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# Research perspectives of sediment waves and drifts: Monitors of global change in deepwater circulation

J. Mienert

GEOMAR, Research Center for Marine Geosciences, Kiel, Germany

R.D. Flood

Marine Sciences Research Center, Stony Brook, New York

W.C. Dullo

GEOMAR, Research Center for Marine Geosciences, Kiel, Germany

The purpose of this special section in *Paleoceanography* is to present interdisciplinary approaches for contributing to the reconstruction of ocean circulation and its response to climate changes. A high-priority objective for understanding the causes and mechanisms of climate change is the monitoring of past ocean circulation and oceanic heat and nutrient transport. *Lehman and Keigwin* [1992] have shown that cooling, for example, during the younger Dryas event, may have culminated in a cessation of the oceans conveyor circulation. The cooling in the North Atlantic was apparently the result of reduced northward heat transport in the upper water masses of the North Atlantic conveyor belt. In contrast, intervals with a strong surface and deepwater circulation were marked by a high northward heat transport. For the understanding of the causes and the timing of such rapid, highfrequency events, marine records of high deposition rate cores are needed. These cores should provide evidence for changes in abyssal circulation and heat transport, as well as a record of surface and deepwater characteristics. The sediment drifts of the North Atlantic and in other ocean basins are one of the major targets for the recovery of sediments with high deposition rates (>10 cm/kyr) and for reconstructing the role of both intermediate and deepwater production in the conveyor belt, that is drawing low-latitude heat northward. We stress the need for international programs targeting high deposition rate areas on sediment drifts and sediment waves in order to understand (1) the evolution of the conveyor belt and (2) its dynamics and variability. The North Atlantic, where sediment drifts are concentrated, will provide ideal study areas with time resolutions comparable to those of ice core records but with records linked directly to the record of changing bottom water flow. Therefore one can address the changes in circulation, heat and carbon budget on high and ultrahigh resolution records.

Within the northern North Atlantic region there are seven major sediment drifts [e.g., *McCave and Tucholke*, 1986], which run from northeast to southwest: Snorri, Eirik, Gloria, Gardar, Bjorn, Hatton, and Feni containing high sediment accumulation rate areas and one of the best clues for monitoring climatic induced changes in thermohaline circulation patterns. These northern North Atlantic sediment drifts have a much greater areal extent than what has previously been indicated [*Wold*, this issue].



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Feni Drift is the oldest sediment drift in the region, originating near the Eocene Oligocene boundary [*Masson and Kidd*, 1987]. It was followed by accumulation of Bjorn, Gardar, Hatton, and Snorri Drifts from the late early to middle Miocene. Eirik and Gloria Drifts may have begun to form in the early Pliocene. As an alternative to the hypothesis of the Norwegian Sea water overflowing the Iceland-Faeroe Ridge in the early-middle Miocene, *Wold* [this issue] suggests that dense water formed along shallow segments of the Iceland-Faeroe Ridge and then flowed into the South Iceland Basin to begin the accumulation of Bjorn, Gardar, and Snorri Drifts. The initiation of sediment accumulation on Eirik Drift is attributed to the formation of shallow shelf sea northwest of Iceland approximately 5 Ma. Dense water that formed on the shelf seas northwest of Iceland flowed south through the Denmark Strait and may have altered circulation patterns west of Reykjanes Ridge such that accumulation of Gloria Drift was initiated at the same time as the Eirik Drift.

This complex pattern illustrates clearly the need of detailed investigations to shed light on the assumptions that force us to write so often "may," "could be," and "most likely." Furthermore, it is worth focusing quantitatively on the frequency and importance of drift sediments through time. In the briefly discussed example from the northern North Atlantic it seems, apparently another assumption, that drift sedimentation has dominated the sedimentary pattern of accumulation between the Greenland-Scotland Ridge and the Charlie Gibbs Fracture Zone during Quaternary and Pliocene, while it was restricted to relatively small areas during late and middle Miocene time.

A good example of the complexity of the interaction of bottom currents and pelagic depositional processes was first given by the High Energy Benthic Boundary Layer Experiment (HEBBLE) [e.g., *Hollister and McCave*, 1984] in a small area at the Nova Scotia Rise and the Project Mudwaves in a small area of the Argentine Basin [e.g., *Manley and Flood*, 1993]. Deep sea drifts, which are elongated ridges, often several 100 km long and several kilometers thick and many times mantled by sediment waves, appear to be not only accumulation but also erosional features where the deep, thermohaline currents flow. This combination of sedimentary environments provides many opportunities for understanding the record of current flow. Previous studies of the paleontological record of sediment drifts were based on widely distributed gravity and piston cores or Deep Sea Drilling Project/Ocean Drilling Program (DSDP/ODP) sites [e.g., *Stow and Holbrook*, 1984; *Keigwin and Jones*, 1989]. Our understanding of how sediment drifts are formed and evolve needs to be reconsidered in the light of our present understanding of deep-ocean currents that apparently fluctuate significantly in strength with time. As a result, the relationship between sediment drifts [e.g., *Van Weering and de Rijk*, 1991], sediment waves [e.g., *Sarnthein and Mienert*, 1986] (and other bedforms) and thermohaline circulation patterns [e.g., *Lonsdale*, 1982; *Weatherly*, 1993], water mass chemistry, and climatic variability is still poorly understood.

An important step toward sorting out the climatic variability and its effects of paleoceanographic changes in the deep-sea conveyor belt involves establishing a precise and high resolution chronostratigraphy, with a resolution greater than the duration of climatic and oceanographic events. Among the best suited regions are areas of high sediment accumulation on sediment drifts and waves that often mantle the drifts. Only a few Deep Sea Drilling cores meet some of the criteria and are located on drifts in the North Atlantic. Site 611, from the Gardar Drift, sites 553 and 552, from the Hatton Drift, and site 610 from Feni Drift [e.g., *Kidd and Hill*, 1987; *Robinson and McCave*, this issue] allowed to study the paleoceanography. Here Norwegian Sea overflow enters the North Atlantic, building up the northern end member of the deep conveyor belt. Because of its high salinity, it flows as a density-driven geostrophic current cyclonically within the basins. The sedimentary sequences recovered from these sites are typically pelagic in character. However, sedimentation rates at several of these sites are relatively high compared with most pelagic sites. *Robinson and McCave* [this issue], note that site 610 is not affected by strong bottom currents but lies downward from regions capable of winnowing the fine fraction of the sediments. Thus there is a large potential to drill and recover ultrahigh resolution records on Feni drift. An ODP proposal by *Broecker et al.* [1991] entitled "North Atlantic climatic variability: sub-orbital, orbital, and super-orbital time scales" stressed the need for such a study.

The initiation of an interdisciplinary and international program is also needed to monitor (1) the present-day morphology and sediment distribution in relation to ocean bottom thermohaline circulation and (2) to determine and model past changes in the "great ocean conveyor belt," which dominates the Atlantic ocean. We need to collect long-term sedimentary records to reconstruct the past heat and nutrient transport, and to use water samplers, velocimeters, and other techniques to document today´s hydrodynamic and sedimentary regimes on drifts along the major pathways of thermohaline circulation. In particular, the circulation models [*Haupt et al.*, this issue] and the reconstruction of past hydrodynamic processes [*Robinson and McCave*, this issue; *Flood*, this issue] will provide pertinent information to select the locations of long sediment cores and to interpret their records. This will allow us to link directly the present day physical oceanography and sedimentary processes with the reconstruction of the past water mass chemistry and water mass flow of the deep-sea conveyor belt.

As the scientific community working on drift sediments and mud waves has already gathered some potential data sets for the North Atlantic and this region is a key region for the understanding of the conveyor belt as driving force, we suggest to concentrate future research on this region. However, we also realize the potential for understanding ocean circulation at locations outside the North Atlantic. This present volume, with other excellent contributions from the world ocean, should be a vehicle for such an initiative, which should be discussed on the occasion of the next International Conference on Paleoceanography meeting in Halifax.

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W. C. Dullo and J. Mienert, GEOMAR, Research Center for Marine Geosciences, Wischhofstr. 1-3, D-24148 Kiel, Germany.

R. D. Flood, Marine Sciences Research Center, Endeavour Hall, SUNY, Stony Brook, NY11794-5000.

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