Oil & Natural Gas Technology

DOE Award No.: DE-FE0010667

Research Performance Progress Report

Quarterly Report: October 2013 to December 2013

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

Submitted by:
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Prepared for:
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Office of Fossil Energy

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EXECUTIVE SUMMARY

Toward the end of Budget Period 1 (BP 1), the Principal Investigator (PI) finished describing all available and useful Uteland Butte cores from the Uinta Basin, Utah. During the first quarter of BP 2, efforts shifted to drafting core descriptions alongside geophysical logs and other core analyses. These core logs are vital to understanding the play's regional extent, facies variations, and internal heterogeneity. After relating core to geophysical logs, several key stratigraphic intervals can be traced and mapped across the basin. Taking the lead on the geomechanics portion of this project is a new PhD level student at the University of Utah. This student will continue to collaborate with Newfield on core from the productive over-pressured area of the basin and soon begin research on a Bill Barrett Uteland Butte core from a more normally pressured, and less economic, area.

To aid in our understanding of the Cane Creek shale play in the Paradox Basin, several additional Cane Creek cores have been located and agreements have been made to acquire or borrow this material for use with this study. This new core material will greatly aid in the analysis of geophysical logs from wells without core, helping to create a regional geologic understanding of the play. To this end, several preliminary structure and thickness maps of the Cane Creek play have been created. The project team has also begun analysis of the Gothic shale, stratigraphically above the Cane Creek, as this shale also has potential for liquid production.

An abstract focusing on the geological characteristics and productive potential of the Cane Creek shale was accepted as an oral presentation to the American Association of Petroleum Geologists (AAPG) Annual meeting, which will take place in early April 2014. The Utah Geological Survey will also have an exhibit booth at the meeting with materials and posters describing progress on this project.

PROGRESS, RESULTS, AND DISCUSSION

Task 1.0: Project Management Plan

During the month of October, the PI wrote and submitted the project's fourth quarterly report for July to September 2013. This report was subsequently sent via email to all interested parties and posted on the UGS project website. In addition, The PI updated the Project Summary in October 2013.

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 fourth quarterly report and emailed it to all interested parties. It is also available on the project website.
- An abstract on the Cane Creek tight oil play was accepted as an oral presentation in the Unconventional Resources: Tight Oil Plays session at the AAPG annual meeting in Houston.
- An article summarizing the geology and current drilling and research activities of the Uteland Butte and Cane Creek tight oil plays was submitted for publication in the AAPG-EMD (Energy and Minerals Division) Shale Gas and Liquids Committee Midyear Report

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

Uteland Butte Member: All available Uteland Butte cores have been described (figure 1) and details of the descriptions are currently being drafted alongside geophysical logs and other available data. With the completed examination of the cores, focus has now shifted towards understanding the regional geologic setting associated with this zone. For example, project team members have begun picking tops on geophysical logs and mapping the individual marker beds and productive carbonate intervals within the Uteland Butte to determine lateral variations and heterogeneity. In addition, a north-south cross section

(trace is displayed on figure 1) is under construction (the west-east section is available on the 2013 AAPG poster). This section will highlight facies changes from near shore to deep lake, including the pinching out of the Uteland Butte member to the north.

Cane Creek Shale: The Cane Creek shale typically consists of three primary intervals (facies) informally named from top to bottom, A, B, and C (figure 2). Intervals A and C typically consist of carbonate (mostly dolomite) with nodular anhydrite and occasional anhydrite- or halite-filled fractures. Interval B is the primary target for oil development and consists of dolomite, dolomitic siltstone, and organic-rich shale with occasional open fractures. Interval B is identified on gamma-ray logs as typically having a high gamma-ray spike at the top of the interval and relatively high readings throughout the interval. Intervals A and C have highly variable gamma-ray readings with numerous low readings in the anhydrite beds.

Interval (facies) tops and bases were identified on geophysical logs from about 170 wells and entered into a well database used for mapping. Regional structure mapping of the top of the Cane Creek shows the preliminary shale play area lies between the Paradox Fold and Fault Belt to the northeast and the Paradox Shelf to the southwest (figure 3). The Paradox Fold and Fault Belt is poorly defined by well data due to the low number of penetrations but is well defined on surface geologic mapping. The Fold and Fault Belt is dominated by large diapiric folds. Thick deposits of salt thin from the Fold and Fault Belt to the southwest onto the Paradox Shelf, which is dominated by carbonate strata.

Thickness mapping of the Cane Creek shale shows a general southeast to northwest trend (figure 4). The thickness trend follows depositional strike within the Paradox Basin during Cane Creek time. The Cane Creek thins to the southwest, onlapping onto the Paradox Self. It becomes unrecognizable as a distinctive shale unit where the overlying and underlying evaporates are no longer present. Thinning to the northeast may be more reflective of the lack of data points (penetrations) than actual thinning.

Thicknesses of the A, B, and C intervals were also mapped (figures 5, 6, and 7) to determine if thick or thin trends might identify sweet spots within the Cane Creek shale play area. Preliminary reviews seem to indicate that variations in the isopach maps do not correlate to possible play area sweet spots. The thickness of interval A (figure 5) generally follows the southeast to northwest depositional trend of the Cane Creek. Most Cane Creek producing wells have more than 10 feet of interval A. The transitional nature of interval A may serve as a hydrocarbon reservoir seal preventing naturally occurring fractures in the productive B interval from extending upward into overlying salt bed. Thickness of the productive B interval (figure 6) also follows the general depositional strike of the Cane Creek. Most wells producing from the Cane Creek have 10 to 30 feet of the B interval. Many of the productive Cane Creek wells were drilled horizontally; as a result, the thickness of the Cane Creek and its individual intervals are not available for many of these wells. Similarly, the thickness of the C interval (figure 7) generally follows the same southeast to northwest depositional strike. Many of the Cane Creek producing wells penetrated less than 10 feet to 20 feet of C interval. Like interval A, interval C may serve as a lower seal for the productive B interval.

The project team also made progress in locating additional Cane Creek core material. The Cisco State 36-13 core, located in the southern portion of the play area (figure 8), was delivered to UGS in December 2013. The core will be described and the data analyzed in the following quarter. In addition, arrangements have been made to have the Cane Creek section of the Gibson Dome #1 core slabbed. After the slabbing is finished, project team members will travel to the Texas Bureau of Economic Geology in Austin, Texas, to analyze the core and acquire samples for testing. Furthermore, agreement has been made with Fidelity E&P to borrow and analyze two cores (Cane Creek #26-3, and Cane Creek Unit 7-1) from the productive Big Flat field in the northern portion of the play area (figure 8).

Gothic Shale: The Gothic shale of the Paradox Formation is an organic-rich unit similar to the Cane Creek. The Gothic is near the top of the Paradox Formation in cycle 1, compared to the Cane Creek which is part of cycle 21. The Gothic has been identified as one of the source rocks for oil production from the Ismay and Desert Creek carbonate mounds along the Paradox Shelf. Deeper in the Colorado

portion of the basin, the Gothic is gas productive. Operators are currently looking at the Gothic as a potential shale oil play in the Monticello area (figure 9). The thickness of the Gothic (figure 10) follows a northwest-southeast depositional trend similar to the Cane Creek.

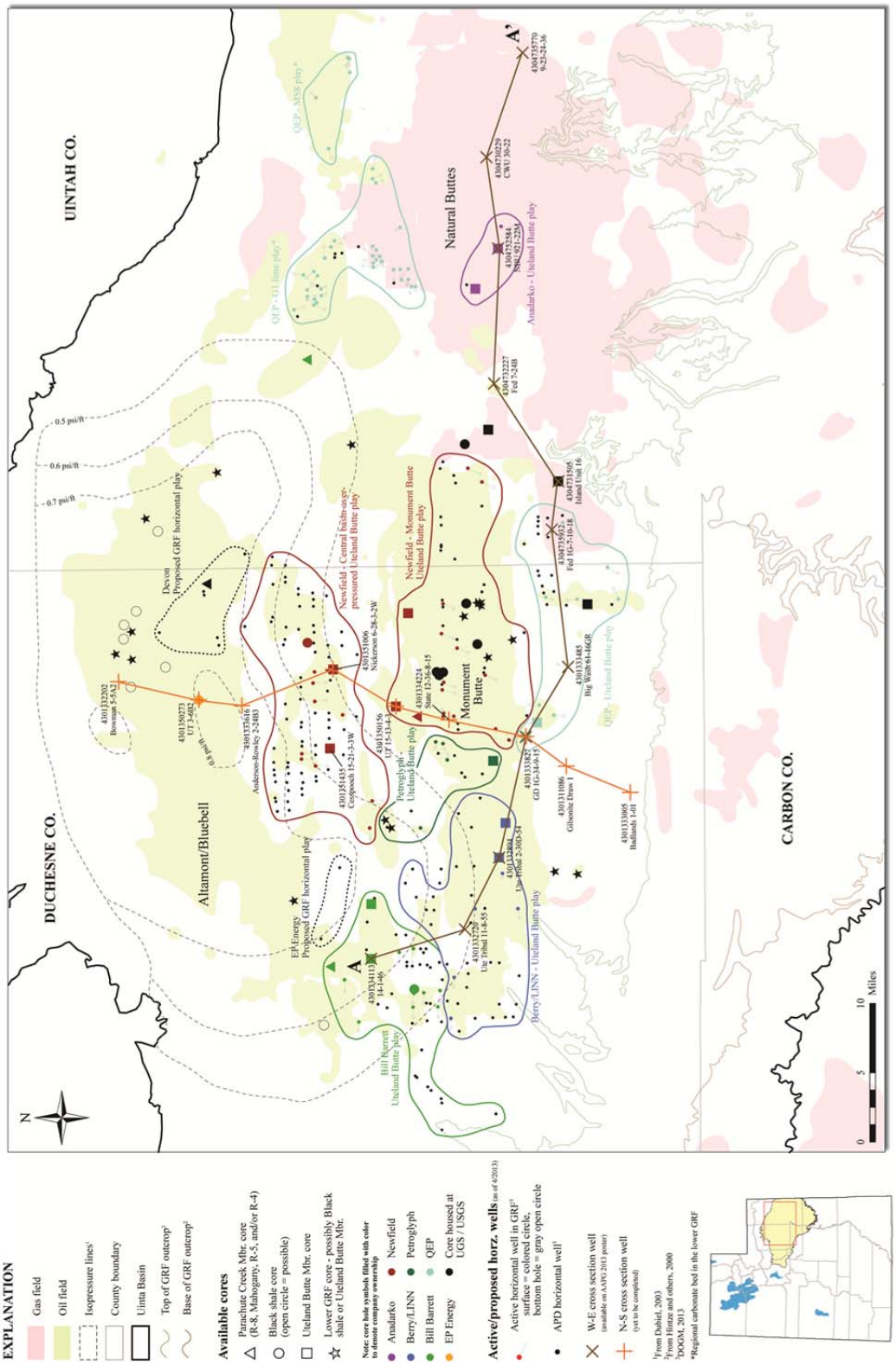

Figure 1. *Map of the Uinta Basin, Utah, showing the location of available Green River Formation cores and horizontal wells.*

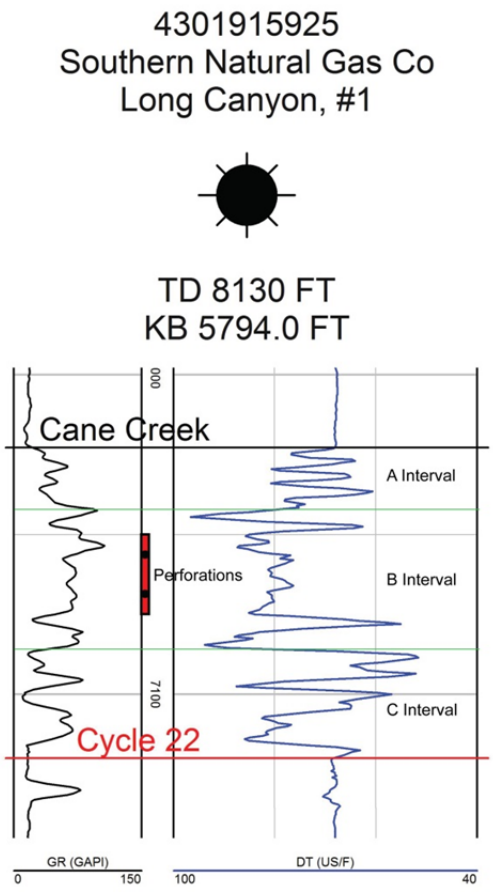

Figure 2. *Gamma-ray and sonic log from the Long Canyon 1 well showing the A, B, and C intervals of the Cane Creek shale in the Pennsylvanian Paradox Formation. More than 1.1 million barrels of oil have been produced from the vertically drilled Long Canyon 1 well since its completion in 1962. The well is currently (November 2013) producing less than 10 barrels of oil per day.*

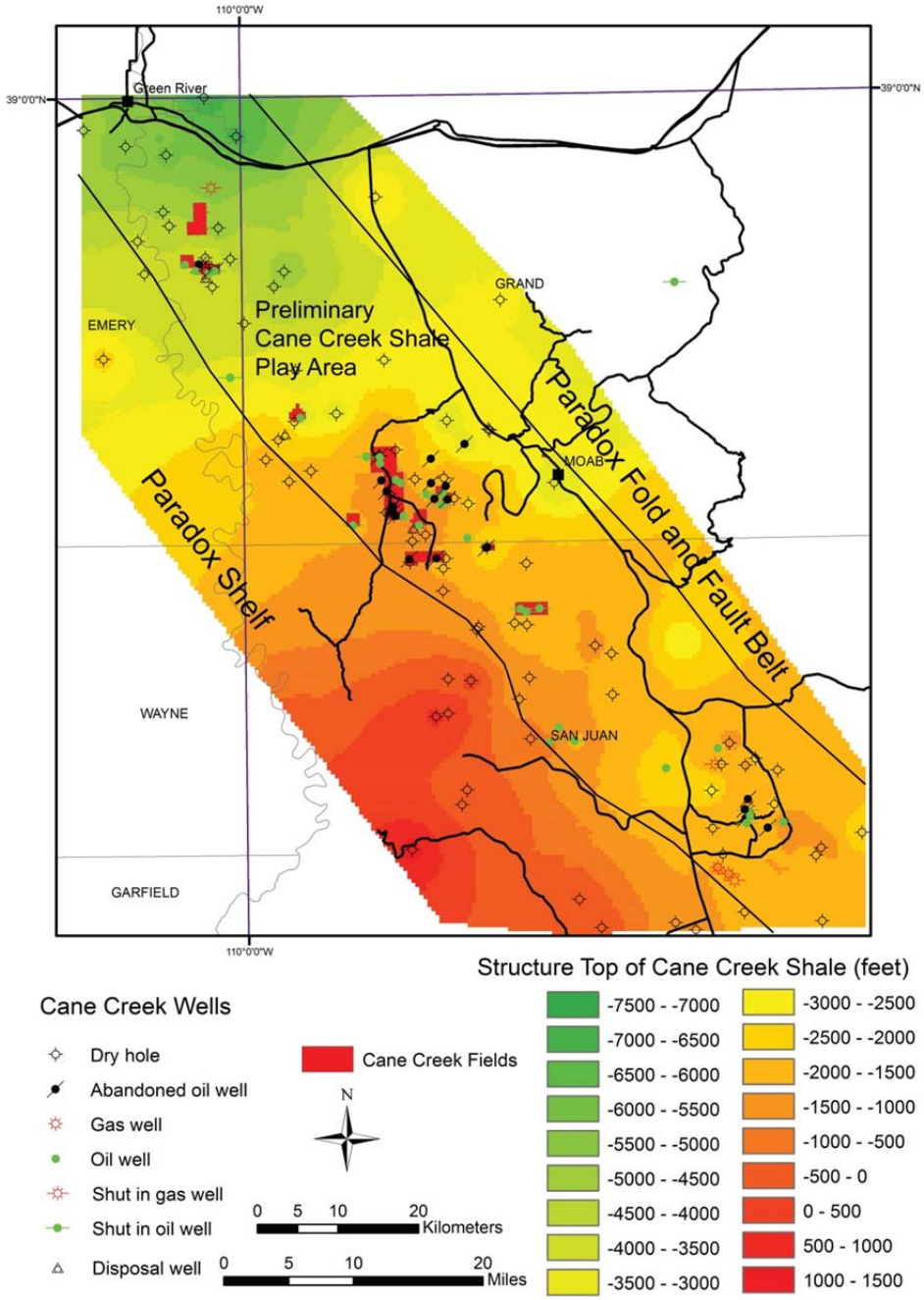

Figure 3. *Structure map on the top of the Cane Creek shale. The Cane Creek shale play area lies between the Paradox Fold and Fault Belt and the Paradox Shelf.*

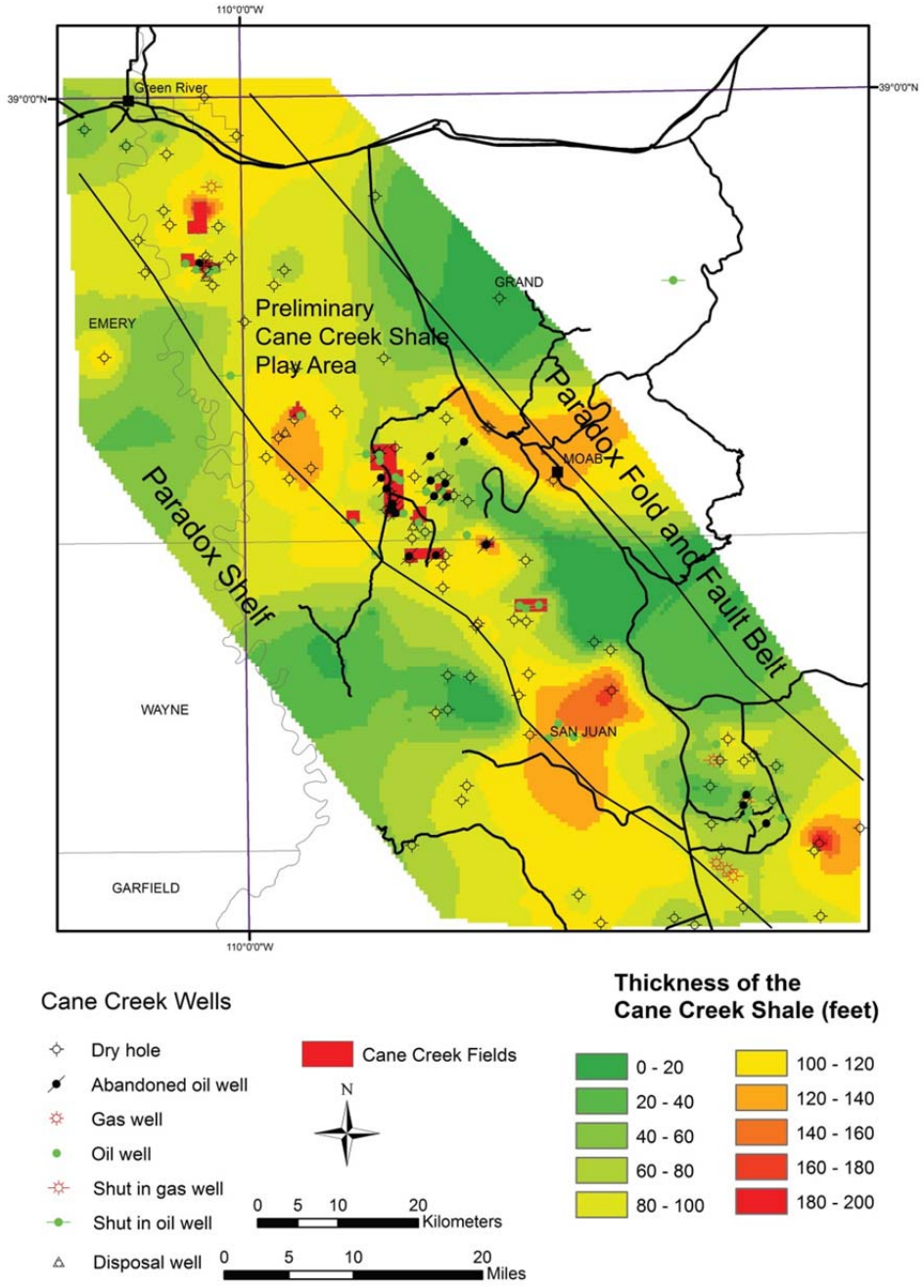

Figure 4. *Thickness of the Cane Creek shale showing a southeast to northwest depositional trend. Perceived thinning to the northeast may be a result of limited well penetrations.*

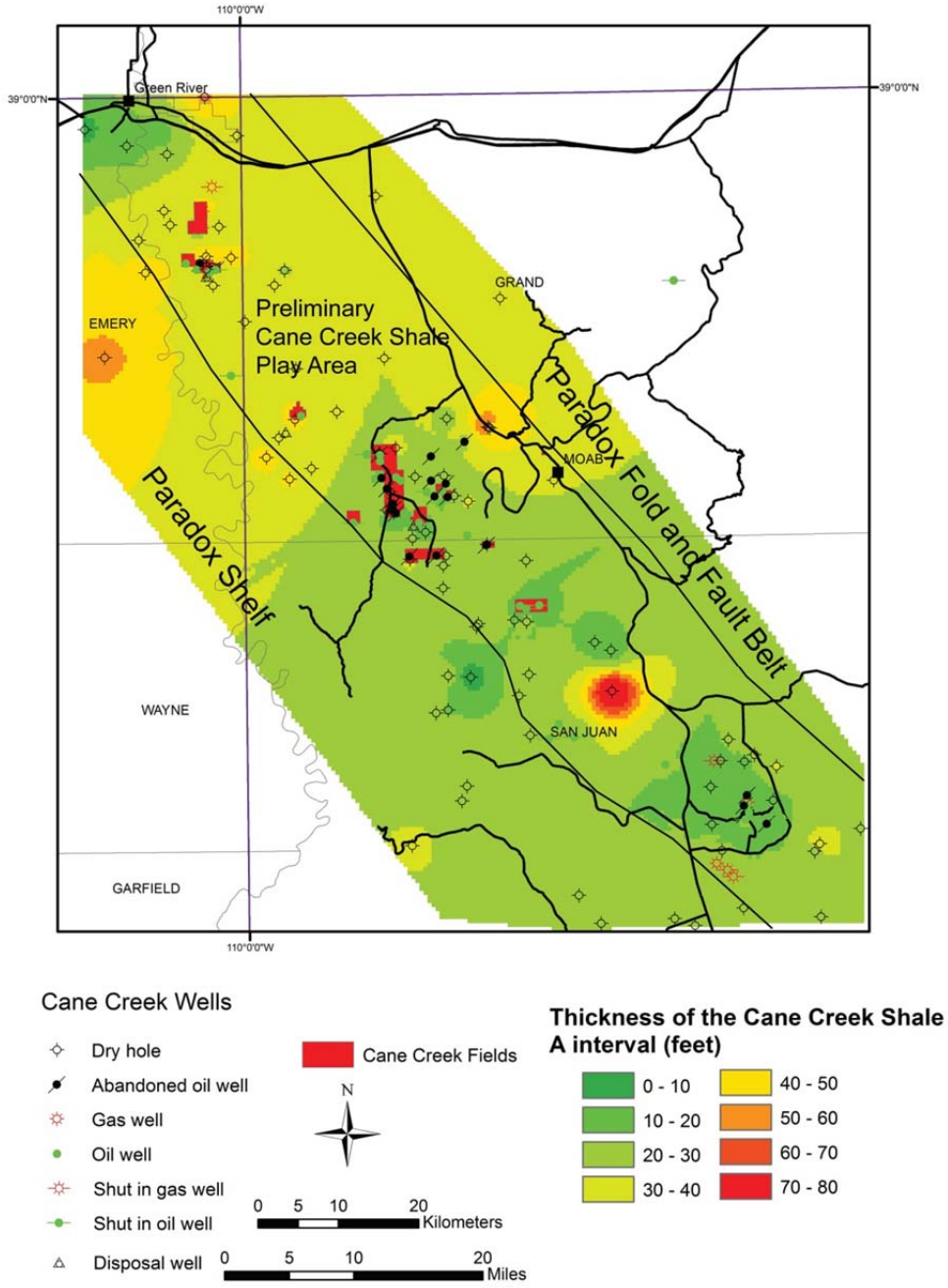

Figure 5. *Thickness of the Cane Creek A interval, which is transitional between the productive B interval and overlying salt beds. The A interval may provide an overlying seal for Cane Creek production.*

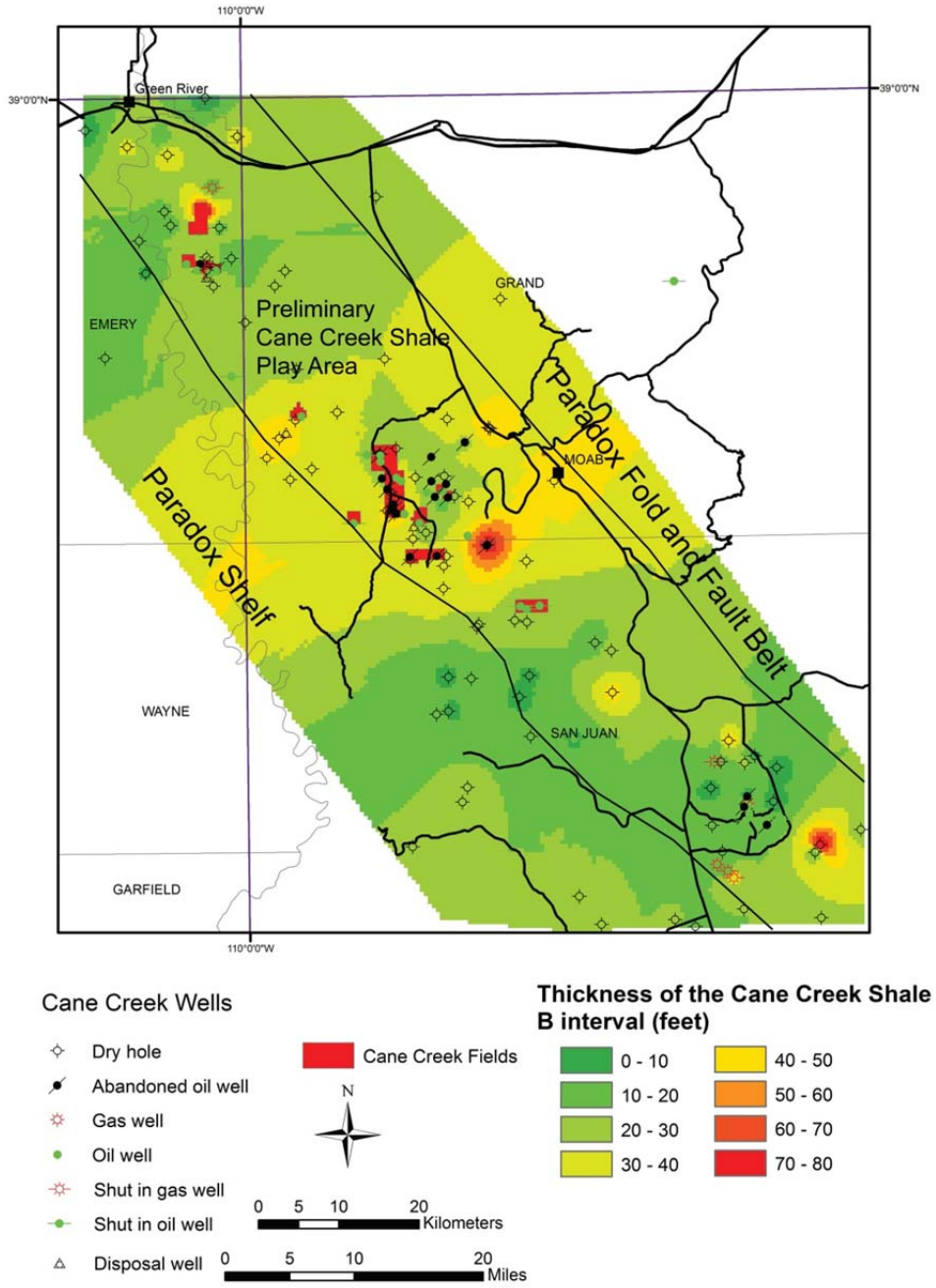

Figure 6. *Thickness of the Cane Creek B interval, the oil-productive facies.*

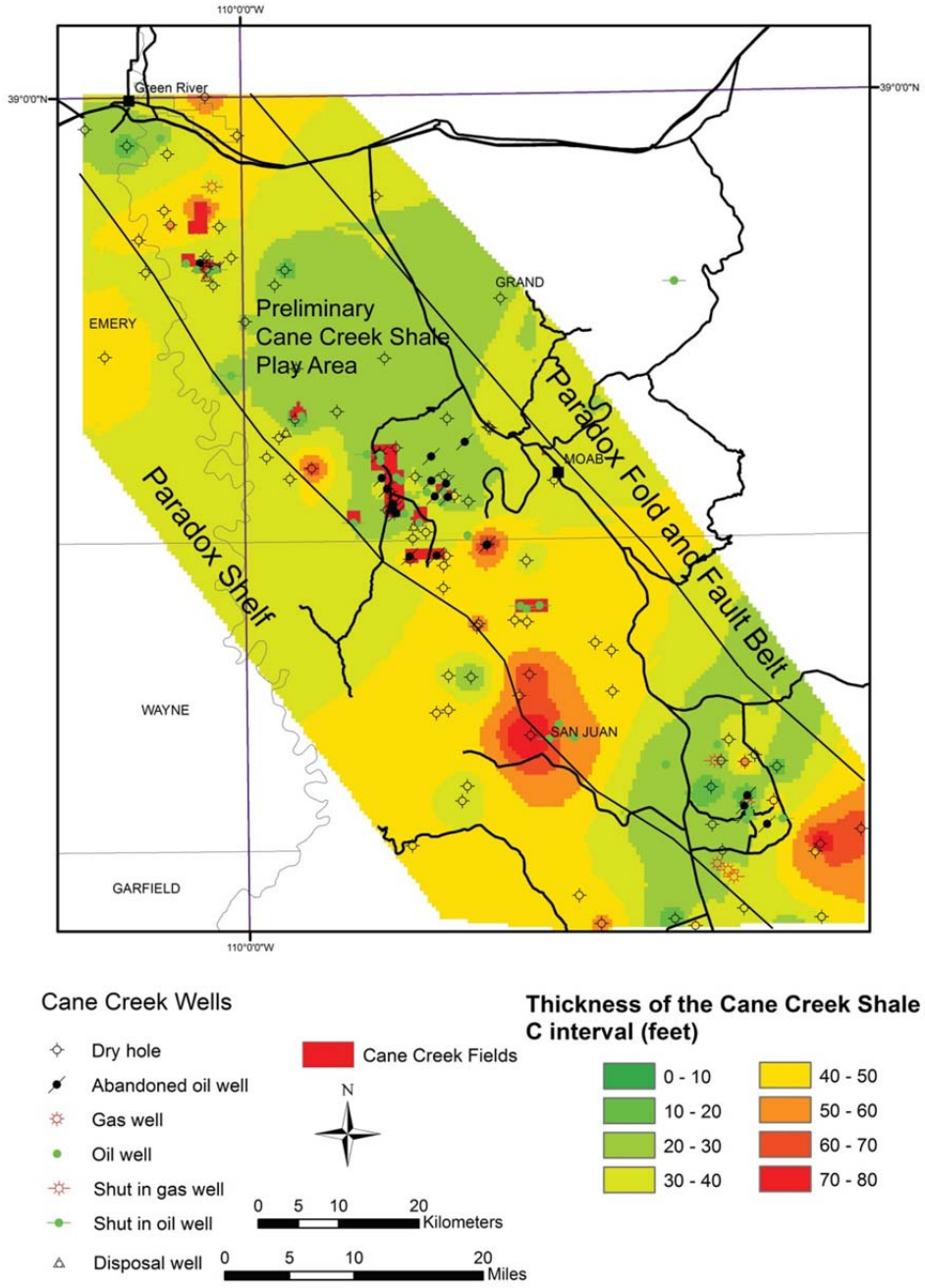

Figure 7. *Thickness of the Cane Creek C interval, which is transitional between the productive B interval and underlying salt beds. The C interval may provide an underlying seal for Cane Creek production.*

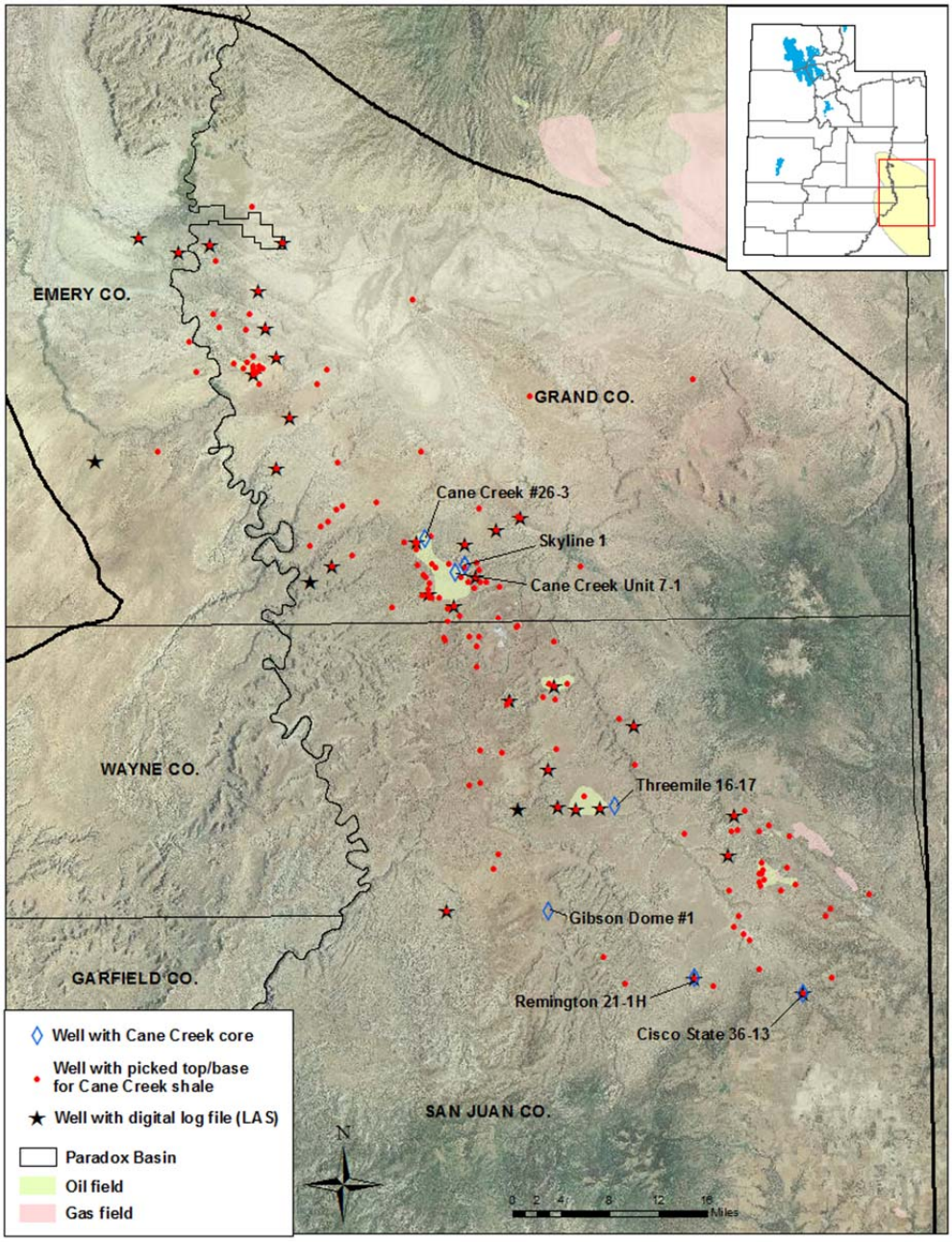

Figure 8. *Map of the Paradox Basin, Utah, showing the location of wells with Cane Creek core, picked Cane Creek top/base, and digitized log files (LAS files).*

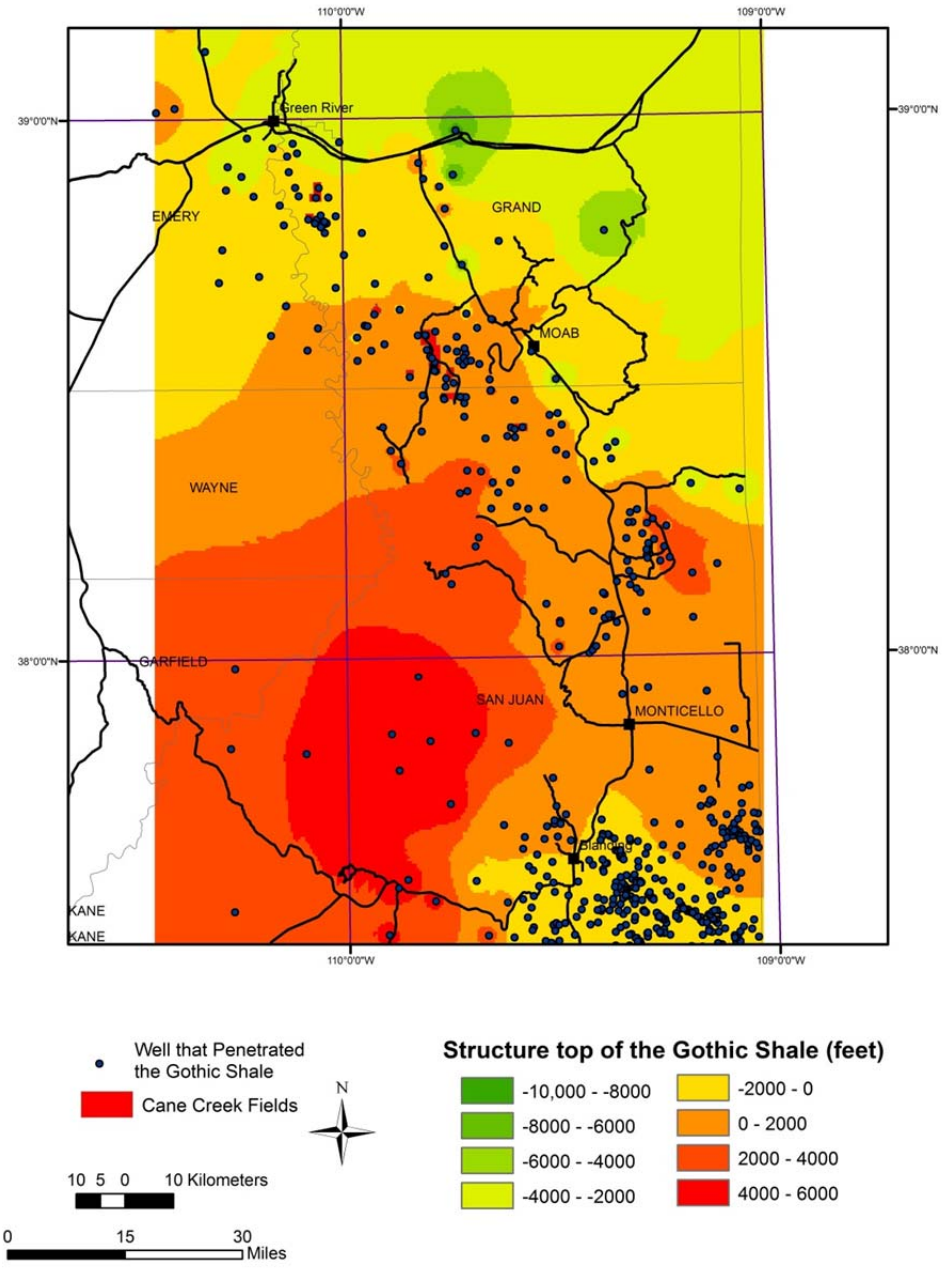

Figure 9. *Structure on top of the Gothic shale of the Paradox Formation.*

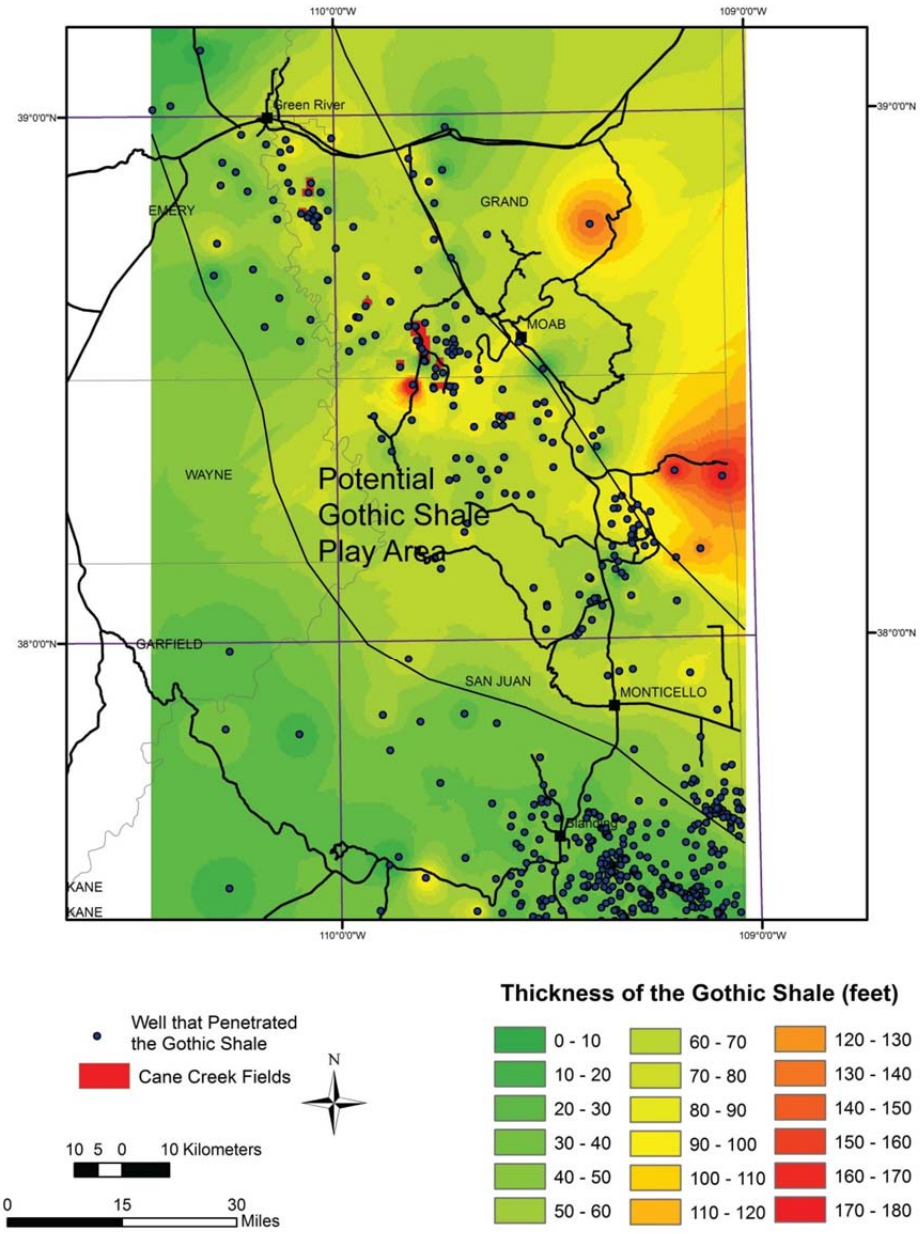

Figure 10. *Thickness of the Gothic shale of the Paradox Formation. Operators are currently looking at the Gothic as a possible shale oil play in the Monticello area. If successful, a Gothic play could develop along the southeast to northwest depositional trend.*

Task 6.0: Well Completion Optimization

Currently, production success in the Uteland Butte is most prevalent in the central, over-pressured portion of the Uinta Basin, where Newfield has a significant leasehold (figure 1). In areas farther to the south, east, and west, the Uteland Bute is under normal to only slight over-pressure, making economic production from such target areas more challenging. Goals for Task 6 will be to conduct a comprehensive geomechanical program on cores from normal and over-pressure areas, with the goal of unlocking the economic potential of the more normal pressured areas.

Project team members are collaborating with Newfield in testing fresh core from the Uteland Butte in the play's over-pressure zone. Core from the Cesspooch 15-21-3-3W well was recovered in late July 2013 and the project covered expenses for "scratch" testing the core in selected lithologic regimes. "Scratch" testing is a method where an indentor, under normal stress, is dragged along the external axis of a core sample or slab. The required shear force to scribe a groove on this surface is used in conjunction with the applied normal stress to infer a continuous measure of the friction angle, the unconfined compressive strength, and ideally other mechanical properties. In addition to the scratch test, XRD was performed extensively along the length of the core and is being related to mechanical properties. Other rock mechanics and special core analyses are ongoing.

Sample intervals from the Bill Barrett 14-1-46 Uteland Butte core, located outside the main over-pressured productive area, were determined for a comprehensive geomechanics testing program. Sampling collection (drilling of core plugs) and testing will commence in winter 2014.

CONCLUSION

Drafting of the Uteland Butte core descriptions is ongoing and work continues on picking stratigraphic well tops for regional mapping. Several additional Cane Creek shale cores were located and are in the process of being acquired or borrowed. Regional mapping of the Cane Creek is well underway and will continue to be refined into the next quarter. Details of a geomechanical testing program are still being finalized for both the Uteland Butte play in the Uinta Basin and the Cane Creek play in the Paradox Basin.

COST STATUS

Table 1. *Project costing profile for Budget Period 2.*

	Oct 2013		Nov 2013		Dec 2013	
	Plan	Actual	Plan	Actual	Plan	Actual
UGS-personnel	$9,930	$8,952	$9,930	$8,570	$9,930	$8,133
Travel Expenses	$1,020		$1,020			
Analyses[1]		$3,320	$19,364			$320
Miscellaneous[3]		$59			$500	
SUBTOTALS	$10,950	$12,331	$30,314	$8,570	$10,430	$8,453
UGS OVERHEAD (34.44%)	$3,771	$4,247	$10,440	$2,951	$3,592	$2,911
SUBCONTRACTS						
EGI	$6,771	$0	$6,771	$0	$6,771	$0
Eby	$2,287	$0	$2,287	$0	$2,287	$0
GRAND TOTALS	$23,778	$16,578	$49,811	$9,217	$23,079	$11,364

[1]Oct and Dec – "Scratch" test on Uteland Butte core
[2]Oct – Poster lamination

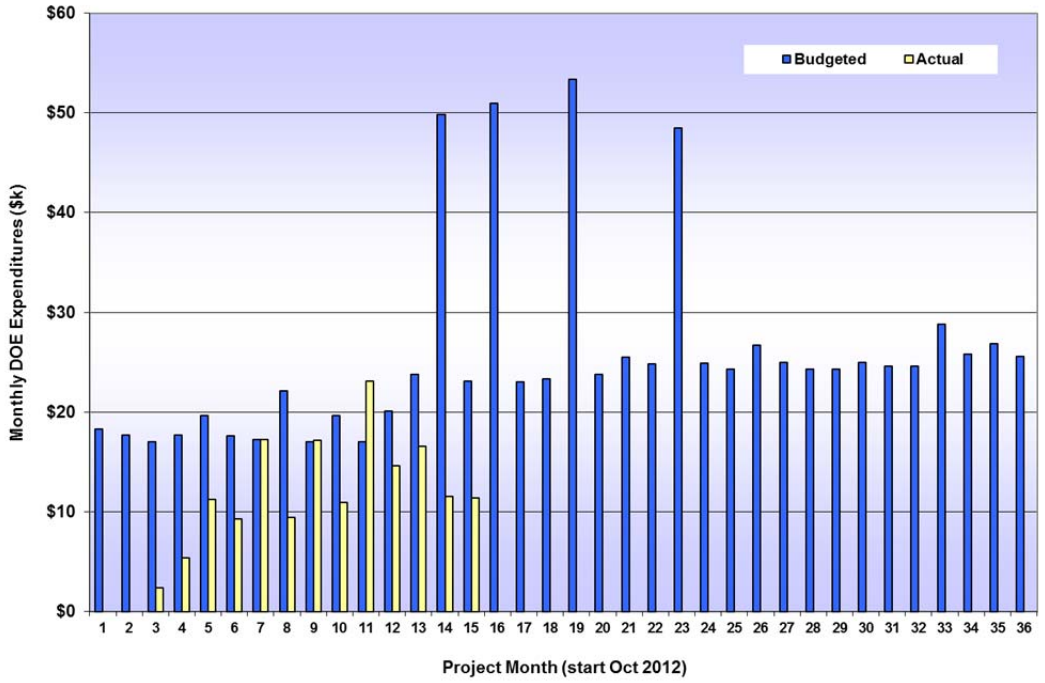

Figure 11. *Project costing profile.*

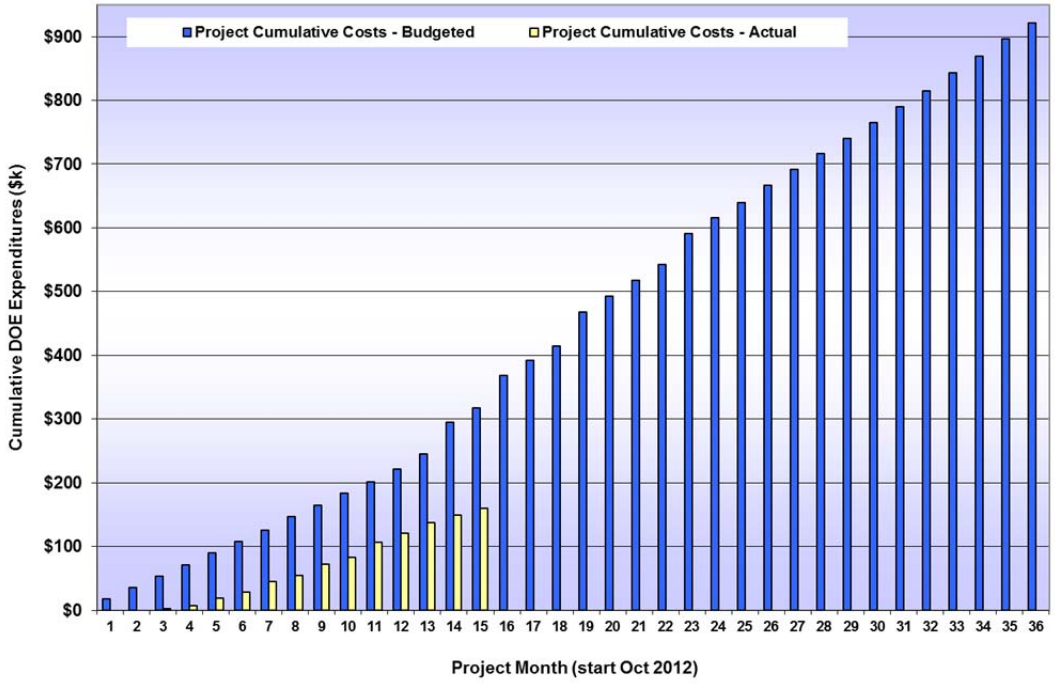

Figure 12. *Project cumulative costs.*

MILESTONE STATUS

Table 2. *Milestone log for Budget Period 2.*

	Title	Related task or subtask	Completion Date	Update/comments
Milestone 14	Quarterly updates of website	Subtask 2.1	Quarterly	Ongoing
Milestone 15	Quarterly reports	Subtask 2.2	Quarterly	Ongoing
Milestone 16	Technical presentations at National AAPG	Subtask 2.4 & 5	Apr-14	Abstract on Cane Creek accepted for oral presentation
Milestone 17	Technical presentations at Regional AAPG	Subtask 2.4 & 5	Jun-14	Two abstracts planned for submittal
Milestone 18	Measure & describe key outcrops	Subtask 5.1	30-Jun-14	Spring 2014
Milestone 19	Outcrop sample collection	Subtask 5.2	30-Jun-14	Spring 2014
Milestone 20	Fracture analyses of outcrop	Subtask 5.3	30-Jun-14	Spring 2014
Milestone 21	Sample analyses from core	Subtask 4.2	30-Sep-14	Ongoing
Milestone 22	Epifluorescent measurements on cuttings	Subtask 4.3	30-Sep-14	Cutting collection started Winter 2014, analysis planned for Spring 2014
Milestone 23	Organic geochemical analyses	Subtask 4.4	30-Sep-14	Ongoing
Milestone 24	Fracture analyses of core	Subtask 4.5	30-Sep-14	Ongoing
Milestone 25	Rock mechanics testing	Subtask 4.6	30-Sep-14	Ongoing
Milestone 26	Lab analyses of samples	Subtask 5.4	30-Sep-14	
Milestone 27	Methodologies for brittle behavior	Subtask 6.1	30-Sep-14	
Milestone 28	Methodologies for fracture growth	Subtask 6.2	30-Sep-14	
Milestone 29	Identify algorithms	Subtask 6.3	30-Sep-14	
Milestone 30	Second debriefing meeting	Subtask 2.3	Sep-14	
Milestone 31	BP 2 Decision Point	Task 1	30-Sep-14	

ACCOMPLISHMENTS

- Acquired a new Cane Creek core (and associated data) from the Cisco State 36-13 well, located in the southern portion of the play area.
- Developed an agreement with Fidelity E&P Co. for access to two Cane Creek cores, Cane Creek 26-3 and Cane Creek 7-1, both located in the productive Big Flat field.
- Initiated a geomechanical testing program with Fidelity for the Cane Creek 7-1 core.

PROBLEMS OR DELAYS

A contract has been set up with the Energy and Geoscience Institute (EGI), University of Utah, and a PhD level student will start working on this project in January 2014. As a result of the delay in finding a student, the overall project will be under-billed until research begins at EGI. In addition, the Eby contract has been delayed until the second quarter of BP 2.

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 2013
  - Completed late October and is available on the project website.
- Abstract – 2014 AAPG annual meeting, Houston, TX, April 6-9, 2014
  - An abstract titled "Geological Evaluation of the Cane Creek Shale, Pennsylvanian Paradox Formation, Paradox Basin, Southeastern Utah" was accepted as an oral presentation in the Unconventional Resources: Tight Oil Plays session, Wednesday morning, April 9, 2014.
  - The abstract is available on the UGS project website.
- Article for the AAPG-EMD (Energy and Minerals Division) Shale Gas and Liquids Committee Midyear Report
  - Project team member Tom Chidsey wrote an article summarizing the geology and current drilling and research activities of the Uteland Butte and Cane Creek tight oil plays.
  - The article is available on the UGS project website.

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