The radiogenic isotope chemistry of North Atlantic Deep Water during the Neogene recorded by hydrogenous ferromanganese crusts

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North Atlantic Deep Water (NADW) plays a key role in modern ocean thermohaline circulation. General circulation model simulations suggest that before closure of the Central American isthmus, some 3–4 Myr ago, the flow of low-salinity water from the Pacific to the Atlantic would have led to a reduced NADW production. It has been proposed that the changes in ocean circulation and poleward heat transport initiated by Isthmus closure may have led to the growth of continental ice sheets and the intensification of Northern Hemisphere glaciation (e.g. Stanley, 1995). Stable isotope data suggests that the salinity of Caribbean waters did indeed begin to increase around 4 Ma (Keigwin, 1982) and sediment accumulation patterns (Wold, 1994) geophysical data and nutrient proxies (e.g. Raymo *et al.*, 1992) all show evidence of strengthening of NADW flow around 3–4 Ma. However, the same sediment patterns and carbon isotope gradients indicate that NADW flow was stronger at 3–4 Ma than the present time. Furthermore, there is general agreement that NADW has been produced continuously since the late middle Miocene (10–12 Ma) and it also seems likely that there was production of Northern Component Water (equivalent to NADW) during the early Middle Miocene (20–16 Ma) both times when the Isthmus was still open. Finally, evidence suggests that there was minor glaciation during the middle Miocene during an interval of NADW shutdown. Taken together, these observations suggest that if closure of the Central American Isthmus contributed to NADW and glacial intensification then this must have been through a causal or coincident change in the mode of deep-water formation. Recent model simulations suggest that deep-water formation in the Labrador Sea is particularly sensitive to Isthmus closure (Mikolajewicz and Crowley, 1997) whereas it has also been suggested that deep-water production is critically dependent upon overflow across the Greenland-Iceland-Scotland ridge, which in turn is controlled by volcanic activity beneath Iceland.

NADW today comprises a balance of input from the Greenland-Iceland and Labrador seas, and possesses a distinct radiogenic isotope signature (e.g. Nd, Pb and Os) that reflects local input through the erosion of old continental material. This study presents Nd, Pb and Os isotopic records preserved by hydrogenetic ferromanganese crusts from the New England seamount chain, in the western North Atlantic, which lie in the path of NADW on its passage south. Preliminary results for these samples were poorly constrained because Sr isotope stratigraphy did not yield consistent results and by the low resolution of the sampling. Recent Be data for these crusts (O'Nions *et al.*, in press) when taken with the results presented here provides a high-resolution isotopic record of the evolution of NADW during the Neogene. These results indicate that for the interval from 20 to 4 Myr there was no resolvable variation in the Nd or Pb composition of seawater sampled by these crusts. Between 3 and 4 Ma crusts from 2.6 km water depth show a shift in Nd isotopic composition towards a less radiogenic isotope composition (crust ALV539; Fig. 1) whereas for Os and Pb isotope compositions become more radiogenic. A crust from a shallower water depth, around 1.8 km, shows the same isotopic patterns but the shifts in both Nd and Pb did not occur until after 3 Myr (crust BM1969.05; Fig. 1). This could be due either to shoaling of NADW or else an inconsistency in the crust chronologies, but at present available data cannot distinguish between these or other possibilities. However all these records are consistent with a strengthening of the signal associated with NADW between 3 and 4 Ma. As noted above sedimentation

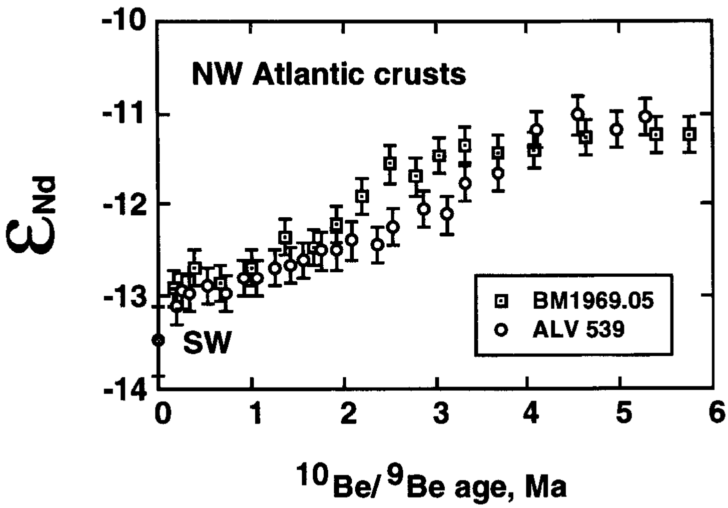

FIG. 1.

patterns and nutrient proxies also indicate an increase in NADW flow around the time of Isthmus closure, but these records do not allow changes in the different NADW sources to be distinguished. Of the major sources of NADW only Labrador Sea Water (LSW) has a composition capable of imposing the unradiogenic Nd composition of 'well mixed' NADW, and these results suggest a gradually increasing contribution from LSW.

Finally, the Fe-Mn crust data themselves cannot distinguish between (i) increased erosional input into the Labrador Sea (ii) changes in the source and hence composition of eroded material or (iii) increased deep-water formation in the same area. Recent model simulations provide some support for an increased rate of deep-water formation in the Labrador Sea following closure of the Central American Isthmus (Mikolajewicz and Crowley, 1997). However, new Nd data for foraminifera and sediments from the Labrador Sea (Vance and Burton, this volume) suggest that there was a significant change in the isotopic composition of the source material being eroded after 2 Ma, which may, in turn, reflect a change in the style of erosional transport accompanying Northern Hemisphere glaciation.

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