Heterogeneity and scatter of helium isotopic ratios in MORB

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Introduction

The statistical analysis of the isotopic ratios of Sr and Nd in Mid Oceanic Ridge Basalts world-wide have shown, that there exists a relation between the dispersion of the isotopic data and the spreading rate of the ridge (Allègre *et al.*, 1984; Holness and Richter, 1989). One conclusion of these studies was the so-called 'blob cluster' model (Allgre *et al.*, 1984; Allègre and Turcotte 1985).

Here we present a similar study for the $^4He/^3He$ ratios for different ridges, North Atlantic, South Atlantic, East Pacific Rise, South West Indian Ridge, Central Indian Ridge, Reykjanes Ridge and the Juan de Fuca Ridge. We used a total of 490 individual data points, about 150 from our own laboratory, the remaining 340 data from the litterature. In order to avoid the larger weight of multiple analyses of samples, we calculated the mean value for each dredge and result in 228 different dredges (Tables 1).

Even though the mean values for different ridge segments are not dramatically different (except Reykjanes Ridge, Table 1), the standard deviations, reflecting the scatter show significant variations, which can be related to the spreading rate of the ridge segment. Ridge segments which are characterized by small spreading rates show larger standard deviations (see SWIR) than segments which are characterized by high spreading rates (Central Indian and Carlsberg Ridge). We plotted this example in Figure 1: $^4He/^3He$ ratios versus latitude for samples from the Indian Ocean (note that north is to the right and south to the left). The inset ilustrates the mean spreading rate for the same area. While $^4He/^3He$ ratios of samples from the South West Indian Ridge (SWIR) show a large scatter between 74,000 to 115,000, combined with a small spreading rate of 1.7 cm/year, the scatter is much smaller for samples from the Central Indian (CIR) and Carlsberg Ridge, which show larger spreading rates between 3 to 5 cm/year. The results for other ridges are shown in Figure 2, where the standard deviations are plotted versus spreading rates on a logarithmic scale.

$^4He/^3He$ heterogeneities in the upper mantle are formed either through ^3He-rich plumes from the lower mantle or ^4He-rich blobs from old subducted sediments (ex. Allègre and Turcotte, 1985).

As spreading rates are related to mantle convection, the most simple interpretation for such a correlation (Figure 2) is the effect of mixing through convection. It seems that world-wide, the mean $^4He/^3He$ ratio is amazingly constant (Table 1), however mantle domains which are characterized by rapid convection may wipe out heterogeneities quite quickly, while mantle domains characterized by slow convection and small

TABLE 1.

Ridge segment:	number of dredges	mean $^4He/^3He$	standard deviation	spreading rate [cm/year]
North Atlantic	47	89376	9597	2.3
South Atlantic	52	92647	6146	3.5
SWIR	14	92431	10708	1.7
CIR + Carlsberg	25	85273	4682	3.6
Reykjanes Ridge	22	41617	7937	1.9
Juan de Fuca	25	87771	3511	6.0
Pacific	43	83052	7930	13.4

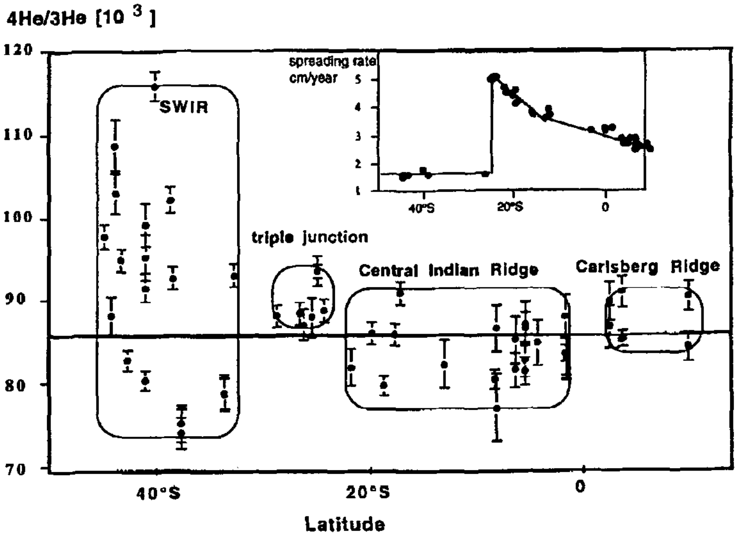

FIG. 1.

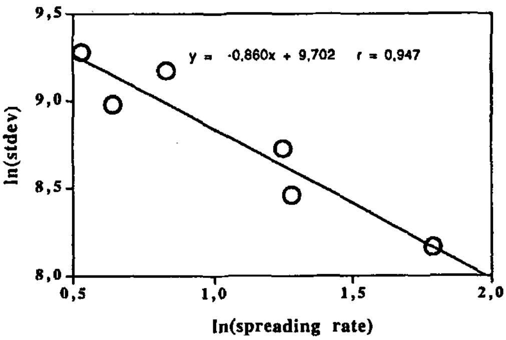

FIG. 2.

spreading rates maintain such heterogeneities over larger time scales.

The only exception in this picture represents the East Pacific Rise, which has an extremely high spreading rate of 13.4 cm/year and should show the most uniform $^4He/^3He$. This is not the case (Table 1). The reason for that could be the extremly high concentration of hot spots and seamounts in this area.

References

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