Geophysical Research Abstracts,
Vol. 11, EGU2009-9132, 2009
EGU General Assembly 2009
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Cleaveage domains control the orientation of mylonitic shear zones at the brittle-viscous transition (Cap de Creus, NE Spain) – a combined field and numerical study

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Propagation of greenschist-facies shear zones is often preceded by the formation of fractures in their tip process zones. These fractures tend to have a tensile nature and are generally considered as having triggered the formation of mylonites by focusing fluid flow and locally accelerating strain softening. The often-observed parallelism between the tensile fractures and the mylonitic shear zones indicates that the fractures not only control the position but also the orientation of the shear zones.

The mechanical antagonism in this parallelism is usually resolved with a reorientation of the stress field between fracture formation and mylonitic shearing. Where fractures were clearly shown to form parallel to the shear zone in the same deformation, this might be due to the influence of mechanical anisotropies in the host rock.

In our combined numerical and field study, we test the potential of a foliation to influence the orientation of a microfracture. We designed a numerical experiment using the finite element code Abaqus® (Hibbit et al. 2003) to simulate strain localization in metapelitic and metapsammitic rocks at greenschist-facies conditions. The experimental setup comprises a 2D parametric model with two rheological phases (‘cleavage domains’ and ‘microlithons’ consisting of muscovite and quartz respectively). The geometry of the model is described in terms of probability distributions which allow us to quickly generate different realizations of 2D sections with prescribed muscovite content, cleavage domains size, orientation and distribution. We consider the specific heat, thermal expansion and thermal conductivity of both materials, as well as anisotropic elastic properties for the muscovite. The plasticity flow laws used consider the temperature, pressure and strain rate dependencies. Our models are deformed under simple shear applied with velocity boundary conditions on a thin buffer zone surrounding the sample, at 450°C and under a confining pressure of 300MPa. The simulations are run using an implicit solver for the coupled system of continuity, momentum and energy equations and the energy equation is considering the shear heating feedback (Regenauer-Lieb 2006).

Our models show that the amount, distribution and orientation of cleavage domains control the stress distribution in the model and hence administer strain localization on a microscale at greenschist-facies metamorphic conditions. Cleavage domains generally appear sheared; stress concentrates at the tips of individual cleavage domains causing stress perturbations in the surrounding microlithon. Individual perturbations tend to interconnect at low angles to the shearing plane, forming stress bridges. We interpret these stress bridges as the sites of microfracture formation. Experiments with low mica contents show microfractures forming at small angles to 1. In contrast do runs with high mica contents and contiguity, with cleavage domains oriented at high angles to the shearing plane, show microfracture at up to 90° with respect to 1. Our simulations demonstrate how a foliation defined by muscovites controls the orientations of microfractures at greenschist-facies conditions. Since these exert a dominating influence on mylonitic strain localization (Fusseis & Handy, 2008), our results indicate that preexisting mechanical anisotropies might have controlled the orientations of greenschist-facies mylonitic shear zones at the Cap de Creus.

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