Relationships of banded amphibolites and Ordovician orthogneisses in pre-Variscan basements of the Alps

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Despite of the individual character of each of the pre-Variscan basement units of the Alps, they show analogous formations (paragneisses, migmatites, peraluminous orthogneisses, and amphibolites) and structures indicating similar genetic processes. There is consensus regarding the protoliths of the gneisses and migmatites. But the protoliths of the amphibolites are under discussion because their age is largely unknown and original structures often are overprinted by Variscan and Alpine tectonics. However, the amphibolites (i) are typically banded from millimeter to meter-scale (in all units; e.g., Fig. 1a), (ii) are intercalated with para- and orthogneisses on a map-scale (especially in the Aar massif and Silvretta nappe), (iii) can vary in percentage from 3 area% (Strona-Ceneri zone) to 22 area% (Silvretta nappe), (iv) are associated with metagabbros, meta-ultramafics and (meta-) eclogites (in all units), (v) can be migmatic and occur within migmatite formations (Aar massif).

Most studies interpret the banded amphibolites as members of an ophiolite sequence (due to their MORB signature and association with eclogites and ultramafic rocks) or bimodal metavolcanics (due to their compositional banding). Both tectonic settings are supported by case studies. But from a general perspective of subduction-accretion tectonics of the Ordovician orogeny (Fig. 1b and Zurbriggen 2017) they cannot serve as main setting due to following reasons: A clear ubiquitous ophiolite stratigraphy is lacking and obduction is the exception rather than the rule in accretionary complexes. Furthermore, a rhythmic alteration of acidic and basic layers of volcanic rocks might occur as local phenomenon but is unlikely to explain banded amphibolite formations over geographically large distances.

New field observations from Sassella (Silvretta nappe), Lötschental, Betten, Gletsch (Aar massif), Val Piora (Gotthard nappe), and Molinetto (Strona-Ceneri zone) indicate that the banding of the amphibolites results from a tectono-metamorphic overprint of (i) sets of mafic dykes, (ii) multiple intrusions and intermingling of acidic, intermediate and mafic magmas, (iii) migmatites, and (iv) tectonic mélanges of sediments, mafic and ultramafic rocks. This large variety of protoliths of banded amphibolites (Fig. 1c) reflects the dynamics in a subduction channel, the overlying mantle wedge and the base of a subduction-accretion complex (Fig. 1d). The mantle underneath large subduction-accretion complexes can be of lithospheric and asthenospheric type and its melting can be induced by fluids and decompression, respectively. As a result, large amounts of basaltic melts intrude the accreted sediments and induce their melting. This produced a similar amount of peraluminous magmas, the cause for widespread acidic Ordovician magmatism in these basement units.

It is proposed that the production of banded amphibolite formations occurs in two major steps. The first step is related to magma interaction processes in the “zone of intermingling” (c. 5-10 km thick) at the base of a subduction-accretion complex (Fig. 1b). There, basaltic melts (and slices of mélange diapirs containing ultramafics and eclogites) intrude the metagreywackes causing their melting. The solidus of a basaltic melt (c. 900°C; drawn in Fig. 1b) is near to the liquidus of greywacke. Therefore, homogeneous mixing of the two major magmas is unlikely as can be observed in the compositional gap in chemical diagrams. Thus, dyke intrusion and intermingling are major processes, which significantly increase the interface area and resulting heat exchange between crystallizing basaltic melts and cooler metagreywackes and their peraluminous melts (Fig. 1d). The second step is related to thrusting within the accretionary complex. Similarly, as the peraluminous magmas, which intrude syntectonically along steep thrust zones to form sheets of orthogneisses, the intermingled and interlayered mafics are sheared into steep thrust zones and get mylonitized under amphibolite facies conditions. The products are banded amphibolites in all variations. Their spatial association with metagabbros, meta-ultramafics and (meta-) eclogites is due to the intersection of the steep thrust zones with the "zone of intermingling" (Fig. 1b) containing these lithologies as described above (see first production step).

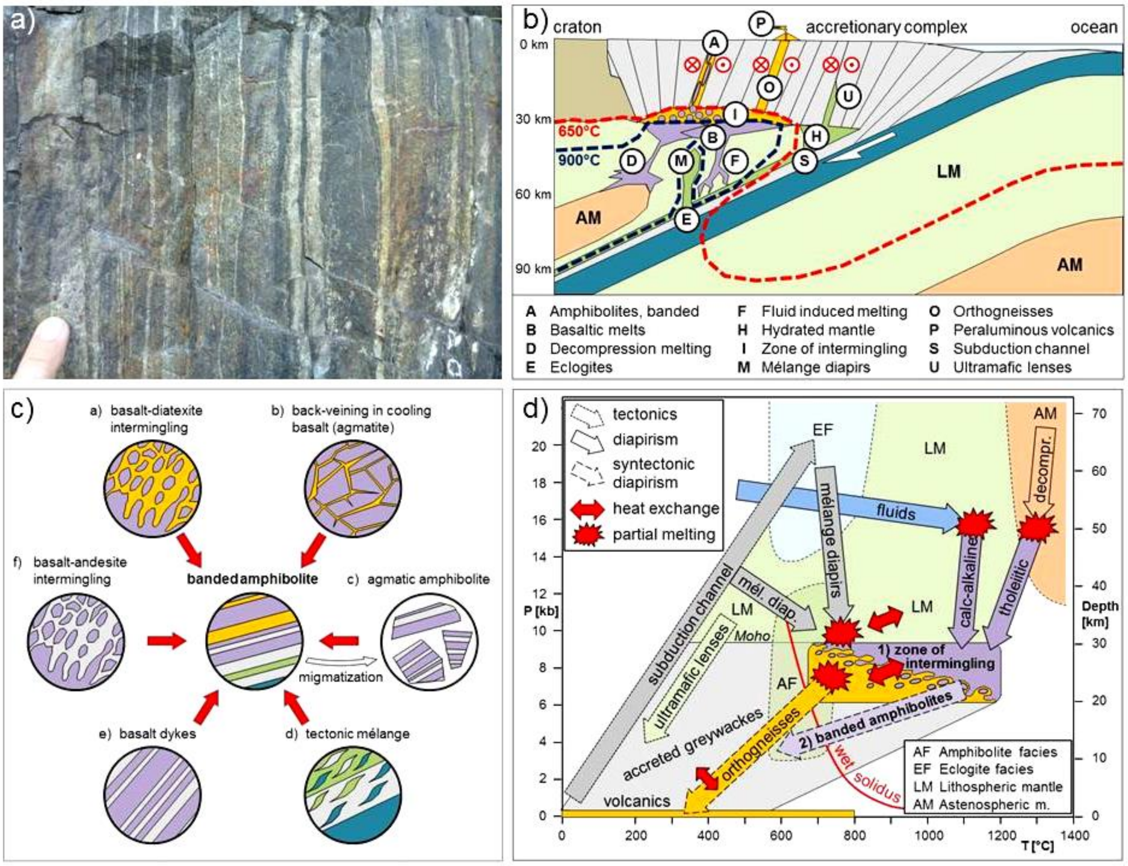

Figure 1: (a) Banded amphibolite from Molinetto (Strona-Ceneri zone; finger for scale). (b) Tectonic setting of an early Paleozoic subduction-accretion complex (Zurbriggen 2017). (c) Scheme of possible protoliths (a-f), which are metamorphosed and mylonitized (red arrows) to result in banded amphibolite. (d) P-T diagram illustrating the two-step production of banded amphibolites in a subduction-accretion complex with peraluminous magmatism.

REFERENCE

Zurbriggen, R. 2017: The Cenerian orogeny (early Paleozoic) from the perspective of the Alpine region. IJES, 106, 517–529.