Oil & Natural Gas Technology

DOE Award No.: DE-FE0010667

Research Performance Progress Report

Quarterly Report: January 2015 to March 2015

Liquid-Rich Shale Potential of Utah's Uinta and Paradox Basins: Reservoir Characterization and Development Optimization

Project period: October 1, 2012 to September 30, 2015

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Office of Fossil Energy

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EXECUTIVE SUMMARY

As the project progresses through Budget Period 3, several different research activities are on track to help better characterize Utah's tight oil plays. Core analysis and regional mapping activities are helping to create a clearer understanding of the Uteland Butte tight oil play. In addition, new research on the origin and diagenesis of the Uteland Butte dolomites will aid in reservoir characterization and regional facies analysis. Several research projects are also underway looking at the Cane Creek shale. Epifluorescence analysis on Cane Creek cuttings has been completed and results will be presented at the May 2015 AAPG conference in Denver, CO. Also, completed fluid inclusion analyses of Cane Creek core have provided insights into fracture formation and timing of fluid migration within the play. Geomechanical data measured on cores from both the Uteland Butte and Cane Creek are currently being analyzed by collaborators at the Energy & Geoscience Institute, University of Utah. This data will be vital in helping inform better well completion strategies and potentially improve production.

Technology transfer remains a vital tool for communicating the project results with interested stake holders. Two presentations will be given at the upcoming AAPG meeting in Denver, CO: a core poster highlighting both the Uteland Butte and Cane Creek plays and a poster presentation on the aforementioned epifluorescence analyses. In addition, a collaboration with the U.S. Geological Survey on the geology of the Uteland Butte member of the Green River Formation has resulted in a paper which was submitted for inclusion in the upcoming 2015 Rocky Mountain Association of Geologists Source Rock Compendium volume.

PROGRESS, RESULTS, AND DISCUSSION

Task 1.0: Project Management Plan

During the month of January 2015, the PI wrote and submitted the project's ninth quarterly report for October to December 2015. This report was subsequently sent via email to all interested parties and posted on the UGS project website.

Task 2.0: Technology Transfer

- The UGS project website was updated with new information - http://geology.utah.gov/emp/shale_oil
- The PI completed the ninth quarterly report and emailed it to all interested parties. It is also available on the UGS project website.
- Two posters will be presented at AAPG in Denver, June 2015: a core poster that will include discussions of both the Uteland Butte and Cane Creek, and a poster detailing the completed epifluorescence analyses on the Cane Creek.
- In collaboration with the U.S. Geological Survey (USGS), a paper detailing the Uteland Butte tight oil play was submitted to the editors of the upcoming 2015 Rocky Mountain Association of Geologists Source Rock Compendium volume. The volume is slated to be published in late 2015.

Tasks 3.0 and 4.0: Data Compilation and Core-Based Geologic Analysis

Uteland Butte Member: The PI updated the Uteland Butte play map, which shows the location of all Uteland Butte horizontal wells (over 80 wells), individual company play areas, locations of Uteland Butte core, as well as proposed (APDs) horizontal Green River Formation wells (Figure 1). Recently, Newfield has switched to drilling ~11,000 foot laterals as opposed to the more typical ~5000 foot laterals. These new "super long laterals" (SXL) are located in Newfield's Central Basin play area within the overpressured zone. Figure 2 displays production bubbles for all horizontal Uteland Butte wells. In order to compare production rates and well success regardless of well age, only the first three full months of production was included. Initial production rates for shorter laterals (~5000 ft) range from ~10 to ~300 barrels of oil equivalent (BOE) per day in the southern part of the play, averaging 112 BOE per day, and ~70 to ~800 BOE per day in the northern overpressured area, averaging 383 BOE per day. The SXL horizontal wells in the overpressured zone range from ~770 to ~1200 BOE per day and average 945 BOE. As shown on the map, the most productive area to date lies within the overpressured zone of the central basin.

The formation of lacustrine dolomite is very poorly understood. With the main reservoir of the Uteland Butte being a porous dolomite, it is vital to understand how these deposits formed and to understand how the facies change across the basin. To help investigate this problem, we have set up a collaboration with Dr. Hans Machel, renowned dolomite expert from the University of Alberta. Dr. Machel and a graduate student traveled to Salt Lake City in November, 2014, and Denver in February, 2015, to analyze several Uteland Butte cores (8 cores total). Several sections of each core, focusing on the dolomite intervals, but also including examples of adjacent facies, were selected for thin section analysis. In addition, the same intervals will be analyzed using a scanning electron microscope, as well as analyzed for specific isotopes and mineralogy. These tests will help determine the origin of the dolomites, whether they are the result of primary precipitation or related to diagenetic processes. A model of deposition will be created that will help delineate facies changes and reservoir characteristics across the basin.

Cane Creek Shale: Understanding the relationship between fractures in the Cane Creek shale and timing of oil migration will be vital to understanding the petroleum system as a whole and determining areas that might be supportive of economic production. These relationships can be investigated by analyzing the fluid inclusions trapped within the fracture-fill precipitates.

Fluid inclusions are fluid- and/or gas-filled vacuoles sealed within different minerals, including fracture-fill material. Analysis of an inclusion can provide the composition and salinity of the fluid as well as the temperature and pressure at which it became trapped (i.e., crystal mineralization). Fluid inclusion analysis can also provide insight into the migration history of fluids through a suite of rocks. Analysis of thin section samples from the Cane Creek will aid our understanding of oil maturation history and timing of fluid migration. Twenty core samples from three different Cane Creek wells (the Cane Creek 26-3 core from the productive Big Flat field, the Remington 21-1H core from the currently non-productive southwestern play area, and the Cisco State 36-13 core from the currently non-productive southeastern play area near Lisbon) have been analyzed. Preliminary results for the Cisco State 36-13 core indicate that trapped fluids within the fractures are saline and the minimum trapping temperature was roughly 85° to 95°C (Figure 3). Live oil has also been observed in samples from this well, with fluorescence of the oil indicating a 35° to 40° API gravity (Figure 3). These preliminary analyses indicate that at some point oil migrated through the Cane Creek in this area.

A much more detailed report on the fluid inclusion analyses will be available as part of the Final Report on the Cane Creek tight oil play.

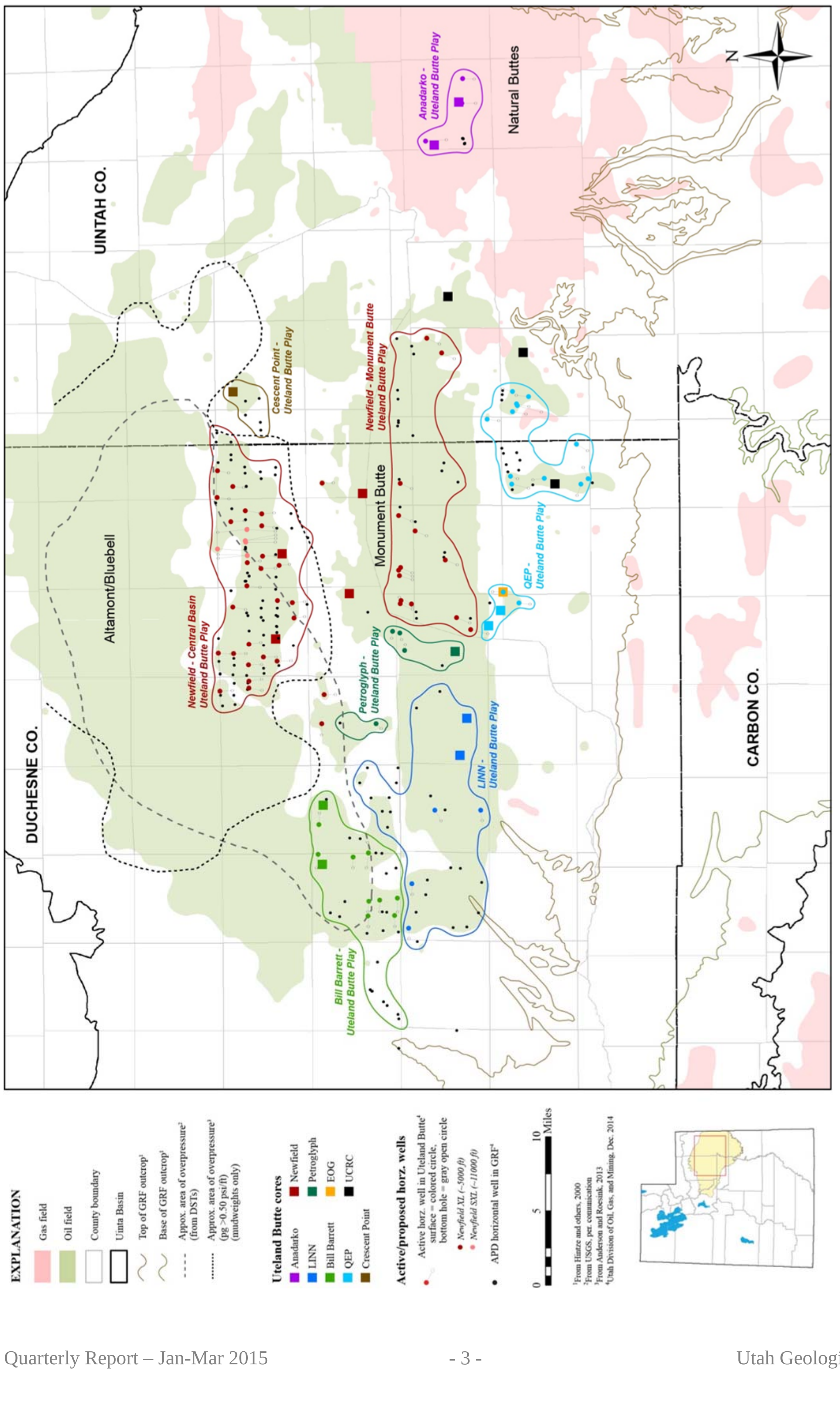


Figure 1. *Updated Uteland Butte play map.*

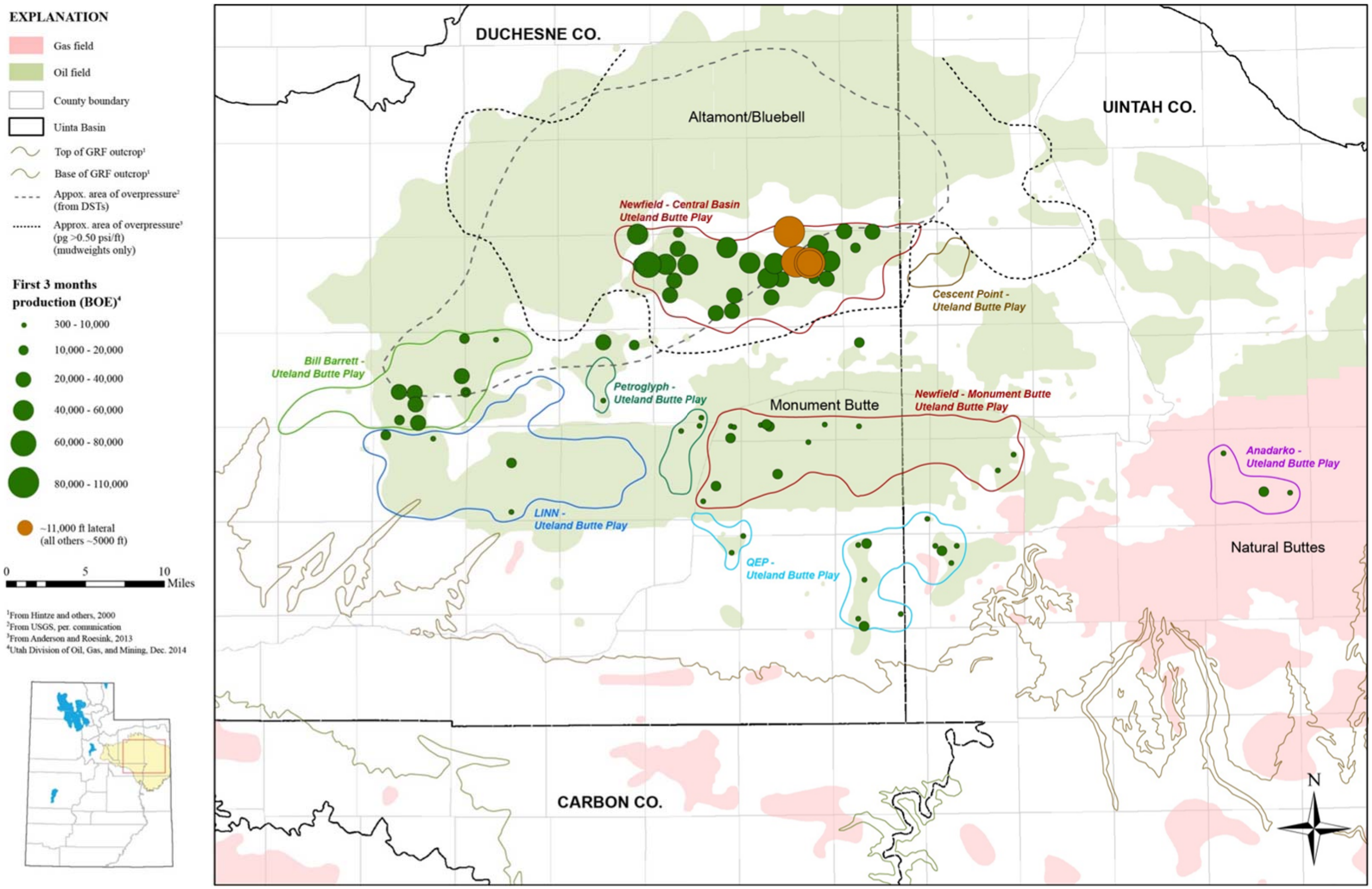


Figure 2. *Uteland Butte production map showing the first three months of production from horizontal wells.*

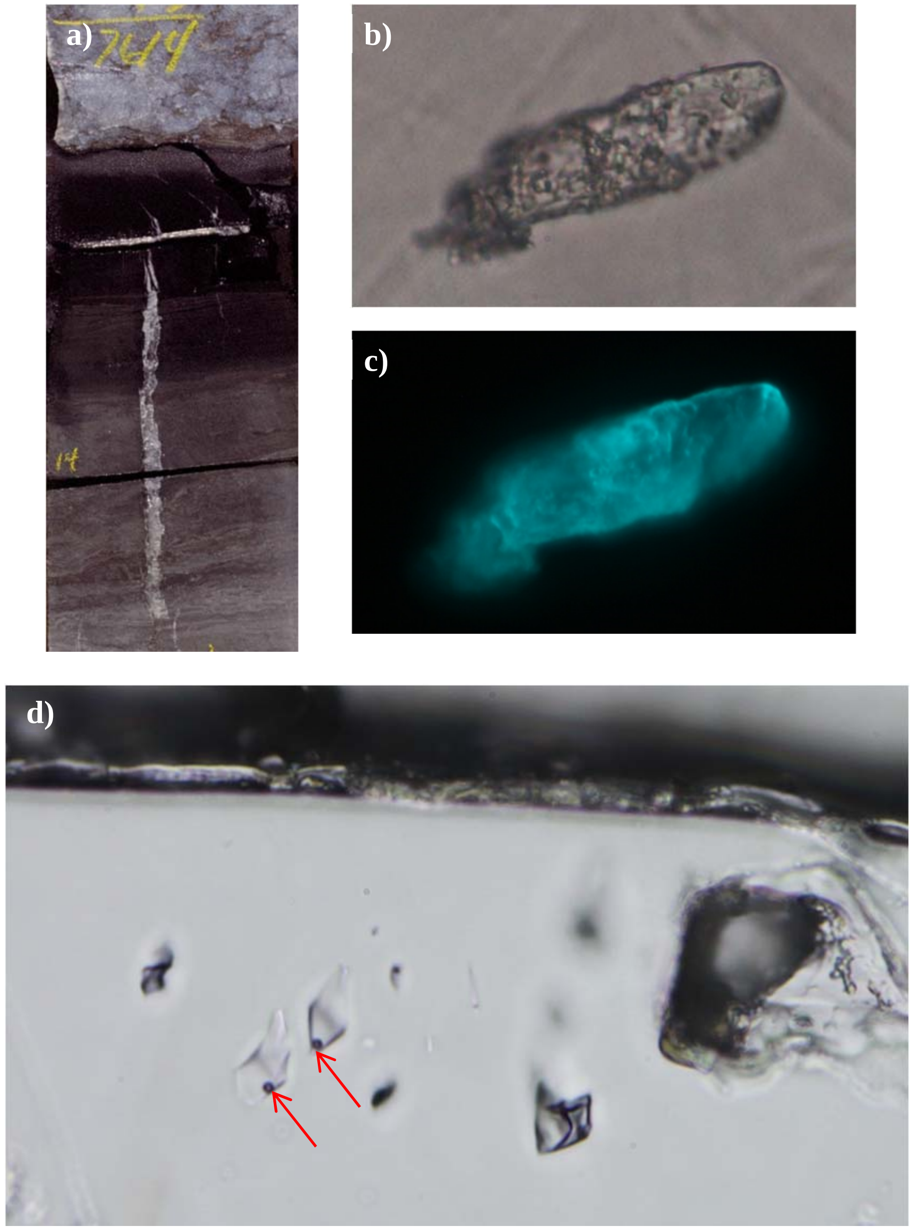


Figure 3. *Examples of fluid inclusions within halite-filled fractures from the Cisco State 36-13 core, depth 7614.6 ft, scale ~50x. a) Halite-filled fracture as seen in the core. b) Thin section photo of fluid inclusion under plane light. c) The same inclusion under fluorescence; analysis indicates 85-95°C minimum trapping temperature, while the blue fluorescence indicates oil at roughly 40° API. d) Examples of air bubbles (red arrows) within fluid inclusions.*

Task 5.0: Outcrop Examination and Characterization – Uinta Basin

An important collaboration has been set up with Dr. Rick Sarg, prominent carbonate geologist at the Colorado School of Mines (CSM). UGS is partially funding a CSM graduate student to research the Uteland Butte on the eastern side of the Uinta Basin. The student has measured several Wasatch-Green River-transition outcrop sections on the western flank of the Douglas Creek arch and will compare them to the Anadarko Uteland Butte cores from the Natural Buttes gas field. Meanwhile, the UGS will continue to focus its research efforts on the main producing area of the Uteland Butte (the distal portion) on the western side of the Uinta Basin, and CSM will help determine how the unit changes to the east. The Uteland Butte is much shallower to the east and the organic-rich intervals are thermally immature. Preliminary core interpretations by the PI suggest that the overall facies changes eastward and represents a more proximal, fresher water lacustrine depositional setting. Even though the Uteland Butte in this area is not "self-sourcing," hydrocarbons are most likely migrating to these shallower reservoirs from deeper, mature rocks to the west, but the overall play in this eastern area is much more speculative.

Task 6.0: Well Completion Optimization

The following report was provided by Dr. John McLennan, Energy and Geoscience Institute, University of Utah, and Task 6 team leader.

Summary of Ongoing Work

This quarterly report summarizes initial fracture toughness testing results on surrogate samples. The purpose is to develop alternative measurement techniques that will show the influence of fluid rock interaction. Also provided are preliminary results for Energy Release criteria that can be used in place of physically unfounded brittleness indicators. Ongoing work will extend both of these research efforts. In addition, adaptation of civil engineering indices (Rock Quality Designation (RQD) and Geologic Strength Index (GSI)) will be investigated, as will more simple techniques such as correlating vertical and lateral growth with indirect tensile strength and acoustic measurements.

Fracture Toughness Measurements

Preliminary fracture toughness tests are being made on surrogate cement paste samples. Actual rock samples will be evaluated in the near future.

Sample Preparation: Using a three-point bending apparatus, a satisfactory preliminary cutting method was developed to emplace starter fractures, and a suitable load frame was located to measure fracture toughness on air-dried cement samples. The cement samples were used to identify any usability flaws with the sample machining and testing apparatus. Three- and four-inch diameter cement cylinders were cast and cured in tap water. These samples were cut into half disks of appropriate size with a circular saw. This bottom face is then surface ground to be acceptably parallel with the tangent of the peak of the arc of the half-cylinder. Once the samples were surface ground, the dimensions were retaken to check tolerances and new sample dimensions and a notch was cut into them. The notch was cut with a customized band saw blade with a thickness of 0.020 inches. Most of the sample slots were perpendicular to the bottom, while a few were not, resulting in some of the samples being mixed mode fracture toughness.

***Testing*:** Each sample was installed into the three-point bending apparatus and loaded parallel to the notch. Certain minor design modifications were identified. Twelve samples were tested and the results are summarized below.

Results: Load versus vertical displacement plots are shown in Figures 4 and 5 for the three and four inch samples, respectively. Most of the samples experienced brittle failure, as expected. This is indicated by the sharp peak at the maximum load. The samples that failed in this way had fractures that propagated from the notch tip toward the peak of the arc of the sample. The samples with more post-peak displacement failed with somewhat different mechanisms. Some of these samples had void defects from water elution out of the sample during curing. In these samples, the fracture moved directly toward the defect and then failed upward from there. These are the multiple peaks seen.

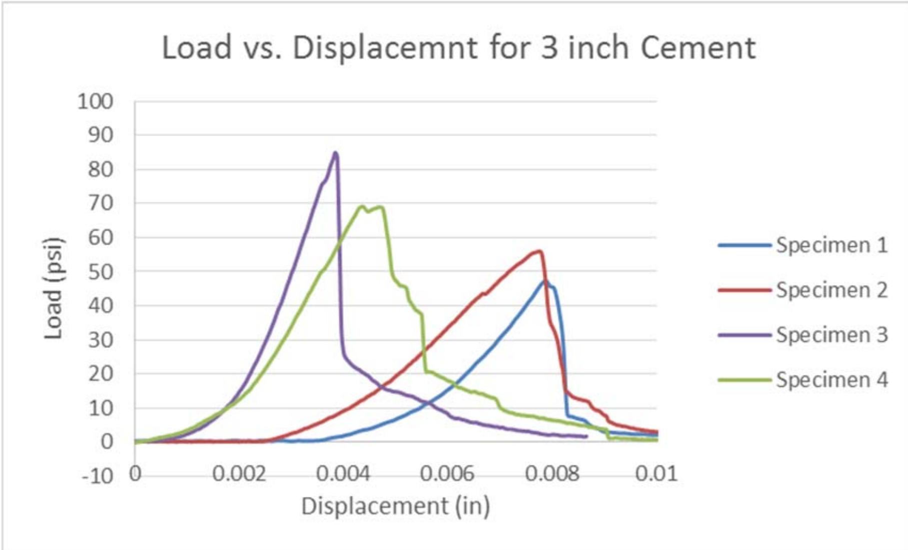


Figure 4. *Load versus displacement for 3-inch cement samples.*

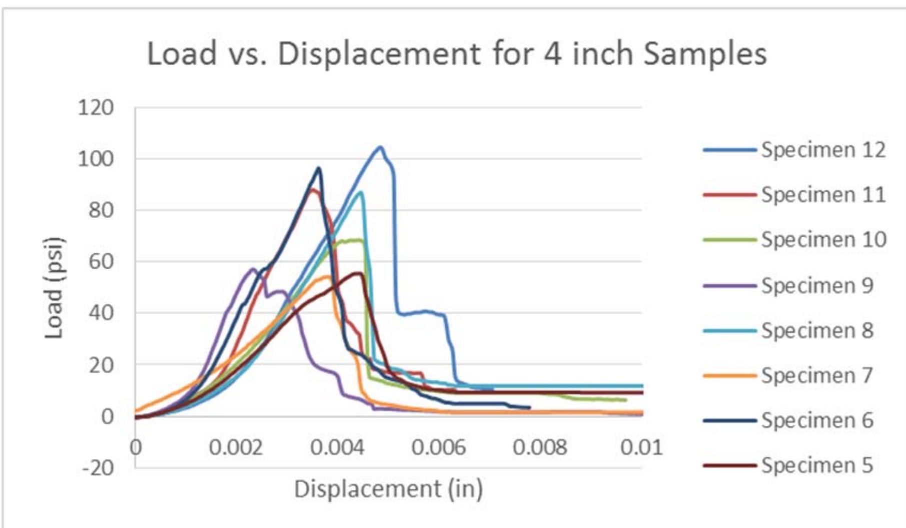


Figure 5. *Load versus displacement for 4-inch cement samples.*

The fracture toughness was then calculated from the peak load and the geometric parameters using the "ISRM-Suggested Method for Determining the Mode I Static Fracture Toughness Using Semi-Circular Bend Specimen" by Kuruppu, M.D., Obara, Y., Ayatollahi M.R., Chong, K.P. and Funatsu, T. The fracture toughness results are shown below in Table 1.

Table 1. Static mode I fracture toughness results for cement samples.

Specimen	Diameter (inches)	Maximum Load (lbf)	Extension at Maximum Axial Load (inches)	[1]B (in)	K_{IC} (kPa-$m^{0.5}$)	K_{IC} (psi-$in^{0.5}$)
1	3	47.34	0.00788	1.18	107.05	97.40
2	3	56.02	0.00775	1.21	123.38	112.26
3	3	85	0.00384	1.17	193.50	176.05
4	3	69.19	0.00437	1.06	173.84	158.17
5	4	55.49	0.00437	1.57	94.10	85.62
6	4	96.37	0.00362	1.56	165.51	150.58
7	4	54.25	0.00382	1.57	92.46	84.13
8	4	86.86	0.00446	1.59	145.49	132.37
9	4	57.02	0.00234	1.57	96.70	87.98
10	4	68.54	0.00442	1.57	116.24	105.76
11	4	88.08	0.0035	1.61	145.73	132.59
12	4	104.45	0.00485	1.65	169.51	154.23

[1]B is the average distance to the mouth of the notch along the lower flat surface.

The resulting cement fracture toughness was found to be lower than the range found for concrete, which ranges from 0.2-1.2 MPa-$m^{0.5}$. While acknowledging that concrete and cement are different, it is important to note that notch geometry, especially tip geometry, and sample defects can result in lower values.

Apparatus Modifications: A new top roller support and adapter are being machined. The base will also have a centered measuring scale etched onto it in both metric and English units. A method for fixing the bottom roller supports in place has not yet been devised but is anticipated. Once these changes are in place, issues with repeatability and usability should be resolved.

Future Testing: Additional cement samples have been poured and are curing. These samples will be used to further set up and calibrate the testing system. A high speed video camera will be incorporated in order to attempt to capture/quantify the fracture propagation. We will also experiment with a high-speed infrared camera. This method is interesting because ahead of the crack tip, microfractures form and energy is released in the form of newly formed surfaces and heat. The heat would be picked up by the infrared camera and is a possible method to measure fracture propagation.

Once the camera and testing setup is determined to be ready, appropriate samples from selected Uteland Butte and Cane Creek cores will be taken, machined to the appropriate size, and tested.

Available Indices for Brittleness

Researchers have argued that Rickman's index accounts for geomechanical characteristics of brittleness. While this index can have merit from the perspective of convenience, it is patently not a representation of brittleness or ductility because it only incorporates elastic properties. By comparing various mechanical properties of rocks, the Task 6 team hopes to develop energy release indices to better assess if there is a preferred calculation. The indices the team will investigate are as follows.

For comparative purposes, the team will assess mineralogically-based indices (Figure 6).

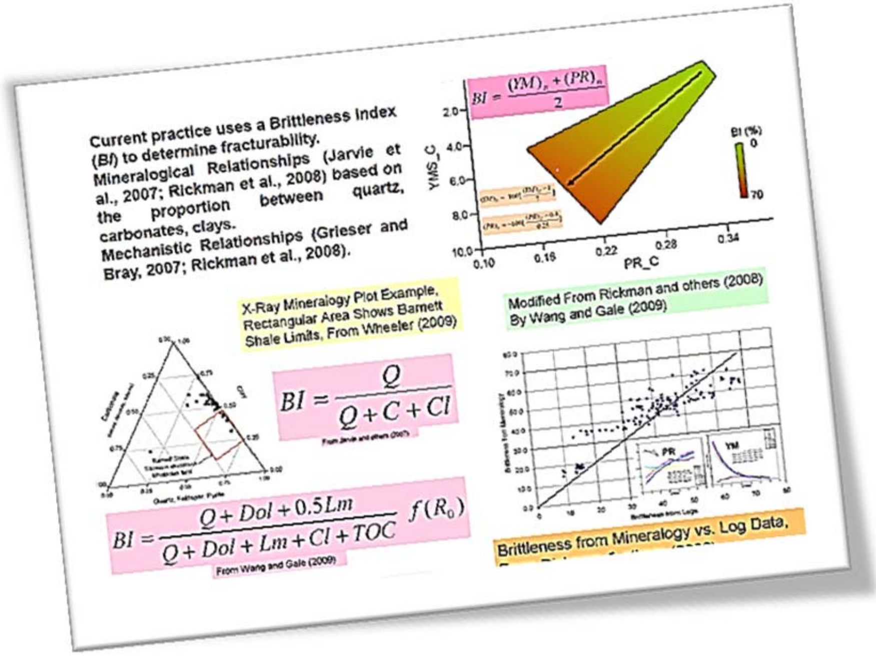


Figure 6. *Various mineralogic indices for so-called brittleness prediction.*

The two indices include:

$$BI = \frac{Quartz}{Quartz + Calcite + Clay} \qquad BI = \frac{Quartz + Dolomite + 0.5Limestone}{Quartz + Dolomite + Limestone + Clay + TOC} f(Ro)$$

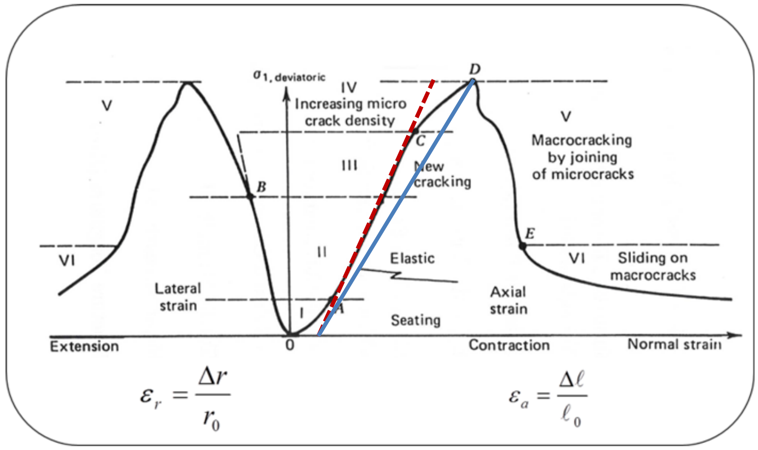
For comparative purposes, the team reports the Rickman-type brittleness index:

$$BRIT = 0.5\left\{\left(\frac{E-1}{8-1}\right)\times 100 + \left(\frac{\nu - 0.4}{0.15-0.40}\right)\times 100\right\}$$

The team has also developed four descriptive indices for understanding potential energy release on failure.

- The first Energy Release Index (ER1) qualitatively suggests energy loss up to the peak load:

$$ER1 = \frac{Tangent\ Modulus}{Secant\ Modulus}$$



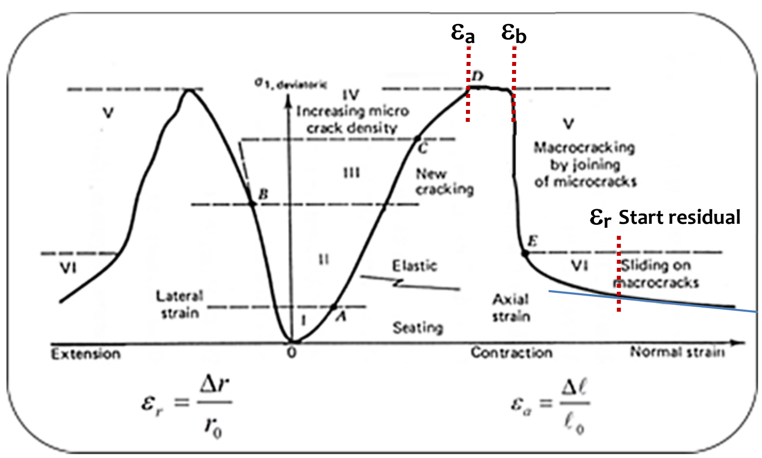
The slope of the red dashed line indicates a tangent, elastic Young's modulus. The slope of the solid blue line is a secant. Notice that these do not need to pass through the origin if there is "seating" and/or microcrack closing.

The larger this ratio, the more energy is released before ultimate failure and there will be less extreme release of energy on failure.

- The second Energy Release Index (ER2) is based on the relative amount of axial deformation after the peak strain:

$$ER2 = \frac{\varepsilon_b - \varepsilon_a}{\varepsilon_r - \varepsilon_a}$$

- ε_b is the strain when rapid, unstable load capacity degradation is first experienced.
- ε_a is the strain at or near peak loading (post-yield, initiation of strain hardening or perfect plasticity.
- ε_r Onset of residual load-bearing capacity (notice the backwards trending tangent).



Ratio of Stable Plastic Strain to Strain at Residual (axial)

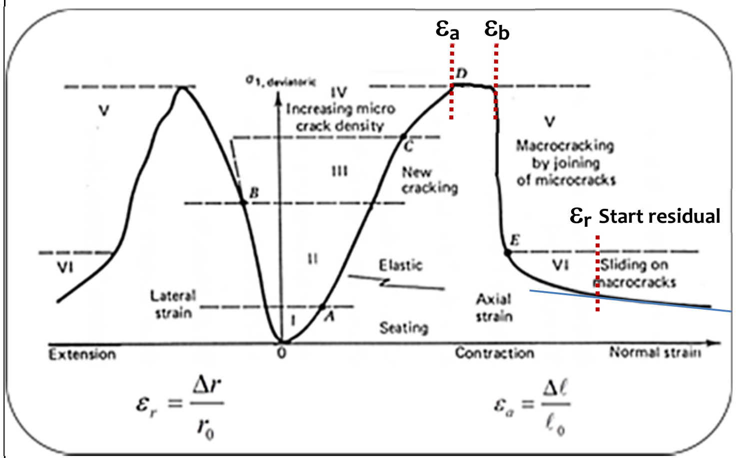
a) If this ratio is small and the onset of residual strain is small, behavior is brittle.
b) If this ratio is small and residual is large, behavior is ductile.
c) If this ratio is about 1, the ductility is indeterminate.

- The third Energy Release Index (ER3a) is based on the relative amount of energy released after the peak strain, using only axial stress and strain:

$$ER3 = \frac{V_f}{2mE_t}\left[\left.(\sigma_1 - \sigma_3)\right|_2 - \left.(\sigma_1 - \sigma_3)\right|_3\right]^2$$

$$V_f = \pi \frac{D^2}{4}(\varepsilon_b - \varepsilon_r)(1 - 2\nu)$$

- ε_b is the strain when rapid, unstable load capacity degradation is first experienced.
- ε_r is the onset of residual load-bearing capacity (notice the backwards trending tangent) for axial strain.



Ratio of Stable Plastic Strain to Strain at Residual (axial)

- σ_1 is the peak axial stress (Pa)
- σ_3 is the total hydrostatic confining pressure (Pa)
- $\sigma_1 - \sigma_3$ is the peak axial differential stress (Pa)
- m is the mass of the sample (kg)
- E_t is the tangent Young's modulus (Pa)
- V_f is a proxy for the volume impacted (-)
- D is the sample diameter (m)
- V_f is the axial strain drop from b to residual plus an approximation for two radial strains in the same load space. The approximation uses a proxy for radial strain (Poisson's ratio) but uses the elastic value.
- ν is Poisson's ratio

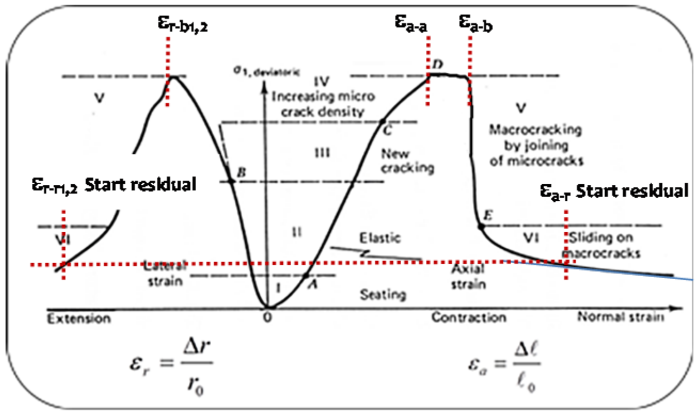
The larger this ratio, the more energy is released during post-peak deformation and load bearing capacity degradation. This was modified from Tang and Kaiser's work.

- A corollary Energy Release Index (ER3b) is based on the relative amount of energy released after the peak strain, using volumetric strain. It is analogous to ER3 with the exception that volumetric deformation is considered:

$$ER3 = \frac{V_f}{2mK}\left[\left.(\sigma_1 - \sigma_3)\right|_{a-b} - \left.(\sigma_1 - \sigma_3)\right|_{a-r}\right]^2$$

$$V_f = \pi \frac{D^2}{4}\left\{(\varepsilon_{a-b} - \varepsilon_{a-r}) + \sum_{i=1,2}(\varepsilon_{r-bi} - \varepsilon_{r-ri})\right\}$$

- ε_{a-b} is the strain when rapid, unstable load capacity degradation is first experienced.
- ε_{a-r} is the axial strain at the onset of residual load-bearing capacity (notice backwards trending tangent).



Ratio of Stable Plastic Strain to Strain at Residual (axial)

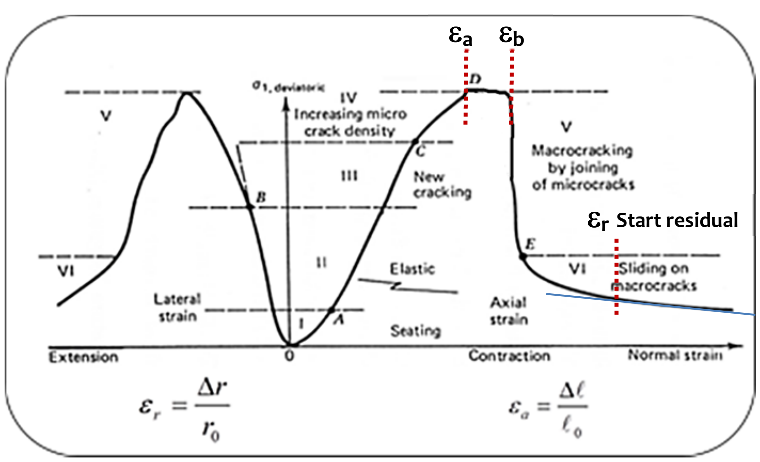
- σ_1 is the peak axial stress (Pa)
- σ_3 is the total hydrostatic confining pressure (Pa)
- $\sigma_1 - \sigma_3$ is the peak axial differential stress (Pa)
- m is the mass of the sample (kg)
- K is the elastic, isotropic bulk modulus (Pa)
- V_f is a proxy for the volume impacted (-)
- D is the sample diameter (m)
- V_f is the volumetric strain drop from b to r (residual).

The larger this ratio, the more energy is released during post-peak deformation and load bearing capacity degradation. This was modified from Tang and Kaiser's work.

- The fourth Energy Release Index (ER4) is based on the ratio of the peak and the residual axial differential stresses at in-situ conditions:

$$ER4 = \frac{\left.(\sigma_1 - \sigma_3)\right|_a}{\left.(\sigma_1 - \sigma_3)\right|_r}$$

- σ_1 is the total axial stress (Pa)
- σ_3 is the total hydrostatic confining pressure (Pa)
- $\sigma_1 - \sigma_3$ is the axial differential stress (Pa)
- Subscript "a" is for peak and "r" is for residual in the accompanying plot.



Ratio of Stable Plastic Strain to Strain at Residual (axial)

If this ratio is large, substantial energy release can be anticipated. It is not an absolute identifier because absolute magnitudes of the numerator and denominator are important as well.

These calculations are documented in Appendix A. Appendix B shows the indices plotted against logging parameters for the Bill Barrett 1-14-46 Uteland Butte core. The data for the other wells are being similarly evaluated.

CONCLUSION

Progress continues to be made on both parts of this project, the Uteland Butte and Cane Creek tight oil plays. Research into the origin and diagensesis of the Uteland Butte dolomites has commenced as several cores are being analyzed via thin section and a range of other analyses. Fluid inclusion and epifluorescence analyses on Cane Creek cores and cuttings are now completed, and a presentation on the epifluorecensce will be given at the upcoming AAPG meeting. All geomechanical testing is now complete and the Task 6 team has begun analyzing the data.

COST STATUS

Table 2. *Project costing profile for Budget Period 3.*

	Jan 2015		Feb 2015		Mar 2015	
	Plan	Actual	Plan	Actual	Plan	Actual
UGS-personnel	$11,027	$8,726	$11,027	$6,333	$11,027	$10,106
Travel Expenses[1]		$154		$591		$1,420
Analyses[2]						$450
Miscellaneous[3]				$362	$500	$450
SUBTOTALS	$11,027	$8,880	$11,027	$7,286	$11,527	$12,426
UGS OVERHEAD (34.44%)	$3,798	$3,058	$3,798	$2,509	$3,970	$4,279
SUBCONTRACTS						
EGI	$6,771	$6,974	$6,771		$6,771	
Eby[4]	$2,724		$2,724	$5,420	$2,724	
CSM				$35		
GRAND TOTALS	$24,320	$18,913	$24,320	$15,250	$24,992	$16,705

[1]Jan – Trip to Vernal in December to pick up Uteland Butte oil samples; Feb and Mar – trip to Denver in February to examine Cane Creek cuttings using epifluorescence and sample Uteland Butte cores
[2]Mar – RockEval analyses on Cane Creek core
[3]Feb – Triple O Slabbing charges for core layout and sampling; Mar – AAPG registration for PI
[4]Feb – Includes $975 in cost share

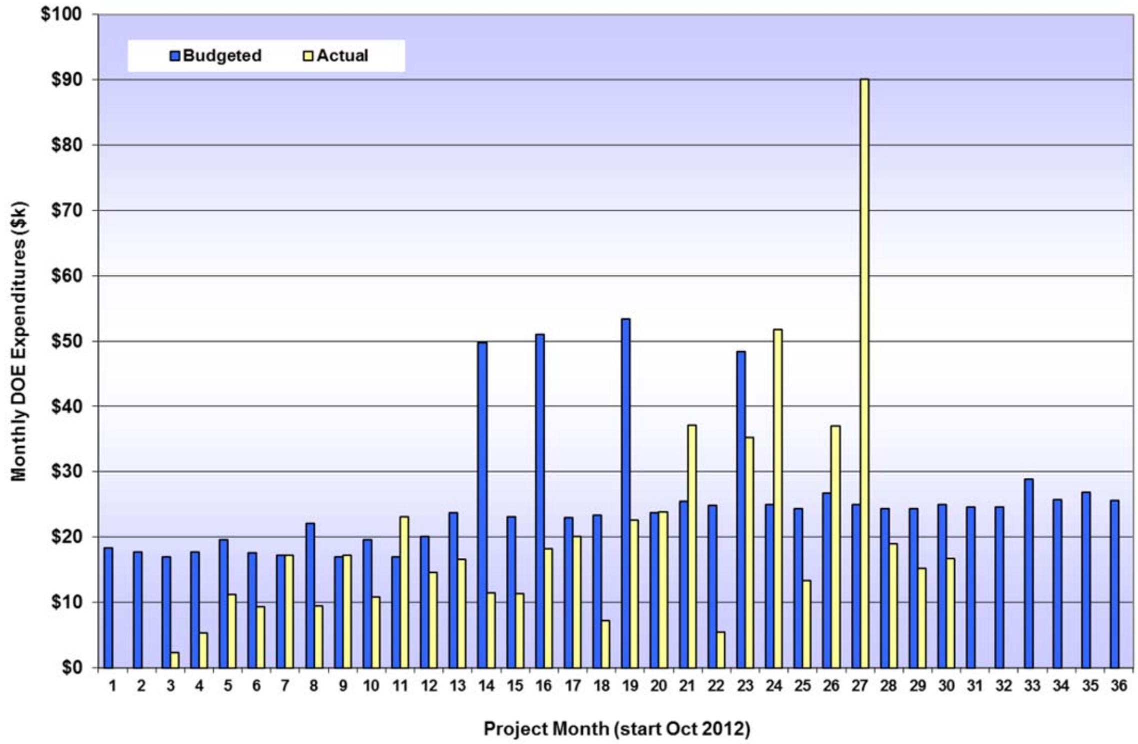


Figure 7. *Project costing profile.*

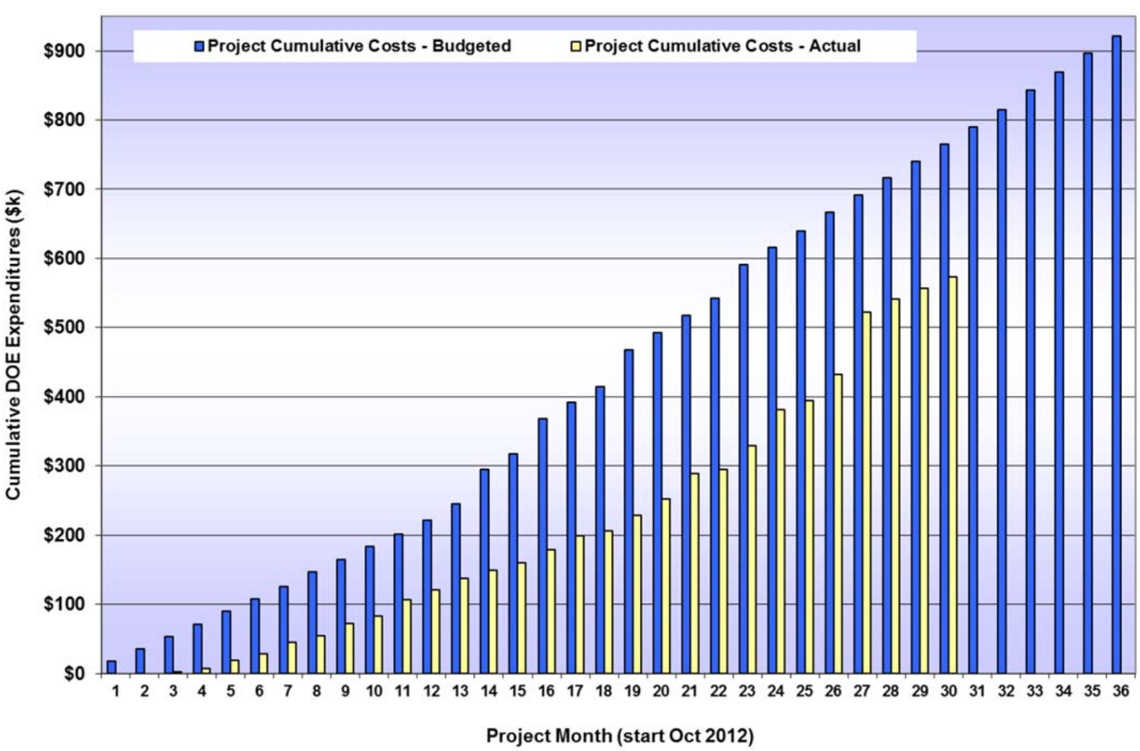


Figure 8. *Project cumulative costs.*

MILESTONE STATUS

Table 3. *Milestone log for Budget Period 3.*

	Title	Related task or subtask	Completion Date	Update/comments
Milestone 32	Quarterly updates of website	Subtask 2.1	Quarterly	Ongoing
Milestone 33	Quarterly reports	Subtask 2.2	Quarterly	Ongoing
Milestone 34	Profiles of mechanical stratigraphy	Subtask 6.5	31-Mar-15	Ongoing
Milestone 35	Regional Correlation and Mapping	Subtask 7.1	31-Mar-15	Ongoing
Milestone 36	Regional cross sections	Subtask 7.2	31-Mar-15	Ongoing
Milestone 37	Sweet spot maps	Subtask 7.3	31-Mar-15	Ongoing
Milestone 38	Technical presentations at National AAPG	Subtask 2.4 & 5	Apr-15	2 presentations at 2015 AAPG
Milestone 39	Core workshop and/or field trip	Subtask 2.7	Jul-15	Delayed
Milestone 40	Locating completions	Subtask 6.4	30-Sep-15	Ongoing
Milestone 41	Stimulation diagnostics modeling	Subtask 6.6	30-Sep-15	Ongoing
Milestone 42	Reservoir simulations/stimulation locating	Subtask 6.7	30-Sep-15	Ongoing
Milestone 43	Final publications	Subtask 2.6	30-Sep-15	Delayed
Milestone 44	Final interpretation	Task 8	30-Sep-15	Delayed

ACCOMPLISHMENTS

- Commenced research partnership with University of Alberta and began Uteland Butte dolomite investigation. Sampled several Uteland Butte cores (8 cores total) in Salt Lake City and in Denver for thin section analysis and other analytical tests.
- Dr. Joe Moore, Energy and Geoscience Institute, University of Utah, completed his analysis of fluid inclusions in Cane Creek cores.
- In collaboration with the USGS, the PI co-wrote a paper on the Uteland Butte and submitted it for publication in the upcoming Rocky Mountain Association of Geologists source rocks volume (scheduled for publication in fall 2015).

PROBLEMS OR DELAYS

Several subcontracts (EGI, TerraTek, Eby Petrography & Consulting, University of Alberta) were significantly delayed due to new, unanticipated, and exceedingly cumbersome State of Utah contract procedures; therefore the PI anticipates needing a one year, no-cost extension, pushing the project end date to September 30, 2016. Sufficient project funds are available for the extension as the project is currently only 74.8% of budget.

PRODUCTS AND TECHNOLOGY TRANSFER ACTIVITIES

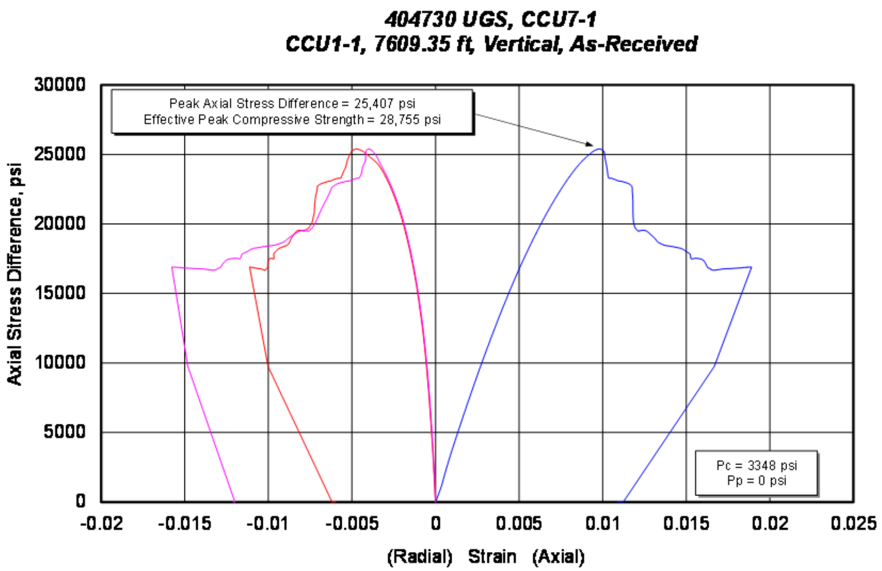
- Project website

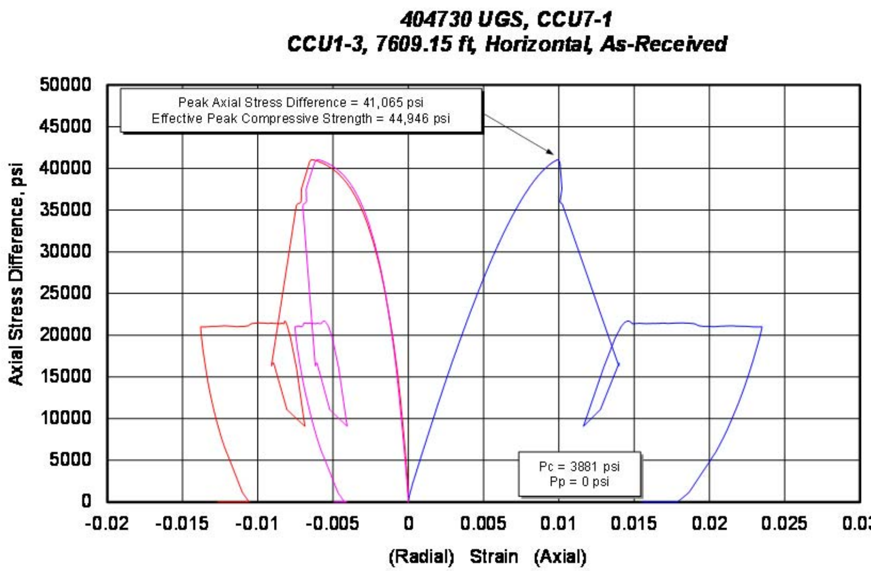
    - The project website has been updated with new reports and abstracts.
    - http://geology.utah.gov/emp/shale_oil
- Quarterly Report – October to December 2015
    - Completed late January and is available on the project website.
- Abstracts (2) – 2015 AAPG Annual Meeting, Denver, CO, May 31-June 3, 2015
    - Two abstracts were accepted for presentation at the 2015 AAPG meeting in Denver.
    - A poster titled *Analyzing Core from Two Emerging Tight Oil Plays in Utah: The Uteland Butte Member of the Green River Formation in the Uinta Basin and the Cane Creek Shale within the Paradox Formation in the Paradox Basin* will be presented in the "Core – The Ultimate Source of Underground Truth" session on Monday, June 1, 2015 (all day poster session).
    - A poster titled *Potential Oil-Prone Areas in the Cane Creek Shale Play, Paradox Basin, Utah, U.S.A., Identified by Epifluorescence Techniques* will be presented in the "Tight Oil Plays" session on Monday, June 1, 2015 (all day poster session).
    - Both abstracts are currently available on the UGS project website and the posters will be available on the website after the conference.
- 2015 RMAG Source Rock Compendium volume
    - In collaboration with the USGS, a paper detailing the Uteland Butte tight oil play was submitted for the upcoming 2015 Rocky Mountain Association of Geologists Source Rock Compendium volume. The volume is expected to be published in late 2015.
- Project team member, Craig Morgan, wrote an article on the Cane Creek tight oil play for the upcoming issue of *Survey Notes*, the UGS newsletter, scheduled for publication in May 2015.

Appendix A

Processed Triaxial Stress Data

Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
Fidelity Cane Creek CCU7-1									
silty dolomite	CCU1-1	7609.35	Vertical	2.624	3348	28,755	20,162	3.447	0.23
	CCU1-3	7609.15	Horizontal	2.599	3881	44,946	24,935	5.507	0.30

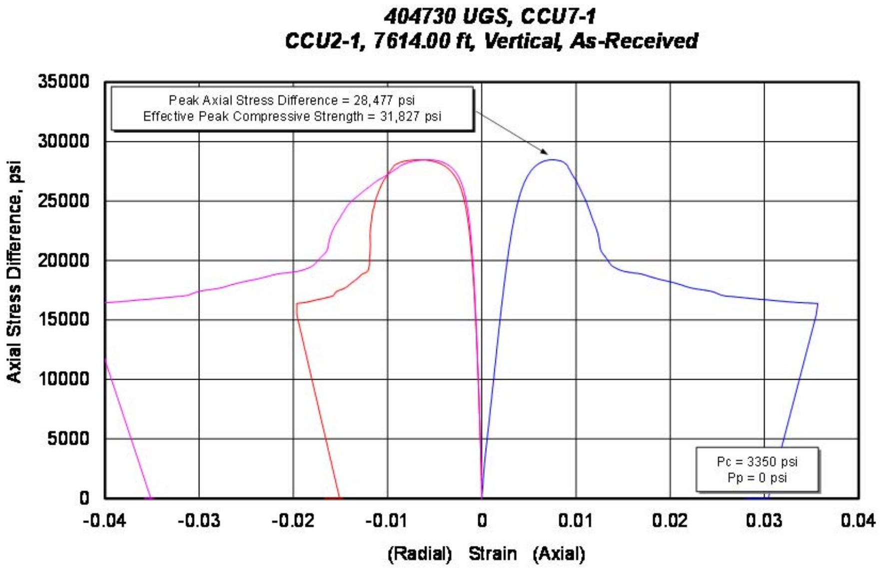


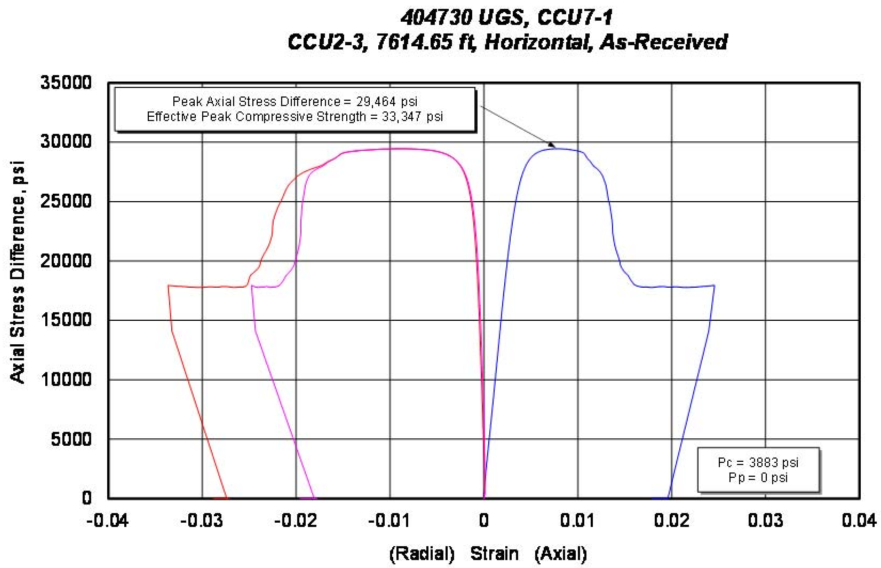


Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.36
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.006
Zone 3a: Tang and Kaiser Index (Axial): 0.68 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 2.48 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.51

Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.35
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0
Zone 3a: Tang and Kaiser Index (Axial): 1.615
Zone 3b: Tang and Kaiser Index (Volumetric): N/A
Zone 4: Peak to Residual Strength Ratio: 1.88

Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
Fidelity Cane Creek CCU7-1									
anhydrite	CCU2-1	7614.00	Vertical	2.886	3350	31,827	19,750	7.383	0.34
	CCU2-3	7614.65	Horizontal	2.954	3883	33,347	21,675	8.060	0.33



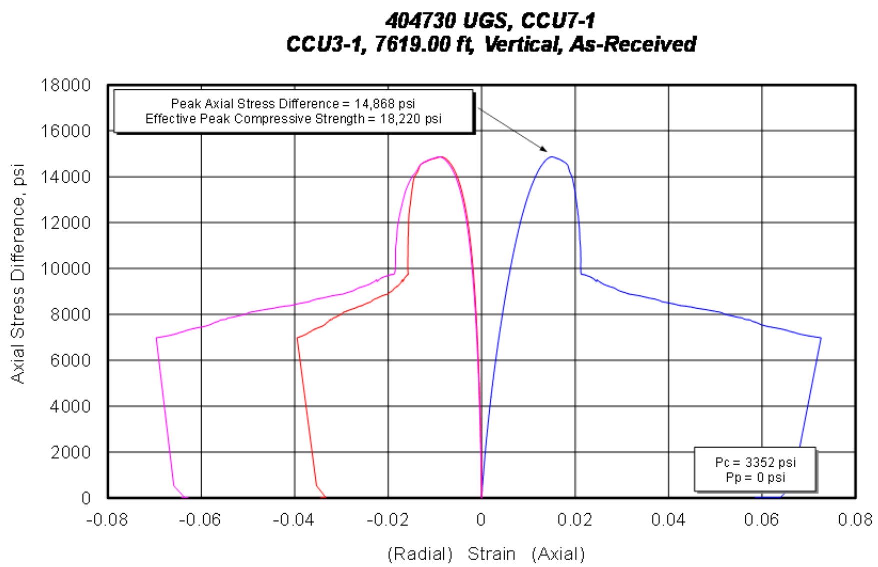


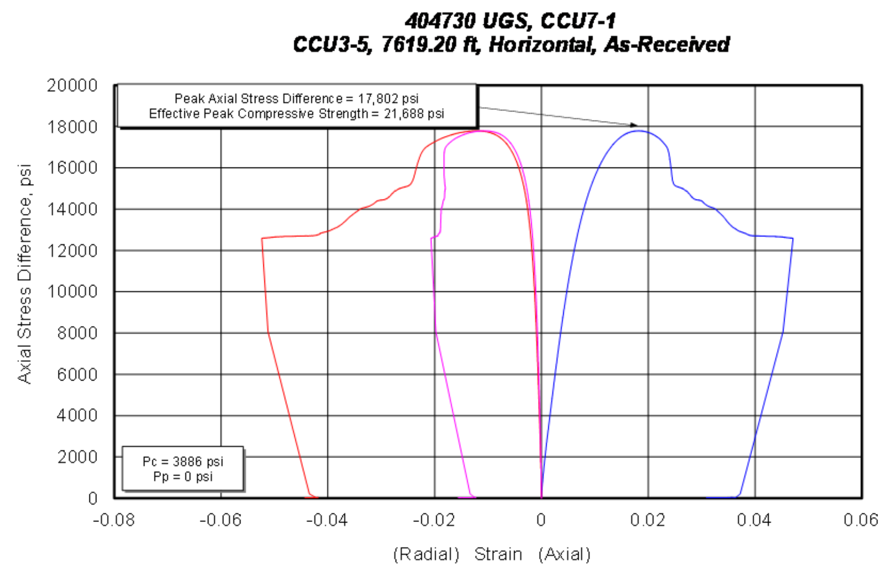
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.94
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.186
Zone 3a: Tang and Kaiser Index (Axial): 0.186 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 0.733 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.48

Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.90
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.293
Zone 3a: Tang and Kaiser Index (Axial): 0.379 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 0.2.45 J/tonne
Zone 4: Peak to Residual Strength Ratio:1.64

Fidelity Cane Creek CCU7-1

Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
silty dolomite - shale	CCU3-1	7619.00	Vertical	2.509	3352	18,220	-	1.686	0.28
	CCU3-5	7619.20	Horizontal	2.500	3886	21,688	16,561	2.054	0.24



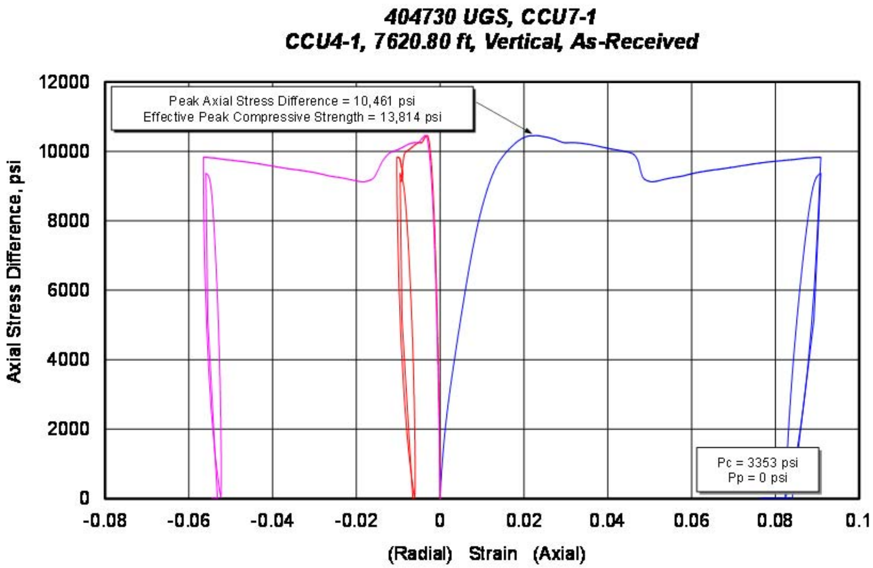


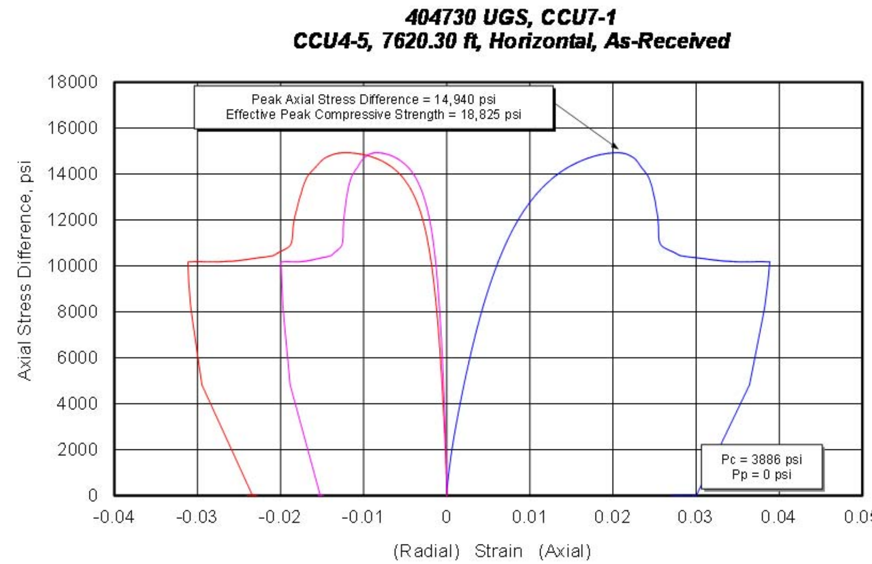
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.73
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.482
Zone 3a: Tang and Kaiser Index (Axial): 0.171 /tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 0.971 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.51

Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.90
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.309
Zone 3a: Tang and Kaiser Index (Axial): .889 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 3.97 J/Tonne
Zone 4: Peak to Residual Strength Ratio:1.39

Fidelity Cane Creek CCU7-1

Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm³)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
shale	CCU4-1	7620.80	Vertical	2.487	3353	13,814	-	0.820	0.15
	CCU4-5	7620.30	Horizontal	2.514	3886	18,825	14,071	1.118	0.24



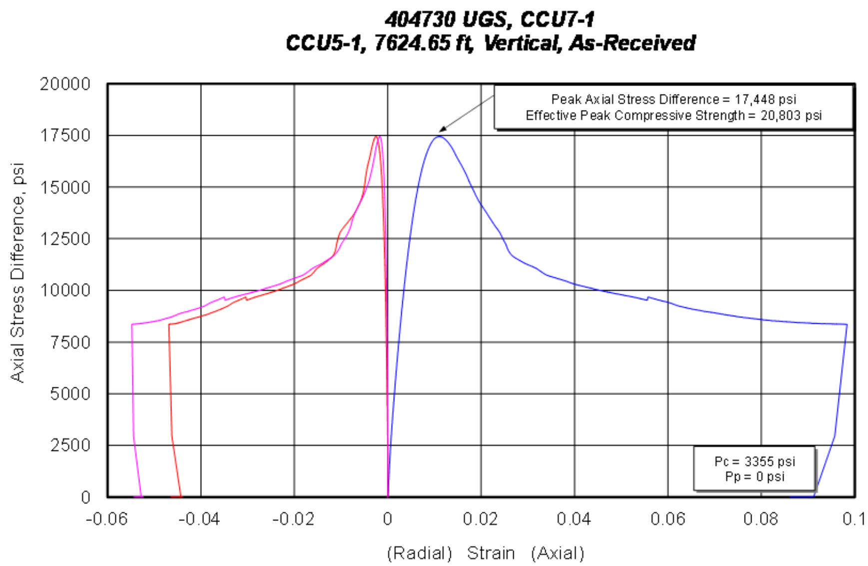


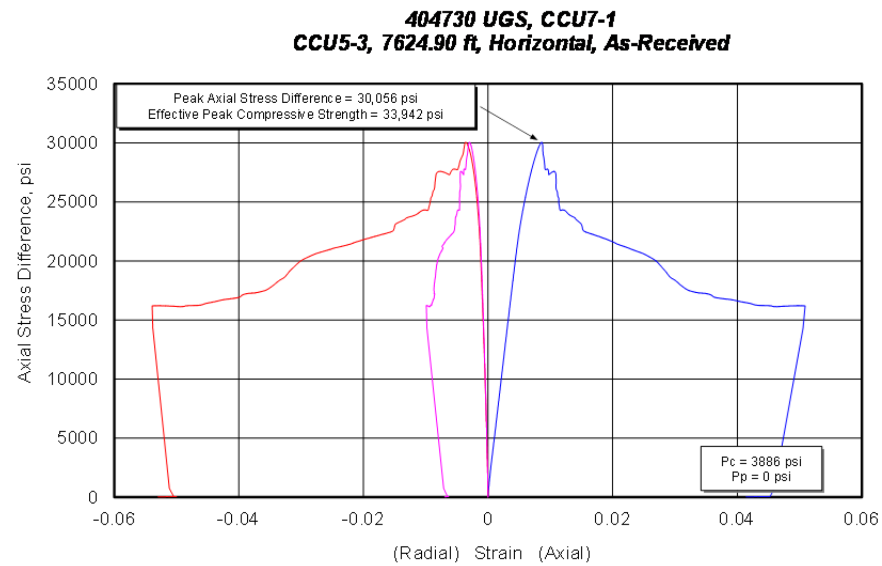
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.67
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.92
Zone 3a: Tang and Kaiser Index (Axial): .0045
Zone 3b: Tang and Kaiser Index (Volumetric): .047
Zone 4: Peak to Residual Strength Ratio: 1.05

Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 2.24
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.33
Zone 3a: Tang and Kaiser Index (Axial): .031 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 0.88 J/tonne
Zone 4: Peak to Residual Strength Ratio:1.41

Fidelity Cane Creek CCU7-1

Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
silty dolomite	CCU5-1	7624.65	Vertical	2.597	3355	20,803	11,732	2.696	0.13
	CCU5-3	7624.90	Horizontal	2.591	3886	33,942	20,104	4.517	0.25



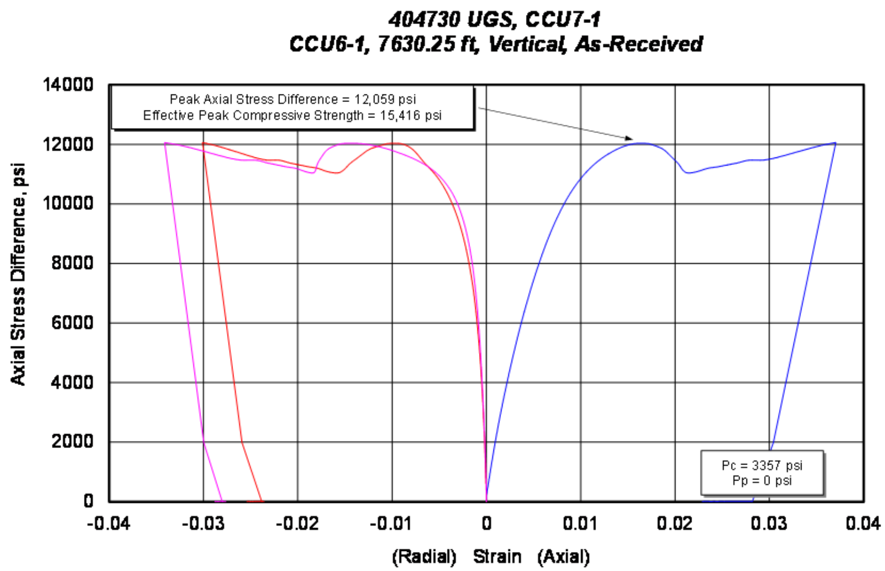


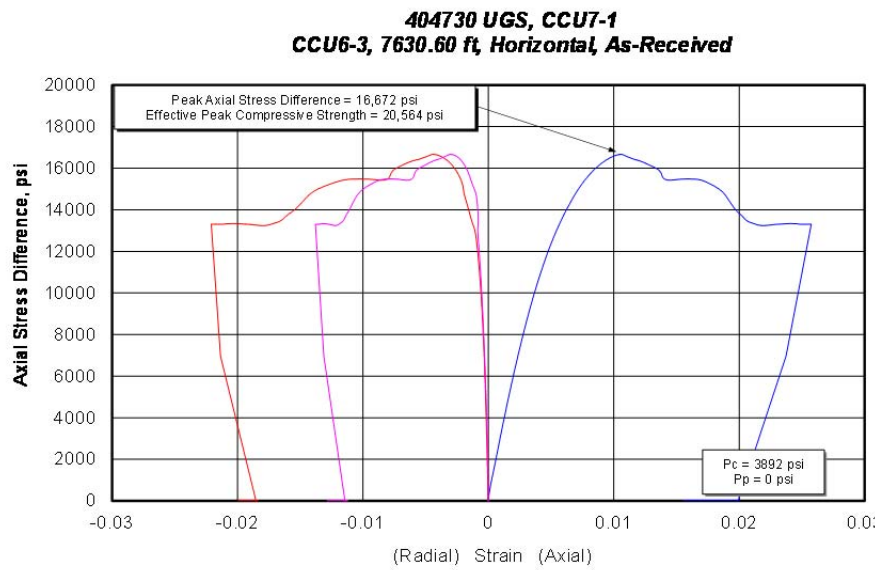
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.68
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.017
Zone 3a: Tang and Kaiser Index (Axial): 1.7 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 24.1 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.62

Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.28
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.096
Zone 3a: Tang and Kaiser Index (Axial): 3.37 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 9.99 J/tonne
Zone 4: Peak to Residual Strength Ratio:1.71

Fidelity Cane Creek CCU7-1

Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
silty dolomite	CCU6-1	7630.25	Vertical	2.504	3357	15,416	-	1.5060	0.24
	CCU6-3	7630.60	Horizontal	2.530	3892	20,564	17,198	2.774	0.15

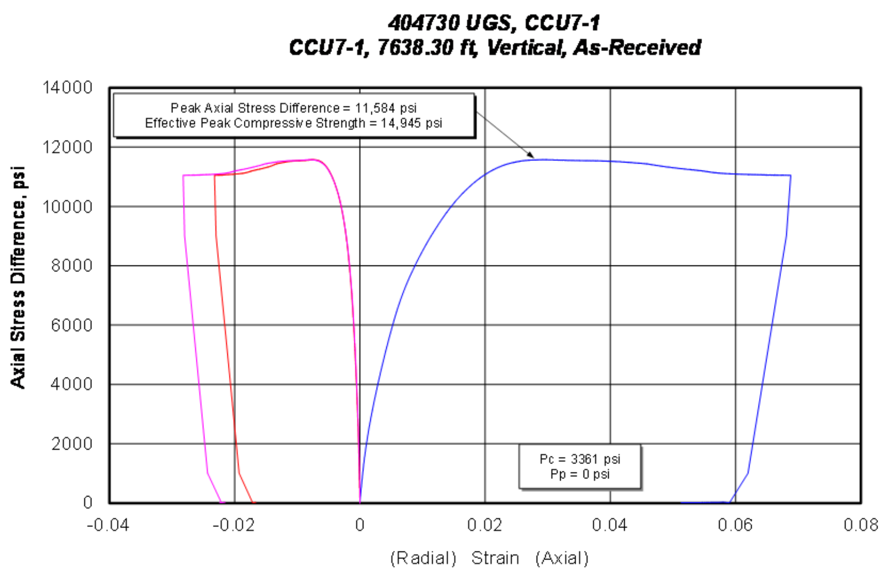




Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.88
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.459
Zone 3a: Tang and Kaiser Index (Axial): 0.0855
Zone 3b: Tang and Kaiser Index (Volumetric): .0257 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.08

Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.74
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.749
Zone 3a: Tang and Kaiser Index (Axial): 0.01597 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 0.0421 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.26

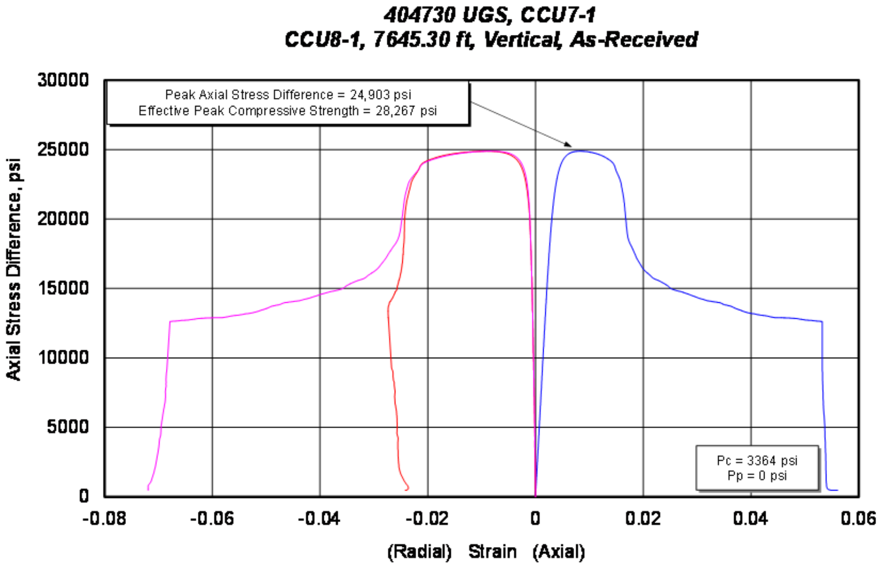
Fidelity Cane Creek CCU7-1									
Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
shale	CCU7-1[2]	7638.30	Vertical	2.458	3361	14,945	14,459	0.972	0.18

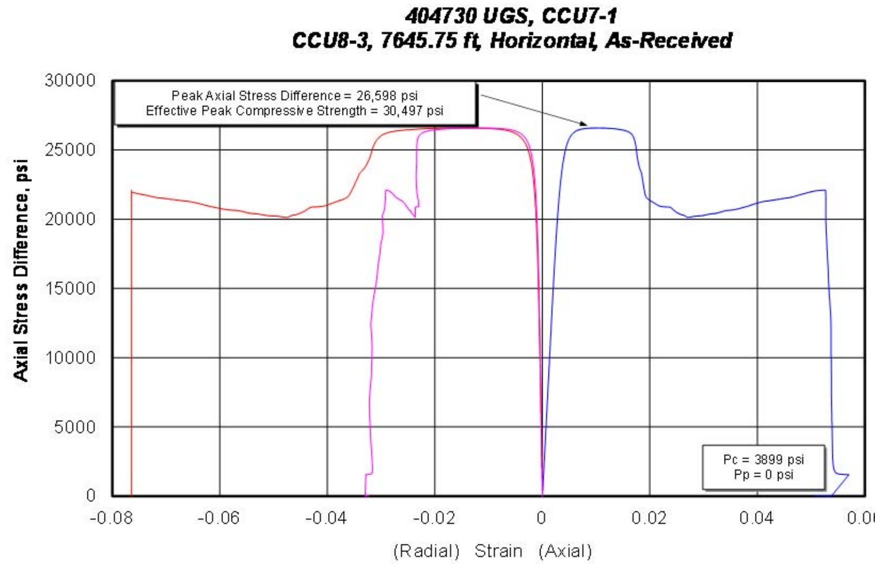


Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 2.17
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.605
Zone 3a: Tang and Kaiser Index (Axial): 0.0089 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 0.01 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.04

[2] CCU7-1 – Not enough material available to obtain additional samples, thus, no horizontally oriented sample was tested

Fidelity Cane Creek CCU7-1									
Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
anhydrite	CCU8-1	7645.30	Vertical	2.940	3364	28,267	-	7.233	0.35
	CCU8-3	7645.75	Horizontal	2.931	3899	30,497	-	7.603	0.35



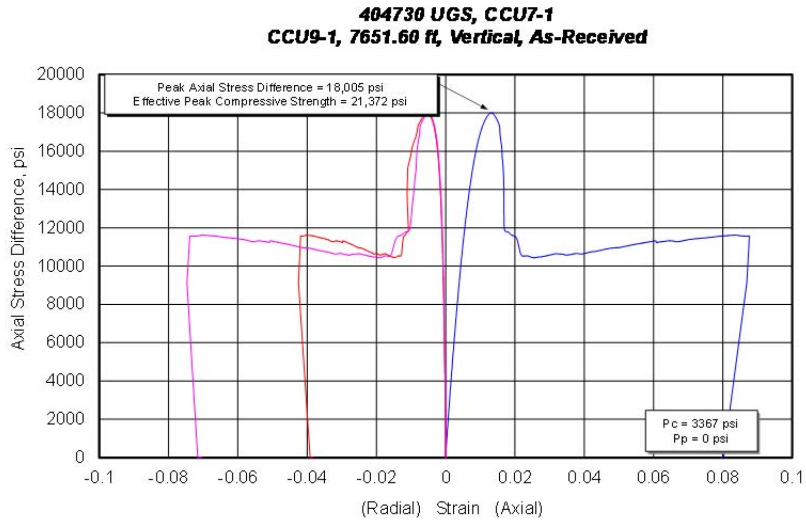


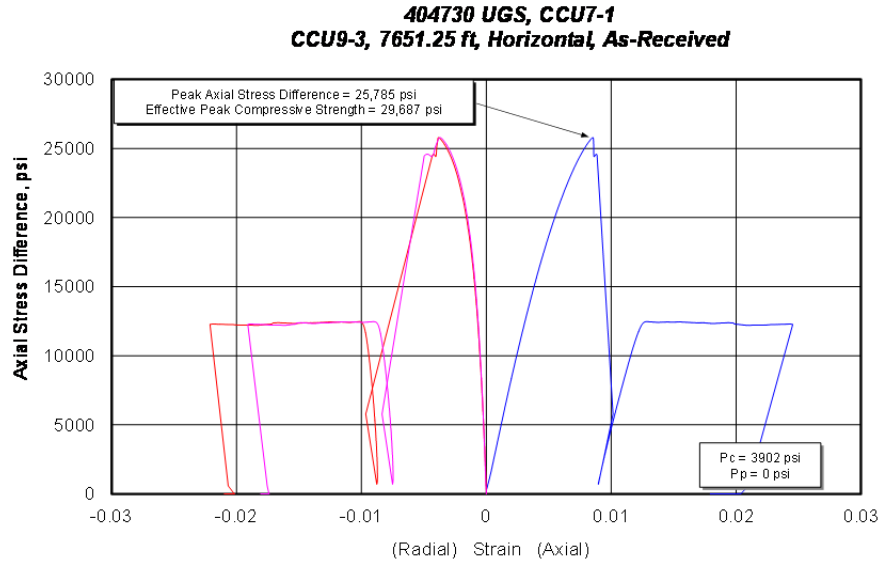
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.68
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.244
Zone 3a: Tang and Kaiser Index (Axial): 1.05 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 1.72 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.86

Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.71
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.542
Zone 3a: Tang and Kaiser Index (Axial): 0.108 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 0.251 J/tonne
Zone 4: Peak to Residual Strength Ratio:1.30

Fidelity Cane Creek CCU7-1

Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
silty dolomite	CCU9-1	7651.60	Vertical	2.577	3367	21,372	14,963	3.891	0.17
	CCU9-3	7651.25	Horizontal	2.582	3902	29,687	16,128	3,891,000	0.24



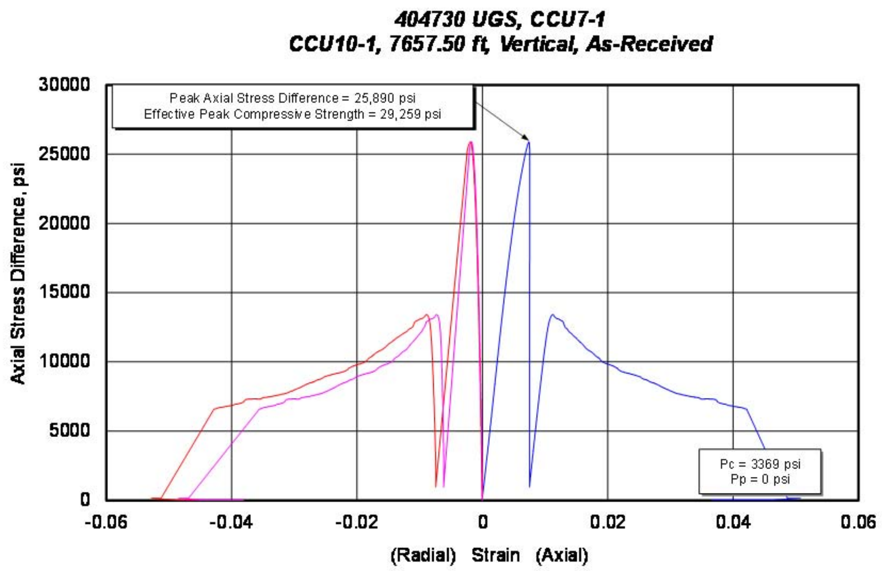


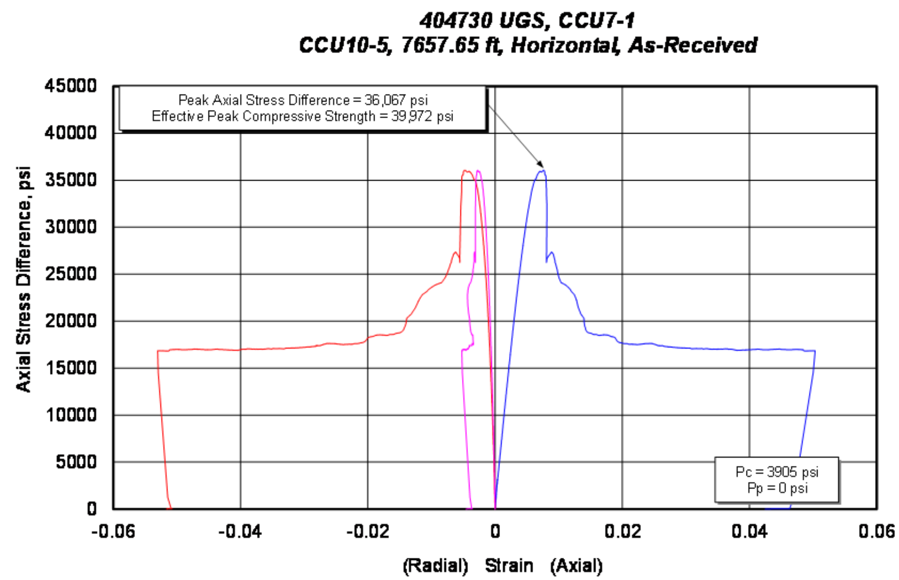
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.64
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.232
Zone 3a: Tang and Kaiser Index (Axial): 0.899 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 3.09 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.70

Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.29
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0
Zone 3a: Tang and Kaiser Index (Axial): 0.901 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 3.09 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.70

Fidelity Cane Creek CCU7-1

Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
fractured silty dolomite	CCU10-1	7657.50	Vertical	2.678	3369	29,259	-	4.290	0.18
	CCU10-5	7657.65	Horizontal	2.696	3905	39,972	20,882	6.534	0.33



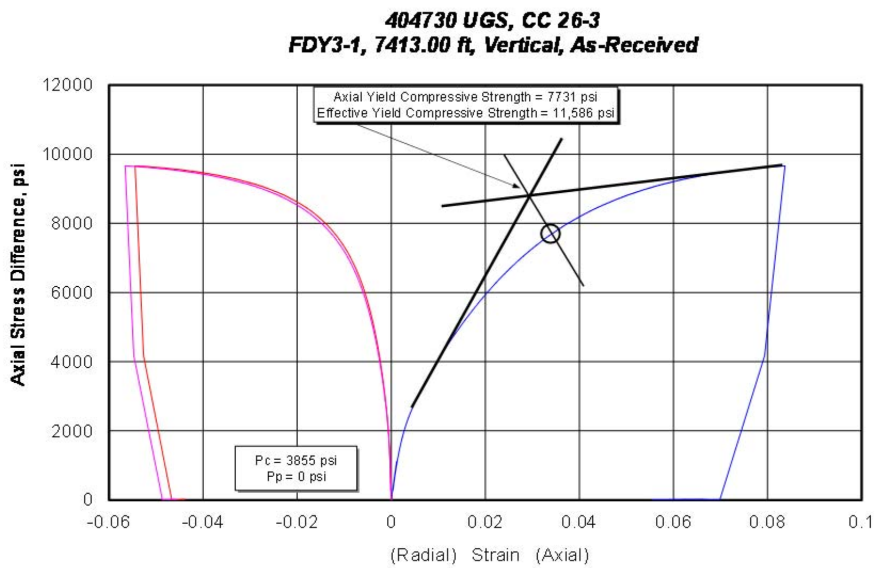


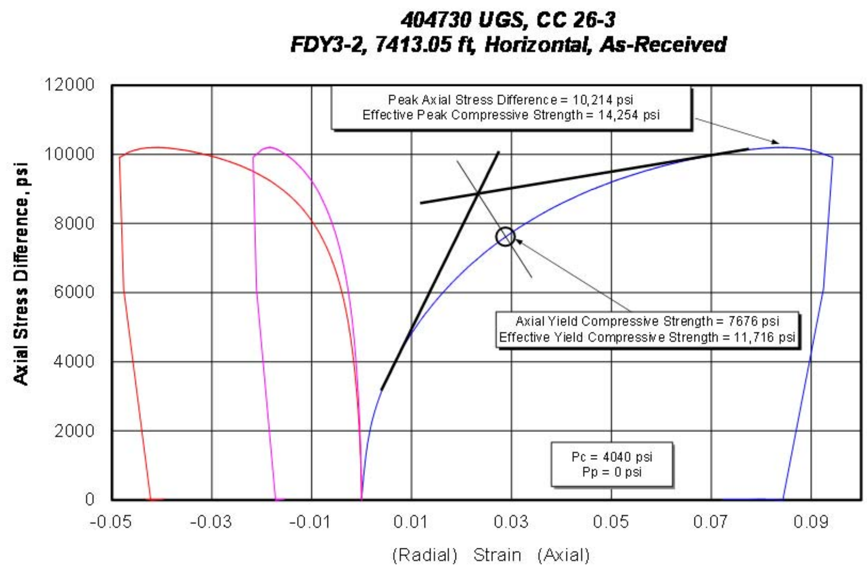
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.22
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0
Zone 3a: Tang and Kaiser Index (Axial): 0.765 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 5.43 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.94

Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.23
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.15
Zone 3a: Tang and Kaiser Index (Axial): 0.785 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 4.77 J/tonne
Zone 4: Peak to Residual Strength Ratio:1.84

Fidelity Cane Creek 26-31

Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
shale	FDY3-1	7413.00	Vertical	2.041	3855	11,586 (Y)	-	0.706	0.23
	FDY3-2	7413.05	Horizontal	2.009	4040	11,716 (Y)[3] 14,254	-	1.128	0.25





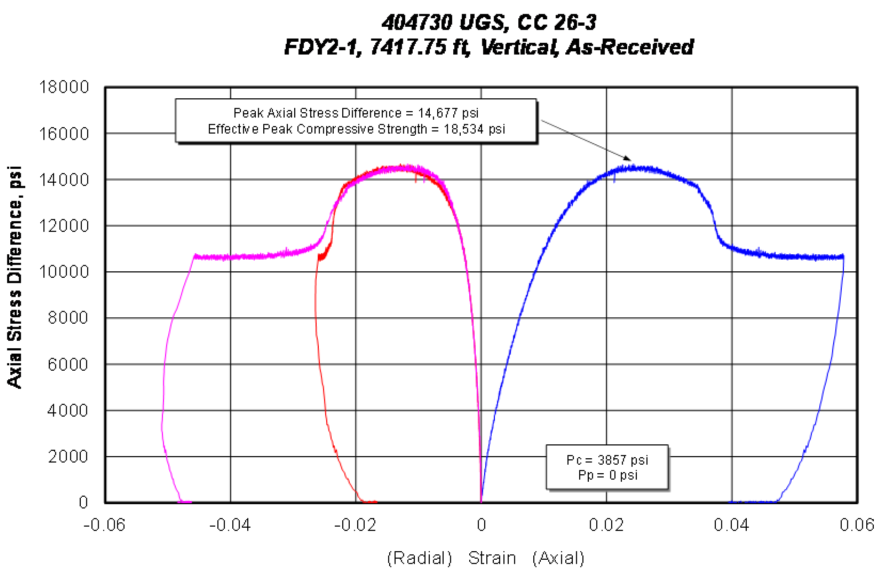
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 5.05
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.994
Zone 3a: Tang and Kaiser Index (Axial): 5.08×10^{-8}
Zone 3b: Tang and Kaiser Index (Volumetric): 1.88×10^{-4}
Zone 4: Peak to Residual Strength Ratio: 1.00

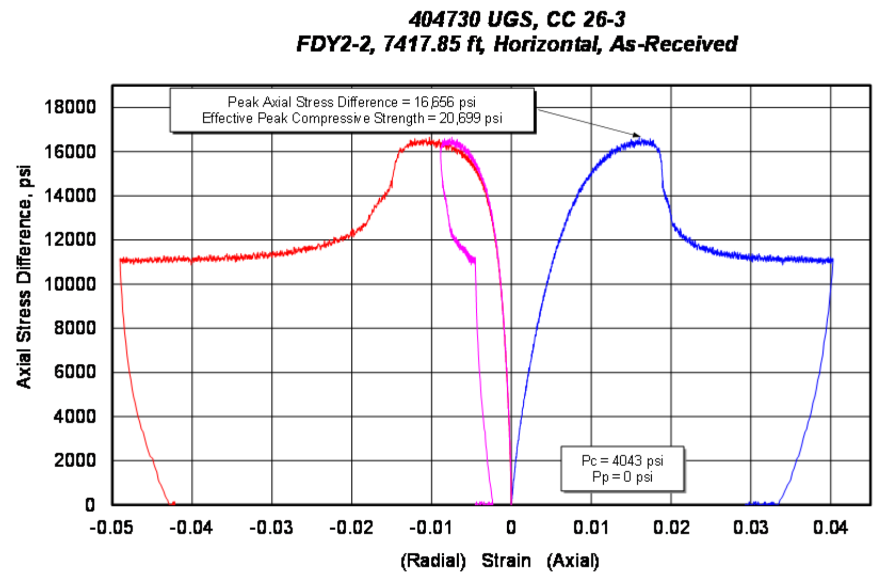
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 8.98
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 1
Zone 3a: Tang and Kaiser Index (Axial): 0
Zone 3b: Tang and Kaiser Index (Volumetric): 0.0077
Zone 4: Peak to Residual Strength Ratio:1.02

[3] (Y) denotes axial yield

Fidelity Cane Creek 26-31

Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
shale	FDY2-1	7417.75	Vertical	2.407	3857	18,534	14,557	1.119	0.24
	FDY2-2	7417.85	Horizontal	2.406	4043	20,699	15,143	2.074	0.30

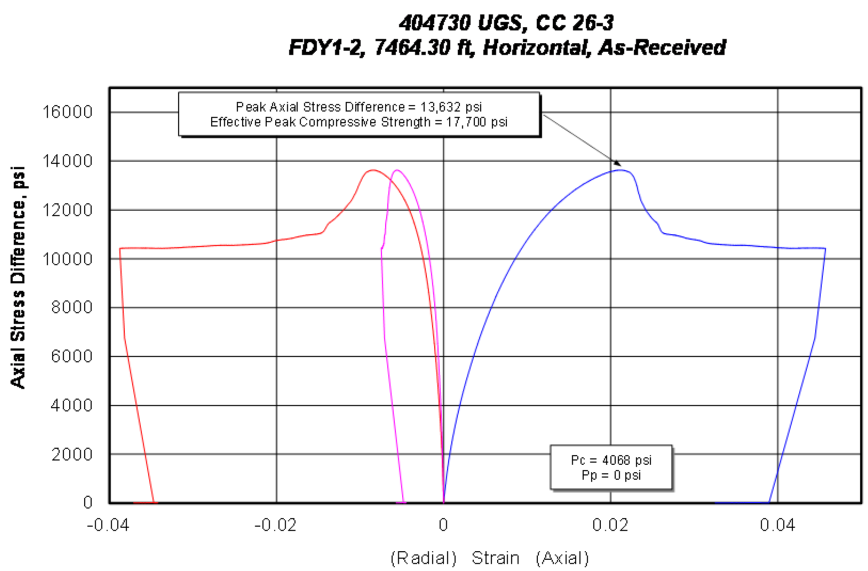




Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.82
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.737
Zone 3a: Tang and Kaiser Index (Axial): 0.427 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 1.42 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.34

Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.77
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.198
Zone 3a: Tang and Kaiser Index (Axial): 0.518
Zone 3b: Tang and Kaiser Index (Volumetric): 0.812
Zone 4: Peak to Residual Strength Ratio:1.46

Fidelity Cane Creek 26-31									
Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
shale	FDY1-2 [4]	7464.30	Horizontal	2.310	4068	17,700	14,498	1.571	0.22

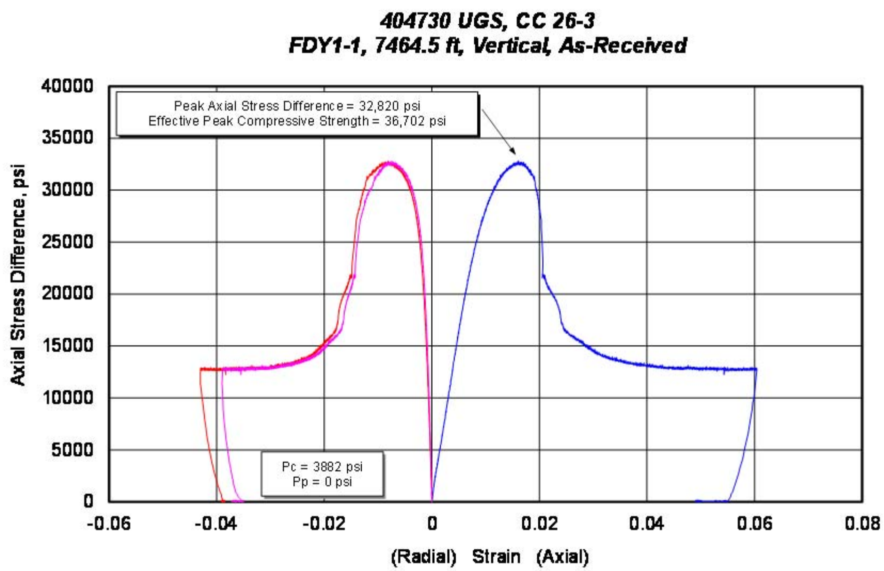


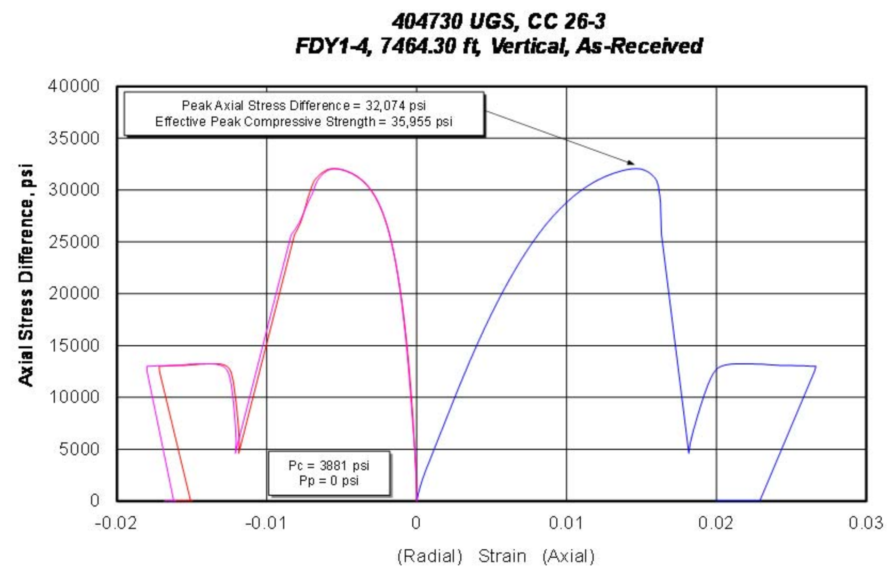
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 2.32
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.403
Zone 3a: Tang and Kaiser Index (Axial): 0.0078 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 0.152 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.23

[4] FDY1-2 – No additional shale material remains for a matching horizontal sample, from this backup shale depth interval.

Fidelity Cane Creek 26-31

Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
silty dolomite	FDY1-1 [5]	7464.50	Vertical	2.617	3882	36,702	16,682	3.276	0.23
	FDY1-4	7464.50	Vertical	2.611	3881	35,955	16,935	3.620	0.18



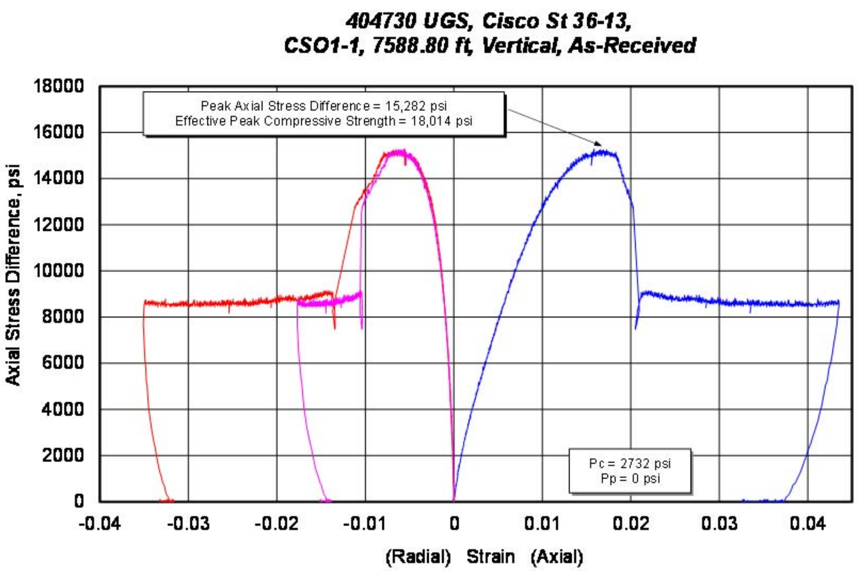


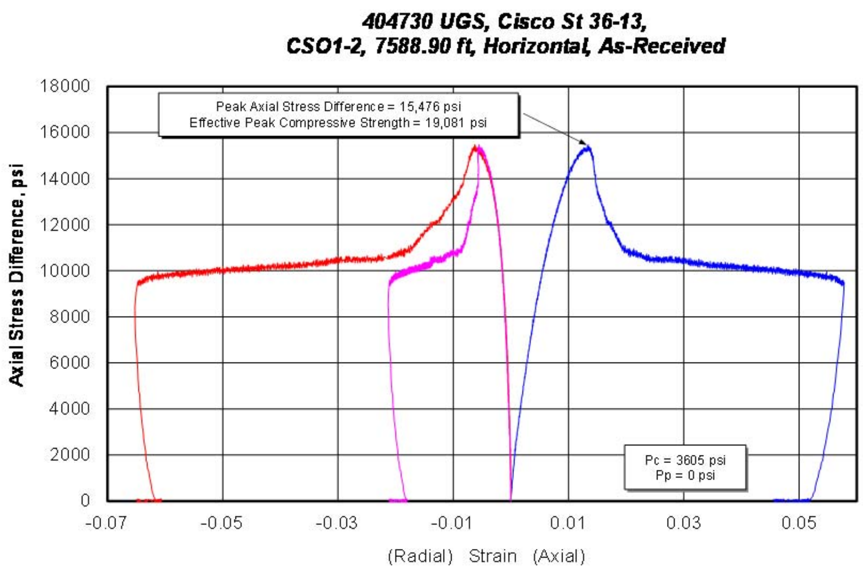
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.58
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.133
Zone 3a: Tang and Kaiser Index (Axial): 8.49 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 14.58 J/tonne
Zone 4: Peak to Residual Strength Ratio: 2.38

Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.66
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.385
Zone 3a: Tang and Kaiser Index (Axial): 1.798
Zone 3b: Tang and Kaiser Index (Volumetric): 66.1
Zone 4: Peak to Residual Strength Ratio:2.46

[5] FDY1-1 – No additional silty dolomite material for a matching horizontal sample. Sample FDY1-4 tested as accident, originally marked with an incorrect depth.

Fidelity Cisco State 36-13									
Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
dolomite	CSO1-1	7588.80	Vertical	2.512	2732	18,014	11,332	1.338	0.19
	CSO1-2	7588.90	Horizontal	2.503	3605	19,081	14,105	1.782	0.25



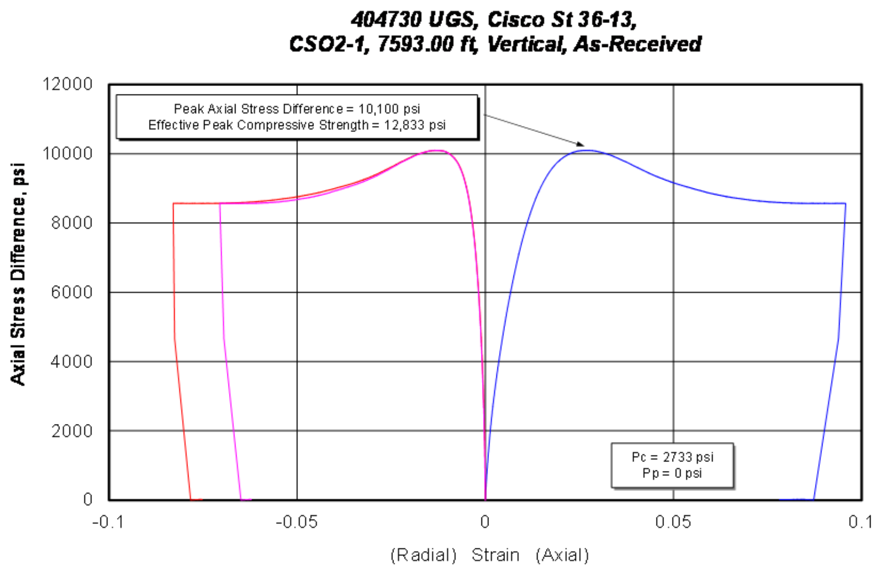


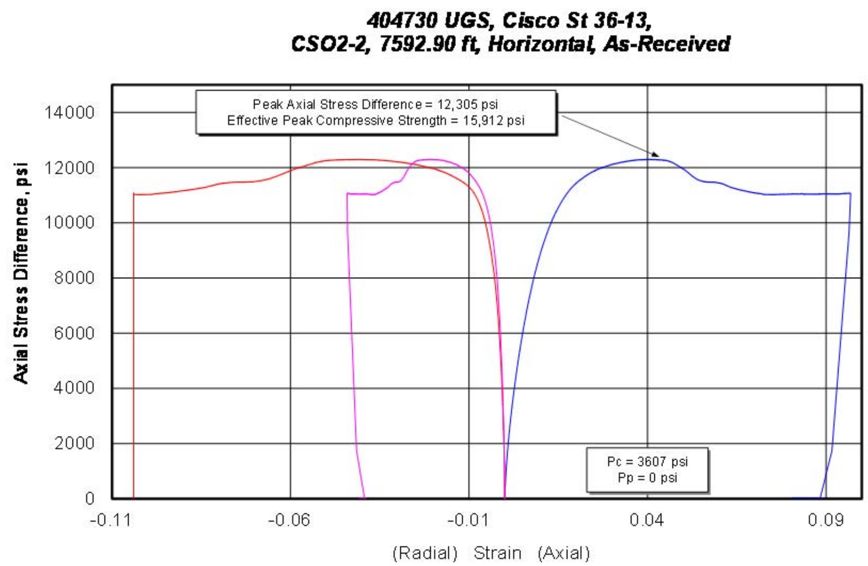
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.28
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.566
Zone 3a: Tang and Kaiser Index (Axial): 0.497 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 3.97 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.65

Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.40
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.227
Zone 3a: Tang and Kaiser Index (Axial): 0.269 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 1.122 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.37

Fidelity Cisco State 36-13

Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
shale	CSO2-1	7593.00	Vertical	2.327	2733	12,833	11,298	1.356	0.22
	CSO2-2	7592.90	Horizontal	2.364	3607	15,912	14,647	1.763	0.24



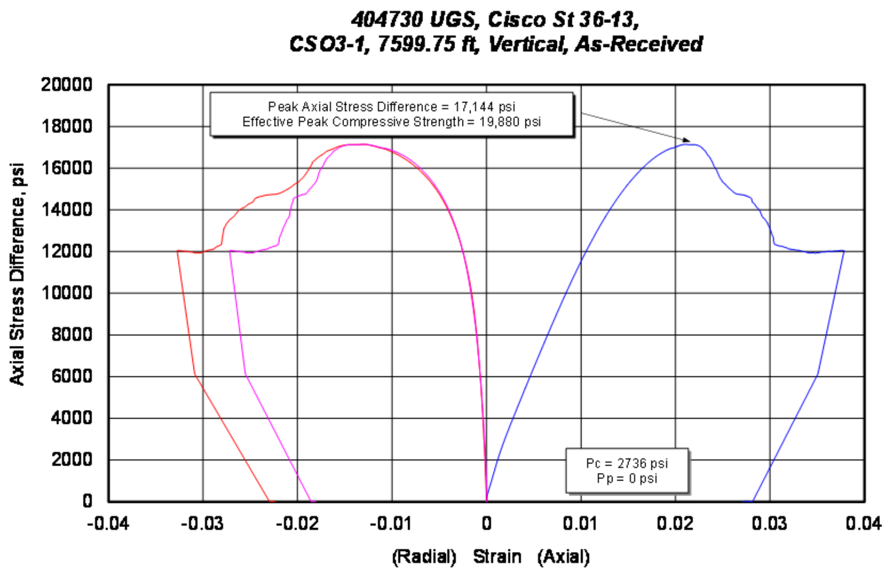


Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 3.2
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.166
Zone 3a: Tang and Kaiser Index (Axial): 0.286 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 0.839 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.16

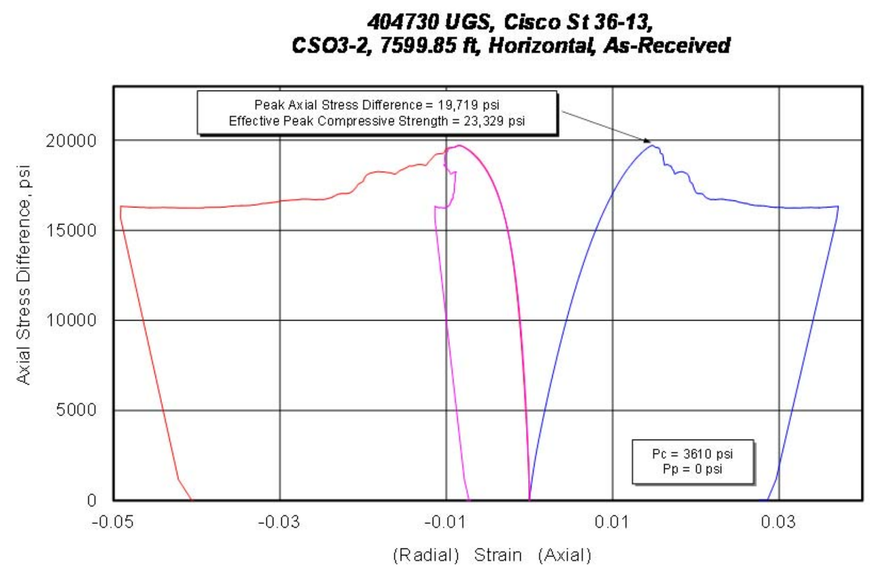
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 4.81
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.601
Zone 3a: Tang and Kaiser Index (Axial): 0.0107 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 0.111 J/tonne
Zone 4: Peak to Residual Strength Ratio:1.06

Fidelity Cisco State 36-13

Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
shale	CSO3-1	7599.75	Vertical	2.582	2736	19,880	14,736	1.104	0.17
	CSO3-2	7599.85	Horizontal	2.537	3610	23,329	19,880	2.037	0.27



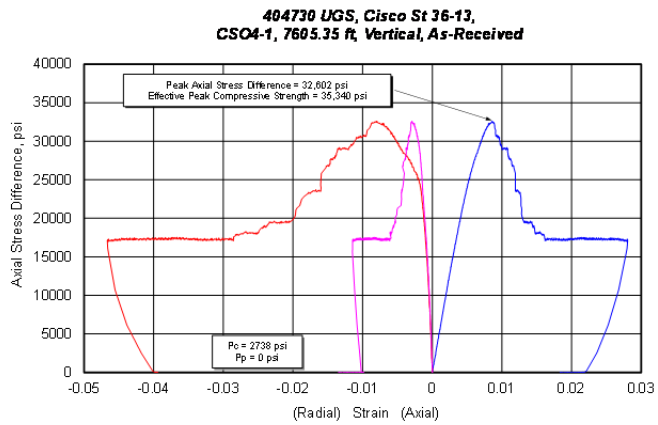
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.32
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.163
Zone 3a: Tang and Kaiser Index (Axial): 0.101 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 0.593 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.38



Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.50
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.0045
Zone 3a: Tang and Kaiser Index (Axial): 0.0098 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 0.578 J/tonne
Zone 4: Peak to Residual Strength Ratio:1.17

Fidelity Cisco State 36-13

Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
silty dolomite	CSO4-1	7605.35	Vertical	2.636	2738	35340	20120	5.071	
	CSO4-4	7605.65	Vertical	2.564	2738	19,646	13,002	1.282	0.18
	CSO4-2	7605.65	Horizontal	2.534	3613	22,643	17,113	1.985	0.25



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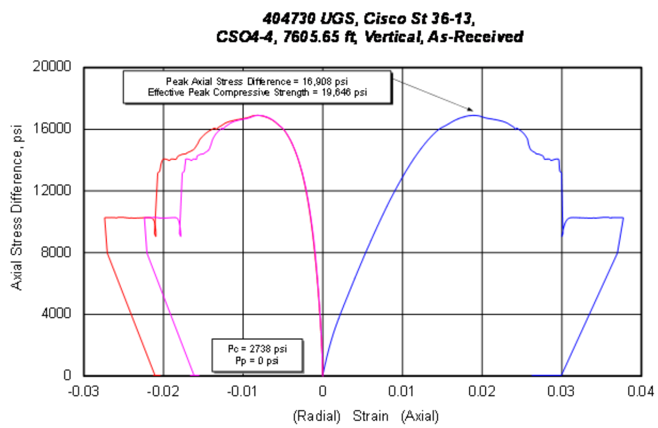
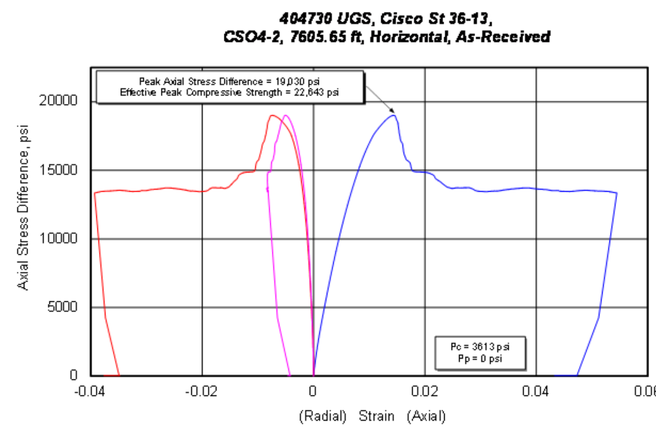
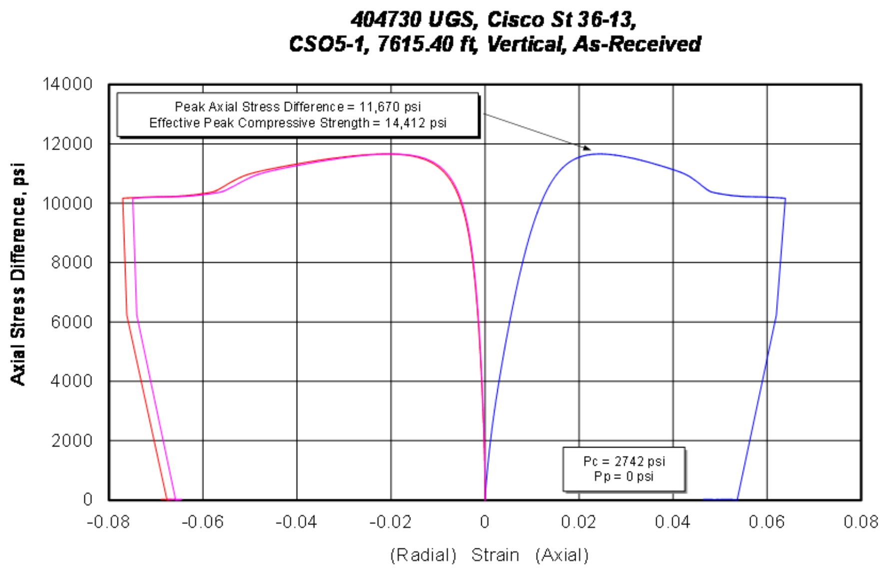


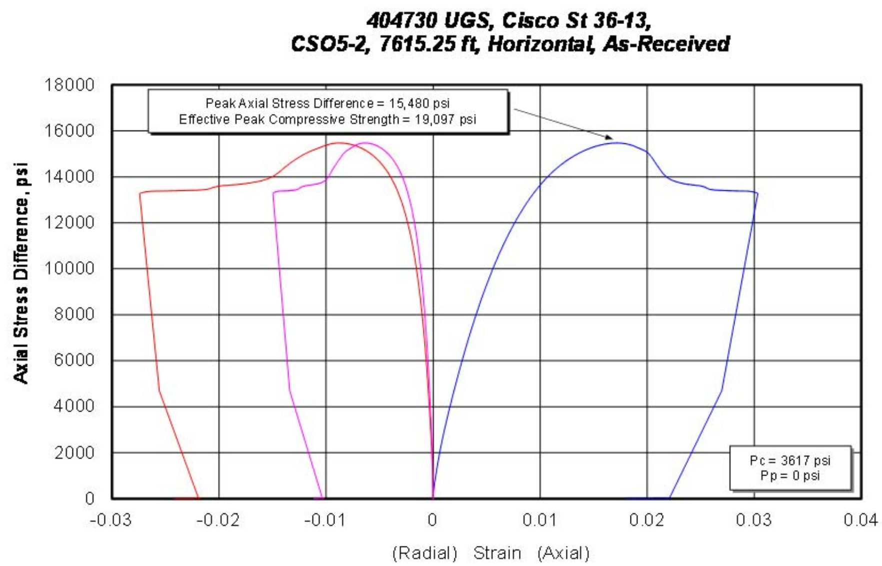


Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.34 Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0 Zone 3a: Tang and Kaiser Index (Axial): 1.42 J/tonne Zone 3b: Tang and Kaiser Index (Volumetric): 9.77 J/tonne Zone 4: Peak to Residual Strength Ratio: 1.90	
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.44 Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.856 Zone 3a: Tang and Kaiser Index (Axial): 0.005 J/tonne Zone 3b: Tang and Kaiser Index (Volumetric): 0.103 J/tonne Zone 4: Peak to Residual Strength Ratio: 1.14	Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.44 Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.095 Zone 3a: Tang and Kaiser Index (Axial): 0.541 J/tonne Zone 3b: Tang and Kaiser Index (Volumetric): 0.0098 J/tonne Zone 4: Peak to Residual Strength Ratio: 1.36

Fidelity Cisco State 36-13

Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
silty dolomite	CSO5-1	7615.40	Vertical	2.464	2742	14,412	12,942	1.094	0.27
	CSO5-2	7615.25	Horizontal	2.511	3617	19,097	17,017	1.755	0.23



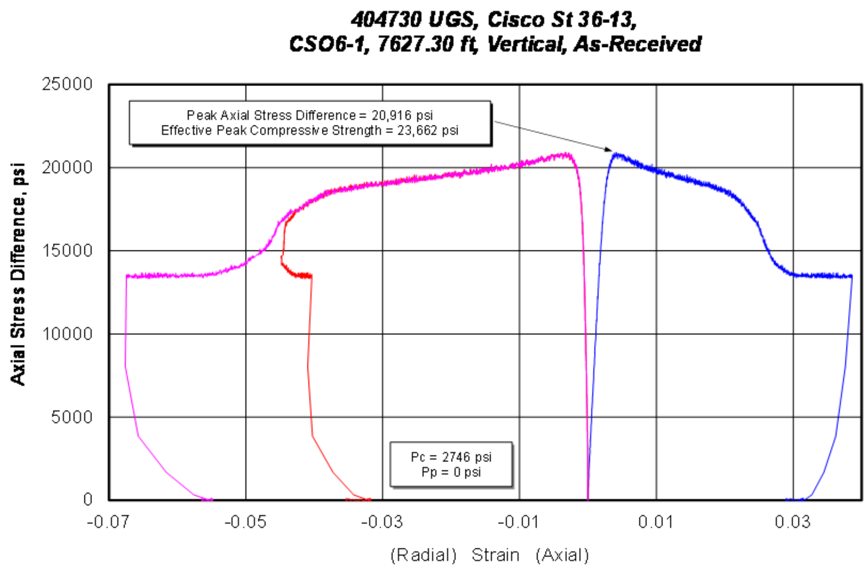


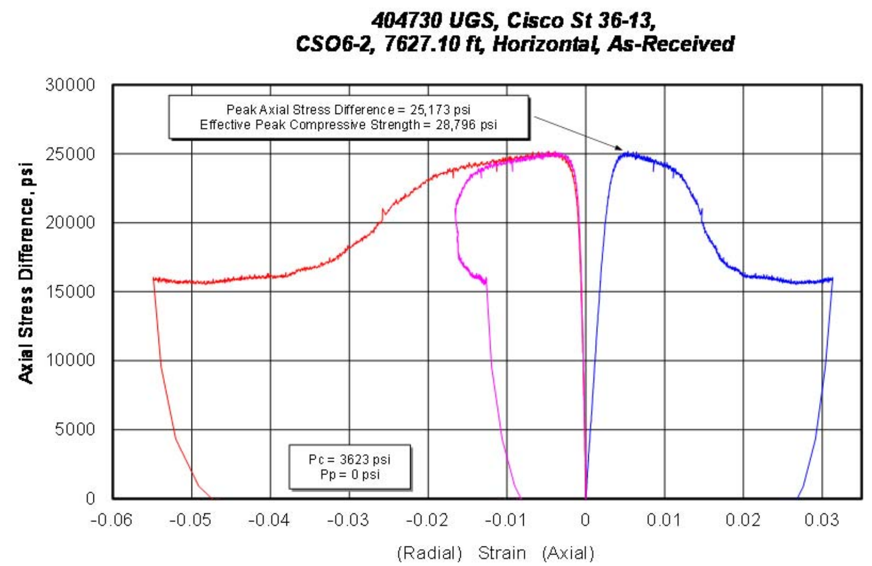
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 2.10
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0
Zone 3a: Tang and Kaiser Index (Axial): 0.124
Zone 3b: Tang and Kaiser Index (Volumetric): 1.56
Zone 4: Peak to Residual Strength Ratio: 1.11

Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.90
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.71
Zone 3a: Tang and Kaiser Index (Axial): 0.0034 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 0.234 J/tonne
Zone 4: Peak to Residual Strength Ratio:1.10

Fidelity Cisco State 36-13

Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
anhydrite	CSO6-1	7627.30	Vertical	2.944	2746	23,662	16,346	8.081	0.34
	CSO6-2	7627.10	Horizontal	2.937	3623	28,796	19,423	8.780	0.33

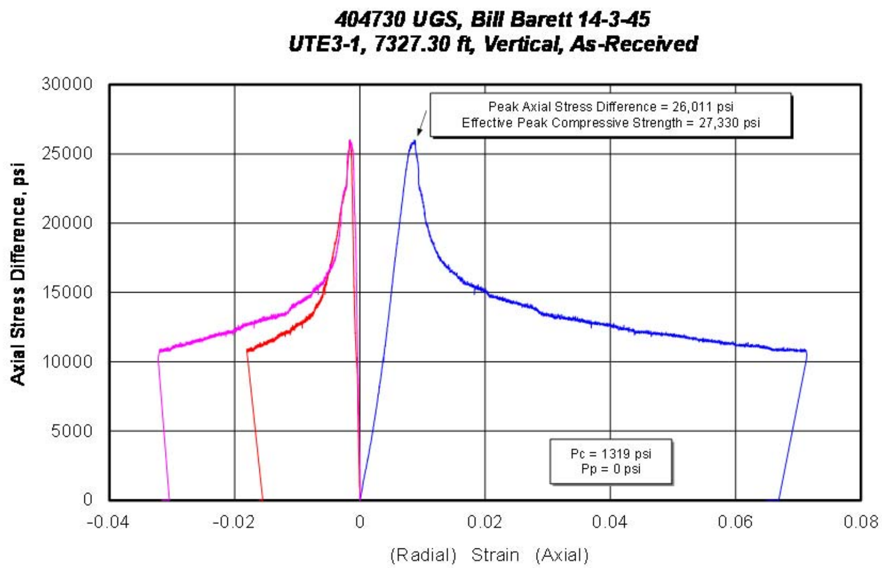


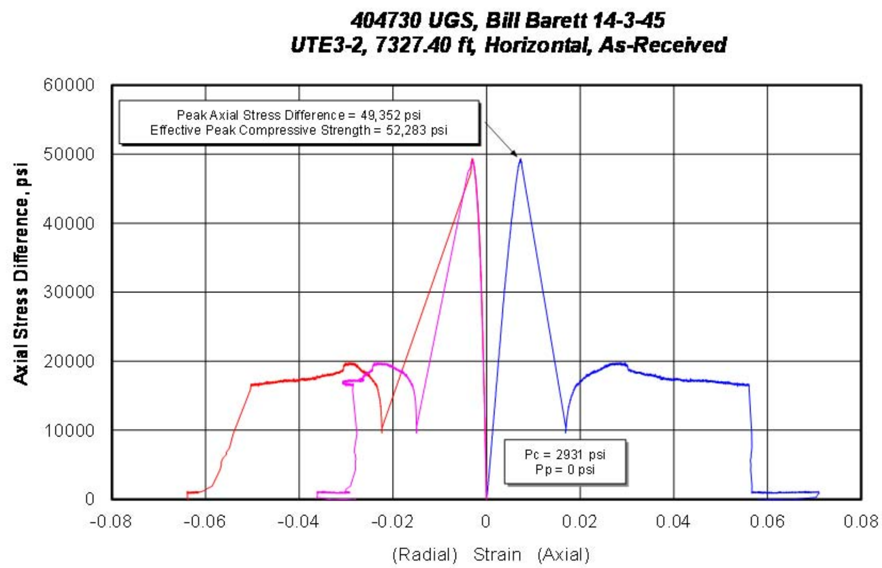


Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.43
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.675
Zone 3a: Tang and Kaiser Index (Axial): .0062 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 1.45 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.52

Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.76
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.443
Zone 3a: Tang and Kaiser Index (Axial): 0.139 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 1.47 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.53

Bill Barrett 14-3-35									
Lithology	**Sample ID**	**Depth (ft)**	**Orientation**	**As Received Bulk Density (g/cm^3)**	**Confining Pressure (psi)**	**Peak Effective Compressive Strength (psi)**	**Effective Residual Compressive Strength (psi)**	**Young's Modulus (10^6 psi)**	**Poisson's Ratio**
dolomite	UTE3-1	7327.30	Vertical	2.645	1319	27330	12200	3.196	0.18
	UTE3-2	7327.40	Horizontal	2.655	2931	52280	19630	8.166	0.30

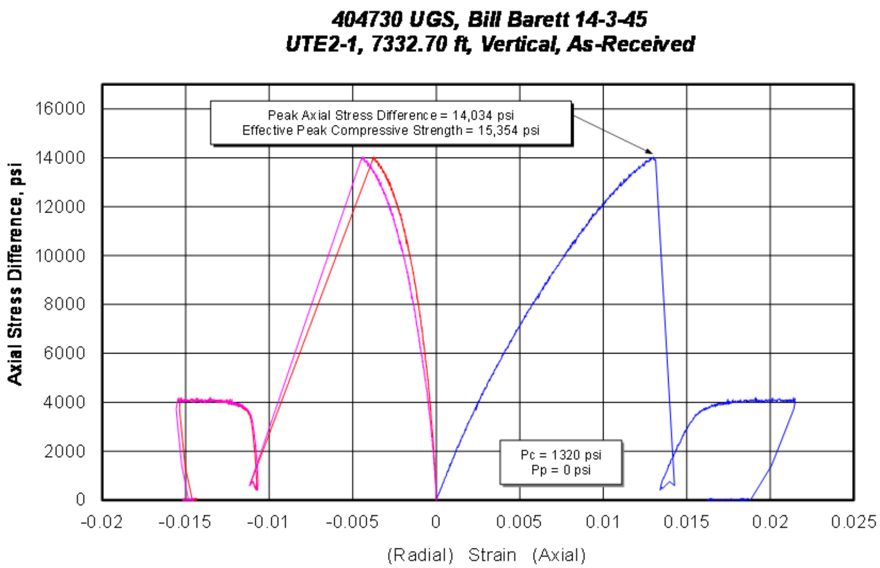


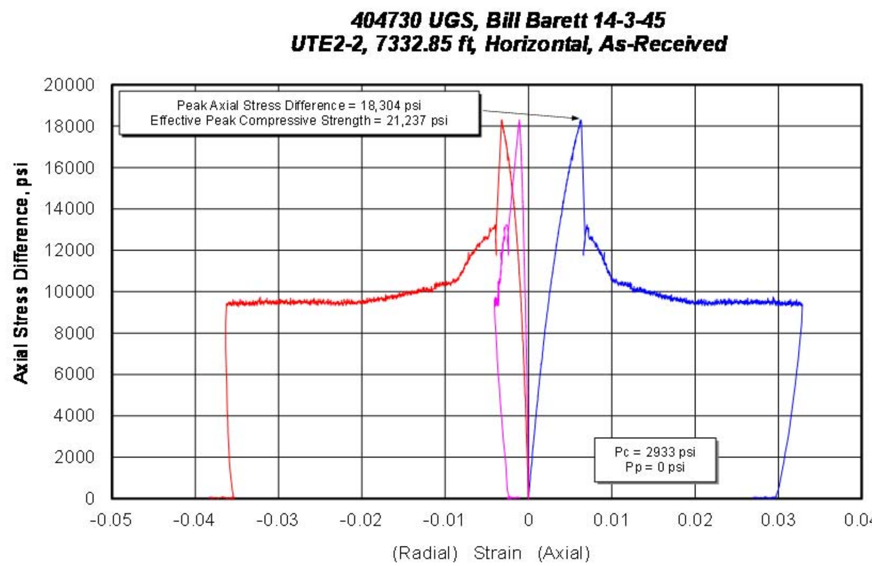


Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 0.85
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0
Zone 3a: Tang and Kaiser Index (Axial): 5.82
Zone 3b: Tang and Kaiser Index (Volumetric): 13.61
Zone 4: Peak to Residual Strength Ratio: 1.93

Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.19
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0
Zone 3a: Tang and Kaiser Index (Axial): 9.62 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 29.8 J/tonne
Zone 4: Peak to Residual Strength Ratio:2.63

Bill Barrett 14-3-35									
Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
shale-finely laminated	UTE2-1	7332.70	Vertical	2.382	1320	15350	5400	1.411	0.21
	UTE2-2	7332.85	Horizontal	2.342	2933	21240	12430	3.962	0.27

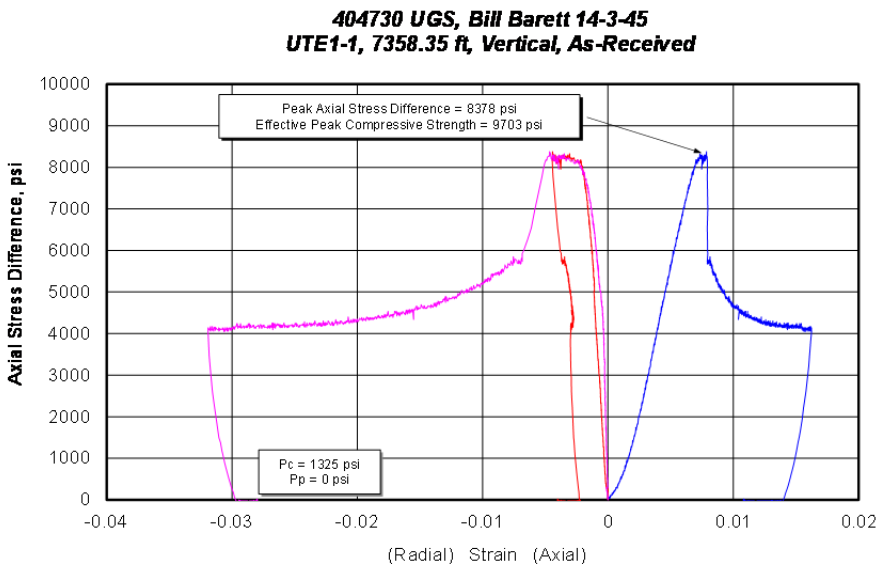


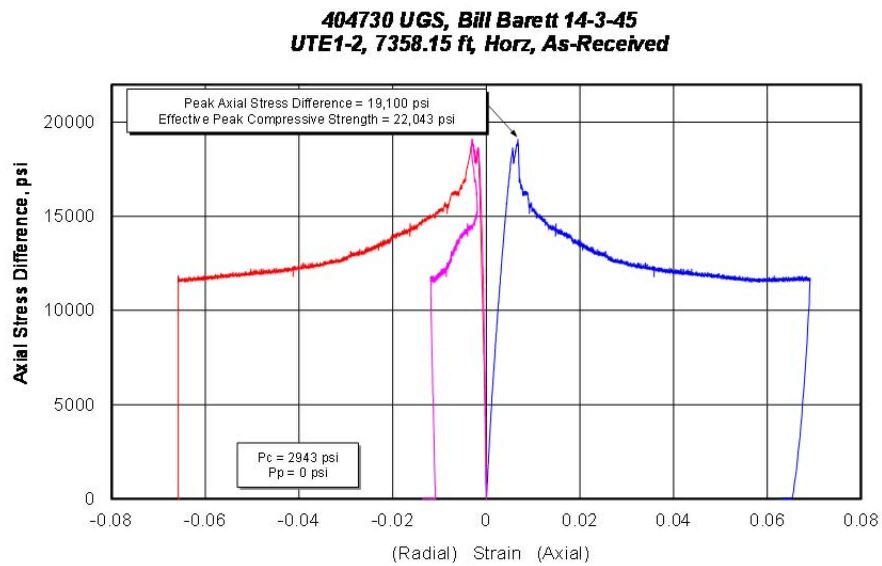


Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.32
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0
Zone 3a: Tang and Kaiser Index (Axial): 1.86 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 14.5 J/tonne
Zone 4: Peak to Residual Strength Ratio: 3.54

Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.87
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0
Zone 3a: Tang and Kaiser Index (Axial): 0.13 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 1.04 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.90

Bill Barrett 14-3-35									
Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
shale	UTE1-1[6]	7358.35	Vertical	2.439	1325	9700	5510	1.428	0.21
	UTE1-2	7358.15	Horizontal	2.584	2943	22040	14640	3.963	0.26





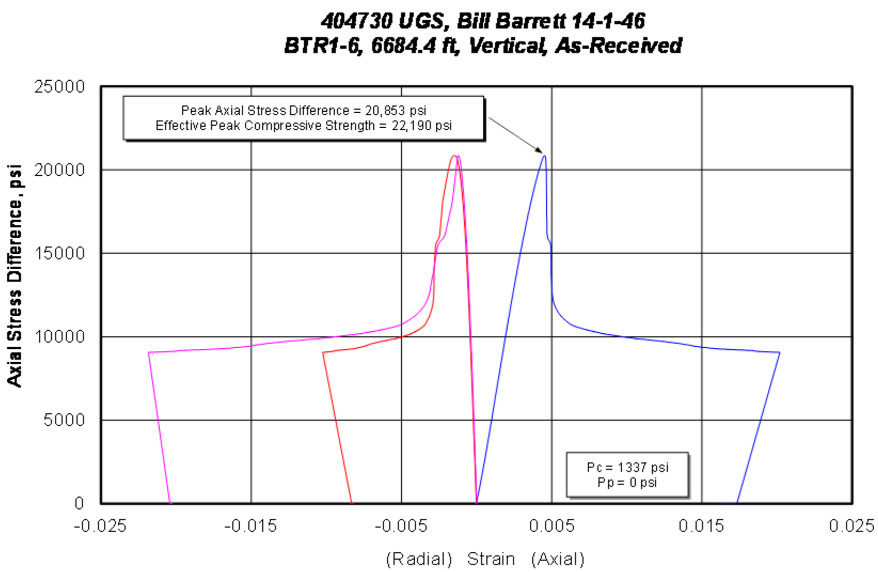
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.23
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.16
Zone 3a: Tang and Kaiser Index (Axial): 2.69x 10^{-4} J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 1.89 x 10^{-4} J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.91

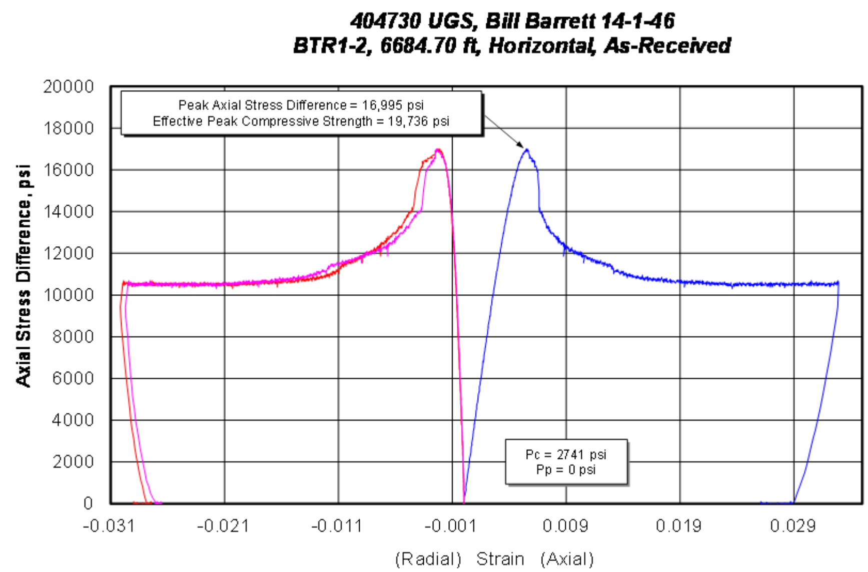
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.19
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.052
Zone 3a: Tang and Kaiser Index (Axial): 0.785 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 1.45 J/tonne
Zone 4: Peak to Residual Strength Ratio:1.45

[6] Note density difference between UTE 1-1 and UTE 1-2. No additional material available.

Bill Barrett 14-1-46

Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
tan dolomite	BTR1-1	6684.40	Vertical	2.282	1337	19420	9580		
	BTR1-6	6684.40	Vertical	2.348	1337	22190	10410	5.390	0.22
	BTR1-2	6684.780	Horizontal	2.140	2741	19740	13240	3.829	0.27



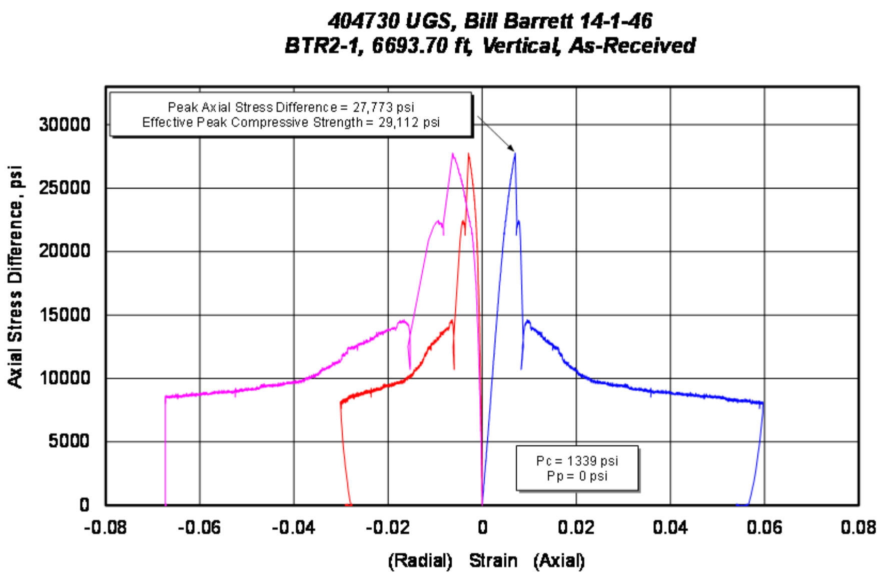


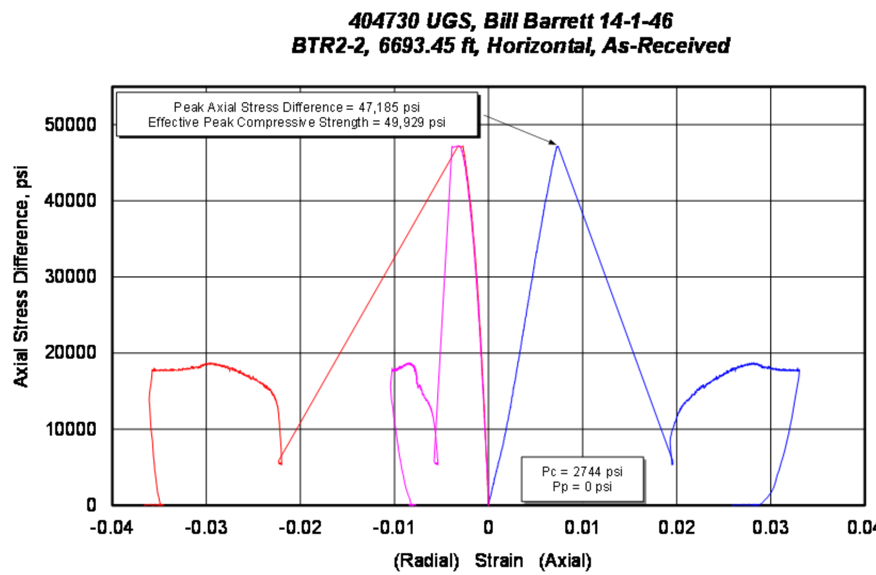
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.15
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.009
Zone 3a: Tang and Kaiser Index (Axial): 0.245 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 2.87 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.86

Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.23
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.044
Zone 3a: Tang and Kaiser Index (Axial): 0.69 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 3.987 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.59

Bill Barrett 14-1-46

Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
dolomite	BTR2-1	6693.70	Vertical	2.428	1399	29110	9470	4.861	0.29
	BTR2-2	6693.45	Horizontal	2.544	2744	49930	20490	7.011	0.29
	BTR2-5	6693.45	Horizontal	2.433	2744			4.796	0.31



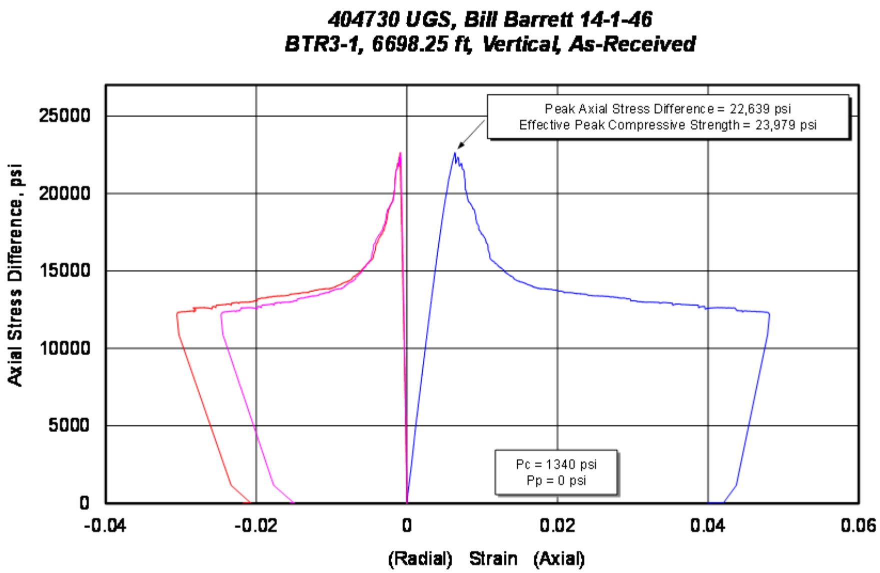


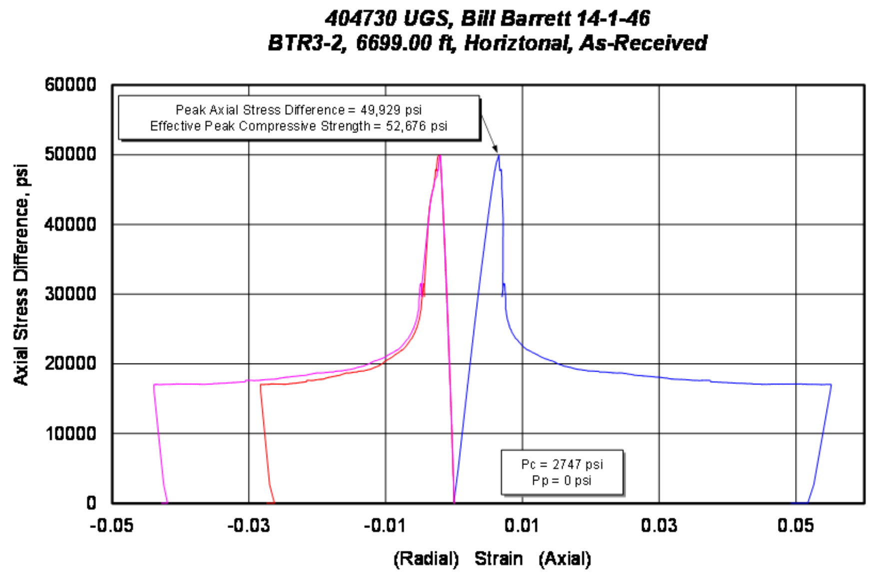
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.20
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0
Zone 3a: Tang and Kaiser Index (Axial): 3.94 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 21.25 J/tonne
Zone 4: Peak to Residual Strength Ratio: 2.72

Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.08
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: N/A
Zone 3a: Tang and Kaiser Index (Axial): N/A
Zone 3b: Tang and Kaiser Index (Volumetric): N/A
Zone 4: Peak to Residual Strength Ratio: N/A

Bill Barrett 14-1-46

Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
gray limestone	BTR3-1	6698.25	Vertical	2.586	1340	23980	13700	4.038	0.14
	BTR3-2	6699.00	Horizontal	2.614	2747	52680	19850	8.657	0.32



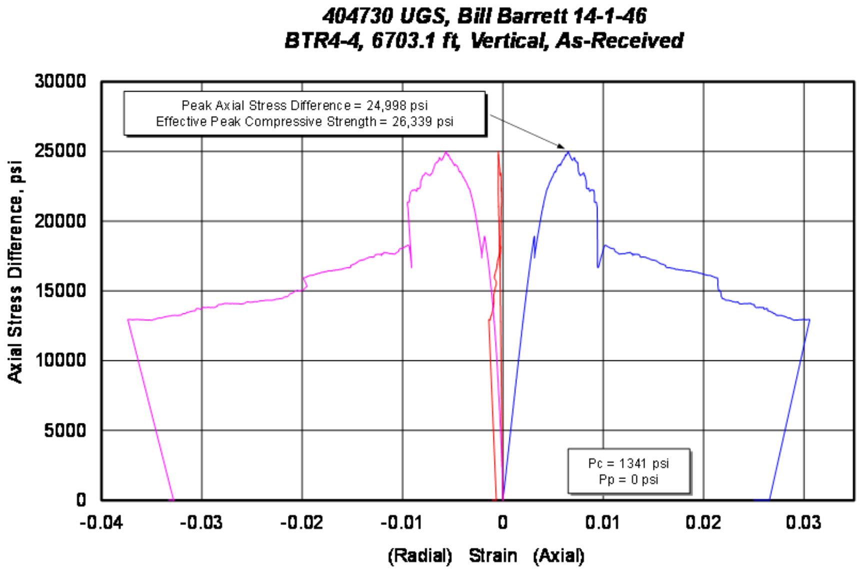


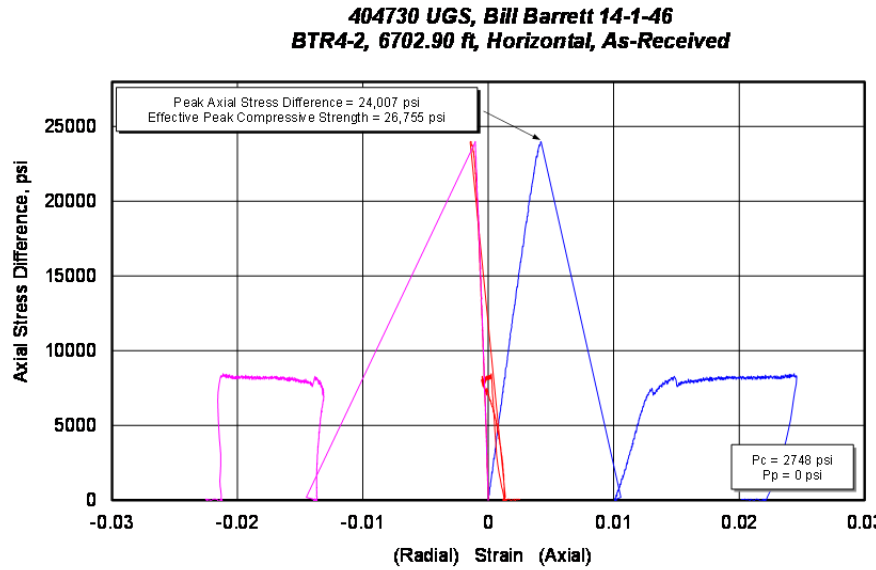
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.13
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.093
Zone 3a: Tang and Kaiser Index (Axial): 0.972 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 1.82 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.60

Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.12
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0
Zone 3a: Tang and Kaiser Index (Axial): 4.34
Zone 3b: Tang and Kaiser Index (Volumetric): 12.75
Zone 4: Peak to Residual Strength Ratio: 2.58

Bill Barrett 14-1-46

Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
tan dolomite	BTR4-4	6703.10	Vertical	2.543	1341	23340	14290	6.422	0.28
	BTR4-2	6702.90	Horizontal	2.473	2748	26760	11050	6.223	0.26



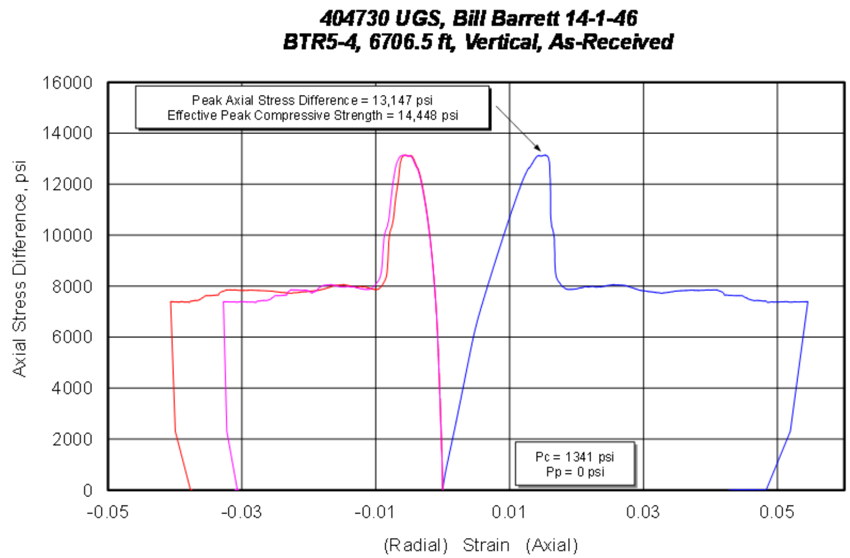


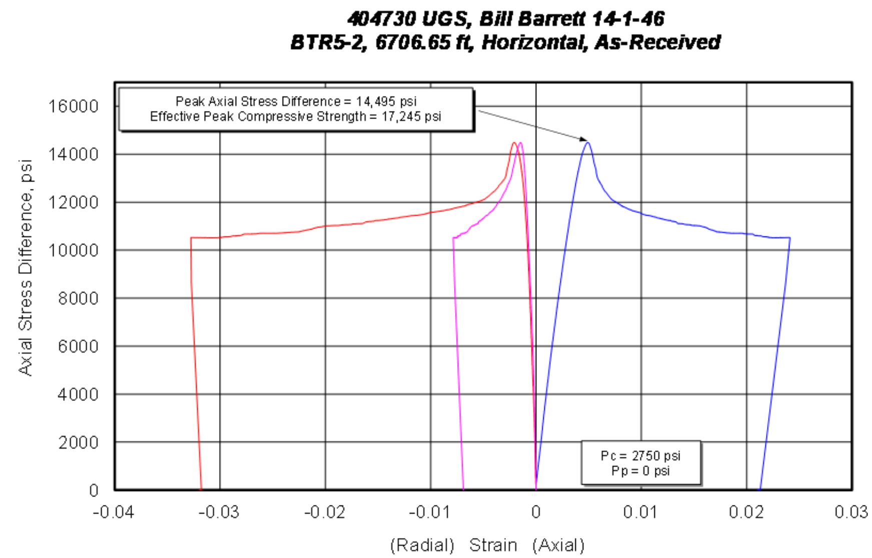
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.62
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.902
Zone 3a: Tang and Kaiser Index (Axial): 0.0039
Zone 3b: Tang and Kaiser Index (Volumetric): 0.0132
Zone 4: Peak to Residual Strength Ratio: 1.44

Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.06
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: N/A
Zone 3a: Tang and Kaiser Index (Axial): N/A
Zone 3b: Tang and Kaiser Index (Volumetric): N/A
Zone 4: Peak to Residual Strength Ratio: 3.17

Bill Barrett 14-1-46

Lithology	Sample ID	Depth (ft)	Orientation	As Received Bulk Density (g/cm^3)	Confining Pressure (psi)	Peak Effective Compressive Strength (psi)	Effective Residual Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
shale	BTR5-4	6706.50	Vertical	2.487	1341	14450	9190	1.295	0.18
	BTR5-2	6706.65	Horizontal	2.502	2750	17250	13270	3.797	0.26



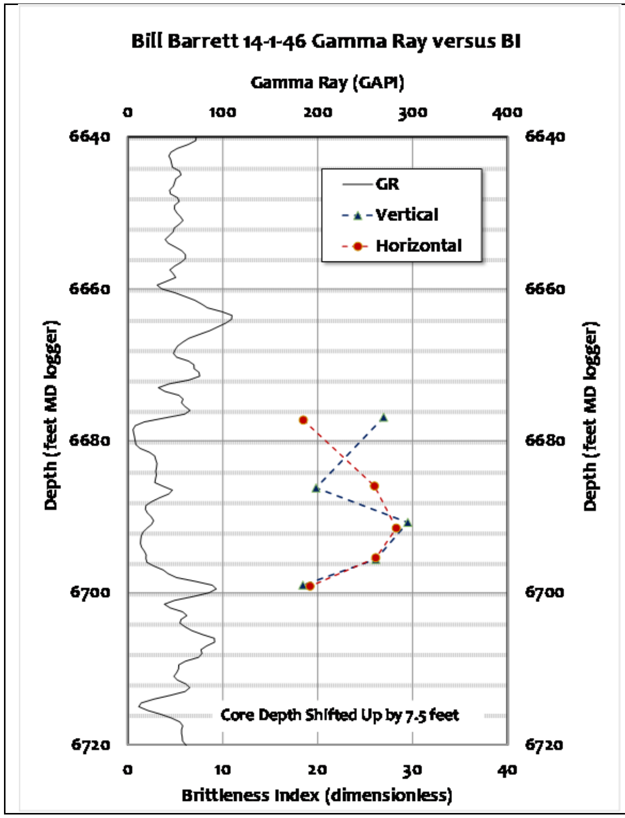


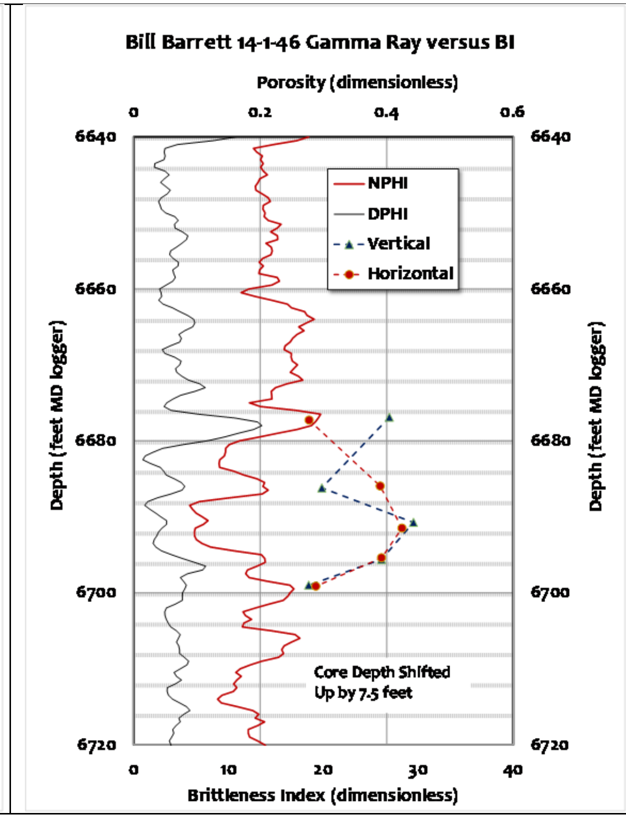
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.38
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.48
Zone 3a: Tang and Kaiser Index (Axial): 0.205 J/tonne
Zone 3b: Tang and Kaiser Index (Volumetric): 1.576 J/tonne
Zone 4: Peak to Residual Strength Ratio: 1.60

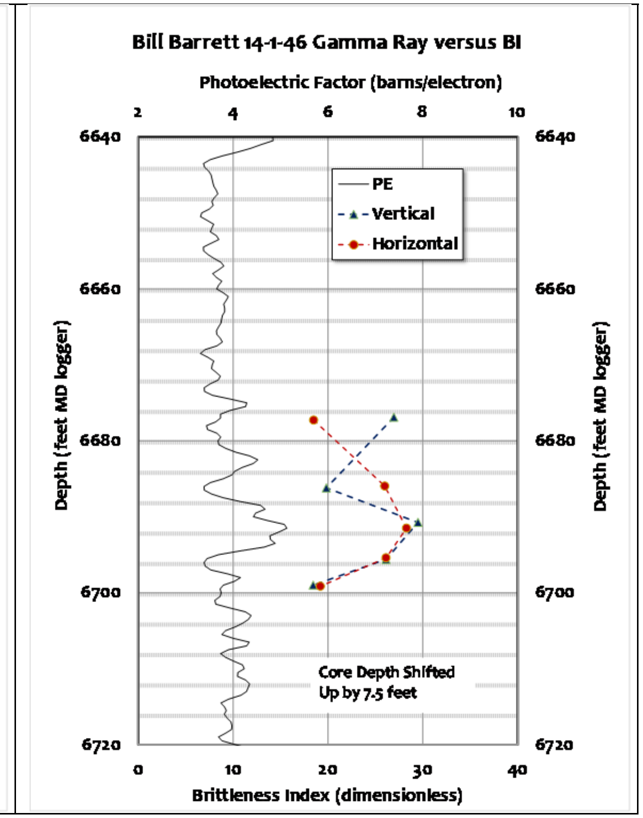
Zone 1 Deformation Index: Ratio of Secant E at Peak to E: 1.22
Zone 2 Ductility Index: Amount of Plastic or Strain Hardening Strain: 0.083
Zone 3a: Tang and Kaiser Index (Axial): 0.00527
Zone 3b: Tang and Kaiser Index (Volumetric): 0.196
Zone 4: Peak to Residual Strength Ratio: 1.24

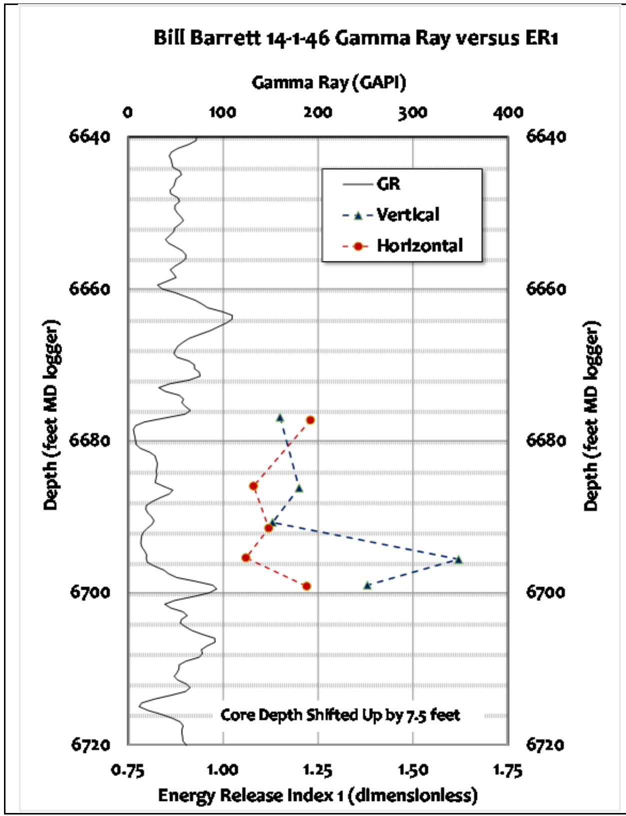
Appendix B

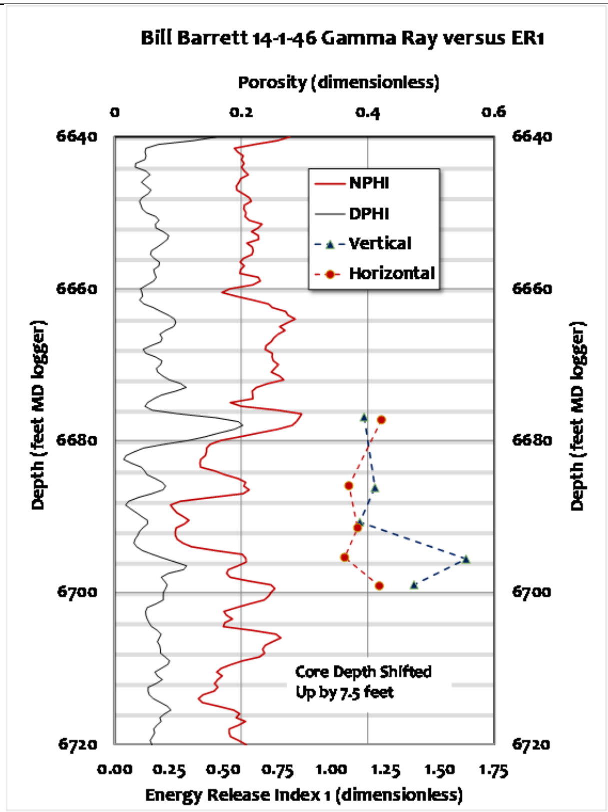
Processed Energy Release Indices

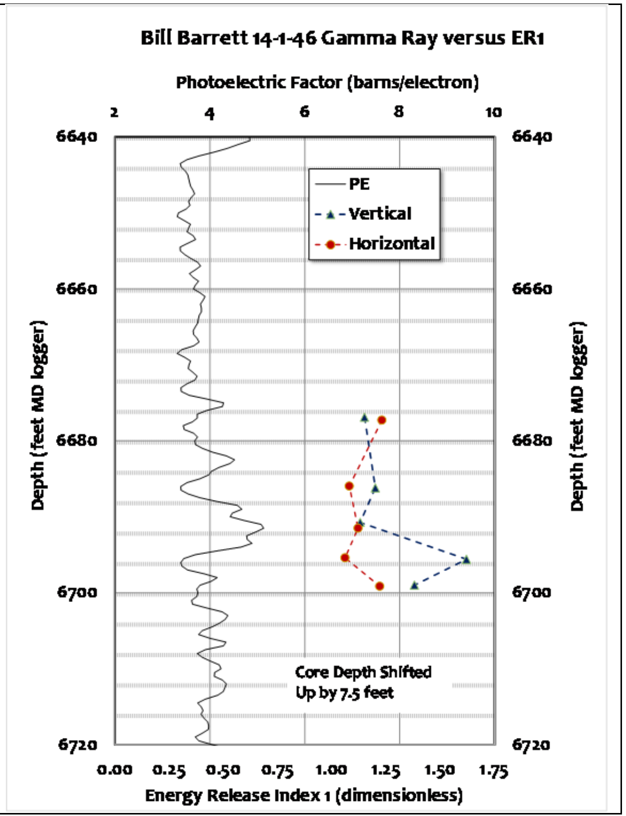

Bill Barrett 14-1-46 Gamma Ray versus BI
Gamma Ray (GAPI)
GR
Vertical
Horizontal
Core Depth Shifted Up by 7.5 feet
Depth (feet MD logger)
Brittleness Index (dimensionless)

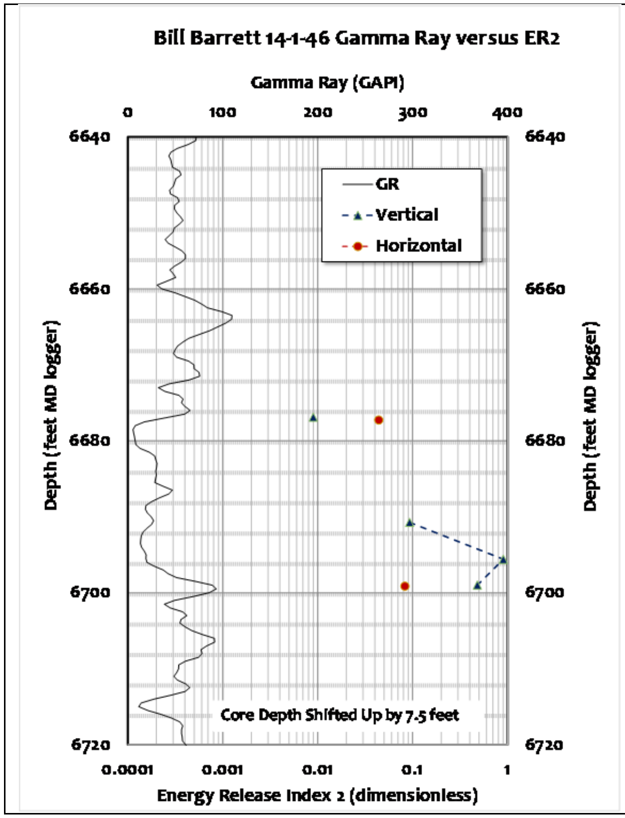

Bill Barrett 14-1-46 Gamma Ray versus BI
Porosity (dimensionless)
NPHI
DPHI
Vertical
Horizontal
Core Depth Shifted
Up by 7.5 feet
Depth (feet MD logger)
Brittleness Index (dimensionless)

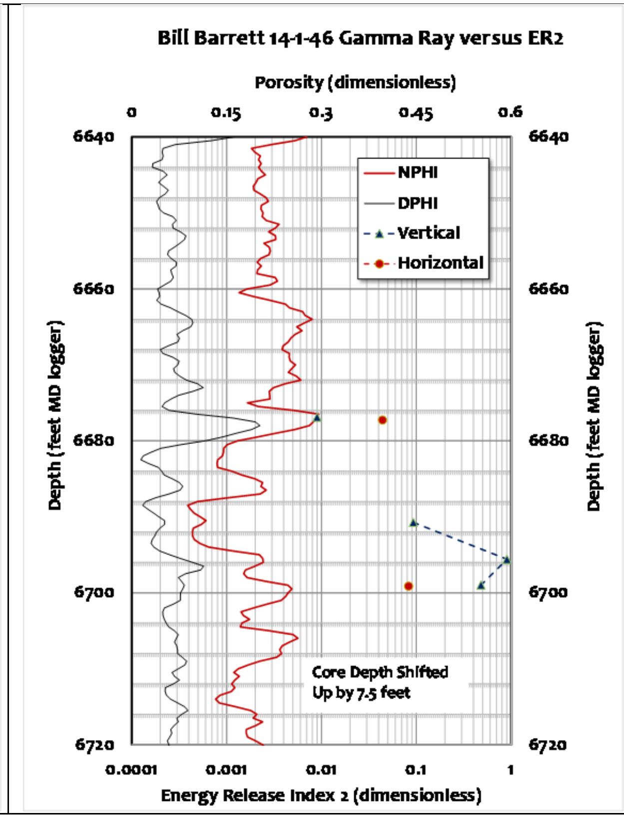

Bill Barrett 14-1-46 Gamma Ray versus BI
Photoelectric Factor (barns/electron)
PE
Vertical
Horizontal
Core Depth Shifted
Up by 7.5 feet
Depth (feet MD logger)
Brittleness Index (dimensionless)

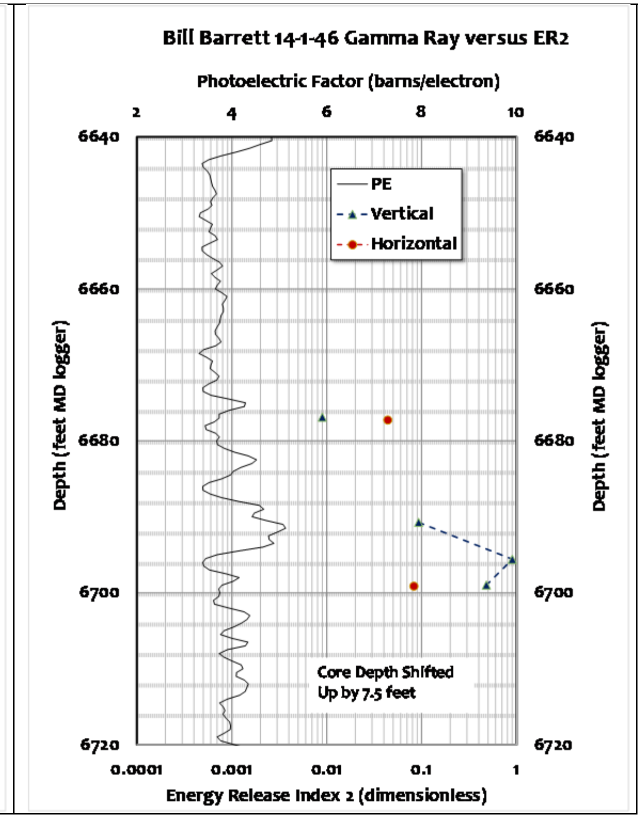

Bill Barrett 14-1-46 Gamma Ray versus ER1
Gamma Ray (GAPI)
0
100
200
300
400
6640
6660
6680
6700
6720
Depth (feet MD logger)
GR
Vertical
Horizontal
Core Depth Shifted Up by 7.5 feet
0.75
1.00
1.25
1.50
1.75
Energy Release Index 1 (dimensionless)

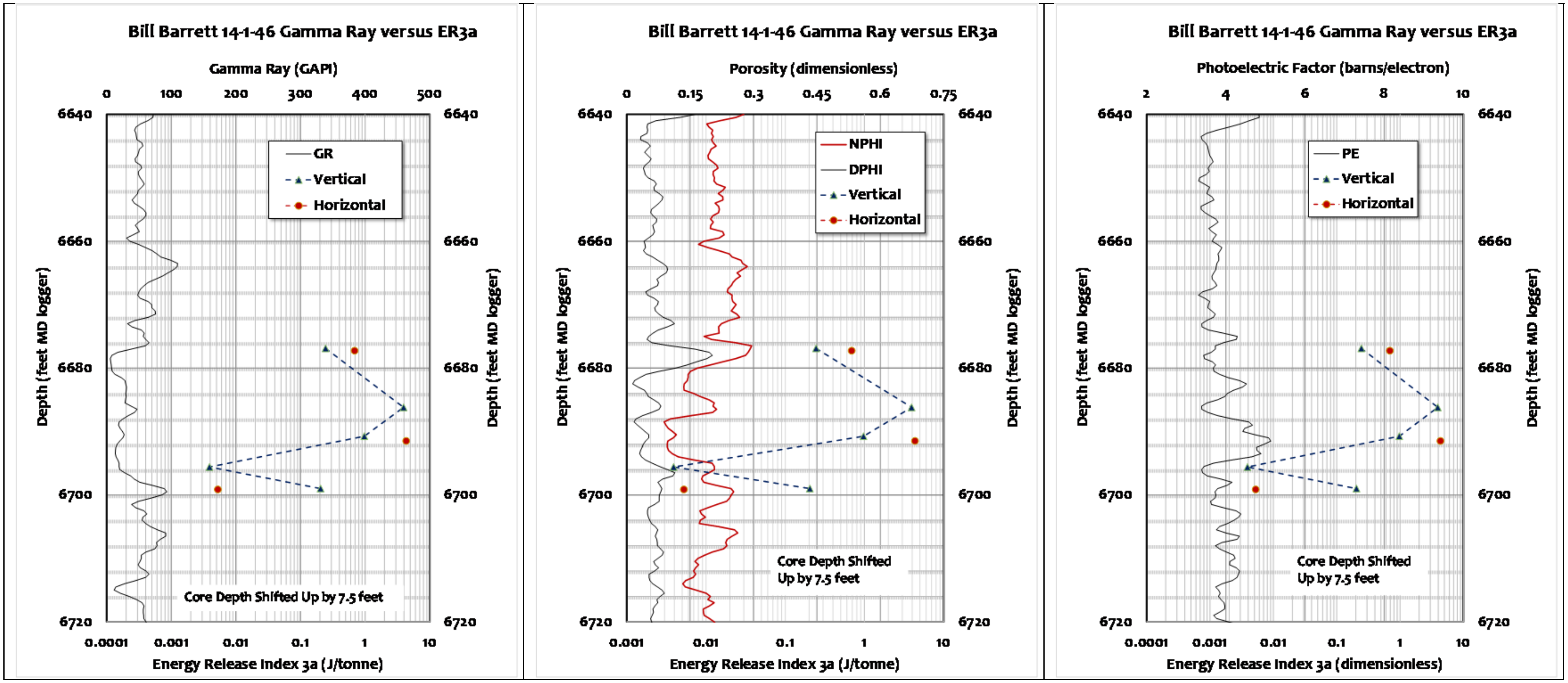

Bill Barrett 14-1-46 Gamma Ray versus ER1
Porosity (dimensionless)
0
0.2
0.4
0.6
6640
6660
6680
6700
6720
Depth (feet MD logger)
NPHI
DPHI
Vertical
Horizontal
Core Depth Shifted
Up by 7.5 feet
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
Energy Release Index 1 (dimensionless)


Bill Barrett 14-1-46 Gamma Ray versus ER1
Photoelectric Factor (barns/electron)
2
4
6
8
10
6640
6660
6680
6700
6720
Depth (feet MD logger)
PE
Vertical
Horizontal
Core Depth Shifted
Up by 7.5 feet
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
Energy Release Index 1 (dimensionless)

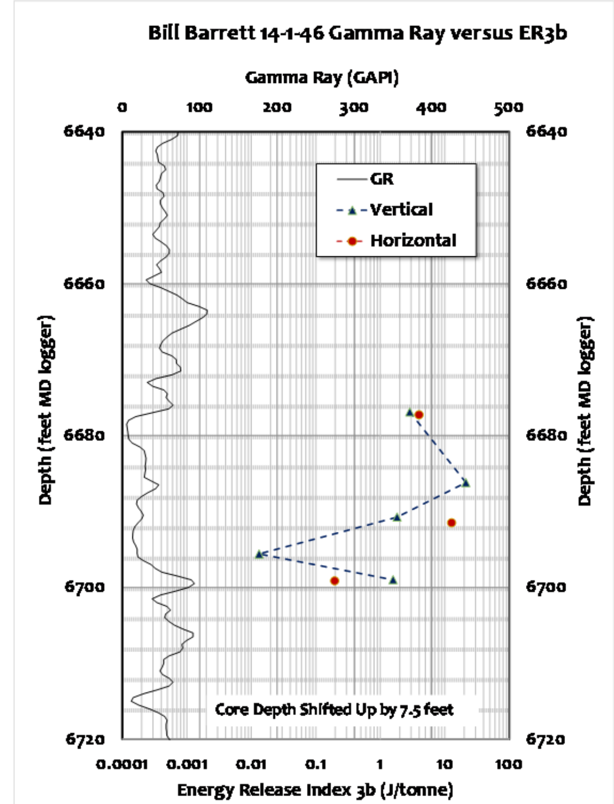

Bill Barrett 14-1-46 Gamma Ray versus ER2
Gamma Ray (GAPI)
GR
Vertical
Horizontal
Core Depth Shifted Up by 7.5 feet
Depth (feet MD logger)
Energy Release Index 2 (dimensionless)

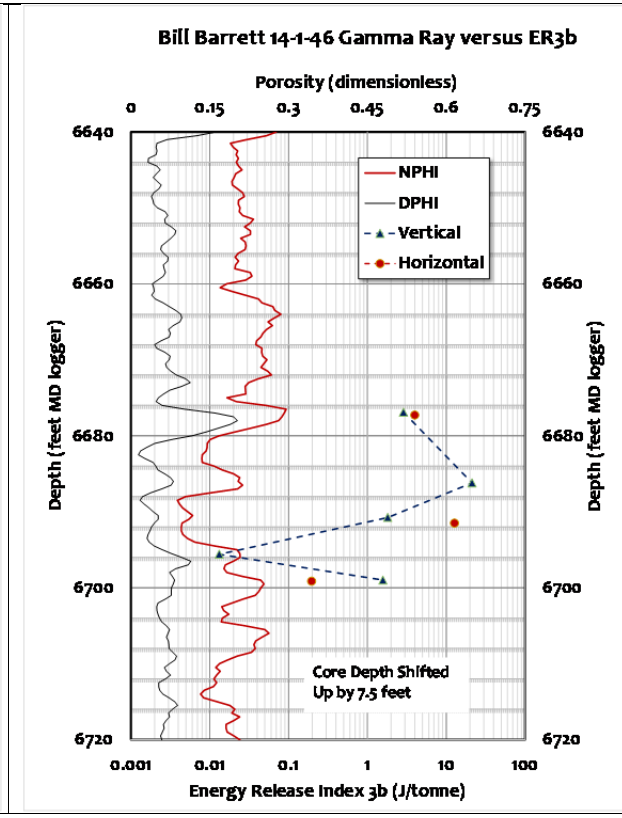

Bill Barrett 14-1-46 Gamma Ray versus ER2
Porosity (dimensionless)
NPHI
DPHI
Vertical
Horizontal
Core Depth Shifted
Up by 7.5 feet
Depth (feet MD logger)
Energy Release Index 2 (dimensionless)

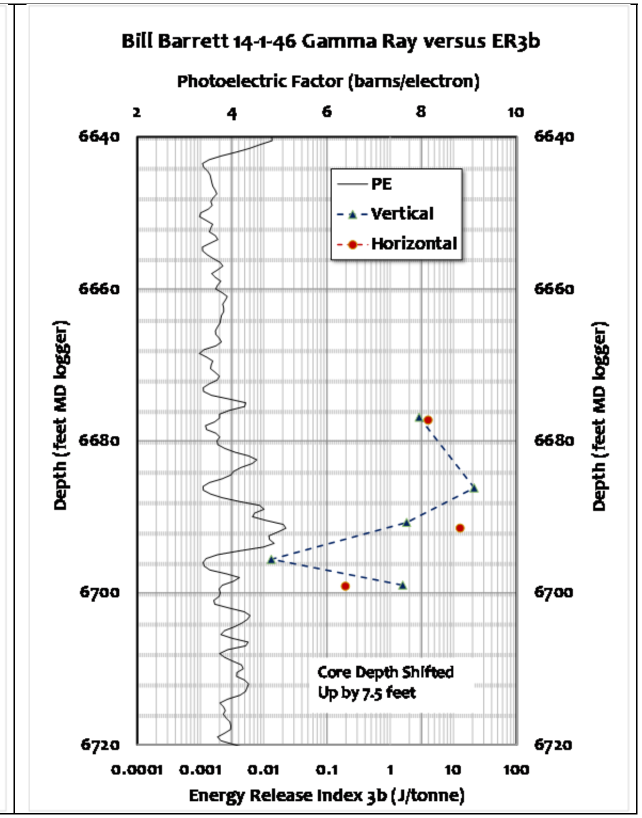

Bill Barrett 14-1-46 Gamma Ray versus ER2
Photoelectric Factor (barns/electron)
PE
Vertical
Horizontal
Core Depth Shifted
Up by 7.5 feet
Depth (feet MD logger)
Energy Release Index 2 (dimensionless)

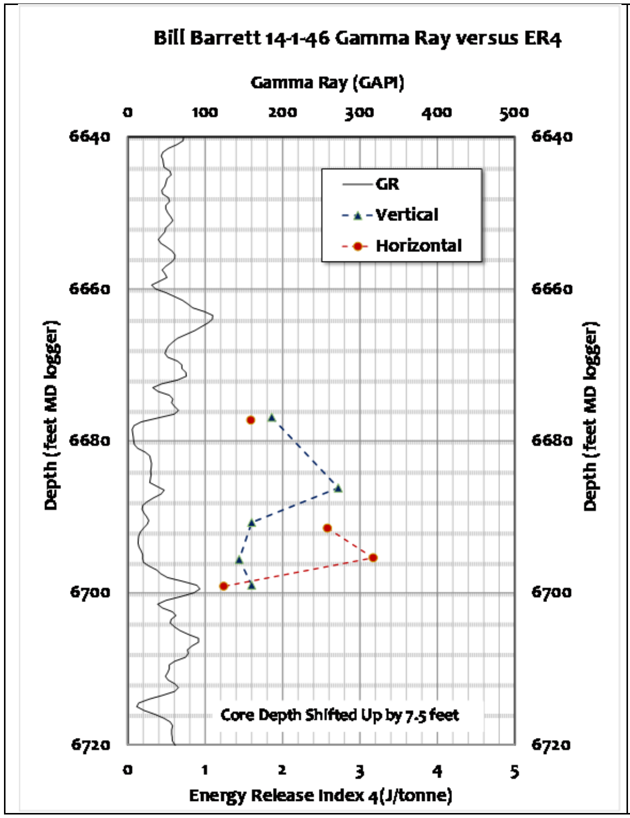


Bill Barrett 14-1-46 Gamma Ray versus ER3a
Gamma Ray (GAPI)
0
100
200
300
400
500
GR
Vertical
Horizontal
Core Depth Shifted Up by 7.5 feet
Depth (feet MD logger)
6640
6660
6680
6700
6720
0.0001
0.001
0.01
0.1
1
10
Energy Release Index 3a (J/tonne)
Bill Barrett 14-1-46 Gamma Ray versus ER3a
Porosity (dimensionless)
0
0.15
0.3
0.45
0.6
0.75
NPHI
DPHI
Vertical
Horizontal
Core Depth Shifted Up by 7.5 feet
Depth (feet MD logger)
0.001
0.01
0.1
1
10
Energy Release Index 3a (J/tonne)
Bill Barrett 14-1-46 Gamma Ray versus ER3a
Photoelectric Factor (barns/electron)
2
4
6
8
10
PE
Vertical
Horizontal
Core Depth Shifted Up by 7.5 feet
Depth (feet MD logger)
0.0001
0.001
0.01
0.1
1
10
Energy Release Index 3a (dimensionless)

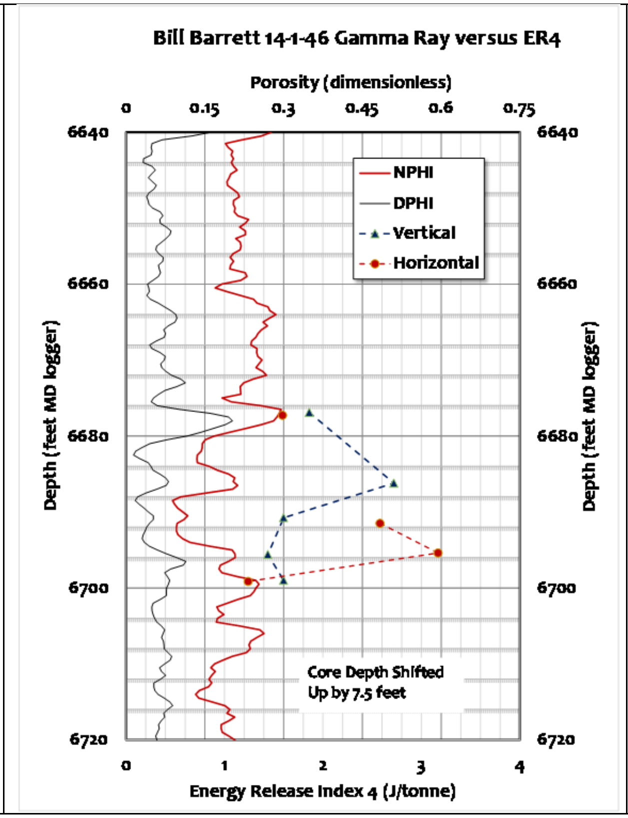

Bill Barrett 14-1-46 Gamma Ray versus ER3b
Gamma Ray (GAPI)
0
100
200
300
400
500
6640
6660
6680
6700
6720
GR
Vertical
Horizontal
Core Depth Shifted Up by 7.5 feet
Depth (feet MD logger)
0.0001
0.001
0.01
0.1
1
10
100
Energy Release Index 3b (J/tonne)


Bill Barrett 14-1-46 Gamma Ray versus ER3b
Porosity (dimensionless)
0
0.15
0.3
0.45
0.6
0.75
6640
6660
6680
6700
6720
NPHI
DPHI
Vertical
Horizontal
Core Depth Shifted
Up by 7.5 feet
Depth (feet MD logger)
0.001
0.01
0.1
1
10
100
Energy Release Index 3b (J/tonne)

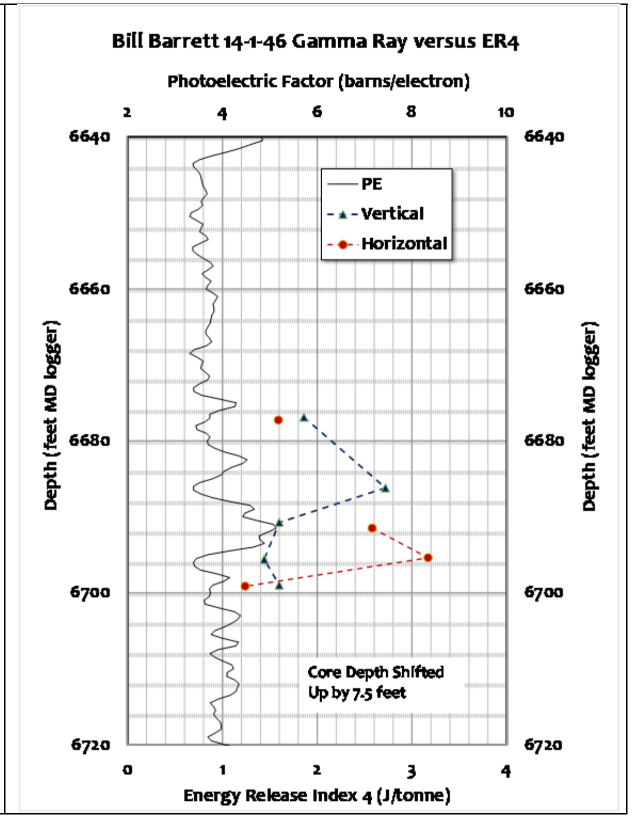

Bill Barrett 14-1-46 Gamma Ray versus ER3b
Photoelectric Factor (barns/electron)
2
4
6
8
10
6640
6660
6680
6700
6720
PE
Vertical
Horizontal
Core Depth Shifted
Up by 7.5 feet
Depth (feet MD logger)
0.0001
0.001
0.01
0.1
1
10
100
Energy Release Index 3b (J/tonne)



Bill Barrett 14-1-46 Gamma Ray versus ER4
Gamma Ray (GAPI)
Depth (feet MD logger)
GR
Vertical
Horizontal
Core Depth Shifted Up by 7.5 feet
Energy Release Index 4(J/tonne)



Bill Barrett 14-1-46 Gamma Ray versus ER4
Porosity (dimensionless)
Depth (feet MD logger)
NPHI
DPHI
Vertical
Horizontal
Core Depth Shifted
Up by 7.5 feet
Energy Release Index 4 (J/tonne)



Bill Barrett 14-1-46 Gamma Ray versus ER4
Photoelectric Factor (barns/electron)
Depth (feet MD logger)
PE
Vertical
Horizontal
Core Depth Shifted
Up by 7.5 feet
Energy Release Index 4 (J/tonne)

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