A high-resolution benthic foraminiferal carbon-isotope record (Friedrich et al., 2009) enables inter-site correlation to the other sites of this study (

formation near the sediment–water interface and are generally robust to later alteration (Gutjahr et al., 2007; Martin et al., 2010). To evaluate the quality of Nd-isotope data from ferromanganese coatings as archive of the ε

late Campanian–

Thomas, 2006

Extended shelf seas prevailed due to the high sea level until the Maastrichtian. Although the mode of exchange between shelf and oceanic water masses is largely unknown for the Cretaceous, the shelves most likely served as multiple source areas for distinct intermediate waters. Thus, the Nd-isotopic composition at upper bathyal depths of Exmouth Plateau (Site 762) suggests the presence of a water mass that acquired its isotopic signature from contributions of continental sources and was not dense enough to sink to abyssal depths (Fig. 6). Similarly, the Nd-isotope signatures at bathyal sites of the Falkland Plateau (Site 511) (Robinson et al., 2010), Demerara Rise (MacLeod et al., 2008, 2011) and Goban Spur (Martin et al., 2012) differ significantly from those at abyssal sites (Robinson and Vance, 2012), thus predominantly reflecting local weathering contributions from the hinterland.

Modern intermediate and thermocline waters are formed by subduction along the Subtropical and Polar frontal systems forced by the wind stress of the westerly winds (Hay, 2008). The stability of westerly wind forcing is maintained by the polar high pressure cell related to the presence of permanent ice shields today. The situation in the Cretaceous was completely different. The lack of permanent polar ice together with the palaeogeographic constellation of an isolated Arctic ocean, an almost isolated North Atlantic and a narrow South Atlantic might have resulted in seasonally pronounced latitudinal and longitudinal shifts of the atmospheric low and high pressure cells in polar areas and the development of variable wind systems at mid-latitudes (Hay and Flögel, 2012). Hay (2011) proposed a model, in which the instability of the westerly wind system favours the formation of meso-scale eddies instead of oceanic frontal systems. Deep oceanic convection was achieved by down- and upwelling of water masses in anticyclonic and cyclonic eddies. Their position was strongly controlled by the geometry and bathymetry of ocean basins and density differences among water masses were mainly controlled by salinity changes related to the regional balance of evaporation and precipitation. Our compilation of new and available seawater Nd-isotope data clearly shows the broad variety of Late Cretaceous abyssal seawater Nd-isotope signatures. Such a pattern is difficult to maintain under conditions of large scale globally connected deep water convection. Furthermore, the tectonic restrictions in the young Atlantic Ocean inhibited the development of a global thermohaline circulation system encompassing all ocean basins. Although the “Hay Ocean” is only a hypothesis, the growing evidence of distinct seawater Nd-isotopic compositions in different Late Cretaceous sub-basins supports the idea that deep ocean site investigated, which suggests a circulation system that was fundamentally different from the modern. In particular, the occurrence of a water mass with a radiogenic Nd isotope signature on top of the RWS indicate this structure to have been a barrier for deep-water exchange between the Southern Ocean and North Atlantic basins until the late Maastrichtian. The narrow geometry of the Atlantic Ocean together with tight to closed connexions towards the Tethys and the Pacific Ocean limited volumetrically substantial deep-water exchange and promoted a local mode of deep oceanic convection in the Atlantic. Available Nd isotope data from the North Atlantic indicate the prevalence of different water masses in the abyssal plains and support a mode of ocean circulation that was maintained by down- and upwelling in various meso-scale eddies as proposed by Hay (2011).

Climatic cooling as evident from the benthic $\delta^{18}O$ compilation (Friedrich et al., 2012; Zachos et al., 2008) and the opening of gateways between 83 and 78 Ma may have initiated SCW formation in the southern hemisphere oceans (Robinson and Vance, 2012; Robinson et al., 2010; Martin et al., 2012). However, distinct deep water Nd-isotopic compositions in different Late Cretaceous sub-basins in the young Atlantic Ocean suggest that tectonic restriction instead of climate change controlled deep-water formation there. SCW formation did not drive global ocean circulation before gateway opening and mid-ocean ridge subduction further deepened ocean basins (Müller et al., 2008) between 68 and 58 Ma. These consecutive plate-tectonic events played a crucial role in the global linkage of oceanic deep-water reservoirs and the establishment of a similar to modern global thermohaline circulation system.

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