Heterogeneous velocity-dependency structures of lithospheres as inferred from the friction to flow law

*Toshihiko Shimamoto[1], Hiroyuki Noda[2]

1. Institute of Geology, China Earthquake Administration, 2. Disaster Prevention Research Institute, Kyoto University

Behaviors of large-scale faults across lithospheres and plate boundaries are characterized by frictional slip at shallow depths, though shearing deformation in the intermediate regime, and high-temperature shearing deformation. Friction to flow law (Shimamoto and Noda, 2014) can describe transition from friction to flow using only frictional 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 merge the two laws. There are abundant data on rock friction and flow laws of representative rocks, and the friction to flow law is applicable to diverse faults and shear zones. In particular, this law is bound by friction law at shallow depths and by flow law at at great depths, and it smoothly connect the two laws. Velocity dependency of friction or shear resistance (called velocity dependency hereafter) affects fault motion dramatically, including seismic fault motion. This presentation explores heterogenous velocity-dependency structures of lithospheres as inferred from the friction to flow law, and discusses how the heterogeneity affect the seismic fault motion.

Velocity dependency of friction is generally quite small, whereas the velocity dependency increases sharply in the intermediate regime, undergoes its peak, and decreases towards fully plastic regime. The velocity dependency in pressure-insensitive fully plastic regime decreases with decreasing flow stress. If the velocity dependency is expressed by a parameter, corresponding to ($a-b$) parameter in friction, and is plotted against the depth, a curve similar to strength profile of a lithosphere is obtained. However, very large changes in the velocity dependency occur within the intermediate regime, and hence the profile for the velocity dependency is much sharper than the strength profile. The upper half of the velocity-dependency profile is similar to the velocity-dependency models used in earthquake modeling since Tse and Rice (1986). Flow properties are not specified in such models, but earthquake modeling is possible because the sharp increase in velocity dependency stops earthquake rupture propagation to greater depths.
Velocity-dependency model of earthquakes is a static model, assuming a fixed ($a-b$) versus depth relationship. Whereas, the friction to flow law allows to calculate changes of the velocity dependency for rocks with different flow laws, temperature, normal stress, pore pressure and slip rate, during seismic and interseismic periods. Locations and magnitude of peak velocity dependency depends largely on temperature for the onset of high-temperature flow and on slip rate. Quartz-containing rocks undergo plastic flow at lower temperatures than quartz-free rocks containing feldspar, amphiboles and pyroxene. Thus the largest heterogeneity in the velocity dependency is expected in the core of lithosphere and in the overall transitional regimes from friction to flow. If different rocks of various sizes having different flow properties coexist, rocks still keeping frictional properties can coexist with rocks having very high velocity dependency. This heterogeneity in the velocity dependency is far larger than the heterogeneity arising from different frictional properties. Pelitic rocks are abundant in subduction zones, but unfortunately its flow law is not established yet. However, it is likely to be the weakest rocks, and hence subducting plate boundary near the bottom of seismic zone is probably characterized by frictional patches surrounded by matrix with very high velocity dependency. Such a matrix will suppress growth of rupture to grow into a large earthquake and may promote slow slip and low-frequency earthquakes. It would be of great interest to conduct earthquake modeling incorporating the heterogeneous velocity dependency, as expected from

the friction to flow law.

Keywords: friction to flow law, fault rheology, earthquake mechanisms, fault mechanics, lithosphere rheology