Serpentinites of the Tethys lithosphere and their role in the exhumation of the HPLT Zermatt-Saas ophiolites

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Large volumes of serpentinite are intimately associated with the Zermatt-Saas ophiolite of the Central Alps. The ophiolite represents Tethys ocean floor that formed in the Mesozoic and was destroyed by subduction in the late Cretaceous to early Tertiary. The ophiolite consist of high-P metagabbro, blueschist, eclogite and metasediments.

Antigorite schist is the dominant rock of the serpentinite. The isotopic composition of antigorite is typical of serpentinization by seawater or by “metamorphic water” with δD rangeing from -65 to -55 ‰ and $\delta^{18}O$ from 2 to 7 ‰.

Assemblages in mafic rocks of the ophiolite suggest that the subduction PT path has reached 27 kbar and 600˚C. At this depth (~ 80 km), conditions for serpentinite dehydration are reached. Continued subduction has the consequence that serpentinite (ρ = 2700 kg/m^3) is transformed into dense chlorite-bearing harzburgite (ρ = 3300 kg/m^3) over a small depth interval. This can be referred to as the serpentine-out isograd in subduction. No rocks from the high-grade side of the isograd have been found in the Zermatt-Saas ophiolite. Once the slab has passed the isograd, rocks may not be returned to the surface by buoyant backflow and high-density peridotite and eclogite will disappear into the deeper mantle.

Dehydration of serpentinite at 90 km depth in the Zermatt-Saas subduction zone released a large amount of water (~100kg/m^3) which has several significant effects. (i) It creates a water excess zone at return point depth. In this area, portions of the overlying mantle wedge was serpentinized so that serpentines formed structurally above mafic rocks of the ophiolite. Thus, many of the Zermatt-Saas serpentinite slices may represent a depleted sub-continental harzburgite protolith rather than ophiolitic mantle. Serpentinite formed in this manner can by scraped off the wedge. Together with serpentinite from the oceanic mantle they enclose lenses of eclogite and other high-P mafic rocks and return them to the surface due to buoyant flow aided by lubrication of dehydration water. (ii) In the water excess zone at return point depth, the mantle part of the oceanic lithosphere is completely serpentinized. Normally, oceanic mantle is serpentinized to variable extent (~20–30%). The ultramafic rocks of the Zermatt-Saas complex have been serpentinized 100%, and most of this serpentinization occurred in the water excess zone at return point in the subduction zone.

Upheaval Dome – Impact approved

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Upheaval Dome (Utah, USA) has earlier been interpreted, amongst others, as a pinched-off salt diapir [1] or as an impact structure [2]. In previous petrographical studies, no non-ambiguous evidence for shock metamorphism was identified [2]. Nevertheless, most arguments, such as seismic reflection studies, structural features [3], and microstructures in quartz grains [4] agree with an impact origin of Upheaval Dome.

We recently found some single quartz grains in sandstones of Upheaval Dome target rocks suspect to be shocked quartz with multiple sets of planar deformation features. Planar elements in quartz grains of sandstones of the Upper Jurassic Kayenta Formation turned out to be impact-diagnostic planar deformation features provided by both microscopic studies and our TEM investigation.

Shock wave attenuation to magnitudes below the Hugoniot elastic limit of quartz can be deduced for most zones of the target rocks presently exposed at Upheaval Dome [3]. In sandstones of the Kayenta Formation, inhomogeneities in the stress wave induced maximum pressure peaks of ~10 GPa, necessary to generate planar deformation features in quartz grains. Microstructures in quartz grains investigated by the authors have to be explained as distinct features of shock metamorphism and, thus, we interpret this as ultimate evidence for shock metamorphism in the target rocks and for the impact origin of Upheaval Dome.

References

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