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Media release / 6 June 2018

Water transport to the Earth’s interior: Clues from high-pressure Alpine rocks (Zermatt, Switzerland)

Water in the Earth’s interior influences many geological processes. The evolution of our planet and the development of life is tightly linked to the deep water cycle. Rocks from Zermatt (Switzerland) document formation at the ocean floor, followed by subduction to 80 km depth prior their incorporation into the Alpine belt. The detailed investigation of these rocks by researchers from the University of Bern provides evidence how and how much water can be incorporated in minerals at these subduction zone conditions and how water might be transported to even greater depth. The results are published in the journal “Geology”.

The shallow water cycle that links atmosphere and hydrosphere is crucial for life on Earth. However, there exists also a deep water cycle in which water is transported over millions of years through the Earth’s interior. Hydrothermal alteration of oceanic crust results in the formation of minerals that incorporate water into the crystal structure. Through plate tectonics and subduction of such oceanic crust, the hydrous minerals are transported to increasingly greater depths. As the rocks are heated up during burial, the hydrous minerals break down at 50-100 km depth and are replaced by anhydrous minerals resulting in the liberation of the stored water. Would it be possible that traces of water are still incorporated into these newly formed minerals? Would this provide a mechanism to transport water to even greater depth and how would this influence the very long term, hundred million years water cycle?

To answer these questions, PhD student Elias Kempf and Prof. Jörg Hermann from the Institute of Geological Sciences at the University Bern investigated rocks from a former subduction zone in the Zermatt area with sophisticated analytical techniques.

A fossil ocean floor subducted to 80 km depth

The study focusses on minerals in serpentinites, which are exposed at the lower Theodulglacier, Zermatt. Serpentinites incorporate 12 weight percent water during hydrothermal alteration of upper mantle rocks at the ocean floor, as documented in recoverd rocks from the middle of the Atlantic. The formation of the Zermatt serpentinites took place 160 Million years ago at the floor of the Tethys ocean, which separated Africa and Europe prior to the Alpine collision. During the convergence of Africa and Europe, parts of this oceanic crust were subducted to 80 km depths before the rocks were exposed at the Earth’s surface due to the Alpine collision. This allows geologists to investigate subduction zone processes on rocks that build now the famous peaks of the Swiss Alps.

Institut für Geologie
Baltzerstrasse 1+3
3012 Bern
info@geo.unibe.ch

Traces of water in metamorphic olivine

The rocks from Zermatt document the metamorphic transformation of the hydrous minerals brucite and serpentin to „anhydrous“ olivine, which took place at temperatures of 550°C and 80 km depth. The detailed investigation of infrared light absorption at microscopic scale showed that 100-140 ppm (0.01-0.014 weight percent) water is incorporated in the newly formed olivine. Water incorporation into olivine has mainly been studied in laboratory experiments conducted at much higher temperatures. Olivine from the Earth’s mantle, brought to the surface by volcanic eruptions, contain also traces of water. However, the process of water incorporation cannot be observed. The amount of water found in the olivine from the Zermatt serpentinites are among the highest measured so far in natural olivine. The current study is also the first one to demonstrate that metamorphic olivine in subduction zone rocks can host significant amounts of water.

Important for the deep water cycle

The new data provides evidence for a transfer of water from serpentine to olvine in a subduction zone environment. While hydrous phases such as serpentine are only stable to about 100 km depth, olivine is the main constituent of the upper mantle. Therefore, water incorporated into olivine can be subducted to even greater depth and replenish the mantle with water. A mass equivalent to 1/3 of the oceans could be stored in the Earth’s interior if the entire mantle would contain 140 ppm water. At this stage it is still unclear, weather the deep water cycle is in a dynamic equilibrium in which water input through subduction zones is balanced by water loss through volcanism.

Publication:

Elias Kempf & Jörg Hermann: *«Hydrogen incorporation and retention in metamorphic olivine during subduction: Implications for the deep water cycle»*, Geology v.46, no 6, p571-574 Publication on 1.6.2018, doi.org/10.1130/G40120.1

Further information:

Prof. Dr. Jörg Hermann, Institut für Geologie der Universität Bern
Tel. +41 31 631 84 93 / 079 814 18 73 / joerg.hermann@geo.unibe.ch

Elias Kempf, Institut für Geologie der Universität Bern
Tel. +41 31 631 47 38 / elias.kempf@geo.unibe.ch

Press release incl. Photos:

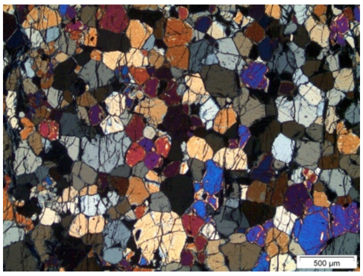
www.geo.unibe.ch/about_us/media_and_pressreleases/medienmitteilungen/180606_zermatt

Bildlegenden

1. View of the lower Theodul glacier, Zermatt with Breithorn. The investigated serpentinites crop out directly at the border to the glacier. Foto © J. Hermann, Institut für Geologie, Universität Bern

2. Detailed view of serpentinites with metamorphic olivine. Foto © E. Kempf, Institut für Geologie, Universität Bern

3. Photo of metamorphic olivine taken with an optical microscope from a thin section using crossed polarized light. (Scale in micrometer)



4. Water distribution map in a grain of olivine. The grain outline is traced with a white line. The water content is colour-coded in ppm (100 ppm = 0.01 wt%). (Scale in micrometer).