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Changes in current patterns in the Fram Strait at the Pliocene/Pleistocene boundary

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A B S T R A C T

Seismic reflection profiles from the northwestern and central part of the Fram Strait show thick packages of drift type sediments mainly along the western Yermak Plateau flank, but also in the central, flat part of the Fram Strait. North of 80.5°N, a large-scale field of sediment waves along the Yermak Plateau rise separates a western, lower from an eastern, upper drift body. These drift bodies were deposited by bottom currents, most likely the northbound Yermak Branch of the West Spitsbergen Current, but we cannot rule out that the western drift body may also have been influenced by southbound bottom currents. A stratigraphic boundary is clearly visible within the drift bodies and even more pronounced within the sediment waves, separating a lower package of waves migrating upslope at low angle (~5°) from an upper package with significantly increased wave crest migration (~16.5°). This stratigraphic boundary could be tracked along the seismic network and corresponds to the lithostratigraphic boundary between units IA and IB at ODP Leg 151, Site 911 that was dated to 2.7 Ma. The increase in wave-crest migration angle indicates a shift towards higher sedimentation rates at 2.7 Ma, which corresponds to the intensification of the Northern Hemisphere glaciation with a major expansion of the Greenland, Scandinavian, northern Barents Sea and North American ice sheets. The subaerially exposed Barents shelf and the expansion of the northern Barents Sea ice sheet (as well as Svalbard) are likely sources for enhanced erosion and enhanced fluvial input along the pathway of the West Spitsbergen Current, resulting in higher sedimentation rates in the Fram Strait.

1. Introduction

The Fram Strait is the only deep-water connection between the North Atlantic and the Arctic Ocean, and this narrow gateway channels both inflowing relatively warm and saline North Atlantic as well as outflowing cold and less saline water. Sediments along the eastern flank as well as in the central part of the Fram Strait are deposited mainly as contourites influenced by these currents (e.g., Eiken and Hinz, 1993; Howe et al., 2008). The Arctic Ocean and its surroundings are highly sensitive to climate change, and paleoclimate reconstructions in the Arctic realm have thus become a major research focus during the past decade (e.g., Moran et al., 2006; Tripati et al., 2008; Jakobsson et al., 2010; Melles et al., 2012). Paleoclimate change in the Arctic Ocean led to significant shifts in the current patterns (e.g., Knies et al., 2007; Haley et al., 2008), and since almost all Arctic water masses traverse the Fram Strait upon leaving the Arctic Ocean, it is highly likely that the changes in the current patterns would somehow be recorded in the Fram Strait sediments. Studying these sediments therefore helps to unravel the paleocurrent patterns in the Arctic Ocean and, thus, get a better insight into paleoclimate change that affected the Arctic realm.

In this study, we use a network of seismic reflection data (i) to map the sediment structures and geometries along the western flank of the Yermak Plateau and in the central part of the Fram Strait, and (ii) to identify changes in the sedimentation regime.

2. Study area

The area investigated in this current study comprises the Fram Strait and the adjacent western flank of the Yermak Plateau (Fig. 1). The Fram Strait is the only present deep-water connection between the North Atlantic and Arctic Ocean (Eiken and Hinz, 1993). It is located between the Svalbard Archipelago to the East and Greenland to the West between 78°N and 82°N and has a water depth of up to 3000 m and a width of 200 km. The bow-shaped Yermak Plateau is located north of the Svalbard archipelago with water depths of 700–800 m over large parts. The initial basement

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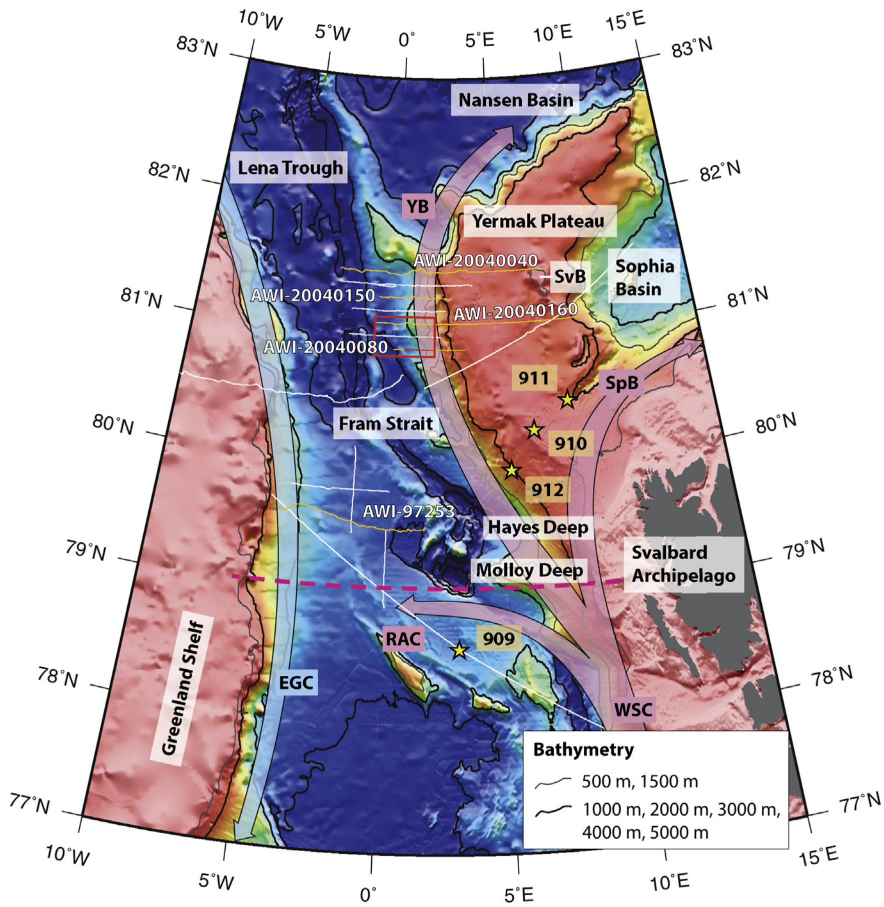

Fig. 1. Geographical overview of the Fram Strait and its surroundings. Blue and red arrows mark the present-day predominant surface water flows in this area (Manley et al., 1992). Spacing of bathymetry contour lines is 500 m down to 2000 m water depth and 1000 m at >2000 m water depth. Map was created from the IBCAO dataset (Jakobsson et al., 2013) using GMT software tools (Wessel and Smith, 1991). Geographical names: SvB: Sverdrup Bank; Currents: EGC: East Greenland Current, RAC: Return Atlantic Current, SpB: Spitsbergen Branch, WSC: Western Spitsbergen Current, YB: Yermak Branch. The yellow stars mark the positions of ODP Leg 151 Sites 909 to 912. Tracklines of the seismic profiles used in this study are shown in white; those mentioned in the text and/or shown in other figures are labeled and shown in yellow. The red part of profile AWI-20040080 is shown in Fig. 9a, and the red rectangle marks the position of the bathymetry detail in Fig. 9b. The dashed pink line at 79° marks the approximate position of the oceanographic transect in Fig. 10.

topography of the Yermak Plateau is rather rough with many deep troughs separating the basement heights (Jokat et al., 2008; Geissler et al., 2011). Cenozoic sediments of up to 4 km in thickness almost level this initial topography (Geissler et al., 2011) with exceptions of some basement heights such as the Sverdrup Bank that is still outcropping and not yet leveled completely. The sediments are generally well-layered and can mostly be interpreted as contourite deposits along the basement heights, deposited by bottom currents. Large parts of the Yermak Plateau exhibit glacial overprint of the uppermost sediment layers indicated both by an overconsolidated diamicton and by mega-scale lineations of deep-keeled tabular icebergs and curvilinear plow marks of smaller, single icebergs (e.g., Vogt et al., 1994; Dowdeswell et al., 2010; Jakobsson et al., 2010; O'Regan et al., 2010; Gebhardt et al., 2011), but the western flank is characterized by well-layered drift-type sediments (e.g., Pulm, 2010; Gebhardt et al., 2011; Geissler et al., 2011).

2.1. Evolution of the Fram Strait

Even though seafloor spreading in the central Atlantic propagated northwards as early as in the late Cretaceous, the Arctic Ocean stayed isolated from the Atlantic Ocean probably until the separation of the Yermak Plateau from northeast Greenland some 35 Ma ago (Moran et al., 2006; Jokat et al., 2008; Ehlers and Jokat, 2013). The onset of significant water exchange through the Fram Strait, however, is still under debate, but deep water exchange and, thus, ventilation of the Arctic Ocean, is likely to have started at 18.2 Ma, and a significant deepening of the Fram Strait is documented from 17.5 Myrs on (Jakobsson et al., 2007). The abyssal plain in the northern Fram Strait is underlain by young oceanic crust and the Lena Trough is still active as the current spreading center (Läderach et al., 2011).

2.2. Oceanographic circulation through the Fram Strait

The Fram Strait is channeling the flow of surface and deep waters between the Arctic and North Atlantic and allows the deep-water exchange between both polar hydrospheres (Fig. 1). The currents flowing from the North Atlantic through the Norwegian Sea and towards the Arctic Ocean include the northward inflow of relatively warm and saline waters via the Norwegian Current and further as the West Spitsbergen Current along the western margin of Svalbard, and the southward outflow of cold and low saline waters along the Greenland shelf via the East Greenland Current (e.g., Bourke et al., 1988; Manley et al., 1992; Rudels et al., 2012) (Fig. 1). Within the Fram Strait, the West Spitsbergen Current splits into three components north of approximately 78°N (e.g.,