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Petrophysical characterization of the Upper Cretaceous Second White Specks alloformation, Willesden Green – Gilby area, Alberta

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Summary

The Upper Cretaceous Second White Specks Formation, a lithologically heterogeneous mudrock, is a prolific hydrocarbon source and reservoir rock within the Western Canada Foreland Basin (WCFB) of Alberta. Although significant volumes of light oil have been produced from this unit, finding success in this stratigraphic interval has been problematic due to unreliable inflow performance – most of the recoverable resource still remains trapped in the ground.

This study aims to understand what is creating storage and flow capacity for hydrocarbons in the Second White Specks Formation within a 110-township study area in the Willesden Green area of west-central Alberta. Previous studies have assumed production in this unit is tied to the location of natural fractures in brittle (calcareous and siliceous) rocks (Bloch et al. 1999), but new revelations in mud microstructure have revealed that porous depositional fabrics can be preserved even after deep burial (Schieber, 2010; Jiang and Cheadle, 2013); these may also contribute to production.

By combining an allostratigraphic (geologic, spatial, and temporal) framework for the study area with petrophysical rock property (porosity, organic richness, brittleness, mineralogy) and production maps of the Second White Specks Formation, this study aims to map the spatial distribution of rock properties to help identify better locations for well placement. This study will elucidate the heterogeneity of the Second White Specks Formation in the Willesden Green area, which can be extrapolated regionally across the basin and compared to analogous mudstone formations.

Theory

Wave ripples, hummocky cross-stratification, and graded beds observed by Zajac and Pedersen (2014) in mudstones, siltstones, and occasional sandstones of the Second White Specks support the interpretation of Tyagi et al. (2007) that the Second White Specks Formation was deposited in a storm-influenced shallow marine shelf environment. Although Bloch et al. (1999) characterized the Second White Specks Formation as the record of deposition in a deep, quiescent marine basin, other workers (Tyagi et al., 2007; Varban and Plint, 2008a, b; Zajac and Pedersen, 2014) concluded that portions of the Second White Specks Formation was deposited under energetic conditions above storm wave base.

The Second White Specks Formation is an effective source rock that is enriched in marine, oil-prone type II organic matter (up to 12 wt% TOC) compared to other lower Colorado Group mudstones (Bloch et al., 1999). Although largely thermally immature across much of the WCFB, the 110-township study area is situated in the proximal foredeep of the basin where the Second White Specks Formation was buried sufficiently deep to trigger the onset of oil generation.

The producibility of many carbonaceous mudstone reservoirs relies on permeability created by natural fracturing (Bloch et al., 1999; Gale et al., 2007). Siliceous and calcareous components impart brittle characteristics to their host rocks (Bloch et al., 1999; Canadian Discovery, 2014). This is true of the Second White Specks Formation, which has a significant carbonate lithological component derived from dispersed coccoliths, coccolith-rich fecal pellets, as well as other bioclastic grains and carbonate cements. Using oxygen isotopic data from calcite fracture fills, the fracture formation temperature of the Second White

Specks Formation was calculated by Bloch et al. (1999) to be between 40 to 50°C. The low temperature of fracture formation suggests fractures developed before the Second White Specks Formation was charged with hydrocarbons, allowing later migration of hydrocarbons into those fractures (Bloch et al., 1999). Fractures are only observed where Lower Colorado Group mudstones are thermally mature, which suggests diagenesis also contributes to brittleness (Bloch et al., 1999).

Although natural fracturing is one component of a producible carbonaceous mudstone reservoir, production performance of the Second White Specks Formation may also rely on intrinsic depositional mudstone porosity (Schieber, 2010; Greff and Cheadle, 2012). This porosity develops during deposition and compaction of the mudstone, and can survive extensive burial (Jiang and Cheadle, 2013; Plint and Cheadle, 2015).

Methods

The objective of this research is to evaluate the relative contributions of mappable reservoir properties to fluid inflow performance of completions in the Second White Specks succession in the Willesden Green – Ferrier – Gilby field areas. For the purposes of this study, flow unit properties corresponding to completion intervals will be assigned on the basis of high-frequency time-stratigraphic intervals (allomembers). Allomember property maps in this study represent records of coeval depositional systems bounded by stratigraphic discontinuities such as marine flooding surfaces (MFS), transgressive ravinement surfaces (TRS), regressive surfaces of marine erosion (RSME), or bentonitic ashfall layers coincident with one of the foregoing surfaces. Typical allomembers thicknesses are in the range of three to ten metres, and are bounded by low-permeability mudrock beds. In this context, such maps provide robust “time slices” of rock properties at a vertical scale that closely matches hydraulic flow units in pressure communication with a perforation interval.

The well data for this study is sourced using geoLOGIC’s geoSCOUT software, and Divestco’s EnerGISite web portal. Cross-sections and maps are constructed in IHS Petra, and petrophysical analysis and modeling uses Schlumberger’s Petrel, PetroMOD and Techlog software suites. From an original database of 20,000 wells drilled within the study area, a subset of wells that penetrate the Second White Specks Formation were selected. Previous work on this project by Greff and Cheadle (2012) included developing a digital log database of approximately 1700 wells drilled into the Second White Specks Formation.

Each well was examined individually and ranked based on data quality, because a greater variety of logs and core availability allows for increased confidence in the quality and consistency of correlations made based on that data. Wells with superior data quality were used preferentially in cross-sections. The study area overlaps with, and correlations are tied into, a regional, high-frequency allostratigraphic study of the Second White Specks Formation and equivalent alloformations (Tyagi et al., 2007; Tyagi, 2009). In addition to geophysical well logs, selected cores in the Second White Specks Formation were logged to provide physical confirmation of stratigraphic bounding surfaces throughout the area.

The completed high-frequency allostratigraphic framework is used for zonal analyses of petrophysical characteristics including mineralogy, porosity, estimated organic content, and geomechanical attributes (e.g.: brittleness). Biot (1941) recognized that geomechanical properties in porous rocks are related to pore geometries and network configurations; these are directly related to depositional modes (Schieber, 2010), underscoring the necessity of stratigraphically-constrained mapping.

Results

The regional high-frequency allostratigraphic framework (Tyagi et al., 2007; Tyagi, 2009) is consistent with the field- and pool-scale correlations in this study, providing a reliable basis for zonal mapping of the coeval reservoir bodies. Although the poster presents work in progress, the preliminary results reveal a relatively high degree of lateral heterogeneity in the stratigraphically-constrained flow units corresponding to producing completions.

The next phase of the work will focus on development of a very high-density correlation grid in a 20-township high-graded area exhibiting extreme variability in inflow performance from a single allomembers of the Second White Specks alloformation. Petrophysical modeling, mapping, and statistical analysis of covariance between rock properties and production performance in this refined grid will guide the creation of generalized workflows for reducing uncertainty and managing risk in the development of oil resources in the Second White Specks play.

Conclusions

The unpredictability of oil production from the Second White Specks Formation is problematic for exploitation, despite established source and reservoir capacity. We seek to address this challenge by testing the predictive capacity of mappable petrophysical attributes within a high-frequency time-stratigraphic framework. Although the research is currently in an early phase, the preliminary results are encouraging and suggest the strategy will reveal spatial correlations between modeled rock properties and inflow performance in the Willesden Green – Ferrier – Gilby field areas. If successful, the method has broad application for well placement and completion design in self-sourcing reservoirs with similar heterogeneity.

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