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Geologic Record of Arid Climate Cyclothems in the Upper Pennsylvanian and Lower Permian Tobermory and Kananaskis Formations of Fortress Mountain Ridge Section, Kananaskis Country, Southern Alberta

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Summary

The Upper Carboniferous and Lower Permian strata of the Front Ranges of the Rocky Mountains of Alberta contain a record of depositional cyclicity. This cyclicity is interpreted to be correlative with the depositional cyclicity noted in strata of Late Paleozoic age in the American Midwest (the classic Midwestern cyclothem). The record of depositional cyclicity in the Tobermory and Kananaskis formations of Fortress Ridge Section is denoted by alternating lower shoreface/shallow offshore marine carbonates with shoreface to foreshore siliciclastics, representing a relative rise and fall of sea level respectively. Previous work on these units in the Kananaskis area and elsewhere in equivalent strata has suggested an arid to semi-arid paleoenvironment, an inference supported by paleogeographic reconstructions that indicate a paleolatitude of approximately 20-30º N on the western margin of Pangea. This relative aridity is a marked contrast to the sub-tropical wet paleoenvironment of the coal bearing American Midwest cyclothems and is thought to account for the low clastic input and subsequently, the subtle nature of depositional cyclicity in Upper Paleozoic strata of Alberta and northeastern BC. In terms of controls, the primary driving mechanism for this cyclicity is thought to be glacial-eustatic in origin, associated with the glacial-interglacial cycles of the Late Paleozoic. The ultimate control for the glacial cycles is theorized to be Milankovitch orbital variations. The cycles present in the strata of the Tobermory and Kananaskis formations may be linked to Milankovitch orbital cycles, specifically the ~100,000 and ~400,000 year eccentricity cycles.

Introduction

The Late Carboniferous to Early Permian depositional systems of western Canada were focused in two main depositional centres, including the Peace River Embayment and the Prophet Trough (Ishbel Trough in the Permian). The Peace River Embayment (PRE) was formed as a result of the collapse of the structurally high Devonian Peace River Arch (PRA) in the early Carboniferous. This collapse was driven primarily by extension, which created a subsequent depositional basin. The Prophet/Ishbel Trough formed as a downfaulted margin (distal foreland basin) that extended from the northern Yukon and Alaska southward to join the Antler Foreland Basin of the western United States (Richards et al., 1994). The formation of this trough has been linked to the development of the Antler Orogeny in the western United States (Smith et al., 1993). The Kananaskis and Tobermory formations of this study were deposited in a shallow marine to coastal system that deepened markedly towards the Prophet/Ishbel Trough to the west.

Depositional sequences of a repetitive nature within the Pennsylvanian – Lower Permian succession in Kananaskis Country, Alberta were first described by David Moore (unpublished M.Sc. Thesis 2002). This research project builds upon those findings to characterize the geologic record of these depositional environment variations by focusing on the sedimentology and biostratigraphy of the Pennsylvanian aged Tobermory Formation and Pennsylvanian-Permian Kananaskis Formation. The end goal will be to formulate an arid cyclothem depositional model. Previous research involving cyclothems has focused primarily on the tropical-humid coal bearing Pennsylvanian strata of the Eastern United States (e.g. Heckel, 1995) and as such, a model for arid climate cyclothems has not yet been proposed. The investigation into the depositional controls acting upon this basin during the Late Paleozoic will contribute to the understanding of the global distribution of Late Paleozoic cyclothems and also aid in further understanding of the evolution of the Western Canada Sedimentary Basin (WCSB).

Methods

The Fortress Ridge outcrop section located in Kananaskis Country, Alberta (Figure 1) was visited and measured in detail. The outcrop was examined for bulk lithology, sedimentary structures and trace fossils. In addition, rock samples were gathered for preparation of thin sections and processing for conodont microfossils. Gamma ray logging was also carried out on the outcrop during the field excursion. Rock samples from the nearby Fortress Roadcut Section were also processed for conodonts. Lithology and sedimentological information from previous work on the Fortress Roadcut Section was available and used as complementary data (from: Moore, D. unpublished M.Sc. Thesis 2002).

Results

From the detailed logging of the Fortress Ridge outcrop section, a stratigraphic column was produced (Figure 2). Based on this column and sedimentologic analysis, the nature of the cyclicity present in these units is characterized. The 25 m thick Fortress Ridge Section contains parts of three large-scale cycles averaging ~10 m each and typically defined by three primary lithofacies (base to top): (1) thin, dark silty shale, (2) silty dolomitic mudstone, and (3) well-sorted dolomitic sandstone with rare trough and common planar stratification. The thin basal silty shale is inferred to record the deepest water facies, whereas the dolomitic carbonate mudstone and dolomitic sandstone are inferred to record probable shoreface to foreshore environments in a restricted shallow ramp setting. Within these large scale cycles, smaller scale, higher frequency cycles are also present, ranging from 2 to 4 m and defined by two primary lithofacies (base to top): (1) silty to very fine sandy dolostone and (2) well sorted dolomitic sandstone with abundant planar and cross stratification, rare tough cross bedding and ripple marks. The silty dolostone of the higher frequency cycle likely represents a shallow marine to lower shoreface setting and the dolomitic sandstone a shoreface/foreshore depositional environment.

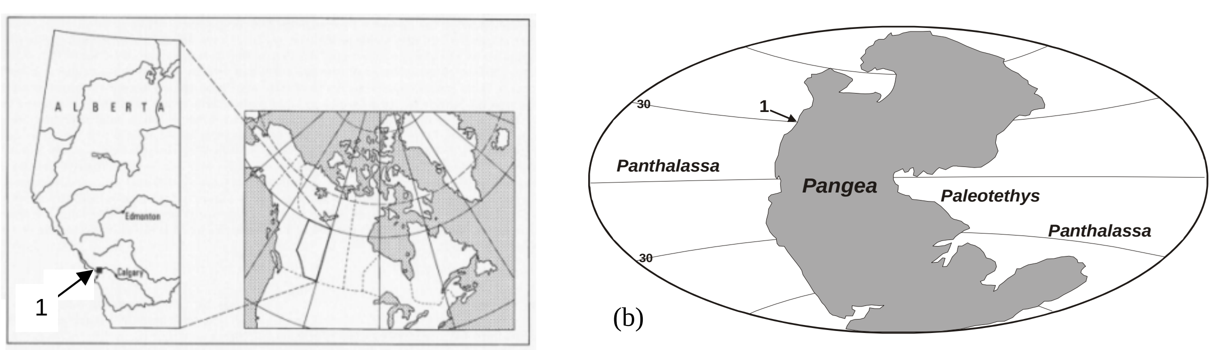
In terms of depositional cyclicity, the three ~10 m cycles present in the Fortress Ridge Section appear to be characterized by a shallowing upward succession associated with a drop in relative sea level. The foreshore/shoreface lithofacies at top of each cycle is bounded by a sharp contact that appears to abruptly change to the basal deeper water lithofacies of the overlying cycle. This sharp transition is suggested to be a result of erosion during a transgressive event. This is supported by the presence of a shoreline ravinement surface at the top of the middle 8.5 metre thick cycle. No obvious surfaces of sub-aerial exposure are noted in the section, perhaps removed by the shoreline ravinement surfaces if present initially. It is theorized that these three ~10 m cycles may represent the geologic record of glacial-eustatic variations driven by ~400,000 year Milankovitch orbital eccentricity cycles.

The smaller 2 to 4 m cycles present within the larger cycles are also characterized by a transition from relatively deeper to shallower water associated with a relative change in sea level. Essentially, these cycles appear to represent a smaller scale and higher frequency record of the same process of transgression-regression observed in the ~10 m cycles. The cycles are primarily characterized by alternating silty dolostone of shallow marine/lower shoreface origin and shoreface/foreshore dolomitic sandstone layers. It is speculated that these 2 to 4 m cycles may represent the geologic record of glacial-eustatic variations driven by ~100 000 year Milankovitch orbital eccentricity cycles. The lack of the deeper water shale lithofacies as observed in the ~10 m cycles could perhaps suggest that sea level change was more subdued in these higher frequency cycles.

Conclusions

Detailed sedimentologic analysis and outcrop mapping of the Fortress Ridge Section in Kananaskis Country, Alberta demonstrates the presence of a geologic record of arid climate Late Paleozoic cyclothems within the Tobermory and Kananaskis formations. Characterized by a transition from shallow offshore marine/lower shoreface silty carbonates to upper shoreface/foreshore siliciclastics, the cycles present within the rock record at this location seem to be driven by glacial-eustatic sea level variations. Ultimately, it is theorized that the driving mechanism of these sea level transgression-regression cycles is Milankovitch eccentricity orbital cycles. Better understanding the depositional controls on these arid-cyclothems will improve exploration models for correlative carbonates in east-central BC where they represent an important hydrocarbon reservoir.

(a)



(b)

Figure 1: Location map (a) Kananaskis Country in southern Alberta, denoted by the number 1. (b) Paleo-location of study area on western margin of Pangea, denoted by the number 1. Modified from: Golonka, J., et. al., 1994.

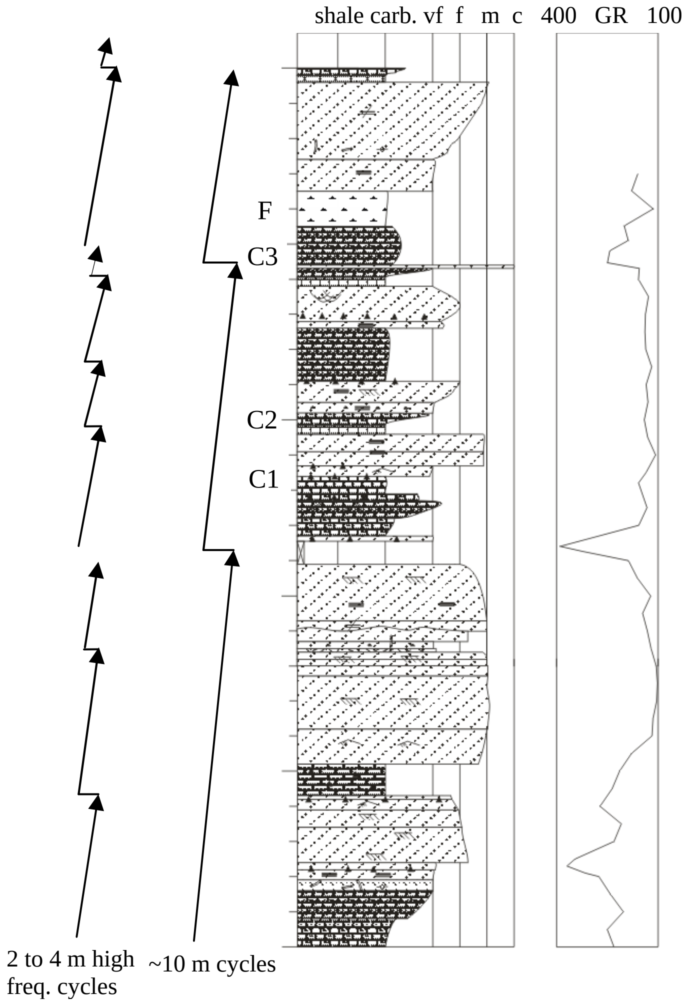
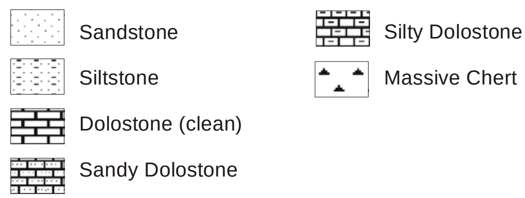


Figure 2: Stratigraphic Column with gamma ray log from Fortress Ridge Section, Kananaskis Country. Arrows indicate three ~10 m cycles along with higher frequency 2 to 4 m cycles. (vf, v, m, c refer to grain size). Conodont species of the genera *Neognathodus* and *Idiognathodus* from samples C1 and C2 indicate correlation with lowermost Moscovian (Verean substage) or Lower Atokan (USA). Conodonts from C3 and the fusulinacean (F) *Profusulinella fittsi* are consistent with the second substage of the Moscovian (Kashirian) or mid-Atokan (USA).

Legend



F – Fusulinacean

C – Conodont locality

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