Fault models revisited based on friction to flow law

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Friction to flow law (Shimamoto and Noda, 2014, JGR) can describe a transition from friction to flow using only friction and flow parameters, and shear zone width *w*. Friction and flow laws are described in terms of velocity and displacement, and shear strain rate and shear strain, respectively, and *w* is needed to relate velocity and shear strain rate to merge the two laws. The friction to flow law is a mixing law connecting friction and flow laws smoothly, and no other parameters are required probably because no new deformation mechanisms operate in the intermediate regime. In JpGU last year, Shimamoto and Noda argued (i) that the velocity dependency of shear resistance is by far the most heterogeneous in the intermediate regime between friction and flow, and (ii) that frictional patches can be surrounded by viscous matrix in the middle part of lithosphere because temperature for the onset of flow depends on rock types. This presentation will discuss (1) how fault models change in view of the friction to flow law, (2) how to construct realistic mechanical models of faults and plate boundaries that are usable in modelling earthquake generation, and (3) how to reproduce friction to flow transition for important rocks in laboratory.

Shimamoto and Noda (cited above) already discussed a revised fault model using results from earthquake modelling based on friction to flow law. A new problem addressed here is a question which of power law (dislocation creep) and grain-size sensitive flow law (diffusion creep or superplasticity) should be used as a flow law to describe fault properties. The latter law has often be favoured because the cores of deep shear zones are often composed of very fine-grained ultramylonites, grain size being on the order of microns or even smaller. Both flow laws are determined for calcite and plagioclase (Heard and Raleigh, 1972, GSA Bull.; Schmit et al., 1977, Tectonophysics; Rybacki and Dresen, 2000, JGR). Thus, strength profiles were constructed with the friction to flow law, assuming *w* = 0.1~10 m and velocity = 10 mm/yr. Results clearly show that diffusion creep occurs at lower stresses for both minerals (although this is not the case in laboratory experiments). Power-law creep is expected in the middle and lower parts of lithospheres, whereas diffusion creep is expected to be dominant in fault and plate-boundary zones. Thus, frictional patches can be surrounded by linear or nearly linear viscous flow matrix at some depths, and this can be quite important in analysing low-frequency earthquakes and slow slips.

Traditional fault models, started from Sibson (1977, J. Geol. Soc. London), have proposed how materials controlling friction and flow properties, types of fault rocks reflecting deformation mechanisms, and fault geometry such as fault and shear zone widths changes with increasing depth. Such models are bases for constructing realistic mechanical models for faults and plate boundaries. However, the models alone are not usable in modelling earthquakes and plate-boundary behaviours. Friction to flow law captures essential changes in fault properties with depth in a very simplified manner. Both transient and steady-state properties are included and the law can be used in earthquake modelling. However, the law for single material can never describe complex and variable properties of faults and plate boundaries. I want to discuss what has to be done to connect fault and earthquake studies, as much as possible in my presentation. Here I point out the importance of three problems; (I) to check if the friction to flow laws holds for important rocks or not in laboratory experiments, (II) to determine flow laws for important rocks constituting fault and plate-boundary zones, and (III) to determine transient flow properties in flow laws (see Noda and Shimamoto, 2010, GRL). I will give apparatus capabilities required for (I). Unfortunately, there are only small amount data on (II) and (III).

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