Precise measurement of growth rate variations in Atlantic, Indian and Pacific ferromanganese crusts, derived from $^{10}Be/^{9}Be$ ratios

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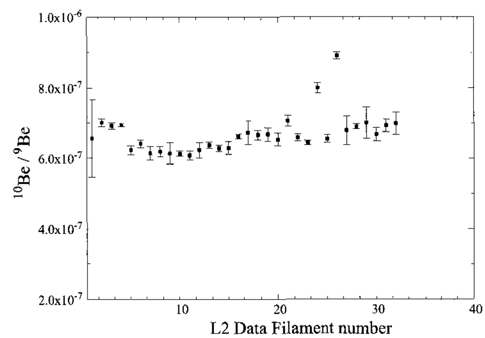
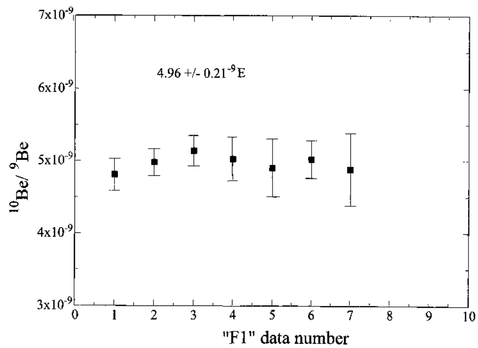
Ferromanganese crusts provide an important record of palaeoceanographic conditions through their trace element and isotopic signatures. The unlocking of information contained within crust growth layers requires reliable and precise dating. We will present a synthesis of dating results so far produced from ferromanganese crusts using $^{10}Be/^{9}Be$ ratios measured on the Oxford ISOLAB120.

Alternative attempts to date crusts have included the comparison $^{87}Sr/^{86}Sr$ profiles with the global seawater $^{87}Sr/^{86}Sr$ curve, (Burton *et al.*, 1997; Ling *et al.*, 1997) but with only one consistent data set providing meaningful age information having so far been generated (Burton *et al.*, 1997). These data, however, disagree with the $^{10}Be/^{9}Be$-based dating approach on the same crust. ^{230}Th and ^{231}Pa profiles have been employed but they only yield information on growth rates over the last 300 and 150 kyrs, respectively. A Co constant flux model, which is based on an empirical relationship between Co content and radiometrically derived growth rate, has proved to be a valid approach for Co-rich equatorial Pacific seamount crusts (Puteanus and Halbach 1998), but does not appear to be generally applicable to crusts from other parts of the world's oceans.

Direct measurement of the $^{10}Be/^{9}Be$ ratio of crust surfaces has shown that each ocean basin has a distinct signature (von Blanckenburg *et al.*, 1996) that is assumed to have remained constant over the period of growth of the crusts studied. Using a ^{10}Be half-life of 1.5 Ma, Ling *et al.* (1997) analysed three crusts from the Pacific and gained a consistent data set of the Nd- and Pb-isotopic evolution of the Pacific Ocean. $^{10}Be/^{9}Be$-based dating of crusts has also been applied successfully to crusts from the Atlantic and Indian oceans, implying that $^{10}Be/^{9}Be$ ratios provide a robust dating tool for element or isotope time series data in ferromanganese crusts from the world,s oceans.

Direct measurement of the $^{10}Be/^{9}Be$ ratio removes the problem of variations caused by dilution effects which are encountered in dating approaches which only utilise measurements of a single isotope. The sampling resolution, which on average corresponds to 0.5 Ma, integrates over variations in the global ^{10}Be flux caused by changes in production rate of





FIGS 1 (*left*) and 2 (*right*) show the reproducibility of the F1 and L2 standards. Data for standard F2 shows the internal error for individual analyses is approximately 40%, the main contribution to this large error originates from counting statistics.

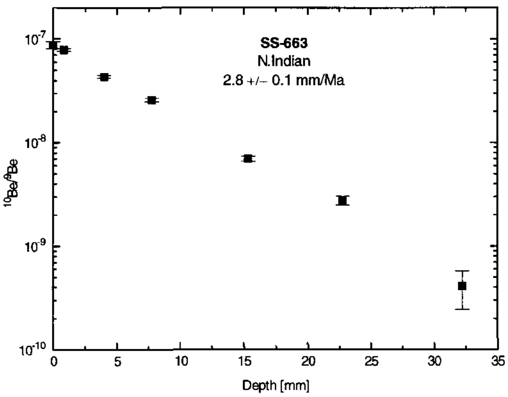


FIG. 3. $^{10}Be/^{9}Be$ profile from crust SS-663 from the Indian Ocean. (Frank and O'Nions, 1998).

^{10}Be as a result of magnetic field strength and cosmic ray flux variations. Production rate changes of ^{10}Be should therefore not affect the dating results.

Refinements to the original analytical technique of Belshaw *et al.* (1994) have led to improvements in measurement precision of $^{10}Be/^{9}Be$ ratios. Changes to the data acquisition routine on ISOLAB have allowed reproducibility to be improved by more than a factor of 2, to less than 2% for the 1σ error. Sample preparation and loading has also been improved allowing longer counting times and greater ionisation efficiency of the sample. Calculated total efficiencies are in the order of 0.1% ions per atom, from preparation of samples to collection of ions during analysis. This has been particularly important for allowing the measurement of very low $^{10}Be/^{9}Be$ ratios, $< 5 \times 10^{-9}$, where ion counting statistics are the major contributing factor to the overall error of each sample. The improvements have also allowed the amount of Be required for an analysis to be reduced to 5 ng.

Two in house dilutions of NIST SRM3105a have been produced, F1 and F2, the $^{10}Be/^{9}Be$ ratios of which have permitted an assessment of the linearity of $^{10}Be/^{9}Be$ measurements on ISOLAB over a range from 1×10^{-6} to 1×10^{-10}. These standards have also yielded reproducible data at ratios of $^{10}Be/^{9}Be = 5 \times 10^{-9}$ with a 1σ error of 2% and at $^{10}Be/^{9}Be = 5 \times 10^{-10}$ with a 1σ error of 20%. For comparison, $^{10}Be/^{9}Be$ values from Fe-Mn crust surfaces are at maximum 1.3×10^{-7} and therefore crust profiles can be measured reliably over the period of the last ~10Ma, corresponding to 6-7 half lives of ^{10}Be.

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