Friction and earthquakes : Bridging across scales

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What is the key to comprehending earthquake generation processes from a physical point of view ? [1] In a classical physics approach, we usually decompose a complicated issue into more simplified sub-issues. Namely, we divide the process into smaller elements and comprehend them on a step-by-step basis. In the case of earthquakes, the comprehension of the complex internal structure of earthquake faults is one of such sub-issues. Additionally, the frictional properties of rocks are important sub-issues since an earthquake is the shear rupture of faults. The structure of faults could be revealed by the seismological, geological, and electromagnetic methods, whereas the frictional properties of rocks have been examined by laboratory experiments of rocks and core samples.

However, there is a serious scale-gap problem : The frictional surfaces examined in typical laboratory experiments are on the order of ten square centimeters, whereas the fault slip of actual earthquakes can occur over areas of up to several hundreds of square kilometers. Namely, the spatial scale of actual earthquakes is many orders of magnitude larger than the experimental samples : The area in which an earthquake occurs would be composed of 10^{10} to 10^{12} experimental samples. This number is less than the Avogadro number, but similar to the number of molecules in a cube of material with sides of several microns. Generally, the phenomena at the molecular-scale and those at the micron-scale are qualitatively different. Does this also mean that the physical properties obtained in laboratory experiments and those observed and/or inferred in natural earthquakes are also qualitatively different ? If so, then how can we comprehend earthquakes based on their elementary processes ?

The following road map immediately comes to mind. Since it is virtually impossible to model earthquakes on a fault divided into laboratory-scale meshes, observation-scale meshes are usually adopted, the size of which are several kilometers. Although the laboratory-scale friction law is being applied to these meshes in most simulations, there is no guarantee that the friction law would hold true for geological materials that are thousands of times larger than the laboratory samples. The characteristics of the system, which are essentially defined by centimeter-scale samples, could be different from those of actual geological material. Our mission is to find a friction law that is theoretically applicable to the plate interface at the scale of several kilometers [2].

Références

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