Pb and Nd isotopic evolution of global seawater during the last 60 Ma from ferromanganese crusts

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Hydrogenetic ferromanganese crusts (hereafter called crusts) scavenge and incorporate trace metals from ambient seawater and thereby record its isotopic composition with respect to Nd and Pb. Isotopic time series of these elements determined on crusts from the Atlantic, Indian and Pacific oceans (TIMS and MC-PSMS measurements) are applied to reconstruct the Nd and Pb isotope composition of global deep-water for the last 60 Ma which is expected to vary as a consequence of major palaeogeographic changes. Age-depth relationships were determined using $^{10}Be/^{9}Be$ profiles of the same crust sections (measured by ISOLAB). For crust sections older than 12 Ma the growth rates derived from the $^{10}Be/^{9}Be$ ratios were extrapolated to the base of the crust and were verified for Co-rich Pacific seamount crusts applying a Co-constant flux approach (Puteanus and Halbach, 1988) (Fig. 1). For Co-poor deep-water and seamount crusts a modification of the Co-based method of estimating ages is presented which extends its applicability to all hydrogenetic crusts.

Reconstruction of Tertiary seawater Pb and Nd isotopic composition

The strong provinciality of the ocean's dissolved Nd isotope distribution between the 3 ocean basins which was observed from water column data and ferromanganese nodule and crust studies has persisted over the last 60 Ma although major palaeoceanographic and palaeogeographic events such as the opening and closing of oceanic gateways and the uplift of the Himalayas occurred over this period of time (O'Nions *et al.*, in press.).

The isotopic distribution of Pb in the ocean which during the last 300 kyr has shown a provinciality similar to Nd (von Blanckenburg *et al.*, 1996) was expected to have even been more controlled by regional inputs due to its shorter oceanic residence time. Surprisingly, the 3 ocean basins show a clear separation in the $^{206}Pb/^{204}Pb$ and $^{207}Pb/^{206}Pb$ ratios only for the last ~5 Ma. Prior to this a separate Indian Ocean signal is not observed. Our data imply that the Pb isotope composition of the Indian sector of the Southern Ocean (crust 109D-C) separated from an Atlantic-type signal only ~5 Ma ago. This was caused by a combination of influences from the closure of the Panama Gateway and the enhancement of input of material with a highly radiogenic Pb isotope composition into the north Atlantic Ocean since the onset of northern hemisphere glaciation. In contrast, the northern Indian Ocean $^{206}Pb/^{204}Pb$ and $^{207}Pb/^{206}Pb$ signature (crust SS663) became distinct from a Pacific-type signature ~15 Ma ago. This is related to the evolution of the Indonesian Arcs which have inhibited water mass exchange between the Pacific and Indian Ocean basins but also have delivered erosional material with a distinct Pb-isotopic composition since that time. Similarity of the Pb isotopic composition of the Atlantic and Pacific Pb isotopic data prior to 45 Ma ago suggests efficient water mass exchange between the two basins at that time.

Whilst crust 109D-C obviously has been constantly bathed in Circum Polar Deep-water (CDW) over the last 20 Ma, crust SS663 from the northern Indian Ocean has recorded the history of Himalayan uplift for the last about 26 Ma in its $^{208}Pb/^{206}Pb$ ratios (Fig. 2). The record of this crust confirms rapid exhumation of the Himalayas starting ~20 Ma ago and a decrease of erosional input into the Bengal Fan at about 7.5 Ma ago.

The comparably weak impact of Himalayan erosion products on the Nd isotopic composition of SS663 may either be interpreted as a mass balance effect between Nd and Pb in the erosional input and the deep-water or as a consequence of the more efficient mixing of Nd in the ocean. Crust VA16 13KD-1 (not shown) from the eastern Indian Ocean, work on which is still in progress, apparently shows typical CDW values in Pb and Nd isotopes for most

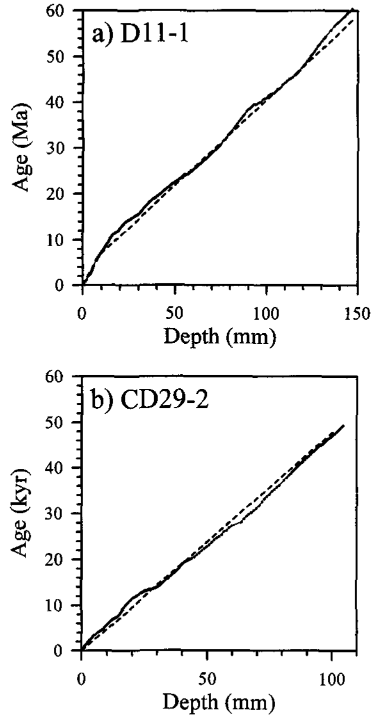

FIG. 1. Comparison between $^{10}Be/^{9}Be$ (dashed line) and Co-constant-flux (diamond symbols and solid line) dating approaches.

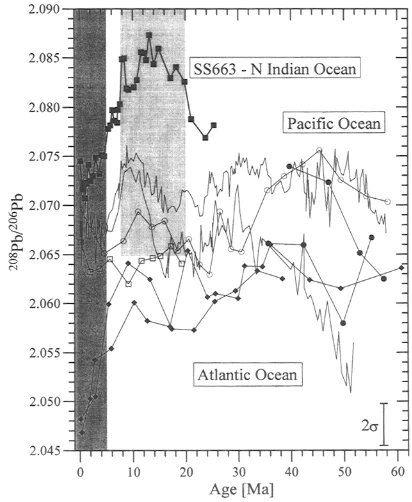

FIG. 2. $^{208}Pb/^{206}Pb$ of crust SS663 from the northern Indian Ocean () and other records from the southern Indian Ocean () (O'Nions *et al.*, in press), the North Atlantic () (Burton *et al.*, 1997; O'Nions *et al.*, in press), and the Pacific (no symbols) (Christensen *et al.*, 1997), (°,) (Ling *et al.*, 1997). Note that the northern Indian Ocean record is not intermediate between the Pacific and Atlantic, as is the case for other Pb isotope ratios and Nd isotopes. The darkly shaded period marks the last 5 Ma and the lightly shaded period represents the peak $^{208}Pb/^{206}Pb$ ratios in SS663.

of the last 60 Ma. An increase in ε_{Nd} from values around -6.5 prior to 9 Ma ago to -5 at present can not be explained by the closure of the Indonesian Gateway to deep-water exchange but is ascribed to the increasing input of weathering products from the Indonesian Arcs. In summary, Pb isotopes appear to be more sensitive to palaeogeographic and palaeoceanographic changes than Nd despite the opposite expectation from their respective residence times but it must be noted that information on the input of Pb isotopes from the continents poor. Local effects may at least partly be responsible for the observed features.

High precision Pb isotope time-series (MC-PSMS)

Two high precision Pb isotope time series from southern Indian Ocean crusts (109D-C and VA16 13KD-1) which were measured applying a newly developed technique on a multiple collector plasma source mass spectrometer (MC-PSMS) complement the study. Applying a $^{203}Tl/^{205}Tl$ spike it is possible to determine Pb isotopic compositions by a factor of 5–10 more precisely than by conventional TIMS, with even less effort for chemical preparation. These high precision measurements provide more reliable and more detailed information about the variability of the Pb isotopic composition of the deep southern and eastern Indian Ocean during the Tertiary.

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