Vapor undersaturation in primitive mid-ocean ridge basalt and the volatile content of the Earth's upper mantle

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We present the first report of undersaturated pre-eruptive volatile content for a suite of mid-ocean ridge basalts (MORB) from the Siqueiros intra-transform spreading center. The undersaturation leads to correlations between volatiles and refractory trace elements that provide new constraints on volatile abundances and behavior in the depleted upper mantle. The constant CO_2/Nb ratio of the samples shows that CO_2 is a highly incompatible element during MORB generation and constrains the abundance of CO_2 in the mantle source of ocean ridge basalts to (100±40 ppm), substantially lower than most previous estimates. The incompatible behavior of CO_2 and CO_2/Nb ratio permits primitive CO_2 estimates to be made for degassed MORB magmas, and hence constrains degassing histories. The volatile-rich "popping rocks" that have led to previous high CO_2 estimates for the upper mantle have very high volatile contents in large part because of their incompatible element enrichment (e.g. very high Nb). Our results and the relatively constant $CO_2/^3He$ ratio for MORBs (2.2 X 109)[1] allow constraints on the extent of ^3He degassing in MORBs, the ^3He flux at ridges (586±234 mol/y), and the 3He content of the upper mantle (1±0.4 X 10-15 mol/g). These latter values are consistent with some of the most recent modeling estimates[1]. The constant ratios of H_2O/Ce, F/P, S/Dy and Cl/K in glasses and melt inclusions, and previous estimates of the trace element content in the MORB mantle[2,3] also generate new constraints on the abundances of H_2O (160±40 ppm), F (16±3 ppm), S (150±20 ppm) and Cl (1±0.3 ppm) in the Earth's upper mantle. These abundances are much lower than estimates for the source regions of hotspots, indicating the presence of volatile heterogeneity in the Earth's mantle.

References

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An alternative hypothesis for the origin of the high ^{226}Ra excess in mid-ocean ridge basalts

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Complex melting and percolation models with one or two porosity system have been proposed to explain the extreme ^{226}Ra excess observed in MOR lavas[1]. In here, we present the alternative hypothesis that interaction of MORBs with plagioclase-rich cumulate could be responsible for their high ^{226}Ra excess. For this study, we selected one of the most primitive sample suites in the East Pacific Rise, the Siqueiros intra-transform spreading magmatism. Picrites from this area have one of the highest ^{226}Ra excess ever recorded for MORBs, with ($^{226}Ra/^{230}Th$) activity ratios ranging from 3 to 4[2]. Our results show that the Siqueiros picritic glasses and olivine-hosted melt inclusions are extremely depleted in major and trace element compositions, with the most depleted melt inclusions having trace element patterns with strong enrichment in Sr content, resembling the pattern of plagioclase cumulates. The unusual geochemical signatures of the Siqueiros picritic magmas can be explained by low extent of melting of the residual mantle left after MORB extraction at the top of the melting column and interaction of those depleted melts with plagioclase-rich cumulates (gabbro or troctolites) formed by the differentiation of previous MOR magmatism. The interaction of depleted melts and young (<1000 y) plagioclase-rich cumulates provide an alternative interpretation for the origin of the extreme ^{226}Ra excess measured in MORB. Our calculations suggest that bulk plagioclase assimilation by a primitive plagioclase-undersaturated basalt or diffusive re-equilibration of Ra between plagioclase-rich cumulate and mafic lavas can explain the observed ^{226}Ra excess in MORB. Moreover, new diffusion models (Van Orman et al., in preparation) indicate that the plagioclase-rich cumulate not necessarily has to be young, but it could be old (>1000 y) and still produce high ^{226}Ra excess in MORBs during basalt-plagioclase cumulate interaction.

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