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Constraining t-T conditions during palaeoseismic events – constraining the viscous brake phenomena in nature.

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Melt generated by frictional heating during an earthquake is generally assumed to act as a lubricant, and decrease the frictional resistance to sliding. However, recent experimental [1] and theoretical [2] studies indicate that this might not always be the case. When the earthquake starts, melts form in isolated small patches along the fault, and only later coalesce into more extensive sheets. While the pockets of melt are isolated they have a high resistance to viscous shear and increase the overall strength of the fault: an effect known as the 'viscous brake'. The experimental and theoretical data suggest that the melt pockets can actually stop an earthquake. The crucial parameter that controls if the viscous brake can operate is the normal stress working on the system, which is a function of the mass (i.e. the thickness) of rock above the rupture. It is impossible to directly observe or sample the earthquake source in active faults, and natural examples of the viscous brake have yet to be identified.

We present a novel study that uses a combination of low temperature thermochronometry techniques to investigate the viscous brake in nature, by taking advantage of exhumed faults that preserve a record of ancient earthquakes; i.e pseudotachylytes. Pseudotachylytes are chilled frictional melts and are the only accepted indicator of ancient seismicity along faults. Pseudotachylytes found in the central part of the Sierra Nevada mountain range, California, are thin (<10 mm thick) and laterally restricted to small parts (a few meters long) of km scale faults. The discontinuous nature of these pseudotachylytes suggests that they be natural examples of earthquakes that terminated prematurely due to melt generation. These samples are therefore a key target for investigating the natural system, and improving our understanding of earthquake processes. The pseudotachylytes yield K/Ar ages of 74.9 $\pm$ 1.1 Ma, 78.2 $\pm$ 2.8 Ma and 84.5 $\pm$ 1.4 Ma, but although microstructural observations of the fault rocks assemblage indicate that the pseudotachylytes formed at temperatures of < 300ºC, the depth of formation, and therefore the normal stress are poorly constrained.

In this study we exploit the relationship between the normal stress and the mass (i.e. thickness) of the rocks above the earthquake. We present data from standard thermochronological techniques (Ar/Ar, apatite and zircon (U-Th)/He and apatite fission track) applied to a vertical profile through the pseudotachylyte bearing granite. This enables the complete time-temperature cooling path of the host rock to be determined and the geothermal gradient to be assessed, which in turn allows us calculate the depth at which rupture occurred. We use these results to test the hypothesis that the Sierra Nevada pseudotachylyte acted as a viscous brake. This will ultimately improve understanding of earthquake ruptures by identifying an intrinsic control on the magnitude of earthquakes.

References

1. Di Toro et al. 2006. Science 311. 647-649
2. Fialko & Khazab, 2005, J geophys. Res. 110 B12407