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Earthquake Dynamics in Laboratory Model and Simulation – Accelerated Creep as Precursor of Instabilities

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Shallow earthquakes can be considered as a result of tribological instabilities, so called stick-slip behaviour [1,2], meaning that sudden slip occurs at already existing rupture zones. From a contact mechanics point of view it is clear, that no motion can arise completely sudden, the material will always creep in an existing contact in the load direction before breaking loose. If there is a measureable creep before the instability, this could serve as a precursor.

To examine this theory in detail, we built up an elementary laboratory model with pronounced stick-slip behaviour. Different material pairings, such as steel-steel, steel-glass and marble-granite, were analysed at different driving force rates. The displacement was measured with a resolution of 8 nm. We were able to show that a measureable accelerated creep precedes the instability. Near the instability, this creep is sufficiently regular to serve as a basis for a highly accurate prediction of the onset of macroscopic slip [3]. In our model a prediction is possible within the last few percents of the preceding stick time. We are hopeful to extend this period.

Furthermore, we showed that the slow creep as well as the fast slip can be described very well by the Dieterich-Ruina-friction law, if we include the contribution of local contact rigidity. The simulation meets the experimental curves over five orders of magnitude. This friction law was originally formulated for rocks [4,5] and takes into account the dependency of the coefficient of friction on the sliding velocity and on the contact history. The simulations using the Dieterich-Ruina-friction law back up the observation of a universal behaviour of the creep's acceleration.

We are working on several extensions of our model to more dimensions in order to move closer towards representing a full three-dimensional continuum. The first step will be an extension to two degrees of freedom to analyse the interdependencies of the instabilities. We also plan to install a larger system which is capable of performing events of different spatial extent and magnitude.

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