Frictional Ageing from Interfacial Bonding and the Origins of Rate and State Friction

Li et al., 2011

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Key Points

- Static friction of rocks grows logarithmically with time (ageing). The mechanism for this strengthening is explored in this paper.
- Frictional ageing arises from the formation of interfacial chemical bonds. Plastic creep cannot explain the ageing at the nm scale.
- A single contact (asperity) at the nanoscale level is isolated to investigate the physical origins of ageing process.

Key Points

- Frictional ageing is length-scale dependent: relatively larger at smaller scales.
- Logarithmic dependence is attributed to the rate of the chemical reaction slowing with time.

Methods

- Single Asperity Slide-Hold-Slide friction experiment.
- Nanoscopically sharp oxidized silicon tips and oxidized silicon wafers using Atomic Force Microscope.
- Second experiment between Silicon and Diamond/Graphite shows similarresults.

Discussion

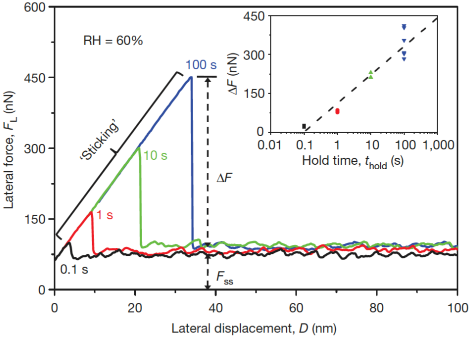

Figure 1 | Lateral force versus nominal lateral displacement data for typical SA-SHS tests after stationary holds at 60% RH. Upon lateral displacement, the tip sticks to the substrate, resulting in linear, elastic lateral loading of the AFM cantilever (Supplementary Figs 1 and 2). When the lateral force exceeds static friction, the tip slips forward, indicated by abrupt drops in lateral force (ΔF), followed by subsequent sliding at the steady-state friction force (F_{ss}). In the inset ΔF varies linearly with the logarithm of hold time. The dotted line is a linear fit of the averaged values.

Discussion

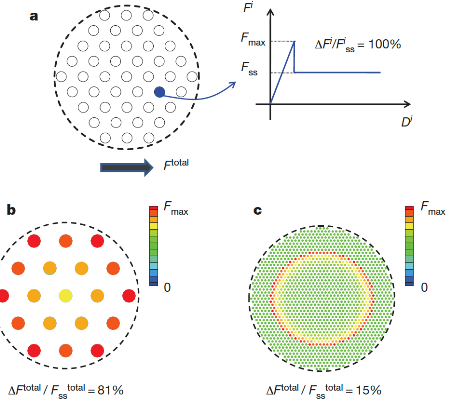

Figure 2 | The quasi-static discrete asperity model. **a**, An interface between a rigid top surface and an elastic half space with a circular nominal contact area encompassing identical close-packed circular asperities at fixed spacing (small circles), all with maximum static friction force F_{max} (with $\Delta F^i/F^i_{ss} = 1$). Upon lateral loading by F^{total}, asperities are uniformly elastically strained up to their maximum static friction, whereupon they slip (see Supplementary Information). The shear force distributions at the peak frictional force for 19 (**b**) and 1,459 (**c**) asperities result in macroscopic relative static friction ($\Delta F^{total}/F^{total}_{ss}$) that is high (0.81) for **a** but much lower (0.15) for **c**.

Discussion

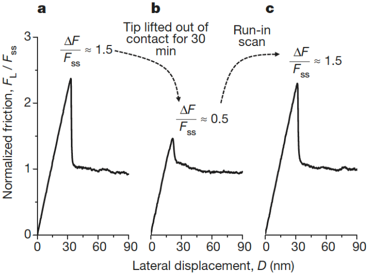

Figure 3 | Normalized friction–displacement curves from three sequential SA-SHS tests. a, Typical, strong ageing is seen immediately after a first run-in scan (cumulative displacement of ~1 mm); $\Delta F/F_{ss} = 1.5$. **b**, Ageing is substantially suppressed after 30 min of exposure of the tip to the humid environment, out of contact with the sample, followed immediately by the SA-SHS test shown; $\Delta F/F_{ss} = 0.5$. **c**, Large ageing returned to the original value after sliding for another run-in scan; $\Delta F/F_{ss} = 1.5$. All tests used a 100-s hold time at 40% RH, with a negative lateral hold force (see Supplementary Information).

Discussion

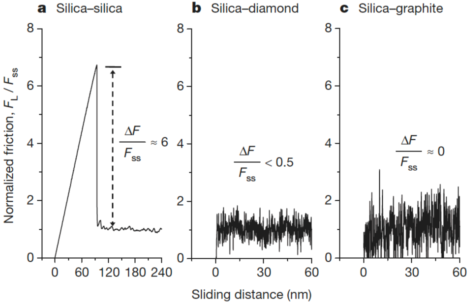

Figure 4 | Three SA-SHS tests between a silica tip and three different surfaces. **a**, Silica–silica; **b**, silica–hydrogen-terminated diamond; **c**, silica–graphite. The tests were all performed at 60% RH for a 100-s hold time. The normal load in each case is maintained at approximately 1 nN. The lateral forces during stationary hold are negative (see Supplementary Information).

Questions and Discussions

- Scaling to macroscopic level?