PS Tight Gas Sands and Natural Fractures in the Cretaceous Mesaverde Group, Greater Natural Buttes Field, Uinta Basin, Utah*

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Abstract

Greater Natural Buttes field (GNB) in the Uinta Basin is the largest gas field in Utah. GNB lies in an area of gentle northwest dip on the southern flank of the basin. The field produces natural gas primarily from low-permeability sandstone in the Mesaverde Group and the Tertiary Wasatch Formation. GNB has produced over 2.1 TCF of gas from about 3,950 wells and continues to be the most active drilling area in Utah.

Most of the gas production is from highly compartmentalized, lenticular, fluvial channel sandstones in the Price River Formation in the upper Mesaverde Group. The Sego and Castlegate Sandstones in the lower Mesaverde typically have higher water saturation and are not generally productive, but have lithologic and fracture characteristics similar to productive sandstones up section. Production in these tight-gas-sand reservoirs is achieved through massive hydraulic fracture treatments, so understanding the natural fracture systems and reservoir heterogeneity created by various depositional environments can aid in hydraulic fracturing optimization and lead to better drilling and completion strategies.

Cores in the Castlegate, Sego, and Price River Formations display classic low-permeability depositional, petrophysical, and geomechanical characteristics that are being used to create reservoir models and simulations for hydraulic fracturing. These cores show that the Mesaverde is mostly sandstone interbedded with black, bioturbated, and carbonaceous shale and silty mudstone. Individual sandstones are very fine to fine grained and have low-angle cross-bedding, flaser bedding, small ripples, sparse burrows, and moderate bioturbation. Depositional environments range from marginal marine to lower coastal plain. Porosity varies from 2 to 8% and permeability varies from 0.002 to 0.07 mD.

Over 90 fractures were identified in core. Most are natural, open fractures, but some are closed and filled or partially filled with calcite. Some fractures appear to propagate from thin coal seams, while others terminate at shale or clay partings. Most fractures are inclined, but horizontal and vertical orientations are also present. Portions of GNB cores illustrating various depositional environments and fracture types will be available for viewing and discussion.

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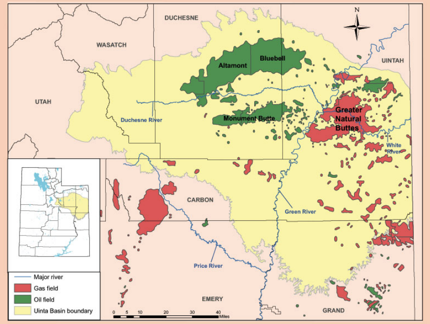
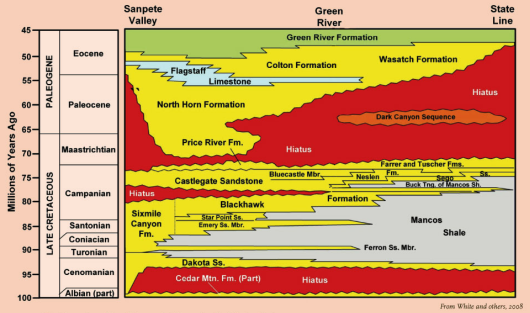
Regional Overview

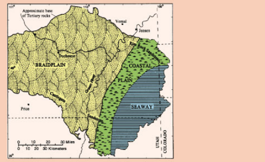


Location of Greater Natural Buttes gas field in the Uinta Basin, Utah.

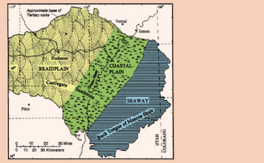


Stratigraphy of the Mesaverde Group in the Uinta Basin.

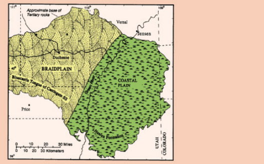
Paleogeography of the eastern Uinta Basin during the Late Campanian of the Late Cretaceous (modifed from Fouch and others, 1992).



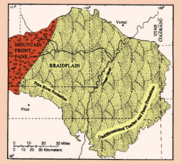
Deposition of the Castlegate Sandstone in a braided stream, lower coastal plain, and marginal marine environment.



Deposition of the Buck Tongue Member of the Mancos Shale in an offshore marine environment and the Sego Sandstone in a marginal marine environment.

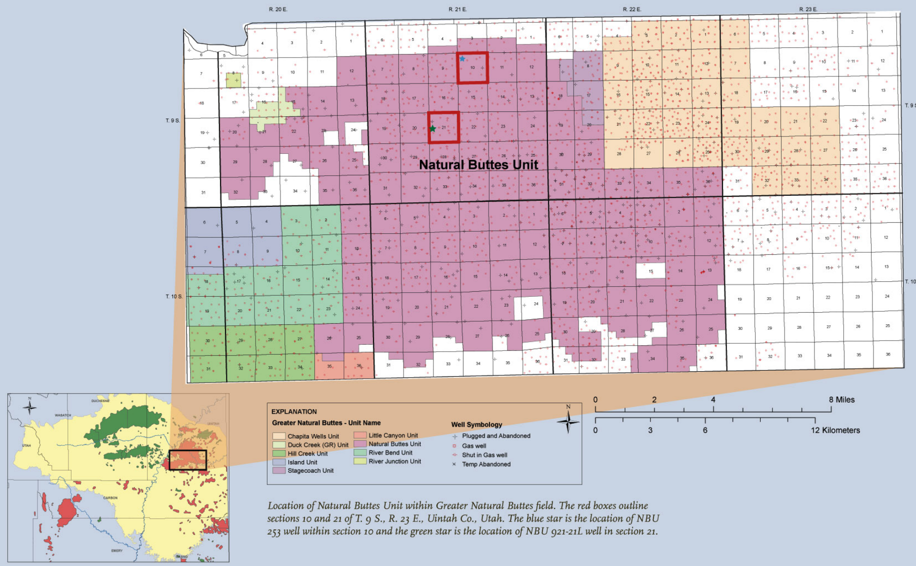


Deposition of the Neslen Formation in a coastal plain environment.



Deposition of the Farrer and Tuscher Formations in an alluvial plain environment.

Greater Natural Buttes Field General Overview



Location of Natural Buttes Unit within Greater Natural Buttes field. The red boxes outline sections 10 and 21 of T. 9 S., R. 23 E., Uintah Co., Utah. The blue star is the location of NBU 253 well within section 10 and the green star is the location of NBU 921-21L well in section 21.

Greater Natural Buttes Discovery Well Data

(Osmond, 1992; Utah DOGM, 2011)

Mesaverde Group

- Continental Oil Co. #1 Chapita Wells Unit (Sec. 16, T. 9 S., R. 23 E., Uintah Co., Utah)
- T.D. – 9517 ft (~ 2900 m)
- Completed – December 15, 1952
- Producing Reservoir – Cretaceous Mesaverde Group
- IPF – 62 BOPD, 275 MCFGPD

Wasatch Formation

- Continental Oil Co. #2 Chapita Wells Unit (Sec. 28, T. 9 S., R. 23 E., Uintah Co., Utah)
- T.D. – 9125 ft (~ 2781 m)
- Completed – February 26, 1955
- Producing Reservoir – Tertiary Wasatch Formation
- IPF – 4618 MCFGPD

Production Data

- Greater Natural Buttes field includes 13 individual units
- Production co-mingled Wasatch Formation and Mesaverde Group
- Currently Producing Wells – 4128
- Monthly Production (December 2010) – 163,424 BO & 19.6 BCFG
- Cumulative Production (as of December 31, 2010) – 17,553,163 BO & 2.28 TCFG
- Estimated Ultimate Recovery per well for co-mingled Wasatch-Mesaverde – 1.4 to 6 BCFG

General Reservoir Data

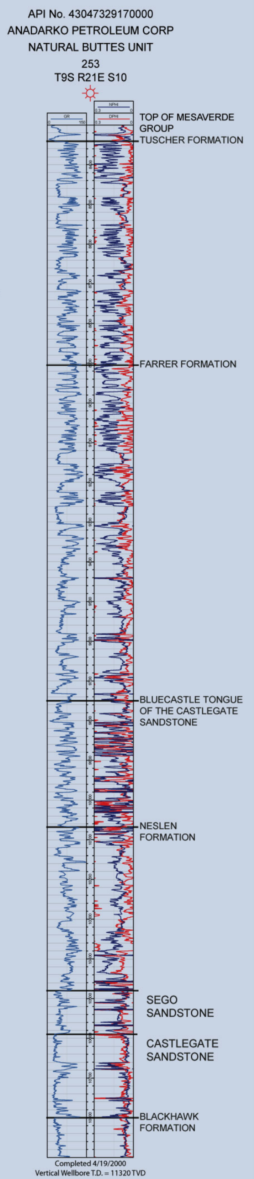
- Lithology:
  - Mesaverde Group - Fluvial and deltaic sandstones
  - Wasatch Formation - Fluvial sandstones
- Spacing – 40 acres
- Net Pay:
  - Mesaverde Group - Individual sand bodies up to 30 ft
  - Wasatch Formation - Individual sand bodies up to 40 ft
- Average Porosity (from core):
  - Mesaverde Group - 8.58%
  - Wasatch Formation - 8.75%
- Median Permeability (from core):
  - Mesaverde Group - 0.028 mD
  - Wasatch Formation - 0.095 mD
- Water Saturation:
  - Mesaverde - Average 50%
  - Wasatch - Average 45%
- Water Resistivity:
  - Mesaverde - 0.15 ohm/m
  - Wasatch - 0.1 to 0.15 ohm/m
- Type of Drive – Pressure depletion

Gas Characteristics

- Average Btu/cubic ft:
  - Mesaverde - 1114 (280 kg/cal)
  - Wasatch – 1088 (274 kg/cal)
- CO_2 Content:
  - Mesaverde - < 2%
  - Wasatch - <0.5%

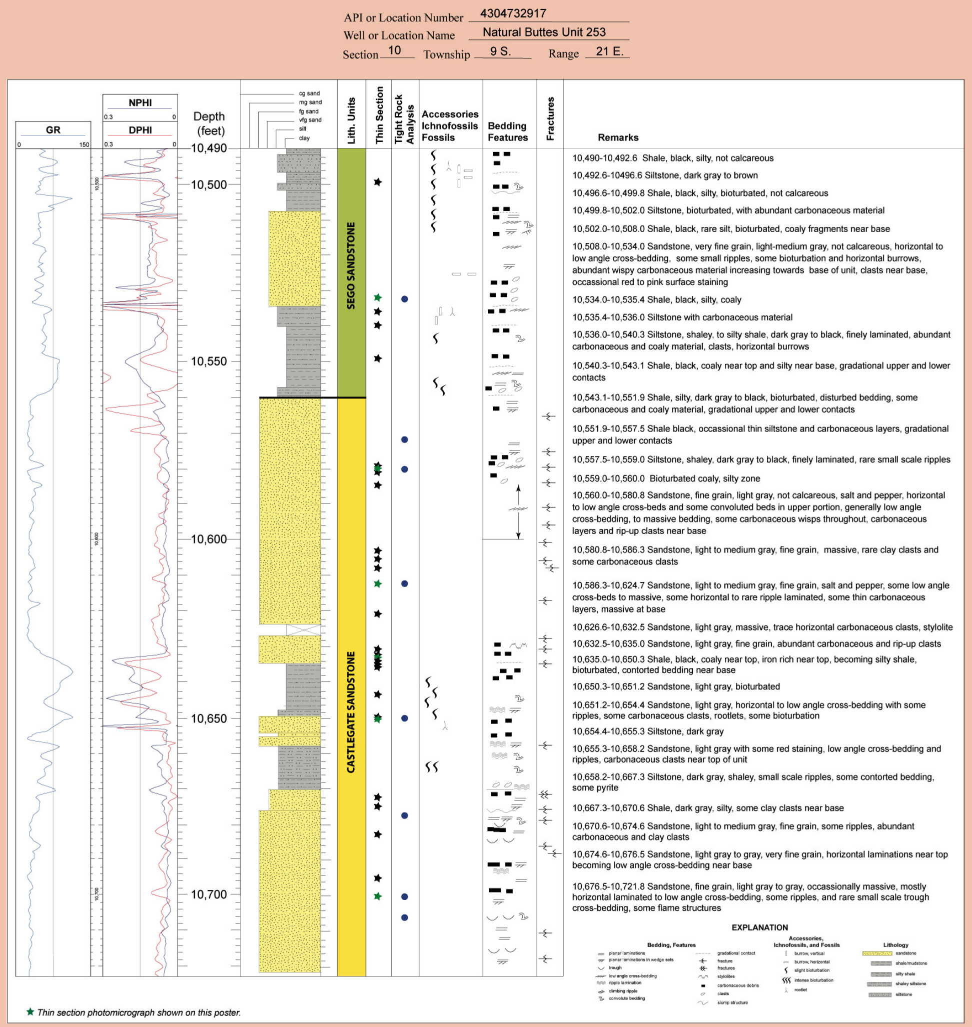
Mesaverde Group Characteristics

- Thickness - 2200 to 2900 ft
- Drill Depths to Base – 6000 to 12,000 ft
- Depositional Environments – Marginal marine at base to upper coastal plain and alluvial-plain deposits at top
- Reservoir Geometry – Stacked, lenticular channels with limited lateral extent



Geophysical well log of the NBU 253 well, Greater Natural Buttes field, Uintah Co., Utah.

Core Description of NBU 253 Well



★ *Thin section photomicrograph shown on this poster.*

Panel I

Lithology, Sedimentary Structures, and Petrology—NBU 253

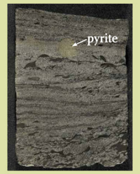
Sego Sandstone

Highly bioturbated siltstone. (10,501 ft)

Bioturbated, fine-grained sandstone with carbonaceous, shaly laminations. (10,519 ft)

Bioturbated, carbonaceous shale. (10,553 ft)

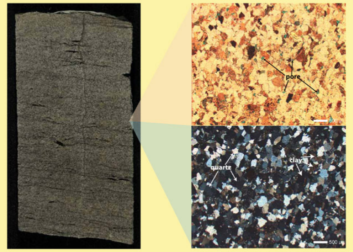
Bioturbated, siltstone with laminated shale above and below. (10,557 ft)



Pyrite nodule and carbonaceous clasts in sandstone. (10,559 ft)

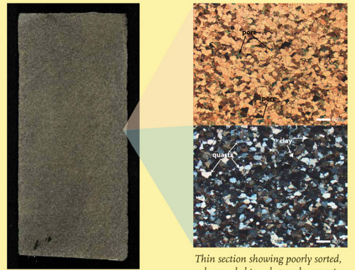
Castlegate Sandstone

Fine-grained sandstone with cross-bedding. Sandstone has 5.69% porosity and 0.068 mD of permeability.(10,572 ft)



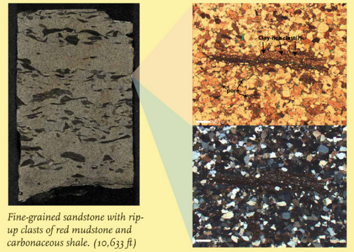
Fine-grained, laminated sandstone with slightly open, vertical, natural fracture. Sandstone has 5.13% porosity and 0.007 mD of permeability. (10,579.7 ft)

Thin section showing moderately sorted, sub-rounded to sub-angular quartz grains in a clay matrix.*



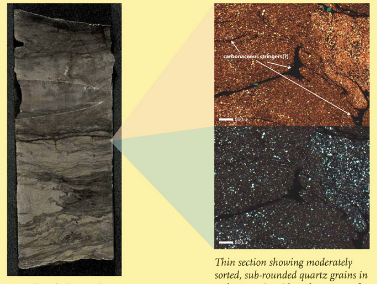
Massive, fine-grained sandstone with 5.74% porosity and 0.042 mD of permeability. (10,612 ft)

Thin section showing poorly sorted, sub-rounded to sub-angular quartz grains in a minor amount of clay matrix. Note lack of porosity.*



Fine-grained sandstone with rip-up clasts of red mudstone and carbonaceous shale. (10,633 ft)

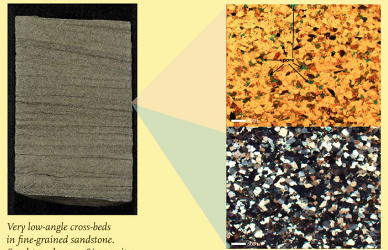
Thin section showing clay-rich clast(?) surrounded by poorly sorted, sub-rounded to sub-angular quartz grains in a clay matrix. Note sparse porosity visible in top photo.*



Bioturbated silty, sandstone with 3.88% porosity and 0.007 mD of permeability. (10,650.5)

Thin section showing moderately sorted, sub-rounded quartz grains in a clay matrix with carbonaceous(?) stringers. Note lack of porosity.*

Fine-grained sandstone with horizontal laminations. Sandstone has 5.43% porosity and 0.007 mD of permeability. (10,677 ft)



Very low-angle cross-beds in fine-grained sandstone. Sandstone has 5.72% porosity and 0.007 mD of permeability. (10,700 ft)

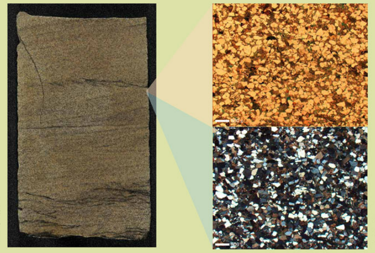
Thin section showing poorly sorted, sub-rounded to sub-angular quartz grains with sparse clay. Note more porosity than other samples.*

Convoluted bedding in fine-grained sandstone. Sandstone has 7.74% porosity and 0.054 mD of permeability. (10,706.5 ft)

*Note: Photomicrographs taken in plane(top) and cross polarized(bottom) light at 2.5 times magnification.

Fractures—NBU 253

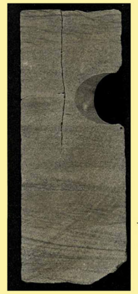
Sego Sandstone



Open fracture in homogenous, fine-grained sandstone with slight iron(?) staining. Sandstone has 2.06% porosity. (10,532 ft)

Thin section showing poorly sorted, sub-rounded to sub-angular quartz grains in a clay matrix.*

Castlegate Sandstone



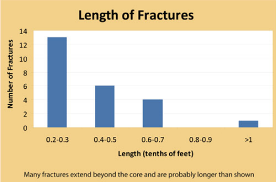
Open, vertical fracture in sandstone. No discernable mineralization in fracture. (10,590 ft)

Vertical, closed fracture offsetting laminated sandstone on left with massive sandstone on the right. Amount of offset is unknown. Fracture is offset at top by thin, carbonaceous laminae. (10,631 ft)

Fine-grained sandstone with high-angle cross-bedding and vertical natural fractures. Fractures are offset and slightly open with no discernable mineral fill. (10,718 ft)

Fracture #	Depth Top (ft)	Depth Base (ft)	Fracture Length (ft)	Orientation	Aperture	Mineral-ization?
1	10,532.0	10,532.2	0.2	Sub-vertical	Open	No
2	10,565.7	10,565.9	0.2	Sub-vertical	Closed	No
3	10,575.5	10,575.7	0.2	Sub-vertical	Closed	No
4	10,579.4	10,579.9	0.5	Vertical	Closed	No
5	10,580.7	10,581.2	0.5	Vertical	Open	No
6	10,584.0	10,584.6	0.6	Vertical	Closed	No
7	10,584.8	10,585.4	0.6	Sub-vertical	Closed	No
8	10,590.0	10,590.7	0.7	Vertical	Open	No
9	10,596.1	10,596.3	0.2	Vertical	Closed	No
10	10,600.7	10,600.9	0.2	Sub-vertical	Closed	No
11	10,606.2	10,606.5	0.3	Sub-vertical	Closed	No
12	10,607.7	10,607.9	0.2	Sub-vertical	Closed	No
13	10,608.5	10,608.7	0.2	Vertical	Open	No
14	10,617.7	10,617.7	0.2	Horizontal	Closed	No
15	10,631.5	10,631.9	0.4	Sub-vertical	Closed	No
16	10,634.7	10,634.9	0.2	Sub-vertical	Closed	No
17	10,657.4	10,657.9	0.5	Vertical	Closed	Possible
18	10,671.7	10,672.2	0.5	Vertical	Closed	No
19	10,671.8	10,672.0	0.2	Sub-vertical	Closed	No
21	10,676.2	10,676.4	0.2	Vertical	Closed	No
22	10,679.1	10,679.6	0.5	Vertical	Open	No
23	10,686.3	10,686.5	0.2	Vertical	Open	No
24	10,688.0	10,688.7	0.7	Vertical	Open	No
25	10,711.5	10,714.0	2.5	Vertical	Open	Yes
26	10,718.0	10,718.7	0.7	Vertical	Closed	No

Table of fractures from NBU 253 Well.



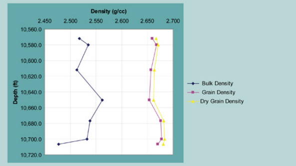
Bar graph showing the variation in vertical length of fractures.

Tight Rock Analysis—NBU 253

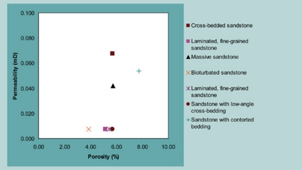
Sample ID	Sample Description	Depth (ft)	As Received Bulk Density (g/cc)	As Received Grain Density (g/cc)	Dry Grain Density (g/cc)	Effective Porosity (% of BV)	Water Saturation (% of PV)	Gas Saturation (% of PV)	Mobile Oil Saturation (% of PV)	Gas Filled Porosity (% of BV)	Bound Hydrocarbon Saturation (% of BV)	Bound Clay Water (% of BV)	Steady-State Permeability (mD)
1	Fine-grained sandstone with fracture	10,532.0	2.655	2.705	2.710	2.06	2.86	88.55	8.59	1.82	0.07	2.80	162.238***
2	Cross-bedded sandstone	10,572.0	2.518	2.660	2.667	5.69	2.13	93.79	4.09	5.34	0.09	0.74	0.068
3	Laminated, fine-grained sandstone	10,580.0	2.535	2.667	2.671	5.13	0.18	96.53	3.28	4.95	0.07	0.83	0.007
4	Massive sandstone	10,612.0	2.513	2.657	2.663	5.74	1.62	94.33	4.05	5.41	0.00	0.51	0.042
5	Bioturbated, sandstone	10,650.5	2.562	2.653	2.662	3.88	4.88	89.03	6.09	3.45	0.00	2.65	0.007
6	Laminated, fine-grained sandstone	10,677.0	2.538	2.676	2.682	5.43	0.86	94.81	4.32	5.15	0.00	0.42	0.007
7	Low-angle cross-bedding in sandstone	10,700.0	2.533	2.677	2.684	5.72	2.46	94.59	2.95	5.41	0.07	0.75	0.007
8	Sandstone with contorted bedding	10,706.5	2.477	2.670	2.681	7.74	3.66	93.38	2.96	7.23	0.00	0.82	0.054

*** Sample contained artificial induced fracture

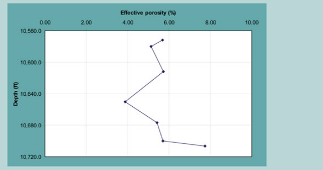
Tight rock analysis results. Color in Sample ID column is keyed to formation sampled; green = Sego, yellow = Castlegate.



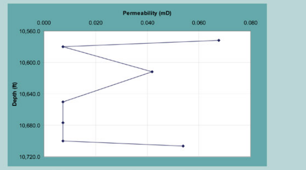
Line graph showing density versus depth.



Cross plot of porosity and permeability.



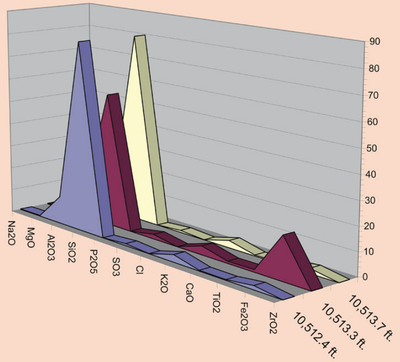
Line graph showing porosity versus depth.



Line graph showing permeability versus depth.

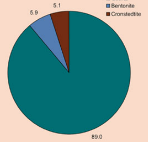
XRF/XRD Analysis of Unusual Sample at 10,513 ft—NBU 253

Bioturbated, fine-grained sandstone with iron staining. (10,513 ft)

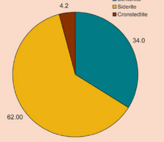


Bar graph of x-ray fluorescence analysis showing spike of iron mid-sample.

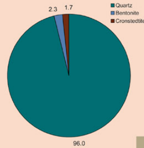
Pie charts showing mineral composition from XRD analysis.



Sampled at 10,512.4 ft.



Sampled at 10,513.3 ft.

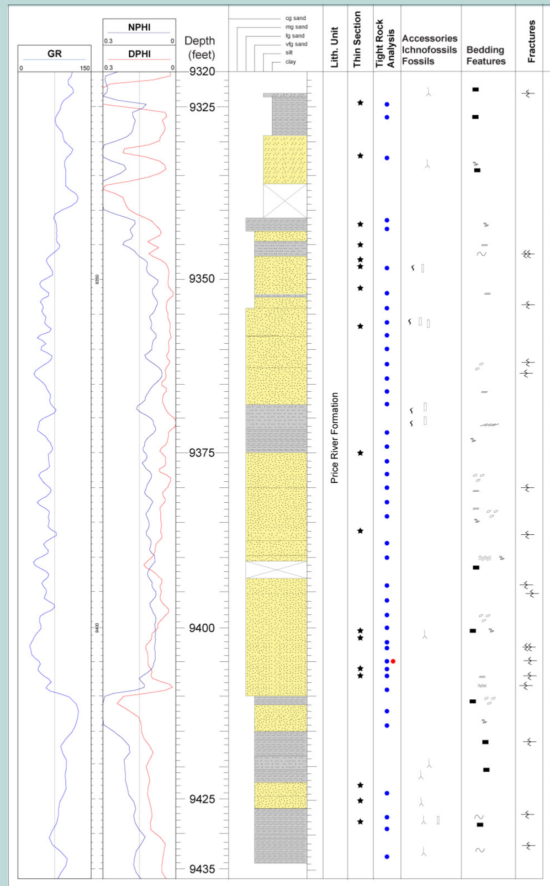


Sampled at 10,513.7 ft.

Panel II

Core Description of NBU 921-21L Well

API or Location Number 4304739256
Well or Location Name Natural Buttes Unit 921-21L
Section 21 Township 9 S. Range 21 E.



Remarks
9323.0-9323.5 Siltstone, disrupted (rooted), dark gray, carbonaceous
9323.5-9329.0 Shale, black to dark gray, carbonaceous, with coaly streaks and mm-thick coal stringers; some rooting disruption and rubbly carbonaceous shale with coal laminations and tree/plant debris
9329.0-9336.2 Siltstone, medium, dark gray, with abundant plant and wood debris, comminuted throughout, no true coals; appears disrupted by rooting/pedogenic activites; soft sediment deformation at base
9341.0-9343.0 Shale, medium gray, with thin lenses of very fine sand and soft sediment deformation
9343.0-9344.5 Sandstone, light gray, very fine grain with thin flaser beds and abundant clay drapes; disrupted, dolomitic and calcareous
9344.5-9346.5 Sandstone and shale, with laminations and soft sediment deformation
9346.5-9352.0 Sandstone, light to medium gray, silt to very fine grain with flaser bedding and slumping near top, sand filled burrows and intercalated thin beds
9352.0-9352.4 Shale, medium to dark gray, laminated silt/mud with wispy very fine sand laminae
9352.4-9354.0 Sandstone, light gray, calcareous with flaser bedding and abundant silt/mud laminae
9354.0-9358.0 Sandstone, medium to dark gray, very fine grain with sand-filled burrows
9358.0-9362.5 Sandstone, medium to light gray, very fine grain with flaser bedding and abundant calcareous mud laminae and drapes
9362.5-9368.0 Sandstone, medium to dark gray, very fine grain to silt with mud chip rip-ups
9368.0-9371.5 Siltstone to shale, laminated, heterolithic on a small scale; laminated/wispy sand in mud/silt with small burrows
9371.5-9375.0 Shale and sandstone, medium gray, mud to very fine grain with soft sediment deformation, low angle cross-bedding in sandstone, and mud drapes
9375.0-9380.0 Sandstone, medium gray, very fine grain to silty with rip-ups, laminations, and a basal biogenic feature that has vesicles similar to a wood fragment; some faint disruption
9380.0-9387.5 Alternating sandstone and shale, medium to dark gray, very fine grain sands; sands are laminated with rip-up clasts near contact with underlying shale; some soft sediment deformation
9387.5-9390.5 Sandstone, medium to light gray, very fine grain with ripples and abundant clay drapes; disrupted at top and base; some soft sediment deformation
9393.0-9410.0 Sandstone, medium to light gray, very fine grain with thin beds of shale; carbonaceous debris, rip-up clasts, and soft sediment deformation; middle has clay drapes and laminae; base is very fine to fine grained sandstone with flaser beds, mud couplets, laminae, and some ripples
9410.0-9411.0 Shale, medium to dark gray, carbonaceous with coaly rip-ups at base
9411.0-9415.0 Sandstone and silty sandstone, very fine grain with soft sediment deformation
9415.0-9418.5 Shale, dark gray, carbonaceous with irregular stingers of coal laminae/debris
9418.5-9420.5 Shale and silt to fine grain sand with faint root traces
9420.5-9422.5 Shale, carbonaceous with a few root traces
9422.5-9424.8 Sandstone, medium to dark gray, very fine grain to silty; variable mud/silt content in clayey shales
9424.8-9426.3 Sandstone, medium to light gray, with root traces and soft sediment deformation
9426.3-9431.5 Shale and silt to very fine sandstone, medium to light gray; shale is carbonaceous with root traces; sandstone has root traces or injection structure and burrows; root traces and slumping at base
9431.5-9434.2 Shale, medium to dark gray with slumping and root traces

EXPLANATION

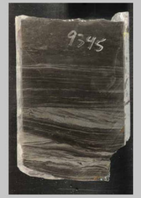
Bedding, Features: planar laminations; low angle cross bedding; ripple lamination; convolute bedding; fracture; fractures; carbonaceous debris; clasts

Accessories, Ichnofossils, and Fossils: burrow, vertical; burrow, horizontal; slight bioturbation; intense bioturbation

Lithology: sandstone; shale/mudstone; silty shale; shaley siltstone

• Triaxial shear test sample, results shown on this poster.

Lithology, Sedimentary Structures, and Petrology—NBU 921-21L



Laminated, very fine sandstone with clay drapes. (9345 ft)

Fine grain sandstone with flaser bedding and silt/mud laminae. (9353 ft)

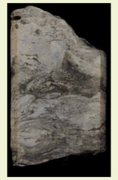
Very fine grain sandstone with ripples and a few mud chip rip-ups. (9359 ft)

Silt to very fine grain sandstone with wavy lamination and mud chip rip-ups at base. (9363 ft)

Rooting or injection structure in silt to very fine sandstone with mineral filled, near vertical fracture. (9428 ft)

Fractures—NBU 921-21L

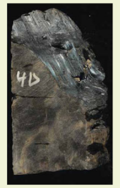
Open, vertical fracture in carbonaceous mudstone. (9324 ft)



Open, sub-vertical fracture in bioturbated, silt to fine grain sandstone. (9386 ft)

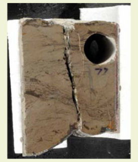
Open horizontal fracture in sandstone with soft-sediment deformation and mineral filled vertical fracture in laminated silt to mudstone. (9399 ft)

Calcite filled, sub-vertical fractures cross cutting burrowed, very fine grain sandstone. (9348 ft)



Slickenlines in carbonaceous mudstone. (9417 ft)

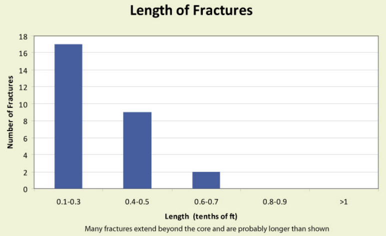
Sub-vertical, mineral-filled fracture in very fine grain sandstone with soft-sediment deformation. (9403 ft)



Multiple, vertical, mineral-filled fractures in very fine grain sandstone. (9401 ft)

Fracture #	Depth Top (ft)	Depth Base (ft)	Fracture Length (ft)	Orientation	Aperture	Mineral-ization?	Notes
1	9323.9	9324.2	0.3	Vertical	Open	No	
2	9347.9	9348.7	0.6	Vertical	Closed	Yes	
3	9348.0	9348.2	0.2	Vertical	Closed	Yes	
4	9348.4	9348.8	0.4	Vertical	Closed	Yes	
5	9348.8	9349.9	0.2	Vertical	Open	No	
6	9357.1	9357.4	0.3	Vertical	Open	?	
7	9362.4	9362.5	0.1	Inclined	Open & Closed	No	
8	9363.2	9663.4	0.2	Vertical	Open	Yes	
9	9367.3	9367.3	0.3	Horizontal	Open	No	
10	9379.2	9379.5	0.3	Vertical	Closed	Yes	
11	9386.5	9386.6	0.1	Vertical	Open	No	
12	9389.1	9389.2	0.1	Vertical	Closed	Yes	
13	9399.6	9399.6	0.3	Horizontal	Open	No	
14	9399.8	9399.9	0.1	Vertical	Closed	Yes	
15	9401.1	9401.3	0.2	Vertical	Closed	Yes	
16	9401.3	9401.5	0.2	Vertical	Closed	Yes	
17	9401.1	9401.5	0.4	Vertical	Closed	Yes	
18	9402.6	9402.8	0.2	Vertical	Closed	Yes	
19	9405.0	9405.7	0.7	Vertical	Open & Closed	No	
20	9407.9	9407.9	0.2	Horizontal	Open	No	
21	9408.3	9408.3	0.4	Horizontal	Closed	No	
22	9408.4	9408.4	0.1	Horizontal	Closed	No	
23	9413.1	9413.1	0.4	Horizontal	Closed	Yes	
24	9417.0	9417.4	0.4	Vertical	Open	No	Slickenlines
25	9428.0	9428.5	0.5	Vertical	Closed	Yes	
26	9433.0	9433.0	0.4	Horizontal	Open	No	
27	9433.2	9433.2	0.4	Horizontal	Closed	No	
28	9434.6	9435.0	0.4	Vertical	Closed	Yes	

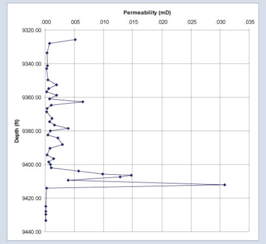
Table of fractures from the NBU 921-21L well.



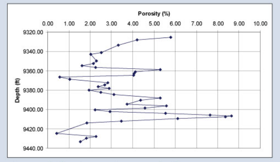
Bar graph showing the variation in length of fractures.

Tight Rock Analysis and Triaxial Compression Test—NBU 921-21L

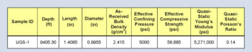
Conventional core plug analysis results.



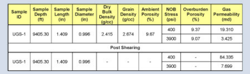
Line graph showing permeability versus depth.



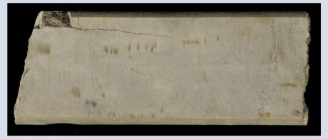
Line graph showing porosity versus depth.



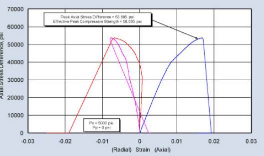
Summary of triaxial compression testing.



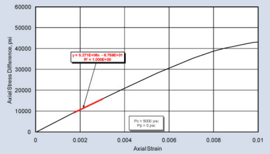
Summary of physical properties testing.



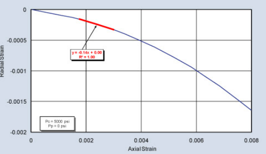
Sample used for triaxial compression test. Fine grain sandstone with long vertical fracture. (9405 ft)



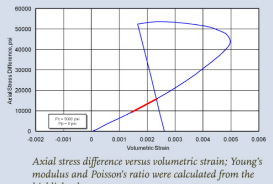
Stress versus time plot.



Axial stress difference versus axial strain; Young's modulus was calculated from the highlighted area on curve.



Radial strain versus axial strain; Poisson's ratio was calculated from the highlighted area on curve.



Axial stress difference versus volumetric strain; Young's modulus and Poisson's ratio were calculated from the highlighted area on curve.

Summary

- The Upper Cretaceous Mesaverde Group was deposited in Campanian time in offshore marine, nearshore marine, coastal plain, and braided stream environments during the last phase of the Cretaceous Interior Seaway.
- Study of core from the Natural Buttes Unit 253 and NBU 921-21L wells shows that the Price River Formation (upper Mesaverde Group) and Castlegate and Sego Sandstones (lower Mesaverde Group) are mostly sandstone interbedded with carbonaceous shale and silty mudstone. Individual sandstones are very fine to fine grained and have low-angle cross-bedding, small ripples, flaser bedding, sparse burrows, and moderate bioturbation. Depositional environments range from marginal marine to lower coastal plain.
- Twenty-five fractures were identified in the NBU 253 core. Most are natural fractures between 2 and 9 inches (8 to 20 cm) long, closed or slightly open with no discernable mineralization. Several appear to be drilling induced and are nearly vertical and very long (~ 2.5 ft [0.75 m]) with no mineralization.
- Over 28 fractures were identified in the NBU 921-21L core. All appear to be natural fractures, many with mineralization. Most fractures are inclined to vertical in orientation, but there is also an abundance of horizontal fractures.
- Our Tight Rock Analysis shows that sands of the Mesaverde Group have very low porosity (0.43 % to 7.74 %) and low permeability (0.002 to 0.068 mD).

Acknowledgments

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