TIGHT GAS SANDS AND NATURAL FRACTURES IN THE CRETACEOUS MESAVERDE GROUP, GREATER NATURAL BUTTES FIELD, UINTA BASIN, UTAH

ABSTRACT

basin. The field produces natural gas primarily from fracture systems and reservoir heterogeneity creat-range from marginal marine to lower coastal plain. low-permeability sandstone in the Mesaverde Group ed by various depositional environments can aid in Porosity varies from 2 to 9% and permeability varies and the Tertiary Wasatch Formation. GNB has prohydraulic fracturing optimization and lead to better from 0.002 to 0.10 mD. duced over 2.2 TCF of gas from over 4000 wells and drilling and completion strategies.

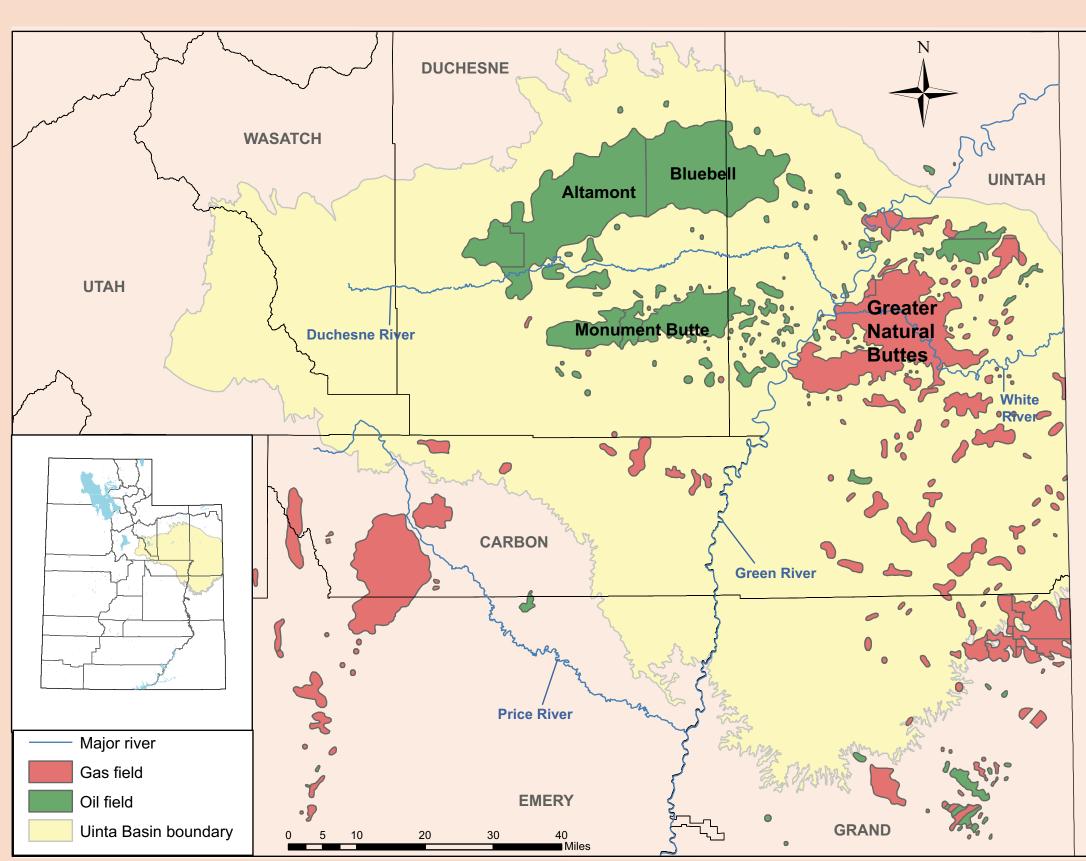
mentalized, lenticular, fluvial channel sandstones in petrophysical, and geomechanical characteristics that to propagate from thin coal seams, while others terthe Price River Formation in the upper Mesaverde are being used to create reservoir models and sim- minate at shale or clay partings. Most fractures are Group. The Sego and Castlegate Sandstones in the ulations for hydraulic fracturing. These cores show inclined, but horizontal and vertical orientations are lower Mesaverde typically have higher water satura- that the Mesaverde is mostly sandstone interbedded also present. Portions of GNB cores illustrating vartion and are not generally productive, but have litho- with black, bioturbated, and carbonaceous shale and ious depositional environments and fracture types logic and fracture characteristics similar to productive silty mudstone. Individual sandstones are very fine are available for viewing and discussion.

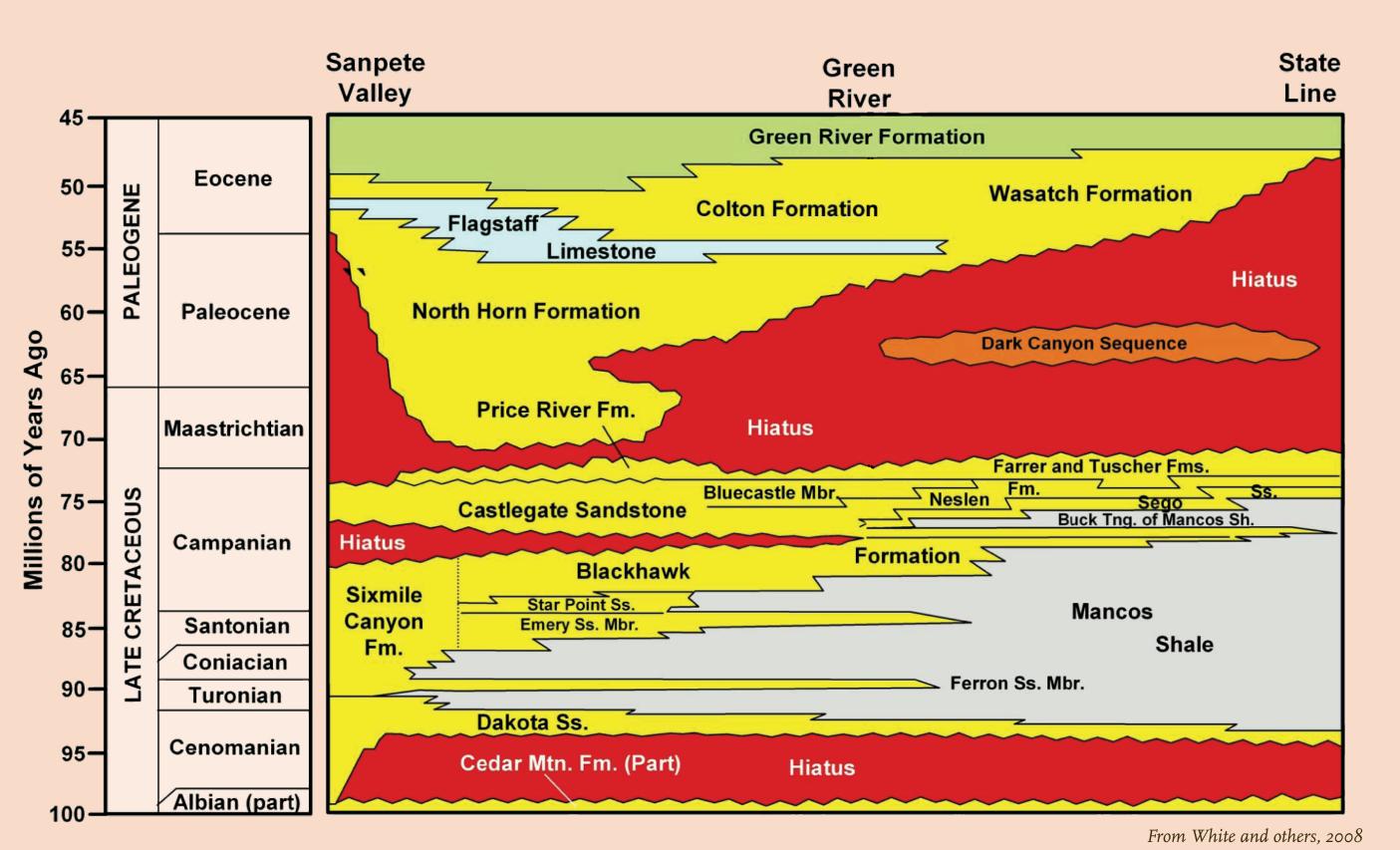
Greater Natural Buttes field (GNB) in the Uinta Basin sandstones up section. Production in these tight-gasis the largest gas field in Utah. GNB lies in an area of gentle northwest dip on the southern flank of the lic fracture treatments, so understanding the natural to fine grained and have low-angle cross-bedding, flaser bedding, small ripples, sparse burrows, and moderate bioturbation. Depositional environments

Over 90 fractures were identified in core. Most are continues to be the most active drilling area in Utah.

Cores in the Castlegate, Sego, and Price River Formanatural, open fractures, but some are closed and filled Most of the gas production is from highly compart- tions display classic low-permeability depositional, or partially filled with calcite. Some fractures appear

REGIONAL OVERVIEW

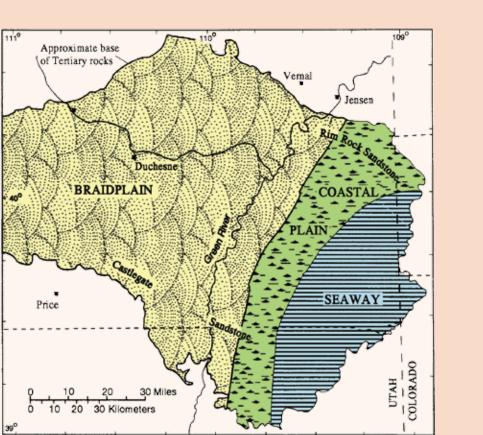




Location of Greater Natural Buttes gas field in the Uinta Basin, Utah.

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).



a braided stream, lower coastal plain, and marginal marine environment.

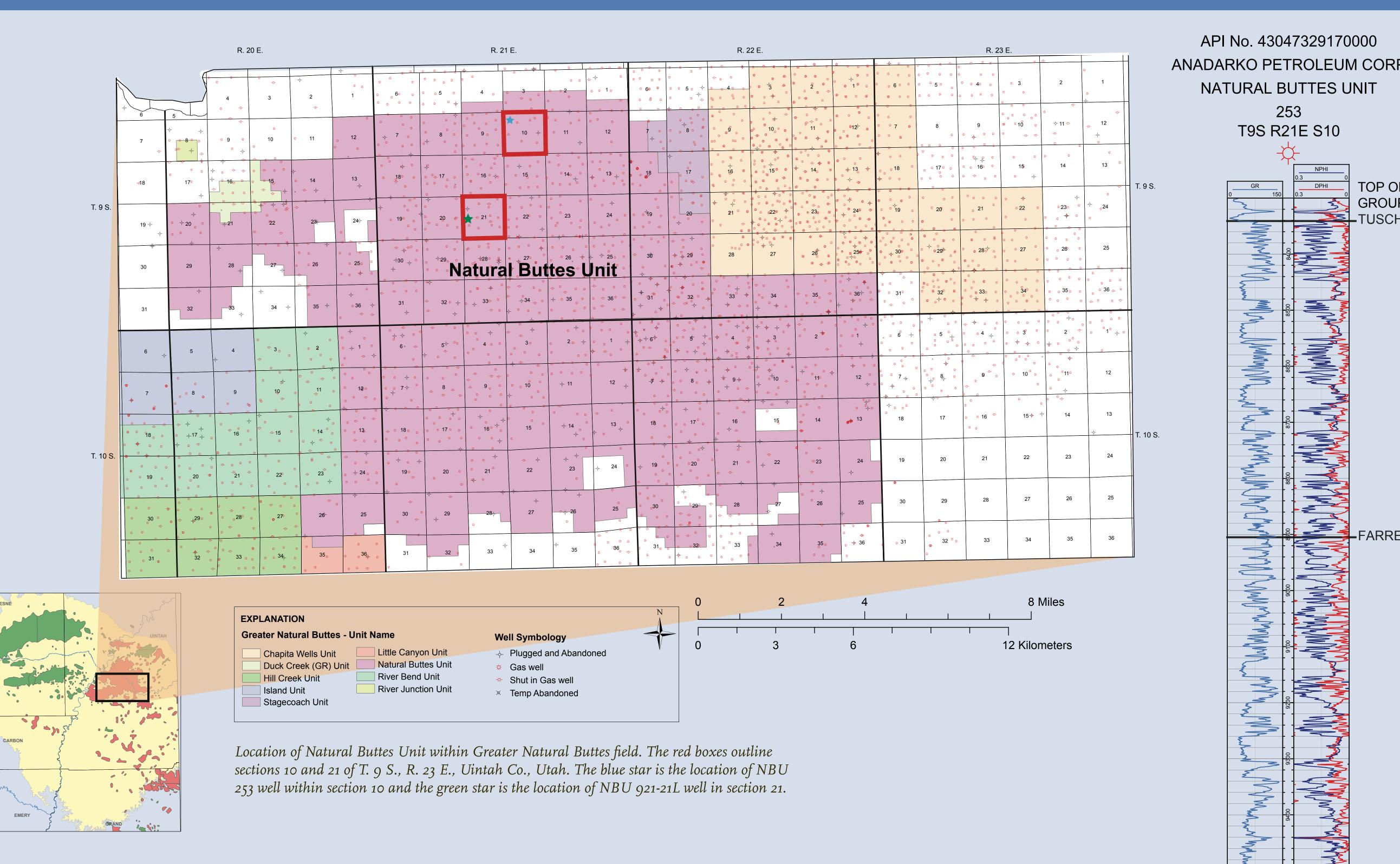
0 10 20 30 Miles 0 10 20 30 Kilometers

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.

0 10 20 30 Miles 0 10 20 30 Kilometers Deposition of the Farrer and Tuscher Formations in an alluvial plain environment.

GREATER NATURAL BUTTES FIELD GENERAL OVERVIEW



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

Mesaverde Group - Individual sand bodies up to 30 ft Wasatch Formation - Individual sand bodies up to 40 ft

BLUECASTLE TONGUE
OF THE CASTLEGATE

SANDSTONE

NESLEN FORMATION

BLACKHAWK FORMATION

Vertical Wellbore T.D. = 11320 TVD

Geophysical well log of the NBU 253 well, Greater Natural

- 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:
- Wasatch 0.1 to 0.15 ohm/m • Type of Drive – Pressure depletion

Mesaverde - 0.15 ohm/m

Gas Characteristics

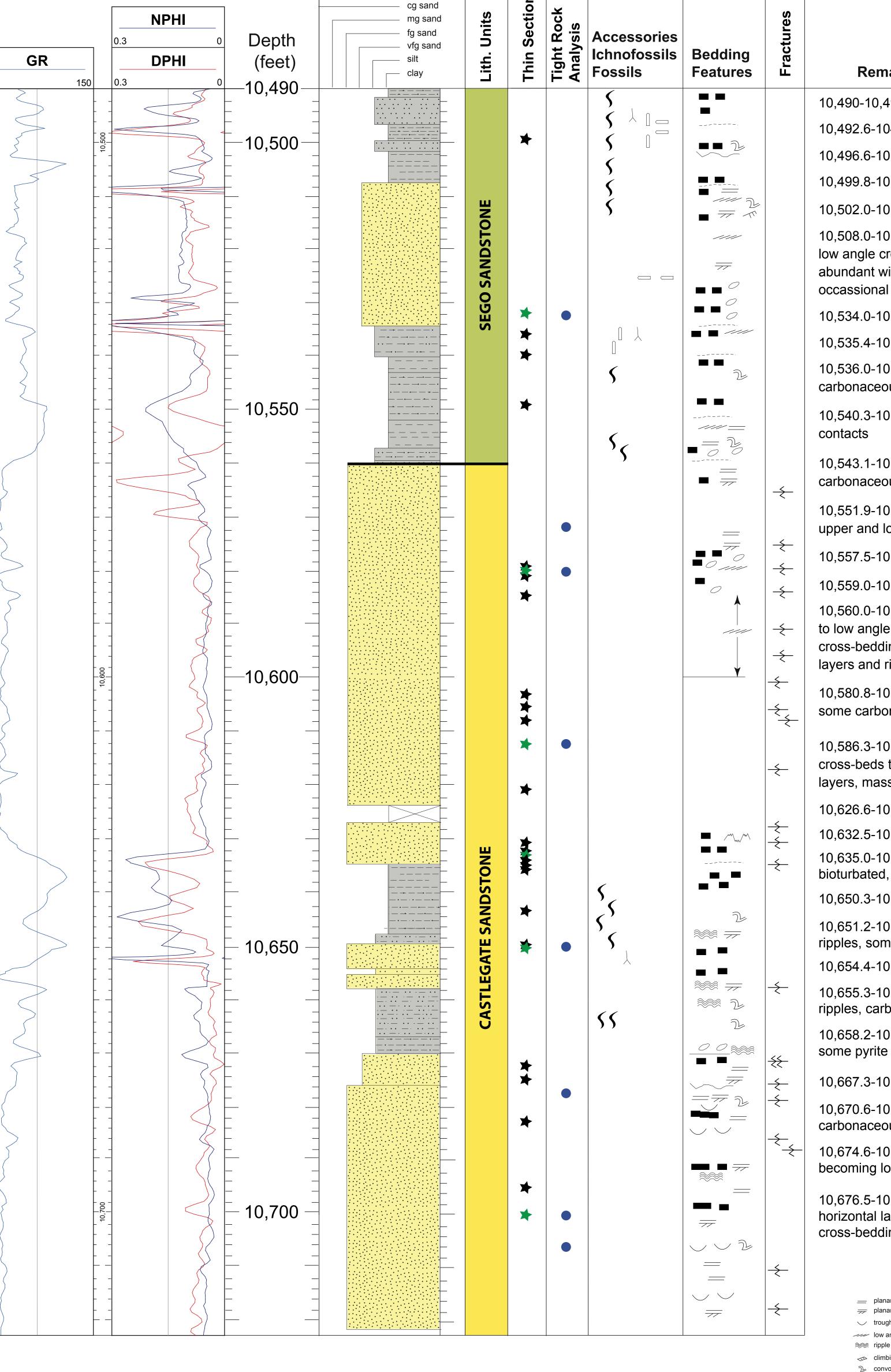
- Average Btu/cubic ft: Mesaverde - 1114 (280 kg/cal) Wasatch – 1088 (274 kg/cal)
- CO2 Content: Mesaverde - < 2% Wasatch - <0.5%

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

CORE DESCRIPTION OF NBU 253 WELL

Section 10 Township 9 S. Range 21 E.



★ Thin section photomicrograph shown on this poster.

10,540.3-10,543.1 Shale, black, coaly near top and silty near base, gradational upper and lower 10,543.1-10,551.9 Shale, silty, dark gray to black, bioturbated, disturbed bedding, some carbonaceous and coaly material, gradational upper and lower contacts 10,551.9-10,557.5 Shale black, occassional thin siltstone and carbonaceous layers, gradational 10,557.5-10,559.0 Siltstone, shaley, dark gray to black, finely laminated, rare small scale ripples 10.559.0-10.560.0 Bioturbated coaly, silty zone o low angle cross-beds and some convoluted beds in upper portion, generally low angle cross-bedding, to massive bedding, some carbonaceous wisps throughout, carbonaceous layers and rip-up clasts near base 10,580.8-10,586.3 Sandstone, light to medium gray, fine grain, massive, rare clay clasts and some carbonaceous clasts

10,586.3-10,624.7 Sandstone, light to medium gray, fine grain, salt and pepper, some low angle cross-beds to massive, some horizontal to rare ripple laminated, some thin carbonaceous layers, massive at base

10,626.6-10,632.5 Sandstone, light gray, massive, trace horizontal carbonaceous clasts, stylolite 10,632.5-10,635.0 Sandstone, light gray, fine grain, abundant carbonaceous and rip-up clasts 10,635.0-10,650.3 Shale, black, coaly near top, iron rich near top, becoming silty shale, bioturbated, contorted bedding near base

10,650.3-10,651.2 Sandstone, light gray, bioturbated

10,651.2-10,654.4 Sandstone, light gray, horizontal to low angle cross-bedding with some ripples, some carbonaceous clasts, rootlets, some bioturbation 10.654.4-10,655.3 Siltstone, dark gray

10,655.3-10,658.2 Sandstone, light gray with some red staining, low angle cross-bedding and ripples, carbonaceous clasts near top of unit

10,658.2-10,667.3 Siltstone, dark gray, shaley, small scale ripples, some contorted bedding

10,670.6-10,674.6 Sandstone, light to medium gray, fine grain, some ripples, abundant 10,674.6-10,676.5 Sandstone, light gray to gray, very fine grain, horizontal laminations near top

becoming low angle cross-bedding near base 10,676.5-10,721.8 Sandstone, fine grain, light gray to gray, occassionally massive, mostly

horizontal laminated to low angle cross-bedding, some ripples, and rare small scale trough cross-bedding, some flame structures

EXPLANATION

Bedding, Featu		Ichnof	ossils, and Fossils	Lithology		
aminations		gradational contact		burrow, vertical		sandstone
aminations in wedge sets	\{	fracture		burrow, horizontal		shale/mudston
	₩-	fractures	5	slight bioturbation		ailtu abala
le cross-bedding	____\	stylolites	<i>(((</i>	intense bioturbation		silty shale
mination	-	carbonaceous debris	,			shaley siltstone
g ripple	0	clasts	λ	rootlet	•••••	siltstone
te bedding	\sim	slump structure				

LITHOLOGY, SEDIMENTARY STRUCTURES, AND PETROLOGY—NBU 253

FRACTURES—NBU 253

TIGHT ROCK ANALYSIS—NBU 253

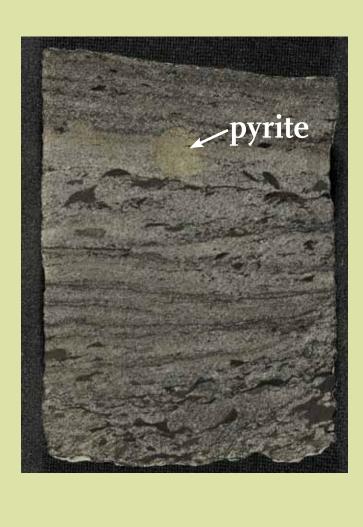
SEGO SANDSTONE





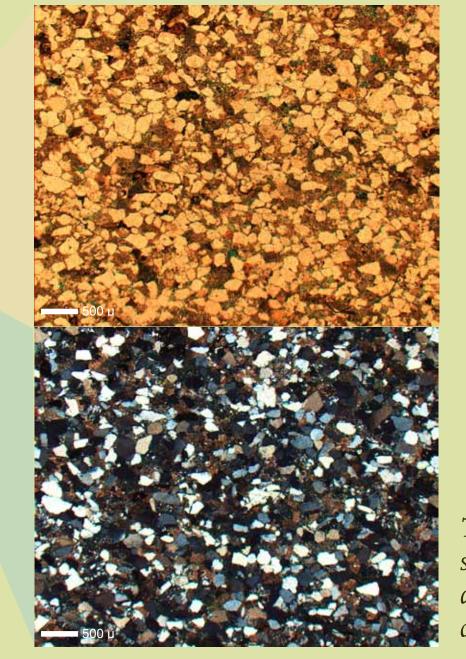




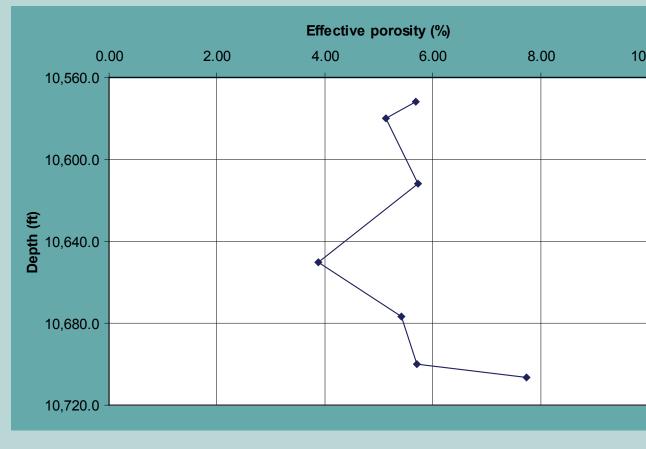


SEGO SANDSTONE



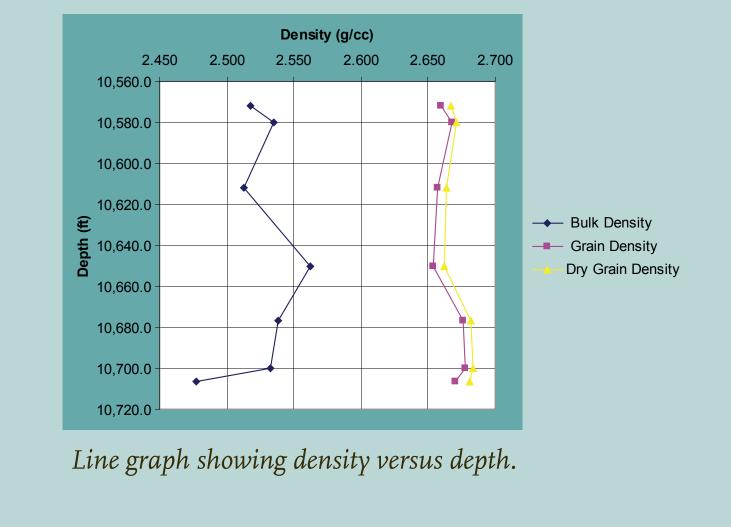


+Sandstone with contorted



XRF/XRD ANALYSIS OF UNUSUAL SAMPLE AT 10,513 FT—NBU 253

Line graph showing porosity versus depth.



Line graph showing permeability versus depth.

CASTLEGATE SANDSTONE



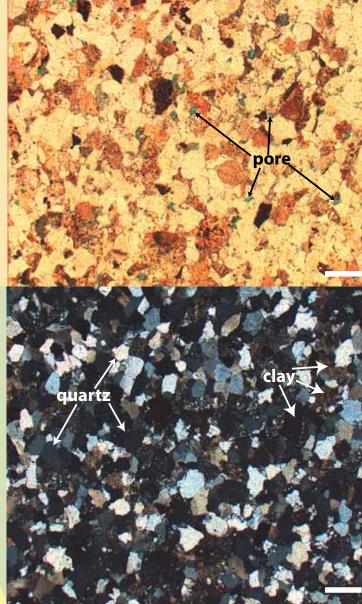
Bioturbated silty, sandstone with 3.88% porosity and 0.007 mD of permeability. (10,650.5)



Thin section showing moderately sorted, sub-rounded quartz grains in

a clay matrix with carbonaceous(?)

stringers. Note lack of porosity.*



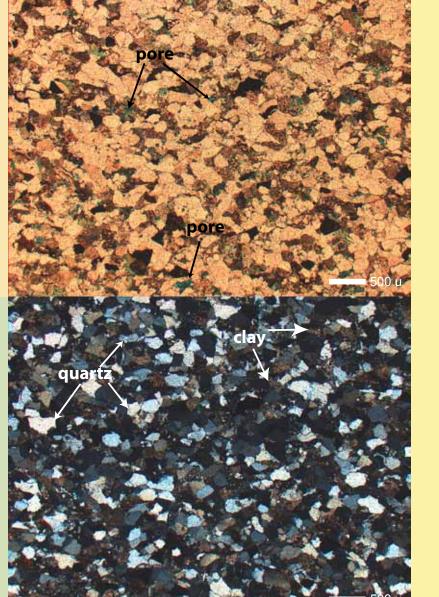
Thin section showing moderately sorted, sub-rounded to sub-angular quartz grains in a clay matrix.*



Fine-grained sandstone with

Sandstone has 5.43% porosity and 0.007 mD of permeability. (10,677 ft)

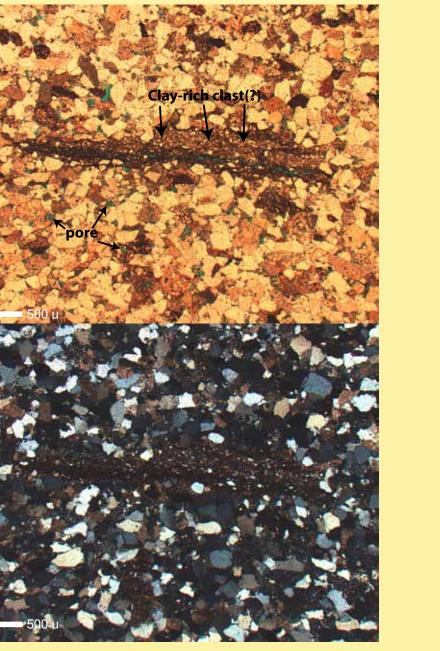
horizontal laminations.



matrix. Note lack of porosity.*

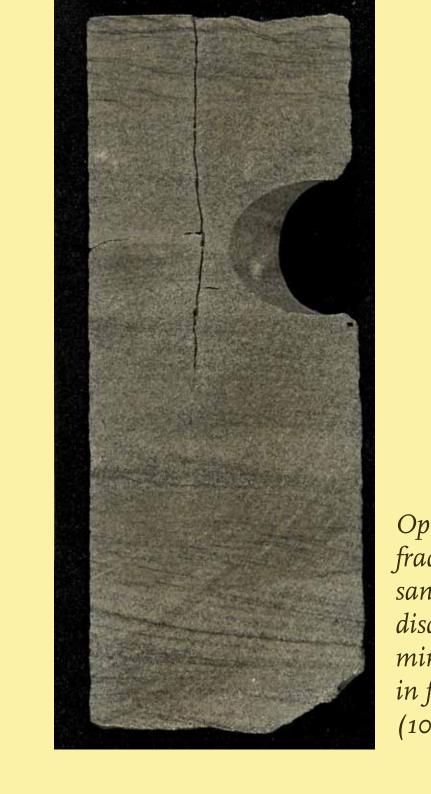


grains with sparse clay. Note more porosity than other samples.*



grains in a clay matrix. Note sparse porosity visible in top photo.*

CASTLEGATE SANDSTONE



sandstone. No

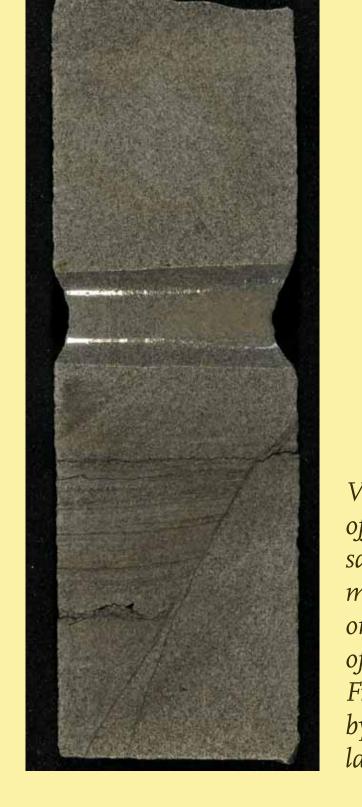
 23
 10,686.3
 10,686.5
 0.2
 Vertical
 Open
 No

 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.

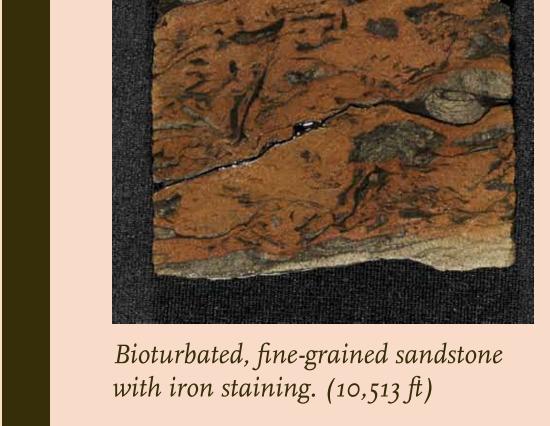


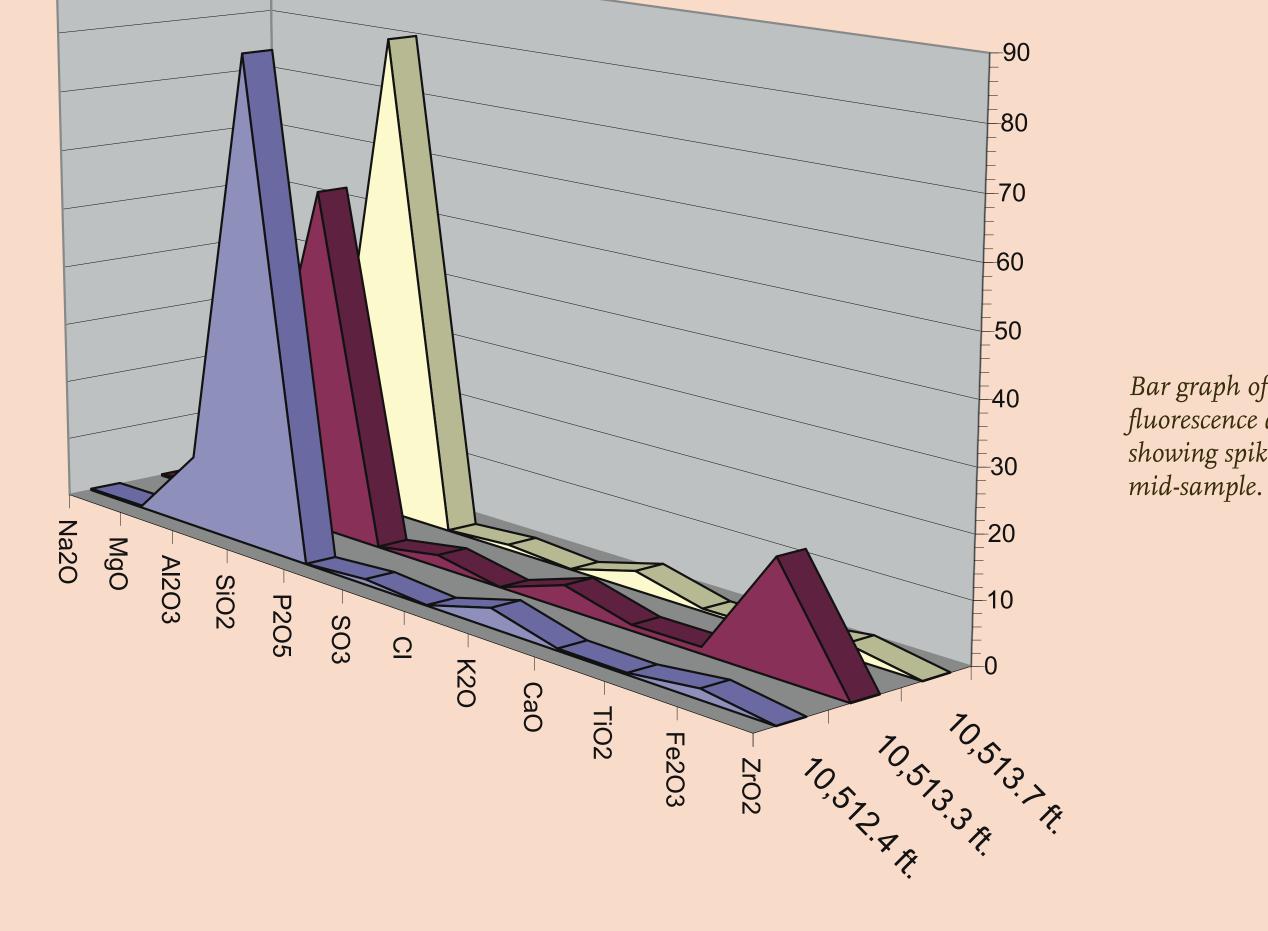
Vertical, closed fracture



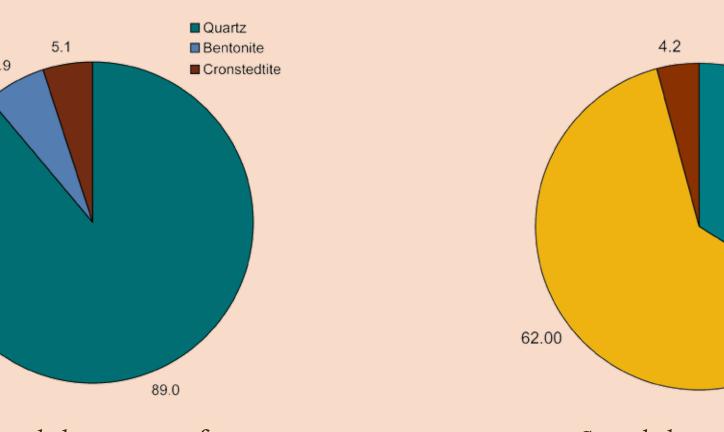
Length of Fractures Many fractures extend beyond the core and are probably longer than shown

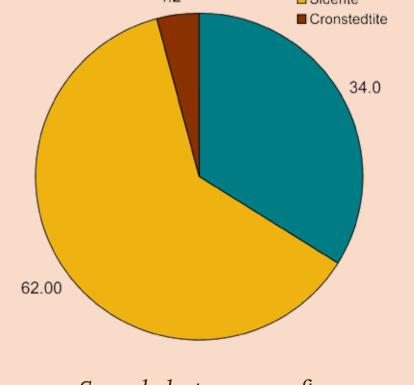
Bar graph showing the variation in vertical length of fractures.

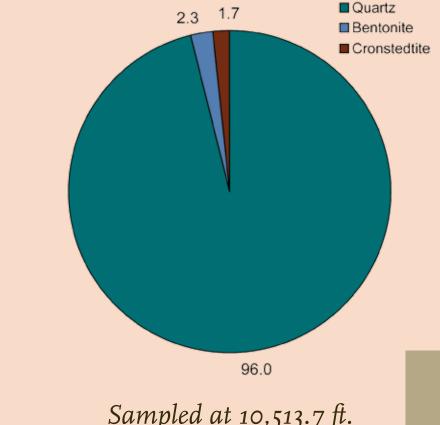




Pie charts showing mineral composition from XRD analysis.





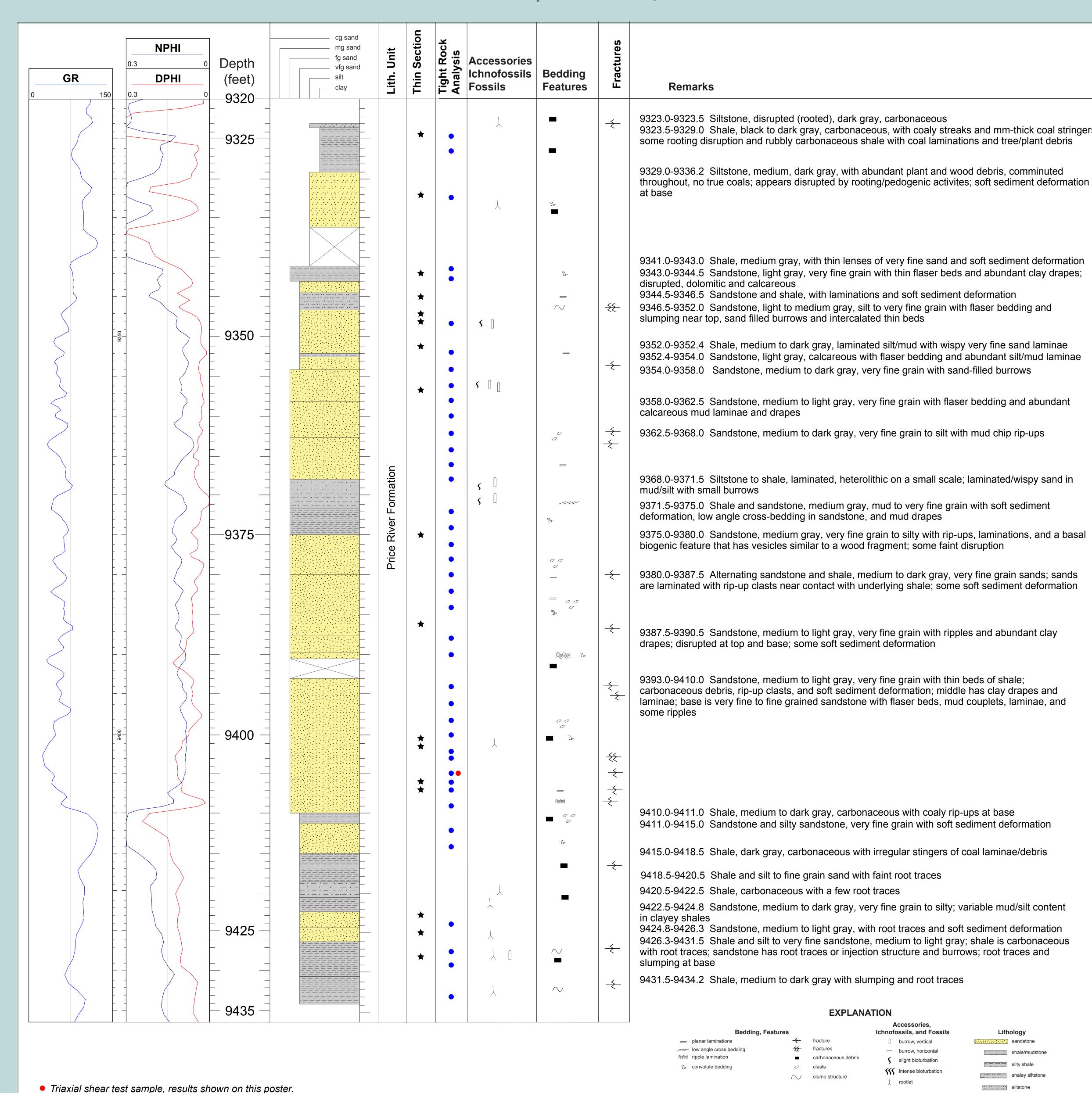


*Note: Photomicrographs taken in plane(top) and cross polarized(bottom) light at 2.5 times magnification.

Very low-angle cross-beds in fine-grained sandstone.
Sandstone has 5.72% porosity and 0.007 mD of permeability.

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.



LITHOLOGY, SEDIMENTARY STRUCTURES, AND PETROLOGY—NBU 921-21L





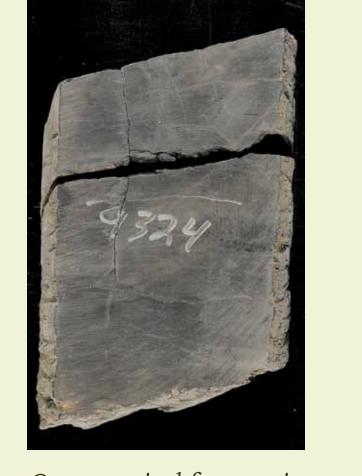






Rooting or injection structure in silt to very

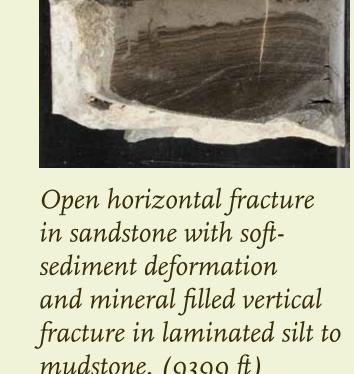
FRACTURES—NBU 921-21L



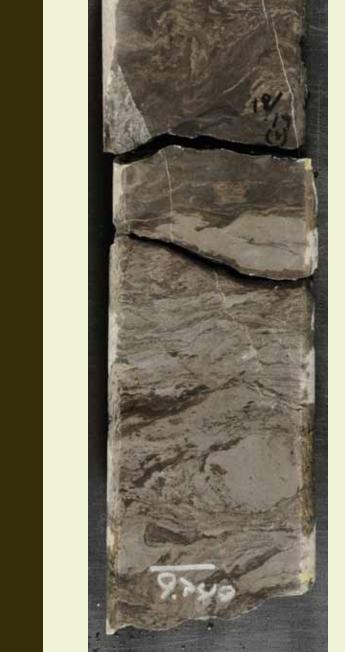






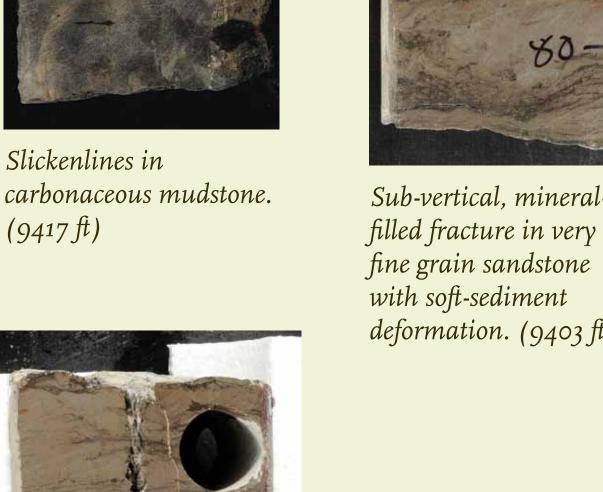


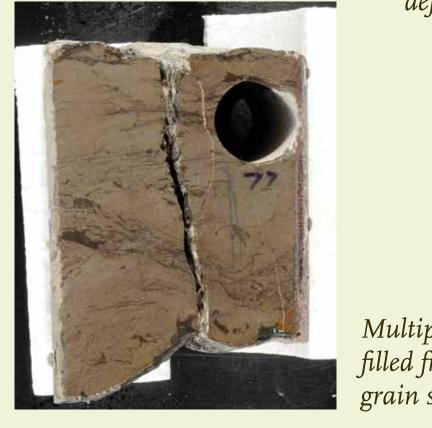












	Fracture						
Fracture	Depth Depth		Length			Mineral-	
#	Top (ft)	Base (ft)	(ft)	Orientation	Aperture	ization?	Notes
1	9323.9	9324.2	0.3	Vertical	Open	No	
2	9347.9	9348.7	0.6	Vertical	Closed	Yes	
3	9348.0	9348.2	0.2	Vertical	Closed	Yes	
4	9348.4	9348.8	0.4	Vertical	Closed	Yes	
5	9348.8	9349.9	0.2	Vertical	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	

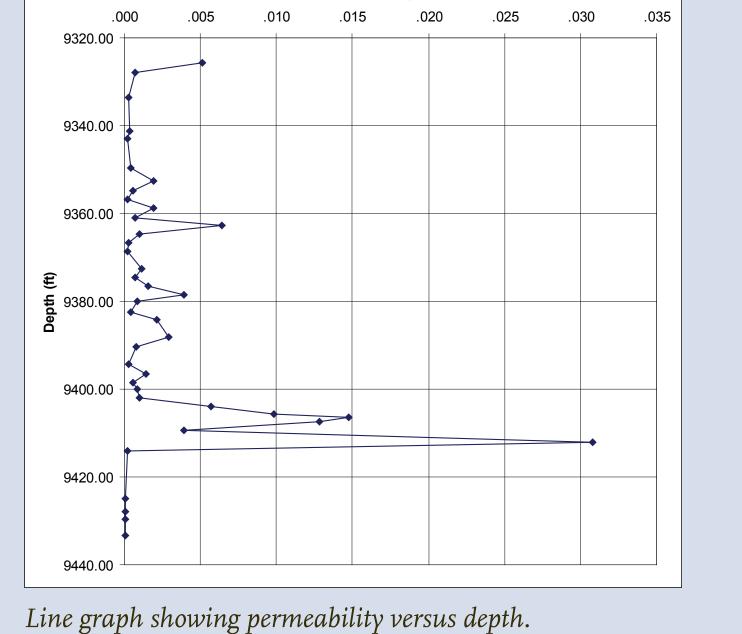
Table of fractures from the NBU 921-21L well.

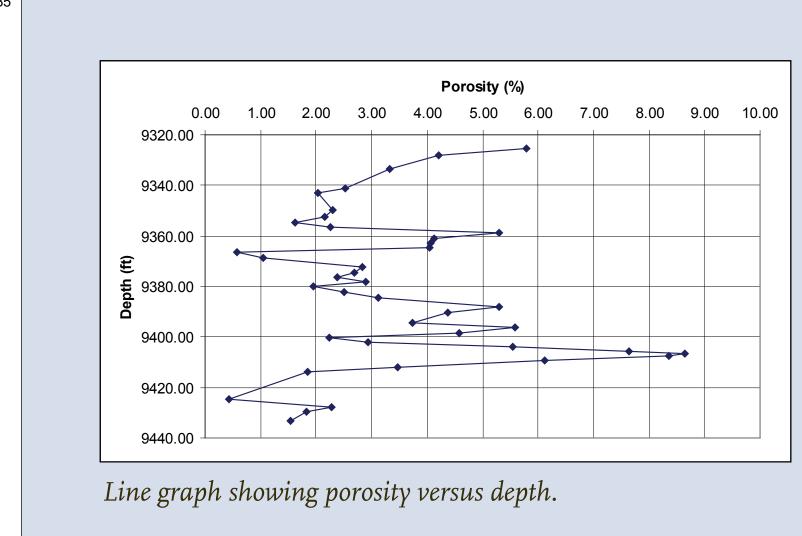
Length of Fractures Length (tenths of ft) Many fractures extend beyond the core and are probably longer than shown

Bar graph showing the variation in length of fractures.

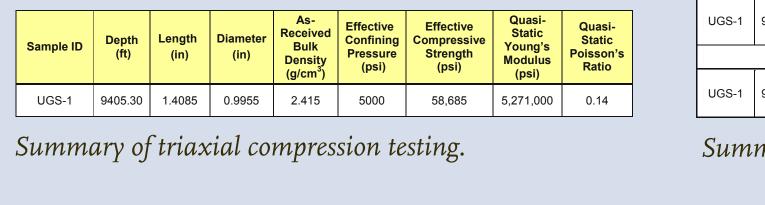
TIGHT ROCK ANALYSIS AND TRIAXIAL COMPRESSION TEST—NBU 921-21L

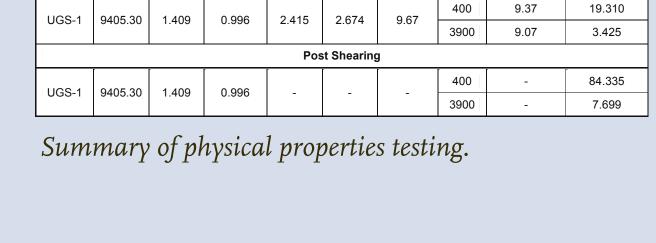
Sample ID	Sample Description	Depth (ft)	Net Confining Stress (psig)	Porosity (%)	Klinkenberg Permeability (mD)	Kair Permeability (mD)	Oil Saturation (% PV)	Water Saturation (% PV)	Grain Density (g/cm³)
2	Carbonaceous siltstone with rooting disruptions	9325.60	1820	5.79	.005	.011	0.0	91.4	2.602
4	Carbonaceous shale with coaly stringers	9327.90	1820	4.22	.001	.002	0.0	92.4	2.629
6	Silty mudstone with plant and woody debris	9333.60	1820	3.33	.0003	.001	0.0	92.8	2.620
9	Siltstone with thin lenses of very fine- grained sandstone	9341.25	1820	2.53	.0004	.001	0.0	78.6	2.680
11	Very fine-grained sandstone with flaser bedding	9343.00	1820	2.03	.0002	.001	0.0	83.1	2.673
20	Fine-grained sandstone with bioturbation and open fractures	9349.70	1820	2.30	.0004	.001	0.0	84.9	2.670
23	Fine-grained sandstone with flaser bedding and silt/mud laminae	9352.50	1820	2.15	.002	.005	0.0	60.6	2.666
27V	Silty sandstone with muddy laminae and burrows	9354.70	1820	1.62	.001	.002	0.0	72.5	2.674
29	Very fine-grained sandstone with burrows	9356.70	1820	2.26	.0002	.002	0.0	71.9	2.674
	Very fine-grained sandstone with ripples and rip-up clasts								
31 34	Very fine-grained sandstone with flaser bedding	9358.70 9360.90	1820 1820	5.29 4.13	.002	.005	0.0	41.2 41.6	2.672
36	Siltstone with mudchip rip-ups	9362.70	1820	4.13	.006	.002	0.0	94.6	2.678
38	Mudstone	9364.70	1820	4.04	.001	.003	0.0	68.8	2.689
40	Siltstone with rootlets	9366.60	1820	0.57	.0003	.001	0.0	84.6	2.667
43	Laminated siltstone Siltstone with soft sediment	9368.60	1820	1.04	.0002	.001	0.0	66.0	2.726
47	deformation	9372.50	1820	2.84	.001	.003	0.0	71.3	2.662
49	Mudstone	9374.50	1820	2.68	.001	.002	0.0	70.7	2.674
E 1	Very fine-grained sandstone with rip-	0276.60	1000	2 20	000	004	0.0	26.0	0.607
51 53	ups Mudstone	9376.60 9378.40	1820 1820	2.39 2.90	.002 .004	.004 .009	0.0	36.0 77.9	2.687 2.676
56	Very fine-grained sandstone with laminations	9380.00	1820	1.94	.001	.002	0.0	68.5	2.691
	Very fine-grained sandstone with soft			-					
58	sediment deformation	9382.40	1820	2.51	.000	.001	0.0	57.5	2.615
60	Very fine-grained sandstone	9384.30	1820	3.13	.002	.005	0.0	72.9	2.643
C.F.	Very fine-grained sandstone with	0000 00	4000	F 00	002	007	0.0	TDD	0.044
65 67	ripples and clay drapes Siltstone	9388.20 9390.30	1820 1820	5.29 4.37	.003	.007 .002	0.0	TBD 53.3	2.644 2.646
69	Very fine-grained sandstone with carbonaceous debris	9394.30	1820	3.73	.000	.002	0.0	68.9	2.629
	Very fine-grained sandstone with								
72	laminations Very fine-grained sandstone with	9396.45	1820	5.59	.001	.004	0.0	45.0	2.651
74	laminations Very fine-grained sandstone with soft	9398.40	1820	4.58	.001	.002	0.0	50.6	2.657
76	sediment deformation Very fine-grained sandstone with	9400.10	1820	2.25	.001	.002	0.0	77.0	2.648
79	multiple, filled fractures Very fine-grained sandstone with soft	9402.00	1820	2.95	.001	.003	0.0	53.3	2.671
81	sediment deformation Fine-grained sandstone with flaser	9403.95	1820	5.55	.006	.008	0.0	TBD	2.650
83	bedding Fine-grained sandstone with flaser	9405.60	1820	7.65	.010	.014	0.0	TBD	2.653
85	bedding	9406.50	1820	8.64	.015	.020	0.0	TBD	2.654
86	Fine-grained sandstone with laminations	9407.50	1820	8.36	.013	.019	0.0	TBD	2.656
89	Fine-grained sandstone with flaser bedding	9409.50	1820	6.11	.004	.009	0.0	TBD	2.651
92	Carbonaceous mudstone	9412.20	1820	3.46	.031	.031	0.0	64.6	2.622
95	Very fine-grained sandstone with soft sediment deformation	9414.00	1820	1.85	.0002	.0006	0.0	85.9	2.664
97	Very fine-grained sandstone	9424.85	1820	0.43	.0001	.0003	0.0	62.3	2.662
99	Very fine-grained sandstone with injection structure	9427.95	1820	2.27	.0001	.0003	0.0	75.0	2.698
100	Very fine-grained sandstone with rooting	9429.70	1820	1.83	.0001	.0003	0.0	85.7	2.664
	Mudstone with rooting	9433.45	1820	1.54	.0001	.0002	0.0	53.7	2.643



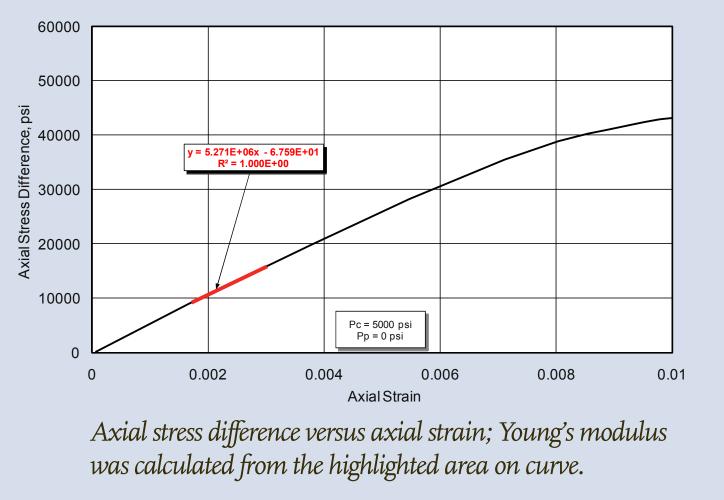


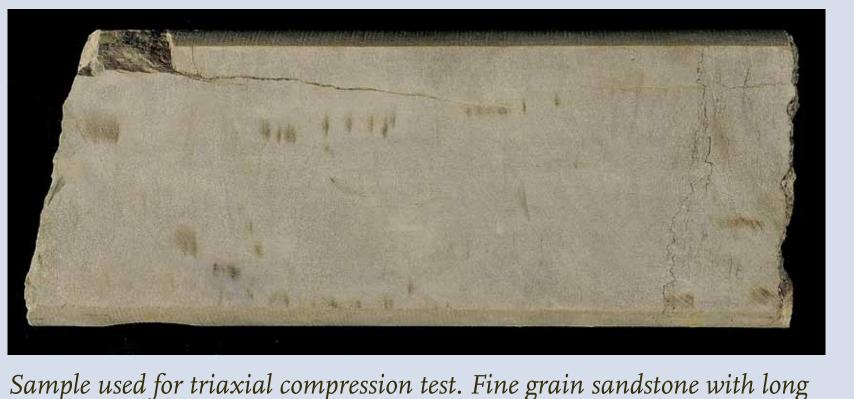




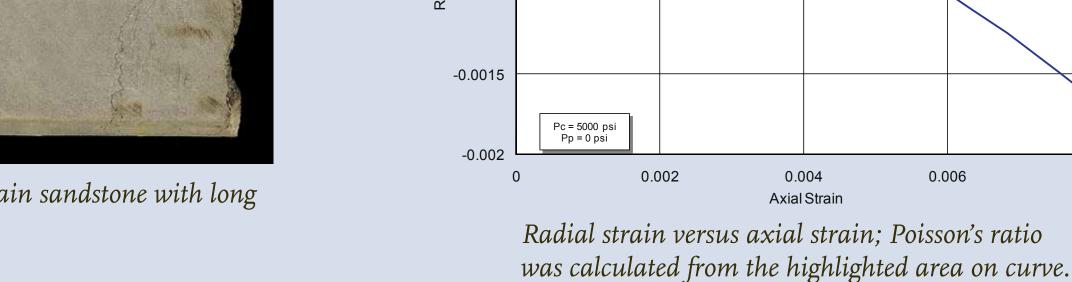


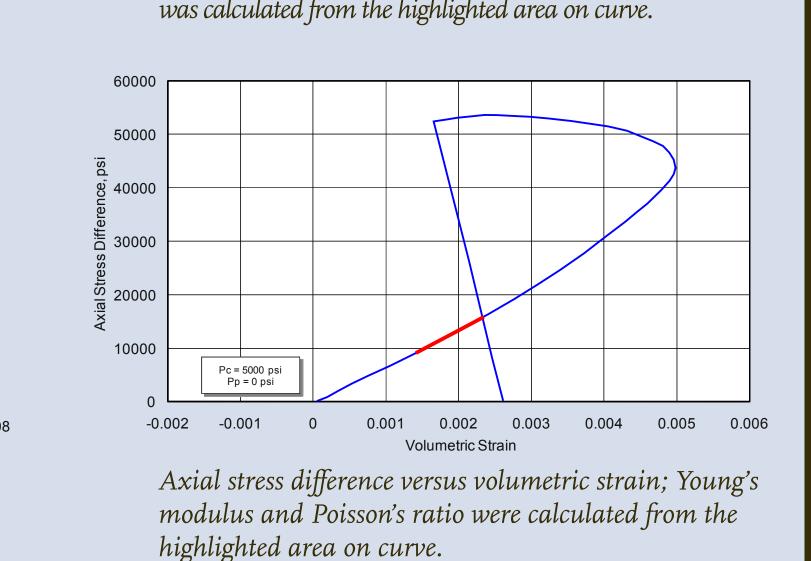






vertical fracture. (9405 ft)





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
- 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



Funding for this project was provided by RPSEA through the "Ultra-Deepwater and Unconventional Natural Gas and Other Petroleum Resources" program authorized by the U.S. Energy Policy Act of 2005. RPSEA (www.rpsea.org) is a nonprofit corporation whose mission is to provide a stewardship

role in ensuring the focused research, development and deployment of safe and environmentally responsible technology that can effectively deliver hydrocarbons from domestic resources to the citizens of the United States. RPSEA, operating as a consortium of premier U.S. energy research universities, industry, and independent research organizations, manages the program under a contract with the U.S. Department of Energy's National Energy Technology Laboratory.



also provided by the Utah Geological Survey. Other partners for this project

include Utah State University, Golder Associates, Inc., Energy & Geoscience Institute, and ITASCA Houston, Inc. Project website: geology.utah.gov/emp/tightgas/index.htm.

Anadarko Petroleum Corp. generously donated core and data to this project. The poster design was by Stevie Emerson and Jeremy Gleason of the UGS. Michael D. Laine, Thomas Dempster, and Brad Wolverton of the UGS Core Research Center prepared and photographed the core. Ryan Sonntag of Utah State University provided photomicrographs of thin sections. Tight Rock Analysis performed by TerraTek, A Schlumberger Company, and Core Laboratories.

REFERENCES

Fouch, T.D., Nuccio, V.F. Osmond, J.C., MacMillan, L., 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., Chidsey, T.C., Jr., editors, Hydrocarbon and mineral resources of the Uinta Basin, Utah and Colorado: Utah Geological Association Guidebook 20, p. 9-48.

Osmond, J.C., 1992, Greater Natural Buttes Gas Field, Uintah County, Utah, in Fouch, T.D, Nuccio, V.F., Chidsey, T.C., Jr., editors, Hydrocarbon and mineral resources of the Uinta Basin, Utah and Colorado: Utah Geological Association Guidebook 20, p. 143-164.

Utah Division of Oil, Gas, and Mining, 2011, Oil and gas production report, December: Online, https://fs.ogm.utah.gov/pub/Oil&Gas/Publications/Reports/Prod/Field/Fld_Dec_2010.pdf accessed April 15, 2011.

Utah Division of Oil, Gas, and Mining well completion files.

White, H., Cole, R., Stancel, S., Lee, C., and MacMillan, L., 2008, "Window" outcrop analogues for Greater Natural Buttes Field, Uinta Basin Utah, in Longman, M.W., and Morgan, C.D., editors, Hydrocarbon systems and production in the Uinta Basin, Utah: Rocky Mountain Association and Utah Geological Association Publication 37, p. 209-236.

