

Rheological weakening as a mechanism for simple shear deformation during lithospheric extension

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The pure and simple shear models were proposed by McKenzie (1978) and Wernicke (1985), respectively, to account for many geological observations in continental extensional zones. Since then, many researchers have been devoted to classify many rifted-basins and passive margins referring to their morphology that are symmetrical or asymmetrical. However, the reason why these two types of rift morphology are present is still unclear. Possibility of onset of simple shear deformation of the lithosphere during extensional tectonics is discussed in this study.

The deformation mechanism of the lithosphere is dependent on its composition, temperature and state of stress. At low temperature and pressure conditions, the rocks deform in brittle fashion. At high temperatures and pressures, in contrast, rocks respond by ductile deformation to applied differential stresses. In ductile deformations, the mechanism that produces the highest strain rate is the rate controlling for a given temperature and applied stress conditions. In typical lithosphere conditions, the dislocation creep seems to be the dominant deformation mechanism (e.g., Kirby, 1983). However, deformation may be achieved by diffusion creep mechanism for fine grain size.

Recently, many authors suggested that the diffusion creep might be important for the formation of shear zones (e.g., Kameyama et al., 1997; Braun et al., 1999). Some observations in strongly deformed shear zones have demonstrated the evidences for softening due to grain size reduction (e.g., Vissers et al., 1995; Jin et al., 1998). If the grain size could be reduced during lithospheric extension, the rock strength may be reduced significantly at this point to cause the strain localization. Mechanisms for reducing the grain size are required.

Dynamic recrystallisation (e.g., Tullis et al., 1990), syntectonic metamorphism (e.g., Brodie and Rutter, 1987) and cataclasis (e.g., Hippler and Knipe, 1990) are suggested as possible mechanisms for reducing the grain size. These effects are incorporated into the model of uniform extension of the lithosphere to investigate the hypothesis that rheological weakening caused by grain size reduction during the pure shear stretching could produce the shear zone possibly leading to the onset of simple shear one. The stress and temperature dependent model by De Bresser (1998) is used for the change in grain size by the dynamic recrystallisation. Linear or non-linear relation between the amount of strain and the grain size is adopted for the grain size reduction, based on a study of Hippler and Knipe (1990), associated with the cataclasis. For the grain size reduction associated with syntectonic metamorphism, spinel lherzortite to plagioclase lherzortite reaction is considered (Newmann et al., 1999). Possibility that the lithosphere could evolve from pure shear to simple shear system during extension will be discussed.