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Deformation partitioning and fabric development during shearing of felsic migmatites (Valpelline Series, NW Alps)

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The relationships between partial melting and deformation in the continental lower crust are critical for understanding lithosphere rheology and the processes leading to melt segregation. In metapelitic rocks in the lower portions of the crust partial melting typically occurs via dehydration of biotite and is generally characterized by a negative volume change when garnet is produced as a peritectic phase. As a result, segregation of biotite-derived melt by fracturing resulting from dilational strain is not common. Hence segregation of biotite-derived melts in the lower crust is likely to be controlled by active deformation via creation of structural anisotropies (fabric), which define migration pathways from the grain-size to the kilometre scale. This study investigates the relations between deformation mechanisms of minerals, fabric development and grain- and meso-scale deformation partitioning in felsic migmatites.

The study area is located in the Valpelline Series of the Dent Blanche Nappe in the north-western Alps, which represents a slice of pre-Alpine lower crust dominated by metapelitic migmatites (i.e. 'kinzigites' in the Alpine literature). The migmatites are stromatic and show a leucosome-melanosome interlayering defining the dominant foliation (S2), which forms along a sinistral shear zone at least 1 km thick and laterally continuous for at least 8 km. Ti-in biotite geothermometry, mineral inclusions in garnet, and literature data indicate that S2 formed at P, T conditions of 800-820°C, 0.4-0.7 GPa, during dehydration melting of biotite.

The melanosomes have about 80 vol% of garnet + biotite + sillimanite and are very poor in quartz and feldspars, indicating almost complete removal of melt. Garnet forms slightly elongated grains wrapped by biotite and sillimanite layers. Compositional maps of the elongated garnet do not show any zonation. EBSD analysis indicates that the elongated garnets are actually clusters of individual grains with no internal misorientation. We interpret these microstructures as deriving from amalgamation of individual garnets in elongated sites during shearing. Prismatic sillimanite has a strong crystallographic preferred orientation (CPO) with the c-axes parallel to the stretching lineation. However, evidence for internal misorientaton is scarce, indicating that the CPO was probably achieved by passive rotation during shearing. Elongated K-feldspar grains also do not show any internal misorientation and crystal plasticity features. They are rich of sillimanite and quartz inclusions, suggesting that they represent melt pockets crystallized near the site of production. K-feldspar has a weak CPO with the (010) planes parallel to the foliation and either <100> or <101> axis parallel to the lineation. The high aspect ratio was probably achieved by oriented growth during crystallization of melt. In summary, deformation mechanisms of minerals during melt removal from the melanosome seem to be dominated by passive rotation and oriented growth during magmatic flow, with negligible contribution of dislocation creep.

A large (at least several hundred metres thick across foliation) low-strain domain of less pelitic, more quartzofeldspathic composition has escaped the pervasive development of S2. This domain preserves an S1 associated with older stages of partial melting. We speculate that the different bulk and mineralogical composition, reflecting the different nature of the protolith but also the effect of pre-existing melting episodes, determined a reduced melting during D2. This resulted in localization of deformation along melt-richer portions of this lower crustal section.