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High Pressure Lab-Quakes Used as Analogues to Help Unravel the Mechanics of Deep-Focus Earthquakes

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In recent years, a series of experimental deformation studies has shed new light on the possible mechanisms of high pressure and temperature faulting responsible for intermediate and deep-focus earthquakes. These studies rely on the traditional analysis of mechanical data and post-mortem microscopy but also on the in situ collection of acoustic data, used to directly identify possible co-seismic faulting (i.e. brittle fractures).

Deep-focus earthquake mechanisms could be investigated at 1.5 GPa and 750-900°C, in a new-generation Griggs-type apparatus using the germanate analogue of olivine, for which the transition towards the high pressure phase (spinel structure) occurs at atmospheric pressure and ~800°C, as opposed to ~14 GPa for the silicate. This transition induces a mechanical instability –the so-called transformational faulting– that leads to macroscopic failure of the samples in a temperature window where the spinel phase nucleates but hardly grows (i.e. where reaction rates are slow).

At 900°C, the mechanical data show a softening, indicative of ductile plastic flow, whereas large amounts of hardening followed by rapid stress drops (and audible stick slips) are recorded at 750°C. Acoustic Emissions (AEs) were detected in both cases. Detection and picking of both P and S waves arrivals was possible and shows that the vast majority of AEs originate inside the sample (a few may originate from the adjacent alumina pistons). Coherence analysis of the AEs seems to suggest that some bursts of events have similar sources. Surprisingly, AEs are more numerous (~600) at higher temperature, when deformation takes place in a ductile way, accommodated by the development of a wide mylonitic shear band. However, at 750°C, far more energy is released acoustically upon brittle faulting despite a lower number of AEs (~100). Therefore, higher temperatures favor larger reaction rates, which, in turn, allow the growth of ductile fine-grained spinel. Our results confirm previous models suggesting that the brittle temperature window is a function of both temperature (reaction kinetic) and strain rate and seems to shift to lower temperatures with decreasing strain rates. This may explain why earthquakes can occur in a slowly reacting metastable olivine wedge at strain rates orders of magnitude lower than in the lab.