Evolution of the Sverdrup Basin: New Insights from Field Studies, Integrated Biostratigraphy & Sediment Provenance Analyses

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Summary

The Late Paleozoic-Mesozoic strata of the Sverdrup Basin and the overlying Cenozoic deposits have been examined during three field seasons on Ellesmere and Axel Heiberg islands, Canadian Arctic. These field studies are supported by an ongoing analytical programme involving integrated biostratigraphic analysis and a variety of sediment provenance analyses. The results from this integrated study will help to constrain not only the tectonic evolution of the Sverdrup Basin and its Cenozoic exhumation, but will also define the character of the sediment sources which were eroded to generate its fill. Here, we present some preliminary data and interpretations.

Study area & techniques

The CASP field areas are located on the north (Bukken Fiord, Axel Heiberg Island), southeast (Slidre Fiord, Ellesmere Island) and northeast (Lake Hazen, Ellesmere Island) sides of the Sverdrup Basin (Fig. 1). The distribution of field sites allows the comparison of sedimentary succession and their provenance around the margins of the basin, trying to identify sediment input points, source areas and ultimately to test for the presence of northerly-derived material (Crockerland as proposed by Embry, 1991; 2009).

CASP fieldwork involves multi-disciplinary teams measuring sections, sampling, and the collecting a wide variety of data (e.g. palaeocurrent, depositional environment and structural data). This information is stored in GIS databases to enable easy searching and comparison of adjacent datasets. Field data are supported by a comprehensive analytical programme.

Integrated biostratigraphic schemes (macropaleontology, micropaleontology and palynology) have been established for each field area. This process combines new biotic identifications with the extensive published literature on the Canadian Arctic to provide an age framework in which to place all of our other data. In addition to providing a depositional age, we also identify sedimentary reworking within the fossil record, in particular using the palynomorph assemblages.

Sandstone provenance tools utilized in this study include petrography (descriptions, point counting), heavy mineral analysis, single mineral geochemistry of separated heavy minerals (including rutile, garnet, tourmaline and apatite), and U-Pb dating of zircon. Sediment provenance analysis does have limitations, e.g. the signature of the sediment source region can be characterized but it is not always possible to determine the age or exact location of the sediment source rock, or to determine whether the sediment is recycled.

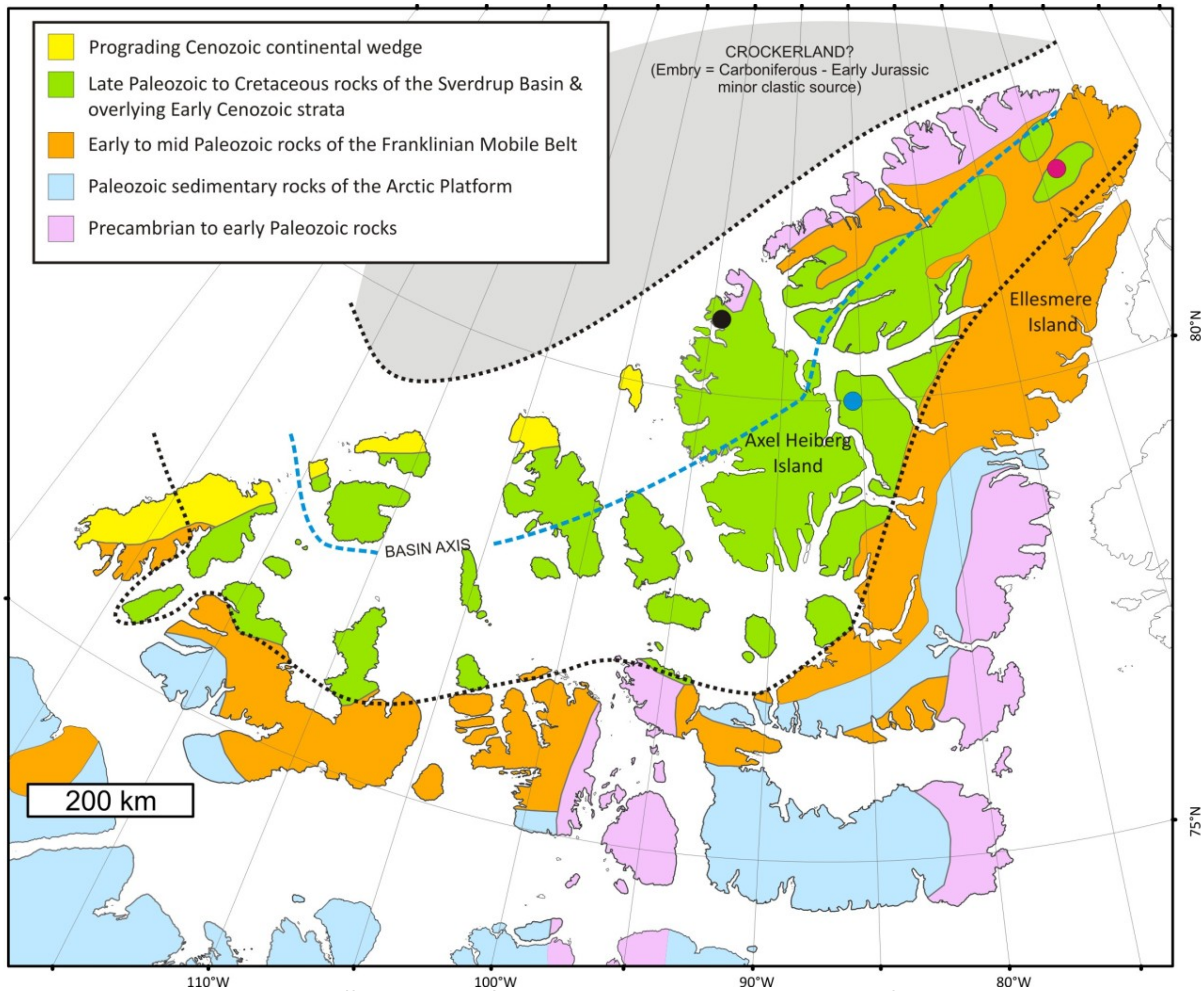

Figure 1: Tectonostratigraphic affinities in the Canadian Arctic Archipelago (adapted from Arne *et al.,* 2002), showing the extent of the Sverdrup Basin, basin axis and the proposed Triassic-Jurassic position of Crockerland (Embry, 2009). Locations of CASP fieldwork are marked by dots: Bukken Fiord, Axel Heiberg Island (black), Slidre Fiord, Ellesmere Island (blue) and Lake Hazen (pink).

Initial results & interpretation from Slidre Fiord, Ellesmere Island

The field area that currently has the most complete dataset is Slidre Fiord on the southeastern margin of the Sverdrup Basin (Fig. 1). The following key observations can be drawn:

- Sandstones of Triassic (Norian and older) and mid Jurassic age have common provenance signature. These sandstones are sublitharenites and subarkoses, with heavy mineral populations characterised by abundant apatite, and contain abundant Permo-Triassic detrital zircons (shown in Fig. 2).
- During Norian-?Pleinsbachian times (Fosheim Member, Heiberg Formation) a pulse of sandstone with a different signature is recorded. These sandstones are mature quartz arenites to subarenites, with heavy mineral populations that are characterised by a lack of apatite and detrital zircon signatures lacking Permo-Triassic detrital zircons (shown in Fig. 2).

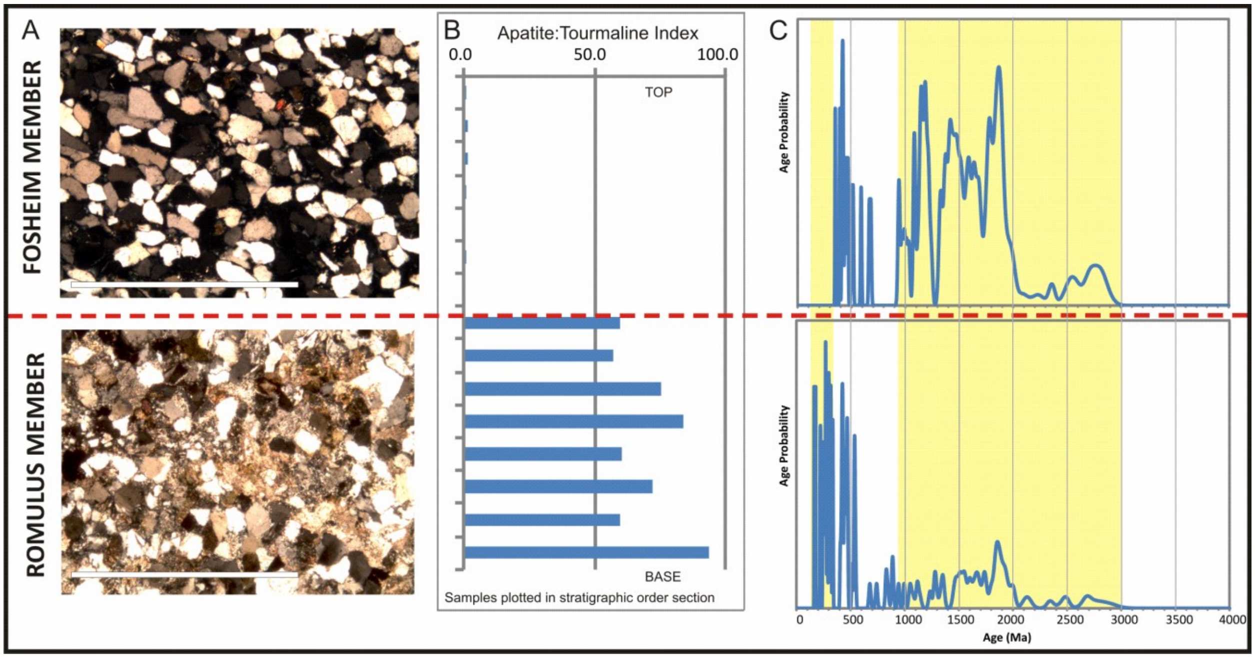

Figure 2: Variation of sandstone provenance signature between the Romulus and Fosheim members of the Heiberg Formation, at Slidre Fiord. **A.** Photomicrographs (bar = 1 mm), Fosheim Member sandstones are more compositionally mature (quartz-rich) than those of the underlying Romulus Member. **B.** Plot showing variation in the Apatite:Tourmaline Index upsection, note the significant change at the boundary between the members. **C.** U-Pb zircon age probability plots. Romulus Member contains abundant Permo-Triassic grains but the overlying Fosheim Member does not.

- During the Jurassic, there was a transition from low-grade to high-grade metamorphic sedimentary sources (based on rutile geochemistry Fig. 3). This may either reflect the introduction of a different source terrane or an unroofing history.

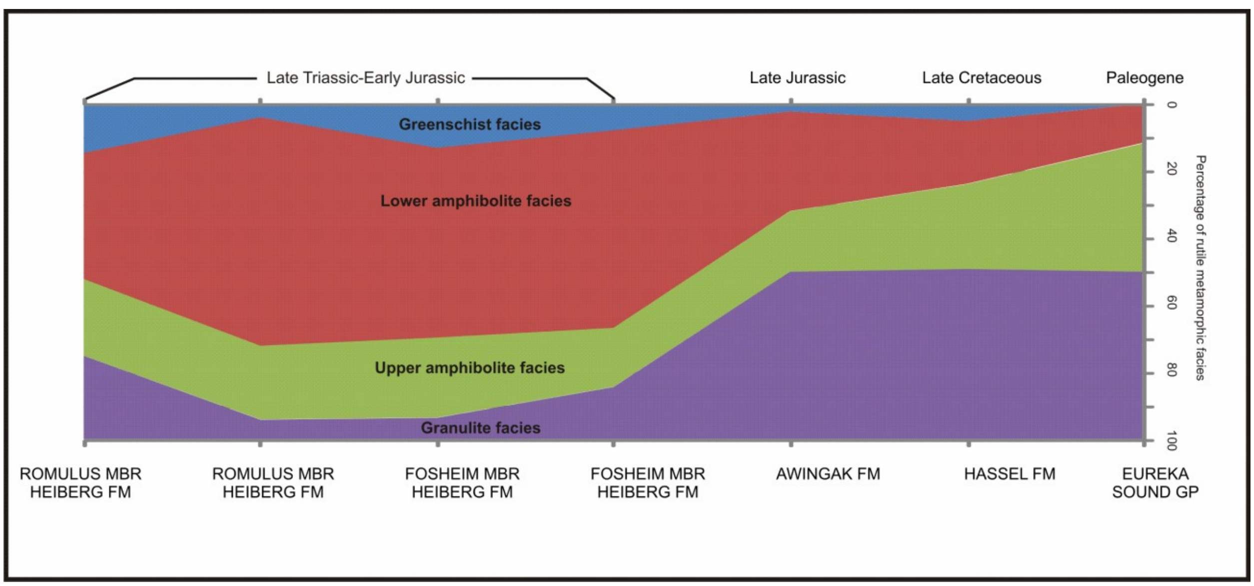

Figure 3: Upsection (left to right) variation in formation temperatures detrital rutile within the section at Slidre Fiord. Low-grade metamorphic rutiles are common in the lower part of the succession whereas higher grade rutile dominates the upper part.

- Early Cretaceous sandstones have a different provenance signature compared with the underlying Mesozoic strata (detrital zircon age profile dominated by Proterozoic-Archean grains), suggesting that these sandstones are (a) not reworked from the underlying strata and (b) have a different or possibly deeper source terrane.

- The Late Cretaceous-Early Cenozoic strata have a provenance area which includes fresh acidic volcanic and kyanite-bearing metamorphic terranes. These have not been observed in the underlying Sverdrup succession (which could be due to loss during diagenesis but further analyses are required).
- Reworked palynomorphs are a common feature of many of the mudstones. Devonian palynomorphs are prevalent in samples older than Early Cretaceous (including and below the Isachsen Formation). In mid Cretaceous and younger samples, reworked Devonian palynomorphs are not recorded. Mesozoic palynomorphs are also found reworked throughout the section. These data are revealing a complex history of sedimentary recycling and redeposition within the Sverdrup Basin. The age of the Mesozoic reworking becomes younger upsection. Palynology has allowed examination of sedimentary recycling in mudstones and fine-grained sediments where standard sandstone provenance tools cannot be utilized.

Comparing the provenance signatures on the margins of the basin

Based on existing current reconstructions for the Sverdrup Basin (such as Embry, 1991; 2009) we would predict that sediments on the north and south side of the Sverdrup Basin may have different provenance signatures. With this in mind we compared data collected from the Slidre Fiord region (southeast Sverdrup) with that from Bukken Fiord (northern Sverdrup). Surprisingly, similar sediment provenance trends are identified on both sides of the basin. In the Bukken Fiord area (Omma *et al*., in press):

- Sandstones of Triassic (Norian and older) and mid Jurassic age are characterised by abundant apatite and Permo-Triassic detrital zircons.
- Within the Heiberg Formation there is a pulse of mature sandstone with few apatite grains and no Permo-Triassic detrital zircons.

Implications & future work

The apparently common provenance signatures on both sides of the Sverdrup Basin suggest that much more work is required to understand sediment transport pathways. As this study is part of CASP'S ongoing work in the Canadian Arctic the interpretations presented here are preliminary and additional fieldwork, sample analysis, data processing and interpretation are all required.

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