DUPAL volatiles: New results on the South West Indian Ridge, EDUL cruise (Aug/Sept. 97)

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A sampling cruise (EDUL) has taken place in August 1997 along the axis of South West Indian Ridge (SWIR), between the Rodriguez triple Junction (RTJ) and 49°E. Despite its great geological interest, this ultra-slow spreading ridge (half spreading rate of 7–8mm/y) was only little sampled before. It actually covers the zone of maximum DUPAL anomaly (e.g. Dupré and Allègre, 1983; Hart, 1984) and is one of the less productive spreading centres of the Earth, associated with a very cold to cold mantle structure.

The present study was carried out to constrain the composition of the mantle source in terms of its volatile contents and to investigate what controls carbon, water and nitrogen contents and isotopic compositions ($\delta^{13}C$, δD and $\delta^{15}N$) in MORB. The exceptionally large variation of depth along the SWIR ocean floor (decreasing from the RTJ to the South-West) is ideal to test pressure-induced degassing effects.

New Fourier Transform Infrared (FTIR) and crushing experiments have being performed on samples from the SWIR together with Central Indian Ridge (CIR), the South East Indian Ridge (SEIR) and RTJ MORB glasses. These new data can be compared on one hand with previous results on step-heating extraction and crushing experiments on CIR, SEIR and RTJ samples (Jendrzejewski, 1994) and with worldwide MORB on the other hand.

Analytical methods

Concentrations of dissolved water and carbon were measured using Transmission FTIR Spectroscopy on doubly-polished basaltic glass wafers (70–250 μ). The molecular absorptivity of carbonate ions at 1,522 cm^{-1} and OH^- groups at 3,540 cm^{-1}, used in this study, are respectively 398 and 78 $l.mol^{-1}.cm^{-1}$ (Jendrzejewski *et al.*, 1996).

Gases (N_2, CO_2, H_2O) from vesicles were extracted by crushing the samples (1–3 g) under ultrahigh vacuum (N_2 blanks $< 0.5 \times 10^{-11}$ mol N_2). The extraction line, routinely used to measure nanoquantities of nitrogen in diamonds (Cartigny *et al.*, 1997), is on-line with a static Mass Spectrometer (MS). Elemental ratios, concentration and isotopic composition of nitrogen ($\delta^{15}N$) were determined by static MS whereas carbon concentrations were determined manometrically before dynamic MS determination of the $\delta^{13}C$. Both $\delta^{15}N$ and $\delta^{13}C$, thus determined on a single aliquot of sample, are given in delta units (‰) relative to air for N and to PDB for carbon.

Results and discussion: Dissolved volatiles

Water concentrations observed on the preliminary 25 results obtained on the SWIR MORBs (1,200–3,700 ppm H_2O) give ranges similar to CIR (1,140–4,770 ppm H_2O), SEIR (1,207–3,390 ppm H_2O) or worldwide (1,000–5,000 ppm H_2O) basalts.

However, whereas the water content on the SEIR seemed to increase regularly from the RTJ to the island of St Paul (965 to 3,390 ppm H_2O) and on the CIR from the RTJ to the connection with the Carlsberg Ridge (1,190 to 4,770 ppm H_2O) (Jendrzejewski 1994), the water content on the SWIR appears maximum close to the RTJ and minimum westward.

Carbon contents determined on samples from the central and south-east ridges were variable (31 to 95 ppm C, Jendrzejewski, 1994). Carbon contents of SWIR MORB vary between 53 and 109 ppm C. Considering the often greater depths of eruption of MORB from the SWIR relative to the CIR and SEIR, these ranges are equivalent. Moreover, the SWIR results are as well within the range of worldwide MORB erupted at similar depths (30–150 ppm C).

Several trends are observed between either the depth of eruption (carbon) or the position of the sample on the ridge (water). We attempt to discriminate between the possible processes which could have produced these trends (i.e. degassing, mixing, partial fusion or crystallisation etc...) by considering the volatiles contents/isotopic compositions in relation to the depth (pressure) of eruption and geological setting. The differences in water contents of the erupted MORB are believed to reflect mantle temperature, degree of melting and source differences. The variation in water contents is likely to have influenced the extraction and differenciation of magmas and is thus important to consider relative to the chemistry of the erupted MORB.

Volatiles in bubbles

New crushing experiments allowing the determinations of both carbon and nitrogen isotopic compositions, have been performed on 36 samples from: the SWIR (EDUL cruise; n = 30), the CIR (n = 2), the SEIR (n = 2) and the RTJ (n = 2).

All $\delta^{15}N$ values obtained on the SWIR vary between −6‰ and 0‰ (±0.5‰) without any strictly positive value. C/N ratios are variable (from 6 to 1,250) even though a majority of sample shows typical mantle C/N values (300–500; Javoy and Pineau, 1991). Uncalibrated to air N/Ar ratios are relatively constant (between 37 and 78 with one exception at 124) and in the mantle domain. However, a finer examination of this ratio seems to reveal different sub-domains coupled with $\delta^{15}N$. $\delta^{13}C$ values of SWIR MORB vary from −8.4 to −5.0‰. They are well comparable to other Indian Ocean MORB and normal MORB worldwide, reflecting average outgassing features.

In terms of ranges of $\delta^{15}N$, $\delta^{13}C$, C/N and Ar/N, the Indian Ocean seems normal compared to the unfortunately limited number of data from other oceans.

The interpretation of $\delta^{15}N$ alone (e.g. Marty and Humbert, 1997) could be misleading. This study coupling $\delta^{15}N$, $\delta^{13}C$, elemental ratios (C/N, Ar/N) shows that all these parameters have to be considered together in order to discriminate between degassing effects, late mixing (e.g. with air or air-saturated sea water) or source differences.

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