Incomplete outgassing of very gas rich MORB from the Mid-Atlantic Ridge at 14°N

Y. Bottinga — Lab. Géochimie et Cosmochimie, URA CNRS-1758, Institut de Physique du Globe, 4, place Jussieu, 75252 Paris, France

M. Javoy — Lab. Géochimie des Isotopes Stables, URA CNRS-196, Institut de Physique du Globe, 4, place Jussieu, 75252 Paris, France

The samples dredged along the Mid-Atlantic Ridge between 8 and 16°N by the R/V *Akademic Boris Petrov* (Vernadsky Institute for Geochemistry), listed in Staudacher *et al.* (1989) and chemically analysed by Bougault *et al.* (1988) and Dosso *et al.* (1991) resemble very much normal MORB. The reason for fame of these samples is that among them were the samples from one dredge haul close to 14°N, known as 2ΠD43, which contained extra ordinary quantities of volatiles reported by Staudacher *et al.* (1989), Sarda and Graham (1990), Javoy and Pineau (1991), Pineau and Javoy (1994), Burnhard *et al.* (1997), and Moreira *et al.* (1998). Besides the porosities of 17 and 5% of 2ΠD43 samples indicated that they contained substantially more gas when they erupted than has been measured by the here fore cited authors. The volatile contents of samples from the other dredge hauls were MORB like with porosities varying from 1 to 3% (Staudacher *et al.*). The enrichments of rare gas isotopic concentrations in 2ΠD43, with respect to the average concentration of the other BP samples amount to factors of 5, 50, 100 and 140, for both helium isotopes, for ^{40}Ar, for ^{20}Ne, ^{36}Ar, and ^{130}Xe, and for ^{84}Kr, respectively. The 2ΠD43 samples were dredged from 3510 m below sea level.

The temperature of and the pressure on the erupting 2ΠD43 lava were larger than those for the overlying deep sea water, and its rare gas, CO_2 and N_2 concentrations are significantly larger than those found in deep sea water. These conditions stand in the way of contamination, implying always a diffusion step, by atmospheric gases in deep sea water. The inferred absence of important atmospheric contamination of the lava at eruption time or while it flowed upwards towards sea bottom is also indicated by the results of the step crushing experiments of Staudacher *et al.* (1989) and Moreira *et al.* (1998) on 2ΠD43. Their data show that most small bubbles had smaller ^{36}Ar/^{40}Ar ratios than the larger ones. If important contamination had taken place the the opposite should have been observed because: (i) ^{36}Ar diffuses faster in the melt than ^{40}Ar, (ii) the mean distance between the small bubbles is smaller than between the large ones, (iii) the surface/volume ratio of a given volume of small bubbles is larger than that of the same volume of large bubbles, and (iv) the atmospheric and deep sea water ^{36}Ar/^{40}Ar ratios are larger than those of 2ΠD43.

Usually, oceanic tholeiites, on their way up to the sea floor, stay for a certain time interval in a magma chamber. During this pause in their ascension, these lavas exsolve volatiles in bubbles. The great majority of these bubbles escape before and during expulsion of lava from the magma chamber. Therefore, upon eruption the total CO_2, N_2 and rare gas contents of the lavas correspond roughly to the dissolved equilibrium concentrations under magma chamber conditions.

We think that the 2ΠD43 lava, on its way up, bypassed a magma chamber stage, as is also inferred for xenoliths-bearing alkali-rich oceanic island lavas. As a result, the 2ΠD43 lava degassed very incompletely in the relatively narrow conduit leading to the sea floor. The degassing caused rheological changes, very turbulent two phase flow, and the occurrence of coalescence and fission of bubbles. These conditions give rise to a spatially varying bubble distribution and the observed local lack of correlation between the small ^{36}Ar and the large ^{40}Ar concentrations. The faster diffusing helium isotopes manage to maintain a homogeneous distribution, hence the linear correlation between ^{3}He and ^{4}He concentrations remains indistinguishable from ^{3}He and ^{4}He concentration correlations shown by MORB and the other BP samples.

This incomplete degassing process, at depth greater than sea bottom, can explane the difference between 2ΠD43 and BP samples. The latter ones degassed to an approximate equilibrium level under magma chamber conditions. They were quenched shortly after being expelled from the magma chamber. The relative sizes of the deficits of the different rare gases of the BP lavas with respect to 2ΠD43 are in the order of decreasing solubilities in silicate melts. The most soluble gas, He, shows the smallest and the heavy rare gases which are the least soluble ones, the greatest deficits.