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Progressive softening of brittle-ductile transition due to interplay between chemical and deformation processes

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The micro-scale shear zones (shear bands) in granitoids from the South Armorican Shear Zone reflect localization of deformation and progressive weakening in the conditions of brittle-ductile transition. We studied microstructures in the shear bands with the aim to establish their P-T conditions and to derive stress and strain rates for specific deformation mechanisms. The evolving microstructure within shear bands documents switches in deformation mechanisms related to positive feedbacks between deformation and chemical processes and imposes mechanical constraints on the evolution of the brittle-ductile transition in the continental transform fault domains. The metamorphic mineral assemblage present in the shear bands indicate their formation at 300-350 ˚C and 100-400 MPa. Focusing on the early development of shear bands, we identified three stages of shear band evolution. The early stage I associated with initiation of shear bands occurs via formation of microcracks with possible yielding differential stress of up to 250 MPa (Diamond and Tarantola, 2015). Stage II is associated with subgrain rotation recrystallization and dislocation creep in quartz and coeval dissolution-precipitation creep of microcline. Recrystallized quartz grains in shear bands show continual increase in size, and decrease in stress and strain rates from 94 MPa to 17-26 MPa (Stipp and Tullis, 2003) and $3.8*10^{-12}$ s^{-1}- $1.8*10^{-14}$ s^{-1} (Patterson and Luan, 1990) associated with deformation partitioning into weaker microcline layer and shear band widening. The quartz mechanical data allowed us to set some constrains for coeval dissolution-precipitation of microcline which at our estimated P-T conditions suggests creep at 17-26 MPa differential stress and $3.8*10^{-13}$ s^{-1} strain rate. Stage III is characterized by localized slip along interconnected white mica bands accommodated by dislocation creep at strain rate $3.8*10^{-12}$ s^{-1} and stress 9.36 MPa (Mares and Kronenberg, 1993). The studied example documents a competition between shear zone widening and narrowing mechanisms, i.e. distributed and localized deformation, depending on the specific mineral phase and deformation mechanism active in each moment of the shear zone evolution. In addition, our mechanical data point to dynamic evolution of the studied brittle-ductile transition characterized by major weakening to strengths $\sim$10 MPa. Such non-steady-state evolution may be common in crustal shear zones especially when phase transformations are involved.

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