Evolution of Frasnian Mixed Carbonate-Siliclastics Systems: Outcrop-Based Characterization of Sequence Stratigraphy and Architecture, Cline Channel and Jasper Basin Areas, Alberta, Canada*

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Abstract

Ten (third-order) Composite Sequences are recognized within a Second-Order depositional sequence spanning the uppermost Givetian to the base of the Famennian from the Alberta basin. The eight youngest composite sequences are defined from the Cline Channel and Jasper Basin areas utilizing stratal and facies stacking patterns, regional correlation of sequence boundaries and maximum flooding surfaces integrated with conodont biostratigraphy. Most sequence boundaries observed are subaerial exposure surfaces, seen in outcrop or inferred from onlap of tidal flat or reef margin deposits onto foreslope facies. The Cline Channel is filled asymmetrically from southeast to northwest within the study area. Progradation is on a foundation of bank derived fine-grained carbonates and extra-basinal clays (forming argillaceous carbonates and calcareous shales). In the Cripple Creek area, on the southern margin of the Cline Channel, the second order Frasnian cycle is characterized by initial retrogradation followed by aggradation to retrogradation and finally, progradation in the upper Frasnian. At Wapiabi Gap, the overall stacking pattern is aggradational. In both the Cline Channel and the Nikanassin area of the Jasper Basin, decreasing accommodation within the second order highstand is exemplified by the reduction of composite sequence thickness and the replacement of open marine with bank interior facies as the basin.

References Cited


ABSTRACT

- Many of the classic Frasnian outcrops from the Alberta Front Ranges, from the Cascade (Burnt Timber) Channel to the South Jasper Basin are placed into a sequence stratigraphic framework.
- Ten third-order composite sequences and their constituent high frequency (fourth-order) sequences span the uppermost Givetian to Frasnian strata. They reflect stratigraphic architecture typical of a (second-order) depositional sequence: transgression followed by regression, or basin-opening and filling.
- The eight youngest composite sequences are defined from the Cline Channel and Jasper Basin areas utilizing stratigraphic and facies stacking patterns and the regional correlation of sequence boundaries and maximum flooding surfaces, integrated with conodont biostratigraphy. Most sequence boundaries observed are subaerial exposure surfaces, seen in outcrop or inferred from onlap of tidal flat or reef margin deposits onto foreslope facies.
- Composite and high frequency sequences (CS and HFS) can be confidently extended from outcrop to subsurface. A combination of well log and outcrop cross-sections, integrated with biostratigraphy, support these correlations. These regional (time) surfaces allow better understanding of basin evolution and architecture.
- The basin was filled asymmetrically by mixed carbonate-clay successions that form the dominant east to west prograding strata. Two main types of sediment contribute to the basin fill: extrabasinal clays and intrabasinal carbonates. Extrabasinal siliciclastics, mostly clay, were ultimately sourced from the Caledonian orogeny which extended from the east coast of Greenland to the Canadian Arctic Islands.
- Influence of the Second-Order sequence is expressed in the architecture of composite and high frequency sequences. For example, the tripartite character (lowstand-transgressive-highstand) of CS in the lower and middle part of the sequence is followed by the appearance of a distinct falling stage component in the upper part of the Frasnian.
- An increased frequency of truncation surfaces and off-lapping strata is consistent with diminishing accommodation. With progressive basin infill and shallow paleobathymetry, foreslope declivity decreased from a minimum of 10° to less than 1.5° as foreslopes became more ramp-like. This is accompanied by a change of lowstand geometry, from wedge to tabular shaped.
- Deposition of coarser terrigenous clastics is also limited in most of the basin, except at CS and HFS boundaries, in the lower part of the second-order sequence. Restricted marine circulation onto the carbonate platforms and basin filling in the late Frasnian coincided with extensive siliciclastic silt deposition in the study area. In the upper Frasnian, particularly in the Jasper Basin, influx of terrigenous silt forms mixed carbonate-siliciclastic deposits. Silt was deposited during third and fourth-order lowstands, by-passed into the basin, and re-worked during intermittent inundation of the carbonate platforms.
- Beyond the basic transgressive-regressive architecture of the Second-Order Givetian-Frasnian Sequence, we document more detailed observations such as: 1) controls affecting the onset, cessation and extent of euxinic shale deposition in the mid-Frasnian and its relation to the second-order MFS; 2) the relative speed and distribution of illitic basin fill within the second-order highstand; 3) the effect of basin fill and off-bank sediment transport on regional and local carbonate platform architecture, such as the configuration of in-situ carbonate lowstands, initiation of reefs along favorable fairways, and overall margin stacking patterns; and 4) the magnitude of relative sea level falls associated with the development of sequence boundaries.

Database

- Outcrop: 64 sections described along the front ranges of Alberta from the Canmore to the Miette area.
- Detailed mapping of 17 continuously exposed, platform to basin transitions where flooding surfaces, sequence boundaries and facies contacts were walked out and/or correlated with photograph panoramas. These outcrop "windows" were linked by additional stratigraphic sections and reconnaissance undertaken between them.
- Extensive subsurface database (partly summarized in Potma et al., 2001) was expanded for this study. A detailed re-interpretation of the Redwater and Golden Spike reefs and the Grosmont Shelf was undertaken. Regional well-log cross-sections, including 30 wells, establish the correlations across the basin.

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Summary of the composite and high frequency sequences recognized, main features of associated sequence boundaries and their systems tract breakdown. Givetian-Frasnian supersequence, Alberta Basin.

Late Devonian (mainly Frasnian) paleogeography of North America showing location of Alberta (black outline) with respect to the paleo-equator (red line). Map from Ron Blakeley, cpcystems.com.

Map showing the location of successive carbonate shelf edges of the Givetian-Frasnian second-order supersequence, Alberta Basin. Numbers record the progression of shelf edges, from the oldest (1) to the youngest (8).

Late Devonian (mainly Frasnian) paleogeography of North America showing location of Alberta (black outline) with respect to the paleo-equator (red line). Map from Ron Blakeley, cpcystems.com.
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Evolution of the WD4 CS at the Nikanassin Range. Shelf edge trajectories (red arrows) track relative sea level rise and fall within the WD4.1 (= WD4.1.1), WD4.1.2 and WD4.2.1 HFS.

Detailed view, southeast margin of the Cline Channel at Cripple Creek, showing the composite and high frequency sequence stratigraphy. The role of clay basin fill is shown by the evolution of foreslope gradients from the WD3.1 to the WI1.1 HFS. Foreslope dips decrease from 10-20° (red arrows) to less than 5° (light blue arrows) with influx of extrabasinal clay and the accompanying change to more ramp-like profiles. The abrupt increased gradient on the WD4.1 surface (dark blue arrow) coincides with the distally steepened segment of the underlying WD3 foreslope.

Stromatoporoid rubble and grainstone foresets of the WD3.2 downlap onto the regressive surface of marine erosion (RSME), developed over lower foreslope strata. The sharp RSME separates grey argillaceous, cherty and nodular-bedded lime mudstone from the overlying skeletal grainstone. This surface continues toward the skyline on the upper right. Wapiabi Gap Skyline photograph showing a channel along the WI1.3 sequence boundary downcutting into lower foreslope deposits (a) of the WI2 HFS. Channel erosion extends approximately halfway down to the level of the WI1.2.1 sequence boundary. Note truncation of foresets. It is infilled by prograding stromatoporoid rubble and grainstone (b). Depth of channel is approximately 15 m. Strata (c) overlying the WD1.1 surface are composed of metre-scale cyclic platform-interior lime mudstone to cryptagal laminite. Locally disrupted beds (d) are likely from collapse associated with gypsum dissolution.

Transverse (upper photograph) and axial (lower) views of second channel at the WI1.3 sequence boundary. Down-cutting extends approximately to the level of the WI1.2.1 surface. It is filled by prograding stromatoporoid rubble and grainstone of upper foreslope and reef-flat origin. This feature is approximately 25 m deep and located 270 m northwest of the previous example.

Lithofacies and sequence stratigraphy of the WI3 to WI3.5 at the Wapiabi Gap skyline. Platform-interior facies are colored according to the dominant facies type. The regressive surface of marine erosion (RSME) is interpreted to be the result of wave erosion during falling relative sea level.

References

The figures in this poster are sourced from the following papers:


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