

The 'zero charge' partitioning behaviour of noble gases during mantle melting

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Noble gas geochemistry is a primary resource in understanding planetary processes from accretion to mantle dynamics and atmospheric formation. However, models derived from noble gas data are often at odds with theories derived from other disciplines, most recently in relation to the 'layered' mantle model. Central to much of the modelling is the crystal-melt partitioning of noble gases during their transfer from the solid mantle via silicate melts, which then ascend and degas at the Earth's surface. To date, there is no consensus as to how noble gases are incorporated into crystalline phases, nor the factors which control their partitioning. Here we present new experimental data to elucidate incorporation mechanisms for noble gases in crystals. We use cpx/melt pairs to show that partition coefficients for the heavier noble gases are consistent with their incorporation as species of zero charge at crystal lattice sites, allowing extrapolation of isovalent 4⁺, 3⁺, 2⁺, 1⁺ trends for 'solid' trace elements to 0⁺. The behaviour of the lighter noble gases is more complex and may lead to decoupling of light from heavy noble gases during mantle melting, but can still be explained by crystal lattice controls.

Our results provide a theoretical framework with which to compare the relative incompatibility of important parent-daughter radionuclides. In the past, the noble gases have been widely regarded as highly incompatible elements with almost 100% extraction efficiency from the solid phase during melting processes. As almost all other trace elements are thought to be less incompatible than noble gases, primordial isotopes, such as ³He and ³⁶Ar, are thought to be efficiently extracted from the mantle and replaced by daughter products, ⁴He and ⁴⁰Ar, through *in situ* radioactive decay of residual U, Th and K. This has traditionally been the basis of the layered mantle paradigm with a 'degassed' upper mantle (MORB source with low ³He/⁴He and ³⁶Ar/⁴⁰Ar) and a lower undepleted or 'primordial' layer (IOB source with much higher ratios). Our results suggest that the assumption of extreme incompatibility for noble gases relative to parent radionuclides can no longer be considered as unequivocal.

Whole-rock and mineral trace element distributions in Alpine and Franciscan eclogites

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Fluids not only mobilise a variety of trace elements during both Alpine and Franciscan eclogite-facies metamorphism (e.g. Philippot and Selverstone, 1991; Sorensen et al., 1997), they also enhance rock deformation. To investigate the interplay of deformation and fluid-mediated mass transfer during subduction, we compared the bulk and mineral trace element chemistry within different eclogite terranes, to rock texture. Eclogites from Alpine localities (Voltri Massif, Monviso) represent both different P-T and fluid-rock regimes than those from the Franciscan Complex of California (USA). Two groups of elements show distinct behaviours in both regions: the large ion lithophile elements (LILE) versus the high field strength elements (HFSE) and V.

Results

Ba and K₂O data for whole rocks and phengitic white micas suggest that deformation leads to net Ba loss. In the Franciscan, this is also reflected in the Ba-contents of phengite (Phg) in deformed versus undeformed eclogite samples. Phg in Monviso eclogites shows no depletion of Ba and K₂O with deformation.

Ba and K₂O are both about one order of magnitude higher in Phg than in bulk Franciscan eclogites. In Alpine eclogites, Ba in Phg is about one, K₂O more than two orders of magnitude higher than in the bulk. The Alpine eclogites likely have another carrier of Ba, possibly minor amounts of plagioclase, which responds to deformation.

The bulk and FeTi-oxide (Rt, Ilm, Ttn) compositions suggest deformation has mobilised both TiO₂ and V. Depletion of V (but not Ti) in Ttn from deformed versus undeformed Franciscan eclogite supports this notion. In contrast, the compositions of Rt and Ilm in Alpine samples show no V depletion with deformation state.

Conclusions

Minor and trace LILE, as well as V, in both phengite and titanite vary with the deformation state of Franciscan eclogites, but not Alpine ones. The latter rocks must contain small amounts of other minerals rich in these elements that respond strongly to deformation.

References

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