The subduction and exhumation path of one UHP-eclogite from the Tso Morari complex

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Eclogites and their host rocks were sampled from the Higher Himalayan Crystalline, south of the Indus-Tsangpo-Suture Zone, from the Tso Morari Complex, NW India. Peak pressures of around ≥39 kbar, for temperatures of 750°C, were obtained by Mukherjee and Sachan, 2009 for coesite-bearing eclogites from this area. This study of one newly collected eclogite reveals >100 µm large coesite grains, confirmed by raman spectroscopy, included in garnet. Garnets are zoned reflecting the prograde and a small part of the retrograde path. Inclusions can be directly correlated with the compositional zoning and are seen as either relicts of the protolith mineral paragenesis and as "snap shots" of the mineral paragenesis during subduction and under peak conditions. The matrix minerals reflect the multi-stage exhumation history.

Petrography

Ca- and Ca-Na-amphiboles, quartz, dolomite, rutile and ilmenite are present in the Ca- and Mn- rich garnet core (X_{Mg}=0.12) reflecting, most probably, protolith remnants. Ca-Na-amphiboles, paragonite, clinozoisite and quartz are present in the Fe-rich garnet mantle, indicating their appearance during subduction, whereas rutile appears from the garnet mantle into the Mg-rich rim. At the border from garnet mantle to rim, calcite is present accompanied by Fe-oxide. In the Mg-rich garnet rim (X_{Mg}=0.45), omphacite and coesite are preserved, reflecting their growth under peak metamorphic conditions.
In the matrix, primary omphacite with a X_{Jd} of 0.42-0.50 is present. Secondary omphacite overgrowing the primary one has a slightly lower X_{Jd} of 0.38-0.49. Na- and Na-Ca-amphiboles replace omphacite, which are themselves surrounded by Ca- amphiboles, either as granoblastic minerals or as symplectites together with albite. Phengite relicts are associated with paragonite. Clinozoisite and zoisite in places contain omphacite and rutile whereas the interaction with carbonates - large grains are intergrown with, smaller grains overgrow carbonates - points to subduction as well as exhumation-related epidote mineral formation. Matrix carbonate is either dolomite with small magnesite cores or ca. 300 µm long magnesite grains with initial cracks filled with dolomite. Secondary cracks passing through dolomite are filled with calcite and are associated with ca. 2 µm wide, parallel veins filled with iron oxide. Dolomite surrounds the magnesite and the youngest cracks contain Ca-rich dolomite and calcite as a part of a larger network of cracks that continue into adjacent minerals and are clearly associated with fluid influx. Magnesite shows an inhomogeneous chemistry enriched in Fe ($Mgs_{0.76–0.80}$ $Sd_{0.20–0.21}$).

REE-geochemistry

Rare earth element (REE) concentrations were obtained by LA-ICP-MS for garnet, mineral inclusions in garnet and matrix minerals. The REE patterns in garnet reflect either mineral decomposition and release of REE or mineral formation and REE uptake during subduction, peak metamorphism and, to a minor extent, during exhumation. REE analyses of mineral inclusions in garnet and minerals from the matrix reveal that white mica and epidote minerals, which normally preferentially incorporate LREEs, reveal higher HREE contents or even equal values of heavy and light REEs.

P-T path reconstruction and conclusions

Standard geothermobarometry reveals peak conditions of 48-51 kbar at 560-750°C, using the most Mg-rich garnet, the most silicic phengite and the most jadeite-rich omphacite. The P-T condition of the subsequent glaucophane formation have been modelled to be at around 500°C at ca. 19 kbar whereas later Ca-amphiboles provide evidence for reheating towards 730°C at pressures as low as 10 kbar.

We applied a Gibbs free energy minimizing modelling to summarize our analytical findings (see Figure 1). The effective bulk rock composition, iteratively corrected for fractionation effects was used for the calculation

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of pseudosections. The inclusions in garnet, supported by the REE distribution pattern in garnet to have been grown during subduction, suggest an isothermal subduction path, at least down to 55 km.

Peak P-T conditions as calculated by standard geothermobarometry were supported by modelling inasmuch as omphacite is stable up to 60 kbar within a temperature range of 620-780°C and the reaction curve dolomite ⇔ magnesite + aragonite was touched. The previously described carbonate textures would indicate an early dolomite that was stable throughout most of the prograde and retrograde stages. Dolomite overgrew magnesite during exhumation, while calcite probably replaced aragonite, which however, could not be identified in this sample. Despite these indicators that the eclogite crossed the graphite–diamond transition boundary, no diamond could be confirmed. A possible reason for the lack of diamond is the presence of carbon bound in the carbonates due to a high oxygen fugacity.

The complex exhumation path shows a stage of initial cooling during decompression, which lead to the formation of glaucophane. The subsequent growth of the second stage Ca-amphiboles and albite requires a significant reheating, before final exhumation. All together the results point to the, already reported, S-shape exhumation path characteristic for both the Tso Morari complex (Guillot et al., 2008) and the Kaghan Valley eclogites (Wilke et al., 2010).

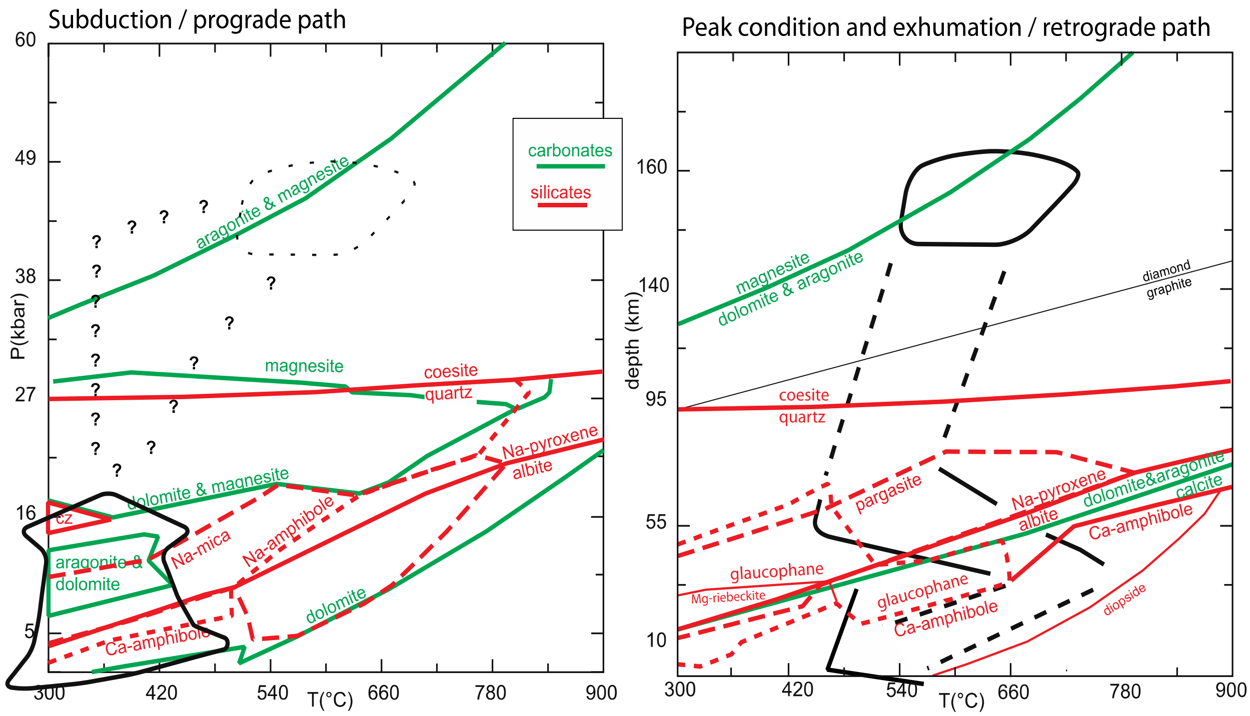

Figure 1. Phase diagrams for garnet-fractionated UHP eclogite bulk rock chemistry calculated with Perple_X. The coesite-quartz and albite = jadeite + quartz equilibria were calculated together with other reaction curves. Mineral phases that were not identified in the eclogite are not given in the diagrams, with the exception of aragonite, diopside and Mg-riebeckite, latter for orientation. Large arrows show our preferred PT-path that was reconstructed with Perple_X phase equilibria modelling for the subduction path and, in addition to that, with conventional geothermobarometry for the exhumation path.

References

Guillot, S., Mahéo, G., de Sigoyer, J., Hattori, K.H., Pêcher, A., 2008, Tethyan and Indian subduction viewed from the Himalayan high- to ultrahigh-pressure metamorphic rocks, Tectonophysics, 451, 225-241.

Mukherjee, B.K., Sachan, H.K., 2009, Fluids in coesite-bearing rocks of the Tso Morari Complex, NW Himalaya: evidence for entrapment during peak metamorphism and subsequent uplift, Geological Magazine, 164, 876-889.

Wilke, F.D.H., O'Brien, P.J., Altenberger, U., Konrad-Schmolke M., and Khan, M.A., 2010, Multi-stage history in different eclogite types from the Pakistan Himalaya and implications for exhumation processes, Lithos, 114, 70-85.