Identifying the origin of macroscopic friction between clay mineral surfaces

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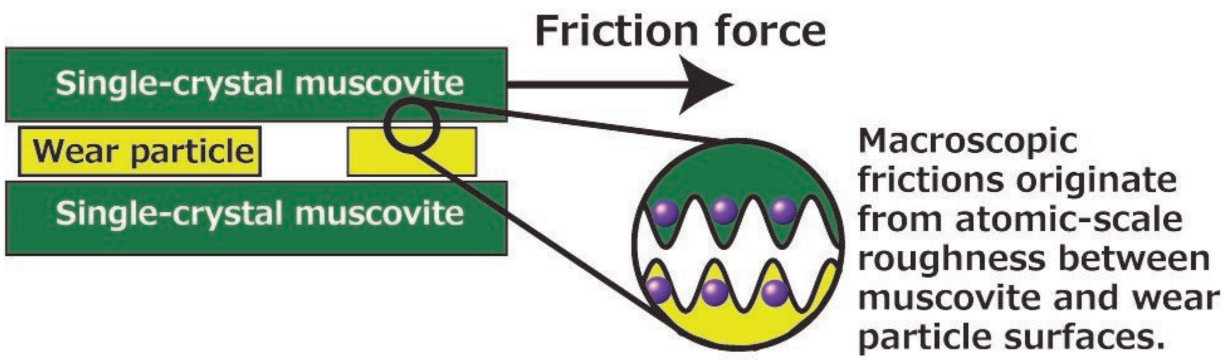

We removed moisture from the space between the muscovite surfaces by applying high pressure under dry conditions. We then measured frictional forces between the muscovite surfaces at different sliding positions. The results of this experiment closely coincided with frictional forces estimated using quantum mechanical calculations, indicating that the frictions occurring between clay minerals are controlled by atomic-scale electrostatic forces. Credit: NIMS

NIMS, the University of Tokyo and Hiroshima University jointly discovered for the first time, through theoretical calculation and experiment, that macroscopic frictions occurring between clay mineral surfaces originate from interatomic electrostatic forces between these surfaces. This finding may facilitate the design of solid lubricant materials and understanding of earthquake-causing fault slip mechanisms.

Frictional forces between the surfaces of layered crystals, such as clay minerals, are generally low. This property is thought to be a cause of landslides and fault movements in nature. Active efforts have been made in research on friction to develop friction-reducing solid lubricants and for other purposes. Origin of Friction between clay mineral surfaces had been thought to be induced by some sorts of bonding forces; however, these forces were not understood in detail due to complex influences of electrostatic and intermolecular forces between clay mineral surfaces, crystallographic orientation differences between these surfaces, surface roughness and the presence of impurities.

This joint research team studied muscovite—a layered clay mineral—with flat and smooth surfaces at the atomic level. The team first removed moisture from the space between the muscovite surfaces (20 cm x 40 cm in area) by applying high pressure under dry conditions. The team then measured frictional forces between the muscovite surfaces at different sliding positions. As a result, the team observed wear particles produced from worn muscovite surfaces and found that these particles may have nullified the effect of crystallographic orientation on frictional forces. The team also determined the frictional forces generated by estimating interatomic electrostatic forces between contacting surfaces using quantum mechanical calculations, assuming that the effect of crystallographic orientation on frictional forces is null. The calculated frictional forces nearly perfectly matched experimental results. Thus, the research team confirmed for the first time that frictions occurring between the surfaces of clay minerals of tens of centimeters in size are controlled by atomic-scale electrostatic forces.

In future studies, the researchers hope to develop a theory that will explain frictional strength in a broad range of clay minerals, in addition to muscovite. Such theory may provide material design guidelines for friction-reducing solid lubricants and other friction-related products.

More information: H. Sakuma et al, What is the origin of macroscopic friction? *Science Advances* (2018). DOI: 10.1126/sciadv.aav2268

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