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Lithofacies and Sedimentary Environments of the Basal Cambrian Unit ('BCS') in Alberta: Insights into CO2 Reservoir Characterization

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Introduction

The Basal Sandstone Unit, commonly referred as the 'BCS' by industry in Alberta, is a sand-dominated lithostratigraphic unit which lies unconformably on crystalline Precambrian rocks of the Canadian Shield, reaching as far north as approximately 54° N latitude in the subsurface of Alberta and Saskatchewan, and extending into southwestern Manitoba (Slind et al., 1994). The 'BCS' is becoming a competitive landscape as companies are trying to secure pore space within this proven CO2 storage reservoir. Thus, its mapping and sedimentological characterization have become of paramount importance to improve our understanding of its vertical and spatial variability to high-grade development areas. Cores provide direct physical evidence of the subsurface geology and remains fundamental in manging subsurface uncertainty and risk. They provide essential data and conceptual ideas for subsurface analysis as they provide an accurate record of lithological, structural, sedimentary, pore system and diagenetic features. Although fine scale heterogeneities at core and thin-section scale are generally not modeled for reservoir dynamic simulations, understanding their genesis, link to sedimentary environments, and their impact to fluid flow, is crucial for effective CO2 management.

Objective and Methods

This study presents a detailed lithological characterization of the Basal Sandstone Unit and Earlie Formation of Alberta. It includes the detailed description of some 250 meters of cores from 5 wells where lithofacies were recognized and discriminated based on lithology, grain size, sedimentary structures, and trace fossil content. Lithofacies were group into assemblages which represent different environments of deposition. Key environmental indicators, include sedimentary structures, grain size trends, stacking patterns and trace assemblages. The environmental framework of MacEachern and Gingras (2007) for bay successions is adopted for this study. These authors distinguished restricted bays (embayments that have limited or intermittent connection to the open sea) and open bays (embayments having virtually unrestricted connection to the open sea). The Lloydminster Embayment (Slind et al., 1994) can be described as a large open bay within an onshore basin fringed to the west by a carbonate platform. The vertical stacking patterns of facies associations were also analyzed to helped interpret depositional environments within a sequence stratigraphic framework.

Results

Fifteen lithofacies were identified in the study and were grouped into 7 facies associations representative of four environments of deposition: (1) Tide-dominated bay margin; (2) Proximal bay; (3) Distal bay; and 4) Offshore. The first two environments were recognized within the Basal Sandstone Unit ('BCS'), while the third and fourth in the lower Earlie Formation.

The 'Tide-dominated Bay Margin' environment comprises four facies associations. Facies Association 1 is characterized by erosively-based cross-stratified sandstone, stacked forming fining-upward units. Bioturbation is absent. This association is a record of high energy dunes and bars developed within channel-belts associated to braided fluvial systems and inner parts of estuaries. Facies Association 2 is composed of cross-stratified sandstone with common mud drapes, horizontal-laminated sandstone, rippled-laminated sandstone and sandy heterolithics. These lithofacies are genetically related and record deposition within subtidal compound dune fields or sand sheets. This facies association is mainly unburrowed (BI: 0–1), only sporadically containing *Skolithos* and *Planolites*. Facies association 3 is composed of muddy heterolithic, sandy heterolithic and mudstone lithofacies recording deposition within low-energy areas within the subtidal compound dune field or sansheet. Its trace fossil content is dominated by *Palaeophycus* and *Planolites* but biorturbation intensity is low (BI: 1–2). Facies association 4 comprises thin and very thin-bedded rippled-laminated sandstone, horizontal-laminated sandstone and planar cross-stratified sandstone deposited within the intertidal zone as mix- and sand-flats. Within this facies association, erosive-based trough-cross stratified sandstone are interpreted as intertidal channels.

The ‘Proximal Bay’ environment, Facies Association 5, comprises mudstone, sandy heterolithics, bioturbated sandstone, bioturbated muddy sandstone, cross-stratified sandstone and mudstone lithofacies. These facies are commonly organized in coarsening- and shallowing-upward cycles. Bioturbation intensity is moderate to strong (BI: 2-5) including *Skolithos*, *Palaeophycus Diplocraterion*, *Planolites*, *Teichichnus* and *Rosselia*. These bioturbated intervals developed on the fringes of the subtidal compound dune fields or sand sheets in the offshore direction (Desjardins et. al., 2012).

The ‘Distal Bay’ environment comprises fine-grained deposits including in sandy heterolithics, muddy heterolithics, bioturbated heterolithics and bioturbated mudstone and mudstone which are group into Facies Association 6. Bioturbation intensity is commonly moderate to strong (BI: 3-5) and tend to be dominated by *Teichichnus* and *Planolites*. Other trace fossils include *Palaeophycus*, *Rosselia* and *Skolithos*.

The ‘Offshore’ environment of deposition is represented by Facies Association 7 which is composed of bioturbted heterolithics, wave-rippled laminated glauconitic sandstone and mudstone. Trace-fossil diversity is typically higher than in the other facies associations. The ichnofauna is dominated by *Palaeophycus*, *Asterosoma*, *Planolites*, *Rosselia, Teichichnus* and *Skolithos*. Degree of bioturbation is highly variable but commonly intense (BI: 2–5). This Facies association is the record of episodic sand sedimentation during storm events and mudstone deposition during fair-weather periods in a fully marine offshore setting.

Conclusion

The lithofacies and facies associations recognized in core enabled the interpretation of sedimentary environments, providing a framework for multidisciplinary data integration, enabling reservoir quality prediction in un-core wells and away from control points. This study also improved the understanding of the subsurface and allowed for the development of robust and predictive reservoir models.

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