

EGU21-10718

<https://doi.org/10.5194/egusphere-egu21-10718>

EGU General Assembly 2021

© Author(s) 2022. This work is distributed under the Creative Commons Attribution 4.0 License.



Reaction-enhanced ductile deformation during carbonation of serpentinitized peridotite

Manuel D. Menzel¹, Janos L. Urai¹, Peter B. Kelemen², Greg Hirth³, Alexander Schwedt⁴, and Andras Kovacs⁵

¹RWTH Aachen University, Tectonics and Geodynamics, Aachen, Germany (manuel.menzel@emr.rwth-aachen.de)

²Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY, USA

³Brown University, Department of Earth, Environmental and Planetary Sciences, Providence, RI, USA

⁴RWTH Aachen University, Central Facility for Electron Microscopy, Aachen, Germany

⁵Forschungszentrum Jülich, Ernst Ruska-Centre (ER-C) for Microscopy and Spectroscopy with Electrons, Jülich, Germany

Carbonated serpentinites record carbon fluxes in subduction zones and are a possible natural analogue for carbon capture and storage via mineralization, but the processes by which the reaction of serpentinite to listvenite (magnesite-quartz rocks) goes to completion are not well understood. Large-scale hydration and carbonation of peridotite in the Oman Ophiolite produced massive listvenites, which have been drilled by the ICDP Oman Drilling Project (OmDP, site BT1) [1]. Here we report evidence for localized ductile deformation during serpentinite carbonation in core BT1B, based on observations from optical microscopy, cathodoluminescence microscopy, SEM, electron backscatter diffraction (EBSD) and transmission electron microscopy (TEM) in segments of the core that lack a brittle overprint after listvenite formation [2].

Microstructural analysis of the serpentinitized peridotite protolith shows a range of microstructures common in serpentinite with local ductile deformation manifested by a shape and crystallographic preferred orientation and kinking of lizardite. Listvenites with ductile deformation microstructures contain a penetrative foliation due to a shape preferred alignment of magnesite spheroids and/or dendritic magnesite, bending around Cr-spinel porphyroclasts. Locally the foliation can be due to aligned dendritic overgrowths on euhedral magnesite grains. Magnesite grains have a weak but consistent crystallographic preferred orientation with the c-axis perpendicular to the foliation, and show high internal misorientations. Locally, the microcrystalline quartz matrix also shows a crystallographic preferred orientation with the c-axes preferentially oriented parallel to the foliation. Folding and ductile transposition of early magnesite veins indicates that carbonation initiated before the ductile deformation stage recorded in listvenites with penetrative foliation. On the other hand, dendritic magnesite overgrowths on folded veins and truncated vein tips suggest that folding likely occurred before complete carbonation, when some serpentine was still present. TEM analysis of magnesite revealed that subgrain boundaries oriented at high angle to the foliation can consist of nano-cracks sealed by inclusion-free magnesite precipitates. High dislocation densities are not evident suggesting that dislocation creep was minor or negligible, in agreement with very low predicted strain rates for magnesite dislocation creep at the low

temperatures (100 – 200 °C) of serpentinite carbonation. This points to dissolution-precipitation, possibly in addition to grain boundary sliding, as the main mechanism for the formation of the shape preferred orientation of magnesite. The weak magnesite crystallographic preferred orientation may be explained by a combination of initial growth competition in an anisotropic (sheared) serpentine medium with subsequent preferred dissolution of smaller, less favorably oriented grains. We infer that transient lithostatic pore pressures during listvenite formation promoted ductile deformation in the reacting medium through grain boundary sliding accommodated by dilatant granular flow and dissolution-precipitation. Because the reaction product listvenite is stronger than the reacting mass, deformation may be preferentially partitioned in the reacting mass, locally enhancing transient fluid flow and, thus, the carbonation reaction progress.

[1] Kelemen et al., 2020. Site BT1: fluid and mass exchange on a subduction zone plate boundary. In: Proceedings of the Oman Drilling Project: College Station, TX

[2] Menzel et al., 2020, JGR Solid Earth 125(10)