Geophysical Research Abstracts
Vol. 21, EGU2019-11771, 2019
EGU General Assembly 2019

Lessons from lawsonite chemistry and microstructure for subduction processes

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The hydrous Ca-Al silicate mineral lawsonite is important in element cycling in subduction zones because it is a major carrier of water and trace elements from the crust to the mantle. Lawsonite is also important in subduction dynamics because its dehydration may induce earthquakes; furthermore, lawsonite crystallographic preferred orientation (CPO) may influence seismic properties of slabs and therefore our understanding of slab rheology. Lawsonite occurs in metabasaltic, metasedimentary (quartz-rich, carbonate), and metasomatic rocks and has a broad pressure stability at low temperatures; it is predicted to occur in normal to cold subduction zones at depths of 45-300 km. The rare preservation of lawsonite in the geologic record – i.e. in blueschist and particularly in eclogite – indicates that the top of the slab commonly experiences an increase in temperature during exhumation, during which lawsonite is typically replaced by epidote and other hydrous minerals. We have used the exceptional opportunity of fresh lawsonite in 6 subduction complexes to investigate the oxygen isotope and minor-element composition and microstructure (CPO), as well as metamorphic ages from associated minerals, to document and compare lawsonite characteristics in blueschist and eclogite in mélanges (Franciscan/USA; Rio San Juan/Dominican Republic; Port Macquarie/Australia) and more coherent terrains (Sivrihisar/Turkey; Corsica/France; Pinchi Lake/Canada). All lawsonite analyzed exhibits some zoning in minor elements (e.g. Ti, Fe, Cr, REE), with strong oscillatory zoning in Cr occurring in some samples in both mélange and coherent terrains, particularly those proximal to serpentinite. Within a single crystal, zoning type varies with element: e.g. sector zoning of Ti in a crystal with Cr oscillatory zoning and distinct core/rim zoning in Fe. Lawsonite Sr/Pb ratios vary among samples analyzed within terranes and, with significant exceptions, correlate with host rock type (high ratio in metabasalt, low in metasediment); the exceptions may indicate cases of fluid-mediated mass transfer between oceanic crust and sediments during high-P metamorphism. With the major exception of lawsonite from Corsica, which has extremely low δ18O values (3.7-4.3‰, mélange lawsonite has lower δ18O values (~7.5-10.5‰ than lawsonite analyzed from coherent terrains (~11.5-14.8‰. Analyzed lawsonite does not exhibit strong variation within grains (core, rim) or among grains within a sample (inclusions, matrix, vein lawsonite). Microstructural (EBSD) analysis of lawsonite from one locality (Sivrihisar) reveals different CPO in metabasalt and quartzite, and shows that lawsonite may retain its peak-metamorphic CPO even as the dominant matrix minerals recrystallize during retrograde transformation from eclogite to blueschist facies assemblages. Deformation also affects distribution of minor elements in lawsonite, as seen by Ti enrichment along subgrain and grain boundaries. These data, integrated with ages that document that in many cases lawsonite blueschist forms by retrogression of eclogite, show the power of lawsonite as an archive of chemical and physical information for tracking subduction metamorphism and deformation.