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Characterizing Organic Rich Mudstone Facies and Stratal Architectures of the Upper Cretaceous Second White Specks Petroleum System, Implications for Reservoir Fairway Distribution across West-central Alberta, Canada

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Summary

The Upper Cretaceous Second White Specks petroleum system is actively being explored as an emerging shale oil resource play across western Alberta. Historically, several highly productive vertical oil wells (+1 million barrels) testify the prolific character of the Second White Specks petroleum system, although often dismissed as an unpredictable fracture controlled play based on poor production in offsetting wells. The petroleum system is comprised of a 500-1200 m thick succession of organic rich mudstones, containing variable amounts of siliciclastic and calcareous components. These units are separated into the siliceous, organic rich mudstones of the Fish Scales Formation, the non-calcareous, siliciclastic rich mudstones of the Belle Fourche Formation and the calcareous, organic rich mudstones of the Second White Specks Formation. Characterizing the stratal architectures and facies distributions associated with these units aids in identifying the various light oil fairways to be exploited by multistage hydraulically fractured horizontal wells.

Introduction

Recent research related to bed load transport and dispersal mechanisms of mud particules have raised questions concerning the way mud dominated successions are interpreted in ancient and modern settings (Schieber et al., 2007; Varban and Plint, 2008; Schieber and Southard, 2009; Schieber et al., 2010; Schieber, 2011; Plint et al., 2012; Nishida et al., 2013). Building on these studies, a detailed sequence stratigraphic framework from regional cross-sections across units comprising the Second White Specks petroleum system reveals a complex stratal architecture that suggests significant stratigraphic heterogeneity. This is supported by the presence of compositionally and sedimentologically distinct facies groups that document such heterogeneities.

Each facies group contains distinct pore-size distributions as well as porosity types which have been previously documented by Jiang & Cheadle (2013) and Furmann et al. (2014). These parameters can be used to gain insight into storage and flow characteristics that have significant implications from a reservoir perspective.

From a regional scale, correlations reveal multiple, stacked parasequences that form transgressive-regressive parasequence sets ranging from 5-15 m in thickness and can be correlated laterally over 70km across the study area. Comprehending lateral and vertical variability of facies groups within these parasequences provides a greater understanding of regional depositional conditions and proves essential for the identification of reservoir fairway trends.

Methods

Regional cross sections using 296 well logs across a study area, T35-45, R24W4-9W5, were used to evaluate parasequence stacking patterns.These correlations build on an allostratigraphic framework established by Tyagi et al. (2007) to which concepts of sequence stratigraphy are applied. The description of 10 cored intervals and 40 petrographic thin sections throughout the study area were used to define sedimentary facies of the Fish Scales, the Belle Fourche and the Second White Specks formations. X-ray fluorescence (XRF) and x-ray diffraction (XRD) data additionally served to constrain sequence stratigraphic interpretations as well as corroborate with sedimentary facies. Scanning Electron Microscopy (SEM) backscatter images and x-ray element mapping of Al, Ca, Mg, K, Fe, C and Si were produced to compliment XRF and XRD data of key sedimentary facies. Lastly, pore-size distribution data serves to identify facies that contain greater storage and flow potential.

To illustrate the lateral distribution of sedimentary facies across the study area, parasequence isopach maps, complemented by facies distribution and facies isopach maps are created. This is accomplished by applying petrophysical cut-offs to resistivity and photo-electric (PE) logs to ultimately estimate sediment depocenters as well as to constrain reservoir facies widths.

Conclusions

Parasequence isopach mapping suggests the presence of stacked, western and eastern tapering wedges that form transgressive-regressive parasequence sets within a sequence stratigraphic context. From a depositional standpoint, sedimentary bedforms (uni-directional current-ripples, combined flow structures, graded beds) observed within the entire succession documents a depositional setting predominantly just below or above storm wave base, with deposition from a wide range of traction and bottom-water currents in a low gradient, storm-dominated, shelf environment. Facies descriptions additionally suggest the presence of multiple sediment sources that have contributed to framework and matrix components within this succession, largely from siliciclastic, organic and calcareous rich source areas.

Collectively, with reservoir parameters characterizing storage and flow properties of each facies, together with an understanding of facies distribution, evidence from a sequence stratigraphic and sedimentological point of view suggests significant heterogeneity previously unappreciated within the Second White Specks petroleum system.

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