TECHNOLOGY STATUS ASSESSMENT

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

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DISCLAIMER

1. CURRENT STATE OF TECHNOLOGY

The high price of crude oil, coupled with lower natural gas prices, has generated renewed interest in exploration and development of liquid hydrocarbon reserves. Following on the success of the recent shale gas boom and employing many of the same well completion techniques, petroleum companies are now exploring for liquid petroleum in shale formations. In fact, many shales targeted for natural gas include areas in which the shale is more prone to liquid production. In Utah, 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 carbonates for their conventional resource recovery. With the advances in horizontal drilling and hydraulic fracturing techniques, operators in these basins are now starting to explore the petroleum production potential of the shale units themselves.

The Green River Formation (GRF) in the Uinta Basin has been studied for over 50 years since the first hydrocarbon discoveries. However, those studies focused on the many conventional sandstone reservoirs currently producing oil and gas. In contrast, very little information exists in the public domain on the more unconventional crude oil production potential of thinner shale/carbonate units such as the Uteland Butte member, Black Shale facies, deep Mahogany zone, and other deep Parachute Creek Member organic-rich units. Some operators have recently conducted geochemical and geomechanical characterization, natural fracture analysis, and thickness mapping in these prospective GRF units, but this work has only been completed for a limited geographic area, usually where the operators have leases, and the results are often confidential.

The Cane Creek shale of the Paradox Basin has been a target for exploration on and off since the 1960s and produces oil from several small fields. The play generated much interest in the early 1990s with the successful use of horizontal drilling (Morgan and others 1991; Morgan, 1992). Recently, the USGS assessed the undiscovered oil resource in the Cane Creek shale of the Paradox Basin at 103 million barrels at a 95% confidence level and 198 million barrels at a 50% confidence level (USGS, 2012). Nonetheless, limited research has been conducted or published to further define the play and the reservoir characteristics. The field operators and those exploring in the region are small independents that lack both the staff and the funds to conduct the detailed basin-wide research required to fully understand the tight oil potential of the Cane Creek. This type of information would help reduce risk and possibly increase hydrocarbon production and reserves. In addition to the Cane Creek, several other organic-rich shales are present in the Paradox Formation, creating the potential for significant reserve base additions (Gothic, Chimney Rock, and Hovenweep shales 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) (USGS, 2012).

Finally, there are no specific publications, data compilations, or recommendations concerning optimal well drilling and completion design for either the GRF tight oil plays or the Paradox Formation shales. Well and horizontal lateral spacing, horizontal lateral length and orientation, and effective hydraulic fracturing techniques have not been fully evaluated in these discoveries.

By and large, the companies operating in the Uinta Basin are relatively small (at least their Uinta Basin divisions), with limited budgets for research and development. The companies in the Paradox Basin currently exploring Paradox Formation shales are even smaller, often consisting of only a handful of employees. Typically, their limited budgets are only geared toward drilling and completing wells. This is in contrast to heavily explored and researched tight oil plays such as the middle Bakken/Three Forks, Eagle Ford, Niobrara, Utica, and others. Several companies have indicated that the frontier tight oil plays of the Uinta and Paradox Basins have vast potential, but require government research assistance in understanding their basic geologic framework and developing successful well completion strategies.

With federal assistance, research organizations like the Utah Geological Survey and the University of Utah can merge the available site-specific data from several companies and develop a basin-wide characterization that otherwise would not be feasible. In fact, several companies have recently drilled new cores in the above-mentioned target formations and have mostly agreed to share their data with the current study (figures 1 and 2). This not only benefits the operators, providing the data they need to expand operations and produce more domestic hydrocarbons, but it also benefits the State of Utah and the United States as a whole, both economically and in terms of creating useful liquid-rich shale production analogs that can be applied to other basins.

Recent guidebooks published by the Utah Geological Association on the Uinta Basin (Longman and Morgan, 2008) and the Rocky Mountain Association of Geologists on the Paradox Basin (Houston and others, 2009) contain virtually nothing on the tight oil potential of the GRF or the Paradox Formation shales. In addition, these potential plays are only peripherally described in the recent trade journals of the American Association of Petroleum Geologists or the Society of Petroleum Engineers. The recent USGS (2012) assessment of the Paradox Basin, presently available only as a fact sheet, claims that the shales of the Paradox Formation could contain significant oil resources, but a detailed geologic and engineering characterization needs to be completed before companies can fully exploit this resource or similar resource in the Uinta Basin.

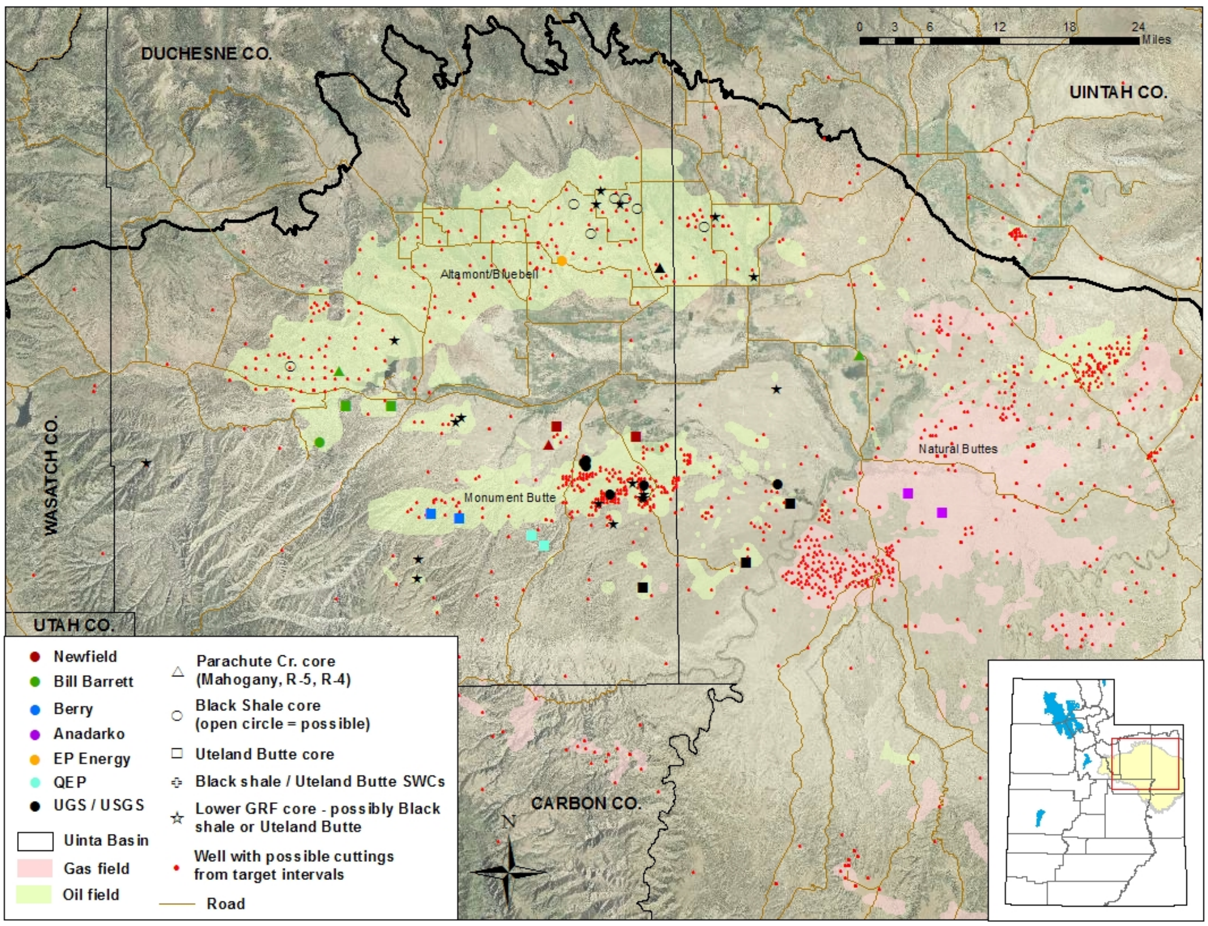

Figure 1. *Location of several newly drilled GRF cores (colored symbols, by company and unit) in the Uinta Basin, Utah, as well as older GRF cores housed at the Utah Geological Survey or the U.S. Geological Survey.*

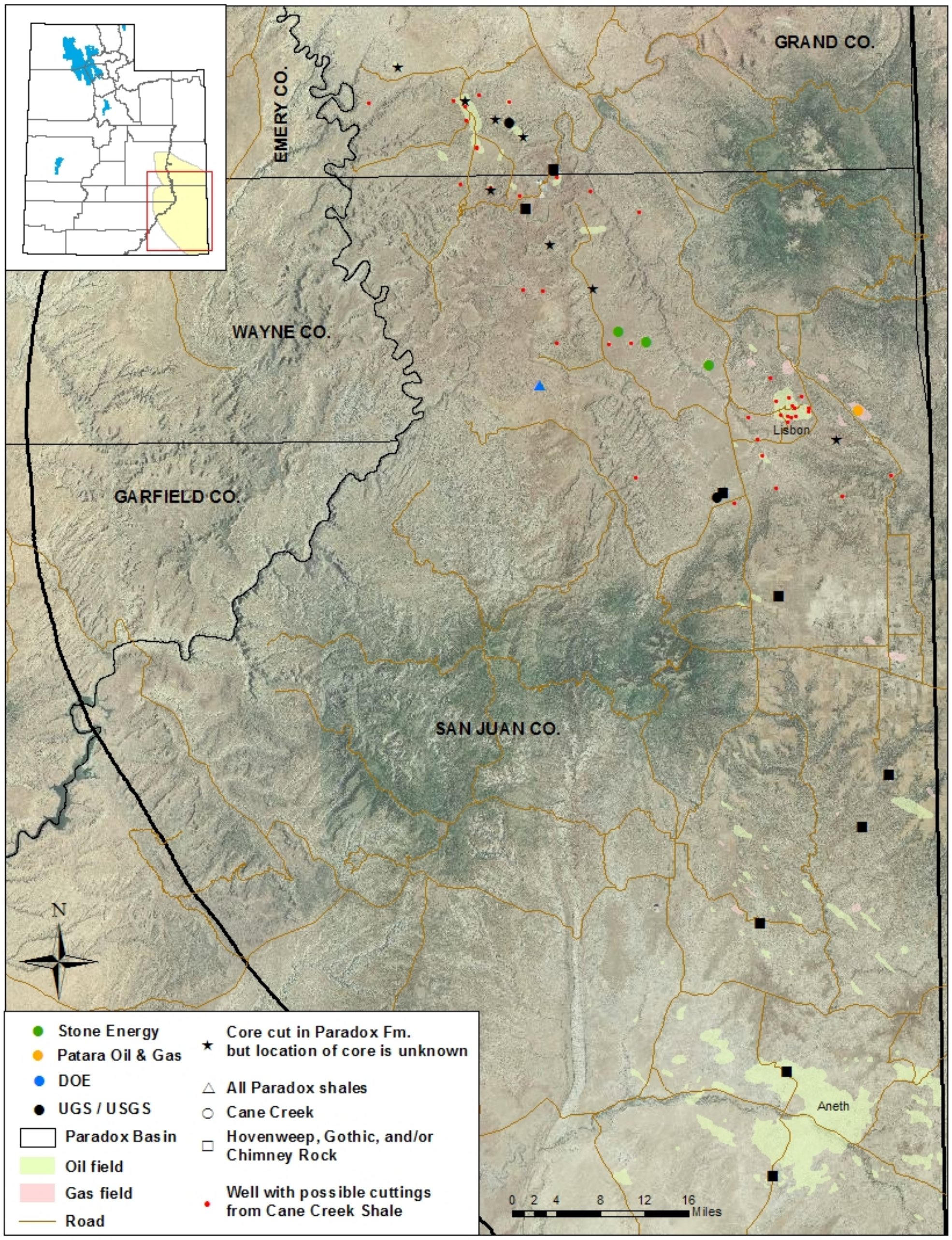

Figure 2. *Location of newly drilled Cane Creek shale cores (colored symbols, by company) in the Paradox Basin, Utah, as well as older Paradox Formation cores housed at the Utah Geological Survey or the U.S. Geological Survey.*

2. DEVELOPMENT STRATEGIES

The overall goal of our study is to provide reservoir-specific geological and engineering analyses of the emerging GRF tight oil plays in the Uinta Basin and the established, yet understudied Cane Creek shale (and possibly others) in the Paradox Basin. All results will be made public through an established technology transfer plan.

The specific objectives of the research are to: (1) characterize geologic, geochemical, and geomechanical rock properties of target zones in the two designated basins by compiling data and by analyzing available cores, cuttings, and well logs; (2) describe outcrop reservoir analogs of GRF plays (Cane Creek shale is not exposed) and compare them to subsurface data; (3) map major regional trends for targeted intervals and identify "sweet spots" that have the greatest oil potential; (4) reduce exploration costs and drilling risks, especially in environmentally sensitive areas; (5) improve drilling and fracturing effectiveness by determining optimal well completion design; and (6) 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 GRF tight oil zones and the Paradox Formation shales where operations encounter technical, economic, and environmental challenges.

In addition to a thorough geologic characterization of the target zones, we will perform tests to characterize the geomechanical properties of the zones of interest to inform/guide well completion strategies. Well stimulation is often required in low and ultralow permeability reservoirs and effective stimulation requires creation or reactivation of fracture systems that reduce the distance hydrocarbons need to travel before reaching highly conductive networks. In addition, fabric and stratigraphy are also relevant to effective stimulation. The implication is that pre-existing fractures (open or healed), latent fractures (metastable environments), and heterogeneities are all relevant, including formations being brittle enough to favor these fractures in the first place. One major goal of this project is to study the brittle characteristics of the target intervals 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. This relates to a new discipline that can be labeled as "mechanical stratigraphy" rather than "fracability." This method incorporates predicting the ability of a formation to carry applied stresses and how it will deform. It implicitly accounts for transversely isotropic, orthotropic, or fully anisotropic behavior associated with bedding planes (vertical containment of fractures), grain orientation, fractures, and other discontinuities. It also designates how the facies or units will respond after they have yielded. Similar geomechanical and fracture studies were recently performed at the University of Utah for a RPSEA-funded project on the Mancos shale gas potential (Kennedy, 2011), as well as studies performed on the Pennsylvanian black shale reservoirs in the Paradox Basin (Bereskin and McLennan, 2008). Overall, this 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 will be 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. This technique was used successfully on cuttings from the Mississippian Leadville Limestone in the Paradox Basin, resulting in a regional "sweet spot" map identifying significant oil-prone areas (Eby and others, 2008).

3. FUTURE

This project will meet the goal of evaluating the frontier liquid-rich shale reservoirs in the Uinta and Paradox Basins that currently have only limited geologic characterization. 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. The project will provide (1) improved and detailed reservoir characterization of the GRF tight oil plays in the Uinta Basin and the Paradox Formation shale oil plays (in particular the Cane Creek shale) in the Paradox Basin, targeting specific, brittle, high potential intervals, and (2) improved methods for identification of "sweet spots" using methods such as epifluorescence analysis of regional well core and cuttings. The reservoir characterization and analysis will be based on newly acquired and donated core (figures 1 and 2), well logs, and well cuttings, which will be used to improve well placement and establish a relationship between natural fractures and productivity, thus reducing the number of wells and the environmental impact of drilling. Analysis of in-situ stress, using geophysical and other geomechanical data, will be used to improve hydraulic fracture design for development of new fields or expanding established fields. The project will provide operators with the information they need to reduce exploration and development costs and drilling risks while maximizing oil recovery and increasing reserves.

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