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A revised Early Miocene age for the instigation of the Eirik Drift, offshore southern Greenland: Evidence from high-resolution seismic reflection data

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ABSTRACT

The Eirik Drift lies on the continental slope south of Greenland, where it has been formed under the influence of Northern Component Water (NCW). NCW flow is an essential part of the global Thermohaline Circulation (THC), which is closely connected to the world's climate. Changes in pathways and intensity of NCW flow bear information about modifications of the North Atlantic THC in a changing climate. There is some disagreement about when deep-current controlled sedimentation at the Eirik Drift started. While the onset of drift building was previously dated as early Pliocene or late Miocene in age we suggest that the effect of large-scale current deposition had been initiated by at least 19–17 Ma based on the seismostratigraphic analysis of sedimentary structures identified in a set of high-resolution seismic reflection data. This assumption of an early Miocene onset of NCW flow is supported by regional evidence regarding the breaching of the Greenland–Scotland Ridge, which is documented in several erosional unconformities within the North Atlantic. After the onset of deep-current controlled sedimentation at the Eirik Drift, two major changes in the deep-current system are revealed during the Miocene: At the mid- to late Miocene boundary (12–10 Ma) and at 7.5 Ma.

1. Introduction

The global Thermohaline Circulation (THC) is closely connected to major changes in Earth's climate (Dickson and Brown, 1994). The surface branch of the THC transports heat and freshwater around the world's oceans and interacts with the overlying atmosphere through surface fluxes (Schmitz, 1996). The formation of deep water in the basins of the northern North Atlantic, Arctic and Antarctic is a mechanism driving the global THC (Dickson and Brown, 1994; Schmitz, 1996). The Eirik Drift, located offshore southern Greenland is built under the influence of the deep-water currents originating as overflows from the Nordic Sea deep-water formation regions (North Atlantic Deep Water (NADW)) (Fig. 1; e.g. Arthur et al., 1989; Hunter et al., 2007a; Wold, 1994). Therefore, the sedimentary structures and packages of the Eirik Drift archive changes in strength and direction of these deep-water currents. As the NADW flow is today's main contributor to the lower branch of the North Atlantic THC, decoding of these deep-water currents yields information about the development of the global THC (Schmitz, 1996).

Even though it is certain that the Eirik Drift was built under the influence of these deep-water currents (e.g. Arthur et al., 1989; Wold, 1994; Hunter et al., 2007a,b), the timing of the onset of development of the Eirik Drift remains ambiguous. Arthur et al. (1989) suggested that the “modern” pattern of deep circulation in the Labrador Sea was established sometime in the late Miocene (8.2–7.5 Ma), but they dated the onset of deep current-controlled deposition at 4.5 Ma. By investigating accumulation rates of sediment drifts in the northern North Atlantic, Wold (1994), however, found that drift building at the Eirik Drift may have started 7–8 Ma ago. The study regarding the North Atlantic deep circulation by Wright and Miller (1996) is based on the findings of Wold (1994), but dates the onset of drift accumulation at Eirik Drift at 5–6 Ma. This date of onset of drift building at the Eirik Drift is used in further investigations by several authors (e.g. Wright, 1998; Cramer et al., 2009; Miller et al., 2009). On the other hand, recent works of Hunter et al. (2007a) and Hunter et al. (2007b) based their investigations at the Eirik Drift on the interpretation from Arthur et al. (1989) with the onset of deep-current controlled sedimentation at 4.5 Ma. In this study, we aim to reappraise the question of the timing of the onset of drift accumulation at Eirik Drift on the basis of an analysis of a tight grid of newly collected seismic reflection data. We incorporate these seismic data with geological information and age-models of Ocean Drilling Program (ODP)/Integrated Ocean Drilling Program (IODP) drill sites, including ODP Leg 105 Site 646 and IODP Expedition 303 Sites U1305, U1306 and U1307 in a bid to better define the inception of drift growth offshore southern Greenland (Figs. 1 and 2).

2. Settings

2.1. Geological settings and drift morphology

The Labrador Sea basin is about 900 km wide and opens to the SE into the North Atlantic (Fig. 1; Chalmers and Pulvertaft, 2001). This basin formed as a consequence of continental rifting between

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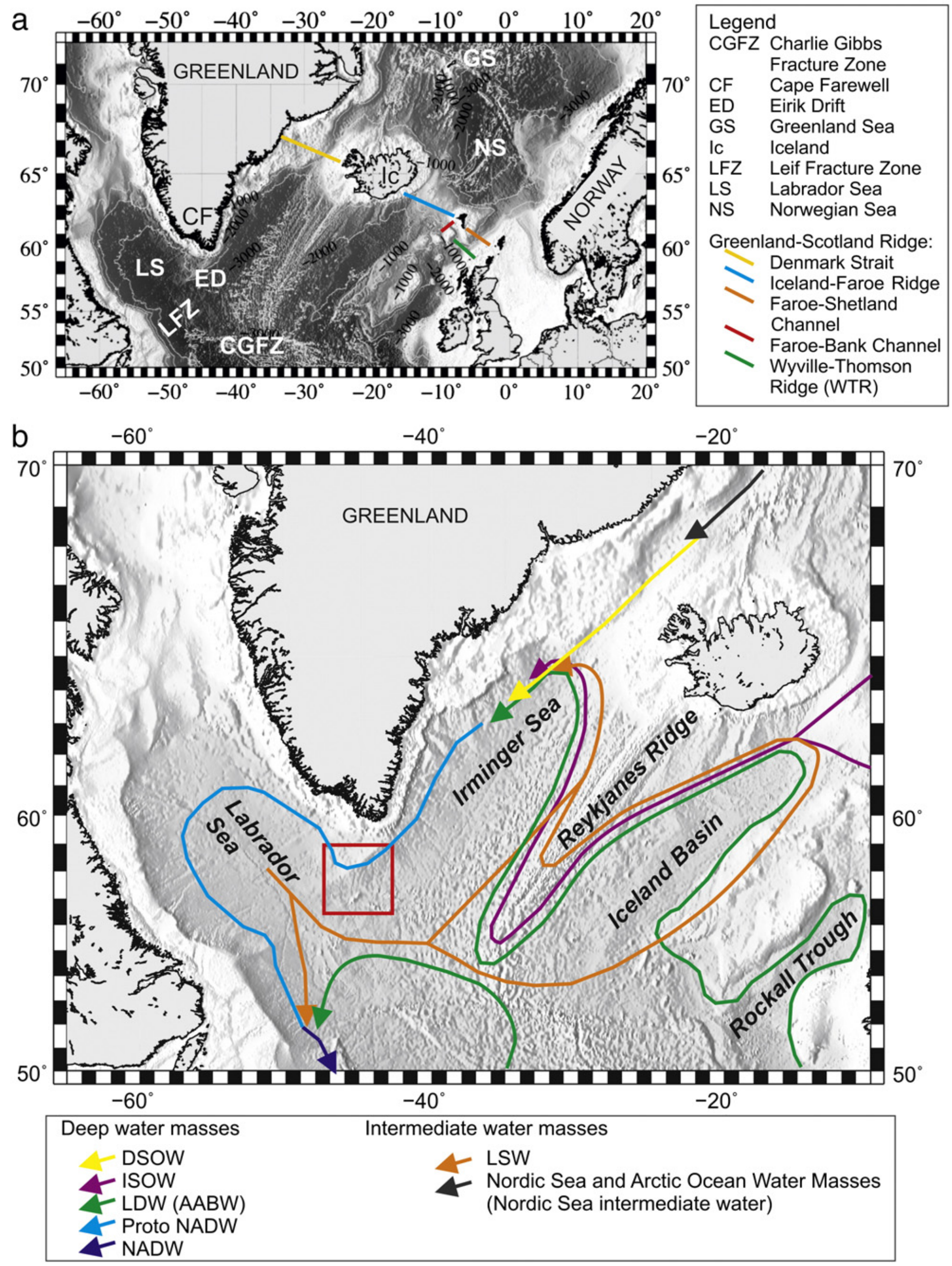

Fig. 1. Satellite-derived bathymetry map (Smith and Sandwell, 1997) of the North Atlantic. (a) Basins, ridges and fracture zones in the northern North Atlantic (see text for description). (b) Water mass contribution to the formation of the North Atlantic Deep Water (modified from Schmitz, 1996; see text for description). The red box shows the study area (see Fig. 2). Water mass abbreviations: DSOW, Denmark Strait Overflow Water; ISOW, Iceland-Scotland Overflow Water; LDW, Lower Deep Water; AABW, Antarctic Bottom Water; NADW, North Atlantic Deep Water; LSW, Labrador Sea Water.

Greenland and Labrador, which commenced during the Late Cretaceous (anomaly 27, ~63 Ma) (Chalmers and Pulvertaft, 2001), but had ceased by ~35 Ma ago (Srivastava and Roest, 1999). The Eirik Drift is located in the eastern part of the Labrador Sea, south of the southern tip of Greenland (Fig. 1). Two narrow parallel WSW-trending basement ridges, which formed during the rifting process between about 61 and 40 Ma (Mueller et al., 2008), underlie the Eirik Drift (Fig. 2; Le Pichon et al., 1971; Srivastava and Arthur, 1989). These basement elevations are believed to have controlled the onset of drift building in this region (Srivastava and Arthur, 1989; Hunter et al., 2007b). At present, the main Eirik Drift crest extends from a water depth of 1500 m in the NE to ~3600 m, and extends a total length of 360 km in the SW over these basement ridges (Fig. 2; Hunter et al., 2007a). The Eirik Ridge is classified as a detached giant elongated drift formed under the influence of deep contour currents (e.g. Stow et al., 1998; Faugères et al., 1999). Hunter et al. (2007a) reported three NW-trending subsidiary ridges, which extend to the NW from the main drift crest (Fig. 2).

The Greenland–Scotland-Ridge (GSR; Fig. 1a) is the gateway for northern-sourced deep-water into the northern North Atlantic. Therefore, its formation and subsidence history is important for the evolution of the Eirik Drift but has yet to be fully understood. The western part of the GSR between Greenland and Iceland is called the Denmark Strait (Fig. 1a). Here, first significant overflow was observed at ~7 Ma (Bohrmann et al., 1990) and the present sill depth lies at ~620 m (Hansen and Østerhus, 2000). The eastern part of the GSR is a complex ridge–channel-system (Fig. 1). The Iceland–Faroe-Ridge with a present maximum sill depth of ~480 m (Hansen and Østerhus, 2000) experienced first significant overflows at ~13–11 Ma (Bohrmann et al.,