High-energy contourite settings related to North Atlantic Deep Water flow

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Abstract: *North Atlantic deep convection in the Greenland Sea region and Labrador - Irminger Sea basins leads to strong bottom current activity associated with Greenland-Scotland Ridge (GSR) overflow and deep western boundary current circulation. Seismic records and other evidence (e.g. side scan sonar) document strong bottom current action on the seabed in relation to the Nordic Seas overflow pathway from the Faroe-Shetland gateway via the Southern Greenland margin towards Davis Strait. Seabed evidence from the Greater Antilles Outer Ridge north of Puerto Rico demonstrates strong boundary current activity still persisting far south at western North Atlantic lower latitudes. Geomorphological response to this high-energy bottom boundary current regime is expressed in a variety of dynamic bedforms ranging from mega-scale contourites via well-defined sediment waves, sand ribbons and erosional furrows to small-scale ripple marks. Boundary current activity may interact with other seabed shaping processes as, for instance, downslope mass flow and turbidity currents. Combining known relationships between various bedform types and bottom water dynamics with results from actual current measurements and sediment core studies demonstrate important variations in this flow pattern having had a significant impact on contourite development through time.*

Key words: *Contourite, North Atlantic, Greenland-Scotland Ridge Overflow, North Atlantic Deep Water, bottom current activity.*

INTRODUCTION

Ocean deep convection has a major impact on the environmental conditions and ventilation of the deep ocean basins. In the northern North Atlantic deep convection occurs in the Nordic Seas and Labrador-Irminger Sea basin, from where North Atlantic Deep Water (NADW, Fig. 1) strongly concentrated in the high-energy Deep Western Boundary Undercurrent (DWBU) flows south along the North American continental slope (Dickson and Brown, 1994). Deep convection and associated bottom water flow have, however, been found to display significant variations, both at inter-decadal and at geological time scale (Sy et al., 1997; Kuijpers et al., 2003), with several studies showing a negative correlation between deep convection activity in the Nordic Seas north of the Greenland-Scotland Ridge (GSR) and processes in the Labrador Sea region. Significant deep-water transport from the Nordic Seas via the main GSR gateways, i.e. the Faroe-Shetland Channel system and Denmark Strait, into the North Atlantic Basin has been found responsible for the formation of most of the North Atlantic sediment drifts (Wold, 1994). Many studies have documented climatic control of these overflow processes having been significantly reduced or virtually ceased during glacial climate conditions (Kuijpers et al., 1998).

DATA AND RESULTS

Both seismic and acoustic data as well as sediment core records and seafloor photographs have been used to document seabed morphological and depositional response to cold water, high-energy bottom currents associated with GSR overflow and Labrador Sea Water formation on a transect from the GSR region towards the northern Caribbean. Within this framework detailed attention is given to the Faroe-Shetland gateway, both the southeast and southwest Greenland margin, and to the Greater Antilles Outer Ridge, north of the Caribbean. The data correspondingly show evidence of intense bottom current action along the entire transect under recent, i.e. interglacial, climate conditions. Intermittent, maximum near-bottom current speed inferred from current-induced bedforms exceeds 0.5 $m.s^{-1}$, and may locally reach 1.0 $m.s^{-1}$ or even more (Kuijpers et al., 2002; Kuijpers et al., 2003). The latter maxima particularly apply to the Faroe region and SE Greenland margin. Sediment core evidence from these areas correspondingly indicates a significant reduction in flow speed under full glacial climate, but an interesting difference in overflow activity when focusing on the Younger Dryas. In contrast to the contourite deposits from the Faroe region, contourite development on the SE Greenland margin displays many large-scale features revealing interaction with downslope processes that appear to have been particularly active in relation to glaciations. In contrast, the contourite setting from the SW Greenland margin (Nielsen et al., 2011) shows a more simple alternation of depositional stages characterized by either downslope sediment transport processes (e.g. glacial debris flows, Nielsen and Kuijpers, 2013) or along-slope current transport. Significant long-distance sediment transport associated within the DWBU and associated high bottom current speed is further confirmed by seabed photographs and composition of sediments collected from the Greater Antilles Outer Ridge in the deep, southwestern North Atlantic basin (Kuijpers and Duin, 1986).

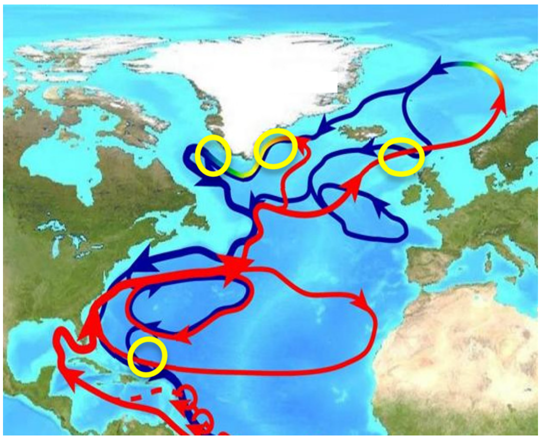

FIGURE 1. Study areas (yellow) with North Atlantic thermohaline circulation pattern. Red and blue arrow lines indicate warm surface and cold bottom water currents, respectively (from NOAA).

DISCUSSION AND CONCLUSION

Significant differences in glacial-interglacial deep water formation and transport patterns have been found, which implies a marked periodicity in the development of North Atlantic contourite systems within the NADW realm. Continental sediment input to the continental slope, rise and adjacent basin is dominated by glacially controlled processes which involve mass wasting, debris flows, turbidity currents and other modes of downslope sediment transport. Re-activation of deep-water formation and associated deep water current activity in course of subsequent deglaciation leads to remobilisation of the previously deposited sediments and thus contributes to the further, intermittent, development of the existing contourite systems. This is, amongst others, also evident from the sedimentary record from the Greater Antilles Outer Ridge, which shows (late) glacial, higher-latitude pollen and turbiditic mineral assemblages initially derived from the North American continent through turbidity flows much further north. If the along-slope processes would be simultaneous with significant downslope processes, instead of a relatively simple, stratified contourite pattern (e.g. Faroe Islands, SW Greenland), a morphologically more complex system may develop. In fact, this is what is observed on the SE Greenland margin (Rasmussen et al. 2003). Several studies indeed do indicate continuation of deep water convection (‘Glacial North Atlantic Deep Water’) south of the GSR during glaciation, which apparently also applies to the Younger Dryas (Kuijpers et al. 2003). We therefore conclude that contourite development in the western part of the Irminger basin, and possibly to some extent also bottom-current controlled deposition on Eirik Drift south of Greenland, may have been more continuous and persistent than in other areas farther away from the Irminger Sea Basin. In these other areas, a distinct shift occurred between along-slope and down-slope transport and depositional regimes. Maximum near-bottom current speed inferred from dynamic bedforms in respective areas in combination with information from long-term current meter arrays confirm variations in GSR overflow intensity and NADW bottom current speed, also under present climate conditions.

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