Metamorphic evolution of Variscan migmatites from NE Sardinia, Italy

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The migmatites of the Variscan chain in NE Sardinia are characterised by the widespread occurrence of fibrolite and retrograde coarse-grained muscovite. Kyanite and fibrolite are common in the migmatites of Punta Sirenella and Punta Bados (NE Sardinia) and provide an excellent opportunity to study the metamorphic evolution of these rocks.

The migmatites are principally stromatic and show at least three folding phases (D_1, D_2, D_3). The oldest structure observed in the migmatites is a gneissose layering (D_1), pre-dating the most pervasive D_2 tight folds with sub-vertical axes. D_2 phase is followed by D_3 folds with sub-horizontal axes.

Mesosomes are medium-grained, with a fabric defined by the alignment of biotite parallel to S_2 schistosity. Mesosomes consist of quartz (25–42%), plagioclase (15–35%), biotite (20–35%), garnet (1–2%), fibrolite (1–15%), kyanite (1–4%), muscovite (8–17%) and K-feldspar (<1%). Accessory phases are apatite, titanite, rutile, monazite and zircon.

Leucosomes are small, no longer than 50 cm, and folded. The leucosome/mesosome ratio varies greatly, ranging from 5 to 30 %.

Leucosomes are coarse-grained, poorly foliated rocks, consisting of quartz (33–55%), plagioclase (15–44%), muscovite (5–11%), biotite (4–8%), kyanite (0–3%), fibrolite (0–31%), garnet (0–2%) and minor K-feldspar (<1%). Accessory minerals are, apatite, titanite, rutile, monazite and zircon.

Plagioclase is a poorly zoned oligoclase (Ab =73%–78%) with a slight decrease in albite content (up to 3%) from the core to the rim. Garnet (approx. 0.6 mm in diameter) is almandine-rich (59–67%), with high pyrope (12–21%) and spessartine (10–20%), but low grossularite (1–3%) content. The X_{Mg} of biotite ranges from 0.46 to 0.53.

The main textural features of migmatites are the following: i) kyanite is partially replaced and rimmed by fine to medium grained muscovite; ii) fibrolite occurs as isolated needles growing on and mantling biotite flakes; iii) K-feldspar occurs as small rare crystals, restricted to inclusions within coarse-grained biotite; iv) biotite, other than in the matrix, often grows on garnet; v) coarse-grained muscovite, crosscutting the fabric, includes fibrolite needles.

The metamorphic evolution of migmatite can be schematically represented in three stages.

The first stage is muscovite-dehydration melting:

(1) Ms+ Pl+ Qtz = Ky+Kfs+melt

with the formation of K-feldspar, kyanite and melt predating D_2 deformation.

Garnet used for geothermobarometry shows Fe decrease (up to 5%) and Mn increase (up to 7%) towards the rim, suggesting retrograde diffusion zoning. Using the garnet core and rim composition, two points of the pressure-temperature path have been determined in some samples using conventional thermobarometry. Garnet core composition and biotite matrix yield temperatures between 550 and 700 °C and pressures between 6 and 8 kbar. The garnet rim and coarse-grained biotite produce lower temperatures of about 50 °C and a lower pressure of about 1–2 kbar.

The second stage is documented by the occurrence of biotite-sillimanite intergrowths and by the formation of retrograde biotite on garnet during D_2 deformation, probably due to the following reaction

(2) Grt +Kfs+ H_2O = Bt + Sil

undergone by the rocks during exhumation.

The third stage is documented by post-D_2 widespread occurrence of coarse-grained muscovite formed by the reaction

(3) Kfs +Sil + H_2O = Ms+ Qtz

which consumes H_2O probably released by the crystallization of residual melt. This reaction is possible if, during the retrograde path, the rocks exceed the invariant point IP1 (P= 3.5–4 kbar; T= 650 °C; Spear et al. 1999) in the NKFMASH system.

K-feldspar-consuming reactions (2) and (3) can account for the very low K-feldspar content observed in the leucosomes.

The metamorphic evolution of the migmatites, inferred from textural features and geothermobarometric data, suggest a clockwise PT path similar to that of other high-metamorphic grade rocks from northern Sardinia described by Franceschelli et al. (1989) and Ricci (1992)

According to these authors, this part of the chain underwent crustal thickening (minimum age 344±7 Ma; Ferrara et al. 1978) as a consequence of Carboniferous continental collision. After collision, the migmatite underwent uplift and surfaced in a short time, as documented by Permian volcanites resting on high grade rocks.

References

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