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Invited review

The Cretaceous Polar and Western Interior seas: paleoenvironmental history and paleoceanographic linkages

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ABSTRACT

This study reviews the Cretaceous histories of the Polar and Western Interior seas as recorded in the Canadian High Arctic Sverdrup Basin, Beaufort-Mackenzie Basin of northwest Canada and Western Canadian Foreland Basin. Newly emerging stratigraphic, paleoclimatic and paleoenvironmental interpretations from the polar realm allow for a fresh look at the response of this oceanic system to global climatic trends and sea-level histories over 35 Ma. Sverdrup basin localities on Axel Heiberg and Ellef Ringnes islands represent shelf to slope environments that contrasted with the shallow water and low gradient settings of the Canadian Western Interior Sea. Both marine systems, connected throughout Aptian to Maastrichtian time, responded to global transgressive–regressive cycles resulting in dynamic paleogeographic changes. The upper Aptian to Campanian succession of the Polar Sea shows at least two unconformable boundaries; one at the Albian/Cenomanian transition and another within the upper Cenomanian. The shallow basin setting and in particular the forebulge and backbulge settings of the Western Canadian Foreland Basin are characterized by multiple erosional surfaces throughout the Cretaceous succession. The Upper Albian disconformity is widely discernible close to the entrance of the Western Interior Sea to the Polar Sea. This suggests a short-lived closure of the latest Albian Mowry Sea that might have been responsible for the large loss of benthic foraminiferal species at this time. Several oceanic anoxic events are documented in these basins representing their response to global climate dynamics. During the Late Cretaceous temperature maximum benthic foraminiferal communities were severely restricted by bottom water hypoxia in both basins. A stratified water column might have been the result of increased freshwater runoff under warm, humid conditions. These conditions supported vegetation up into the polar latitudes that added abundant organic matter to marine shelf systems. Conversely, the Canadian Western Interior Sea biotic communities were controlled by watermasses of two or maybe three different sources and physical properties including the Polar, Tethyan and a possibly third source from the emerging Labrador Sea through the Hudson Seaway. Where the southern and northern watermasses mixed, plankton might have been influenced by oceanic fronts, forming mass kills through sinking of dense waters. Migration of calcareous phyto- and zooplankton was controlled by a temperature and salinity gradient and did not invade northern regions. Siliceous plankton occurred and is more commonly found in the Sverdrup Basin, but taphonomic loss through deep burial needs to be taken into account.

1. Introduction

The Cretaceous is frequently regarded as an ancient analogue for a warming future earth (e.g., Hay, 2011) and has received a large body of work including a rich data set addressing the Western Interior Sea of North America (compilations as in Caldwell, 1975; Ricketts, 1989; Nations and Eaton, 1991; Leckie and Smith, 1992; Caldwell and Kauffman, 1993; Shurr et al., 1994; Dean and Arthur, 1998). Due to large hydrocarbon reserves in the Western Canada Basin, outcrop data is supplemented by abundant subsurface wells. In contrast, the Canadian Polar region has been studied far less frequently due to its remoteness; however, the recent Canadian GEM (Geomapping for Energy and Minerals) Project has given us a fresh look at the Cretaceous history of the Sverdrup Basin as exposed in outcrop on the Queen Elizabeth Islands (Nunavut).

The North American Foreland Basin and associated Cretaceous Western Interior Sea with a vast expanse over 45° latitudes at peak transgression times have no modern analogues. It had a length of 6000 km from the Gulf of Mexico to the Arctic Ocean with a width of more than 1600 km at maximum extent (Leckie and Smith, 1992; Hay et al., 1993). Its complex marine ecosystem responded to paleoenvironmental changes that were caused by overriding factors such as the Cretaceous greenhouse climate and its drivers, by its existence as a variably restricted epeiric sea with changing connections to bordering oceans (e.g., Jeletzky, 1971; Williams and Stelck, 1975; Ziegler and Rowley, 1996) and a unique watermass distribution pattern (e.g., Hay et al., 1993; Fisher et al., 1994). The Western Interior Sea was connected to the Arctic Polar Sea during most of its existence allowing for paleoceanographic and faunal exchange. The Arctic Polar Sea is often

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referred to as the Boreal Sea; however, the Canadian Arctic was of temperate climate during the Cretaceous (e.g., Chumakov et al., 1995) and therefore the term Boreal Sea is not used here. To date, scientific drilling in the Arctic Ocean (IODP Expedition 302) has produced cores that penetrate strata only as old as Campanian (e.g., Jenkyns et al., 2004; Setoyama et al., 2011). Thus, the Sverdrup Basin and its successions are valuable targets for understanding Cretaceous polar climate dynamics and ecosystems and their controls. The Polar Ocean with its paleoceanographic linkages imposed a dominant control on Cretaceous biota within the Canadian Western Interior Sea. Connections to the southern Tethyan Ocean were only intermittent during the early Cretaceous, but became more established during the late Cretaceous (Jeletzky, 1971; Williams and Stelck, 1975). Existing and newly emerging work on the Cretaceous history of the Sverdrup Basin allow researchers to revisit stratigraphic correlations, and evidence of paleoceanographic connections and faunal exchange between the Sverdrup and Western Canadian Foreland basins. Hence, this paper has the following objectives: a) Review the evidence for established marine connections between the Sverdrup Basin, Mackenzie Corridor, Eagle Plain, Peel Plateau, Liard Basin and Canadian Western Interior Basin (Fig. 1A, B); b) Analyze the response of fossil assemblages with emphasis on foraminifera to paleoenvironmental changes in these basins; c) Speculate on the taphonomic overprint and its causes that has left relict faunas that might bias our interpretations; d) Establish biostratigraphic correlations between these basins and link faunal changes and turnovers to the global transgressive/regressive mega cycles (Gradstein et al., 2012) and other significant paleoecological events; e) Revisit existing paleogeographic reconstructions and construe how the interplay between expanding and restricting basin phases might have influenced ecosystems; and f) Discuss global

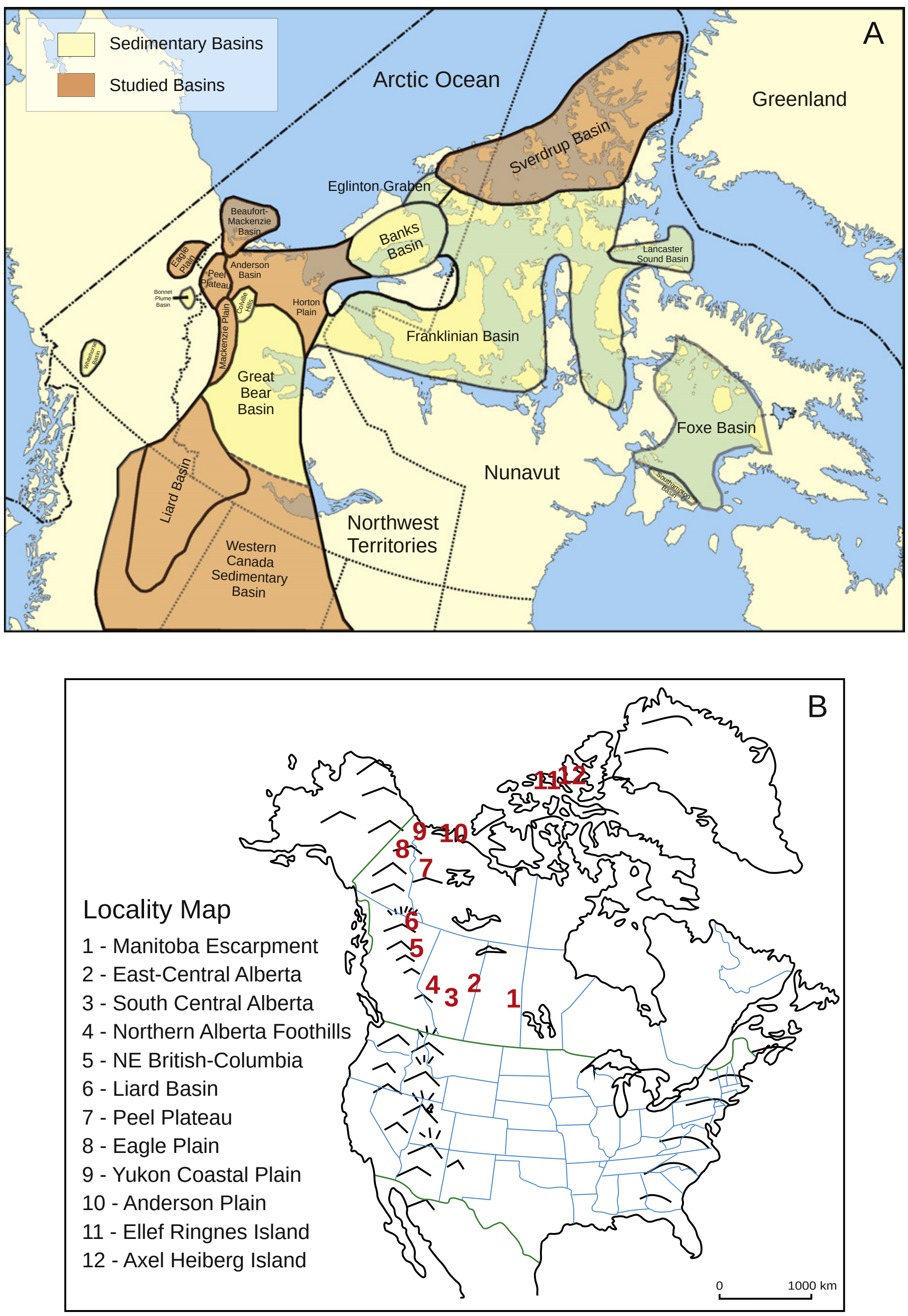

Fig. 1. A) Sedimentary basins of Western and Arctic Canada (modified after http://www.aadnc-aandc.gc.ca) and B) localities where Cretaceous strata in outcrop and subsurface drill cores were gathered by the author.