A Mudstone Lithofacies Classification of the Horn River Group, British Columbia: Integrated Stratigraphic Analysis and Inversion from Wireline Log and Seismic Data

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Summary

The Devonian-aged strata of the Horn River Basin host a giant shale gas play. A classification scheme of ten distinct mudstone reservoir and non-reservoir lithofacies that can be recognized in core, differentiated with a suite of wireline well logs and inverted from seismic data will be presented. These facies are predictable within a sequence stratigraphic framework which allows us to interpret the depositional processes and map the resulting depositional geobodies.

Introduction

Lithofacies classifications associate sedimentary characteristics with depositional processes. In petroleum exploration and development, lithofacies classifications are typically tied to porosity and permeability - the two key parameters that control productive capacity. A powerful tool is obtained when the lithofacies classification is constructed within a predictive sequence stratigraphic framework that integrates geological and geophysical data. Although depositional processes and environments for fine-grained, organic-rich sedimentary rocks are not as well established as those for coarse siliciclastic or for carbonate systems, conventional workflows can be adapted to shale hydrocarbon systems.

Methodology

Given the fine-grained nature and characteristic dark colour of these rocks, lithofacies are most confidently identified and classified by fully integrating petrographic observations made at the core, thin-section and SEM scale with chemical, mechanical and fluid flow properties. Ten distinct lithofacies are recognized. Four of these are organic-rich and bio-siliceous and define gas-bearing reservoir facies, three are dominantly calcareous and are waste rocks and three are dominantly argillaceous and form seals.

Interpretation requires integration of physical depositional processes, along with an understanding of the controls on bio-productivity and organic matter preservation. Understanding diagenetic processes is crucial, as it strongly impacts the pore architecture and rock fabric. Additionally, the lithofacies need to be integrated not only with the porosity and permeability characteristics of the rock, but also with the elastic properties (bulk and shear moduli) as these have a strong impact on the response of the rocks to fracture stimulation. There is a unique relationship between lithofacies and elastic properties within the Horn River basin mudstones that we have utilized to directly invert the lithofacies from acoustic parameters as recorded in wireline logs and seismic data.

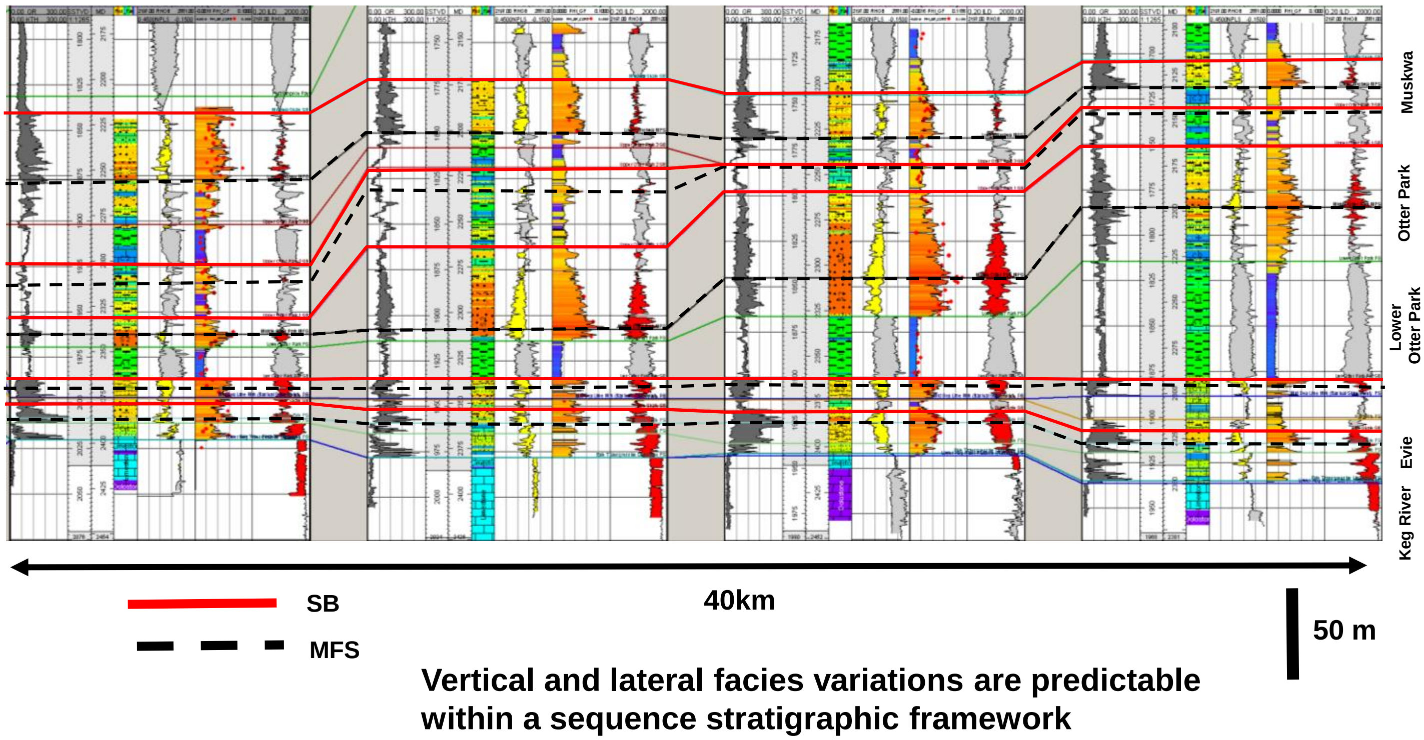

Figure 1: Dip Well Section in a Portion of the Horn River Basin. Siliceous shales in warm colours and illitic shales in cool colours. Limestone in blue.

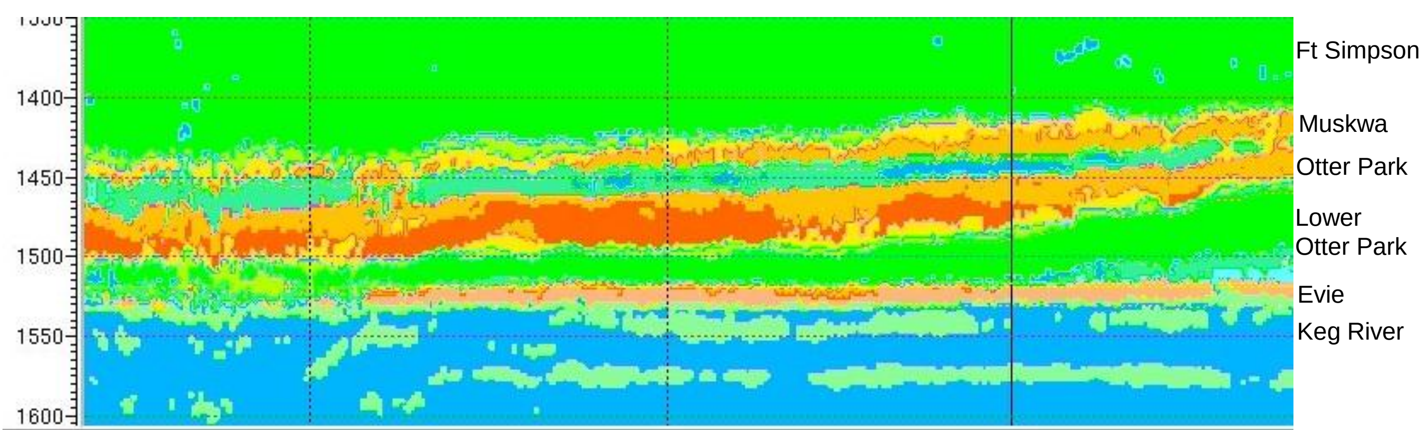

Figure 2: Dip Section Through Seismic Facies Inversion Volume. Siliceous shales in warm colours and illitic shales in cool colours. Limestone in blue.

Conclusions

Ten distinct Devonian mudstone lithofacies can be identified, correlated and mapped within the Horn River Basin. These form the building blocks of a predictive understanding of the depositional system that is critical for resource identification, delineation and development.

The vertical and lateral variations of lithofacies are predictable within a sequence stratigraphic framework. The sediments reflect the interplay of intrabasin organic (algae) production and associated blooms of zoo-plankton (mainly radiolaria and tentaculids) versus extrabasinal detrital siliciclastic input (dominated by clay minerals) and input of carbonate through sediment gravity flows from pre-existing and/or age-equivalent platforms and build-ups along the basin edges. Lowstand deposits tend to be argillaceous due to dilution of the system by incoming clay and silt. Transgressive and early highstand deposits form the best reservoirs as they are dominated by bio-silica and organic matter. Late highstand deposits again see dilution by detrital clay and silt as well as carbonate debris. Laterally, time-equivalent sediments are more bio-siliceous away from clay input points in the basin.

A similar approach may be applicable in other siliceous mudstone plays.

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