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EXHUMATION OF ALPINE ECLOGITES – DATA AND MODELS

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In general, eclogites as well as blueschist facies metamorphic rocks are important as records of ancient subduction. These rocks are either exposed within accretionary wedges, within obducted ophiolite units, or within single eclogite facies nappes. Furthermore, high pressure rocks may occur within continental basement sequences that indicate a former rift environment, and an extended continental margin. This suggests that many Ultrahigh Pressure/High Pressure (UHP/HP) units may represent the distal portions of former passive continental margins. The conditions of eclogite facies metamorphism are reached at relatively deep levels within the subduction zone, beginning at 40 to 50 km depth. Therefore, special mechanisms are necessary to bring these eclogite facies rocks back to shallow crustal levels ("exhumation"). Basically, the long-term preservation of high-pressure/low-temperature assemblages requires a mechanism of either continued refrigeration by a cold subducted lithospheric slab and uplift to avoid re-equilibration during prolonged periods of static heating, or very fast exhumation. Several mechanisms may contribute to remove material in the hanging wall of HP units within an ancient subduction zone, and to the emplacement of these rocks in shallower lithospheric levels. The processes by which HP rocks reach the Earth's surface are important to an understanding of the thermal and barometric evolution of metamorphism and the preservation potential of peak metamorphic assemblages. The scope of this study on the evolution of Alpine high-pressure units is to combine the textural and microfabric evolution of eclogites with P-T data. This gives access to a more detailed view of the eclogitic and post-eclogitic deformation history from burial by subduction to subsequent exhumation.

Eclogites that are related to the early Alpine history (Cretaceous) are restricted to the Austroalpine nappe complex (ANC), especially to the Middle Austroalpine basement complexes of the Kor- and Saualpe, the Kreuzeckgruppe, the Schobergruppe, the southern part of the Ötztal-Silvretta nappe (Texel Group), and the Sesia Zone. Eclogites that are related to the Paleogene evolution are exposed in the Penninic units of the Western and Central Alps, and within the Tauern Window (TW) of the Eastern Alps.

Within the Koralm/Saualm unit of the ANC most eclogites are eclogitic mylonites documenting plastic deformation of omphacite and garnet. The meso- and macroscale structures indicate an overall extensional regime, possibly related to a large-scale SE-directed ductile low-angle normal shear zone. The eclogites are associated with migmatite-like structures and are intruded by pegmatites. This indicates decreasing pressure, but isothermal or even increasing temperature conditions during exhumation.

In the Eclogite Zone (EZ) of the central southern TW, eclogites and associated high pressure metasediments are intercalated between Penninic basement units (Venediger Nappe (VN)) in the footwall and the Rote Wand-Modereck Nappe (RWN) in the hanging wall). The EZ experienced a polyphase metamorphic evolution, described by a b–shaped P-T path. The EZ and southern (oceanward) parts of the RWN were affected by eclogite facies metamorphism (20–22 kbar, 600–620°C) (M1). However, pressures of only 12 kbar are documented within the VN. The VN, EZ, and RWN were subsequently affected by blueschist facies metamorphism (7–12 kbar, ca. 450° C)(M2), and by upper greenschist to lower amphibolite facies metamorphism (M3). Nappe stacking postdated subduction-related M1, and was contemporaneous to M2. M2 overprint of

the eclogites indicates refrigeration by a cold subducted lithospheric slab during exhumation. Long-term preservation of high-pressure/low-temperature assemblages requires such a mechanism. This evolution is compatible with an emplacement model similar to channel flow. However, the EZ behaved as a coherent unit during its emplacement, which suggests thrusting as emplacement mechanism. Anyhow, the M2 overprint requires the emplacement of the eclogite facies assemblages while heating was delayed within an active subduction channel. Remnants of eclogite facies assemblages have been observed within the ophiolitic Glockner Nappe (GN), too, which forms the hangingwall of the RWN. However, M2 has not been observed there. The P-T evolution of the GN is described by a clockwise P-T path, showing moderate cooling during decompression. This argues for a different exhumation mechanism for the eclogites that are associated with former oceanic assemblages than for passive-margin-related ones.

In the Western Alps, recent investigations in the Monte Rosa area have shown that subsequent to the closure of the Piemonte-Ligurian and Valais oceans the European margin descended into the subduction zone, leading to eclogite facies metamorphism in the Monte Rosa Nappe (MR) at about 37 Ma, and melange formation in the Furgg Zone (FZ). The FZ and the EZ of the TW are in a comparable tectonic position. The MR is interpreted to have ascended towards the surface in the back of the Briançonnais nappes in a corner flow mode. In the hanging wall, the Piemont Ophiolites of the Zermatt-Saas Zone (ZS) consist of eclogites structurally beneath greenschist facies rocks. The latter form the kilometre-wide Gressoney Shear Zone, which is dominated by top-to-the SE movement related to crustal extension (REDDY et al., 1999). It operated over the entire period during which the footwall units evolved from eclogite to greenschist facies. Therefore, this shear zone was interpreted to be responsible for eclogite exhumation (REDDY et al., 1999). Post-metamorphic cooling and exhumation of the ZS eclogites must have been taking place while subduction was still operating. Basically, the eclogites of the Sesia Zone in the hanging wall had undergone a significant part of their exhumation before the ZS eclogites had reached their metamorphic peak (REDDY et al., 1999), and these were already exhumed when the MR descended. This is similar to the evolution of the Eastern Alps. In this area the eclogites of the ANC Koralm-Saualm Complex have already been exhumed to at least amphibolite facies metamorphic conditions, while the eclogites of the Penninic lower plate reached their pressure peak.

In particular, two mechanisms of eclogite exhumation have been proposed for the Alps:

Foot-wall accretion causing stretching and extension in the upper plate; this has especially been proposed for the exhumation of eclogites in the ANC units, and for the exhumation of the HP rocks of Piemonte-Penninic ophiolites (e.g., the ZS and Monte Viso units). Normal-sense shear zones, that are related to these extensional processes may also develop due to crustal velocity gradients in the hanging-wall of rock packages while thrusting is taking place at the base of this unit. Such a model may be applicable to the Alps.

Exhumation in terms of a channel flow model; this has especially been proposed for the exhumation of eclogites in the Penninic units which have been derived from the European margin (EZ in the Eastern Alps; MR, FZ in the Western Alps).

Actually, several exhumation models seem to be related to a continuous process of subduction, footwall accretion, and stretching of the upper plate. Therefore, these processes affected both the Austroalpine upper plate, and the Penninic lower plate.

References

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