Tight-Oil and Shale-Gas Plays and Activities in Utah

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The dramatic crash of crude oil that occurred towards the end of 2014, coupled with continued low natural gas prices, has severely affected exploration and development of liquid hydrocarbon reserves in Utah. Following on the success of the recent shale gas boom and employing many of the same well completion techniques, numerous petroleum companies have, until recently, been exploring for liquid petroleum in shale formations in the state. In fact, many shales or low-permeable ("tight") carbonates targeted for natural gas include areas in which the zones are more prone to liquid production. Organic-rich shales in the Uinta and Paradox Basins have been the source for significant hydrocarbon generation, with companies traditionally targeting the interbedded sands or porous carbonate buildups for their conventional resource recovery. With the advances in horizontal drilling and hydraulic fracturing techniques, operators in these basins for the past several years explored the petroleum production potential of the shale and interbedded tight units themselves.

Uinta Basin

Overview

The Uinta Basin is the most prolific petroleum province in Utah. It is a major depositional and structural basin that subsided during the early Cenozoic along the southern flank of the Uinta Mountains. Lake deposits filled the basin between the eroding Sevier highlands to the west and the rising Laramide-age Uinta Mountains, Uncompahgre uplift, and San Rafael Swell to the north, east, and south, respectively. The southern Eocene lake, Lake Uinta, formed within Utah's Uinta Basin and Colorado's Piceance Creek Basin.

The Green River Formation consists of as much as 6000 feet (ft) of sedimentary strata (Hintze and Kowallis, 2009; Sprinkel, 2009) and contains three major depositional facies associated with Lake Uinta sedimentation: alluvial, marginal lacustrine, and open lacustrine (Fouch, 1975). The marginal lacustrine facies, where most of the hydrocarbon production is found, consists of fluvial-deltaic, interdeltaic, and carbonate flat deposits, including microbial carbonates. The open-lacustrine facies is represented by nearshore and deeper water offshore muds, including the famous Mahogany oil shale zone, which represents Lake Uinta's highest water level.

The Uinta Basin is asymmetrical, paralleling the east-west trending Uinta Mountains. The north flank dips 10-35º southward into the basin and is bounded by a large north-dipping, basement-involved thrust fault. The southern flank gently dips between 4-6º north-northwest.

Activity

Recent tight-oil drilling and exploration activities in the Uinta Basin are targeting relatively thin porous carbonate beds of the Uteland Butte Limestone Member of the lower Green River Formation (figures 1 and 2), particularly in an area referred to as the "Central Basin region" between Altamont-Bluebell field to the north and Monument Butte field to the south. The Uteland Butte has historically been a secondary oil objective of wells tapping shallower overlying Green River reservoirs and deeper fluvial-lacustrine Colton Formation sandstone units in the western Uinta Basin.

The Uteland Butte records the first major transgression of Eocene Lake Uinta after the deposition of the alluvial Colton Formation, and thus it is relatively widespread in the basin (figure 3). The Uteland Butte ranges in thickness from less than 60 ft to more than 200 ft and consists of limestone, dolomite, organic-rich calcareous mudstone, siltstone, and rare sandstone (figures 2, 4, and 5). The dolomite (figure 2), the horizontal drilling target, often has more than 20% porosity, but is so finely crystalline that the permeability is very low (single mD or less).

Several companies (Newfield, LINN, Bill Barrett Corporation, Crescent Point, QEP Resources, and Petroglyph) have had recent and continued success targeting the Uteland Butte with horizontal wells in both the central, normally pressured part of the basin near Greater Monument Butte field, and farther north in the overpressured zone in western Altamont field (figure 1). There are over 84 active horizontal wells producing from the Uteland Butte. Production from these wells averages 500 to 1500 barrels of oil equivalent (BOE) per day from horizontal legs up to 4000 ft in length. As of January 1, 2015, cumulative production from the Uteland Butte was 4.4 million barrels (bbls) of oil and 7.3 billion cubic feet of gas (BCFG) with 2.3 million bbls of water (Utah Division of Oil, Gas, and Mining, 2015a). There were also over 200 applications for permits to drill (APDs) for horizontal wells targeting the Uteland Butte and other potential Green River tight-oil zones (figure 1) (Utah Division of Oil, Gas, and Mining, 2015b) at the beginning of 2015. However, at the time of this report there were no rigs drilling horizontal wells in the Uinta Basin. Prior to the oil price collapse, Newfield had completed six super-extended lateral wells (horizontal lengths greater than 5000 ft) in the central basin Uteland Butte play area (figure 1) at rates of about 1800 barrels of oil per day (BOPD) (IHS Inc., 2014b).

Paradox Basin

Overview

The Paradox Basin is located mainly in southeastern Utah and southwestern Colorado with small portions in northeastern Arizona and the northwestern corner of New Mexico. The Paradox Basin is an elongate, northwest-southeast-trending, evaporitic basin that predominately developed during the Pennsylvanian, about 330 to 310 Ma. The basin was bounded on the northeast by the Uncompahgre Highlands as part of the Ancestral Rockies. As the highlands rose, an accompanying depression, or foreland basin, formed to the southwest—the Paradox

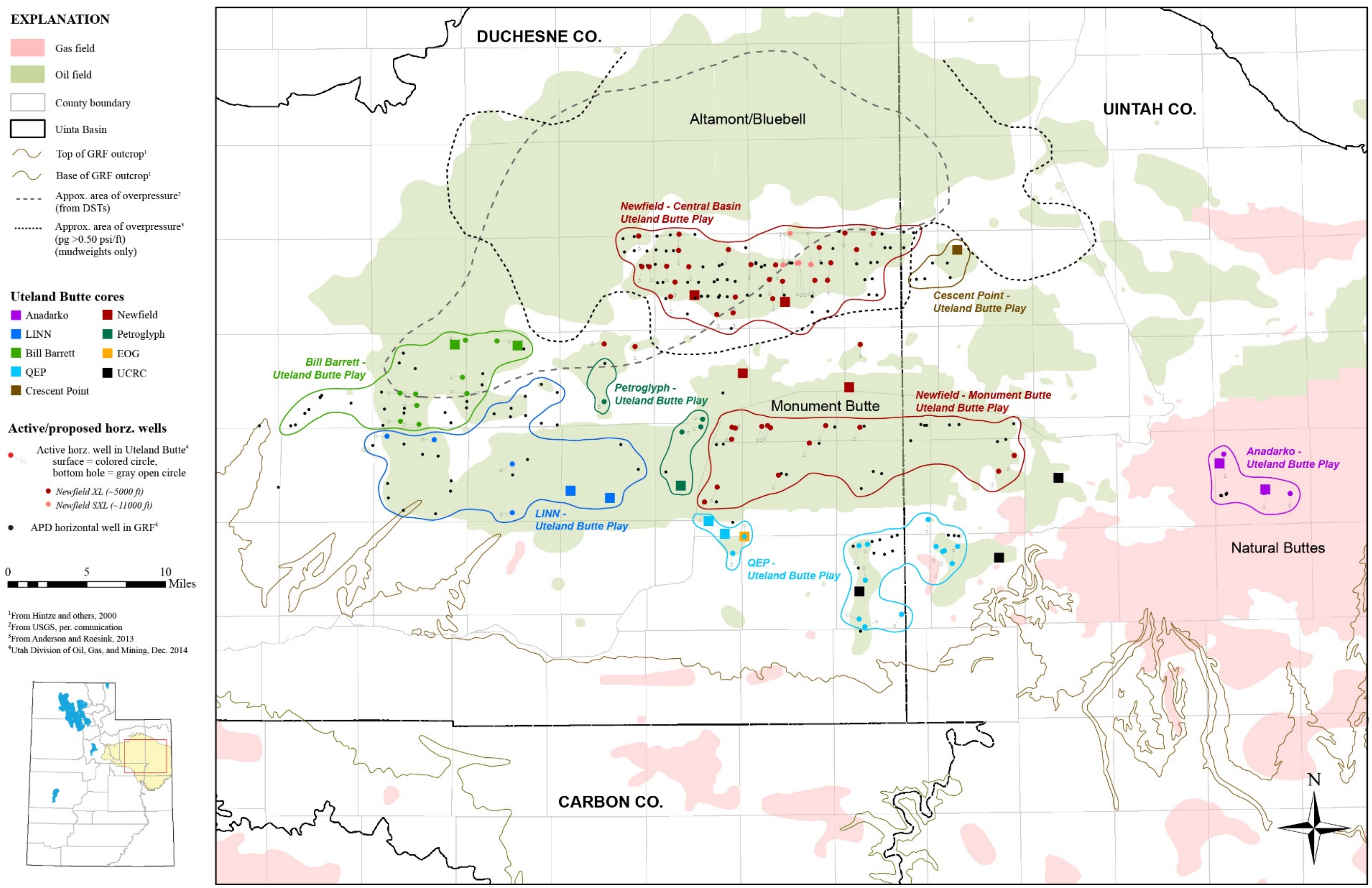

Figure 1. Map of the Uinta Basin, Utah, showing play areas for the Uteland Butte Limestone Member of the Tertiary Green River Formation, APD horizontal well locations, and active horizontal wells by operators.

Figure 2. Uteland Butte core from the Bill Barrett 14-1-46 well. The horizontal drilling target is the roughly 5-ft light brown dolomitic interval. Porosity in this interval ranges from 15-30% and permeability averages 0.06 mD. The dolomite is interbedded with organic-rich mudstones and limestones averaging between 1% and 3% TOC. Note the abundant shell fragments indicating deposition in a freshwater lacustrine environment.

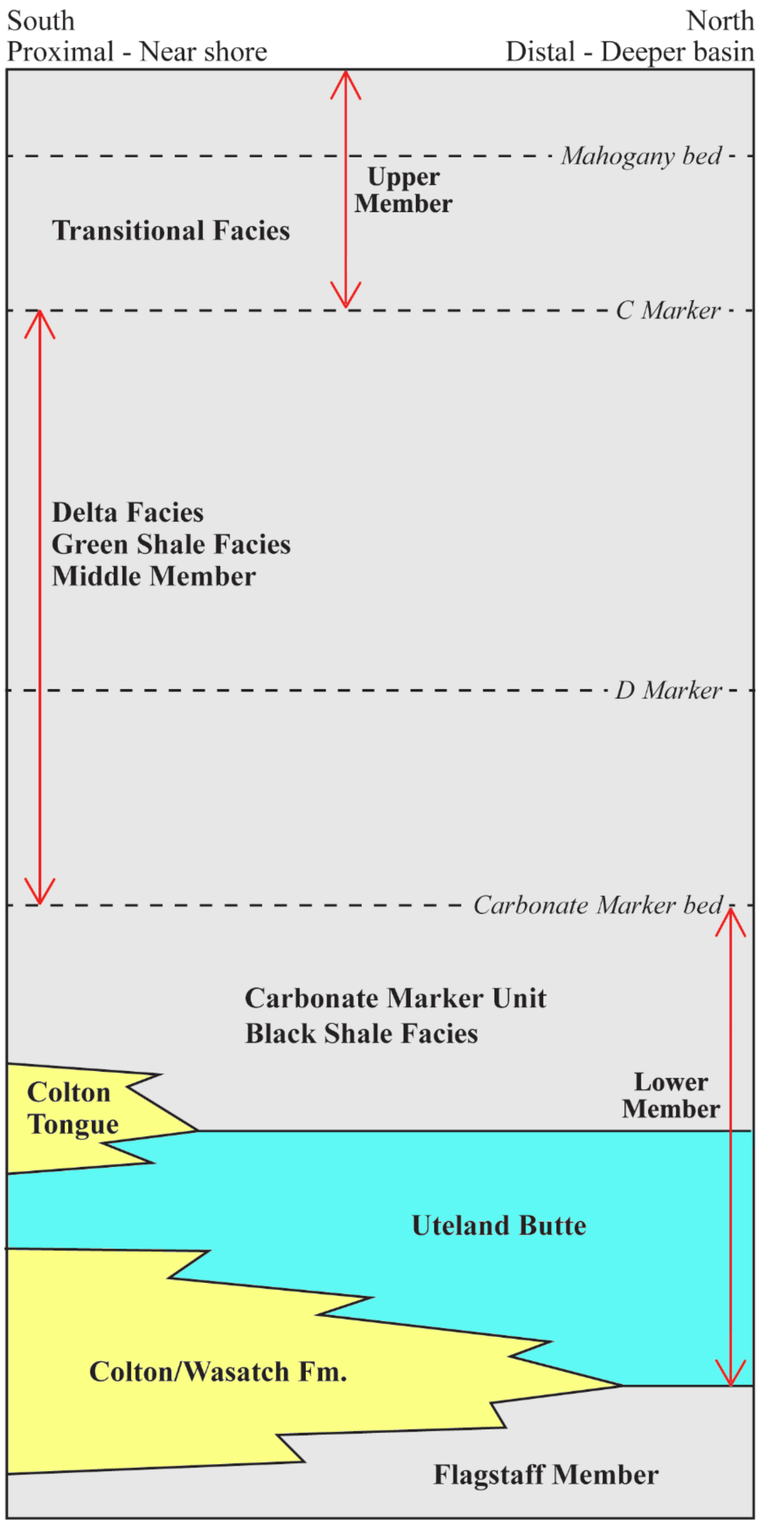

Figure 3. General stratigraphy of the Green River Formation in the western Uinta Basin (not to scale). The Uteland Butte Limestone, the primary horizontal drilling target in the basin, and its relationship to the Colton/Wasatch Formation is shown.

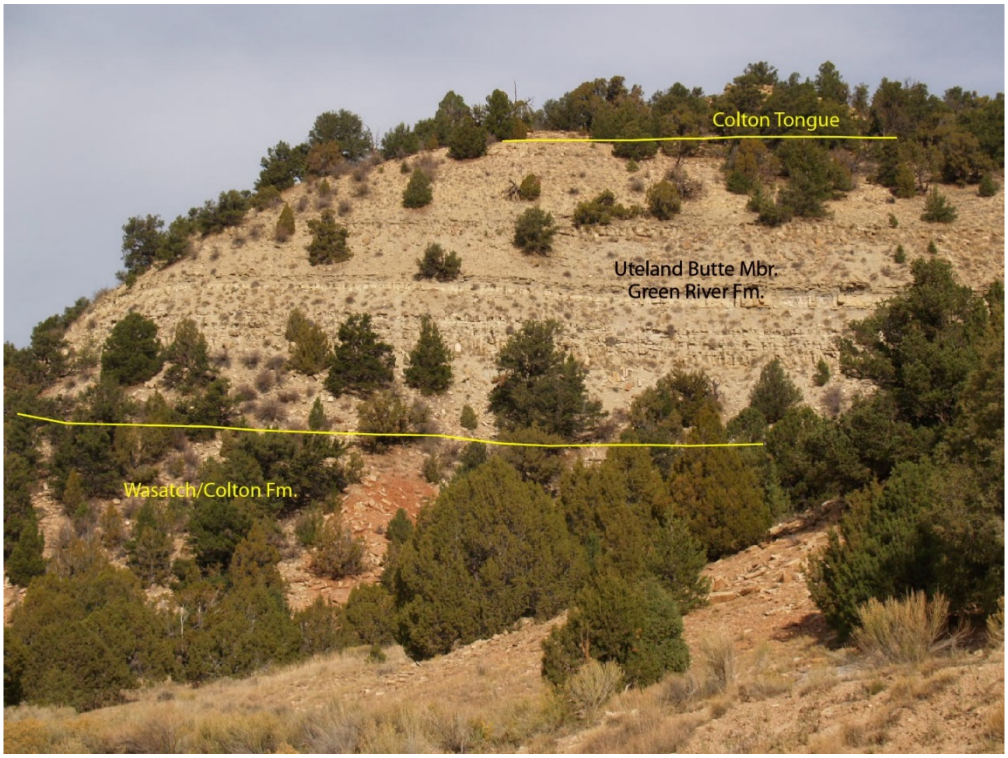

Figure 4. Outcrop of the Uteland Butte Member of the Green River Formation, Nine Mile Canyon, central Utah.

Figure 5. Fresh road cut exposure of Uteland Butte Member of the Green River Formation consisting of interbedded dolomite and mudstone/limestone, Nine Mile Canyon, central Utah.

Basin. Rapid basin subsidence, particularly during the Pennsylvanian and continuing into the Permian, accommodated large volumes of evaporitic and marine sediments that intertongue with non-marine arkosic material shed from the highland area to the northeast. Deposition in the basin produced a thick cyclical sequence of carbonates, evaporites, and organic-rich shale of the 500- to 5000-ft-thick Pennsylvanian Paradox Formation (Hintze and Kowallis, 2009).

Rasmussen (2010) divided the middle part of the Paradox Formation in the evaporite basin into as many as 35 salt cycles, some of which onlap onto the basin shelf to the west and southwest (figure 6). Each cycle consists of a clastic interval/salt couplet. The clastic intervals are typically interbedded dolomite, dolomitic siltstone, anhydrite, and black, organic-rich shale—the sources of the petroleum in the basin. The clastic intervals typically range in thickness from 10 to 200 ft and are generally overlain by 200 to 400 ft of halite.

The Paradox Basin can generally be divided into three areas: the Paradox fold and fault belt in the north, the Blanding sub-basin in the south-southwest, and the Aneth platform in the southernmost part in Utah. The area now occupied by the Paradox fold and fault belt was the site of greatest Pennsylvanian/Permian subsidence and salt deposition. Folding in the Paradox fold and fault belt began as early as the Late Pennsylvanian as sediments were laid down thinly over, and thickly in areas between, rising salt. Spectacular salt-cored anticlines extend for miles in the northwesterly trending fold and fault belt. Reef-like buildups or mounds of carbonates consisting of algal bafflestone and oolitic/skeletal grainstone fabrics in the Desert Creek and Ismay zones of the Paradox Formation are the main hydrocarbon producers in the Blanding sub-basin and Aneth platform. Oil in these zones is sourced above, below, or within the organic-rich Gothic, Chimney Rock, Hovenweep, and Cane Creek shales (figure 6).

Activity

The Cane Creek shale zone of the Paradox Formation has been a target for tight-oil exploration on and off since the 1960s and produces oil from several small fields (figure 7). The play generated much interest in the early 1990s with the successful use of horizontal drilling. Currently, eight active fields produce from the Cane Creek in the Paradox Basin fold-and-fault belt, with cumulative oil production over 6.6 million bbls and 7 BCFG (Utah Division of Oil, Gas, and Mining, 2015a). Until the recent drop in oil prices, the Cane Creek and other Paradox zones have been targeted for exploration using horizontal drilling.

The Cane Creek shale zone records an early stage of a transgressive-regressive sequence (cycle 21) in the Paradox Formation and consists of organic-rich marine shale with interbedded dolomitic siltstone and anhydrite (figure 8). The unit is up to 160 ft thick and areally extensive within the Paradox Basin. It is divided into the A, B, and C zones, with the shale and silty carbonates of the B zone considered both the source rock and reservoir. The A and C zones are anhydrite rich and provide an upper and lower seal to the B zone. The unit is highly overpressured, with measurements ranging between 5000 and 6200 psi, which is probably the result of hydrocarbon generation between very impermeable upper and lower anhydrite seals. The B zone is naturally fractured, and oriented cores show that fractures trend northeast-southwest, matching the regional structural trend.

As of the beginning of 2015, Fidelity Exploration & Production Company had 12 permitted horizontal wells targeting the Cane Creek shale including delineating Hatch Point field (IHS, 2015) (figure 7); the company holds 140,000 acres in leases. Fidelity announced a successful horizontal offset, the 17-2 Cane Creek Unit well, to the 2014 discovery (figure 7), the

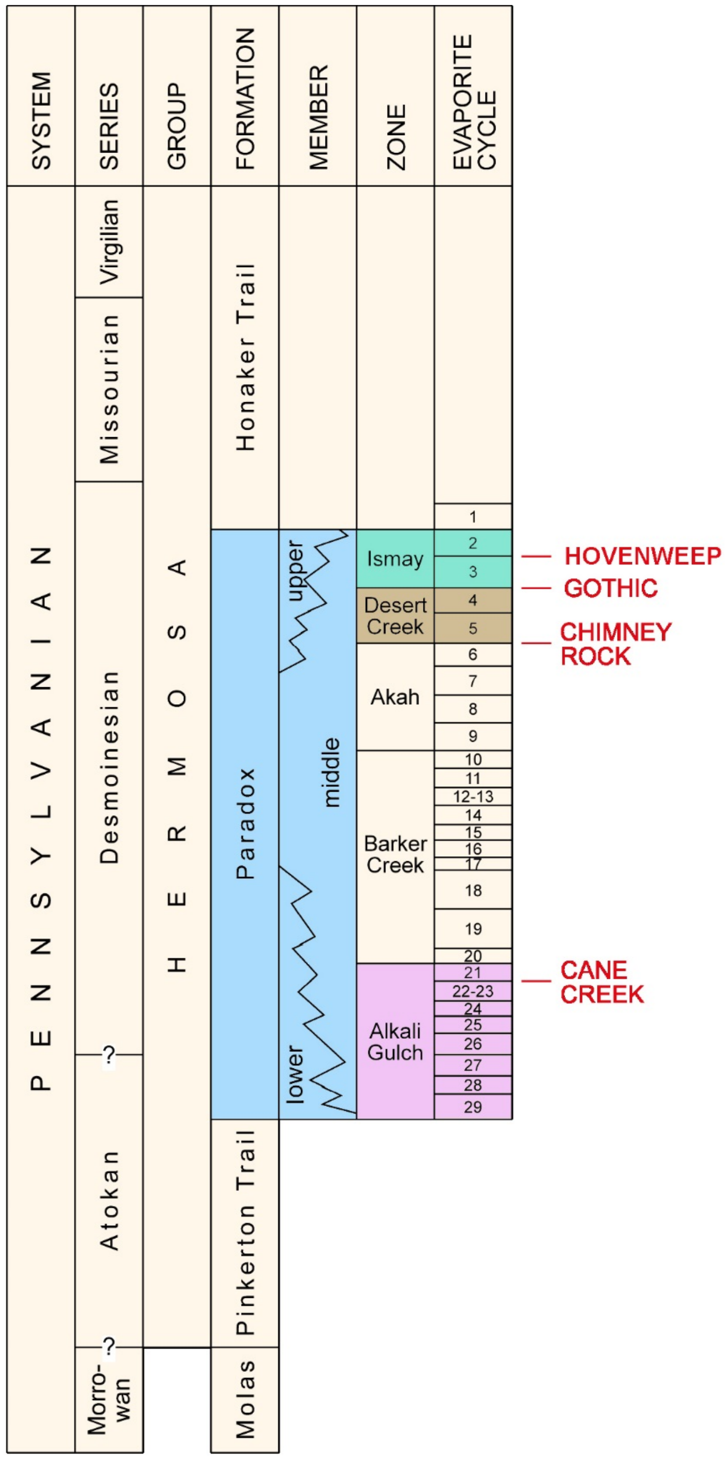

Figure 6. Pennsylvanian stratigraphic chart for the Paradox Basin, informal organic-rich shale units are highlighted. Modified from Hite (1960), Hite and Cater (1972), and Reid and Berghorn (1981).

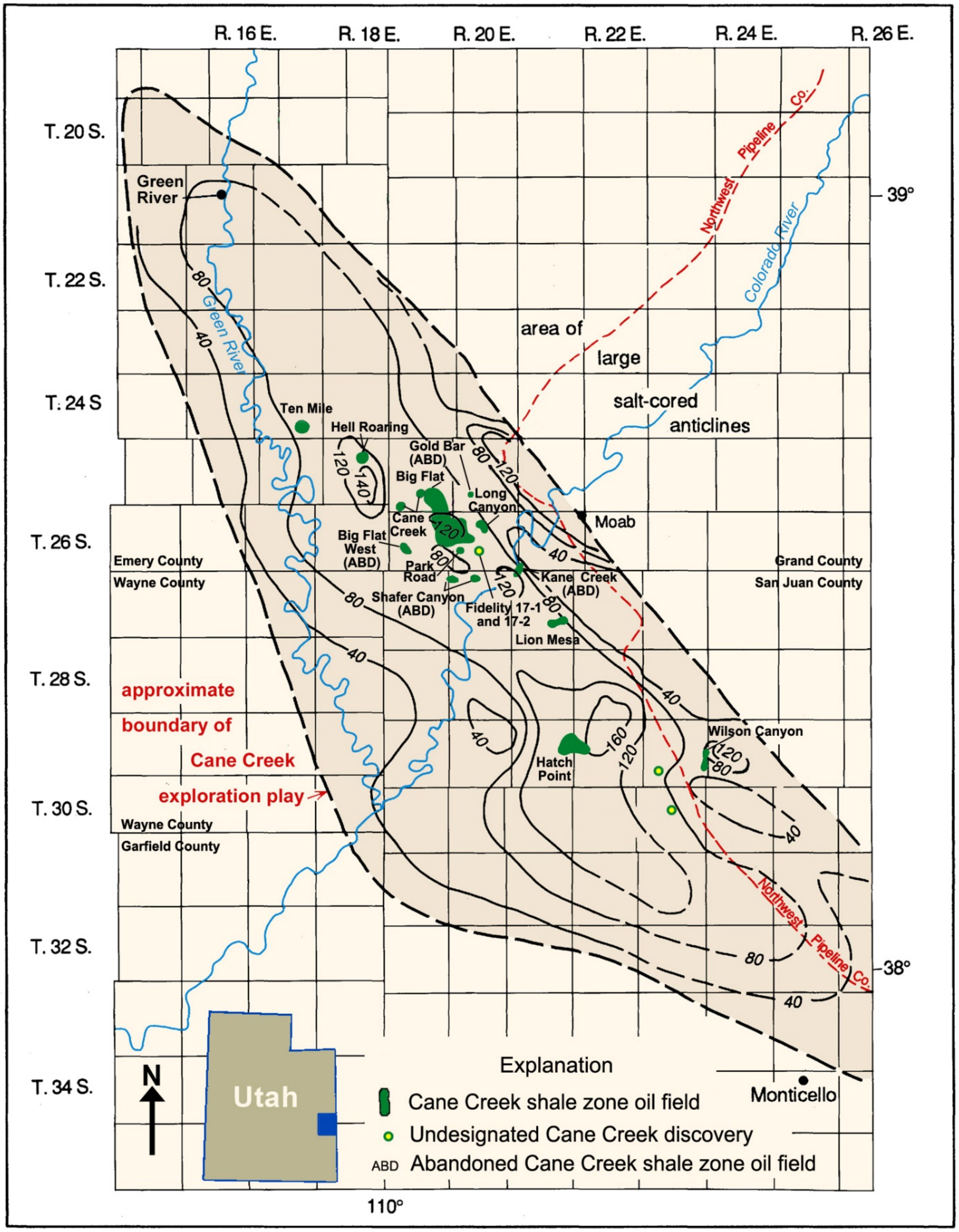

Figure 7. Thickness map and exploration play area of the Cane Creek shale zone of the Pennsylvanian Paradox Formation, northern Paradox Basin, Utah, showing Cane Creek fields. Contour interval = 40 ft. Dashed red line is natural gas pipeline.

Figure 8. Cane Creek shale zone core from the Union Pacific Resources Remington 21-1H well (section 21, T. 31 S., 23 E., SLBL&M, San Juan County, Utah) displays interbedded medium gray dolomite with organic-rich dark gray/black shale. Also present is mottled light gray to white anhydrite.

17-1 Cane Creek Unit well (SWSE section 17, T. 26 S., R. 20 E., Salt Lake Basin Line & Meridian [SLBL&M], Grand County) just east of Park Road field; the new well having been drilled from the same pad. The 17-2 well was drilled in a south-southeast direction and averaged 394 BOPD and 63 MCFGPD (IHS, 2014c). Fidelity completed several additional wells in Big Flat field in 2014 including the 28-3 Cane Creek Unit (NESE section 28, T. 25 S., R. 19 E., SLBL&M, Grand County) for 600 BOPD, the 13-1 Cane Creek Unit (SENE section 13, T. 26 S., R. 19 E., SLBL&M, Grand County) for 255 BOPD, and the 26-3H Cane Creek Unit (NESW section 26, T. 25 S., R. 19 E., SLBL&M, Grand County) for 276 BOPD and 222 MCFGPD (IHS, 2014a, 2014c, 2015). The company estimates that with extended horizontal drilling, the estimated ultimate recovery could be as much as 1.7 million bbls of oil per well (IHS Inc., 2014c). However, lower than expected flow rates in recent wells indicate that the Cane Creek is "tighter" than originally thought and test fracture stimulations are planned in the future. Fidelity is also constructing a 24-mile, 12-inch diameter gas gathering system and processing facilities; gas has been flared for many years.

The U.S. Geological Survey (2012), Whidden and others (2014), and Anna and others (2014) re-assessed the undiscovered oil resource in the Cane Creek shale at 103 million barrels at a 95% confidence level and 198 million barrels at a 50% confidence level. In addition to the Cane Creek, several other organic-rich shale zones are present in the Paradox Formation, creating the potential for significant resource base additions. The Gothic, Chimney Rock, and Hovenweep shales (figure 6) in the Blanding sub-basin and Aneth platform are estimated to hold an undiscovered oil reserve of 126 million barrels at a 95% confidence level and 238 million barrels at a 50% confidence level (U.S. Geological Survey, 2012; Whidden and others, 2014; and Anna and others, 2014).

Blue Gate and Tununk Shale Members, Cretaceous Mancos Shale, Central Utah

Overview

In central Utah, potential shale gas reservoirs include the Blue Gate and Tununk Shale Members of the shallow marine Upper Cretaceous Mancos Shale. The Mancos was deposited in the Western Interior Seaway in the foredeep basin east of the Sevier orogenic belt, and the Mancos intertongues westward with coarser-grained clastic sediments shed from the belt. The Blue Gate contains an upper high-TOC interval with dense, non-fissile, dark gray claystone and scattered, light gray silt laminae and bivalve fragments. The Tununk consists of dark gray calcareous mudstone with interbeds of silt to very fine sand laminae containing silt-filled burrows. The Mancos has produced gas in the Uinta Basin of eastern Utah where it represents a secondary objective in wells targeting tight-gas sands in the Mesaverde and Wasatch sections above. However, the extent and resource potential of this frontier play in central Utah are unknown.

Activity

In late 2014, Whiting Oil & Gas Corporation drilled the Moroni 11M-1107 well (SWSW section 11, T. 15 S., R. 3 E., SLBL&M, Sanpete County) just northwest of the abandoned Cimarron Energy 1AXZ (SENW section 14, T. 15 S., R. 3 E., SLBL&M) that tested 163 bbls of oil and 588 MCFG from a horizontal leg in the Tununk Shale. The Whiting 15,656-ft well (measured depth) was also drilled horizontally in the Tununk and is capable of producing between 400 to 500 MCFG per day (Utah Division of Oil, Gas, and Mining Board Hearing Docket No. 2015-001, Cause No. 176-05). Whiting has permitted two additional horizontal wells in the same area targeting the Tununk or Blue Gate Shales.

Current Research

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

The Utah Geological Survey (UGS), with funding from the National Energy Technology Laboratory, U.S. Department of Energy (DOE), is in the third year of a four-year project titled "Liquid-Rich Shale Potential of Utah's Uinta and Paradox Basins: Reservoir Characterization and Development." The overall goals of this study are to provide reservoir-specific geological and engineering analyses of the (1) emerging Green River Formation tight-oil plays (such as the Uteland Butte Limestone Member, Black Shale facies, deep Mahogany zone, and other deep Parachute Creek member high-organic units) in the Uinta Basin, and (2) the established, yet understudied Cane Creek shale (and possibly other shale units such as the Gothic and Chimney Rock shale zones) of the Paradox Formation in the Paradox Basin. To accomplish these goals, the project will:

- Characterize geologic, geochemical, and petrophysical rock properties of target zones in the two designated basin areas by compiling various sources of data and by analyzing newly acquired and donated core, well logs, and well cuttings.
- Describe outcrop reservoir analogs of Green River Formation plays and compare them to subsurface data (not applicable in the Paradox Basin since the Cane Creek shale is not exposed).
- Map major regional trends for targeted liquid-rich intervals and identify "sweet spots" that have the greatest oil production potential.
- Suggest techniques to reduce exploration costs and drilling risks, especially in environmentally sensitive areas.
- Improve drilling and fracturing effectiveness by determining optimal well completion design.
- Suggest techniques to reduce field development costs, maximize oil recovery, and increase reserves.

The project will therefore develop and make available geologic and engineering analyses, techniques, and methods for exploration and production from the Green River Formation tight-oil zones and the Paradox Formation shale zones where operations encounter technical, economic, and environmental challenges.

In addition to a thorough geologic characterization of the target zones, tests will be performed to characterize the geomechanical properties of the zones of interest to inform/guide well completion strategies. The brittle characteristics of the target intervals will be studied in detail using energy-based calculations. This approach acknowledges both mechanical properties and in-situ stress conditions, as well as geometric lithologic constraints and the mineralogy that regulates fracturing. The study will establish a template for more effective well planning and completion designs by integrating the geologic characterization and formation evaluation with state-of-the-art rock mechanical analyses. This will help companies access oil they know is present, but technically difficult to recover.

To aid in the identification of hydrocarbon "sweet spots," novel concepts for exploration are being employed, such as the use of low-cost, low-environmental impact, epifluorescence analysis of regional core and well cuttings. Epifluorescence microscopy is a technique used to provide information on diagenesis, pore types, and organic matter (including "live" hydrocarbons) within sedimentary rocks. It is a rapid, non-destructive procedure that uses a petrographic microscope equipped with reflected-light capabilities, a mercury-vapor light, and appropriate filtering. Epifluorescent intensities obtained from core and cuttings are being mapped to help identify areas with potential for significant hydrocarbon production. The detailed reservoir characterization and rock mechanics analyses will provide the basis for identification of "sweet spots" and improve well completion strategies for these undeveloped and under-developed reservoirs.

For more information about this ongoing project, including available posters and talks (in pdf), refer to the Utah Geological Survey's project website: http://geology.utah.gov/resources/energy/oil-gas/shale-oil.

Cretaceous Mancos Shale, Uinta Basin, Utah: Resource Potential and Best Practices for an Emerging Shale-Gas Play

The University of Utah and the UGS, with funding from the Research Partnership to Secure Energy for America (RPSEA) and the National Energy Technology Laboratory, DOE, is in the final year of a four-year project titled "Cretaceous Mancos Shale, Uinta Basin, Utah: Resource Potential and Best Practices for an Emerging Shale-Gas Play." The overall goals and/or benefits of this study are to (1) identify and map the major trends for target shale intervals and identify areas with the greatest gas potential, (2) characterize the geologic, geochemical, and petrophysical properties of those reservoirs, (3) reduce exploration costs and drilling risk, especially in environmentally sensitive areas, and (4) recommend the best practices to complete and stimulate Mancos gas shales to reduce development costs and maximize gas recovery. To accomplish these goals and benefits, the project will:

- Compile data from existing wells and publications.
- Conduct petrophysical, geochemical, and rock mechanical analysis of cores and cuttings from the UGS collection and samples provided by industry partners.
- Examine outcrops and collect samples.
- Evaluate logs of geochemical and petrophysical properties.
- Analyze seismic reflection attributes of 3-D data supplied by industry partners.
- Model discrete fracture networks.
- Develop regional maps and cross sections that show structure, thickness, thermal maturity, and depositional facies of key reservoirs.
- Design, describe, and recommend the best completion practices (drilling, fracturing, acidization, perforation, etc.) for the Mancos gas reservoirs based on parameters defined by the study.

Successful development of shale-gas plays requires integration of accurate geologic characterization and reservoir-specific engineering practices. Existing gas production in Utah's Uinta Basin could be greatly enhanced by the addition of recoverable gas reserves in the Upper Cretaceous Mancos Shale. While the Mancos is an emerging shale-gas play, both the geologic and engineering insights are still relatively immature compared to better-established shale-gas plays. The thickness of the Mancos (averaging 4000 ft in the Uinta Basin) and the variable lithology present drillers with a wide range of potential stimulation targets. Identifying and mapping favorable reservoir units within the Mancos will allow development of completion strategies based on appropriate geologic models. At least four members of the Mancos have shale-gas potential: in descending order, they are the Prairie Canyon (Mancos B), Lower Blue Gate Shale, Juana Lopez, and Tununk Shale. Organic matter in the shales has a large fraction of terrigenous material derived from the shorelines of the Sevier belt. Thicknesses of organic-rich zones within individual highstand system tracts exceed 12 ft. Vitrinite reflectance values from a limited number of samples at the top of the Mancos range from 0.65% at the Uinta Basin margins to >1.5% in the central basin. As some wells in the central basin produce from depths greater than 13,000 ft, Mancos exploration can entail considerable financial risk. This project hopes to reduce that financial risk, particularly for independent operators, by providing the industry with an integrated compilation of geologic and engineering data relevant for Mancos exploration and production.

All final project maps, data reports, and results will be publicly available and presented to the petroleum industry (both small and large operators) through a technology transfer plan that includes exhibits and presentations at national and regional conferences, meetings with industry partners, workshops, website postings, and UGS publications. This project began activities in November 2010 and will conclude in the fall of 2015. For more information about this ongoing project, including available posters and talks (in pdf), refer to the UGS’s project website: http://geology.utah.gov/resources/energy/oil-gas/shale-gas/cret-shale-gas/.

Recent Presentations

“Geologic Evaluation of the Cane Creek Shale, Pennsylvanian Paradox Formation, Paradox Basin, Southeastern Utah,” by Stephanie M. Carney, Peter J Nielsen, and Michael D. Vanden Berg, April 9, 2014 AAPG Annual Convention, Houston, Texas.

“Differentiating Green River Formation Oils Sourced from Freshwater and Saline Lacustrine Facies in the Uinta Basin, Utah,” by Justin Birdwell, Ronald C. Johnson, Paul G. Lillis, Michael Brownfield, July 20-22, 2014 AAPG Rocky Mountain Section Meeting, Denver, Colorado.

“Comparative Geochemical and Spectral Gamma-Ray Study of the Lower Mancos Shale, Southwestern Piceance Basin, Southern Douglas Creek Arch, and Southeastern Uinta Basin, Colorado and Utah,” by Rex Cole, William C. Hood, Richard Bingley, Anna Dunn, James Rice, Richard Root, Thomas Spain, and Aaron Tofsrud, July 20-22, 2014 AAPG Rocky Mountain Section Meeting, Denver, Colorado.

“Wide-Azimuthal 3-D Seismic Data Integrated with Geologic Information from Open-Hole Logs Unlocks the Secrets of a Naturally Fractured Trap in the Western Uinta Basin, Utah,” by Jeffrey Ehrenzeller, Walter Korenkiewicz, and Julie Pyle, July 20-22, 2014 AAPG Rocky Mountain Section Meeting, Denver, Colorado.

“Calibration of Petrophysical Log Response in the North and Eastern Uinta Basin to Allow Extension of Outcrop Belts into the Subsurface Using Well Data,” by James D. Hogan, J. Frederick Sarg, Kati Tanavsuu-Milkeviciene, July 20-22, 2014 AAPG Rocky Mountain Section Meeting, Denver, Colorado.

“Play Analysis of the Cane Creek Shale, Pennsylvanian Paradox Formation, Paradox Basin, Southeast Utah,” by Craig D. Morgan, Stephanie M. Carney, Peter Nielsen, Michael D. Vanden Berg and Rebekah E. Wood, July 20-22, 2014 AAPG Rocky Mountain Section Meeting, Denver, Colorado.

“Correlation of Niobrara-Equivalent Strata in the Eastern Uinta Basin, Utah,” by Robert Ressetar, Andrew McCauley, Lauren Birgenheier, and Jeffrey Quick, July 20-22, 2014 AAPG Rocky Mountain Section Meeting, Denver, Colorado.

“Geological Characterization of the Uteland Butte Member of the Eocene Green River Formation: An Emerging Unconventional Carbonate Tight-Oil Play in the Uinta Basin, Utah,” by Michael D. Vanden Berg, Rebekah E. Wood, Stephanie M. Carney, and Craig D. Morgan, July 20-22, 2014 AAPG Rocky Mountain Section Meeting, Denver, Colorado.

“Microbial Mat Textures in Lithofacies of the Paradox Formation, Paradox Basin, Utah,” by Katherine J. Whidden, Russell F. Dubiel, Jennifer D. Eoff, Sarah J. Hawkins, Kristen R. Marra, Ofori N. Pearson, Janet K. Pitman, July 20-22, 2014 AAPG Rocky Mountain Section Meeting, Denver, Colorado.

“Utah’s Emerging Tight Oil Plays: Uteland Butte, Basal Green River Formation, Uinta Basin, and Cane Creek Shale, Paradox Basin,” by Michael D. Vanden Berg, September 10, 2014, RPSEA Onshore Production Conference – Unconventional Hydrocarbon Reservoirs and Produced Water Management, Salt Lake City, Utah.

“Well Completion Strategies and Geomechanics of the Uteland Butte and Cane Creek Tight Oil Plays,” by John McLennan, September 10, 2014, RPSEA Onshore Production Conference – Unconventional Hydrocarbon Reservoirs and Produced Water Management, Salt Lake City, Utah.

“Hydrocarbon Potential of Utah’s Mancos Shale,” by Lauren Birgenheier, September 10, 2014, RPSEA Onshore Production Conference – Unconventional Hydrocarbon Reservoirs and Produced Water Management, Salt Lake City, Utah.

“Paleozoic Shale-Gas Plays in Utah,” by Thomas C. Chidsey, Jr., September 10, 2014, RPSEA Onshore Production Conference – Unconventional Hydrocarbon Reservoirs and Produced Water Management, Salt Lake City, Utah.

“Advancing a Web-Based Tool for Unconventional Natural Gas Development with Focus on Flowback and Produced Water Characterization, Treatment, and Beneficial Use,” by Mengista Geza, September 10, 2014, RPSEA Onshore Production Conference – Unconventional Hydrocarbon Reservoirs and Produced Water Management, Salt Lake City, Utah.

“Development of GIS-Based Tool for Optimized Fluid Management in Shale-Gas Operations,” by Ken Carlson, September 10, 2014, RPSEA Onshore Production Conference – Unconventional Hydrocarbon Reservoirs and Produced Water Management, Salt Lake City, Utah.

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