and sandstone (70 microns). Siltstone grades upward to sandstone.

Unit 15: Siltstone, very coarse grained. Unit truncated to east-southeast, siltstone clasts.

Unit 14: Sandstone:, fines upward (110 to 70 microns). Base sharp and slightly wavy; wedge shaped, top of unit slopping 20° ESE; basal 7.9 inches is trough or tabular-tangential crossbedded, 7.9-11.8 inches above base is planar laminated, 11.8 inches to top is rippled and contains numerous small hematite concretions and some linear concretions in upper 15.7 inches.

Unit 13: Siltstone and mudstone. Laminated, medium-grained siltstone containing black laminae in places, grades upward to very light green, calcareous, slightly silty mudstone.

Unit 12: Limestone. Base sharp; basal 2.3 feet is ostracodal limestone, ostracodes mainly grain-supported; upper 21.7 inches is yellow silty limestone containing bone fragments and vertical burrows ; top of unit is irregular and has 3.9-5.9 inches of relief, numerous well-rounded carbonate grains.

Unit 11: Sandstone (65-100 micron) and siltstone. Fines upward from 65-70 micron sandstone with some 90-100 micron sandstone to very coarse grained siltstone.

Unit 10: Limestone and sandstone. Base is gradational; lower half is thinly interbedded ostracodal and ooid limestone, sandy ostracode limestone, and sandstone; upper half mainly 70 micron sandstone.

Unit 9: Mudstone. Upward change from dusky yellow green (5GY 5/2), moderately silty, noncalcareous mudstone to pale-olive (10Y 6/2), very silty, slightly calcareous mudstone; typical mudstone weathering, scattered red-brown mottles.

Unit 8: Sandstone, fines upward (130 to 65 microns). Base sharp and scoured; most sedimentary structures obscured by desert varnish and lichen, some planar laminations in lower half and ripples in upper half.

Unit 7: Siltstone, coarse-grained to very coarse grained. Contains several lenticular (3.3-6.6 feet wide by 0.8 inches thick) 110 micron sandstone beds.

Unit 6: Sandstone, 100-110 microns. Base sharp, 3.9 inches of scour; planar laminations, minor wave ripples, and trough crossbeds, in places planar laminations appear wavy and have low-angle truncations (HCS); middle of unit contains 10 percent ostracodes.

Unit 5: Siltstone, very coarse grained. Structureless.

Unit 4: Sandstone, 100 microns. Base and top are sharp and flat, few vertical burrows in upper half, structureless.

Unit 3: Interbedded green mudstone, sandstone, and siltstone. Lower half is frable structureless sandstone (80 percent) and green silty mudstone (20 percent); upper half is interbedded green mudstone (60 percent), rippled, very fine grained sandstone (30 percent), and siltstone (10 percent).

Unit 2: Sandstone, 90-110 microns. Base gradational; 20 percent rippled and 80 percent covered by desert varnish.

Unit 1: Mudstone. Green, contains concretions.

LEGEND

LITHOLOGY

Sandstone
Shale
Silty Sandstone
Limestone
Siltstone
Mudstone
Covered
Chert

CONTACTS

Sharp

PHYSICAL STRUCTURES

- Trough Cross-Strat.
- Planar Lamination
- Hummocky Cross-Strat.
- Scour
- Mud Drapes
- Soft Sediment Deformation
- Ripples, Unknown
- Wave Ripples
- Wavy Planar Laminations
- Intraformational Conglomerate (IFC)
- Stromatolite, Domal
- Stromatolite, Small Pillars

LITHOLOGIC ACCESSORIES

- Oolites
TAR - Tar

ICHNOFOSSILS

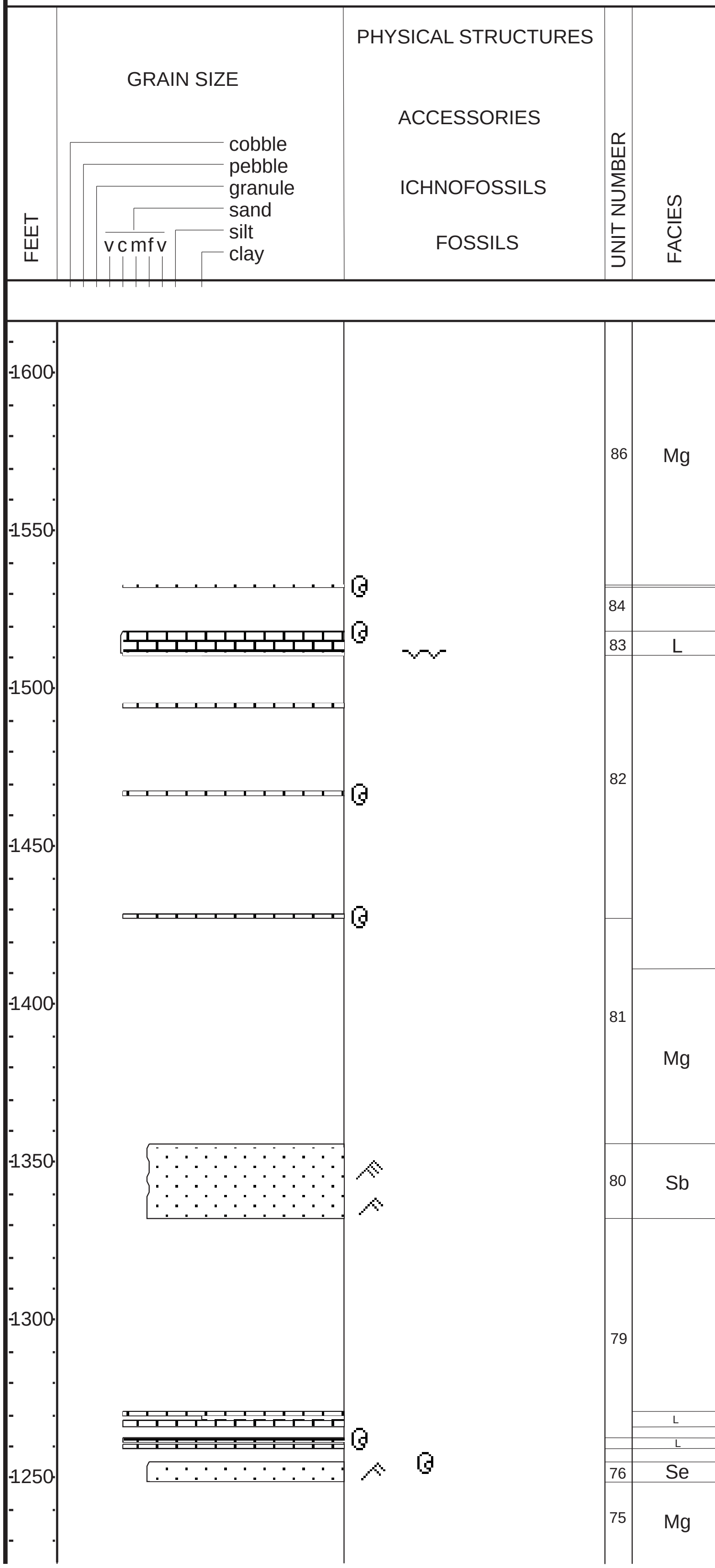
- Vertical Burrows

FOSSILS

- Carbonate Debris
- Fish Scales
- Ostracodes

REMY 16

The section is located in Nine Mile Canyon and begins in the SE1/4SE1/4 and ends in the NE1/4NW1/4 section 11, T. 12 S., R. 13 E., of the Salt Lake Base line and Meridian, Duchesne County, Utah.



Unit Number - Lithologic description

Unit 86: Covered. Relatively abundant fragments of greenish-gray mudstone. Top of measured section is at top of ridge.

Unit 85: Limestone. Ostracode grainstone.

Unit 84: Covered.

Unit 83: Limestone. Ostracode grainstone, basal foot is interbedded greenish-gray mudstone and ostracode grainstone with mudcracks and burrows.

Unit 82: Covered. Few beds of micrite containing ostracodes.

Unit 81: Covered. Probably greenish-gray mudstone.

Unit 80: Sandstone, 90-150 microns. Base covered; basal 9 feet is mainly structureless and contains minor ripples; 9-20 feet above base contains well-exposed current ripples; top 3 feet is only partly exposed and contains possible greenish-gray mudstone interbeds.

Unit 79: Covered. About 3 feet above base thin beds of limestone are composed of ostracodes and limestone clasts, limestone beds have mudcracks and very thin green mudstone interbeds.

Unit 78: Limestone. Basal 1.1 feet is ostracode grainstone; 1.1-1.5 feet is covered; 1.5-2.1 feet is micrite containing ostracodes; 2.1 feet to top is ostracode grainstone.

Unit 77: Covered. Fragments of green mudstone.

Unit 76: Sandstone, 170 microns. Rippled, few percent ostracodes.

Unit 75: Covered. Fragments of green mudstone.

Unit 74: Limestone. Ostracode grainstone.

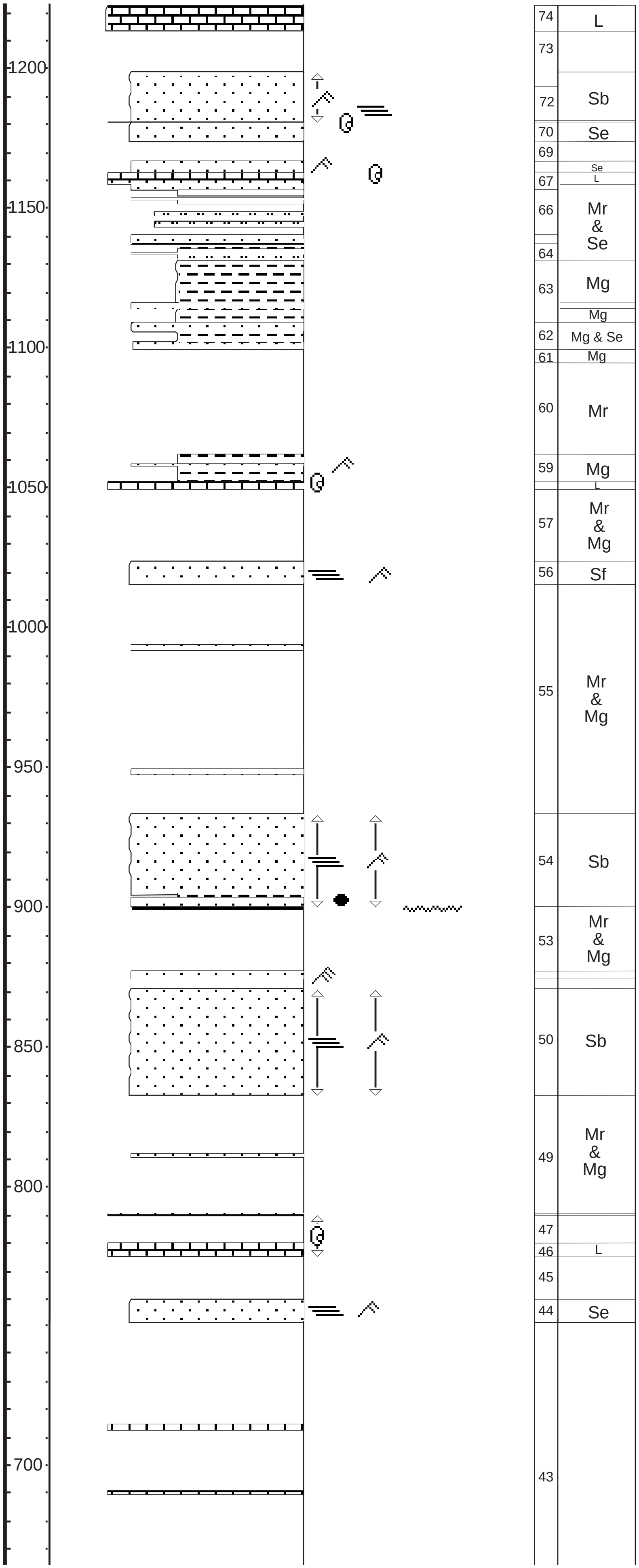
Unit 73: Covered (66 percent) and sandstone (34 percent). Lower third is rippled, very fine grained sandstone; upper two-thirds is covered.

Unit 72: Sandstone, fines upward (170 to 125 microns). Base sharp and flat, planar laminations and ripples.

Unit 71: Limestone. Contains ostracodes, forms recess beneath unit 72.

Unit 70: Sandstone, 100 microns. Rippled.

Unit 69: Covered.



Unit 68: Sandstone, very fine grained. Rippled.

Unit 67: Sandstone and limestone. Basal 2.3 feet is very fine grained sandstone containing ostracodes; upper 4.3 feet is ostracode grainstone. Unit forms prominent yellow band that can be traced for 330 feet to the west and 1600 feet to the east.

Unit 66: Mainly (60 percent) covered; some (40 percent) green mudstone, siltstone, and very fine grained sandstone.

Unit 65: Sandstone, 125 microns. Base sharp and flat.

Unit 64: Interbedded sandstone (very fine grained), siltstone, and mudstone. Mudstone green.

Unit 63: Mudstone. Greenish-gray, 2.3-foot-thick bed of very fine grained sandstone about 5 feet above base.

Unit 62: Interbedded sandstone and mudstone. Sandstone very fine grained; mudstone green.

Unit 61: Covered. Probably green mudstone.

Unit 60: Covered. Red soil and abundant fragments of red mudstone suggest unit is red mudstone.

Unit 59: Mudstone. Greenish gray, one 0.66-foot-thick bed of rippled, very fine grained sandstone about 3 feet below top.

Unit 58: Limestone. Mainly micrite, in places unit consists of ostacode grainstone.

Unit 57: Covered. Red and green soil.

Unit 56: Sandstone, 100 microns. Base covered; 80 percent of unit structureless, 15 percent planar laminated, and 5 percent rippled.

Unit 55: Mainly (95 percent) covered. Fragments of mudstone suggests unit consists of alternating beds of red and green mudstone; two outcrops of sandstone.

Unit 54: Sandstone, coarsens upward slightly (90 to 110 microns). Base sharp, 1-1.3 feet of scour; basal 6.5 feet has 3-4 zones containing green mudstone clasts ; green mudstone bed 3 feet above base; 70 percent structureless, 25 percent contains planar laminations with low-angle truncations, 5 percent is rippled.

Unit 53: Covered. Fragments of red and green mudstone.

Unit 52: Sandstone, 100 microns. Well-exposed current ripples.

Unit 51: Covered.

Unit 50: Sandstone, 90-125 microns. Base covered, 70 percent of unit structureless, 20 percent contains planar laminations, and 10 percent is rippled.

Unit 49: Mainly (95 percent) covered. Surface covered with fragments of red and green mudstone, one 1.3-foot-thick bed of sandstone in center of unit.

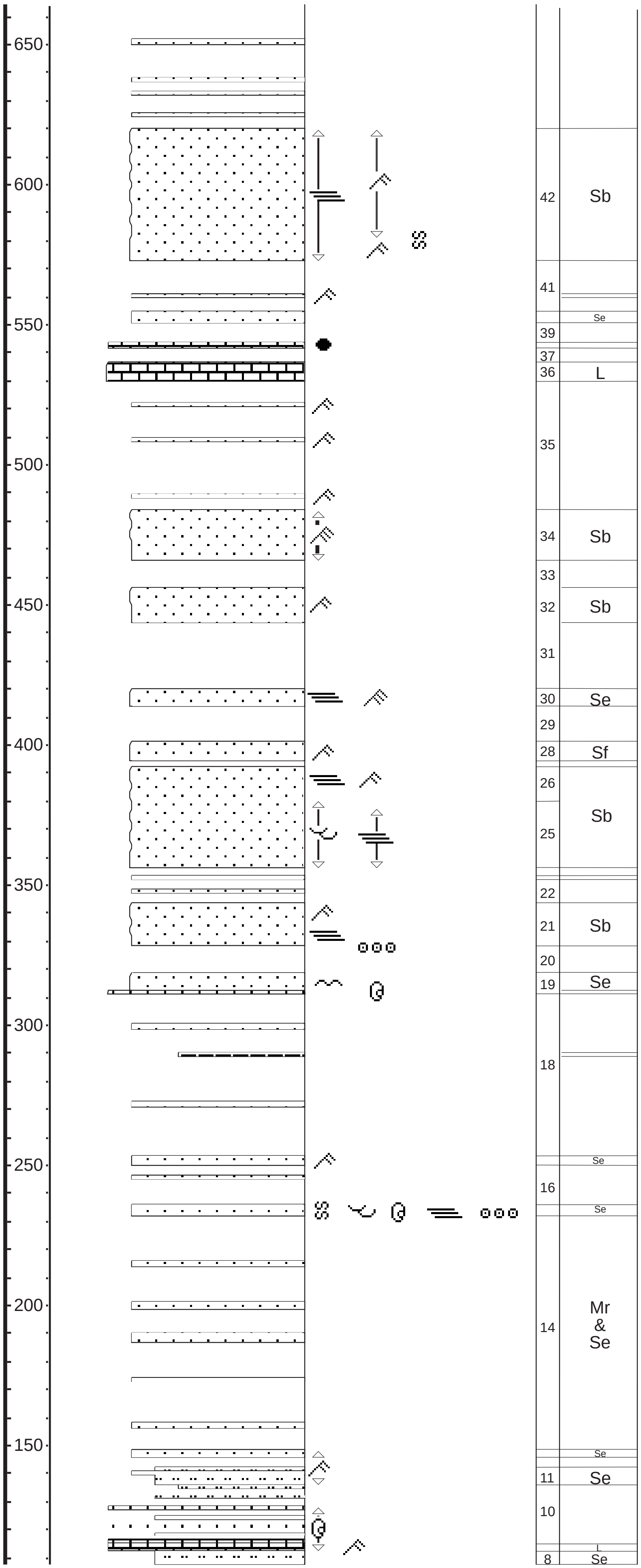
Unit 48: Limestone. Ostracode grainstone.

Unit 47: Covered.

Unit 46: Limestone. Ostracode grainstone.

Unit 45: Covered.

Unit 44: Sandstone, 70-80 microns. Base covered, ripples and planar laminations (in wedge sets).



Unit 43: Mainly covered (95 percent). Basal 33 feet of unit contains 3-4 1-2-foot-thick beds of sandstone; at 68.9 feet above base unit is 0.8-foot-thick bed of ostracode limestone; 91.8 feet above base unit is 0.9-foot-thick bed of ostracode limestone; 98.4-109.2 feet above base are abundant fragments of red mudstone; at 111.5 feet above base unit are fragments of green mudstone.

Unit 42: Sandstone, 90-120 microns. Base is sharp and flat where exposed; basal 8.2 feet contains ripples, planar laminations, and zones with large-scale soft-sediment deformation (deformed trough crossbeds); upper 39.7 feet contains planar laminations (25 percent) and ripples (5 percent), 70 percent is structureless.

Unit 41: Mainly covered. Unit has a 1.8-foot-thick bed of rippled very fine grained sandstone 4.9 feet above base of unit.

Unit 40: Sandstone, 90-100 microns. Most is structureless.

Unit 39: Covered.

Unit 38: Limestone. Abundant limestone clasts and algally laminated zones.

Unit 37: Covered.

Unit 36: Limestone. Ostracode grainstone.

Unit 35: Mainly (95 percent) covered and 5 percent rippled sandstone.

Unit 34: Sandstone, 80-100 microns. Base poorly exposed, 30 percent of unit structureless and 70 percent contains well-exposed current ripples.

Unit 33: Covered.

Unit 32: Sandstone, 70-90 microns. Base covered; 50 percent of unit structureless and 50 percent contains ripples (25-40 inches above base are current ripples).

Unit 31: Covered.

Unit 30: Sandstone, 90 microns. Basal 1.8 feet structureless; 1.8-3.6 feet above base contains well-exposed current ripples; 3.6 feet to top contains planar laminations; unit thins to 1.6 feet about 50 feet east of section.

Unit 29: Covered.

Unit 28: Sandstone, 110-130 microns. Base is covered, most of unit structureless, 20 percent rippled.

Unit 27: Covered.

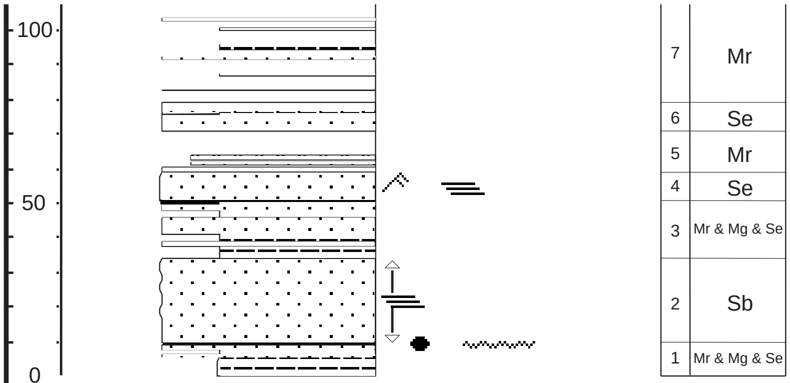
Unit 26: Sandstone, fines upward (140 to 90 microns). Lower third of unit contains planar laminations overlain by trough crossbeds; upper two-thirds of unit is only partly exposed and contains planar laminations and ripples.

Unit 25: Sandstone, 150-190 microns. Base covered, 70 percent structureless and 30 percent contains trough crossbeds (more common in the upper half of the unit) and planar laminations.

Unit 24: Covered.

Unit 23: Sandstone, 100 microns.

Unit 22: Covered by thick soil. One 1.5-foot-thick bed of very fine grained sandstone in center of unit.



Unit 21: Sandstone, 80-115 microns. Base of unit covered; basal few centimeters of unit contains 5-10 percent ooids; lower half of unit contains planar laminations that have some wedge sets; upper half of unit is rippled; unit is laterally continuous (can be seen on ridge 500 feet to west)

Unit 20: Covered.

Unit 19: Sandstone, fines upward (140 to 110 microns). Lenticular bed of ostracode grainstone about 2 inches above base of unit; wave rippled in unit is probably composed of amalgamated .5-1-foot-thick sandstone beds.

Unit 18: Mainly (95 percent) covered. Few minor outcrops of green mudstone and sandstone, soil is gray.

Unit 17: Sandstone, 90 microns. Rippled.

Unit 16: Covered by soil and talus. One 1.3-foot-thick bed of rippled, very fine grained sandstone.

Unit 15: Sandstone, fines upward slightly (150 to 120 microns). Base contains 5-10 percent ostracodes, top of unit 10 percent ostracodes and ooids; unit is planar laminated (50 percent) and trough crossedded (50 percent), about half of trough crossbeds exhibit soft-sediment deformation.

Unit 14: Mainly (90 percent) covered. Lower third has red soil (underlain by red mudstone); upper two-thirds has light gray soil (underlain by green mudstone); few (10 percent) 0.6-1.6-foot-thick beds of sandstone.

Unit 13: Sandstone, 90-100 microns. Rippled.

Unit 12: Covered.

Unit 11: Siltstone and sandstone. Basal 4.1 feet is fissile, rippled siltstone; 4.1-4.9 feet is very fine grained sandstone; 4.9 feet to top is siltstone.

Unit 10: Mainly (60 percent) covered and lesser (40 percent) siltstone and limestone. Limestone contains sparse ostracodes; 1.1-foot-thick bed of gray mudstone crops out beneath unit 11.

Unit 9: Limestone. Mainly rippled ostracode grainstone, several 0.2-0.5-foot-thick micrite interbeds in upper half, micrite is brecciated or mudcracked in places.

Unit 8: Interbedded siltstone (70 percent) and sandstone (30 percent). Sandstone is very fine grained, generally forms ledges; siltstone generally forms slope.

Unit 7: Mainly covered. Most (85 percent) of unit is covered and has red soil (probably weathered red mudstone); few thin outcrops of red mudstone (10 percent) and minor (5 percent) thin beds of very fine grained sandstone.

Unit 6: Sandstone (70-100 microns) and minor mudstone. Basal 4.6 feet consists of structureless 100 micron sandstone; 4.6-5.6 feet is red mudstone; 5.6 feet to top is structureless 70 micron sandstone.

Unit 5: Mainly covered. Red soil covers 85 percent of unit, few outcrops of very fine grained sandstone and siltstone in lower half of unit, bed thickness of sandstone-siltstone is 11.8-15.7 inches.

Unit 4: Sandstone, 70-90 microns. Base sharp and flat, well-exposed planar laminations throughout except for top 2 inches, which is rippled.

Unit 3: Interbedded sandstone (50 percent), red mudstone (45 percent), and green mudstone (5 percent). Middle of unit consists of 4.9-foot-thick bed of very fine grained sandstone.

Unit 2: Sandstone, 90-130 microns. Base sharp, about 0.6 feet of scour, few small intraformational clasts at base; basal 3.3 feet contains well-exposed planar laminations with low-angle truncations in a few places; upper 23 feet of unit contains some planar laminations (40 percent), but most (60 percent) is structureless.

Unit 1: Interbedded mudstone (70 percent) and sandstone (30 percent). Mudstone is red and green; sandstone is two 1-foot-thick beds, top of upper sandstone is 0.6 feet below unit 2.

LEGEND

LITHOLOGY

Sandstone — Mudstone — Covered — Limestone

Siltstone — Shale

CONTACTS

Sharp

PHYSICAL STRUCTURES

- Trough Cross-Strat.
- Planar Tabular Bedding
- Scour
- Wave Ripples
- Ripples
- Current Ripples
- Soft Sediment Deformation
- Intraformational Conglomerate (IFC)

LITHOLOGIC ACCESSORIES

- Oolites

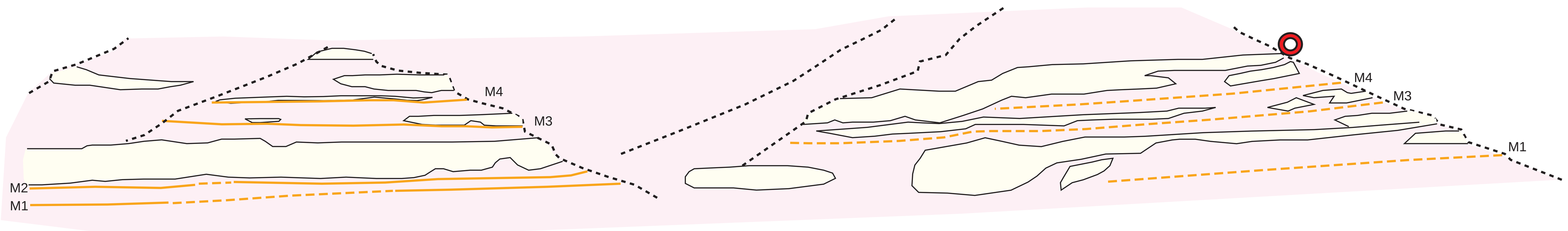
FOSSILS

- Ostracodes

Back to Table of Contents Back to Report

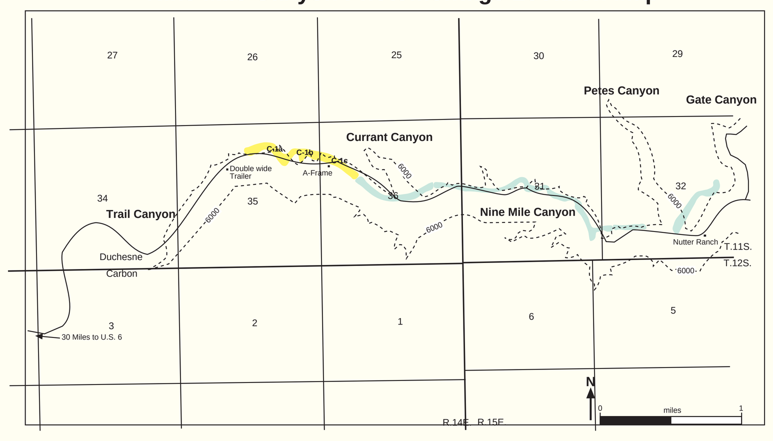
West

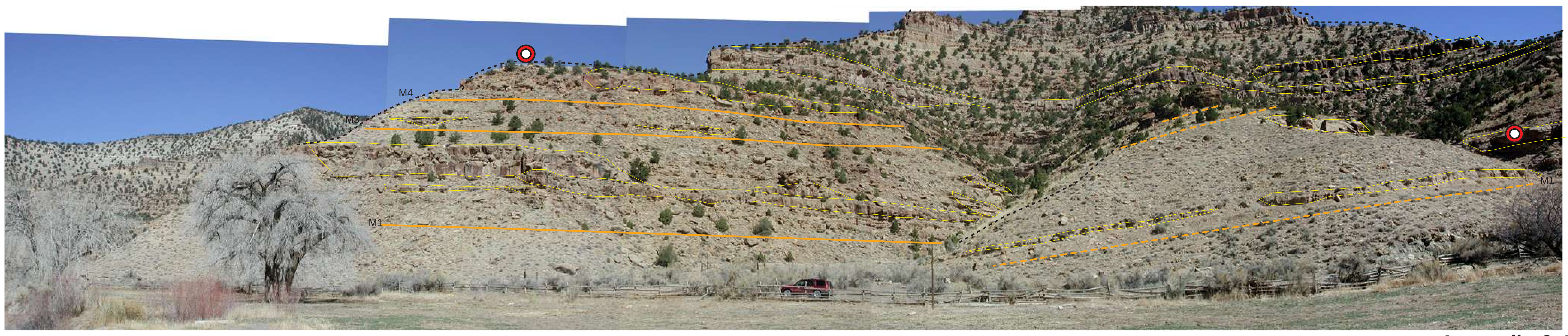
Appendix C-1a



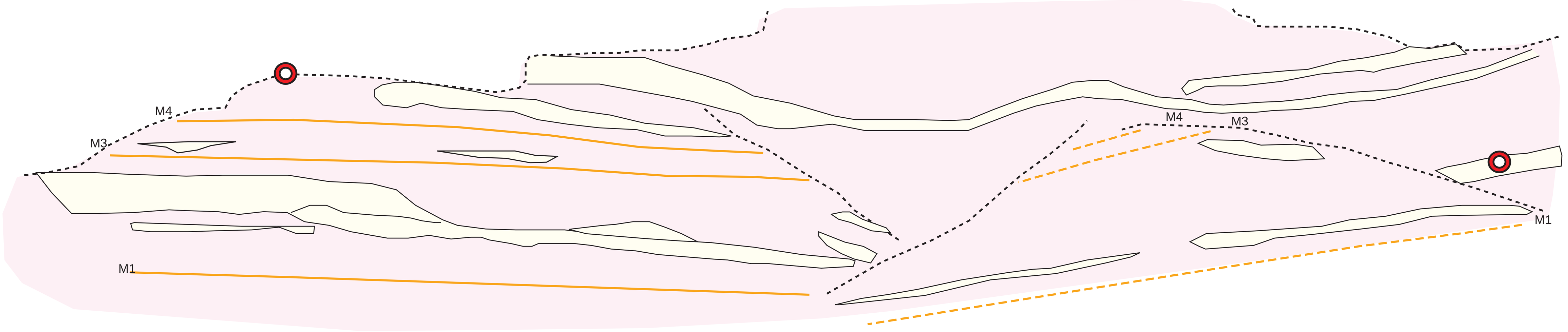
Appendix C-1a

Nine Mile Canyon Photomontage Location Map





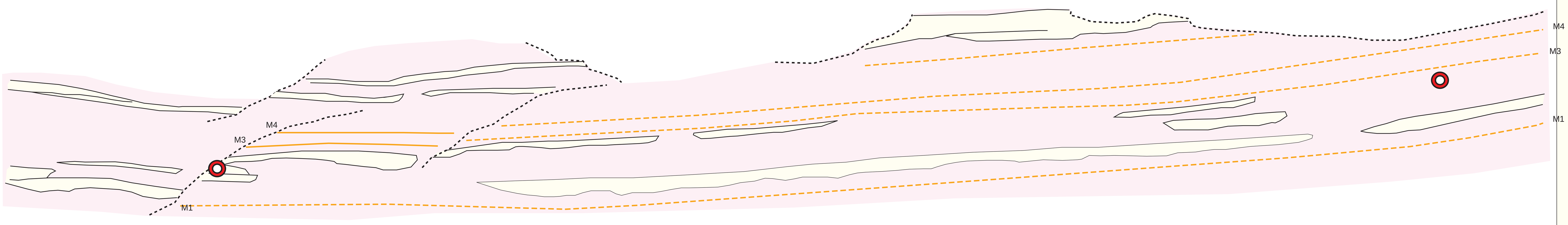
Appendix C-1b



Appendix C-1b

East

Appendix C-1c



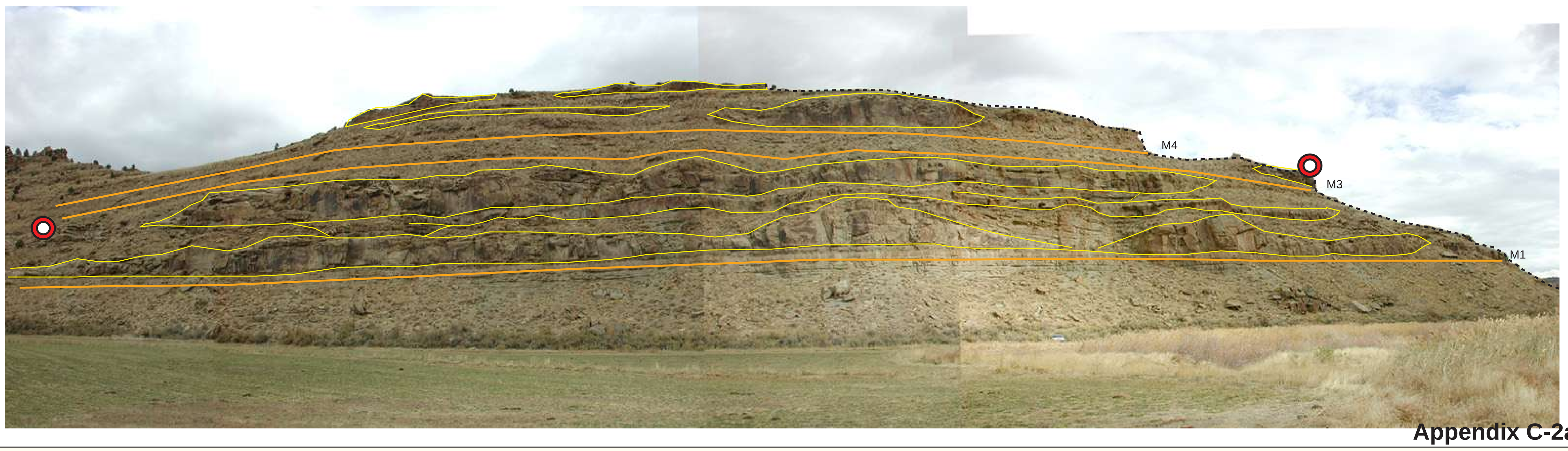
Appendix C-1c

Appendix C-1

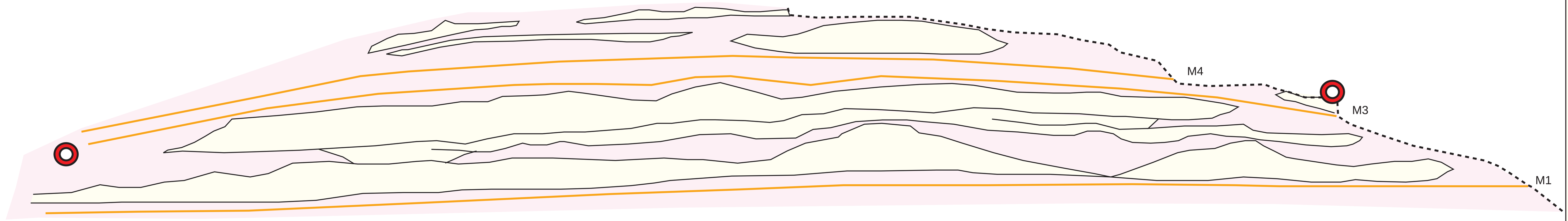
Nine Mile Canyon Photomontages and Correlations

Utah Geological Survey, Salt Lake City, Utah
Reservoir characterization of the lower Green River Formation, southwest Uinta Basin, Utah
Contract: DE-AC26-98BC15103

West

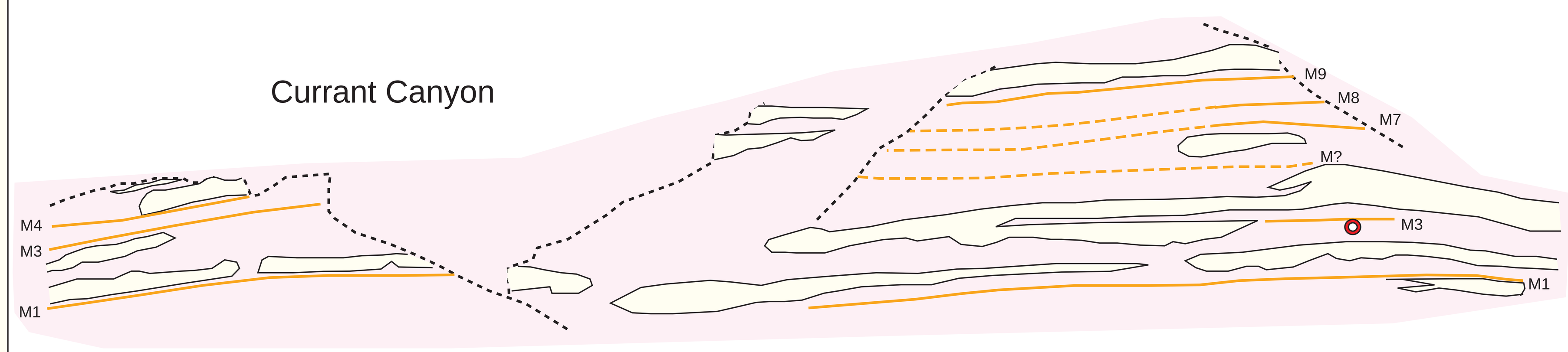


Appendix C-2a



Appendix C-2a

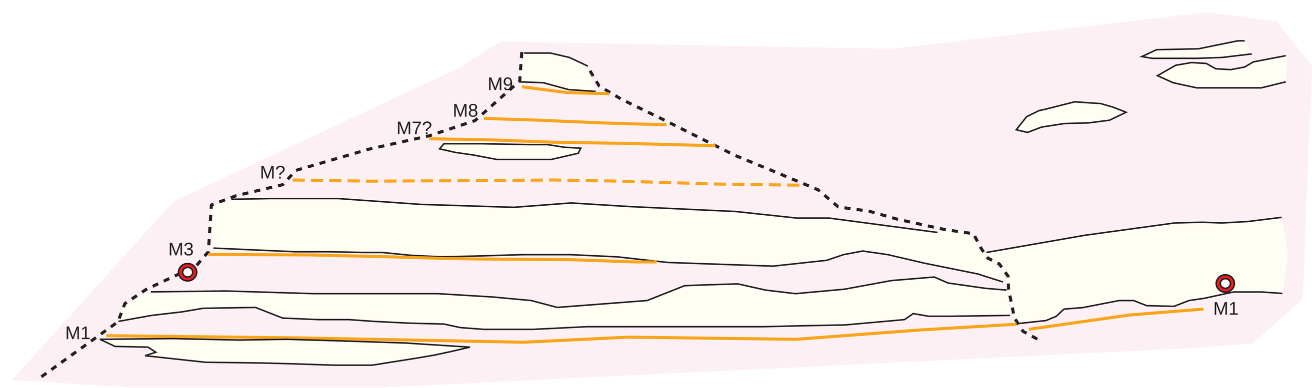
Appendix C-2b



Appendix C-2b

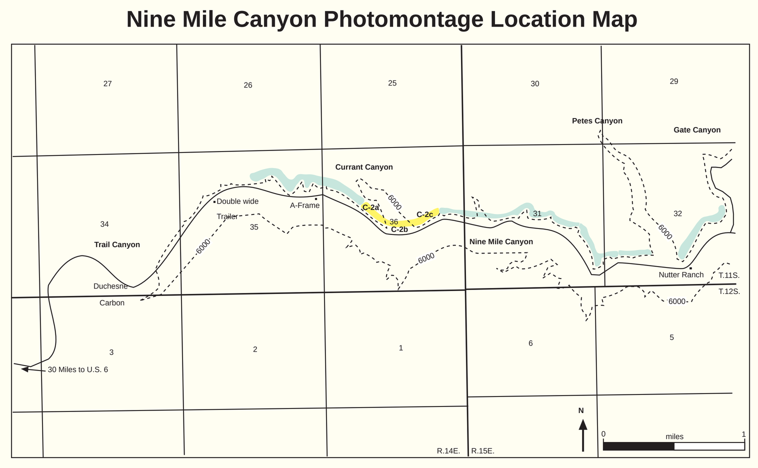
East

Appendix C-2c



Appendix C-2c

Nine Mile Canyon Photomontage Location Map



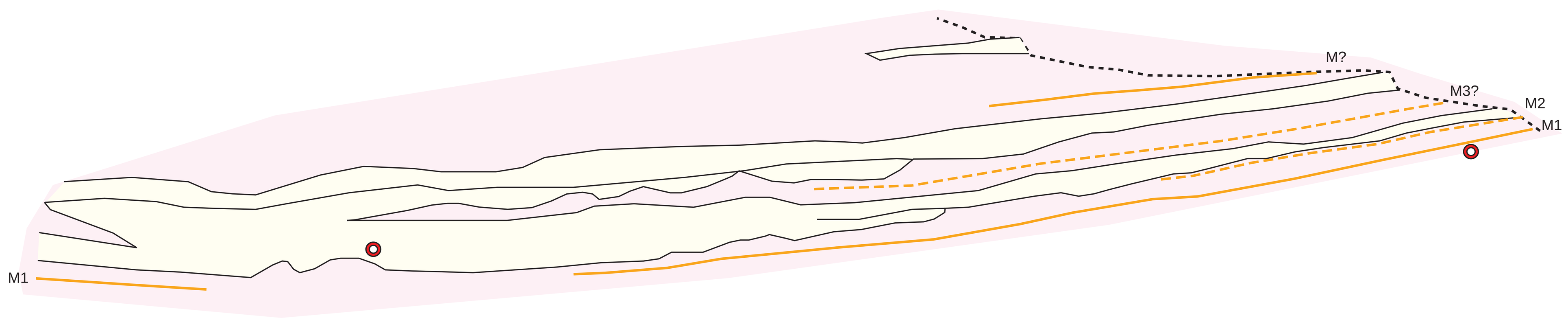
Appendix C-2

Nine Mile Canyon Photomontages and Correlations

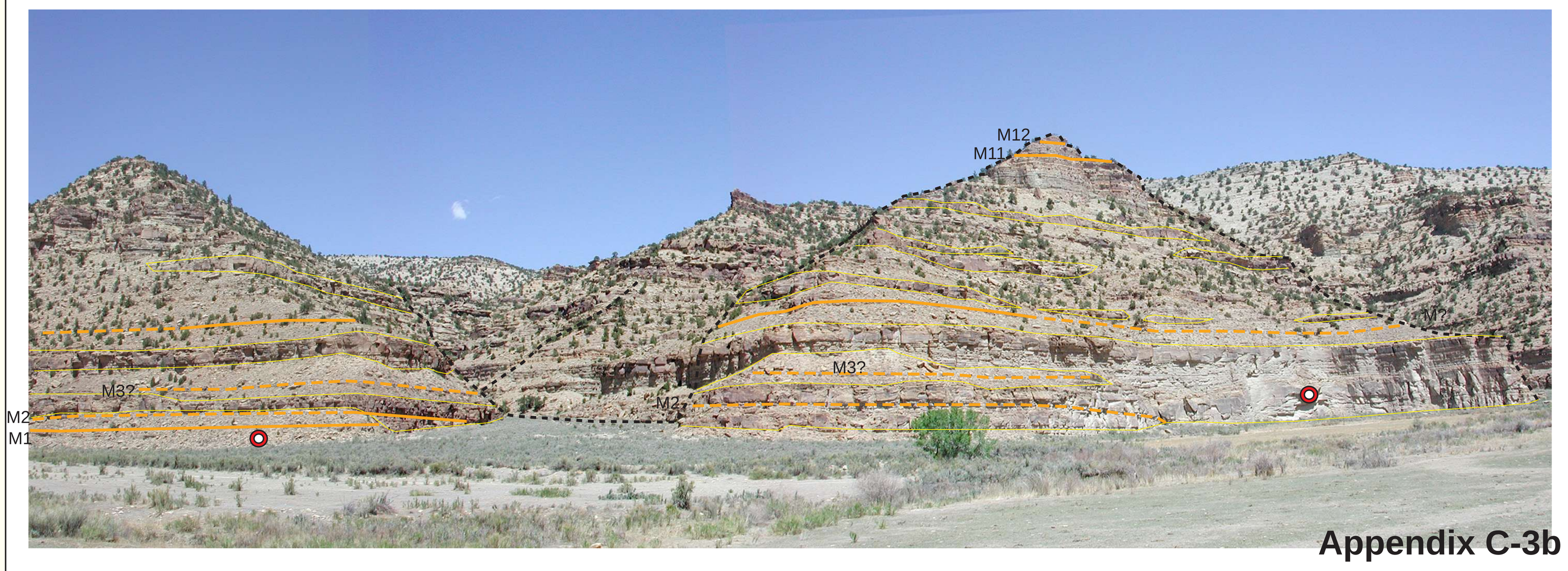
Utah Geological Survey, Salt Lake City, Utah
Reservoir characterization of the lower Green River Formation, southwest Uinta Basin, Utah
Contract: DE-AC26-98BC15103

West

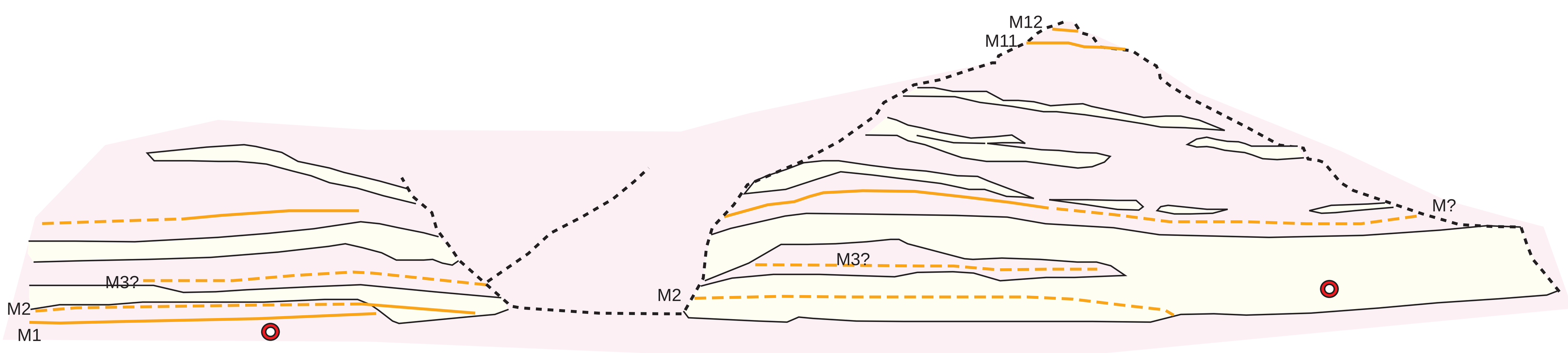
Appendix C-3a



Appendix C-3a



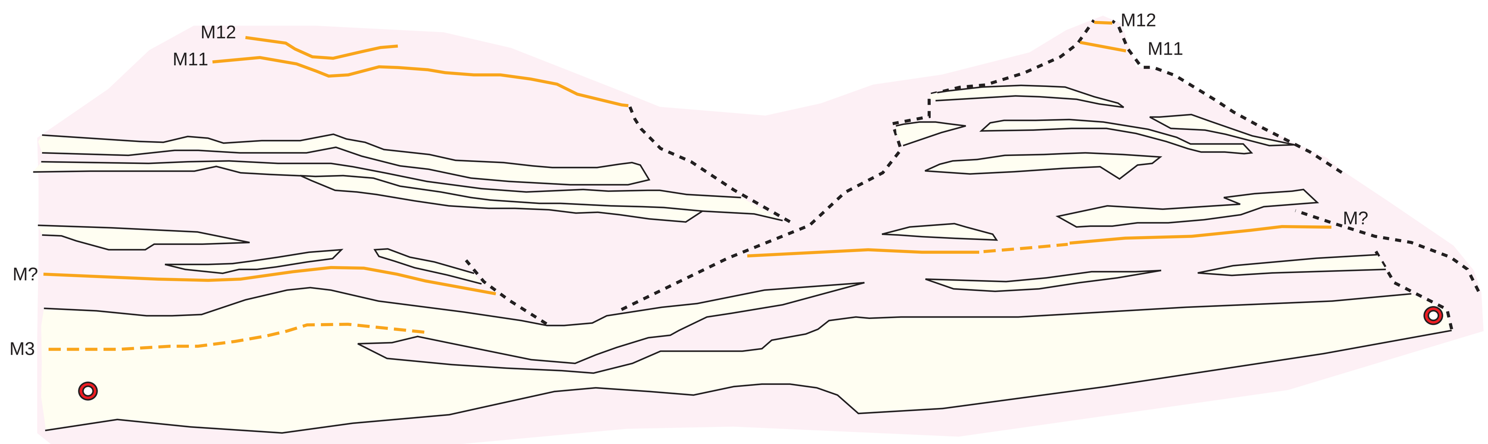
Appendix C-3b



Appendix C-3b

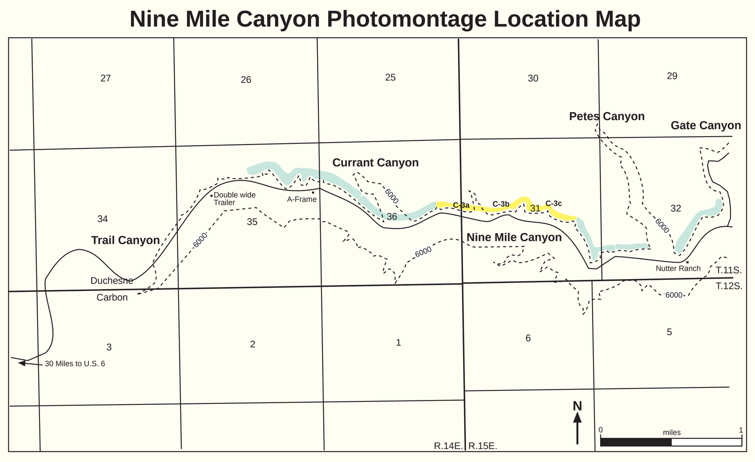
East

Appendix C-3c



Appendix C-3c

Nine Mile Canyon Photomontage Location Map

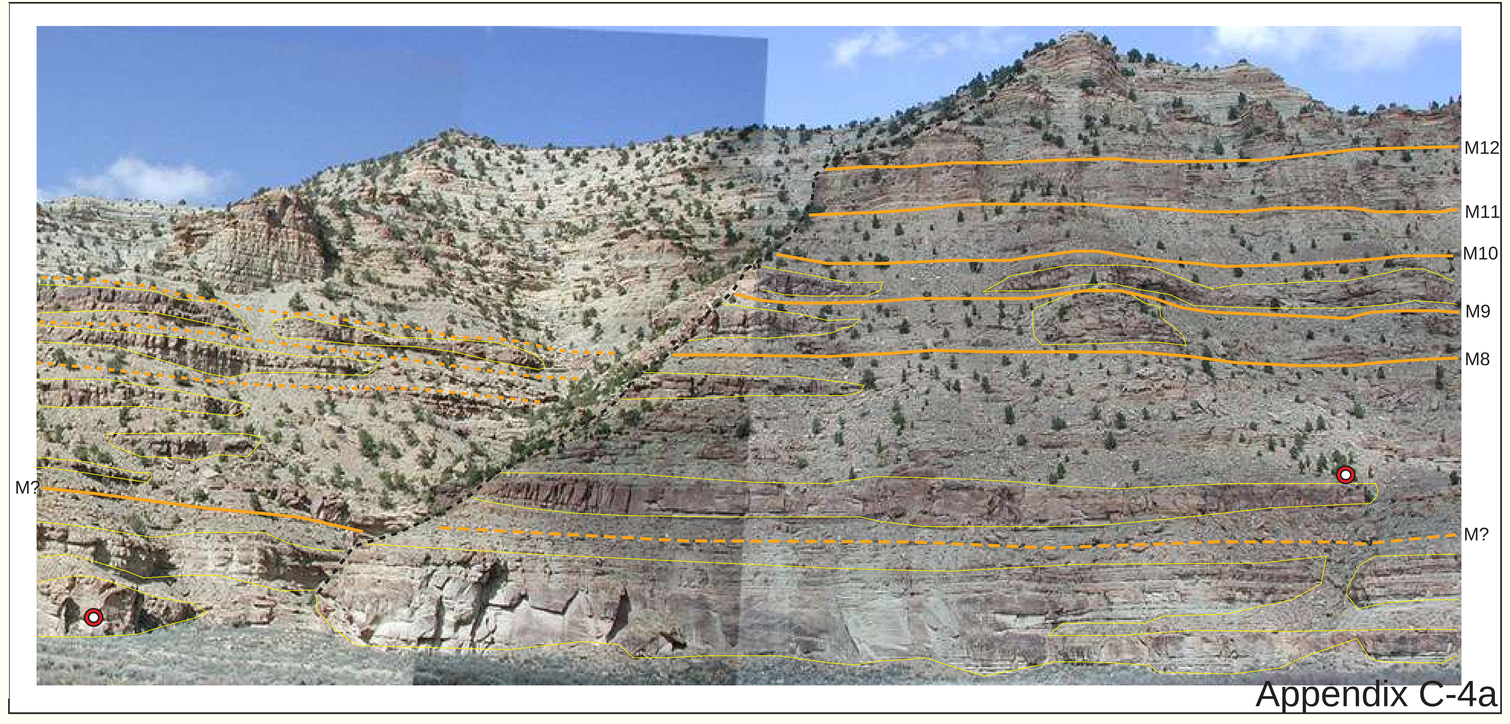


Appendix C-3

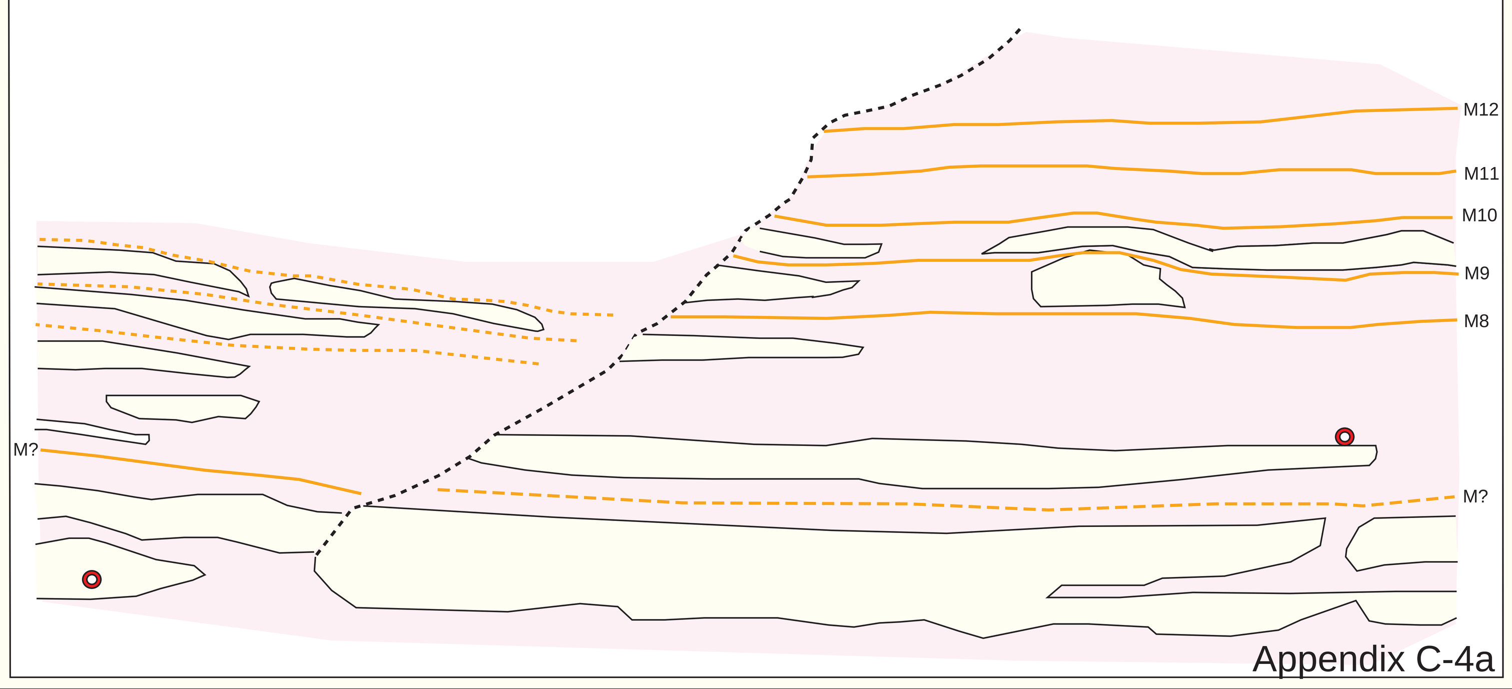
Nine Mile Canyon Photomontages and Correlations

Utah Geological Survey, Salt Lake City, Utah
Reservoir characterization of the lower Green River Formation, southwest Uinta Basin, Utah
Contract: DE-AC26-98BC15103

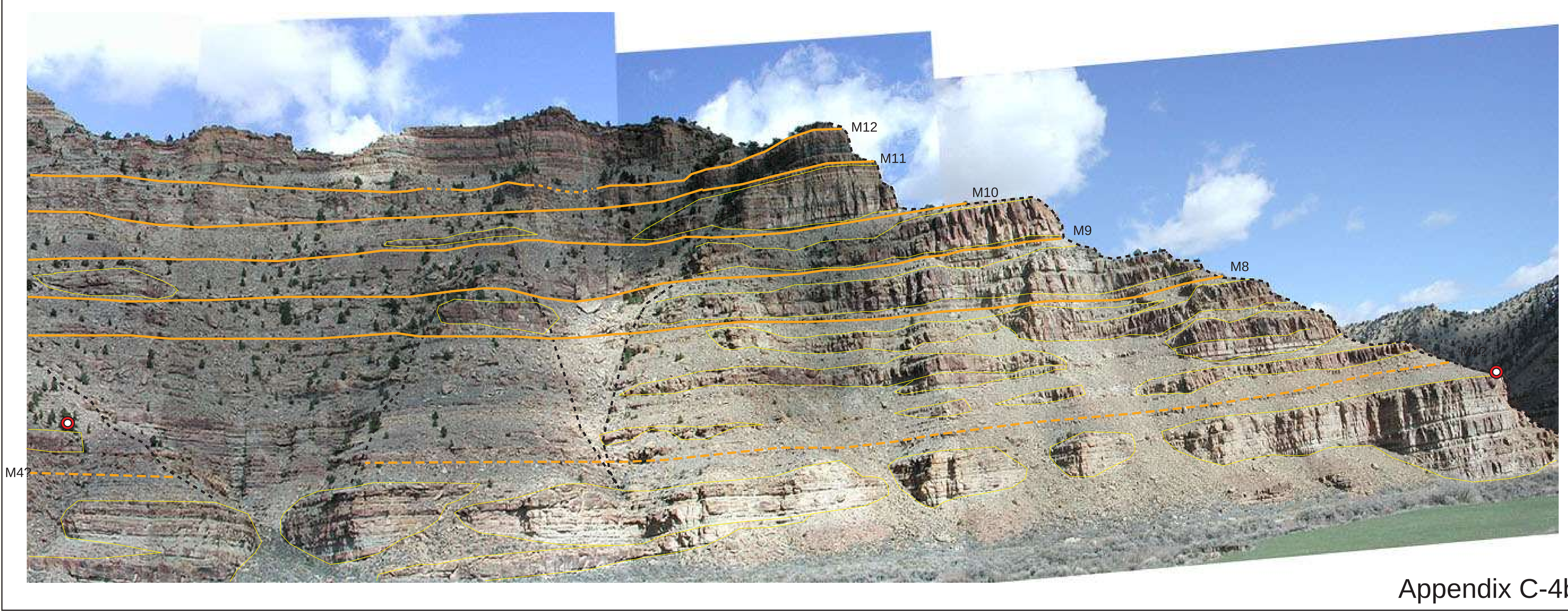
West



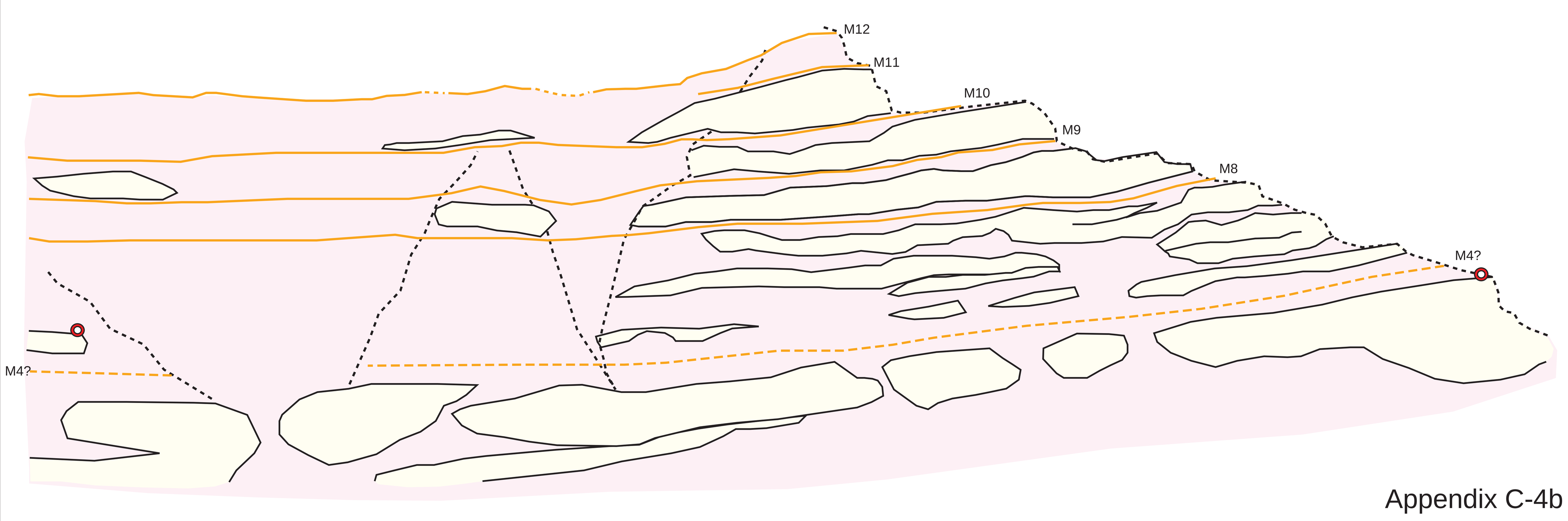
Appendix C-4a



Appendix C-4a

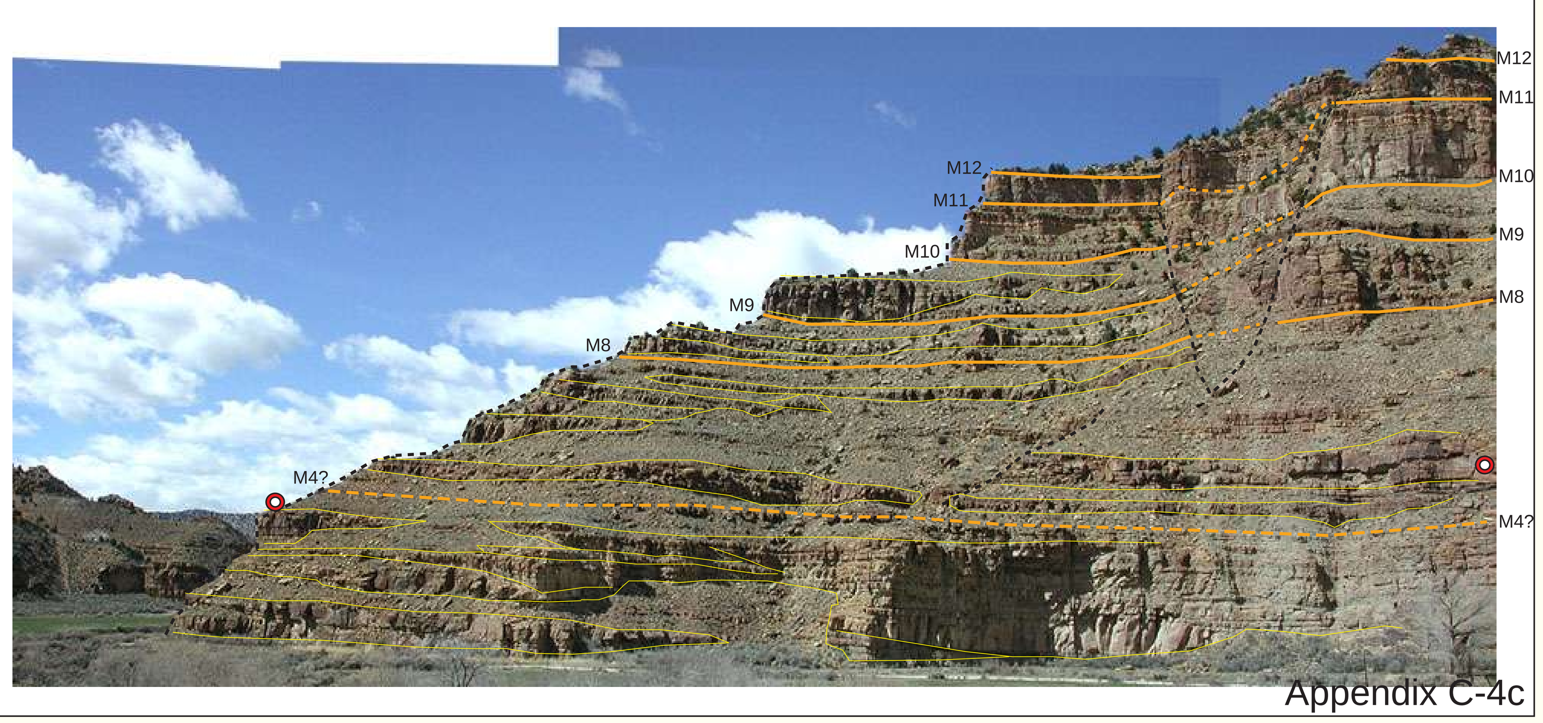


Appendix C-4b

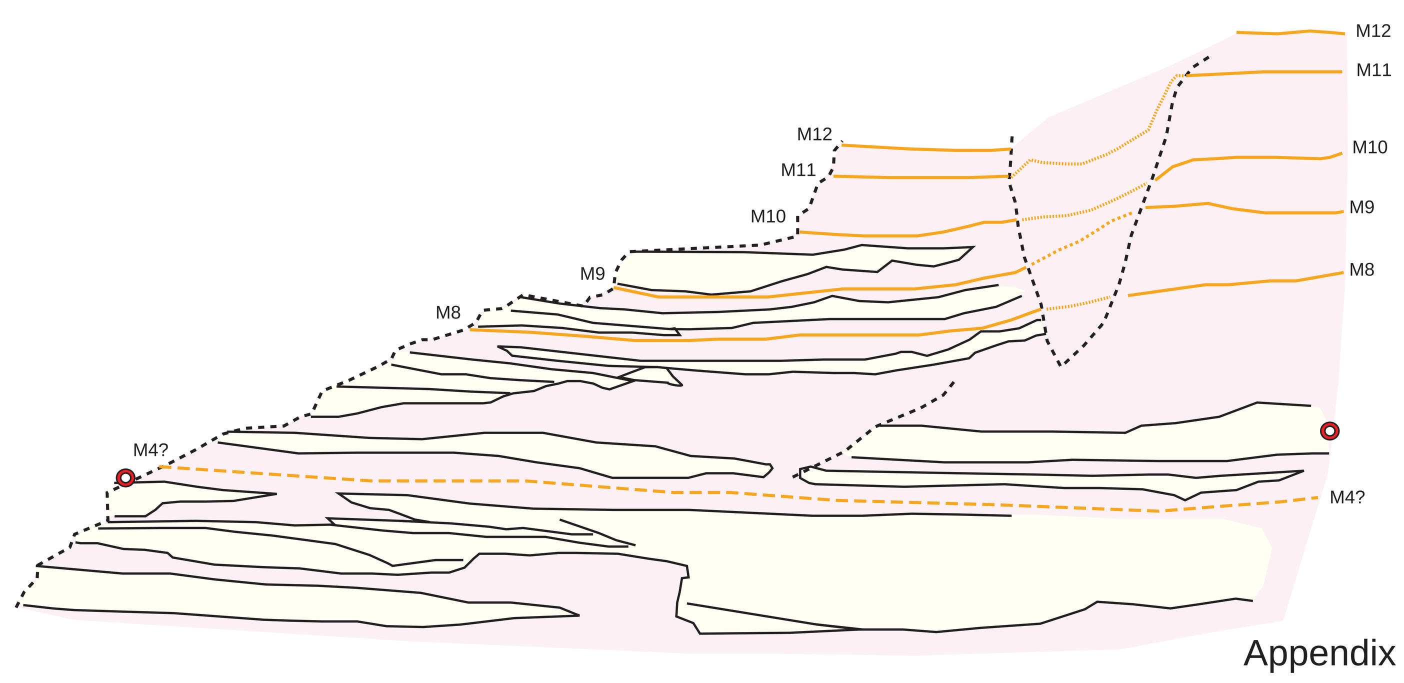


Appendix C-4b

East

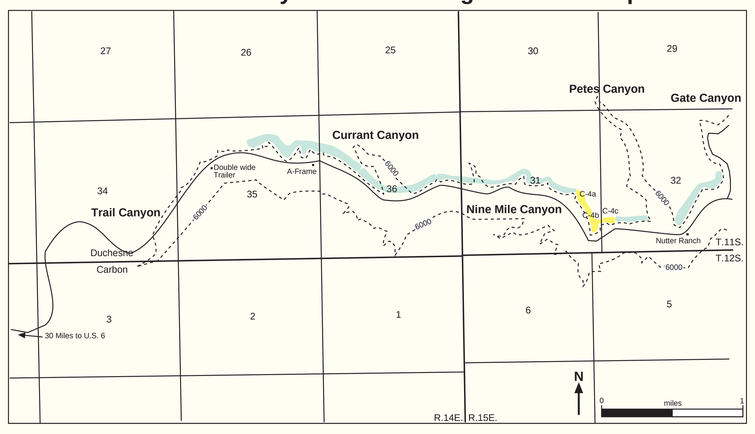


Appendix C-4c



Appendix C-4c

Nine Mile Canyon Photomontage Location Map



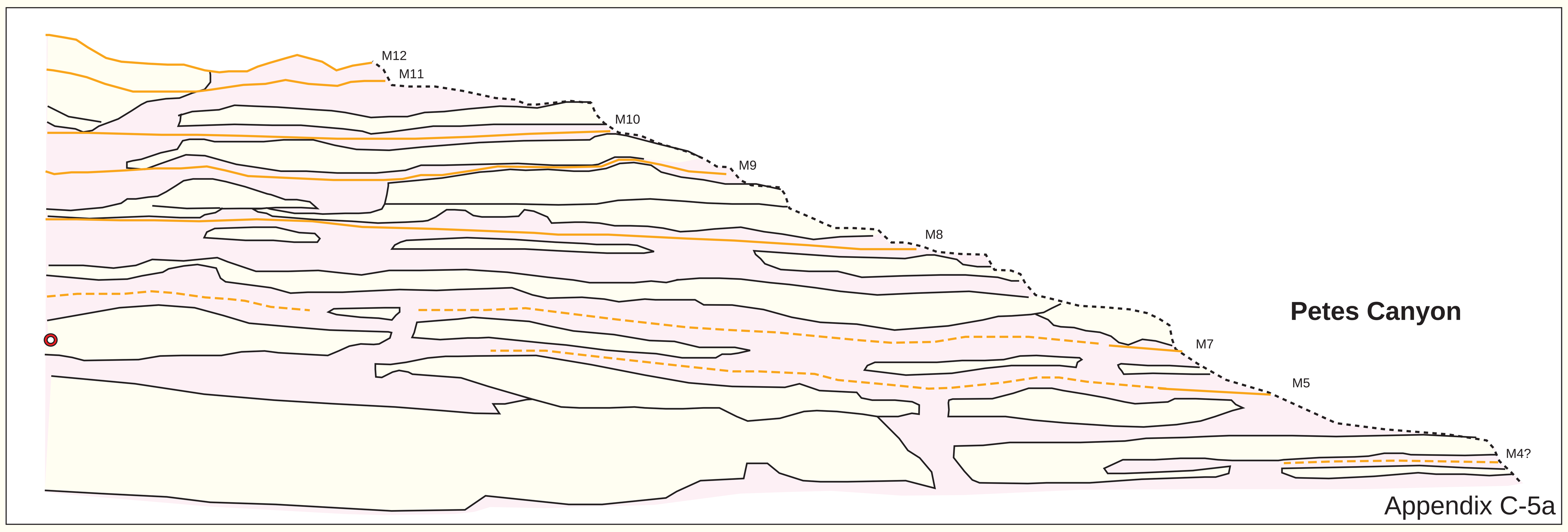
Appendix C-4

Nine Mile Canyon Photomontages and Correlations

Utah Geological Survey, Salt Lake City, Utah
Reservoir characterization of the lower Green River Formation, southwest Uinta Basin, Utah
Contract: DE-AC26-98BC15103

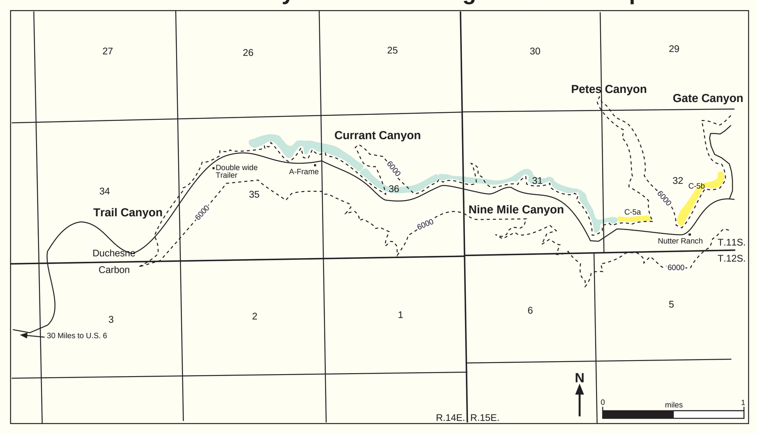
West

Appendix C-5a



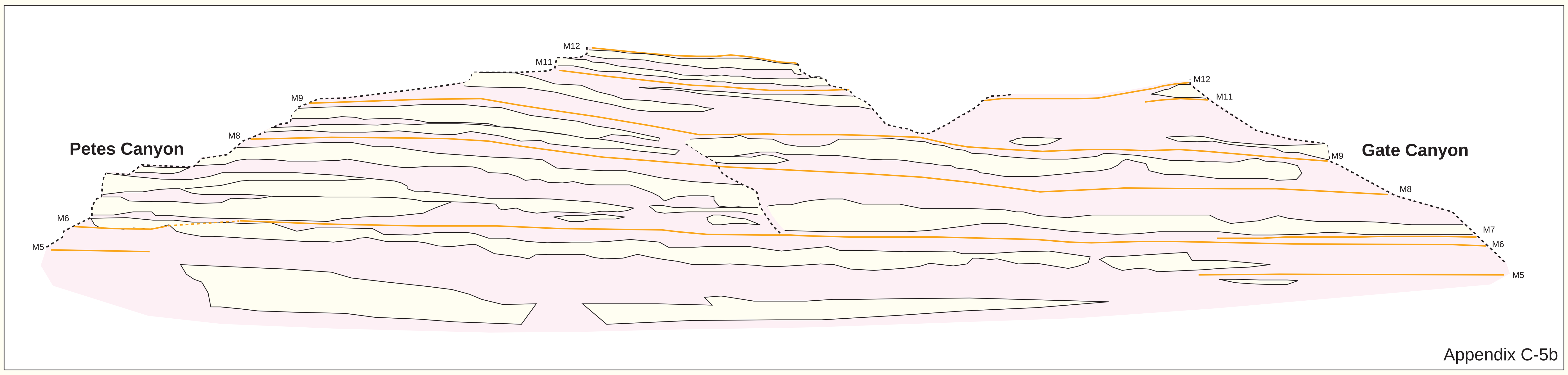
Appendix C-5a

Nine Mile Canyon Photomontage Location Map



East

Appendix C-5b



Appendix C-5b

Appendix C-5

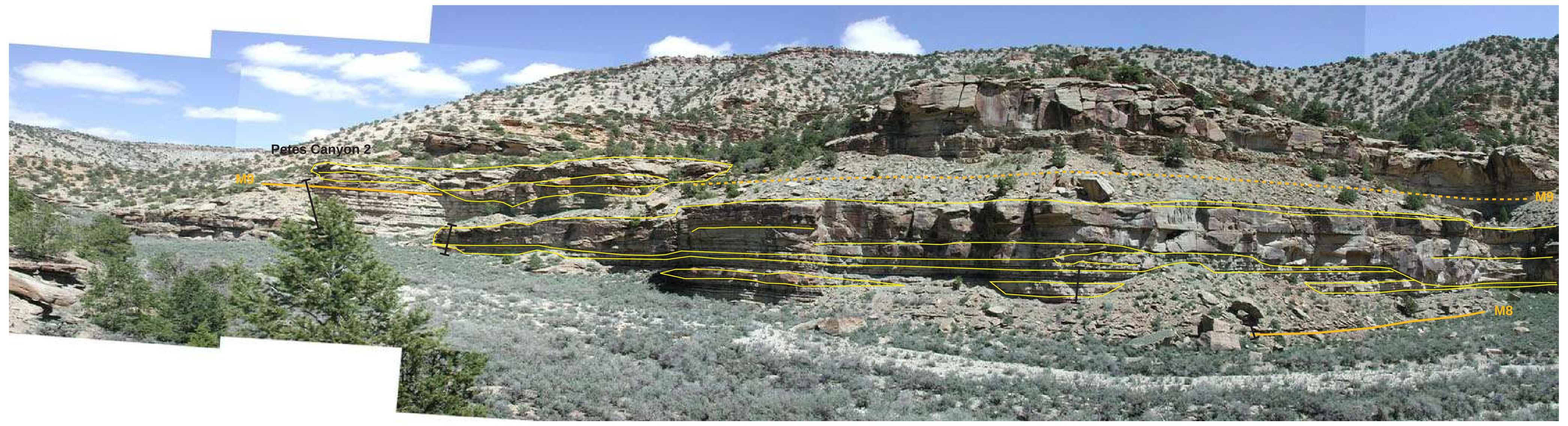
Nine Mile Canyon Photomontages and Correlations

Utah Geological Survey, Salt Lake City, Utah
Reservoir characterization of the lower Green River Formation, southwest Uinta Basin, Utah
Contract: DE-AC26-98BC15103

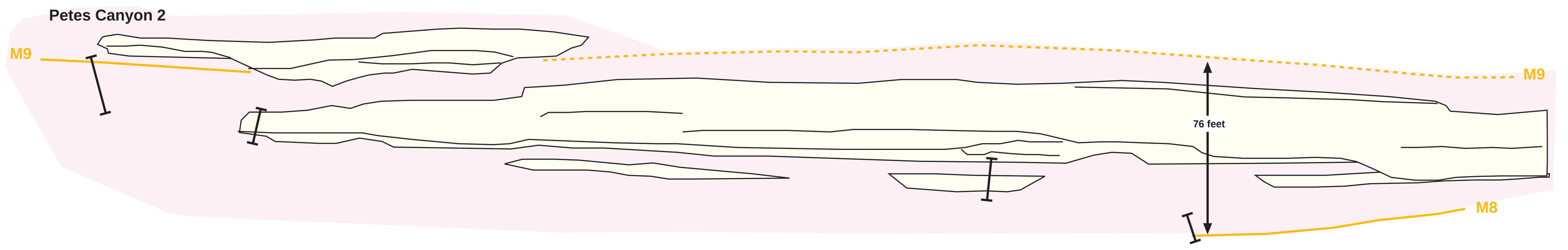
Back to Table of Contents

Back to Report

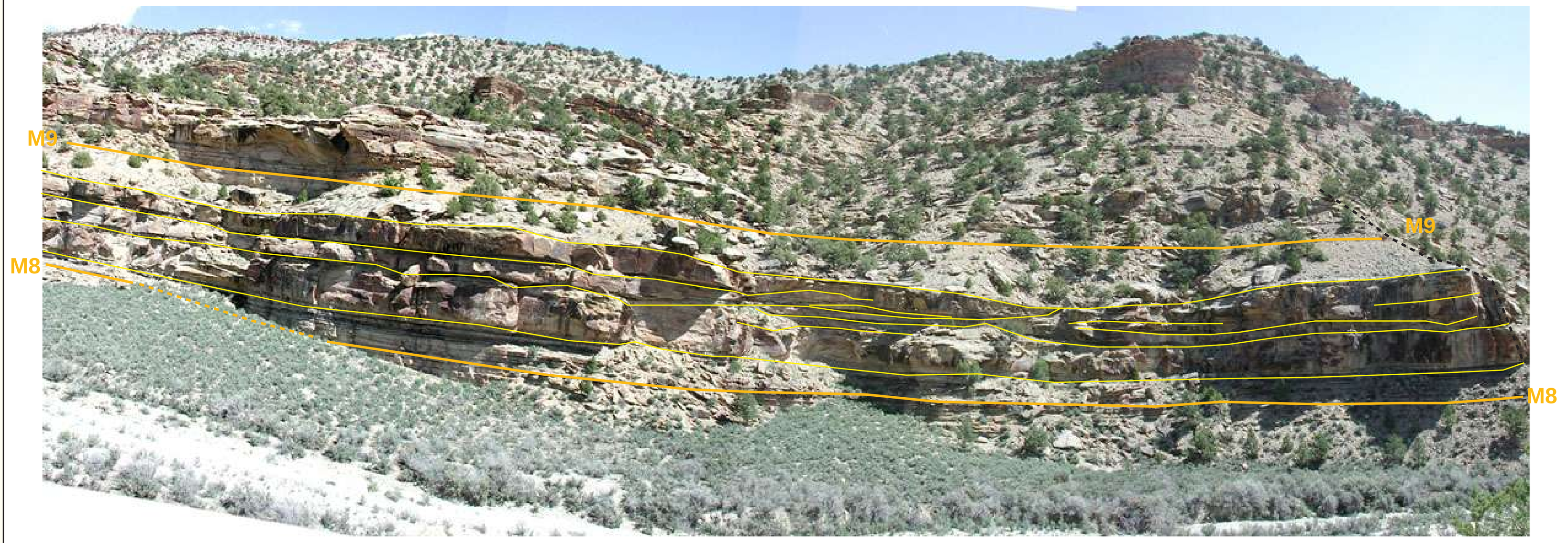
North



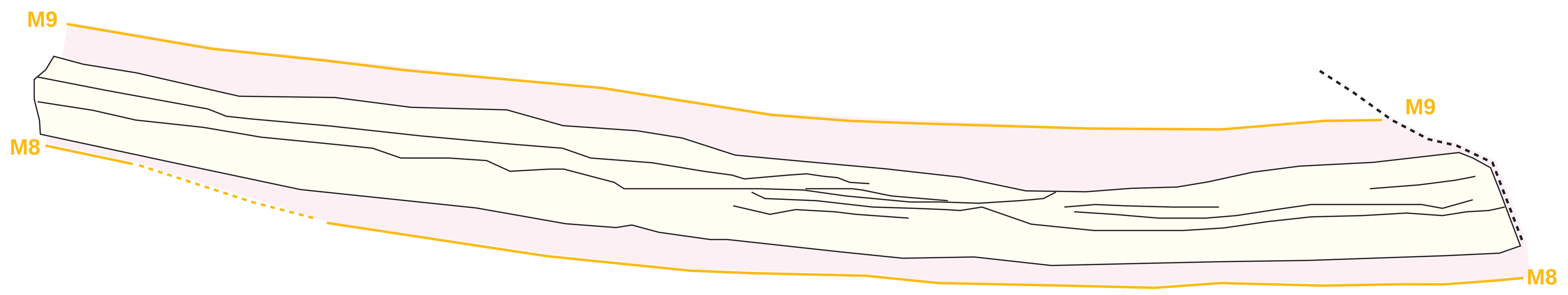
Appendix D-1a



Appendix D-1a

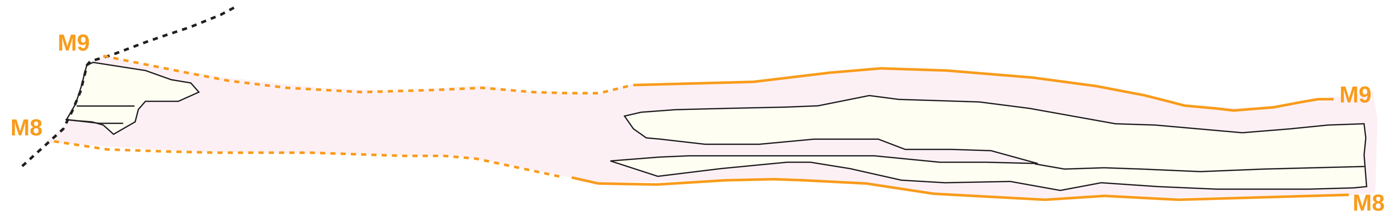


Appendix D-1b



Appendix D-1b

Appendix D-1c



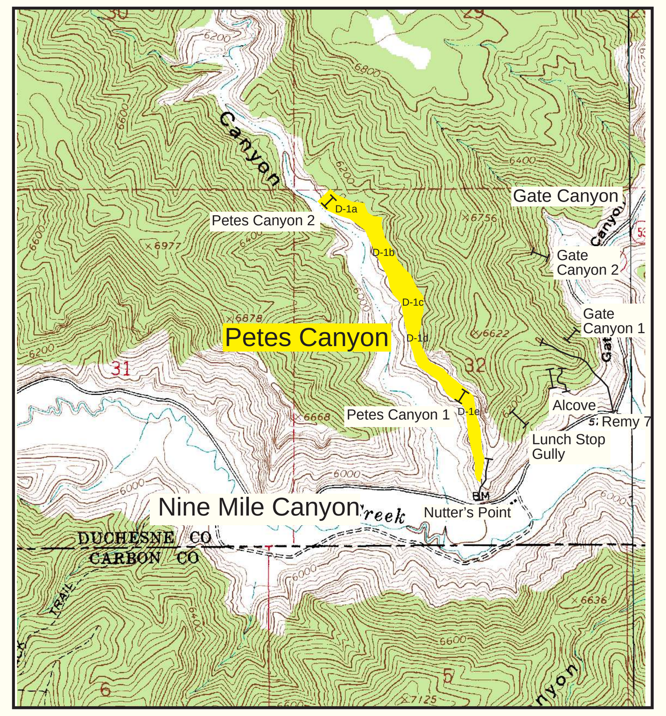
Appendix D-1c

Appendix D-1

Photomontages of the Petes Canyon exposure in the Nutter's Ranch study site.

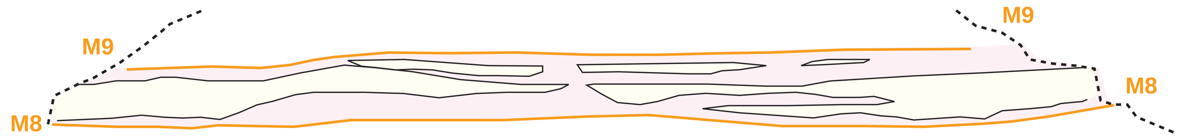
Utah Geological Survey, Salt Lake City, Utah
Reservoir characterization of the lower Green River Formation, southwest Uinta Basin, Utah
contract: DE-AC26-98BC15103

Petes Canyon Photomontage Location



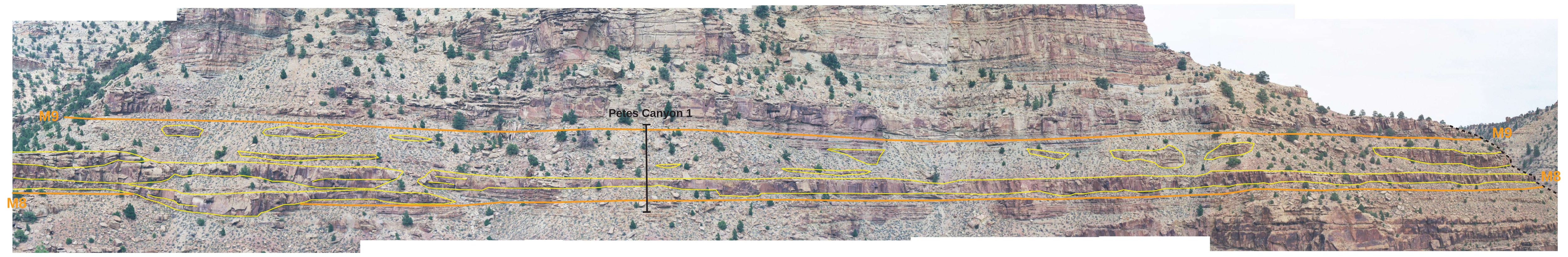
M8 and M9 are carbonate marker beds defining the stratigraphic interval studied. The drawing panels show in yellow, the correlation of the sandstone beds within the stratigraphic interval studied.

Appendix D-1d

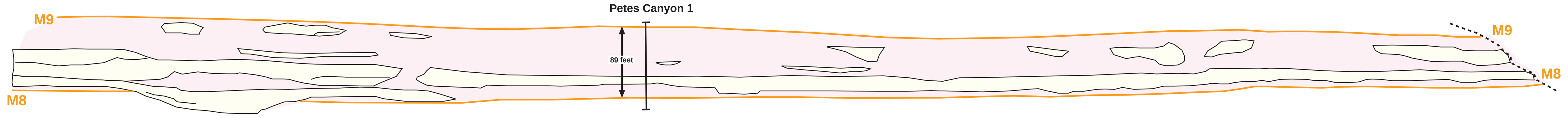


Appendix D-1d

South



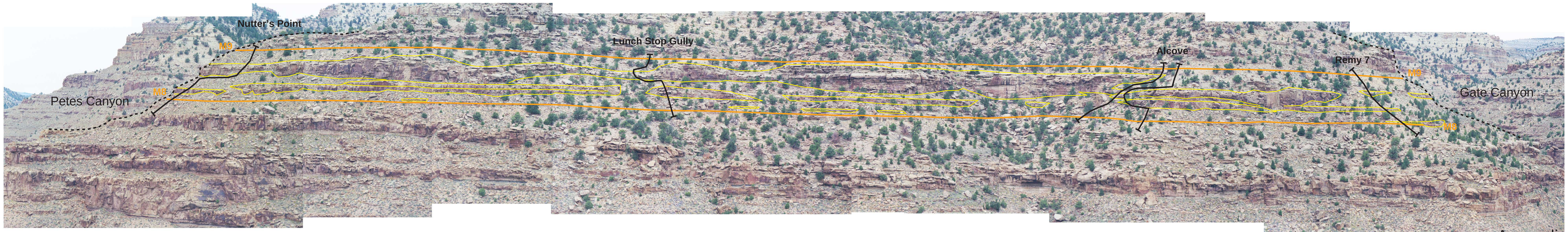
Appendix D-1e



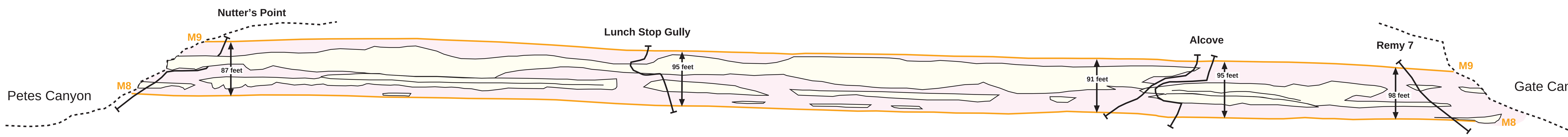
Appendix D-1e

West

East

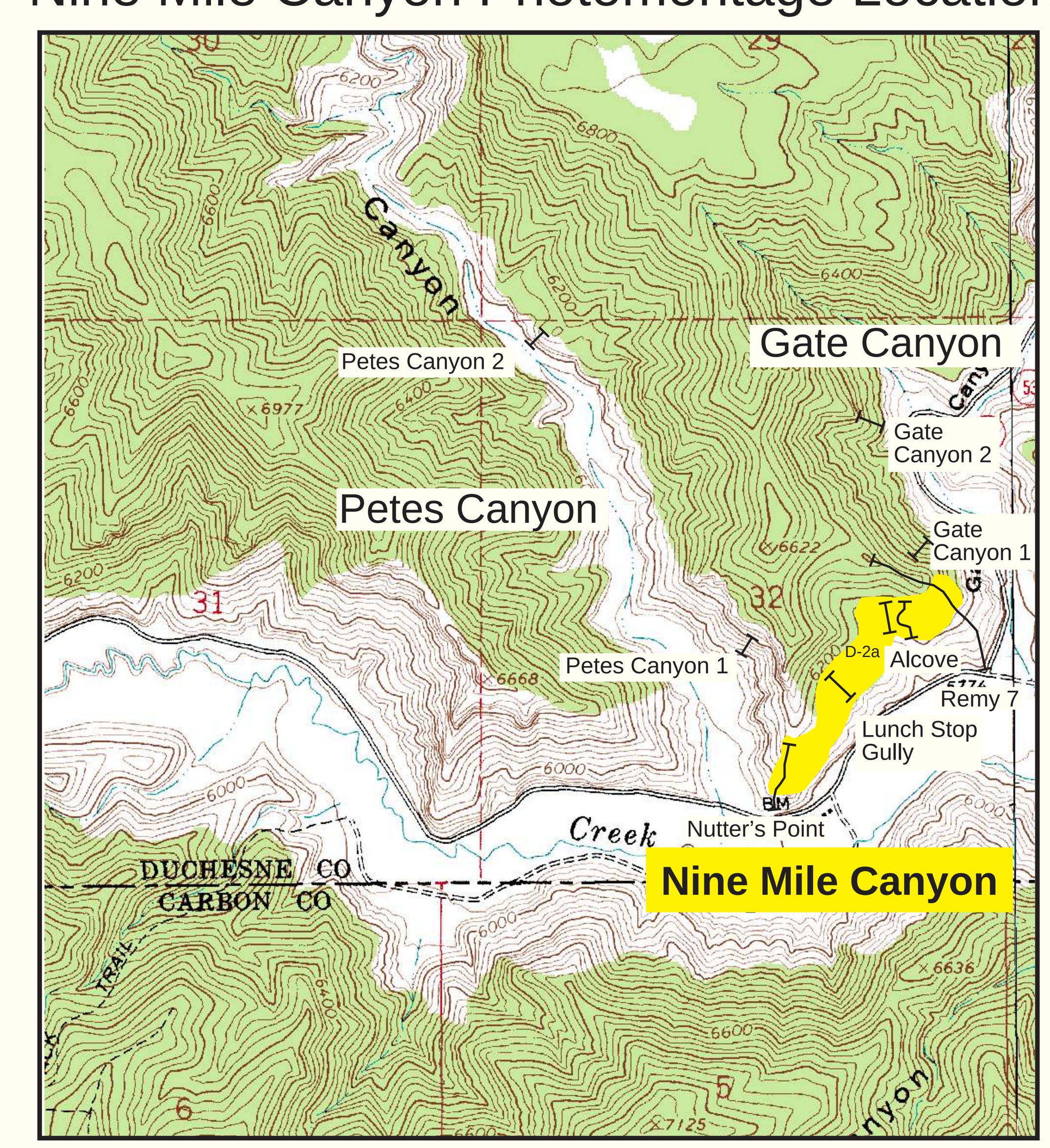


Appendix D-2a



Appendix D-2a

Nine Mile Canyon Photomontage Location



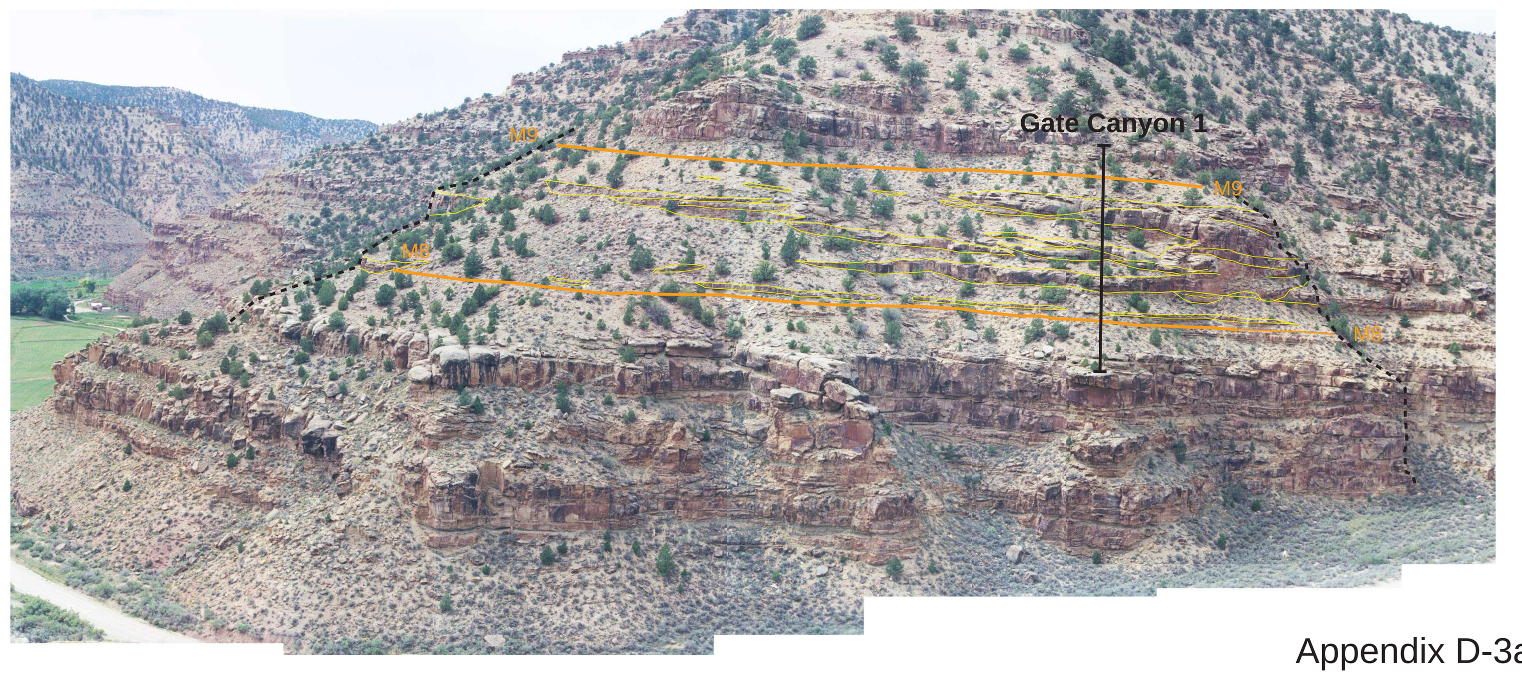
M8 and M9 are carbonate marker beds defining the stratigraphic interval studied.
The drawing panels show in yellow, the correlation of the sandstone beds within the stratigraphic interval studied.

Appendix D-2

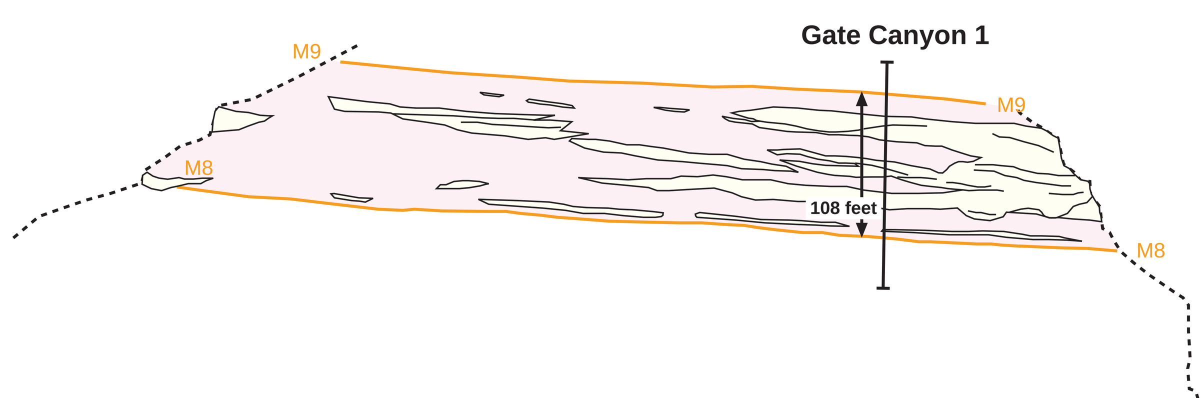
Photomontage of the Nine Mile Canyon exposure in the Nutter's Ranch study site.

Utah Geological Survey, Salt Lake City, Utah
Reservoir characterization of the lower Green River Formation, southwest Uinta Basin, Utah
contract: DE-AC26-98BC15103

South

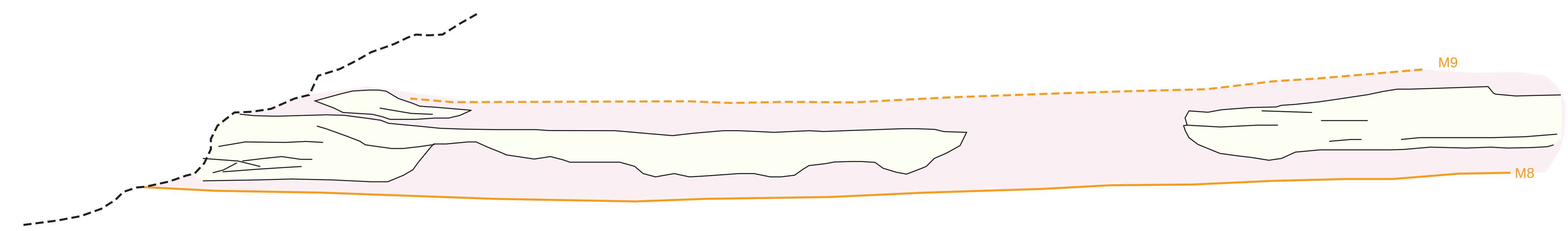


Appendix D-3a



Appendix D-3a

Appendix D-3b



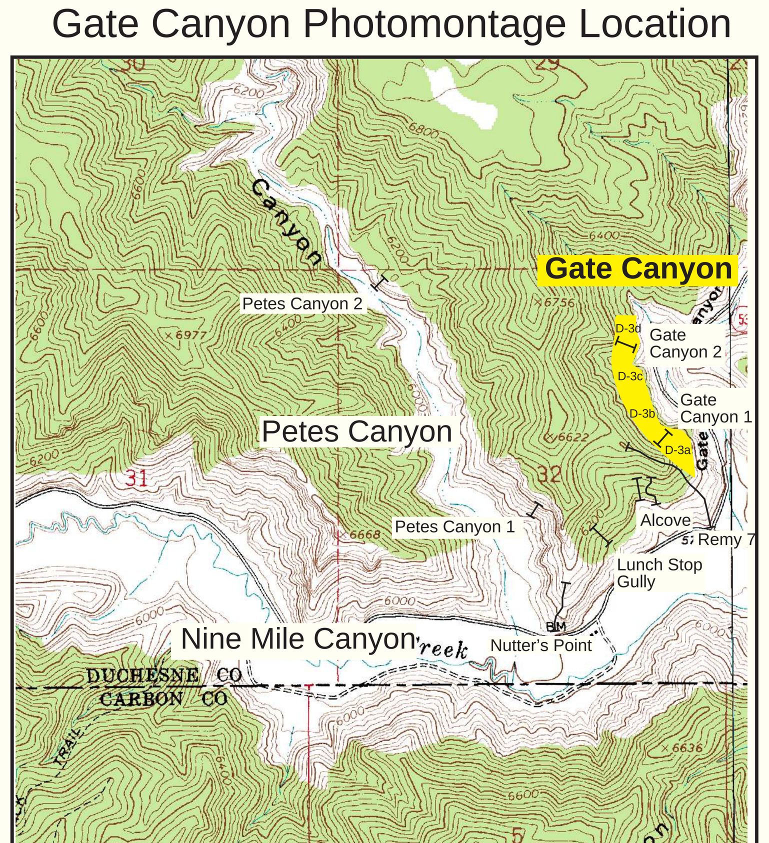
Appendix D-3b

Appendix D-3

Photomontages of the Gate Canyon exposure in the Nutter's Ranch study site.

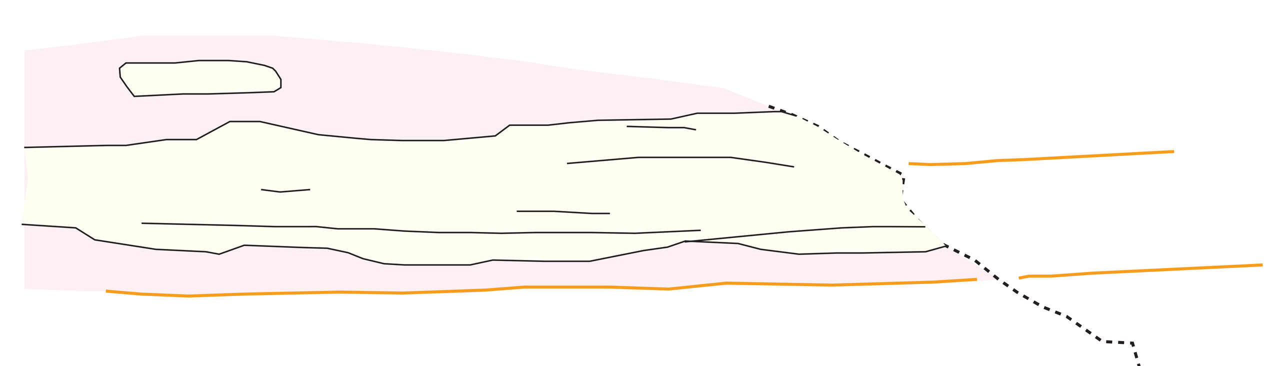
Utah Geological Survey, Salt Lake City, Utah
Reservoir characterization of the lower Green River Formation, southwest Uinta Basin, Utah
contract: DE-AC26-98BC15103

Gate Canyon Photomontage Location



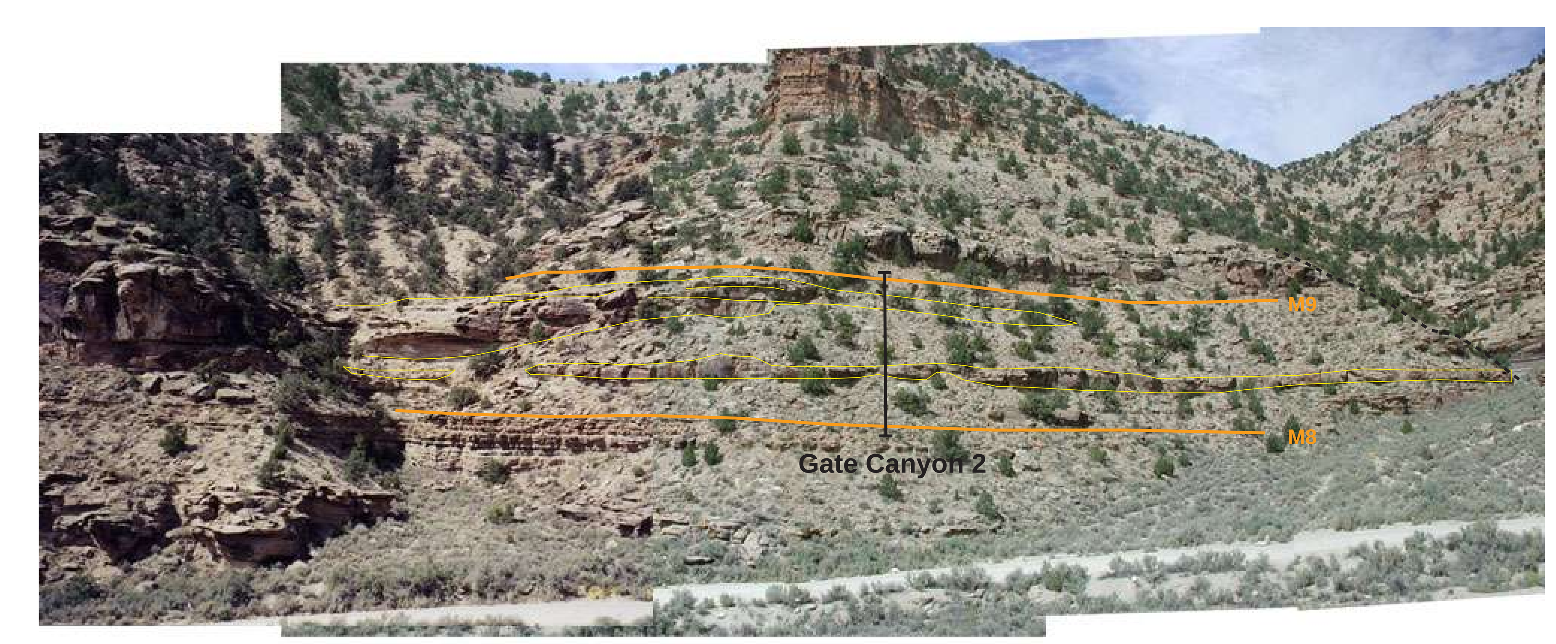
M8 and M9 are carbonate marker beds defining the stratigraphic interval studied.
The drawing panels show in yellow, the correlation of the sandstone beds within the stratigraphic interval studied.

Appendix D-3c

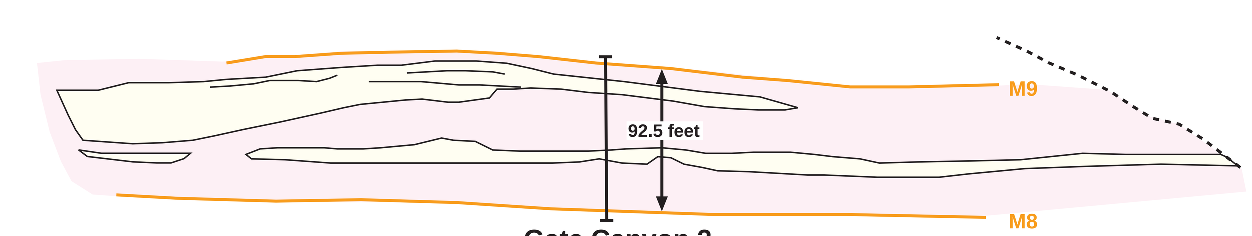


Appendix D-3c

North



Appendix D-3d



Appendix D-3d