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Tectonic studies of the European Alps using neutron texture goniometry

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The European Alps were formed by multiple subduction and continent collision events between the European and Adria plates during the Cretaceous and Tertiary. Exhumation processes make the deep structural levels of the collision suture zones accessible to direct observation and sampling. At these deep levels, deformation occurred under elevated temperatures and pressures. Our results from the Penninic nappes in the Central and Western Alps show that the subduction and collisional deformation did not lead to chaotic rock mixture but instead was accommodated by shear zones in which the rocks were transformed to mylonite through ductile deformation processes, including dislocation glide, dislocation creep, dynamic recrystallisation, grain boundary sliding, and diffusion creep, depending on temperature. These processes lead to reorientation of mineral grains and to crystallographic preferred orientation (texture). Analysing the texture yields information about past motions in shear zones, including shear direction, shear sense, deformation geometry, and temperature during deformation. Therefore, studying the texture and microstructure of these mylonites allows reconstructing the different steps of collisional deformation, back to the pre-collisional palaeogeographic situation.

Of the four most important methods for geological texture analysis, (1) optical orientation analysis, (2) X-ray diffraction texture goniometry, (3) electron diffraction, and (4) neutron diffraction, neutrons have the advantage that their low absorption by matter and generally large beam diameter enable true volume measurements. This allows statistical texture measurement even in coarse-grained samples. At the texture diffractometer SV7b at Forschungszentrum Jülich, linear detectors and appropriate data analysis facilitate the study of polymineralic mylonites. We combine neutron texture analysis with the geometric study of grain boundaries and grain shape.

As examples from our work in the Alps, we show results from the Adula nappe (Eastern Swiss-Italian Alps) and the Monte Rosa nappe (Western Swiss-Italian Alps). Eclogites formed during subduction of the nappes and were mylonitised under high-pressure conditions at 60 to 80 km depth. In the Adula nappe, strong L-type omphacite textures were measured in these mylonites and indicate a constrictional deformation geometry (uniaxial extension) in the subduction channel. After this deformation, the rocks were exhumed during the Late Eocene to Oligocene to a shallower crustal level probably by slab extraction, that is, the downward removal of a wedge of mantle material overlying the subduction channel. Textures related to this exhumation were not found so far because the rocks were afterwards completely overprinted by north-directed thrusting with pervasive mylonitisation, observed both in the Monte Rosa nappe and the Adula nappe, and resulting from further plate convergence between Europe and Adria during the Oligocene. Finally, the nappes were further exhumed by extensional deformation, first in WSW-ENE direction parallel to the strike of the orogen (especially the Monte Rosa nappe), then perpendicular to the strike by top-to-southeast extensional shearing. Quartz textures formed during these events vary depending on the depth of formation and the corresponding temperatures, indicating predominance of prism-<a>-glide at higher temperatures, and rhomb-<a> to basal-<a>-glide at lower temperatures. The combined study of textures and 3-D grain boundary fabrics allows to detect overprinting deformation events.