Friction from the standpoint of single atoms: How nanoscale mineral topography drives macroscale seismicity

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Friction forces play a key role in mechanical phenomena occurring on all scales, from the operation of microelectromechanical systems to interplate earthquakes. Thanks to the development of nanoscale investigation tools such as scanning probe microscopy, the study of friction and wear phenomena down to the atomic scale is becoming a leading topic within the field of surface physics, and has given rise to the science called nanotribology [1]. We focus here on the anisotropic aspects of nanotribology, related in particular to the surface of crystalline materials such as phyllosilicate minerals. We use atomic force microscopy to map in two dimensions the frictional anisotropy at the nanoscale and to carry out data interpretation to unravel the friction–surface structure relationship. As model systems, we analyzed the basal plane of muscovite, phlogopite, and antigorite single crystals, and interpreted the data in terms of constitutive models of anisotropic friction. We show that the basal surface of these minerals is characterized by different degrees of frictional anisotropy, reaching levels as high as 100% in antigorite [2].

It is known that the shear interface of thrust faults is often subjected to a progressive macroscopic anisotropization due to the strain induced preferred orientation of crystals, which reflects in the propagation of seismic waves [3]. An underestimated consequence of such anisotropization, in relation to our nanotribological analysis, is that the fault might increase or decrease in frictional strength depending on the orientation mechanism of crystallites within the fault rocks. This frictional bivalence is not the only peculiarity related to frictional anisotropy of phyllosilicates. We show also that, in the framework of a hardening process, slip trajectories might be substantially declined from the plate convergence direction, giving rise to apparently unexplainable seismic events.

[1] Urbakh & Meyer (2010) *Nat. Mater.* **9**, 8-10. [2] Campione & Capitani (2013) *Nat. Geosci*. **6**, 847-851. [3] Katayama *et al*. (2009) *Nature* **461**, 1114-1117.