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Pliocene West Antarctic Ice Sheet Dynamics -Tying IODP Expedition 379 Drill Records to Seismic Data

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Throughout the past three decades grounding line retreat, accelerated ice flow and ice shelf thinning have characterized the West Antarctic Ice Sheet (WAIS), and its future stability appears to be uncertain. Evidence about the reaction of the WAIS to past warmer-than-present climates including its dynamic behavior to modification in oceanic and atmospheric forcing in the Plio- and Pleistocene may have strong relevance for assessing present and future climate states. During the International Ocean Discovery Program (IODP) Expedition 379, sediment cores from two drill sites were recovered from the Resolution Drift on the continental rise in the Amundsen Sea sector, a key region for understanding past and present WAIS dynamics. Both drill sites provide continuous records from the late Miocene to the Pleistocene including the warmer-than-present intervals of the Pliocene. Drill sites U1532 and U1533 are located on a network of seismic lines enabling a correlation of seismic key horizons and sequence characteristics by core-log seismic integration. We identified an interval with alternating physical properties and high diatom abundance correlating with distinct seismic reflection characteristics. This interval has been dated to 4.2–3.2 Ma and is interpreted to represent a highly dynamic WAIS with prolonged grounding line retreat periods in the Amundsen Sea sector. The extended seismic network allows an extrapolation of the achieved local results to other sediment drift bodies in the Amundsen Sea and Bellingshausen Sea for a larger regional analysis of past WAIS dynamics.

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The opening of the Fram Strait and its influence on sediment transport, climate and ocean circulation between the Arctic Ocean and the North Atlantic

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It is known that during a long period of its Cenozoic history, the Arctic Ocean was isolated from any global thermohaline circulation system (e.g. Jakobsson et al., 2007). Thus, the opening and subsequent widening of the Fram Strait, the only deep-water connection between the Arctic and Atlantic oceans, was a fundamental tectonic process with extensive consequences for the global ocean circulation and paleoclimate evolution as well as for sedimentation processes in the adjacent ocean basins and along the continental margins.

In order to reconstruct both the development of the ocean circulation within and the glacial history of the Arctic-Atlantic gateway we interpreted sediment packages imaged in reflection seismic profiles together with updated stratigraphic information from existing Ocean Drilling Program (ODP) holes (Fig. 1). Our new, high resolution seismic stratigraphy for the Molloy Basin (central Fram Strait) is based on a revised chronology for ODP Site 909 and on a seismic reflection pattern that is better resolved than in previous studies (e.g. Berger and Jokat, 2009).

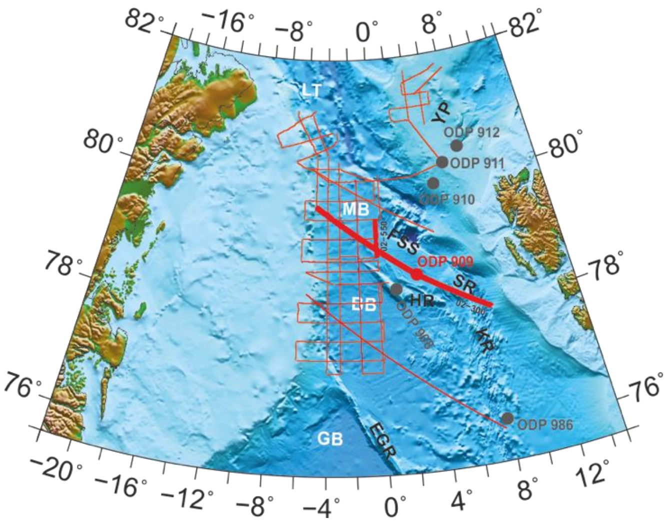

Figure 1: Bathymetry of the central Fram Strait area with locations of re-processed seismic profiles (red lines) and ODP drill sites (dots) and locations of a moored oceanographic array (small orange dots). Geomorphologic features: MB: Molloy Basin, BB: Boreas Basin, GB: Greenland Basin, YP: Yermak Plateau, FSS: Fram Strait Sill, SR: Svyatogor Ridge, HR: Hovgaard Ridge, KR: Knipovich Ridge.

An improved core-log-seismic integration for ODP Site 909 and crossing seismic reflection profile AWI-20020300 (Fig. 2) was substantial in deriving the new seismic stratigraphy as well as characterizing the seismic units lithologically (Gruetzner et al., 2022). The core-seismic integration was combined with a revised magnetostratigraphy calibrated by new palynomorph bioevents which shifts previously used stratigraphies for ODP Site 909 (e.g. Myhre et al., 1995) to significantly younger ages in the time interval from c. 15 Ma to 3 Ma. The new stratigraphy implies that prominent maxima in coarse sand particles and kaolinite, often interpreted as evidence for ice rafting in the Fram Strait occur at c. 10.8 Ma, c. 3 Myr later as previously inferred. In the late Tortonian (< 7.5 Ma), sediment transport became current controlled, most probably through a western, recirculating branch of the West Spitsbergen Current. This current influence was strongly enhanced between c. 6.4 and 4.6 Ma and likely linked to the subsiding Hovgaard (Hovgård) Ridge and the widening of the AAG. Late Pliocene to Pleistocene seismic reflectors correlate with episodes of elevated ice-rafted detritus input related to major steps in Northern Hemisphere ice sheet growth such as the prominent glacial inception MIS M2 and the intensification of Northern Hemisphere glaciation starting at c. 2.7 Ma.

Tracing the most prominent reflectors in a dense net (~5800 km) of re-processed seismic profiles allowed us to extrapolate these events into the Boreas Basin and towards the adjacent Northeast Greenland continental margin. Subsequently compilations of updated digital isochron and depth-to-horizon maps were used to map depocenter geometries of current controlled sediments and mass-transport deposits within the Arctic-Atlantic gateway.

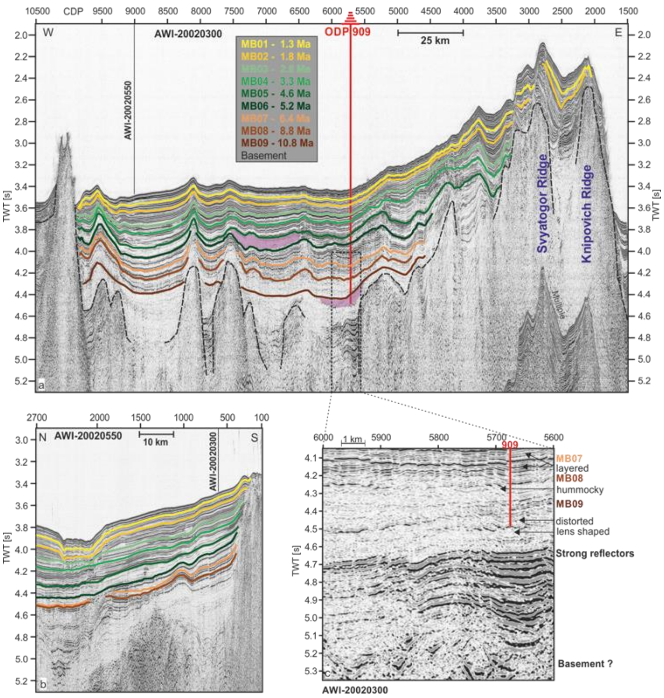

Figure 2: Time migrated and interpreted section of multichannel seismic reflection profile AWI-20020300 across ODP Site 909 (red vertical line), regional reflectors MB01 to MB09 are traced in brownish (Miocene), greenish (Pliocene) and yellowish (Pleistocene) colours. Dashed black line marks acoustic basement. Magenta areas mark debris lobes. (b) Seismic profile AWI-20020550 crossing at CDP 9007 in south-north direction. (c) Close up of profile AWI-20020300 showing the reflection patterns at the base of Site 909.

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Climatically controlled sedimentation dynamics and export productivity at IODP Site U1537 in the Scotia Sea (Southern Ocean) over the past four glacial cycles

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The Scotia Sea in the Southern Ocean (SO) today is a hydrodynamically important area where Antarctic Bottom Water (AABW) that is previously formed within the Weddell Sea is vigorously mixing into the Antarctic Circumpolar Current. Furthermore, the Scotia Sea is the area where most icebergs that are shedding off marine-based portions of the Antarctic Ice Sheet are drifting out of the Weddell Sea within the so-called "Iceberg Alley". During past glacial cycles, the position, dimensions and volume transport of the ACC and AABW were substantially different from the modern configuration.

This IODP research proposal, aimed to be realised in the framework of a PhD studentship, seeks to identify the continental source areas of sediments deposited at IODP Site 1537 (59°6.65′S, 40°54.37′W, in 3713 m water depth) that was drilled during Expedition 382 during early 2019. Using the detrital neodymium and lead isotope composition of the bulk and fine (<5 mm) grain size fraction, we will identify continental source areas of terrigenous sediments deposited over the past 450 kyr, hence covering four 100-kyr glacial cycles and five glacial terminations at near-millennial resolution. During key intervals these records will be corroborated by additional argon isotopic analyses on the same sediments. Source areas are expected to be mostly positioned within or close to the Weddell Sea and include older cratonic East Antarctic sequences, as well as relatively young continental crust that is supplied as glacially weathered sediment from the Antarctic Peninsula, Pacific sections of West Antarctica, or dust from Patagonia. We will further generate uranium/thorium isotopic data on bulk sediments to assess sedimentation dynamics (focusing versus winnowing) and assess bottom water oxygen starvation as a function of elevated export productivity in the region.

Overturning dynamics in the Antarctic zone of the SO were likely much reduced due to a northward shift of the oceanic fronts as well as extended sea ice cover during the past glacial climates. As a consequence, less sediment from more remote locations such as East Antarctica should have been transported to the core site, while regional export productivity was also reduced given extended sea ice and lowered Scotia Sea surface water nutrient concentrations due to reduced glacial upwelling. We hypothesize that sediment provenance, sedimentation dynamics, as well as surface ocean export productivity in the Scotia Sea are strongly linked on millennial timescales. Our aim is to provide a new perspective on the degree of connectivity between, and underlying controls of, the position of SO fronts, the status of Weddell Sea Deep Water export, and bottom water oxygen starvation as a function of elevated surface ocean productivity.

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Pliocene Silicate weathering in the South Asian Monsoon domain

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The accelerated rise in global temperatures due to the release of anthropogenically produced greenhouse gases over the past decades has alarming consequences for the future of Earth's climate system. One crucial component of the climate system is the South Asian monsoon (SAM) given that most South Asian countries depend on this seasonal rainfall for their livelihood. Monsoon precipitation makes Asian rivers the major sediment source to the oceans with seasonal weathering and erosion shaping the landscape. The weathering of silicate rocks is a major sink for atmospheric CO_2 on geological timescales and the monsoon climate makes tropical Asia the hotspot of silicate weathering today. With billions of people depending on monsoon precipitation and silicate weathering being the Earth system's natural way to reduce atmospheric CO_2, it is beyond doubt necessary to better understand the nature of South Asian monsoon variability in the future. This is possible by studying the South Asian monsoon behaviour during past warm periods of Earth's history that can serve as a model system for the coming decades of a warming world. This work will therefore focus on the variability of the South Asian monsoon driven silicate weathering during the Mid-Pliocene warm period, the most recent analogue for the warmer climate of the future. Silicate weathering intensity and provenance in the SAM region will be reconstructed for the Pliocene by employing trace and major elements, radiogenic isotopes including Sr, Nd, Hf, Pb and nontraditional stable isotopes such as Li and Si of marine sediments from International Ocean Discovery Program cores in the Bay of Bengal (IODP Site U1445 and U1443) and the Andaman Sea (IODP Site U1448A). These data will have the high resolution required to enable driving factors to be distinguished when combined with direct proxies for monsoon precipitation strength and local climate. Differences between the sites will reveal spatial heterogeneities of SAM strength and silicate weathering across the region and the relationship between SAM strength and silicate weathering in a warmer world.