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Stratigraphic Architecture and Reservoir Facies Heterogeneity of the Basal Belly River Oil Play, Wilson Creek, Alberta

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ABSTRACT

Introduction

The Belly River Formation was deposited during the late Cretaceous (Lower Campanian) on the western margin of the Western Interior Seaway. The Basal Belly River (BBR) succession consists of deltaic (delta front and distributary channel) and shallow marine (shoreface and offshore transition) deposits that rapidly prograded eastward with limited aggradation. Power and Walker (1996) subdivided the BBR into eight “allomembers” (A to H) corresponding to shoreline units successively younger from west to east, separated by high frequency base level rises punctuating the overall prograding trend. Due to a low accommodation setting in the late Cretaceous of south-central Alberta, these shoreline sandstone units tend to amalgamate, requiring careful and detailed correlation work to separate and map them individually. However, while thousands of wells penetrating the BBR have been drilled in south-central Alberta during the last three decades, very few attempts were made to build on the early work of Power and Walker (1996) and reconstruct the regional stratigraphic architecture of these BBR shoreline units (Hansen, 2007; Jones, 2013). In this work, we reconstructed the stratigraphic architecture and map eight BBR shoreline sandstone units over 230 townships (approx. 21,400 km2) in south-central Alberta. Based on these regional correlations and mapping complemented with detailed sedimentological core descriptions from 21 wells in the Wilson Creek area, we interpreted the depositional history and built a sequence stratigraphic model for these BBR shoreline units.

Regional stratigraphic architecture

Due to the low accommodation setting Basal Belly River deposition, the transition from one shoreline unit to the next can be challenging to identify on well logs because of the vertical amalgamation of sandstone units. To overcome this challenge, we took advantage of the large number and high density of wells with BBR penetrations to correlate over 18,000 wells in our study area (about 80 wells per township on average). We used gamma ray and resistivity logs which are most commonly available and built a dense grid of stratigraphic cross-sections, approaching wells from multiple directions to insure self-consistency in our correlations.

We then built gross sandstone isopach maps of the eight correlated shoreline units revealing well-defined, north-south trending, remarkably linear paleo-shorelines, and more irregular and discontinuous sandstone bodies in a seemingly more distal position within each unit. Based on their shape, distribution and facies analysis from core descriptions, we interpret linear shoreline sandstone bodies as strandplain to wave-dominated deltaic deposits, while irregular sandstone bodies are interpreted as fluvial-dominated deltaic deposits.

Wave-dominated deltaic shoreline deposits form the thickest sand accumulations (up to 25 m) and are interpreted as highstand systems tract with maximum vertical aggradation and lateral continuity alongshore (N-

S azimuth). Fluvial-dominated deltaic discontinuous sandstone bodies are interpreted as lowstand systems tract associated with forced regression due to the low accommodation setting. Given the total duration of the Basal Belly River (approx. 2 My; Eberth, 2024), these shoreline units may represent parasequences bounded by marine flooding surfaces controlled by Milankovitch eccentricity cycles (100 to 400 My duration).

Sedimentology and reservoir quality

A detailed sedimentologic description was conducted on 312m of siliciclastic sedimentary facies of the Basal Belly River from 21 wells in the Wilson Creek study area as part of a broader investigation into the lateral variability and heterogeneity of reservoir parameters and net pay determinations. Calibrations to down-hole log suites and core analysis data (poro-perm, Sw) was conducted for each core. Significant surfaces of allo- and autocyclic origin were calibrated to downhole logs as part of the construction of a sequence stratigraphic framework.

Seven sedimentary facies are interpreted to have been deposited in 12 environments of a mixed wave-fluvial dominated deltaic depositional system. All observed facies are a product of combined wave, tidal and fluvial processes of deposition and occur within two main facies associations: Deltaic and Marine. Paleo-strandline morphology and net thickness of deltaic and marine facies are a function of sediment supply, relative sea-level and wave reworking of fluvial deposited sediment.

A relative reservoir quality determination was made for all cored sedimentary facies based on primary porosity and permeability as observed in core analysis and thin section petrology, and water (Sw) vs. oil (So) saturations. Greatest reservoir quality is associated with: 1.) distributary channel facies, a carbonaceous VF-M grained sandstone characterized by flaser and ripple laminations, planar cross-bedding and variable amounts of Cryptobioturbation with 5-20% porosity and 0.1-15md Kmax; and 2.) delta front facies, a mostly massive-appearing to bioturbated VF-M sandstone with robust traces of Macaronichnus, resedimented plant detritus on bedding plane surfaces and diffuse planar cross-bedding with 4-15% porosity and 0.1-11md Kmax). Thin section petrology and calibration of routine core analysis suggests that bioturbation plays a significant role in preserving a greater component of primary porosity and enhancement of vertical permeability. Shoreface facies are typically densely calcite cemented with permeability rarely exceeding 1.0md Kmax.

A high degree of facies heterogeneity is observed in core and cross-section correlations. The greatest degree of lateral and vertical facies variability is attributable to distributary channel sandstone incision into delta front sandstones creating vertical reservoir continuity yet lateral facies discontinuity.

References

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