

Environmental tracers in hydrogeology: Principles, applications, and challenges

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Environmental tracers (³H, noble gases, CFCs, SF₆, SF₅CF₃ etc) of natural and anthropogenic origin have become mainstream tools in oceanography and hydrology. Primary applications include the quantification of mixing processes and estimation of residence times of aqueous systems. The time scales accessible to these methods range from months to millions of years, with some time brackets covered by multiple tracers, others by barely one. Key challenges in their application are defining the atmospheric boundary conditions, in particular in highly industrialized regions with local sources, subsurface production, contamination issues, and the conversion of tracer concentrations into probability density functions of age. Recently, the hydrogeological community has expanded from the early applications of environmental tracers in simple sandy aquifers to complex heterogeneous sedimentary and fractured rock systems, with mixed success.

One example is the use of ³H/³He, CFCs and SF₆ in the heterogeneous and heavily pumped floodplain aquifers of Bangladesh to understand the processes that mobilize arsenic and to optimize water resources management practices. At a field site 25 km east of the capital Dhaka, CFCs concentrations decrease with depth in the unsaturated zone and then rapidly just below the water table due to degradation under reducing conditions. CO₂ concentrations in this organic-rich environment increase three orders of magnitude to levels up to 12% in the unsaturated zone while O₂ levels drop by an equivalent amount. N₂, noble gas and SF₆ partial pressures generally resemble those in atmospheric air. Noble gas temperatures of shallow groundwater reflect water temperature at the water table. ³H/³He data are mostly consistent with reconstructed ³H concentrations in precipitation but also show effects of non-Gaussian age distributions. SF₆ was detected in ³H-free groundwater, pointing to natural subsurface sources. Arsenic concentrations increase with ³H/³He age suggesting a hydrologic control of dissolved arsenic distributions in the shallow, Holocene aquifer.

Silicate melt inclusions in olivine from the Yushigou harzburgite, North Qilian: Evidence for dynamic partial melting in mantle

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Magma generation by partial melting of upper mantle peridotite is important for understanding the dynamic Earth. Differential stress-induced ductile deformation plays significant roles in melt generation and migration [1,2]. The Yushigou harzburgite in the North Qilian Early Paleozoic suture zone was believed to be a remnant section of a mantle wedge melting residue [3]. Solid-state ductile deformation at the mantle temperatures have been examined [4].

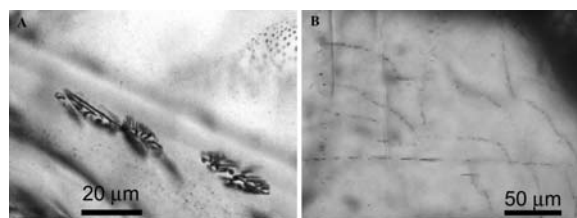


Figure 1: Melt inclusions (A) and their distribution along the subgrain boundaries (B) in olivine

Besides the abundant CH₄+C+H₂ fluid inclusions in olivine [3,5], a large quantity of melt inclusions are also observed in these deformed olivines. These melt inclusions are 0.5-1×5-15 μm in size with dark and bright unmixing phases. BSE analysis reveals that the dark phase is enriched in Fe with minor Ca, Al, Cr and Ti, whereas the bright phase is enriched in Ca and Al. These inclusions distribute orientatedly along the kink-bands and subgrain boundaries of the host olivine. This suggests that melt inclusions most probably form during the process of high-temperature plastic deformation. Decompression and differential stress-induced deformation are responsible for the melting and diffusion of incompatible elements such as Ca, Al, Fe, Cr and Ti in olivine.

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