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The chemical signatures of progressive dehydration stages in subducted serpentinites

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Fluids mediate chemical cycling in subduction zones. Nonetheless, the chemistry of serpentinite-dehydration fluids from down-going slabs and their chemical effects on ascent are only very poorly constrained. We report new data on discontinuous dehydration reactions, including the measurement of individual fluid inclusions in prograde minerals from natural occurrences, and one case study tracing the infiltration of serpentinite-derived fluid in mafic eclogite. Together, these studies demonstrate that serpentinite-derived fluids are commonly dilute, but that there may be selected trace element abundances (and ratios ?) that characterize such fluid provenance.

Brucite dehydration represents the first relevant liberation of crystal-bound water from serpentinites formed on the ocean floor (ocean floor mantle hydration chemistry is addressed in Kodolanyi et al., this session). Discordant olivine-Ti-clinohumite-antigorite-clinopyroxene-magnetite veins in ca. 2.3 GPa antigorite serpentinites of the Erro Tobbio in the Ligurian Alps, Italy, formed from aqueous, dilute fluids containing Li, Sr, Ba, Rb, Pb as determined on texturally-early fluid inclusions in olivine. This prograde olivine preserves high Ni (1500 - 3000 μg/g) and is identified most readily by elevated Li (1-20 μg/g), B (1-20 μg/g) and Mn contents. Aqueous fluid inclusions in some clinopyroxene (Cpx) of the same veins host variably (sometimes highly) saline fluid inclusions, interpreted to represent the "spent" fluid after formation of hydrous vein minerals (chlorite, antigorite). Vein bulk-rock trace-element concentrations show enrichment in Ti, Ba, Nb, Li, HREE and Cu relative to the wall rocks, accompanied by depletion in Cr. This mostly reflects the mineral transformations (sources / sinks) occurring at this stage of serpentinite dehydration.

Antigorite-breakdown is arguably the most prominent water release from down-going slabs. Olivine-orthopyroxene-chlorite rocks at Cerro del Almirez (Spain), recording this dehydration event, contain olivine-hosted polyphase inclusions interpreted to represent fluid inclusions trapped during antigorite breakdown. Preliminary compositional data show enrichments in B, Cs, Pb, Li, Sr, Rb, K, Ba (decreasing order) and depletions in Ca, Ti, La relative to primitive mantle, closely corresponding to the incompatible element pattern of typical island arc lavas. Transfer of such fluids to the melting source of island arc magmas may be critical to developing their distinctive trace element signatures.

Omphacite-rich ($\pm$ garnet, rutile, talc and zircon) veins cutting eclogite (Fe-Ti gabbro protolith, Monviso, W Italian Alps) record serpentinite-derived fluid pathways though the subducted slab at ca. 70 km depth. Although these veins largely formed by local eclogite-derived fluids, they also preserve discrete generations of vein minerals enriched in Mg, Cr, Ni, B, As and Sb, and zircon with elevated Epsilon(Hf) compared to host-rock eclogite zircon. These chemical and isotopic characteristics suggest external fluid input, from serpentinite dehydration. Moreover, distinctive oscillatory or irregular Cr zonations observed in omphacite, garnet and rutile from the veins are interpreted to record episodic fracturing and fluid infiltration over >10 m along transient brittle fractures at high pressures.

Our current data suggest that dehydration fluid pervades the rock at the site of liberation, and that episodic fluid escape from the dehydration site may be effectively channelized. This supports growing evidence for highly focused reactive fluid flow through slabs. Robust constraints on the chemical composition and nature of dehydration fluids from serpentinites and how they evolve during ascent may greatly aid in recognizing such features from outcrop to thin-section scales, in turn providing us with more comprehensive sample material to advance our understanding on fluid-mediated cycling in subduction zones.

Reference

Kodolanyi et al., this session