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Late Eocene to present isotopic (Sr–Nd–Pb) and geochemical evolution of sediments from the Lomonosov Ridge, Arctic Ocean: Implications for continental sources and linkage with the North Atlantic Ocean

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ABSTRACT

New geochemical and isotopic (Sr, Nd, Pb) data are presented for a composite sedimentary record encompassing the past 50 Ma of history of sedimentation on the Lomonosov Ridge in the Arctic Ocean. The sampled sediments encompass the transition of the Arctic basin from an enclosed anoxic basin to an open and ventilated oxidized ocean basin. The transition from anoxic basin to open ventilated ocean is accompanied by at least three geochemical and isotopic shifts and an increase in elements (e.g., K/Al) controlled by detrital minerals highlighting significant changes in sediment types and sources. The isotopic compositions of the sediments prior to ventilation are more variable but indicate a predominance of older crustal contributions consistent with sources from the Canadian Shield. Following ventilation, the isotopic compositions are more stable and indicate an increased contribution from younger material consistent with Eurasian and Pan-African crustal sources. The waxing and waning of these sources in conjunction with the passage of water through Fram Strait underlines the importance of the exchange of water mass between the Arctic and North Atlantic Oceans.

1. Introduction

In 2004, the Integrated Ocean Drilling Program (IODP) as part of the Arctic Coring Expedition (ACEX) drilled four sites atop the Lomonosov Ridge near 88°N and produced a composite sedimentary record measuring almost 430 m in length and comprising about 55 million years of sedimentary history of the Arctic basin (Backman et al., 2006, 2008). The core preserves the transition of the Arctic basin from an essentially warm anoxic body of water with variable salinity in the Late Cretaceous to the open Arctic Ocean of today (e.g., Pagani et al., 2006; Sluijs et al., 2006, 2008).

Initial studies of the composite sedimentary record revealed that the lower portion of the core consisted of a black shale-like sediment. The character of this sediment, the remnants of fresh water flora (Brinkhuis et al., 2006)

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and geochemical markers of low oxygen content (März et al., 2011; Poirier and Hillaire-Marcel, 2009, 2011) suggest that during the Paleocene and most of the Eocene, the Arctic basin was a deep anoxic freshwater to slightly saline, lake. In the Late Eocene, the sediments exhibit alternating black and light grey layers referred to as the "Zebra zone" (Backman et al., 2006, 2008). These sediments are interpreted to record the transition from the anoxic Arctic lake stage to a ventilated open ocean (ibid.). This transition interval is characterized by decreasing anoxic conditions and has been interpreted as recording a shallowing of the basin such that the ridge became subaerial for periods of time creating a depositional hiatus and erosion of the sediment on the ridge (Backman et al., 2006, 2008; März et al., 2011). This interpretation has been challenged by Poirier and Hillaire-Marcel (2009, 2011) who propose its deposition under strong current conditions due to the lake drainage/marine submergence following the opening of Fram Strait.

The length of depositional hiatus or even its presence during the transitional interval has thus been the subject of debate. Backman et al. (2006, 2008) interpreted a depositional hiatus of 26 Ma on the basis of dinoflagellate biostratigraphy. März et al. (2011) concluded that their mineralogical and geochemical proxies strongly supported the hiatus as described by Backman et al. (2006). In contrast, Poirier and Hillaire-Marcel (2009, 2011) argued on the basis of:

- Re-Os dating of the anoxic muds on both sides of this sedimentary gap;
- from initial Os isotope ratios of these muds that the Arctic basin did not experience a 26 Ma depositional hiatus.

They suggested that this sedimentary perturbation and marine incursion/ventilation of the Arctic basin lasted about 0.4 Ma at best. The transition from restricted anoxic basin to open Arctic Ocean occurred at 36 Ma. Another hiatus anywhere within the overlying oxic sediments would be invisible to the Re-Os system, because of the low Os (and Re) content of the oxic material, and because of the flatness of the marine osmium evolution curve for that time interval (Poirier and Hillaire-Marcel, 2011).

Radiogenic isotope studies (Sr, Nd, Pb) of sediments from the ACEX core (Fig. 1) encompassing the past 15 million years reflect a mixture of sources from North American and Eurasian sources that show little variation despite repeated glacial periods over the same period (Haley et al., 2008). In contrast, Hillaire-Marcel et al. (2013) demonstrated that the last glaciation was marked by an isotopic (Sr, Nd) excursion during the Youger Dryas that

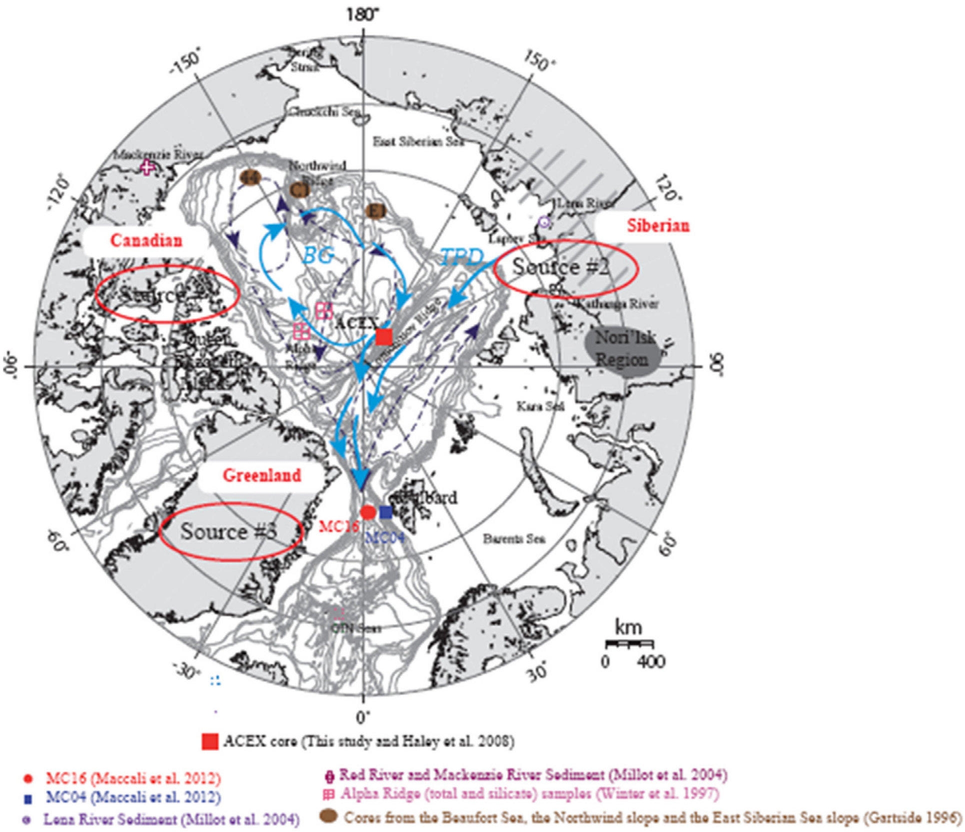

Fig. 1. (Color online.) Map showing location of ACEX core. Also shown are locations of surface sediments and cores discussed in the text as well as the locations of potential sediment sources. BG: Beaufort Gyre; TPD: Trans-Polar Drift.
Modified from Maccali et al., 2012.