The molecular record of thermal history: analyzing organic molecules in faults to unearth past temperature alterations

Sheppard, R. E. [1], Polissar, P. J. [2], Savage, H. M. [3]

1. Earth & Environmental Sciences, Columbia University, New York, NY, United States, 2. Biology & Paleo Environment, Lamont-Doherty Earth Observatory, Palisades, NY, United States, 3. Seismology, Geology & Tectonophysics, Lamont-Doherty Earth Observatory, Palisades, NY, United States.

The heating signature left in a fault after an earthquake is a reliable indicator of the shear stress during slip. To better understand how faults slip during earthquakes, we examined the thermal alteration of organic material in fault zones. Previous research has focused on how pseudotachylyte and high vitrinite reflectance correlate with this heating signature. This study is the first to use extractable organic molecules to ascertain the thermal maturity of a fault, a method that can be applied even when there are no other indicators of heating, such as pseudotachylyte. Due to differences in thermal stability, refractory molecules become more concentrated relative to those that decompose at high temperatures. A high concentration of refractory molecules thus indicates a high thermal maturity and high temperature. We calculated two such ratios in samples from two different faults: the established methylphenanthrene index MPI-1 in samples from the Muddy Mountain Fault, Nevada, and the ratio of highly stable diamondoids to less stable alkanes in the Pasagshak Point Fault, Alaska. Our preliminary analysis of the Muddy Mountain samples found no difference in MPI-1 between the on-fault and off-fault samples. While this may suggest that the fault did not experience heating during slip, we are currently measuring additional samples to verify this result. In the Pasagshak Point fault, there are visible layers of pseudotachylyte. The refractory diamondoid concentrations are higher within and immediately adjacent to the pseudotachylyte, and decrease rapidly even millimeters away from it. The higher diamondoid concentrations in pseudotachylyte-bearing rocks suggest that the thermal maturity of organic material is a reliable indicator of the fault’s thermal history. This result demonstrates that the molecular indicators of thermal alteration are sensitive to the rapid heating that occurs on a fault during an earthquake. This thermal signature in organic molecules is preserved in fault rocks and contains valuable information on the temperature and shear stress a fault has experienced over its lifetime.