Ophiolite carbonation: Constraints from listvenite core BT1B, Oman Drilling Project

Oliver Plümper¹, Andreas Beinlich², Esmée Boter¹, Inigo A. Müller¹, Fatma Kourim³, Martin Ziegler¹, Yumiko Harigane⁴, Romain Lafay⁵, Peter B. Kelemer⁶, and the Oman Drilling Project Science Team

¹Utrecht University, Department of Earth Sciences, Utrecht, Netherlands (o.plumper@uu.nl)
²Department of Earth Science, University of Bergen, Bergen, Norway
³Institute of Earth Sciences, Academia Sinica, Academia Road, Nangang, Taipei 11529, Taiwan
⁴Institute of Geology and Geoinformation, Geological Survey of Japan, The National Institute of Advanced Industrial Science and Technology, 1-1-1 Higashi, Tsukuba, Ibaraki 305-8567, Japan
⁵Géosciences Montpellier, Université Montpellier, Place E. Bataillon, 34095 Montpellier, France
⁶Lamont-Doherty Earth Observatory, Columbia University, Palisades, New York, 10964, USA

The widespread occurrence of the quartz–carbonate alteration assemblage (listvenite) in ophiolites indicates that ultramafic rock represents an effective sink for dissolved CO$_2$. However, the understanding of the carbonation mechanisms is almost exclusively based on surface samples, which adds significant uncertainty to the interpretation of fossil hydrothermal systems. Here we present novel insight into the reaction textures and mechanisms of ultramafic rock carbonation obtained from the 300 m deep BT1B drill hole, ICDP Oman Drilling Project. Hole BT1B recovered continuous drill core intersecting surface alluvium, 200 meters of altered ultramafic rock comprising serpentinite and listvenite, and 100 meters of the underlying metamorphic sole. The ultramafic part of BT1B is dominated by listvenite with only two thin intercalated serpentinite bands at 90 m and 180 m depth.
Results: Microstructures

Microstructural analyses indicate an evolution beginning with non-equilibrium growth of spheroidal carbonate composed of interlayered magnesite and dolomite in the completely serpentinized harzburgite, and magnesite and Ca-magnesite in the listvenite. Carbonate spheroids are characterized by sectorial zoning resulting from radially oriented low-angle boundaries. In the listvenite spheroidal carbonate is overgrown by euhedral magnesite indicative of near-equilibrium growth.

Back-scattered electron (BSE) images and quantitative element distribution maps of carbonate in serpentine and listvenite.

Beinlich et al. (2020), JGR
Microstructural analyses indicate an evolution beginning with non-equilibrium growth of spheroidal carbonate composed of interlayered magnesite and dolomite in the completely serpentinized harzburgite, and magnesite and Ca-magnesite in the listvenite. **Carbonate spheroids are characterized by sectorial zoning resulting from radially oriented low-angle boundaries.** In the listvenite spheroidal carbonate is overgrown by euhedral magnesite indicative of near-equilibrium growth.
Results: Microstructures

Microstructural analyses indicate an evolution beginning with non-equilibrium growth of spheroidal carbonate composed of interlayered magnesite and dolomite in the completely serpentinized harzburgite, and magnesite and Ca-magnesite in the listvenite. Carbonate spheroids are characterized by sectorial zoning resulting from radially oriented low-angle boundaries. **In the listvenite spheroidal carbonate is overgrown by euhedral magnesite indicative of near-equilibrium growth.**

Back-scattered electron (BSE) images and quantitative element distribution maps of carbonate in listvenite.
Carbonate clumped isotope thermometry indicates carbonate crystallization predominantly between 100°C and 200°C. The strong macroscopic brecciation and veining of listvenite indicate that carbonation was facilitated by significant tectonic deformation allowing for infiltration of reactive fluids over an extended duration.
‘Take home messages’

- Large-scale carbonation resulted in pervasive replacement of serpentinite by a magnesite-quartz-fuchsite (listvenite) assemblage.
- Carbonation textures indicate a transition from non-equilibrium spheroidal growth to near-equilibrium euhedral growth.
- Clumped isotope thermometry indicates carbonation temperatures between 50°C and 250°C.

Question? Email to Andreas Beinlich (Andreas.Beinlich@uib.no)