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Late Quaternary stratigraphy and sedimentation patterns in the western Arctic Ocean

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ABSTRACT

Sediment cores from the western Arctic Ocean obtained on the 2005 HOTRAX and some earlier expeditions have been analyzed to develop a stratigraphic correlation from the Alaskan Chukchi margin to the Northwind and Mendeleev–Alpha ridges. The correlation was primarily based on terrigenous sediment composition that is not affected by diagenetic processes as strongly as the biogenic component, and paleomagnetic inclination records. Chronostratigraphic control was provided by ^{14}C dating and amino-acid racemization ages, as well as correlation to earlier established Arctic Ocean stratigraphies. Distribution of sedimentary units across the western Arctic indicates that sedimentation rates decrease from tens of centimeters per kyr on the Alaskan margin to a few centimeters on the southern ends of Northwind and Mendeleev ridges and just a few millimeters on the ridges in the interior of the Amerasia basin. This sedimentation pattern suggests that Late Quaternary sediment transport and deposition, except for turbidites at the basin bottom, were generally controlled by ice concentration (and thus melt-out rate) and transportation distance from sources, with local variances related to subsurface currents. In the long term, most sediment was probably delivered to the core sites by icebergs during glacial periods, with a significant contribution from sea ice. During glacial maxima very fine-grained sediment was deposited with sedimentation rates greatly reduced away from the margins to a hiatus of several kyr duration as shown for the Last Glacial Maximum. This sedimentary environment was possibly related to a very solid ice cover and reduced melt-out over a large part of the western Arctic Ocean.

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1. Introduction

Despite its significance for the study of climate change and the potential for the search of new mineral resources, both the modern sedimentary regime and the history of sedimentation in the Arctic Ocean remain only fragmentarily understood. Even the stratigraphic framework for Arctic marine geological and paleoclimatic studies is far from being established. In particular, the western Arctic Ocean, covered by perennial ice and hydrographically isolated by a gyre circulation, is the least understood oceanic region on Earth both in terms of its long-term and recent geologic history. Meanwhile, this is the region experiencing probably the most dramatic change today, with sea-ice cover diminishing beyond any expectations (Comiso et al., 2008; Stroeve et al., 2008).

Investigation of the Quaternary stratigraphy and paleoceanography of the western Arctic was recently boosted by the results of the 2005 Healy–Oden TransArctic Expedition (HOTRAX) (Darby et al., 2005). Material collected on this transect included sediment cores raised from the major ridges and plateaus of the Arctic Ocean floor such as the Northwind, Mendeleev, Alpha, and Lomonosov ridges, and high-resolution cores from the Alaskan Chukchi margin (Fig. 1). We use the HOTRAX as well as some earlier collected cores to develop a stratigraphic correlation and outline the major patterns of sediment deposition from the Alaskan margin to the interior of the western Arctic Ocean. Analysis of this sedimentary archive is much needed for understanding the paleoclimatic evolution of the Arctic.

2. Geographic and stratigraphic context

The two roughly equal parts of the Arctic Ocean located in the Western and Eastern Hemispheres, and commonly termed the western and eastern Arctic, largely correspond to the Amerasia and Eurasia

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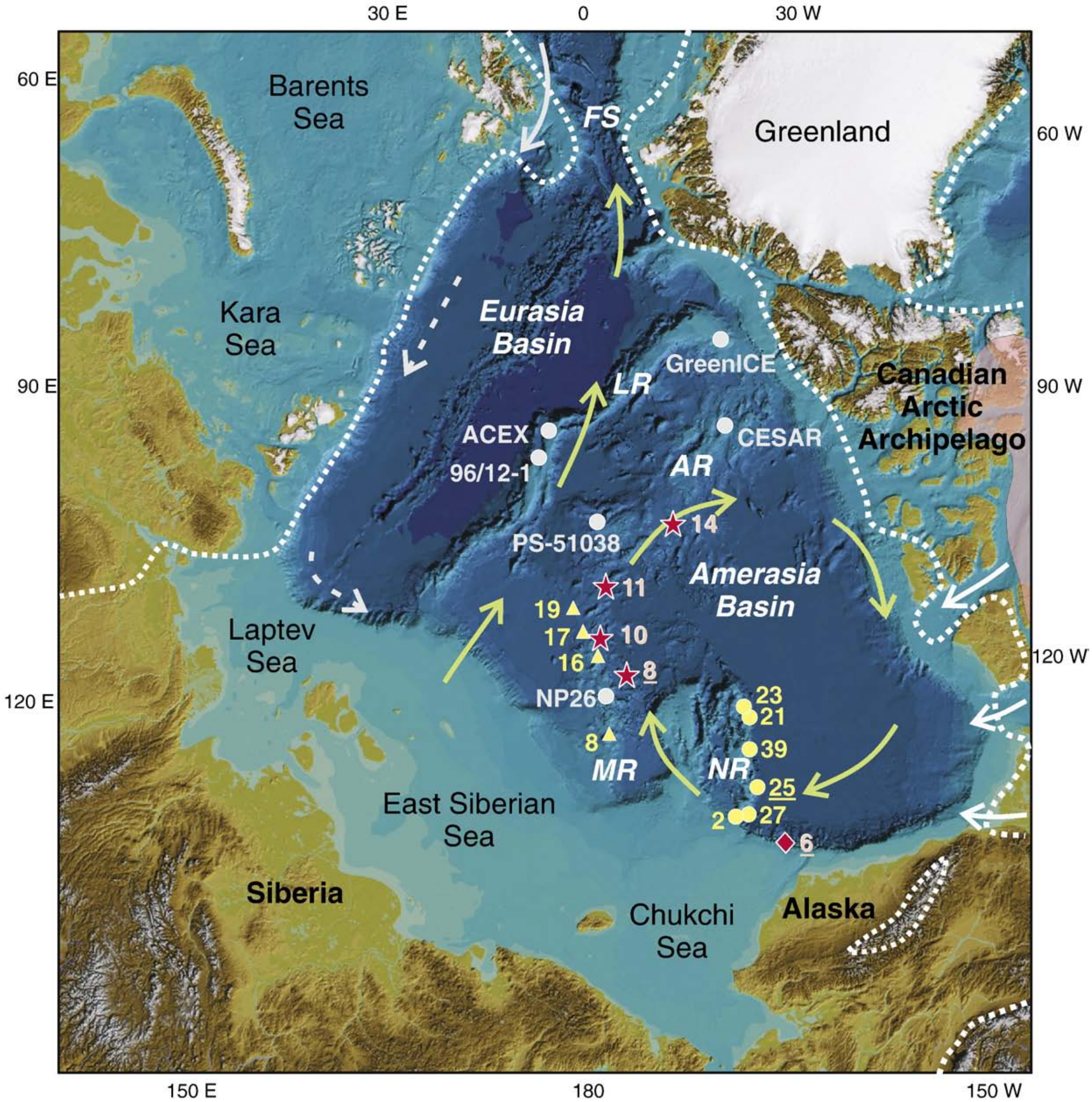

Fig. 1. Index map of the Arctic Ocean showing core sites used in the paper: red diamond/stars are HOTRAX cores HLY0501/03, yellow circles/triangles are P1-92/94-AR piston/box cores, grey circles are other published data. LR, MR, AR, and NR are Lomonosov, Mendeleev, Alpha, and Northwind ridges, respectively; FS—Fram Strait. Colored arrows show major circulation features: Beaufort Gyre, Transpolar Drift, and Atlantic-water inflow (dashed arrows for subsurface current). Base map is the International Bathymetric Chart of the Arctic Ocean (IBCAO-2; Jakobsson et al., 2008a). Dotted lines show the maximal limit of Late Pleistocene glaciations in North America and Eurasia (Dyke et al., 2002; Svendsen et al., 2004), and white arrows show major ice streams at the northern Laurentide margin (Stokes et al., 2005, 2006; Kleman and Glasser, 2007). Semitransparent pink fill in the Canadian Archipelago shows the major source area for dolomitic detrital carbonates in the western Arctic Ocean.

deep-sea basins separated by the Lomonosov Ridge. While the eastern Arctic has a considerable water exchange with the North Atlantic, the western Arctic is more isolated hydrographically due to the Beaufort Gyre surface circulation system and the Lomonosov Ridge barrier to deep water exchange. These conditions in the western Arctic Ocean account for a longer residence time of both surface and deep water masses, heavier ice coverage, high level of endemism in marine biota, and largely self-contained depositional system. This isolation complicates stratigraphic and paleoclimatic studies in the western Arctic by making it very difficult to compare the history of this region with other oceans. Combined with low sedimentation rates, strong dissolution of biogenic skeletal remnants, and logistical problems of obtaining sedimentary records from areas of interest, this setting explains the very slow progress and controversial results in developing the stratigraphy and reconstructing paleoceanography of the western Arctic despite half a century of marine geological exploration.

The early sediment cores from the central Arctic Ocean, collected from Russian ice camps in the 1950s, were shown to hold a record of cyclic lithological and microfaunal variations interpreted to be linked with circum-Arctic glacial and sea-level changes (Belov and Lapina, 1961, 1970). This approach allowed for the first age estimate of Arctic Ocean sediments by importing the contemporaneous age model for Quaternary glaciations in northern Eurasia, which gave meaningful results. Ericson et al. (1964) used a similar approach relating lithological banding to climatic variations in sea-ice cover. Subsequent studies of the 1960s through 1980s, based on sediment cores raised from the western Arctic by the US ice camp T-3, relied on paleomagnetic inclination data to constrain the age model (e.g., Steuerwald