Synthetic fluid inclusions in rutile: A new technique to study mantle fluids

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Experimental studies concerning the major and trace element composition of hydrous fluids migrating in the mantle or released from a subducted oceanic crust are technically challenging. Currently used methods include the weight-loss technique (e.g., Newton and Manning, 2002) and the diamond trap technique (e.g., Stalder *et al*. 2001; Kessel *et al*. 2005), which both have a number of advantages and disadvantages.

Here we follow a new approach by trapping fluids at mantle condtions in rutile, and analyze their major and trace element content by LA-ICP-MS. Rutile is a perfect mineral for this purpose because its solubility in aqueous fluid is relatively low (e.g.: Audétat & Keppler, 2005), but still high enough to allow crack-healing, and because it does not contain most of the elements of interest (except for HFSE). Major advantages of this method include: (i) it is applicable to a large range of P/T-conditions, (ii) there are no limitations regarding the complexity of starting materials that can be used, and (iii) identical batches of the same fluid can be sampled numerous times. Cubes of sintered rutile were loaded into Pt/Rh capsules, together with fine grained minerals (e.g., enstatite, olivine) and 15-25 µl aqueous solution containing 1000 ppm of Cs and Rb, the latter serving as internal standards for the LA-ICP-MS analyses. Experiments are carried out in 200 t piston cylinder apparatus, using pure salt assemblies and stepped graphite heaters. Run conditions are approached along a fluid isochoric path, and then held for two days. Resutling fluid inclusions are 20-40 µm in size, which is appropriate for LA-ICP-MS analyses.

The method is currently being tested on the system quartz-H_2O and olivine-enstatite-H_2O, for which reliable data are available from weight-loss experiments (Manning, 1994; Newton and Manning, 2002).

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Seawater recycling into the deep mantle – And the source of ^{3}He?

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Mantle-derived heavy noble gases (Ar, Kr, Xe) with isotopic components and elemental ratios similar to marine pore fluids have been unambiguously resolved in magmatic well gases and Mid Ocean Ridge 'popping' rock (MORB). This observation has been used to argue that recycling of marine pore fluids into the mantle dominates the non-radiogenic heavy noble gas inventory of the convecting mantle [1]. He and Ne isotopes in the mantle are unaffected because of their low concentration in marine pore fluids. This conclusion is further reinforced by the observation that slab-derived fluids trapped in the overlying mantle wedge have both halogen (Cl, Br, I) and heavy noble gas elemental compositions little different from marine pore fluids [2].

Numerical models of mantle convection provide further insight. In simulations that reproduce surface heatflow and plate motion, a seawater/Ar recycling flux into an initially degassed mantle, combined with internal radiogenic ^{40}Ar ingrowth, can be determined that reproduces the best estimate of the mantle ^{40}Ar/^{36}Ar ratio of ~40,000 [1]. An independent outcome of the model, determined by the fluid dynamic control, is that the noble gas composition in the plume forming region at the core mantle boundary has a substantially lower ^{40}Ar/^{36}Ar, and is consistent with low plume ^{40}Ar/^{36}Ar observed maximum values.

A ^{3}He flux (^{3}He/^{4}He=120Ra) into the same model from either D″ or the core determined to produce a convecting mantle with ^{3}He/^{4}He=8Ra, unsurprising, results in a plume forming region at the core mantle boundary with substantially higher ^{3}He/^{4}He ratios. A 'deep' ^{3}He reservoir remains one explanation for plumes with high ^{3}He/^{4}He having low ^{40}Ar/^{36}Ar. The dual ^{40}Ar/^{36}Ar and ^{3}He/^{4}He result is not matched by models in which the high ^{3}He/^{4}He source is produced as a result of low ^{3}He/U in the residue of shallow convecting mantle melting.

References

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