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New Insights into Early Permian Paleogeography of the Fosheim-Hamilton Sub-Basin, Ellesmere Island, Nunavut

Michael L. Wamsteeker*
Department of Geoscience, University of Calgary, Canada
mlwamste@ucalgary.ca,

Benoit Beauchamp
Arctic Institute of North America, University of Calgary
and
Charles M. Henderson
Department of Geoscience, University of Calgary, Canada

Summary

Sections measured on the north western margin of the Fosheim-Hamilton sub-basin, Ellesmere Island, have provided novel outcrop evidence for the existence and function of the Elmerson High, a Permian paleo high which was previously proposed to restrict the sub-basin and facilitate evaporite deposition. Firstly, evaporitic sediments onlapping the south east flank of Bart reef suggest it became a portion of the Elmerson High during the during lowstand sea levels which restricted the sub-basin. Presence of barrier-bar or beach deposits within the middle Asselian Tanquary Formation at the Mysterious Evaporite section again suggests proximity to an actively eroding high, probably another portion of the Elmerson high. Lastly, evaporite beds discovered in the Raanes Formation at the Mysterious Evaporite section are the youngest yet found in the Sverdrup Basin. Their presence suggests arid climate and restricted marine conditions persisted in portions of the Fosheim-Hamilton sub-basin into the latest Asselian and possibly earliest Sakmarian.

Introduction

The Fosheim-Hamilton sub-basin (Figure 1) is located in the northwestern corner of the Sverdrup Basin- a peri-cratonic rift basin containing shelf to basin carbonate and siliciclastic sediments of Mississippian to Eocene age (Balkwill, 1978). Tropical chloroforam carbonate sedimentation commenced on the basin flanks during Early Pennsylvanian (Bashkirian) time, resulting in the development of large, shallow carbonate shelves (Beauchamp and Desrochers, 1997). While normal marine carbonate sedimentation continued in the main Sverdrup, subaqueous evaporite deposition (Mt. Bailey Formation) occurred from the Late Pennsylvanian (Gzhelian) to Early Permian (Middle Asselian) within the Fosheim-Hamilton sub-basin (Beauchamp and Olchowy, 2003).

Dimensionally, the Fosheim-Hamilton sub-basin is roughly 250 km long and 75 km wide, with the depositional axis trending NNE/SSW (Figure 1). Restricting paleotopography of the Foshiem-Hamilton sub-

basin is primarily understood at regional structural and stratigraphic level. Structurally, rare observations of normal faulting within the Mt. Bailey Formation, combined with rift-like, conglomeratic sedimentation within the Canyon Fiord Formation suggest sub-basin subsidence and reciprocal sedimentation were controlled by a half-graben rift structure (Morin et al., 1991) (Beauchamp et al., 1991). Paleotopographically, four main elements facilitated creation of restricted conditions. The south and eastern margins are bordered by the Bay Fiord High (Beauchamp, 1987) and Sverdrup Basin edge respectively. The Tanquary High, which was emergent during the Pennsylvanian and Permian (Maurel, 1989) has been proposed as the northern restricting element (Scott, 1991). Perhaps the most enigmatic and poorly defined of the highs- The Elmerson High- has been proposed as the north western restricting element (Beauchamp et al., 1991) (Beauchamp and Olchowy, 2003). Before this study, its existance had yet to be conclusively proven, but had been argued for a variety of reasons. Firstly, to create restricted circulation conditions required for evaporite deposition, a barrier would need to be present on the north western margin of the sub-basin to separate it from contemporaneous open marine conditions of the main Sverdrup Basin (Morin and Beauchamp, 1991). Secondly, regional cross-sections demonstrate formations of Pennsylvanian to Triassic age within the sub-basin thin or disappear over proposed area of the Elmerson High (Morin et al., 1991) Late stages of evaporite deposition in the Fosheim-Hamilton sub-basin were punctuated with significant periods of marine carbonate deposition. During this period, the Tolkein and Simpson reef tracts grew on the north western margin of the sub-basin (Beauchamp and Olchowy, 2003) (Wamsteeker et al., 2008). However, periods of evaporitic restriction and sub-aerial exposure resulted in periodic suspension of growth in both. Both tracts were then covered by middle to shallow shelf carbonates of the Middle to Late Asselian Tanquary Formation. The Raanes Formation overlies this succession, comprising mixed siliciclastic-carbonate rocks of transgessive, mid to shallow shelf origin (Beauchamp and Henderson, 1994). Peripheral facies of the Raanes Formation, encompassing microbial-laminated dolomudstones, on the southern edge of the Fosheim-Hamilton sub-basin have been interpreted as lacustrine deposits (Scott, 1991)

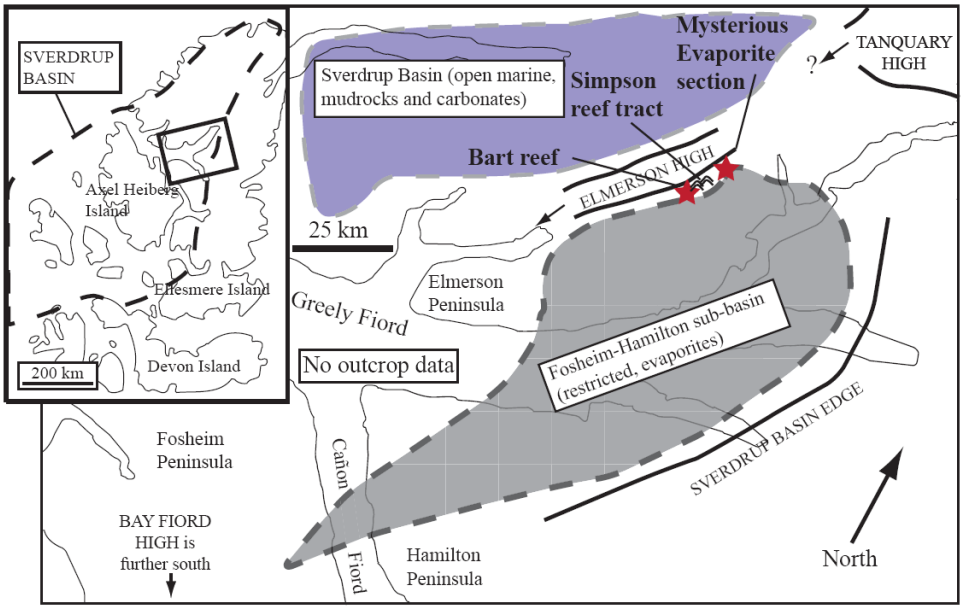

Figure 1: Simplified Early Permian (mid-Asselian) paleogeography of the Hamilton-Fosheim sub-basin, as roughly defined by the extent of the Mount Bailey Formation. Regional paleotopographic elements including the Elmerson and Tanquary highs are included.

Methods

Seven sections, including the Bart reef and Mysterious Evaporite sections, were measured along the north-western periphery of the Fosheim-Hamilton sub-basin during June and July of 2007. Nansen, Tanquary and Raanes formations were measured and described for lithology, sedimentary structures and fossils. Systematic sampling was carried out for conodont microfossil and thin-section analysis. Sedimentologic, biostratigraphic and sequence stratigraphic analysis of these sections enabled a regional correlation and paleogeographic reconstruction of the northwestern margin of the Hamilton-Fosheim sub-basin from the Middle Asselian to Early Sakmarian stages.

Results

Stratigraphic and sedimentological analysis suggests Bart reef participated in restricting the Fosheim-Hamilton sub-basin during the final stages of evaporitic sedimentation, probably forming a portion of the Elmerson high during the middle Asselian. Shallow, evaporitic facies comprising bottom nucleating gypsum pseudomorphs, thrombolites and stromatolites onlap only the southeastern flanks of Bart reef (Figure 2). These facies may constitute the northwestern most evaporitic sedimentation confined to the Fosheim-Hamilton sub-basin. Stratigraphic geometry and facies analysis implies Bart was subaerially exposed during evaporitic sedimentation, suggesting it may have promoted evaporitic conditions within the sub-basin during sea-level lowstands. As in many outcrop studies, the three dimensional size of Bart reef is unknown. However, small scale (~100m height) and reef type (reef-mound or pinnacle) implies it probably did not isolate the sub-basin alone. It is possible that other reefs of the Simpson reef tract may have also participated in restriction, however, this hypothesis would have to be tested through further field work on other Simpson reefs.

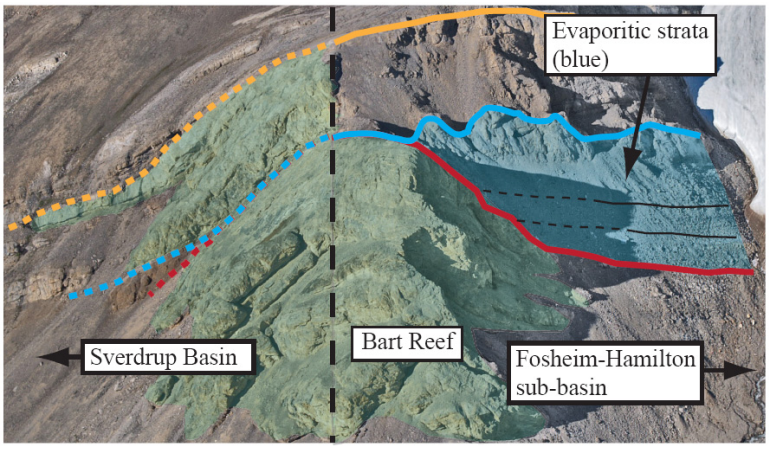

Figure 2: Onlap of restricted, evaporitic sediments onto the flank of Bart reef most proximal to the Fosheim-Hamilton sub-basin. Bart reef is ~100 metres in height. Dashed lines indicate surfaces interpreted through air photo analysis.

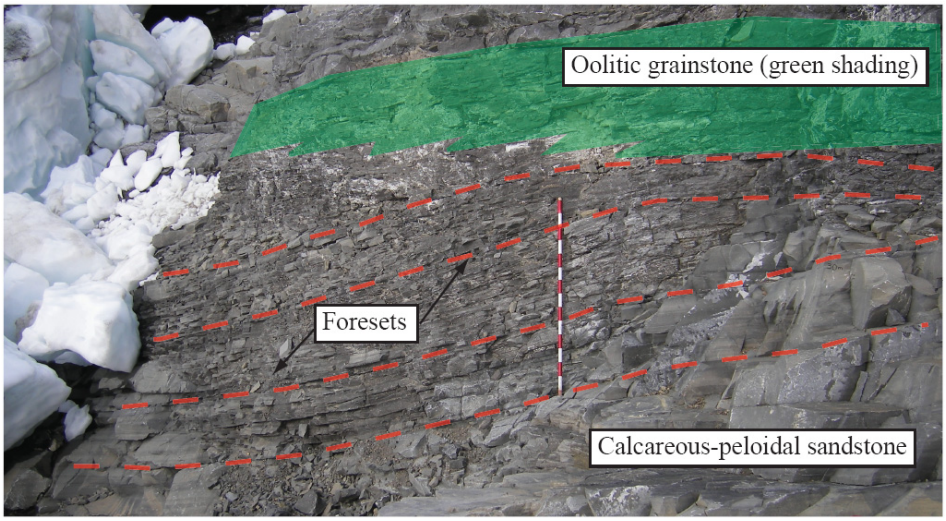

Figure 3: Metre scale, prograding foresets of fine grained, calcareous-peloidal sandstone at within the lower Tanquary Formation at the Mysterious Evaporite section. Foresets are overlain by finely bedded oolitic grainstone. Pogo stick is 1.5 metres in length.

At the Mysterious Evaporite section, lowest portions of the middle Asselian Tanquary Formation contain a 21 metre thick body of finely bedded to laminated, peloidal quartzose sandstone (Figure 3). Framework grains are composed of well sorted, very fine to fine grained, rounded to sub-angular quartz. Undulating bedding surfaces with cross lamination are common. The top of the sandstone body includes ~ 5 metre high prograding, sigmoidal foresets capped by oolitic grainstone with symmetrical ripples and centimetre scale cross lamination. Combined evidence suggests this sandstone body formed a prograding bank (Davies, 1970) or beach (Inden and Moore, 1983) suggesting proximity to an eroding land mass- probably the Elmerson high (Figure 1). Prograding beach foresets further suggest a portion of the Elmerson high comprised an exposed and eroding landmass, providing a siliciclastic source.

Lastly, the Raanes Formation at the Mysterious Evaporite section contains open marine, shelf sediments capped by restricted, evaporitic facies containing thickly bedded evaporites. Conodonts recovered from the basal 5 metres are dominated by specimens of the *Streptognathodus fusus-postfusus* plexus, indicating a late Asselian age (Chernikh and Reshetkova, 1987). The occurance of small foraminifers

Nodosellinoides sp. and *Hedraites* sp. (Pinard and Mamet, 1998), which are typical of the Raanes Formation, have previously been correlated with the Sakmarian stage. Reconciliation of the conodont and foraminifer ages suggests the overlying evaporite is latest Asselian or- possibly earliest Sakmarian. To the author's knowledge, this constitutes the youngest evaporite deposit in the Sverdrup Basin.

Conclusions

Sedimentologic and stratigraphic evidence at Bart reef and the Mysterious Evaporite section provides tangible outcrop evidence for the existence of the Elmerson High, whose existence was previously hypothesized though regional geological analysis. Stratigraphic relationships suggest lowstand sea levels caused exposure of the Elmerson high, which restricted the Fosheim-Hamilton sub-basin, causing the deposition of evaporites. Presence of evaporites within the Raanes Formation suggest arid climate and restricted marine conditions persisted in portions of the Fosheim-Hamilton sub-basin into the latest Asselian and possibly earliest Sakmarian.

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