^{3}He Exposure Dating of Magnetite

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Although the production rate of cosmogenic ^{3}He is very high and the analytical procedures for its measurement are generally faster and cheaper than those of other cosmogenic isotopes including ^{10}Be, ^{21}Ne, ^{26}Al, and ^{36}Cl, widespread application of ^{3}He exposure dating is limited by the paucity of phases which are suitable for ^{3}He measurement. In particular we require phases that quantitatively retain ^{3}He at Earth surface conditions and which do not have high concentrations of indigenous ^{3}He. Olivine and pyroxene are frequent targets for ^{3}He studies, but these phases are generally absent in granitoids and most other rock types dominating the continental landscape. In this study, we report new ^{3}He measurements on magnetite, an accessory phase common to most continental rock types. Our experiments, as well as those of others (e.g., Fanale and Kulp, 1962), leave little doubt that magnetite quantitatively retains helium at Earth surface temperatures. We are presently investigating whether fluid inclusions or the reaction ^{6}Li(n,α) ^{3}H$\longrightarrow^3$He are important sources of ^{3}He in magnetite by crushing experiments, measurements of Li concentration, and by analysis of magnetites obtained from deeply shielded tunnel samples.

We have also attempted cosmogenic dating of magnetites from the Dry Valleys of Antarctica to constrain the cosmogenic production rate. Magnetite was separated from crushed rock using a weak hand magnet and leaching with dilute HF to disaggregate composite grains. Although the magnetites have ^{4}He concentrations of up to ~ 10 μcc/g, these high concentrations do not preclude accurate ^{3}He determinations. Measurements on co-existing pyroxene and magnetite separates from a Ferrar dolerite boulder coupled with ^{3}He production rates in Ferrar pyroxenes outlined by Schäfer et al. (1999) suggest a magnetite ^{3}He production rate of 69 - 77 atoms $g^{-1}\,yr^{-1}$, in excellent agreement with values predicted by Masarik and Reedy (1996). Our preliminary results indicate that magnetite may be a useful phase for cosmogenic ^{3}He dating of many common lithologies.

References

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High-precision Nb/Ta and Zr/Hf ratios in global MORB

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The geochemical twins Nb-Ta and Zr-Hf provide important insights into the melting processes beneath mid-oceanic ridges (MOR), because their ratios are generally little fractionated during magma chamber processes. The concentrations of HFSE (Nb, Ta, Zr, Hf and Lu) were determined to high precision for representative samples from various MOR. The HFSE were measured by isotope dilution using the MC-ICPMS at Münster [1]. The external reproducibility is ±4% for Nb/Ta and ±0.6% for Zr/Hf (2σ), thus improving the analytical resolution nearly by a factor of 10 compared to older techniques.

The dataset includes basalt samples from spreading centers in each of the major ocean basins (S-Atlantic Ridge, East Pacific Rise, Pacific-Antarctic Ridge, Kolbeinsey Ridge, Garrett Fracture Zone and Atlantis Fracture Zone II) covering the full range of spreading rates. The selected samples are variably depleted in incompatible trace elements; Nb varies from 0.27 to 38 ppm, Nb/Ta range from 11.5 to 16.6 and Zr/Hf from 27.7 to 43.6. The Nb/Ta ratios correlate well with Zr/Nb (4.6 to 121.2), but only poorly with Zr/Hf. There are no systematic differences in Nb/Ta and Zr/Hf ratios between ridges from different oceans. The observed patterns confirm that the incompatibility of HFSE increases in the order Hf, Zr, Ta and Nb [2].

The different HFSE ratios of the samples cannot be modelled by partial melting from similarly depleted peridotites. Both the overlap in HFSE ratios between samples from different ridges and the large spread in HFSE concentrations rather indicate the presence of small scale source heterogeneities. Such source heterogeneities reflect multiple melt extraction events as indicated by poorly correlated Zr/Hf and Nb/Ta. The overlap of the element ratios between different ridges furthermore suggests that the degree of depletion is independent of the spreading rate.

Experimental partitioning data for cpx [3] and garnet [4] predict positively correlated Nb/Ta and Zr/Hf ratios in melts. The observed poor correlation of these two element ratios can be explained by different melt porosities, leading to different portions of instantaneous melt that is retained in the peridotites. This process would affect the highly incompatible Nb-Ta to a larger extent than the more compatible Zr-Hf ratios in the MORBs. Nb/Ta and Zr/Hf ratios in MORBs reflect the combined processes of previous and current melt extraction. - We thank D. Mertz, Y. Niu, M. Regelous and J. Snow for providing samples.

[1] Münker et al. (2001), G3, 2. [2] Niu and Batiza (1997), EPSL 148, 471-483., [3] Blundy et al. (1998), EPSL 160, 493-504. [4] van Westrenen et al. (2001), G3, 2.