

## Revised evolution law in rate- and state-dependent friction incorporating a stress-weakening effect

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We observed continuous variation of frictional strength, which is a type of state variable in rate- and state-dependent friction law dependent on the contact state of the interface, in a friction experiment of an interface between two rough granite surfaces with complex slip history imposed. The observation of frictional strength was performed in the following two ways; 1) by using a constitutive relation in rate- and state-dependent friction law with measured stress and slip velocity, 2) by using an acoustic monitoring technique (Nagata et al., 2008). The latter method is usable even when slip velocity is too low to measure and the former method cannot be used. A constitutive parameter  $a$  necessary for the former method has been estimated with a newly proposed method (J169: Direct effect coefficient  $a$  for granite is not about 0.01; it is never less than 0.04, most likely about 0.05).

We compared thus observed variation of frictional strength with the prediction of an existing popular evolution law called Dieterich law or slowness law. The comparison has shown that an additional stress-dependent weakening term is needed for Dieterich law to well reproduce the observed variation of frictional strength. Additional independent support for the existence of stress-dependent weakening was obtained from acoustic observation in experiments carefully designed to suppress the change of frictional strength for reasons other than shear stress. For high shear stress conditions, which is the main concern of fault mechanics and friction experiments, the effect suggested by acoustic data quantitatively agreed with that suggested by the analysis of misprediction of the existing Dieterich law mentioned above. At lower shear stress, the stress-weakening effect seems to become very weak.

The revised Dieterich law incorporating the stress-weakening term can very well predict the variation of both shear stress and frictional strength in various phases of the experiments with the same set of parameter values. As expected from the good agreement with observations, the revised law has resolved two well-known flaws of Dieterich law, slip-weakening distance increasing with initial strength and asymmetric changes of shear stress in velocity step-up and step-down tests, to some extent though the modification was not specifically to fix these flaws. The stress-weakening term may be a result of the breaking of junction bonds by the elastic deformation of asperities on the frictional interface, though this interpretation is still speculative.