Geophysical Research Abstracts
Vol. 20, EGU2018-8002, 2018
EGU General Assembly 2018

Evolution of hydrous shear zones during incipient eclogitization of metastable dry and rigid lower crust (Holsnøy, Western Norway)

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Seismic imaging suggests that within subducting slabs eclogitization of dry crustal rocks often occurs at depths greater than 80 km, where eclogitization of other rocks is almost completed. This indicates a kinetically delayed slab densification. Recent studies show a slight kinking of subducting slabs accompanied by high seismic activity at the depths where eclogitization seems to occur. Hence, weakening of the subducting slab due to eclogitization reactions has a potentially strong impact on the deformation of the slab. Findings from the dry anorthositic granulites of Holsnøy (western Norway) indicate that the local eclogitization is an interplay between brittle deformation, ductile deformation, fluid infiltration and subsequent fluid-rock interactions. The finite result is an interconnected network of hydrous shear zones responsible for the eclogitization of the rigid lower crust.

To decode the development of those shear zones with the main focus on the progressive interaction between eclogitization and deformation, we combine detailed mapping and petrological investigations of natural outcrops with numerical modelling. We examined two key outcrops on Holsnøy, where unreacted granulites are cross-cut by partly to completely eclogitized shear zones on a meter scale.

Both outcrops (A and B) are largely comprised of pristine granulite with minor eclogite-facies shear zones (sz) and adjacent regions of static eclogitic overprint. The sz differ in width and outcrop B contains internally folded shear zones. We assume outcrop A (lower sz-width, dextral bookshelf-style deformation, NE-SW-striking sz, no folds) developed from a parallel setting of N-S-striking sz and represents an early deformation stage prior to that of outcrop B (higher sz-width, E-W-striking and folded sz). The deformation facilitated eclogitization, which gradually progressed into the granulites until either stress relaxed or the trigger mechanism of fluid-induced reactions reduce their significance.

We generated three numerical models to identify the key parameters that have the largest impact on the sz-widening and consequently, leading to sz-folding during ongoing deformation with: (i) considering a constant fluid content throughout the whole sz and the entire evolution of the sz system; (ii) applying a fixed value of free fluid to the sz that distributes while the sz evolves; (iii) implementing a constant fluid content combined with grain size coarsening within the sz center to obtain a viscosity contrast within the evolving sz system.

By applying field- and laboratory-based data it is possible to decipher the geometrical development of the interconnected sz-network as a function of fluid-induced mineral reactions coupled with ongoing deformation. Therefore, 2D-modelling with the described setup provides a new mechanical view on the dynamic weakening processes affecting metastable dry and rigid lower crustal rocks.