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Dissolution-precipitation creep of K-feldspar in mid-crustal granite mylonites

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Abstract

The deformation of K-feldspar within lower amphibolite facies granite mylonites from the Gran Paradiso nappe (North-Western Alps, Italy) is primarily accomplished by dissolution, replacement and precipitation processes, with little or no evidence for dislocation glide or creep. New elongate grains of K-feldspar precipitate in dilational domains within and around K-feldspar porphyroclasts as a part of the process of myrmekite formation that progressively consumes the porphyroclasts. The new grains grow in epitaxial continuity with the parent porphyroclasts, which hinders the development of a bulk crystallographic preferred orientation (CPO) in the aggregates of new grains when large amounts of relict K-feldspar are still present. In mylonites, the magmatic K-feldspar is eventually transformed into 100−300 μm thick, nearly monomineralic, fine-grained (20−50 μm in size) aggregates of new grains showing an oblique shape fabric and a CPO. The observed CPO is not consistent with the activity of any slip system in K-feldspar. Instead, it is interpreted to result from dissolution-precipitation creep, with a slow reaction rate parallel to [010] and [001] crystallographic axes and a fast reaction rate parallel the [100] axis. Consistent with such a dissolution-precipitation mechanism, boundaries of new K-feldspar grains are highly corroded when oriented approximately parallel to the extensional instantaneous stretching axis, whereas boundaries approximately orthogonal to the same stretching axis show well-developed crystal facets. The CPO developed is weak, which suggests that the anisotropy in the dissolution/growth rate of K-feldspar is also weak.

Keywords: K-feldspar microstructure; Electron backscatter diffraction (EBSD); Crystallographic preferred orientation (CPO); Granite mylonite; Dissolution-precipitation creep; Deformation mechanisms

1. Introduction

K-feldspar is a major mineral component of many granitoids and its deformational behaviour is important for establishing the overall rheology of continental crust. Microstructure and crystallographic preferred orientation (CPO, texture) provide the link between natural and experimental examples of dynamically recrystallized aggregates and are thus powerful tools for the interpretation of rock rheology and for estimating different deformation parameters during ductile flow (e.g., Law, 1990; Passchier and Trouw, 1996). Although there are many detailed descriptions of microstructures of K-feldspar developed during deformation under a range of metamorphic conditions from greenschist to eclogite facies (e.g., Debat et al., 1978; Vidal et al., 1980; Simpson and Wintsch, 1989; Pryer, 1993; Altenberger and Wilhelm, 2000), only a few studies report the CPO of K-feldspar in dynamically recrystallized aggregates (Schulmann et al., 1996; Martelat et al., 1999; Franek et al., 2006; Ishii et al., 2007) or discuss the possible active slip systems (Tullis, 1983 and references therein).

The development of CPO in dynamically recrystallized aggregates within deformed rocks is commonly assumed to result by dislocation glide along specific slip systems, although the process of CPO development is not fully understood. Among the concurrent grain-scale processes that compete during recrystallization, dissolution-precipitation creep can be of primary importance in intergranular, fluid-assisted deformation. This mechanism, also referred to as 'stress-induced solution transfer' and/or 'pressure solution' (Vernon,

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2004), implies that grains are dissolved at sites of high normal stress, whereas new material, transported along intergranular fluid pathways, is added at sites of relatively low normal stress. Dissolution-precipitation creep can be efficient under low grade metamorphic conditions in fluid-rich environments (e.g., Hippertt, 1994a; Passchier and Trouw, 1996), but can also be important under amphibolite facies conditions (Berger and Stünitz, 1996; Wintsch and Yi, 2002) and during anatexis (Álvarez-Valero et al., 2005).

Whether dissolution-precipitation creep is capable of producing a CPO or not is still a matter of debate. That dissolution-precipitation creep can play a primary role in CPO development has been established, or at least proposed, for natural quartz deformed under low grade metamorphic conditions (Hippertt, 1994a; Stallard and Shelley, 1995; Takeshita and Hara, 1998), for experimentally deformed quartz (Vernooij et al., 2006), for naturally deformed clinopyroxene within eclogites (Godard and van Roermund, 1995) and for experimentally deformed albite (Heidelbach et al., 2000). Bons and den Brok (2000) also presented a numerical model in which dissolution-precipitation creep associated with rigid body rotation produced different CPOs that varied with the deformation regime.

In this paper we describe the deformation microstructures and CPO of K-feldspar within lower amphibolite facies granite mylonites of the Gran Paradiso nappe (NW Alps, Italy). The CPO data were measured by Electron Backscatter Diffraction (EBSD). Mylonitization occurred under water-rich conditions and was accompanied by grain-scale mass transfer, as shown by the characteristic synkinematic metamorphic reactions (e.g. myrmekite-forming reactions) and by the extensive development of microveins. The studied granite mylonites and the deformation conditions were similar to those described from the Ryoke metamorphic belt, NW Japan, by Ishii et al. (2007), although the metamorphic grade in their examples may be slightly lower (upper greenschist facies). Ishii et al. (2007) considered that the CPO of K-feldspar in the Ryoke granite mylonites was achieved by dislocation creep. Here we show that in the Gran Paradiso mylonites dissolution-precipitation creep was the dominant deformation mechanism of K-feldspar and played a major role in the development of the CPO.

2. Geological setting

The studied granite protomylonites and mylonites were sampled in the Penninic Gran Paradiso tectonic unit of the North-Western Alps (Italy). The Gran Paradiso unit is a slice of pre-Alpine mid-crustal continental rocks originally forming part of the paleo-European continental margin, which was involved in the polyphase Alpine orogeny (Dal Piaz et al., 1972). The pre-Alpine rocks of the Gran Paradiso nappe consist of amphibolite facies paragneisses and metabasites (Dal Piaz and Lombardo, 1986), which were intruded during the Permian by large, dominantly granitic intrusions (Ballèvre, 1988; Ring et al., 2005). The Alpine tectono-metamorphic evolution produced a pervasive reworking of the pre-Alpine protolith and involved an early high-pressure eclogitic stage followed by an upper greenschist to lower amphibolite facies stage during exhumation (Dal Piaz and Lombardo, 1986; Ballèvre, 1988; Borghi et al., 1996; Le Bayon et al., 2006). Granites were extensively converted to augen gneisses and mylonites, but massive- to weakly foliated metagranites are preserved in a kilometre-scale low-strain domain in the Piantonetto Valley (Callegari et al., 1969). Here the Alpine deformation is localized into different sets of discrete, lower amphibolite facies ductile shear zones (Menegon, 2006; Menegon et al., 2006) and it is the mylonites within these shear zones that are the subject of this paper (Figs. 1a,b).

3. The mylonitic shear zones of Piantonetto Valley

The granite protolith consists of K-feldspar (32% by volume), plagioclase (27%), quartz (27%), biotite (13%), and

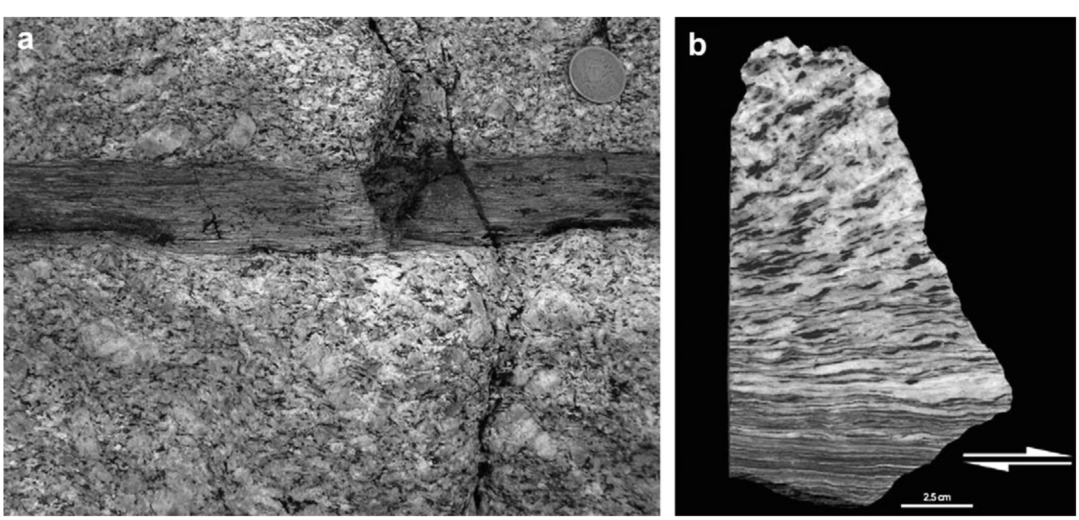

Fig. 1. (a) Localized ductile shear zone within metagranites of the Piantonetto Valley (Gran Paradiso nappe). UTM 32T 5037070 north, 371539 east; (b) The mylonite sample P15Z analysed in this study. UTM 32T 5038458 north, 372896 east. Sense of shear is dextral in both (a) and (b).