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Time Passes – Argon Isotopes as Tracers of Fluids in the Earth's Crust

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Recent experimental measurements of noble gas solubility in silicate minerals (e.g. Jackson et al. 2013, 2015) means that we can begin to explore the use of noble gas partition between minerals and fluids to understand their residence and transport in the Earth's crust. One starting point for this exploration is the distribution of noble gases and halogens in crustal fluids which was reviewed by Kendrick and Burnard (2013). In particular, K&B (2013) noted that time is a key parameter in understanding noble gas tracers in crustal processes; yielding information such as the residence time of water in a reservoir based on 4He acquired from aquifer rocks, and the 40Ar/39Ar age of fluid inclusions based on trapped fluid and minerals in quartz.
Argon isotope variations in natural systems have been measured during studies of 40Ar/39Ar ages to quantify the rates and timescales of crustal processes. There are also studies of fluids in similar rocks, notably in fluid inclusions, providing the opportunity to quantify the variations in the crust. Partition of argon between mineral phases under conditions of varying fluid availability can be compared in systems where 40Ar/39Ar measurements indicate the preservation of non-radiogenic argon (both excess and atmospheric) in the minerals. Rather than a simple picture of radiogenic argon contents increasing with crustal age, and gradual depletion of atmospheric argon in deeper fluids, what emerges is a sometimes dynamic and sometimes static system in different zones of the crust.
While it can be shown that the hydrous fluid in sandstone reservoirs contained excess argon, analyses of authigenic minerals rarely exhibit 40Ar/39Ar ages in excess of the growth age. In this scenario, the incompatible nature of argon means that the fluid acts as an effective infinite reservoir and radiogenic argon dominates the potassium rich authigenic minerals.
The controls on noble gas distribution are also well illustrated by deep crustal rocks such as eclogites which have been studied for both noble gas geochemistry and 40Ar/39Ar geochronology. Non-radiogenic argon contents of fluids and minerals in eclogites indicate precursors that equilibrated with the atmosphere as indicated by Kendrick and Burnard (2013), but other studies indicate very restricted fluid movement (e.g. Warren et al. 2014). By combining argon diffusion and solubility parameters with the database of 40Ar/39Ar ages, we can understand the potential for recycling argon into the mantle, and also why some crustal rock yield cooling ages and others contain excess argon.
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