Reservoir Architecture of the Cardium Formation in East Pembina, Alberta

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Summary

This study presents the reservoir architecture of offshore to offshore transition facies of the Cardium Formation in east Pembina, west-central Alberta. Until recently, oil production from the Cardium has mainly been limited to conglomerate and relatively clean sandstone reservoirs, however new horizontal drilling and hydraulic fracturing technology has allowed economic production from relatively low permeability muddy sandstone reservoirs. The objective of this study is to examine the offshore to offshore transition sedimentary facies of the Cardium Formation and to map the widths of the different facies belts, and thereby the width of the reservoir fairways for these unconventional reservoirs. In addition, the influence of ichnological characteristics on reservoir properties will be addressed.

Detailed core observations and thin section analysis are used to define the sequence stratigraphic framework of the offshore and offshore transition facies and their facies associations. Integrating facies descriptions with their sequence stratigraphic correlations, will allow for better understanding of the facies distributions and facies associations across the study area, as well as the porosity-permeability relationships and distribution within each flow unit.

Facies widths of the shoreface sands have been documented in numerous studies, whereas research on the facies descriptions and widths of offshore and offshore transition facies is poorly documented. The latter facies are now the active exploration target for horizontal wells adjacent to existing Cardium oil pools. The final result will offer an analogue and helpful insights for similar unconventional oil and gas reservoirs found elsewhere.

Introduction

The Pembina Field is the largest oil pool in the Western Canadian Sedimentary Basin and produces from the Upper Cretaceous Cardium Formation (Figure 1). The Cardium Formation is composed of conglomerates, sandstones, siltstones and mudstones/shales, which make up the facies belts of the shallow marine depositional sequence. Until a few years ago, the main reservoirs within the Pembina Pool were conglomerates and shoreface sandstones. Currently, exploration is targeting the large oil reserves within the unconventional, relatively low permeability offshore and offshore transition facies of the Cardium Formation.

This study focuses on the offshore and offshore transition facies comprising the Cardium Formation in east Pembina. These facies are mainly composed of intensively bioturbated shale, siltstone, sandstone and conglomerate. The high degree of bioturbation has destroyed most bedforms and facies contacts, making it difficult to identify sedimentological characteristics and interpret depositional processes. Although the identification of individual ichnogenera can be problematic, careful examination of the bioturbate textures, including density and diversity of trace fossils, can aide in facies analysis. The amount of mud and fine-grained sediments, and the presence of tempestites, places the Cardium in east Pembina in a low energy setting, reflecting deposition below fair weather wave base and above storm weather wave base.

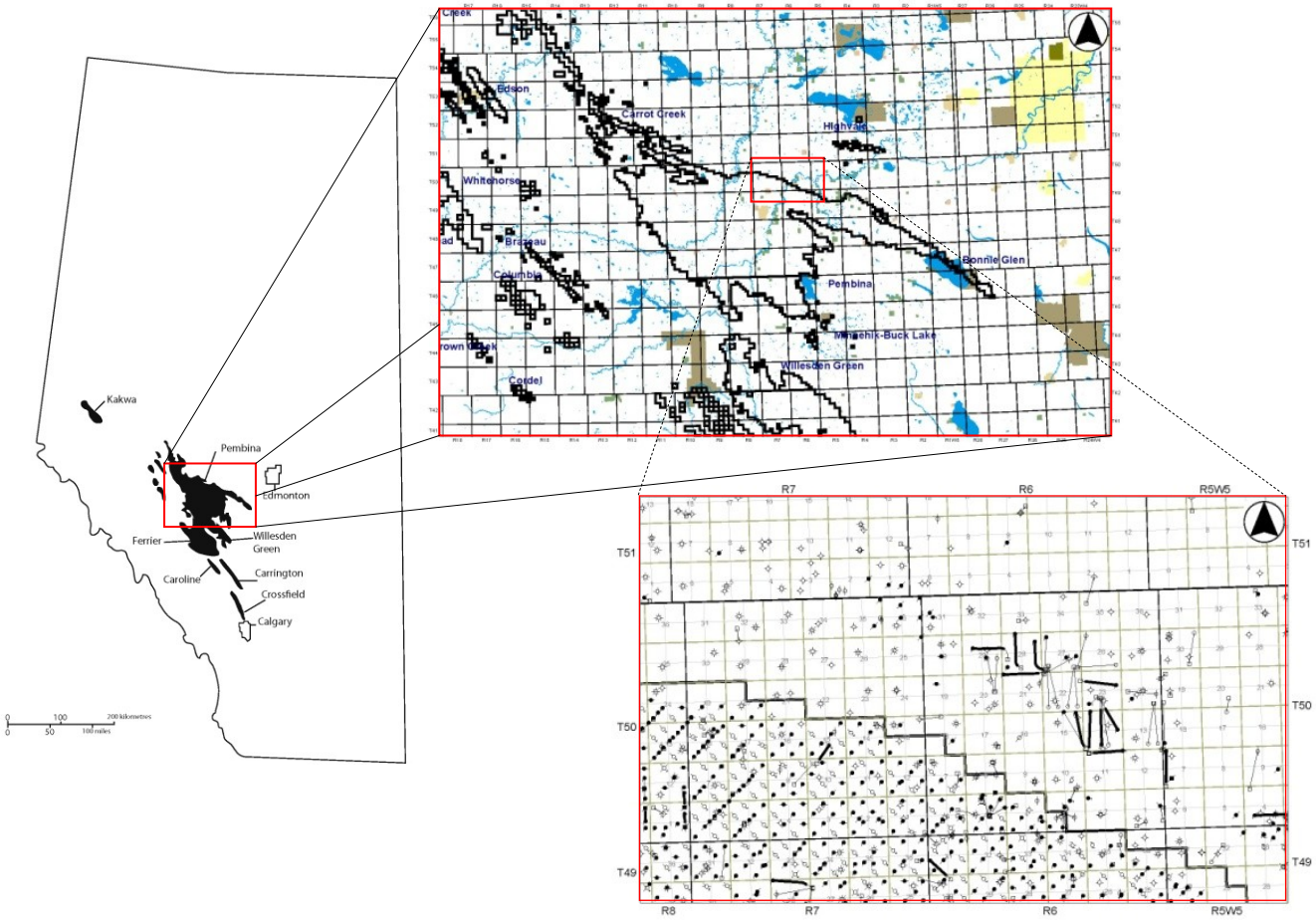

Figure 1: Map of Alberta with major Cardium pools highlighted (left). A detailed map (center) showing the Pembina oil pool and surrounding cities/communities, rivers and lakes, and an enlarged map of the study area within east Pembina (right).

Reservoir Facies

Integrated core descriptions and well-log interpretations are key factors for mapping facies and subsequently determining porosity, permeability and reservoir variability across the different facies.

Through detailed core observations and analysis, six separate facies were identified along a SW-NE transect perpendicular to depositional strike, based on sedimentology, lithology, grain size, bioturbation index, ichnogenera and trace fossil diversity. Vertical stratigraphic positioning of the facies is characterized by mud and silt-sized facies at the base of the sequence, gradually coarsening-upward to sandier facies at the top of the sequence.

Facies 1 is a burrowed mudrock with rare, very fine-grained sandstone lenses that exhibits a reduced diversity of deposit feeding structures. Facies 2 is a silty mudstone with rare lenticular bedding and parallel sand laminations characterized by a greater diversity of deposit feeding traces, and the rare occurrence of dwelling structures such as *Skolithos* and *Diplocraterion.* Facies 3 is an interbedded sandy and silty mudrock with moderate presence of sand lenses and lenticular bedding. It is characterized by an abundance of *Teichichnus* and *Asterosoma*, and exhibits some of the highest trace fossil diversities seen in the analyzed cores. Facies 4 has the highest sand content with a prevalence of vertical dwelling structures such as *Skolithos, Diplocraterion,* and *Arenicolites,* with locally abundant of *Thalassinoides* and *Palaeophycus.* Facies 5 is comprised of interbedded sand and mud beds in the lower half of the facies, commonly associated with *Chondrites*, with massive sandstone deposits (interpreted as tempestites) containing a moderate abundance of *Skolithos* in the upper half of the facies. Typically this facies is capped by Facies 6, an overlying transgressive lag deposit of gravel-sized grains between 2 and 8 mm in size. Passively filled *Thalassinoides* were rarely associated with the lag deposits, indicating that firmground development was not as prevalent within the study area as in other areas of the Pembina Pool.

This presentation will include five producing wells (100/4-27-49-7W5/00, 100/4-28-50-6W5/00, 100/6-7-50-6W5/00, 100/6-20-49-7W5/00 and 100/16-35-49-7W5/00) that are aligned along a SW-NE trending transect across the study area. The purpose of this presentation is to examine the facies and facies associations of the Cardium and determine the widths of the facies belts and the lateral changes in facies both in depositional strike and dip directions. Cross-sections, geophysical well-logs, production data and cross plots (Figure 2) will be used to illustrate the sedimentology, sequence stratigraphy and facies changes within the Cardium Formation (Figure 3).

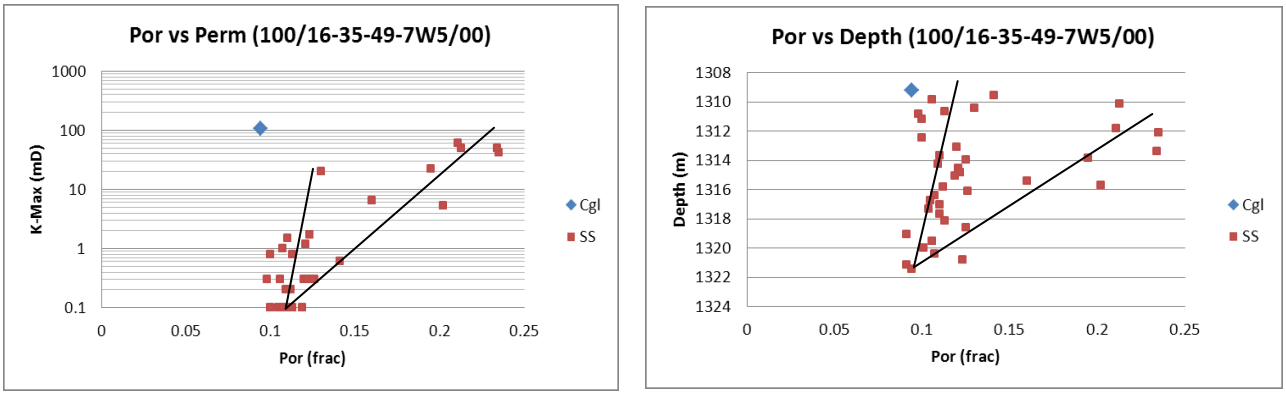

Figure 2: Core analysis cross-plots of Porosity versus Permeability and Porosity versus Depth for well location 100/16-35-49-7W5/00, located within the central part of the East Pembina Pool. Blue diamonds represent conglomerate facies and the red squares represent all other Cardium facies. Black lines represent different trends within the reservoir.

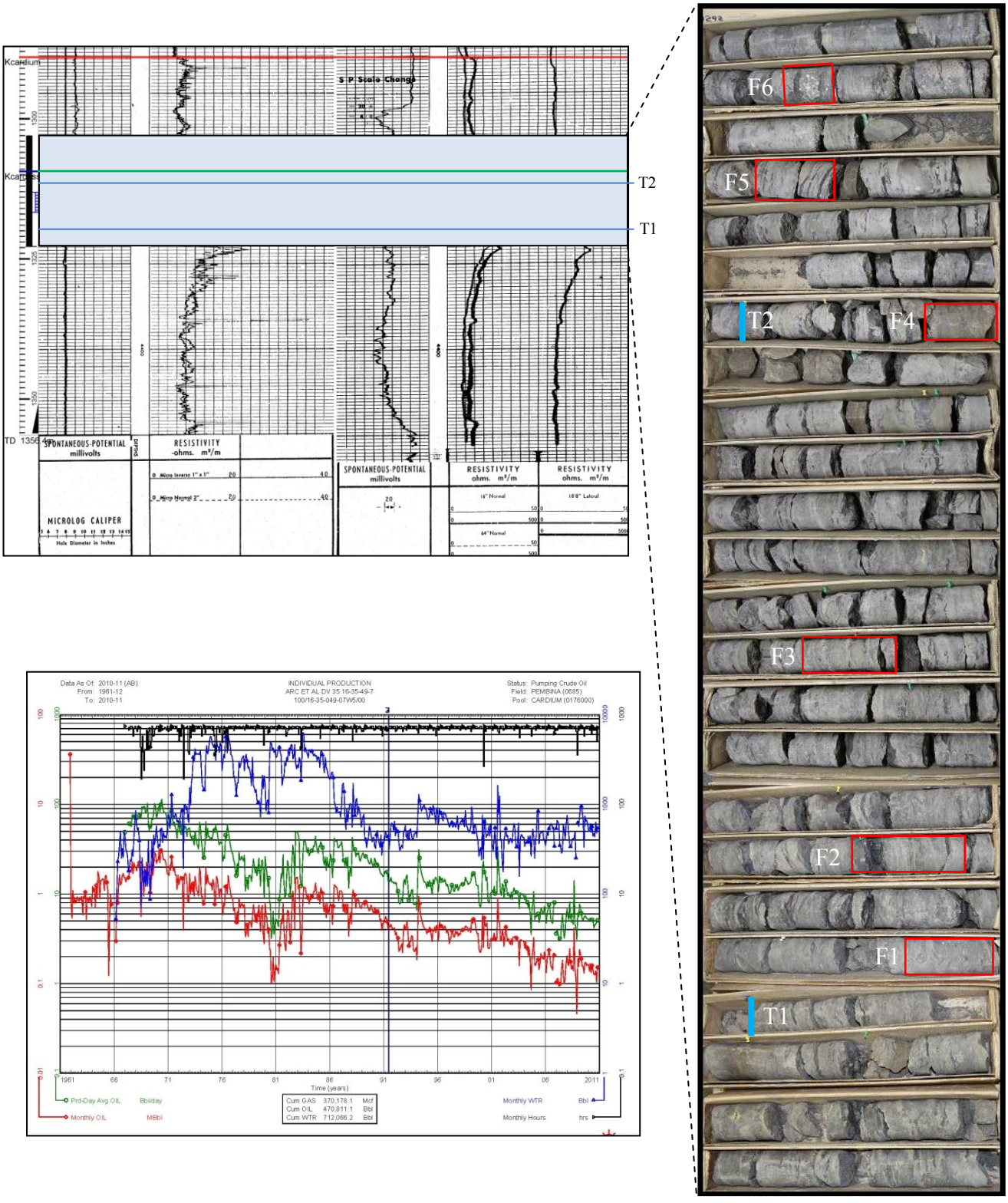

Figure 3: MicroLog and Electrical geophysical well logs (top left) with stratigraphic markers for Cardium zone (red) and Cardium sandstone (green) present in well 100/16-35-49-7W5/00. Whole core interval highlighted by black rectangle. Transgressive surfaces are marked with blue and are labelled T1 and T2, respectively. Facies 1 through 6 are highlighted by red boxes on core photo (right). Daily average oil production (green) and monthly oil production (red) highlighted on production graph for well location 100/16-35-49-7W5/00 (bottom left).