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Coeval deposition of regressive and transgressive stratal packages: An example from a structurally controlled area of the Viking Formation in east-central Alberta

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Summary

The Lower Cretaceous (late Albian) Viking Formation in the Western Canada Sedimentary Basin (WCSB) is a sequence stratigraphically complex succession that has been interpreted previously to record deposition in a low-accommodation basin. Recent studies, however, document areas that are markedly over-thickened. Systems tracts in these over-thickened areas experienced varying degrees of structural reactivation during deposition, leading to pronounced along-strike variability in their orientations, geometries, and stratal stacking patterns. Locally, areas of increased accommodation are attributed to differential basement reactivation of the Paleoproterozoic Snowbird Tectonic Zone (STZ), which flanks areas of anomalously thick Viking Fm and trends approximately normal to the regional strike of the WCSB (Schultz et al., 2019).

Within the WCSB, depositional conditions and shoreline geometries cannot be expected to remain constant along 100s of km of depositional strike. Allogenic (e.g., tectonic, climate, etc.) and autogenic (e.g., delta lobe switching) controls influence the depositional geometries of systems tracts, which lead to variable depositional patterns along strike. Structural reactivation that was active during Viking deposition led to along-strike variability in accommodation space, complex sedimentation patterns, and coeval deposition of both transgressive and highstand deposits over the STZ. The greatest accommodation space was created adjacent to fault margins, which is manifested in preservation of over-thickened transgressive deposits comprising retrogradational stratal stacking patterns. In the center of the STZ, an over-thickened highstand delta is preserved, showing progradational stacking of normal regressive cycles.

Introduction

Sequence stratigraphy describes the relationship and distribution of stratal stacking patterns of sedimentary bodies that are genetically related and conformable at any temporal or spatial range (Catuneanu et al., 2011). In this framework, changes in stratal stacking patterns are attributed to changes in accommodation space and sedimentation rates. Many studies that use sequence stratigraphy are data-driven, with deposits being assigned to falling stage (FSST), lowstand (LST), transgressive (TST) and highstand (HST) systems tracts (Catuneanu et al., 2011; Catuneanu, 2019). Stratigraphic surfaces that separate systems tracts tend to be diachronous.

Few studies have documented the effect(s) of structural control on systems tract development. Coeval deposition of regressive and transgressive units can occur in multiple environmental settings including: i) tectonically active fault zones (leading to differential subsidence); ii) depositional environments where sedimentation rates may vary significantly along strike (e.g., deltas); and iii) areas where sedimentation and accommodation rates are variable (Catuneanu, 2019). Under any combination of these depositional settings, conditions may be created wherein progradational and retrogradational stacking patterns are generated concurrently, leading to challenges when attempting their correlation at a basin-scale.

Coeval deposition of regressive and transgressive units is likely more common than is currently documented in the literature. Modern examples highlight how structural controls and variations in sedimentation and accommodation have a more pronounced role on the development of shoreline architecture than previously considered (Catuneanu, 2019). Creation of high-resolution sequence stratigraphic models requires the incorporation of data-driven methodologies.

Study Area and Methods

The study area encompasses Viking Fm deposits in central to east-central Alberta. The extent of the study area includes the Crystal to Joarcam depositional dip trend, extending northeast towards the Sundance-Edson to Judy Creek depositional dip trend (Fig. 1). In this study, 150 cored intervals were logged in detail and used to create a high-resolution facies model for the Viking Formation. Surfaces that separate different stratal stacking patterns were flagged as potentially sequence stratigraphically significant surfaces. These surfaces were then keyed to their geophysical well log responses and correlated using 1000 well locations to test whether they held stratigraphic significance. The integration of core data (e.g., sedimentology and ichnology) with geophyscial well logs led to the development of a data-driven sequence stratigraphic framework throughout the study area. Mapping the stratigraphic surfaces highlighted areas where the model deviates from an idealized sequence stratigraphic framework. Across the fault zones, sequence stratigraphic surfaces became highly diachronous and stratal stacking patterns display marked along-strike variability. This is manifested by juxtaposed progradational and retrogradational stacking patterns across the fault zone.

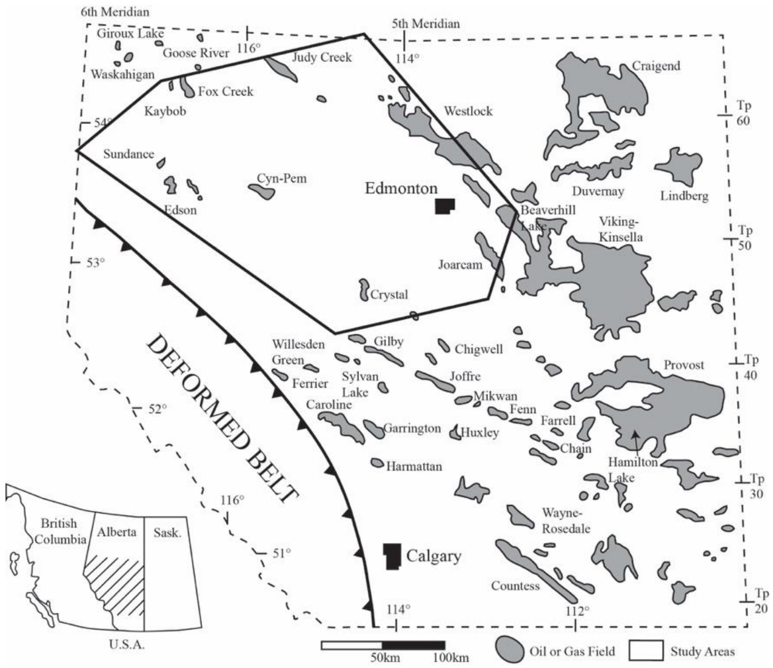

Figure 1: Study area with key fields outlined by the black box. Figure modified from Pattison (1991).

Other Examples of Structural Controls on Sequence Stratigraphy

Modern depositional systems demonstrate the range of stratal stacking patterns and facies relationships that may be intersected when mapping subsurface units. On the Cauvery coast of east India, an active fault zone controls the depositional architecture of a modern delta and estuary (Fig. 2A) (Catuneanu, 2019). The northwestern flank of the fault zone records lower accommodation rates than the southeast flank. In the higher accommodation zone, an estuary has formed, with the shoreline recording retrogradation. By contrast, in the lower accommodation zone, deltaic deposits are developed and display progradational regression. Similar scenarios occur along the coastline of the Adriatic Sea (Fig. 2B). There, longshore drift of sediment has created a progradational shoreline downdrift from sediment input, while a contemporaneous retrogradational shoreline lies updrift of this input (Catuneanu, 2019).

Ancient depositional systems certainly would have experienced similar scenarios of coeval deposition, but documented examples are not widely recorded. In one study of the WCSB, Wehr (1993) documented that variable subsidence rates recorded in the Lower Cretaceous Mannville Group led to along-strike systems tracts variability, indicating that systems tracts and their bounding surfaces could be diachronous across the basin. In the Cretaceous Cozette Sandstone in Colorado, Madof et al. (2015) showed that structural elements within the basement influenced the creation of accommodation space. In the zone of increased accommodation, they documented that some areas of the shoreline show progradation while others record evidence of shoreline aggradation and retrogradation.

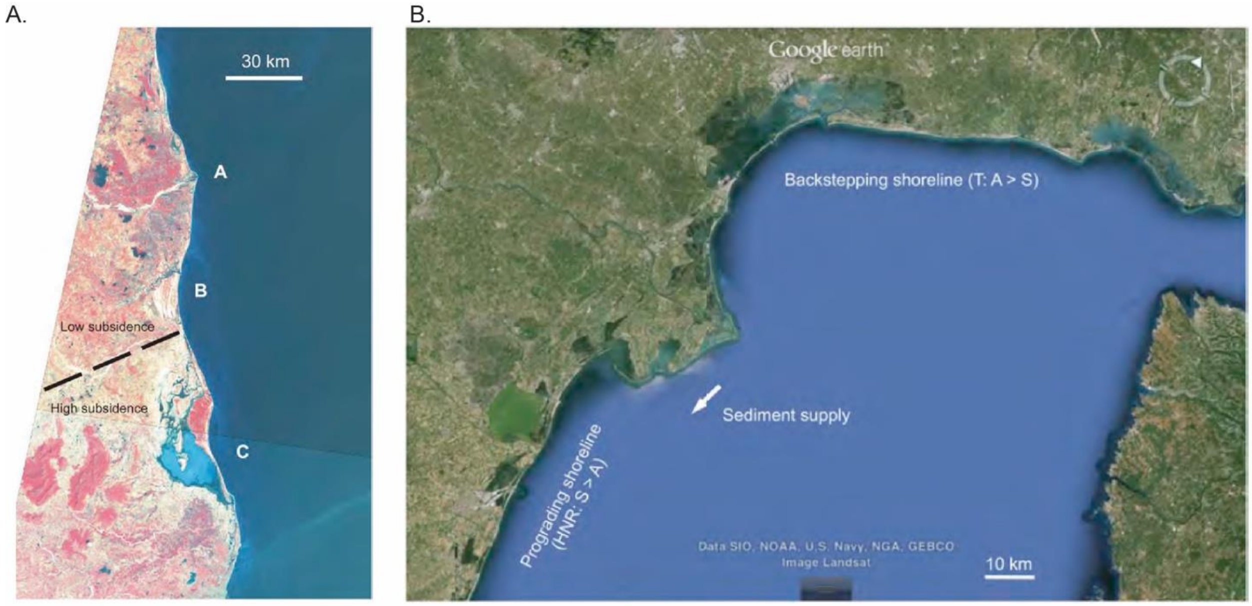

Figure 2: Modern examples of coeval deposition (from Catuneanu, 2019). A) Cauvery coast, India. A= Delta, B= Prograding Strandplain, C= Estuary. B) Po Delta.

Conclusions

The Viking Formation comprises complex deposits that have been affected by periods of structural reactivation. This tectonic activity influenced sedimentation patterns and creation of accommodation space in localized areas of the basin. Across fault boundaries, both progradational and retrogradational stacking patterns occur in broadly contemporaneous deposits. This tectonic influence complicates the correlation of stratigraphic units, and these local structural controls that influence deposition must be incorporated into the working model after bounding surfaces have been identified in cores and well logs.

Deviations from model-driven examples are more common than has previously been documented in the literature. The ability to identify such departures from model-dependent scenarios will allow higher-resolution sequence stratigraphic models to be developed for other subsurface units.

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