Comparison of the Reservoir Properties of the Muskwa (Horn River Formation) with Other North American Gas Shales

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Summary

The Devonian-aged Muskwa Member of the Horn River Formation has been analyzed in conventional core from five wells in Northeast British Columbia. The analytical program includes core description, thin section analysis, focused-ion beam SEM analysis, X-Ray Diffraction Mineralogy, geochemistry, and measurement of rock petrophysical properties such as porosity, permeability, liquid saturations, and rock mechanical properties. The results of this evaluation indicate that the Muskwa is a brittle, organic-rich, gas-bearing shale or mudstone that stands out from other North American shales in terms of its mineralogy and diagenesis which yields a formation that should take and maintain effective artificial fractures.

Introduction

The Muskwa Shale is an organic mudstone that was deposited during the Late Devonian (Frasnian) in a deep basinal setting in present day northeast British Columbia. It has been compared to the Barnett Shale of the Fort Worth Basin in Texas in terms of its dimensions, mineralogy, and petrophysical properties (Brown, 2009). As operators begin to develop the Muskwa as a Shale Gas play key reservoir attributes need to be assessed, and data collected on lithology, organic content, maturation, porosity and pore system structure, permeability, natural fracture intensity and distribution, fluid sensitivity, and rock mechanical properties. These data, combined with production data, will provide critical insight into the production properties, and controls on production properties, that operators can use to risk new plays, select the most effective drilling and completion methods, and maximize their investment.

This paper presents the results of an extensive, multi-faceted evaluation of the Muskwa and a comparison of the Muskwa with other North American Gas Shales. What are the reservoir characteristics of the Muskwa Shale? Are there analogs in North America that can be used to provide initial guidance on drilling and production properties?

Methods

Approximately 160 meters of new conventional core from the Muskwa in five wells in Northeast British Columbia have been described in detail to geologically characterize the cored intervals in terms of depositional facies, environment of deposition, and rock types. Samples were taken, and data and

observations from thin sections, scanning electron microscopy, semi-quantitative X-Ray Diffraction Mineralogy, organic geochemistry (Total Organic Carbon, Rock-Eval Pyrolysis, and Vitrinite Reflectance), and rock petrophysical properties (porosity, permeability, water saturation, gas saturation, bulk density, grain density, and gas-filled porosity) were collected on each sample. In addition, rock mechanical properties (Young's Modulus, Poisson's Ratio, and Mohr-Coulomb Failure Analysis), and fluid sensitivity tests were performed on selected samples.

These data were then correlated and compared to data collected using the same protocols from other North American thermogenic Gas Shale formations in Core Laboratories' gas shale database. This database includes production data which allows the discrimination of productive versus non-productive intervals. By overlaying the production data on the various petrophysical and mineralogical data, an assessment can then be made as to the productive potential of the new formation by comparing the data from known producing and non-producing formations.

Results

Mineralogically the Muskwa is composed predominantly of quartz with volumes ranging from 26% to 87%, and averaging 64%. Clay is present at about 16% on average and is mostly illite. Total carbonates are less than 10% and TOC averages 3.34% by weight, or 7.52% by volume. Thin section analysis indicates that detrital quartz is rare, but the FIB SEM work clearly documents that most of the quartz is present as authigenic, doubly terminated, euhedral crystals of micro-quartz, and as possible quartz overgrowths on the silt grains. This authigenic quartz is pervasive and forms a dense framework with individual crystals either intergrown with, or terminating against neighboring crystals. The source of the quartz is probably biogenic; however, skeletal remains of siliceous organisms are rare. Wispy illite is visible partially bridging the intercrystalline porosity, and appears to be partially intergrown with amorphous organic matter or hydrocarbons.

The dominant pore type is intercrystalline among the quartz crystals, with locally common interparticle porosity within areas of authigenic clay. There is also substantial porosity within the organic matter, although much of it appears to be poorly interconnected.

Rock-eval pyrolysis reveals that the Muskwa samples contain less than 1 mg/gram live and "generatable" hydrocarbons. Tmax values range widely from 350°C to 517°C, and are generally consistent with vitrinite reflectance data (ranging from 1.37% to 2.04%, and averaging 1.80%) indicating, mature, dry-gas window maturation.

Rock petrophysical determinations of porosity and permeability detected no liquid oil, and typically very low water saturations (Dean-Stark Methodolgy). Total porosity (including clay-bound water) ranges from 1.4% to 10.9% and averages 6.3%, and effective matrix permeability ranges from 1.04×10^{-10} md to 1.99×10^{-4} md, and averages 3.59×10^{-7} md. Gas saturation ranges from 17.2% to 86.5% and averages 65.5%, and water saturation ranges from 13.6% to 82.8% and averages 34.5%. Rock-mechanical properties measured on vertical plugs and full-diameter core pieces yield high Young's Moduli ranging from 1.6×10^6 psi to 9.5×10^6 psi (average of 4.2×10^6 psi), and Poisson's Ratios from 0.18 to 0.24.

Comparison of the Muskwa data with data from all North American shales analyzed by Core Lab documents that the Muskwa has the highest volume of quartz, and lowest volume of clay resulting in very

high Young's Moduli. Contributing to the brittleness is the authigenic nature of the quartz and its crystallinity. In fact, the rock mechanical properties of the Muskwa are more similar to the carbonates and sandstones that bound formations such as the Barnett, Woodford, and Marcellus.

In many other aspects the Muskwa is average compared to producing zones in other shale formations. It is slightly less porous than other North American shales, and is similar in organic volume to the Eagle Ford and Haynesville. Matrix permeability is average. However, gas saturation tends to be high and water saturation is low compared to some formations, which is favorable for the Muskwa.

Conclusions

Much of the Devonian-aged Muskwa is composed of abundant, authigenic quartz, with a framework dominated by locally intergrown microcrystals. Intercrystalline porosity is abundant but it is typically filled with hair-like, authigenic illite and organic material or hydrocarbons. This mineralogy results in a very brittle rock with very high Young's Moduli compared to other, North American, thermogenic shales. The brittleness of the Muskwa results in a formation that should respond effectively to artificial fracturing and maintain fracture apertures.

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References

Brown, D., 2009, Shale Plays Make BC Feel Cozy: AAPG Explorer, http://www.aapg.org/explorer/2009/01jan/bc.cfm.