Facies Analysis, Sequence Stratigraphy, Diagenesis and Reservoir Potential of Pennsylvanian-Permian Sandstone-Grainstone Cycles, Sverdrup Basin, Arctic Canada: a Preliminary Assessment

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Summary

Along the southern margin of the Sverdrup Basin in Arctic Canada, Upper Carboniferous to Lower Permian near shore to shallow sub tidal sandstones interfinger with inner shelf carbonates and are arranged in a series of decametre high-order sequences. Also referred to as cycles or cyclothems, these sequences resulted from global glacio-eustatic fluctuations. Basin-fringing sandstones and grainstones associated most likely with cyclothems hold interest in both academia and industry, as a result of their unique depositional relationship and reservoir potential. As seen in the mid-continent of the United States, these sequences can yield good reservoirs as a result of porous units pinching out in between impermeable seals brought on by each transgressive cycle (Heckel, 2002). Porosity development is often attributed to meteoric diagenesis and subaerial exposure of carbonates and sandstones associated with recurring drops in sea level. Furthermore, excellent seals are produced by the recurring transgressions that deposit impermeable shales and mudrocks onto underlying grainstones and sandstones.

Previous studies conducted by Beauchamp (1987) and Morin et al. (1994) have examined Late Carboniferous to Early Permian glacio-eustatic cycles of the Sverdrup Basin, however research has focused on the more distal mid-shelf to outer shelf occurrences. Aside from preliminary observations, the complex interfingering of basin-fringing sandstones and inner shelf, high energy grainstones has been not been examined in any detail. To date, many questions remain unanswered regarding the origin, stratigraphic significance and reservoir potential of grainstone-sandstone dominated cycles along the southern margin of the Sverdrup Basin. This is why a detailed assessment of these unique cycles along the southern margin of the Sverdrup Basin is being conducted on Raanes Peninsula, SW Ellesmere Island (Fig. 1).

This study examines the sandstone-to-grainstone lateral and vertical transition in the Blind Fiord and Trold Fiord area of southwestern Ellesmere Island, where the Carboniferous and Permian succession is well exposed and easily accessible. This area had been the focus of several biostratigraphic studies (e.g. Henderson et al., 1995) that feature conodonts, fusulinids and foraminifera, therefore the Late Carboniferous and Lower Permian chronostratigraphic framework is very well established.

Methods and Data

Samples for this preliminary study were collected by Benoit Beauchamp during the 1989 field season. Additional detailed information will be acquired in the field, during the summer of 2010. Three stratigraphic sections, over a 225 km^2 area, were measured using a Jacob's staff to document the cyclicity within the rock succession in a preliminary fashion. Stratigraphic sections range from 300 to 500 metres thick and are each comprised of dozens of sandstone-grainstone cycles, individually ranging from 5 to 20 metres in thickness. These rocks belong to the Canyon Fiord and Belcher Channel formations. In the field observations were made on trace fossil assemblages, sedimentary structures, erosional surfaces, unconformities, etc. In the laboratory, thin-sections were examined for petrography, micro-fossils, micro-facies and

diagenesis. Thin-sections analysis were also used to determine porosity values within the sandstones and were also particularly useful in the examination of the inter-particular cementation, which will aid in the assessment of the extent and timing of porosity-occluding processes. Some of the key findings of our preliminary study are:

Environmental spectrum

Most carbonates in our study are represented by photozoan grainstones with a rich assemblage dominated by calcareous algae (dasycladaceans, phylloids, beresellids, stacheins, *Tubiphytes*, etc.), and several groups of small and large (fusulinids) foraminifers. Variably large colonial rugose corals locally occur. Some grainstones are oolitic. Fossils are usually abraded and well-rounded. Cross-laminations are observed locally. The carbonates represent deposition in a high energy, normal salinity, shallow inner shelf to nearshore subtidal setting.

Clastic sediments are dominated by medium- to coarse-grained quartzose sandstones. Bedding ranges from massive to cross-stratified with tabular, trough, herringbone cross-sets variably developed. Trace fossils include *Arenicolites*, *Skolitos*, and vertically developed *Zoophycos* (*Spirophyton*). Fossil debris range from rare to common and even abundant where sandstones interfinger with grainstones. The depositional spectrum of the sandstones range from shallow subtidal to intertidal (beach and tidal inlets) in a high energy, low tidal range coastal setting. The absence of non-marine fluvial sandstones in the area suggests that the entry point of clastic sediments in the basin was not in immediate vicinity of the measured sections. The sand was most likely derived from rivers located tens of kilometres to the north on Fosheim Peninsula. It was transported southward along the margin of the Sverdrup Basin (Fig. 1) through longshore currents in a fashion reminiscent of the modern southern coastal area of Belize (Cowan and McNeil, 2002).

Sequence stratigraphic significance

The interfingering of sandstones and grainstone takes place in either one of two distinct sequence stratigraphic settings: a transgressive setting and a regressive setting. In the transgressive setting, sandstones occur immediately above sharp erosional surface interpreted as high-order sequence boundary. Sandstones deepen upward from nearshore deposits to progressively more distal subtidal deposits. They sometimes interfinger vertically with open marine grainstones, which represent maximum flooding. In the regressive setting, packstones and grainstone immediately above maximum flooding surfaces pass upward into increasingly shallow and high energy grainstones that progressively interfinger with mixed clastic-carbonates and eventually sandstones. The latter are often sharply truncated by a regional erosional surface interpreted as high order sequence boundaries.

Diagenesis and reservoir potential

Evidence of episodic subaerial exposure includes the presence of red terra rosa soil-derived material on top of the unconformities, *Microcodium* and other caliche features in the underlying carbonates and sandstones, preferential dissolution of aragonite and high Mg-calcite bioclasts, occasional vadose silts and common equant-spar cement of meteoric origin, as shown by its ^{13}C-depleted isotopic composition. Some sandstones and mixed clastic-carbonates are quite porous with interparticular porosity incompletely occluded by various cements phases. More research will help us determine whether meteoric diagenetic played a role in the generation and preservation of this porosity. Regardless, these porous basin fringing facies have a genuine potential and could constitute interesting targets for stratigraphic traps when, and if, oil and gas exploration resume in the Sverdrup Basin.

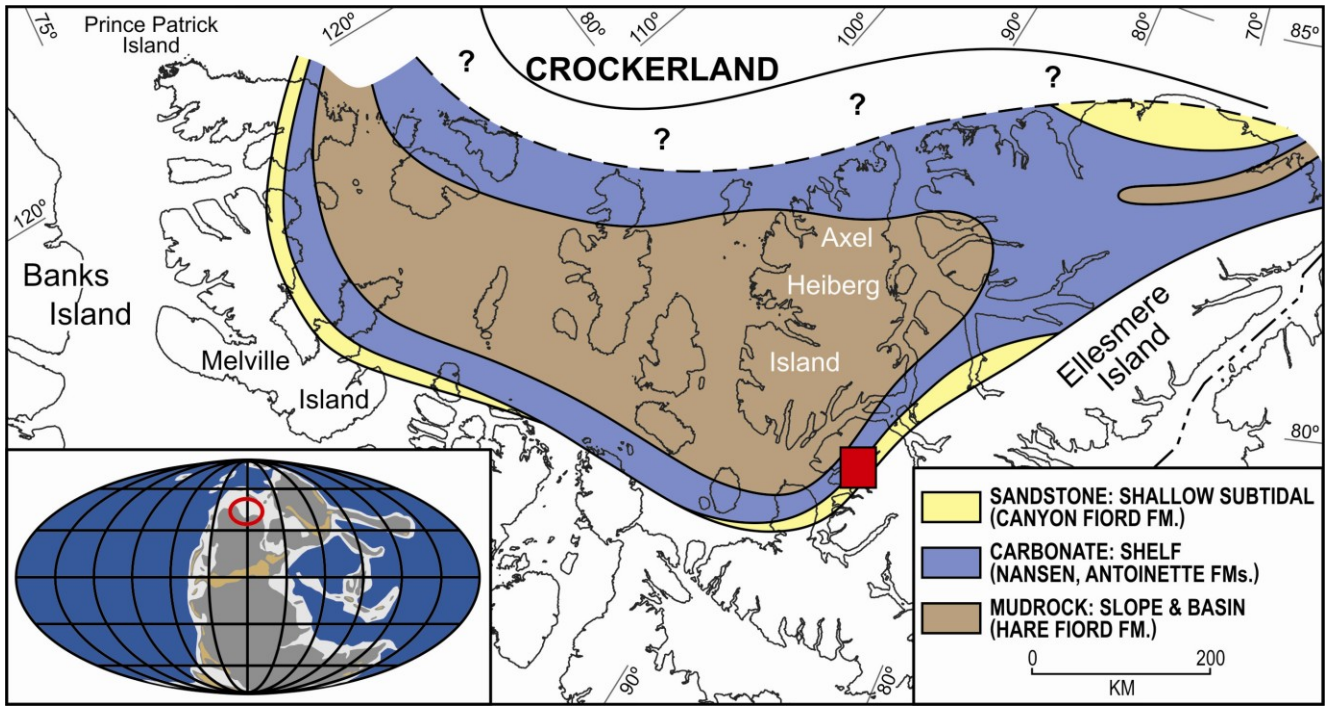

Figure 1: Study area (red square) between Blind Fiord and Trold Fiord, SW Ellesmere Island, Canadian Arctic. Insert shows location of Sverdrup Basin along NW margin of Pangaea.

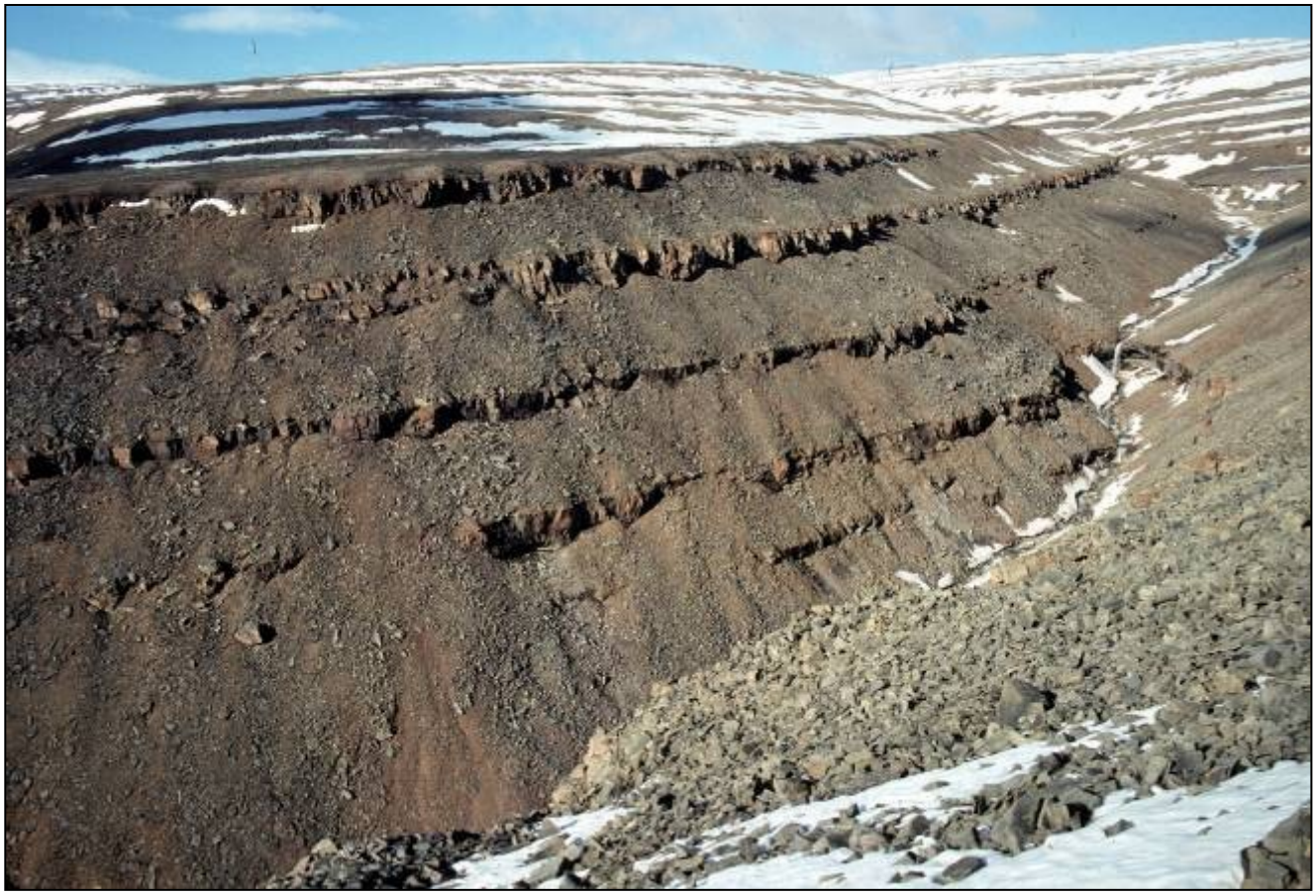

Figure 2: Sandstone-dominated red-weathering cycles, Lower Permian Canyon Fiord Formation, west Trold Fiord, southwest Ellesmere Island.

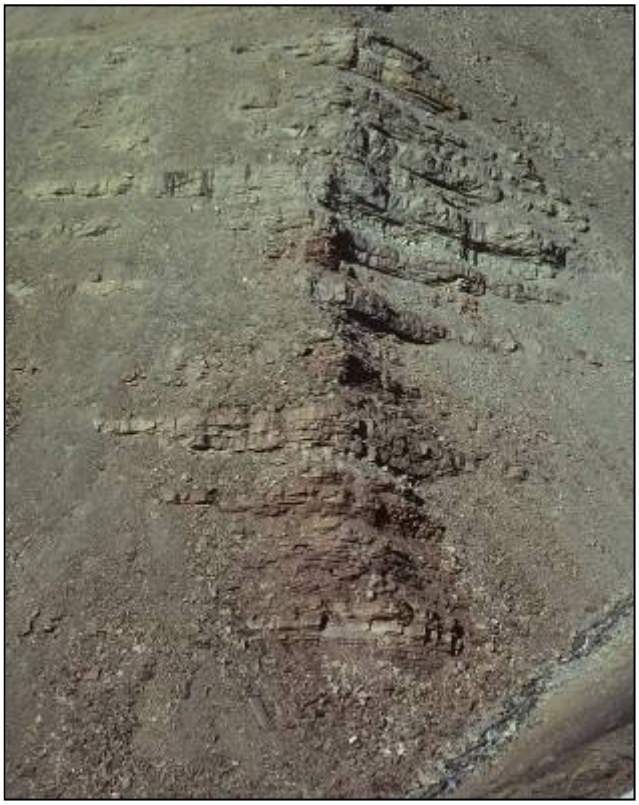

Figure 3 (left): Red sandstones of Canyon Fiord Formation passing vertically into grey carbonated-dominated shelf cycles of Belcher Channel Formation, east Blind Fiord, southwest Ellesmere Island

Figure 4 (above): Cross-bedded red sandstones from middle section of Canyon Fiord Formation shown in Fig. 3

Conclusions

Our preliminary analysis of sandstone-carbonate interstratifications on the southwestern margin of Ellesmere Island has revealed complex sequences stratigraphic, depositional and diagenetic relationships that are indicative of a very active system driven by high order sea level fluctuations likely driven by glacial pulses. Field work in 2010 will allow us to improve our sedimentological interpretations and stratigraphic model, as well as assess the hydrocarbon play potential of this succession.

References

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