2016 PROJECTS

Olivine and fluids in suprasubduction mantle in deep time (3700 Ma)

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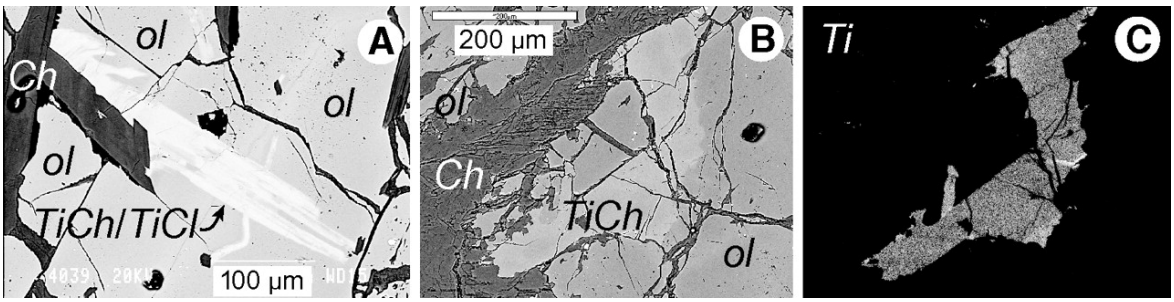
Recent work on rare ultramafic rocks in the Eoarchaean Isua supracrustal belt of Greenland[1] have revealed evidence for their 3700 Ma suprasubduction zone pedigree from two completely unrelated strands of research. The first is via field observations, zircon geochronology, petrographic and mineral chemistry[2] and the second is via olivine lattice studies[3]. The first strand of research shows that prior to intrusion of ~3710 Ma quartz diorites, the ultramafic rocks were incorporated as tectonic lenses (~100 m wide) into the Isua belt which is dominated by basalts of arc-like chemistry[1]. These lenses are heterogeneous, composed of isotropic dunite-harzburgite with depleted mantle major and trace element compositions,, that are traversed by domains with large (up to several cm long) aligned olivines. SEM imaging and LA-ICP-MS trace element geochemistry shows that the large olivines are associated with titanoclinohumites which show enrichment in the HFS elements (the HFS are depleted in the associated arc-like basalts)[2]. The second strand of evidence comes from olivine lattice studies[3], with identification of a class of lattice dislocation fabric that in nature is only known to occur in suprasubduction zone settings. Combined, these lines of evidence make a strong case that the Isua 3700 Ma dunites and harzburgites record the oldest-known suprasubduction zone mantle settings, pointing to operation of plate tectonics from the start of the geological record.

A key process of convergent plate boundary zone magmatism is that dewatering of the subducted slab hydrates the mantle – triggering the arc magmatism. Do the olivine + titanoclinohumite veins represent the pathways of slab-derived watery fluid interacting with the suprasubduction mantle wedge? Via oxygen isotope analysis of different varieties of olivine in the Isua dunites, this idea of 3700 Ma fluxing of the mantle by subduction-related fluids was tested in this 2016 GeoQuEST project.

Bulk oxygen isotope analysis is an inappropriate technique for this work. The reason, as shown in the figure below, is twofold; (i) the olivines are texturally complex, with two present on the scale of a single cross section and (ii) the olivines are not completely free of intracrustal low temperature hydration, giving rise to serpentine and/or chlorite fringes around grains. For this reason high spatial resolution analysis (~20 µm) by the SHRIMP ion microprobe in ANU is necessary.



(A,B) Electron backscatter images of olivine (ol) intergrown with titanoclinohumite minerals (TiCh/TiCl) and overprinted by secondary chlorite (Ch). (C) Titanium map for same area as frame (B).

Polished thin sections with different olivine textural relationships were thoroughly documented via SEM imaging. This included establishing the Fo-number (magnesium content) of the olivines via EDS analysis. This is necessary, because instrumental fractionation of oxygen isotopes is dependent on the compositions of the olivines, thus is a necessary requirement for the acquisition of accurate and precise results. This is particularly pertinent in this study, because the larger, orientated tabular olivines are more magnesian than the groundmass polygonal olivines. Chosen areas of polished thin section were cut-out, and cast into polished epoxy resin discs with San Carlos standard olivine grains[4]. Analyses of the unknowns were calibrated against interspersed analyses of the San Carlos grains. Measurements were undertaken on ANU's SHRIMP-SI instrument in early 2017.

It can be revealed at this stage that the two petrographically-different classes of olivine grains do display significantly different oxygen isotope signatures, and that the orientated tabular higher-Fo grains intimately associated with titanoclinohumites have measurably lighter oxygen. This points to meteoric/oceanic water being incorporated into the oldest-recognised mantle suprasubduction wedge assemblages. For the first time, this indicates directly hydrosphere / mantle interaction in the Eoarchaean.

The results are close to finalisation, and will lead to a manuscript in a leading Earth Science journal.

References cited

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