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Dehydration-driven topotaxy in subduction zones

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Mineral replacement reactions play a fundamental role in the chemistry and the strength of the lithosphere. When externally or internally derived fluids are present, interface-coupled dissolution-precipitation is the driving mechanism for such reactions [1]. One of the microstructural features of this process is a 3D arrangement of crystallographic axes across internal interfaces (topotaxy) between reactant and product phases. Dehydration reactions are a special case of mineral replacement reaction that generates a transient fluid-filled porosity. Among others, the dehydration serpentinite is of special relevance in subduction zones because of the amount of fluids involved (potentially up to 13 wt.%).

Two topotatic relationships between olivine and antigorite (the serpentine mineral stable at high temperature and pressure) have been reported in partially hydrated mantle wedge xenoliths [2]. Therefore, if precursor antigorite serpentine has a strong crystallographic preferred orientation (CPO) its dehydration might result in prograde peridotite with a strong inherited CPO. However for predicting the importance of topotactic reactions for seismic anisotropy of subduction zones we also need to consider the crystallization orthopyroxene + chlorite in the prograde reaction and, more importantly, the fact that this dehydration reaction produces a transient porosity of ca. 20 % vol. that results in local fluctuations of strain during compaction and fluid migration.

We address this issue by a microstructural comparison between the CPO developed in olivine, orthopyroxene and chlorite during high-pressure antigorite dehydration in piston cylinder experiments (at 750ºC and 20 kbar and 1000ºC and 30 kbar, 168 h) and that recorded in natural samples (Cerro del Almirez, Betic Cordillera, Spain). Experimentally developed CPOs are strong. Prograde minerals show a significant inheritance of the former antigorite foliation. Topotactic relations are dominated by (001)atg//(100)ol// (100)opx//(001)chl. The relation [010]atg// [001]ol //[001]opx can also be inferred but it is weaker. Similar topotactic relations are observed in the Cerro del Almirez samples, but the CPOs are weaker and more complex. The complexity arises from constant interfacial angles and systematic low-index interfacial contacts between orthopyroxene-olivine-chlorite (e.g. (001)chl // (100)opx). As a consequence the inheritance from the antigorite serpentinite is partially obliterated. Compaction-related microstructural features are also present including: (1) smooth bending of the former foliation and diffuse olivine veinlets perpendicular to it, (2) gradual crystallographic misorientation (up to 15º) of prismatic enstatite due to buckling, (3) localized orthoenstatite(Pbca)/low clinoenstatite (P21/c) inversion, and (4) brittle fracturing of prismatic enstatite wrapped by plastically deformed chlorite.

These observations suggest that topotactic crystrallographic relations are dominant in undrained systems, but that the mechanisms allowing for compaction and fluid draining significantly affect the final texture in drained systems. Because the second case prevails in subduction zones, compaction mechanisms need to be better understood for modelling the development of CPOs after foliated protoliths in the slab and the mantle wedge.

[1] Putnis, A., 2009. Reviews in Mineralogy and Geochemistry 70, 87-124. [2] Boudier, F., et al. 2010 J. Petrology 51, 495-512.