Geophysical Research Abstracts
Vol. 15, EGU2013-5412, 2013
EGU General Assembly 2013

Reaction-induced porosity and onset of carbonation in abyssal peridotites: insights from 3D high-resolution microtomography

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Serpentinites are products of hydrous alteration of ultramafic rocks and they are particularly common at slow-spreading mid-oceanic ridges, where tectonic faulting causes exposure of abyssal peridotites at the seafloor. Upon interaction with seawater, the chemical composition as well as the physical properties of peridotites change, and both hydration and carbonation are common. To understand the underlying processes, we performed a detailed study on harzburgite samples from ODP Leg 209 Site 1270D, located at the Mid-Atlantic ridge near 14°45'N.

The study focused on one sample taken just 0.75 metres below seafloor. Detailed thin section microscopy revealed a high degree of serpentinization, but relict orthopyroxene (Mg/[Mg+Fe] = 0.91–0.92) and spinel are present. Locally, minor amounts of secondary talc and amphibole were found. Former olivine is completely replaced by serpentine (Mg/[Mg+Fe] = 0.95–0.97) and magnetite in mesh textures. Mesh centers commonly consist either of empty space ($<200\,\mu$m in diameter) or flimsy aggregates of serpentine with micrometer-sized voids. Scanning-electron microscope observations as well as X-ray microtomography confirm the presence of cavities in centers of the mesh texture throughout the sample. These voids are connected by a network of thin ($<15\,\mu$m) aragonite veins (identified by EPMA and XRD). Where aragonite veins intersect porous mesh centers, carbonate fills the small voids in flimsy serpentine aggregates, whereas larger voids remain unfilled. Additionally, larger voids feature an extremely thin inner lining of Fe-oxides/hydroxides.

We suggest the following formation scenario: higher-temperature serpentinization left relicts of olivine in mesh centers. Subsequent low-temperature serpentinization caused formation of serpentine–brucite intergrowths from olivine breakdown, which locally ran to completion. Brucite was then dissolved, providing space for carbonate precipitation. Microtextural observations point to a linkage of aragonite formation and porosity development in the serpentinized harzburgite; in particular, carbonation seems not to have created new permeability by reaction-induced fracturing.

Our study showed that X-ray microtomography is a valuable tool to determine the three-dimensional distribution of pore spaces and secondary minerals, without the drawback of preparation artefacts present in thin sections and SEM samples. In the context of serpentinization, deeply rooted high-temperature reactions are responsible for formation of dihydrogen, which acts as an energy source for microbial life in the deep sea; however, we propose that porosity and permeability formed at lower temperatures contribute to making the deep seafloor habitable for microbial life by providing a suitable substrate.