Characterization of Complex Facies and Stratal Architecture of Organic Rich Mudstones of the Upper Cretaceous Second White Specks Petroleum System, 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 500-1200m thick succession with several organic rich mudstones, separated by siliciclastic and calcareous mudstones. 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 and mapping the reservoir properties of the various facies aid in identifying the various light oil fairways to be exploited by multistage hydraulically fractured horizontal wells.

Objectives

Understanding facies variability, occurring both laterally and vertically, requires comprehension of mud depositional processes and bed load transport mechanisms in both ancient and modern mud-dominated shelf settings which are discussed in previous studies (Nittrouer & Wright, 1994; Myrow & Southard, 1996; Varban & Plint, 2008; Schieber et al., 2009 and Plint & Macquaker, 2012). With these concepts in mind, detailed allostratigraphic analysis from regional cross-sections across Second White Specks, Belle Fourche and Fish Scales stratigraphy reveal a complex stratal architecture, highlighting extreme stratigraphic heterogeneity (Tyagi et al., 2007). To support stratigraphic heterogeneities observed within this mud-dominated succession, detailed studies of macro and micro-scale facies properties are researched. From a macro-scale point of view, comprehending lateral and vertical variability of facies groups delivers a greater understanding of regional depositional conditions and proves essential when considering reservoir fairway trends. From a micro-scale point of view, characterizing compositional

variations in sedimentology, often related to parameters such as porosity development and fracturability, helps define intrinsic reservoir properties across each facies group.

These properties are directly related to unique pore throat systems, often observed in mud-dominated stratigraphy, providing insight into storage and flow characteristics that have significant implications from a reservoir perspective (Jiang & Cheadle, 2013). Mapping the distribution of facies that correspond to unique reservoir properties is critical to establishing a reservoir and depositional model for the Second White Specks petroleum system.

Methods

Well and core data within a study area spanning T35-45, R3W5-9W5 builds on the allostratigraphic framework established by Tyagi et al. (2007) to which concepts of sequence stratigraphy are applied. The description of 8 cored intervals and 27 petrographic thin sections throughout the study area reveals sedimentary facies characteristic of the Second White Specks Formation, the Belle Fourche Formation and the Fish Scales Formation. Variations in overall rock fabric, composition, fracture habit, porosity distribution and sedimentary features are described to distinguish each facies. The resulting lateral and vertical variations in sedimentary facies and depositional environments is illustrated by para-sequence isopach maps, complemented by facies distribution and facies isopach maps. Unique well log signatures observed in resistivity and photo-electric (PE) curves allows for facies and therefore reservoir fairway trends to be correlated regionally.

Conclusions

Results gathered from facies analysis and facies distribution within the Second White Specks petroleum system highlight evidence of alternative mud dispersion/accumulation processes than those described in previous studies. Para-sequence and facies mapping suggest the presence of stacked clinoform bodies across the study area. From a depositional standpoint, sedimentary bedforms (current and wave ripples, graded beds, hummocky cross stratification) 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 currents in a low gradient, storm-dominated, shelf environment. Collectively, with reservoir parameters describing storage and flow properties from 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.

Acknowledgements

I would like to thank Dr. Per Kent Pedersen for providing guidance, technical support, criticisms and supervision for this study. I would also like to thank all the students within the CABS group at the University of Calgary who provided insight and supporting data that aided this project.

References

Jiang, P. and Cheadle, B.A. 2013. Depositional and burial domain influences on microporosity modalities in carbonaceous mudstones of the Upper Cretaceous Colorado Group, western Canada foreland basin: AAPG 2013 Abstract.

Myrow, P.M. and Southard, J.B. 1996. Tempestite deposition: Journal of Sedimentary Research. v. 66 no. 5, p. 875-887.

Nittroyer, C.A. and Wright, L.D. 1994. Transport of particles across continental shelves: American Geophysical Union, v. 32 no. 1, p. 85-113.

Plint, A.G., Macquaker J.A.S., and Varban, B.L. 2012. Bedload transport of mud across a wide, storm-influenced ramp: Cenomanian-Turonian Kaskapau Formation, western Canada foreland basin: Journal of Sedimentary Research. v. 82, p. 801-822.

Schieber, J. and Southard, J.B. 2009. Bedload transport of mud by floccule ripples—direct observation of ripple migration processes and their implications: Geological Society of America. v. 37 no 6, p. 483-486.

Tyagi, A., Plint, A. G., and McNeil, D. H. 2007. Correlation of physical surfaces, bentonites, and biozones in the Cretaceous Colorado Group from the Alberta Foothills to southwest Saskatchewan, and a revision of the Belle Fourche-Second White Specks formation boundary: Canadian Journal of Earth Science, v. 44, p. 871-888.

Varban, B.L. and Plint, A.G. 2008. Paleoenvironments, paleogeography, and physiography of a large, shallow, muddy ramp: Late Cenomanian-Turonian Kaskapau Formation, western Canada foreland basin: Sedimentology. v. 55, p. 201-233.