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Pleistocene variations of beryllium isotopes in central Arctic Ocean sediment cores

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ABSTRACT

Neogene marine sediments can be dated via decay of the cosmogenic radionuclide ^{10}Be. Two cores from the Alpha and Mendeleev Ridges in the Arctic Ocean have been analyzed for seawater-derived beryllium (Be) isotopes in order to date the sediments and to calculate sedimentation rates. The decrease of ^{10}Be concentration in the cores was used to calculate first order sedimentation rates. To eliminate the dilution effect of beryllium caused by short-term changes in sedimentation rate and grain size, the ^{10}Be concentrations were normalized to the terrigenous stable isotope ^{9}Be determined in the same sample aliquot. The measured ^{10}Be concentrations yield low average sedimentation rates for the Alpha and Mendeleev Ridges of 2.3 mm ka^{-1} and 2.7 mm ka^{-1}, respectively. Sedimentation rates calculated from the ^{10}Be/^{9}Be ratios result in similarly low values, ranging from 0.2 to 6.8 mm ka^{-1} for the Alpha Ridge core and from 1.9 to 6.9 mm ka^{-1} for the Mendeleev Ridge core. However, amino acid racemization dating for the past 150 ka of a core adjacent to the Mendeleev Ridge core studied here indicates significantly higher sedimentation rates than calculated from the downcore decrease of ^{10}Be and ^{10}Be/^{9}Be. If such higher rates also prevailed at the locations of our cores, for which there is biostratigraphic evidence, either the supply of ^{10}Be was much lower than assumed or that of ^{9}Be was much higher. This could imply that the signature of the deep waters in this part of the Arctic Ocean compared to today was largely different for most of the past approximately one million years with a significantly lower ^{10}Be/^{9}Be ratio. Our study also addresses the variability of beryllium isotopes in sediment cores across the Arctic Ocean through a comparison of previously published results. Calculated ^{10}Be fluxes reveal low values in the Amerasian Basin and highest values in the Eurasian Basin, near the Fram Strait. The decrease of Be isotopes in the two studied Amerasian Basin cores may thus have been caused by environmental factors such as significantly reduced inflow of Atlantic waters in the past, reduced input of ^{10}Be and/or increased input of ^{9}Be from the shelves, combined with a more efficient sea ice shielding in this part of the Arctic Ocean.

1. Introduction

The cosmogenic radionuclide ^{10}Be has been used as a dating tool in chronostratigraphic studies of Neogene marine sediments (Amin et al., 1975; Bourlès et al., 1989; Aldahan and Possnert, 2000; Frank et al., 2008). ^{10}Be is produced in the upper atmosphere through cosmic ray-induced spallation of oxygen and nitrogen atoms. The half-life of ^{10}Be has been determined to 1.51 ± 0.06 Ma (Hofmann et al., 1987), but there is an ongoing debate on the correct value. Recent suggestions are ranging from 1.34 to 1.36 Ma (Fink and Smith, 2007; Nishiizumi et al., 2007). There are, however, some inherent problems with these recent results that need to be resolved (Fink and Smith, 2007) before there will be a generally agreed revision of the half-life of ^{10}Be. After a short residence time of about one year in the stratosphere ^{10}Be is transferred to the troposphere from where it is quickly removed to the Earth's surface by precipitation. The global average atmospheric production rate of ^{10}Be has been estimated to 1.21 ± 0.26 × 10^{6} atoms cm^{-2} year^{-1} from precipitation collections (Monaghan et al., 1985/86). For the purpose of this study the production rate of ^{10}Be can be considered constant for the late Holocene but it has mostly been higher by on average 30%, sometimes even up to 70%, during the rest of the Pleistocene as a function of variations in the strength of the Earth's magnetic field (c.f. Frank et al., 1997). These variations need to be taken into account when applying ^{10}Be for dating Neogene marine sediments and for the reconstruction of past variations of Be isotopes in seawater.

Two different approaches to derive age constraints based on ^{10}Be have been applied in previous studies of Arctic Ocean cores. The first assumes that secular variations of ^{10}Be concentrations with depth in a core broadly represent glacial–interglacial cycles in that glacial periods are represented by low ^{10}Be concentrations caused by a combination of increased Arctic Ocean sea ice cover and dilution caused by high accumulation rates of ice rafted debris (IRD). This secular glacial–interglacial variation permits the assignment of Marine Isotope Stages (MIS) to the downcore ^{10}Be record. The second

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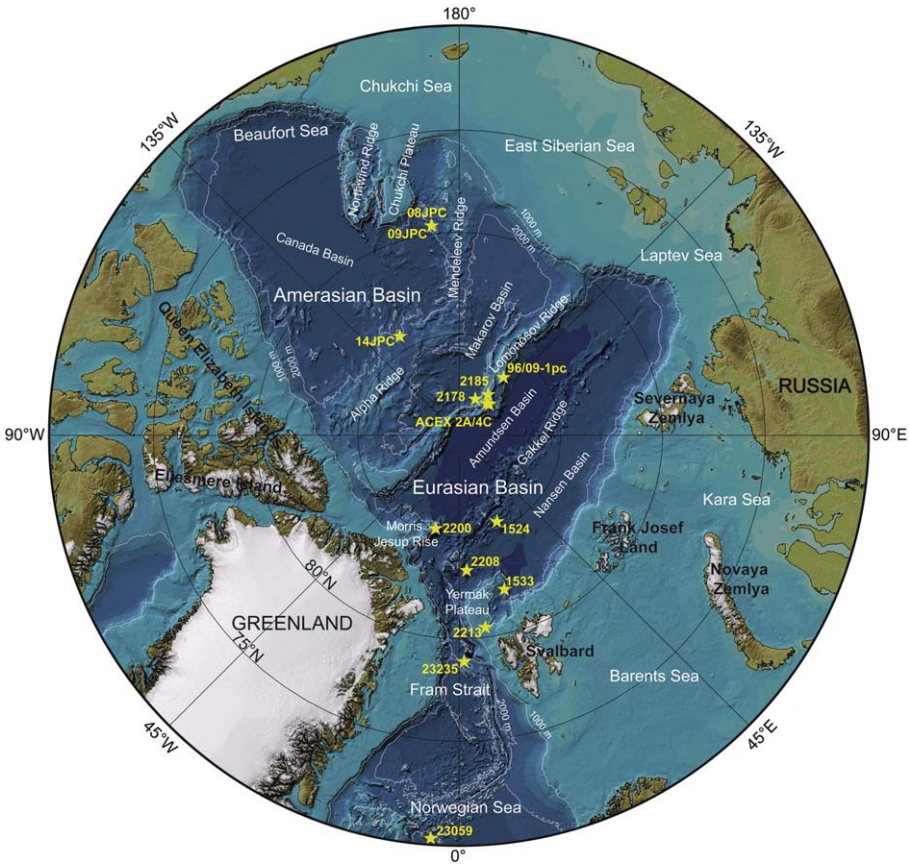

Fig. 1. Schematic map of the Arctic Ocean showing locations of the cores used in this study (yellow stars). The bathymetry is based on the IBCAO DTM (Jakobsson et al., 2008a).

approach uses the downcore decrease in ^{10}Be concentration to calculate average sedimentation rates. This assumes a near constant supply of ^{10}Be through time and a consistent initial concentration at the sediment surface. In other words, the downcore decrease in ^{10}Be concentrations must be caused by radioactive decay only. For this approach, ^{10}Be is often normalized to seawater-derived stable ^{9}Be, which is supplied from the continents and in seawater behaves chemically identical to ^{10}Be thus allowing elimination of disturbing dilution effects from short-term changes in sedimentation rates. The accuracy of this normalization method is dependent on a constant initial sea water ^{10}Be/^{9}Be, which may in fact change as a function of circulation patterns given the oceanic residence time of Be of 500–1000 years (Kusakabe et al., 1987; Kusakabe et al., 1990; Measures et al., 1996).

The former method has been applied on some Arctic Ocean short piston cores (<10 m core length) primarily covering the Pleistocene (Eisenhauer et al., 1994; Aldahan et al., 1997; Spielhagen et al., 1997; Spielhagen et al., 2004), whereas the latter provided the main chronostratigraphic tool for the Neogene part of the IODP Leg 302, the ACEX, drill core from the Lomonosov Ridge in the central Arctic Ocean (Backman et al., 2008; Frank et al., 2008).

Here we present the first study of ^{10}Be in cores retrieved from the Alpha and Mendeleev Ridges in the Amerasian Basin of the Arctic Ocean (Fig. 1). The cores were acquired during the Healy–Oden Trans-Arctic Expedition (HOTRAX) in 2005 (Darby et al., 2005). The purpose of this study is to investigate the possibility to use ^{10}Be for dating Quaternary sediment cores from the Amerasian Basin and to address the variability of ^{10}Be concentrations and fluxes in sediments across the Arctic Ocean. Therefore, we also include previously published results from beryllium isotope studies of cores from the Eurasian part of the Arctic Ocean including the Lomonosov Ridge, the Fram Strait and the Norwegian Sea (Fig. 1).

2. Material and methods

The two cores measured for ^{10}Be in this study are HLY0503-09JPC and HLY0503-14JPC, hereafter referred to as 09JPC and 14JPC. The cores were retrieved from topographic highs on the Mendeleev Ridge and the Alpha Ridge, respectively, during HOTRAX 2005 with the Jumbo Piston Corer system on *USCGC Healy* (Darby et al., 2005) (Fig. 1). The results are compared with published results from previous studies on beryllium isotopes in Arctic Ocean cores (Fig. 1; Table 1).

2.1. Sampling and Be isotope measurements of the HOTRAX cores

The lithostratigraphies for both 09JPC and 14JPC are characterized by a cyclic alternation of dark brown and lighter colored yellowish brown layers. These sediment cycles have been interpreted to reflect interglacial and glacial variability and have been observed throughout the Arctic Ocean (e.g. Poore et al., 1993; Phillips, 1997; Jakobsson et al., 2000; Polyak et al., 2004; O'Regan et al., 2008; Adler et al., 2009-this volume). The samples for beryllium isotope analyses from 09JPC and 14JPC were therefore systematically taken from typical dark brown sediment units interpreted to represent interglacial periods. The reason for this was to avoid the influence of secular glacial–interglacial variations in the ^{10}Be record given that our initial primary intention was to calculate sedimentation rates using the decay of ^{10}Be. A total of 11 samples were taken from core 09JPC, and 20 samples from core 14JPC. All samples consisted of 1-cm thick slices and contained approximately 5 cc of sediment. The samples were dried, homogenized, and subjected to an established weak leaching procedure involving hydroxylamine hydrochloride, which was developed to extract seawater-derived trace metal isotope compositions, such as those of Nd or Pb (Bayon et al., 2002; Gutjahr et al., 2007). A similar