Solving the Second White Specks: Integrating petrophysics and allostratigraphy to find sweet spots

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Summary

Developing a fracture prediction method for the Second White Specks is essential for sweet spotting, as its producibility depends upon intersecting natural fracture networks. This study, focused in a 110-township area in west-central Alberta, tested the predictive capacity of mappable petrophysical attributes (i.e.: porosity, organic richness, brittleness, mineralogy) for locating areas with enhanced oil production potential in the Second White Specks tight oil play.

A multi-mineral model for the Second White Specks and underlying Belle Fourche Formations was developed to compensate for a paucity of mineralogical core analyses in the study area. This model revealed regional mineralogical variations that correlated to increased oil production when constrained to coeval depositional units within a high-resolution allostratigraphic framework.

Introduction

The Upper Cretaceous Second White Specks Formation, a thin-bedded heterogeneous mudrock succession within the Lower Colorado allogroup, is a prolific self-sourcing tight oil reservoir within the Western Canada Foreland Basin (WCFB) in Alberta. Despite significant production (>1 MMBbl) from certain wells, unpredictable inflow performance due to anisotropy and fracture dependency has prevented it from being established as a resource play (Mackay, 2014).

This study seeks to evaluate the relative contributions of mappable petrophysical properties to fluid inflow performance in the Second White Specks Formation by developing an integrated petrophysical and stratigraphic workflow, which could be applied to other analogous mudrock intervals. The Second White Specks tight oil play lends itself well to an integrated study, due to its anisotropic nature and fracture dependency. By placing the petrophysical properties of the Second White Specks into an allostratigraphic framework, areas with enhanced depositional porosity and increased fracture intensity may be more easily located, potentially allowing for better well placement.

Theory

The producibility of many carbonaceous mudstone reservoices, like the Second White Specks, relies primarily on permeability created by natural fracturing of stiff, brittle rocks (Bloch et al., 1999; Gale et al., 2007; Mackay, 2014). When placed under stress, rocks that break without significant deformation exhibit brittle behaviour (Cho and Perez, 2014). Brittle behaviour is enhanced in mudstone reservoirs with higher silica, feldspar, or carbonate content, because siliceous and calcareous components impart brittle characteristics to their host rocks (Bloch et al., 1999; Gale et al., 2014; Canadian Discovery, 2014). Stratigraphically constrained variations in the porosity and mineralogy of allomembers of the Second White Specks will strongly influence the local brittle behavior of the rock under stress. The natural fractures that form as a result of brittle deformation may contribute to enhanced permeability, and thus higher oil production rates, in stratal units with relatively lower clay content.

Natural fracturing is only one essential component of a producible carbonaceous mudstone reservoir. Production performance may also be impacted by 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). Despite extensive research done on the stratigraphy, lithology, and organic matter characteristics of the Second White Specks Formation across the WCFB, far less is known about its porosity systems (Furmann et al., 2014); a definitive porosity model for the Second White Specks does not currently exist.

Methods

Allostratigraphy

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). 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). Six Second White Specks cores were logged at the AER Core Research Centre in Calgary, Alberta to confirm these picks.

The well data for this study was sourced using geoLOGIC's geoSCOUT software, and Divestco's EnerGISite web portal. Cross-sections and maps were constructed in geoSCOUT and Golden Software's Surfer; petrophysical analysis and modeling utilized Schlumberger's Techlog software. 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.

Petrophysics

Previous studies of the Second White Specks and Belle Fourche Formations have not adequately corrected for borehole environmental effects, reducing the reliability and precision of models built using that data. Previous work on this study used Schlumberger's Techlog and built-in Python module for robust data conditioning of raw borehole measurements. This improved the quality of acquired data from intervals affected by severe wellbore instability (Marion and Cheadle, 2016).

Conventional core analyses are rare in the Second White Specks alloformation because the zone has not been a primary exploration target. This limits petrophysical analyses of the Second White Specks Formation because there is a paucity of framework and clay mineralogical data, as well as porosity data. Characterization of the zone below the T01 transgressive surface was emphasized due to its potential as a pay unit. The interval of interest in this study (T01 to K surfaces, Figure 1) includes the lithostratigraphic Unit E and part of Unit D from Zajac (2016).

In order to develop a robust lithological model of the Second White Specks Formation, detailed mineralogical analyses are required in order to ground-truth petrophysically-derived mineralogy. We performed x-ray diffraction (XRD) and x-ray fluorescence (XRF) of framework and clay minerals on a suite of samples from four cores in the study area. Using R, a multiple linear regression model was developed in order to determine the strength of statistical correlation between specific petrophysical logs and mineral content. These relationships were used to build a petrophysically-derived mineral model for the study area.

A porosity model was developed using helium porosimetry data gathered by Furmann (2015; Figure 1); this core data, in conjunction with bulk density logs corrected for mud weight and hole size, was used to calibrate and build a porosity model for the Second White Specks and Belle Fourche alloformations.

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. Isopach maps reveal a relatively high degree of lateral heterogeneity in the stratigraphically-constrained flow units corresponding to producing completions.

The addition of new mineralogical and TOC samples from four cores allowed for the development of a robust mineral model for the study area, which can be used as proxy for brittleness across the area.

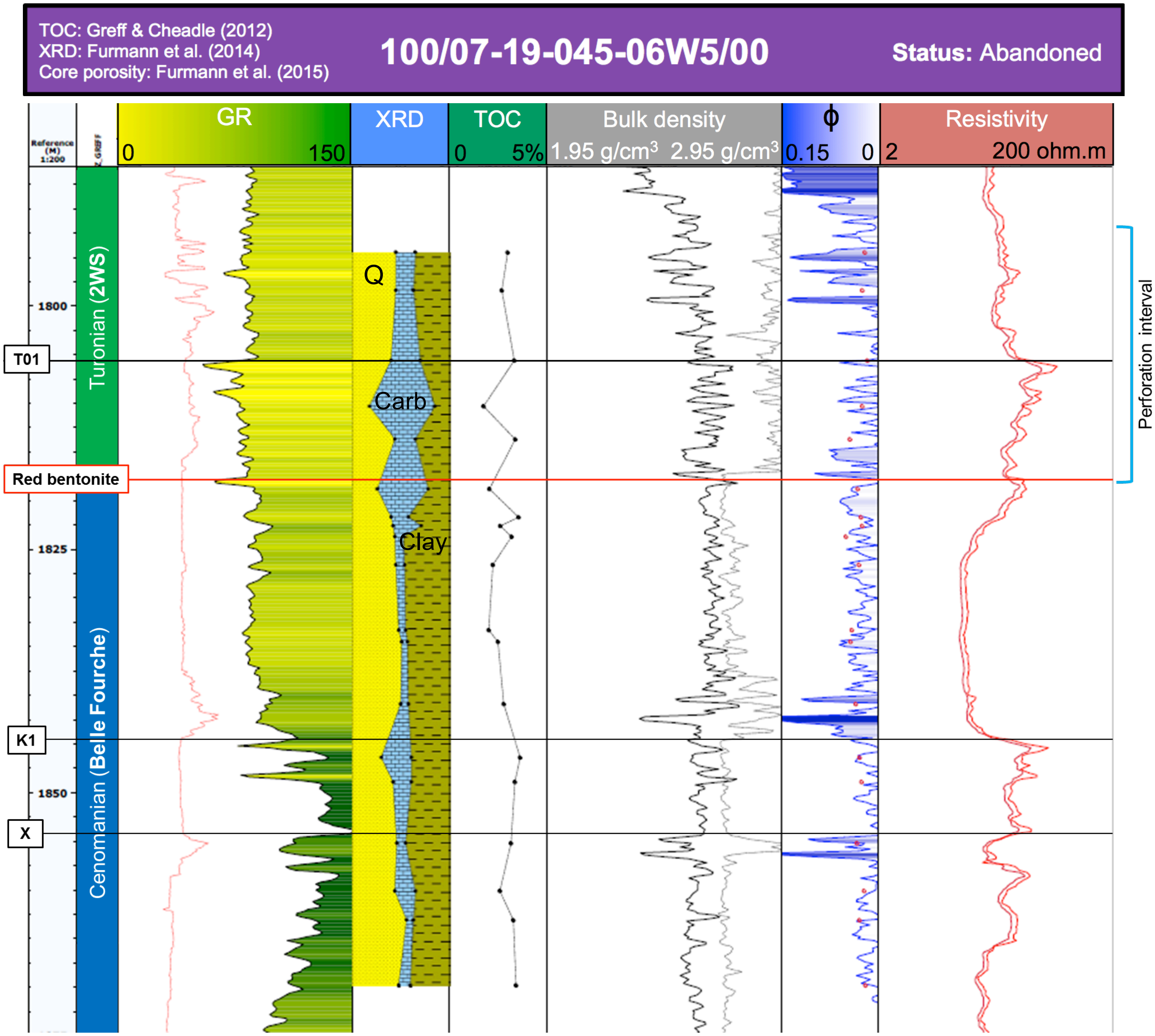

Figure 1:

- The "red bentonite" defines the boundary between the Cenomanian Belle Fourche Formation and the Turonian Second White Specks (2WS; Tyagi, 2009). The upward transition from the Belle Fourche into the Second White Specks is marked by an abrupt change to more calcareous matrix, reduced clay, a suppressed gamma ray profile, elevated resistivity and TOC.
- In this well, a 77.5 m core was taken from 1793.5 to 1871 m; this core is the source of the only core analysis available in the study area. XRD analysis of the 7-19 core by Furmann (2014) showed the T01 unit has elevated carbonate and quartz content relative to clays. This unit, although not productive in this well, has produced significant hydrocarbon volumes in other wells.
- Typical total porosities are in the 0 to 5% range and average 3%. Core derived porosities from Furmann are overlaid and match the model well. The sawtooth nature of the porosity model reflects the vertical heterogeneity and anisotropic nature of this interval.

Conclusions

The mineral model developed in this study is calibrated to core control, and allows for the first approximation of relative brittle behaviour of the Second White Specks and Belle Fourche alloformations. This may prove invaluable for locating prospective zones that are naturally fractured.

By placing the petrophysical properties of the Second White Specks and Belle Fourche alloformations into an allostratigraphic framework, areas and specific stratal zones with enhanced depositional porosity and increased relative brittleness can be delineated, potentially allowing for better well placement. This research has regional application across the WCFB, and may also be applied to analogous mudstone formations in other basins where core analysis is sparse.

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