Pennsylvanian–Early Permian Cyclic Shelf Sedimentation in the Sverdrup Basin at the Time of Contemporaneous Tectonism, SW Ellesmere Island, Arctic Canada (Nunavut)*

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Abstract

Around the world, Bashkirian (Pennsylvanian) to Sakmarian (Lower Permian) strata are arranged in a series of high-order unconformity-bounded transgressive-regressive (T-R) sequences, also known as cyclothems. Because cyclothems accumulated contemporaneous to widespread glacial advances and retreats in Gondwana, they are considered to be of glacio-eustatic origin. Indeed, evidence indicates these sequences were the result of high amplitude (50–100 m) relative sea level fluctuations at a periodicity ranging from 100,000 to 400,000 years. In stable cratonic areas, such as the Midcontinent USA or the Russian Platform, individual cyclothems have been correlated over hundreds to thousands of kilometres laterally providing a reliable temporal "strip-chart" of the sedimentary record. In contrast, areas of contemporaneous tectonic activity (compressional or extensional) display a much less reliable cyclothymic record. In such instances, individual cycles or groups of cycles can be missing, and cycle-to-cycle correlations, even over short distances, is difficult, if not impossible. The Western Canada Sedimentary Basin (WCSB) is one such area that was under the throes of active tectonism and where the Pennsylvanian–Early Permian record comes and goes over short distances, often from well to well. The Sverdrup Basin is another example of a tectonically influenced basin, but contrary to the WCSB, the Pennsylvanian-Lower Permian record is here very thick and superbly exposed. Deciphering the low-order tectonic influence from the high-order glacio-eustatic influence on sequence stratigraphic packaging was one goal of our study.

Our Study – Sverdrup Basin, Arctic Canada

The cyclothymic succession (Canyon Fiord, Belcher Channel and Nansen formations) is well developed in the Sverdrup Basin of the Canadian Arctic Archipelago (Figure 1) due to rapid subsidence, even though synsedimentary faulting and development of local highs and lows occurred in response to episodic tectonism. Here the thick cyclic succession has recorded repeated high-amplitude/high-order base level fluctuations, presumably in response to the waxing and waning of Gondwanan glaciers, against the backdrop of major tectonic events (rifting in the Early Pennsylvanian; transpression and transtension during the Early Permian). To help decipher high-order glacio-eustatic controls from low-order tectonic controls, we studied a thick succession (up to 2 kms) of Pennsylvanian-Early Permian mixed clastic and carbonate shelf cycles that accumulated along the eastern margin of the Sverdrup Basin (Figure 2). Seven stratigraphic sections were measured and sampled between

Blind Fiord and Trold Fiord thrusts on Raanes Peninsula, SW Ellesmere, and two additional sections were measured east of Trold Fiord Thrust. Samples were collected for microfacies analysis and for fusulinid biostratigraphy.

Fifteen microfacies assemblages were recognized, the interpretation of which range from nearshore sandstones to outer shelf carbonates, representing deposition in a complex mosaic of clastic- to carbonate-dominated environments. While individual cycles only display part of the complete depositional spectrum, two “ideal” cycles — proximal and distal — capture the most common recurring sedimentological pattern. Proximal cycles are bounded by subaerial unconformity or ravinement surfaces above and below. The transgressive systems tract (TST) is relatively thick (1-4 m) and comprises fine to medium-grained marginally marine sandstones that pass upward into increasingly marine fossil-rich mixed clastic-carbonates. The maximum flooding surface is generally marked by a rapid shift to carbonate-only lithologies that include fossiliferous packstones, bioclastic packstones and grainstones and oolitic grainstones forming a shallowing-upward, regressive systems tract (RST).

Evidence of subaerial exposure and meteoric diagenesis, including widespread dissolution of aragonitic grains and *Microcodium* crusts, occur in the upper part of the RSTs. Proximal cycles recorded sedimentation in an environment that ranged from high energy carbonate shoals to a complex mosaic of protected, and at times, salinity-restricted, lagoonal deposits and shoreface clastic-dominated deposits. Distal cycles range from unconformable (ravinement surface) to conformably (maximum regressive surface) bounded packages. Here the TST is generally thin (<0.5 m) and comprises fine-grained mixed clastic-carbonate lithologies. The MFS marks an apparent rapid shift to carbonate-dominated lithologies. The RST is thick (5-20 m) and comprises a shallowing-upward succession of bryozoan wackestone passing upward into fusulinid-rich wackestones and packstones. Laterally continuous phylloid algal and *Palaeoaplysina* banks occur locally in the upper of distal cycles. Distal cycles recorded sedimentation in an environment that ranged from deep outer shelf at the limit of the photic zone, to storm-swept open shelf, to broad reefal mud banks that accumulated below wave base. The upper part of distal cycles does not display evidence of subaerial exposure diagenesis.

Dozens of shelf cycles occur in the Pennsylvanian–Early Permian succession of SW Ellesmere Island (Figure 2). Lateral cycle-to-cycle correlations is impossible, in part, due to the poor exposure of some of our measured sections. More importantly, the area was under tectonic influence for a least part of its history. This includes an early episode of Bashkirian rifting, that is recorded in syn-rift red conglomerates and sandstones that represent half-graben sedimentation in an alluvial fan/ braided river setting (section 03 in Figure 2). Marine incursion followed in the latest Bashkirian-earliest Moscovian, which led to restricted marine carbonate and evaporite sedimentation (section 02 in Figure 2). Rifting stopped around the Early to Late Moscovian boundary, an event associated with basin-wide collapse and development of a low-order maximum flooding surface (sections 02, 03 and 09 in Figure 2). The Late Moscovian to Kasimovian comprises a thick cyclothymic succession that prograded basinward over large distances (RST) (sections 01, 03, 05, 08 and 09). Differential subsidence in response to renewed tectonism led to a major unconformity across the Kasimovian-Gzhelian boundary and to development of thick yet localized Gzhelian transgressive succession, in the northern part of the study area (sections 06 and 07). This may reflect reactivation of an older half-graben. Maximum flooding at the Asselian-Sakmarian boundary (*NB*.: This surface is considered mid-Asselian based on conodonts) was accompanied by cessation of differential subsidence. Progradation of a relatively thin Sakmarian (*ibid*.) succession of shelf cycles (low order RST) occurred at that time. Renewed uplift and differential subsidence is marked by a major sub-Sakmarian unconformity.

Conclusions

A thick succession of Pennsylvanian–Early Permian shelf cycles occur in the Sverdrup Basin, attesting for a complex depositional mosaic that ranged from nearshore sandstone to offshore carbonates. However, episodic tectonics operating of a 10-Ma time scale overprinted the glacio-eustatic 100–400 Ka record so that is it virtually impossible to correlate individual cycles from section to section, let alone over large areas as successfully done in stable cratonic areas.

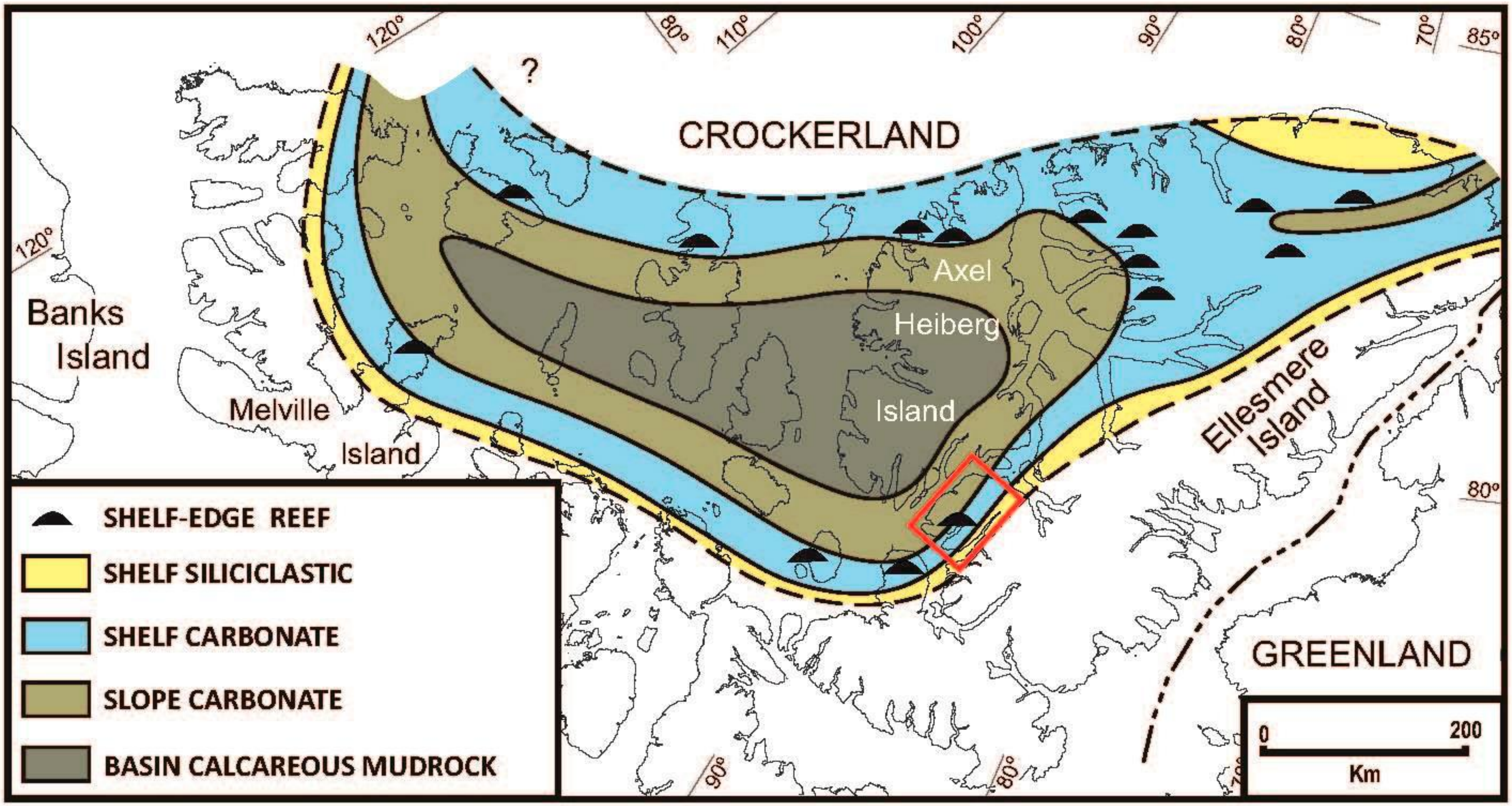

Figure 1. Pennsylvanian paleogeography of Sverdrup Basin, Arctic Canada. Study area indicated by red rectangle.

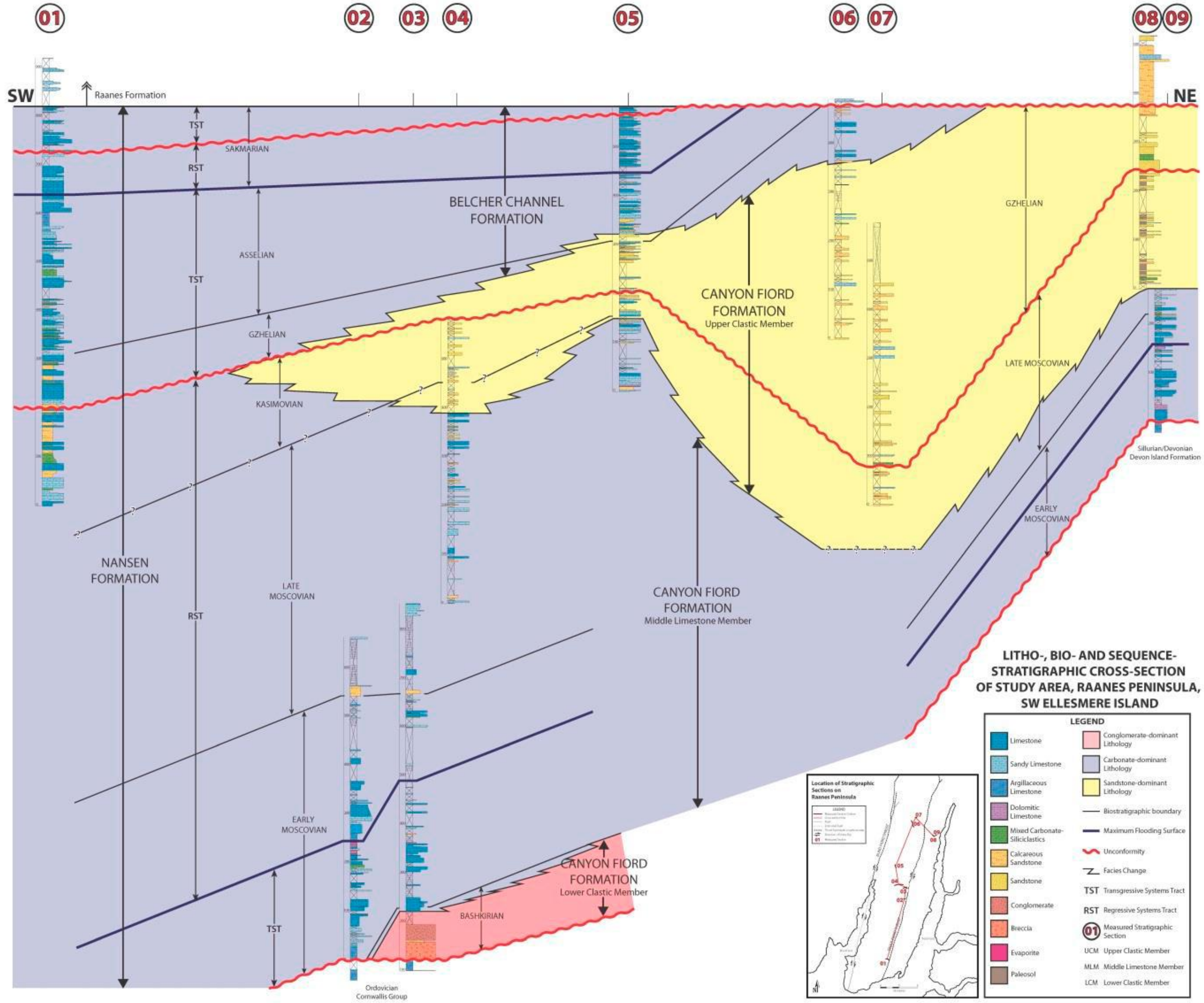

Figure 2. Pennsylvanian–Early Permian litho-, bio- and sequence-stratigraphic cross-section, SW Ellesmere Island, Arctic Canada.