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

TECHNOLOGY STATUS ASSESSMENT

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February 2011

Subcontract No. 09122-07

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INTRODUCTION

Production of natural gas from shale reservoirs in the lower 48 states has increased exponentially from about 100 million cubic feet of gas per day (MMcf/d) in 1997 to more than 5500 MMcf/d in 2008 (Brathwaite, 2009). This increase is part of a trend of increased natural gas production from all unconventional reservoirs, coincidental with a linear decline in production from conventional onshore reservoirs (Deo, 2009). Projections of these trends indicate that by 2025 gas production from onshore unconventional reservoirs will surpass the combined production from onshore conventional, offshore, and Alaskan reservoirs (Deo, 2009).

Among the unconventional resources are 7 trillion cubic feet of gas in the Mancos/Mowry petroleum system of the Uinta and Piceance Basins in Utah and Colorado (U.S. Geological Survey, Uinta-Piceance Assessment Team, 2003). Exploitation of this resource has increased dramatically in recent decades as the number of gas wells drilled since 1980 in the Uinta and Piceance basins more than quadrupled the total that had been drilled before 1980 (Deo, 2009). The Mancos Shale is the second largest shale gas producer in the Rocky Mountains, exceeded only by the Bakken Shale of the Williston Basin (Brathwaite, 2009). Mancos production, however, peaked in the first quarter of 2003 at 44.8 MMcf/d, and by the second quarter of 2008 had declined to 32 MMcf/d (Brathwaite, 2009).

As some wells produce from depths greater than 13,000 feet, Mancos Shale exploration can require considerable financial risk. Reducing that risk, particularly for independent operators, by providing the industry with an integrated compilation of geologic and engineering data relevant for assessing an exploration/production program, is the main objective of this project. Curtis and others (2008) defined eight parameters that need to be evaluated for a successful shale-gas play: 1) total organic carbon (TOC), 2) maturation, 3) gas-in-place, 4) permeability, 5) pore pressure, 6) brittleness, 7) mineralogy, and 8) thickness. Although many studies have been published on the Mancos Shale, no single, publicly available report analyzes all eight parameters. That absence provides the justification for this project.

STATUS OF CURRENT TECHNOLOGY

Current Exploration and Development

The Utah Division of Oil, Gas, and Mining (DOGM) has identified 36 fields with producing or potential natural gas reservoirs in the Mancos Shale (table 1). However, since horizontal drilling has only recently been applied to the Mancos, the bulk of the production in table 1 was probably from other strata. Unfortunately, the DOGM production records do not allow a practical way to determine the total amount of natural gas produced from the Mancos. The majority of Mancos gas production to date has probably come from conventionally completed vertical wells in the sandier facies like the Prairie Canyon and Juana Lopez Members.

A search of the IHS Inc. well database revealed that 87 wells had an initial production test in the Mancos and, in most cases, one or more other formations. This number is probably under-reported since some wells likely were not listed as Uinta Basin, or the operator did not report the perforations as being in the Mancos.

Regional Correlation, Mapping, and Depositional History Determination

The Upper Cretaceous Mancos Shale averages 4000 feet thick across the Uinta Basin, in contrast to the gas shales currently in production in other U.S. basins, whose thicknesses range from 50 to 600 feet (U.S. Department of Energy, National Energy Technology Laboratory [U.S. DOE], 2009). The thickness of the Mancos presents a major challenge to operators in the Uinta Basin, who must evaluate large amounts of data to identify pay zones (Halliburton Company Web document, undated).

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. Schamel (2006) listed four members of the Mancos that have shale-gas potential. From top to base, these are the Prairie Canyon (Mancos B) Member, the Lower Blue Gate Shale Member, the Juana Lopez Member, and the Tropic-Tununk Shale.

Anderson and Harris (2006) established a stratigraphic framework for the lower 650 ft of the Mancos in eastern Utah, and recognized at least five depositional sequences in outcrop. Condensed sections in the sequences provided the basis for regional correlation from the outcrops to well logs from the southeastern Uinta Basin.

The Prairie Canyon Member is about 1000 ft thick in eastern Utah, thinning to the west where it grades into shallow-marine deposits of the Star Point and Blackhawk Formations (Cole and others, 1997). Cole and others (1997) developed an initial sequence-stratigraphic model for the middle part of the Prairie Canyon, and interpreted its depositional environment as dominantly marine-shelf mudstone and fine-grained sandstone deposited below storm wave base at distances of 100± miles from the shoreline.

We will build on these earlier studies by tying them to regional maps and cross sections using standard techniques of log, core, and outcrop analysis. There are no inherent negative points in this technology, but its ultimate success may depend on correlating the detailed stratigraphy in industrial partners' data sets to data in the literature and in uninterpreted logs in DOGM files.

Rock Mechanical and Petrophysical Analysis

Condon (2003) measured natural fractures oriented northwest and northeast in the Ferron Sandstone Member of the Mancos in outcrops south of the Uinta Basin. He attributed the earlier, northwest-striking set to the Sevier orogeny at about 85 Ma maximum age, and the younger, northeast-striking set to the Laramide orogeny at about 75 Ma. Additional published fracture data for the Uinta Basin are probably in the literature, but our data compilations to date have not located any. Natural fracture measurements will be collected during fieldwork for this project and compared with borehole imaging logs to determine whether similar fracture orientations and stress regimes exist at depth.

In addition, cores will be sampled for tight-rock analysis. This recent but proven method has been effectively used in many previous shale studies, appears valuable in correlating core to open-hole log data and potential production rates, and can be used to estimate ultimate reserve numbers. Triaxial and acoustic testing on core plugs under in-situ conditions for shale units will formalize the relationships developed to delineate facies-dependent correlations for Young's modulus, Poisson's ratio, and resulting degree of hydraulic fracturing. This data will be critical in determining the best completion practices for these potential shale-gas reservoirs.

Geochemical Analysis

A few recent studies addressed the organic geochemistry of the Mancos Shale in the Uinta Basin. Schamel (2006) summarized several earlier reports on the organic carbon contents of the lower Mancos Shale. The Tropic/Tununk Shale has average TOC of 1.4 to 1.7%. The lower Bluegate Shale at the River Gas Utah #1 well near Price has an interval >1000 ft thick with TOC >1.5%, in which two intervals of 100 to 200 ft have TOC >2.0%. Anderson and Harris (2006) reported a TOC range of 0.44 to 4.32%, and an average of 1.23% for the lower Mancos in the Larsen State-1 well in the southeastern Uinta Basin. Similarly, Fisher (2007) measured TOC ranging from 0.75 to 2.37% and averaging 1.35% in the Hells Hole 9131 well on the Douglas Creek arch near the Colorado-Utah line. These values tend to be lower than those for other gas shales in the U.S. (U.S. DOE, 2009), so one goal of this project will be to determine whether they are representative of the Mancos Shale. Organic matter in the Mancos has a large fraction of humic (terrigenous) material derived from the vegetated shorelines of the Sevier belt (Schamel, 2006). Thicknesses of organic-rich zones within individual highstand system tracts exceed 12 feet (Anderson and Harris, 2006).

Nuccio and Roberts (2003) reported vitrinite reflectance measurements (Ro) for the top of the Mancos Shale in the southeastern Uinta Basin. These data, from 24 wells, ranged from 0.6% on the basin margin to 1.76% in the basin interior. Seven Ro data points at the base of the Mancos ranged from 0.7% to 3.6%. The lower Mancos on the Douglas Creek arch had slightly lower Ro values of 0.44 to 0.50% (Fisher, 2007). Although these data are few, they indicate a trend where the top of the Mancos is mature for oil and thermogenic gas, and the base is mature to overmature for oil in most of the basin. We will add additional vitrinite data from logs provided by industry partners, and possibly from our core samples.

Seismic Attribute Analysis

In the near absence of horizontal drilling targeting Mancos Shale fractured reservoirs in the Uinta Basin, virtually nothing in the public literature addresses seismic attribute analysis for guiding drilling strategies. However, it is well known that successful shale-gas completions require the maximum interaction between the borehole and the fracture network, and that seismic attribute analyses have been used for fracture detection since the mid 1990s (Chopra and Marfut, 2007). Attributes such as coherence and curvature have been used to identify faults, fractures, and depositional structures (Chopra and Marfut, 2007). Wind River Resources and Pioneer Natural Resources have provided 3-D post-stack, time-migrated seismic data for the application of these techniques to the Mancos Shale.

Best Completion Practices

The current status of best completion practices in an emerging play such as the Mancos Shale in the Uinta Basin is difficult to assess. Nearly all well completions in the Mancos to date have been vertical and typically had rapid decline curves. The first horizontal well in the Mancos—XTO Energy's HCU 1-30F—was completed very recently (in late 2010) and nearly all of the well data are still confidential. The well was drilled in the Natural Buttes field and the first production data on the DOGM Web site were 11,457 Mcf gas and 288 barrels of oil produced during six days in October 2010. The drilling dates and well location are the only additional publically available information.

Project partner Halliburton Company (undated) has noted that the major problems facing Mancos operators are identifying pay zones and completing the well. Halliburton recommends that Mancos operators employ formation evaluation tools to measure, among other factors, permeability, closure strength, natural fractures, and brittleness.

CONCLUSIONS

This research project addresses the information needs of oil and gas exploration companies both large and small. The results of the research will be used to identify favorable target areas to acquire leases and begin active exploration of shale-gas reservoirs. The research can be used by other exploration and service companies as a basis for evaluating leases and development strategies.

There are very few negative aspects of the technology to be used in this study—the techniques are mostly well established. However, the likelihood of the project achieving its goals could be reduced if 1) rock and subsurface data prove inadequate to fully assess the resource on a basin-wide scale, or 2) the study indicates that the Mancos Shale is less favorable for shale-gas reservoirs due to such factors as low TOC, low thermal maturation, or low gas-in-place volumes. Factors that could negatively affect market acceptance are 1) significant reduction in the price of natural gas making the reward-to-cost ratio unacceptable, 2) limited exploration areas reducing the total potential of the plays, 3) promising play areas having significant environmental restrictions, and 4) the techniques needed for efficient stimulations and completions proving to be cost-prohibitive.

The specific ways in which the work will benefit small producers exploring Mancos shale-gas reservoirs in emerging frontier plays are by providing an in-depth understanding of the geochemistry, burial history, rock mechanics, and depositional environments of the shales. These data are often too expensive for small operators to obtain on a basin-wide scale. Our research will provide the necessary data as well as map out play areas within the basin for shale-gas reservoirs, thus providing small operators the data and tools to explore for the reservoirs on an equal footing with larger companies that can draw on a large technical resource base.

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Table 1. *Utah gas fields with reservoirs identified in the Mancos Shale. Gas production data from DOGM (http://oilgas.ogm.utah.gov/Statistics/PROD_Gas_field.cfm accessed January 2011); other data from DOGM (https://fs.ogm.utah.gov/PUB/Oil&Gas/Publications/Lists/field_list.pdf accessed January 2011).*

Field number	Field name	Status	County	Discovery date	Producing stratigraphic unit			Cumulative natural gas production (Mcf)	Discovery well API number
540	Agency Draw	Active	Uintah	1962	Wasatch	Mesaverde	Mancos	845,953	4304711120
543	Atchee Ridge	Active	Uintah	1996	Mancos B			144,547	4304732660
550	Black Horse Canyon	Active	Uintah	1979	Mancos			2,254,677	4304730765
555	Bonanza	Active	Uintah	1963	Wasatch	Mancos		751,285	4304715674
185	Bryson Canyon	Active	Grand	1928	Mancos B	Dakota		25,549,318	4301911306
167	Bushy	Active	Grand	1977	Mancos	Dakota		3,507	4301930361
13	Castlegate	Active	Carbon	1998	Blackhawk	Mancos		8,665,352	4300730119
580	Dry Burn	Inactive	Uintah	1978	Mancos			0	4304730331
600	Flat Rock	Active	Uintah	1963	Wasatch	Mancos		84,951,037	4304710577
792	Gate Canyon	Active	Duchesne	2006	Mesaverde	Mancos		1,366,208	4301332391
20	Gordon Creek	Active	Carbon	1948	Ferron	Mancos		4,395,517	4300716107
205	Greater Cisco	Active	Grand	1925	Mancos	Dakota	Cedar Mountain	27,090,501	4301911513
616	Hells Hole	Active	Uintah	1989	Mancos B	Dakota	Morrison	1,613,132	4304731802
18	Helper	Active	Carbon	1993	Ferron	Mancos		145,864,626	4300730189
617	Hill Creek	Active	Uintah	1984	Wasatch	Mesaverde	Mancos	13,427,057	4304731026
620	Horseshoe Bend	Active	Uintah	1984	Green River	Mesaverde	Mancos	27,861,916	4304715803
626	Lone Spring	Inactive	Uintah	1996	Mancos B			0	4304732705
625	Main Canyon	Active	Uintah	1979	Mancos	Dakota		5,560,308	4304730394
222	Mancos Flat	Inactive	Grand	1981	Mancos			0	4301930789
30	Miller Creek	Inactive	Carbon	1969	Ferron	Tununk	Dakota	0	4300730006
105	Monument Butte	Active	Duchesne	1964	Green River	Mesaverde	Mancos	107,400,856	4301330561
630	Natural Buttes	Active	Uintah	1972	Mesaverde	Wasatch	Mancos	2,222,560,556	4304710095
640	Pariette Bench	Active	Uintah	1962	Green River	Mesaverde	Mancos	29,934,362	4304710873
40	Peters Point	Active	Carbon	1953	Green River	Wasatch	Mancos	87,263,405	4300710216
645	Pine Springs	Active	Uintah	1979	Mancos B	Dakota		4,671,113	4304715923
660	Rat Hole Canyon	Inactive	Uintah	1977	Mancos			0	4304730325
665	Red Wash	Active	Uintah	1951	Green River	Mesaverde	Mancos	356,058,630	4304715135
636	South Canyon	Inactive	Uintah	1981	Mancos B			0	4304731104
685	Sweetwater Canyon	Inactive	Uintah	1978	Mancos			57	4304730332
686	Sweetwater Ridge	Inactive	Uintah	1996	Mancos B			0	4304732593
695	Uteland Butte	Active	Uintah	1962	Wasatch	Mesaverde	Mancos	5,985,489	4304715642
265	Westwater	Active	Grand	1957	Mancos B	Dakota		38,631,566	4301910780
717	Whiskey Creek	Inactive	Uintah	1996	Mancos B			0	4304732602
705	White River	Active	Uintah	1961	Green River	Mancos B		13,362,827	4304715080
707	Wolf Point	Active	Uintah	1984	Mancos	Dakota	Morrison	793,564	4304730622
710	Wonsits Valley	Active	Uintah	1959	Green River	Mesaverde	Mancos	119,092,004	4304716509