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Upscaling of chemical and petrophysical rock properties for modeling serpentinite dehydration using a multiscale dataset

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Dehydration of serpentinized oceanic lithosphere during subduction is a crucial process in the deep Earth water cycle and its chemical and petrophysical consequences. Investigating how the microscale processes of dehydration evolve into large scale efficient fluid pathways is needed to better understand the relation between arc volcanism and subduction zone seismicity. In this study, we explore the behavior of a dehydrating serpentinite in a subducting slab using a multiscale dataset. This dataset includes mineral chemical data from the microscale up to outcrop scale observations of a serpentinite from the Mirdita ophiolite in Albania. This ophiolite has experienced low-temperature seafloor alteration but has not been subducted to conditions that would lead to dehydration.

Electron microprobe element distribution mappings show microscale chemical heterogeneities that result from serpentinization. Raman measurements reveal a mixture of lizardite and intergrown brucite as main mineral assemblage. To account for grain coarsening during the lizardite-antigorite transition we increase the thermodynamic domain size (i.e., the effective bulk composition) from 400 to 2500 μm^2 for which we determine the fluid release and accompanied porosity development. We show that a similar pattern of chemical heterogeneities exists on the thin section scale using EDX element distribution maps and increasing again the thermodynamic domain size up to 10000 μm^2. Our field observations show similar chemical heterogeneities on the outcrop scale.

We use our multiscale dataset derived from field mapping and natural samples as input for thermodynamic calculations along a typical subduction zone P-T path to investigate the effect of chemical heterogeneities and varying thermodynamic domain sizes on the dehydration process. Our results show that anisotropic chemical heterogeneities lead to heterogeneous porosity formation at all scales, which consequently results in an efficient fluid release even at low porosities. For upscaling we describe the lithologies found in the field as effective bulk porous media. We use a numerical model of reactive porosity waves to show how fluids released during dehydration can be extracted from the rock at the kilometer scale.

Our findings demonstrate the effect of increasing thermodynamic domain sizes as well as the importance of natural chemical heterogeneities allow upscaling using effective media approaches.