Behaviour of High Field Strength Elements in Subduction Systems

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Importance of High Field Strength Elements

Knowledge of high field strength elements (HFSE) behaviour is critical for interpreting subduction systems. If HFSE are immobile, they (1) provide a ‘baseline’ from which the fluxes of the subduction-mobile elements can be calculated, (2) allow us to ‘see through’ the subduction process and so determine the provenance, composition and melting behaviour of the mantle wedge, and (3) provide a basis for distinguishing subducted from assimilated crust. If they are mobile, then mantle, subduction and crustal components become much more difficult to separate.

Theoretical Mobility of High Field Strength Elements

Experimental data coupled with numerical modelling indicate that the mobility in subduction zones of the key HFSE (Nb, Ta, Zr, Hf, Ti) is particularly dependent on two factors. The first is minor phase dissolution during melting and dehydration of subducted crust and sediment, which in turn depends mainly on the temperature of the slab-wedge interface and fluid/melt composition. The second is the composition of the mantle with which the resulting fluid and melt interact. Solubility-temperature curves demonstrate that HFSE are released from the subducted slab at all temperatures. Mixing calculations, however, show that the resulting change in composition of the mantle wedge should be imperceptible until slab temperatures reach 700-750C, except in systems involving the most 'productive' subducted sediment or the most depleted mantle wedge.

Observed Mobility of High Field Strength Elements

Magma-crust interaction clearly affects HFSE. However, in arc lavas that have not assimilated crust, HFSE-based plots and/or Hf-Nd isotope systematics show significant HFSE mobility only under two conditions. These are: 1) during subduction of very young oceanic crust; and 2) when continent or plateau collision has slowed subduction rates and so led to increased slab temperatures (as, for example, in the Banda arc). In other arcs we have studied (e.g. Tonga-Kemadec, Vanuatu, Izu-Mariana), we find no evidence that there was sufficient HFSE mobility to affect the use of the HFSE for studying the sub-arc mantle and calculating subduction fluxes. Key evidence for this assertion includes: 1) near-horizontal trends on Hf-Nd isotope plots for arc lavas with variable HFSE anomalies and from homogeneous mantle sources; 2) ultra-depleted HFSE concentrations (down to <0.2 ppm Nb and Hf) coupled with elevated Th/Nb ratios in some arcs and supra-subduction zone ophiolites.

Magnesium isotopic composition of the lithospheric mantle: an in-situ study of mantle-derived olivine

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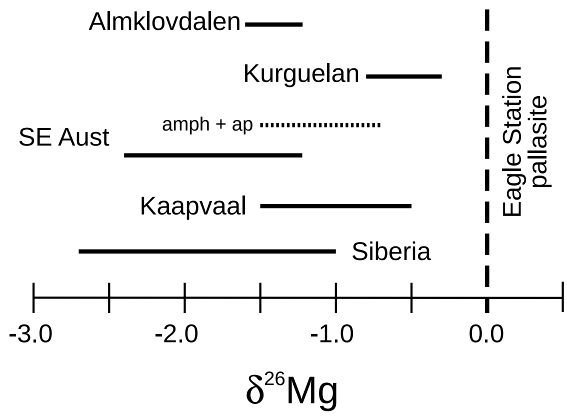
In-situ high precision measurements of $^{26}Mg/^{24}Mg$ and $^{25}Mg/^{24}Mg$ have been made in olivine using a laser ablation microprobe and multi-collector ICPMS. The olivine grains were analysed in a selection of mantle-derived peridotite xenoliths and megacrysts chosen to represent the lithospheric mantle beneath Archean cratons (Kaapvaal, Siberia), Phanerozoic fold belts (south-eastern Australia) and oceanic islands (Kerguelan Island).

Analyses were performed using a New Wave UV laser attached to a Nu Plasma multi-collector ICPMS. Operating conditions for the mass spectrometer followed the method described by Galy et al. (2001). Olivines separated from peridotites from Almklovdalen (Norway) and San Carlos (USA) were analysed as solutions to verify the in-situ technique. Results are reported as $\delta^{26}Mg$ and $\delta^{25}Mg$, or per mil deviations in $^{26}Mg/^{24}Mg$ and $^{25}Mg/^{24}Mg$ from the olivine in the Eagle Station pallasite. Replicate analyses of the Almklovdalen olivine indicate a precision of 0.20 per mil (2σ) for $\delta^{26}Mg$ and 0.12 per mil (2σ) for $\delta^{25}Mg$.

The results show that there are large-scale variations in $\delta^{26}Mg$ and $\delta^{25}Mg$ in the lithospheric mantle with a range from -2.75 to -0.28 per mil $^{26}Mg/^{24}Mg$ and -1.41 to -0.14 per mil $^{25}Mg/^{24}Mg$ in the samples analysed. In general olivines in the more depleted samples have lighter Mg isotopic compositions and the trend towards heavier δ values appears to be related to refertilisation (e.g. Kaapvaal sheared peridotites) or modal metasomatism (e.g. SE Australian amphibole-bearing xenoliths).



The results obtained so far indicate that the in-situ measurement of Mg isotopes provides a valuable new method for investigating processes in the mantle.

References

Galy A. et al., (2001), Int. J. Mass Spectrom. 208, 89-98.