Laboratory Micro-Seismicity during Serpentinite Deformation as a Potential Analogue for Lower Wadati-Benioff Plane Seismicity

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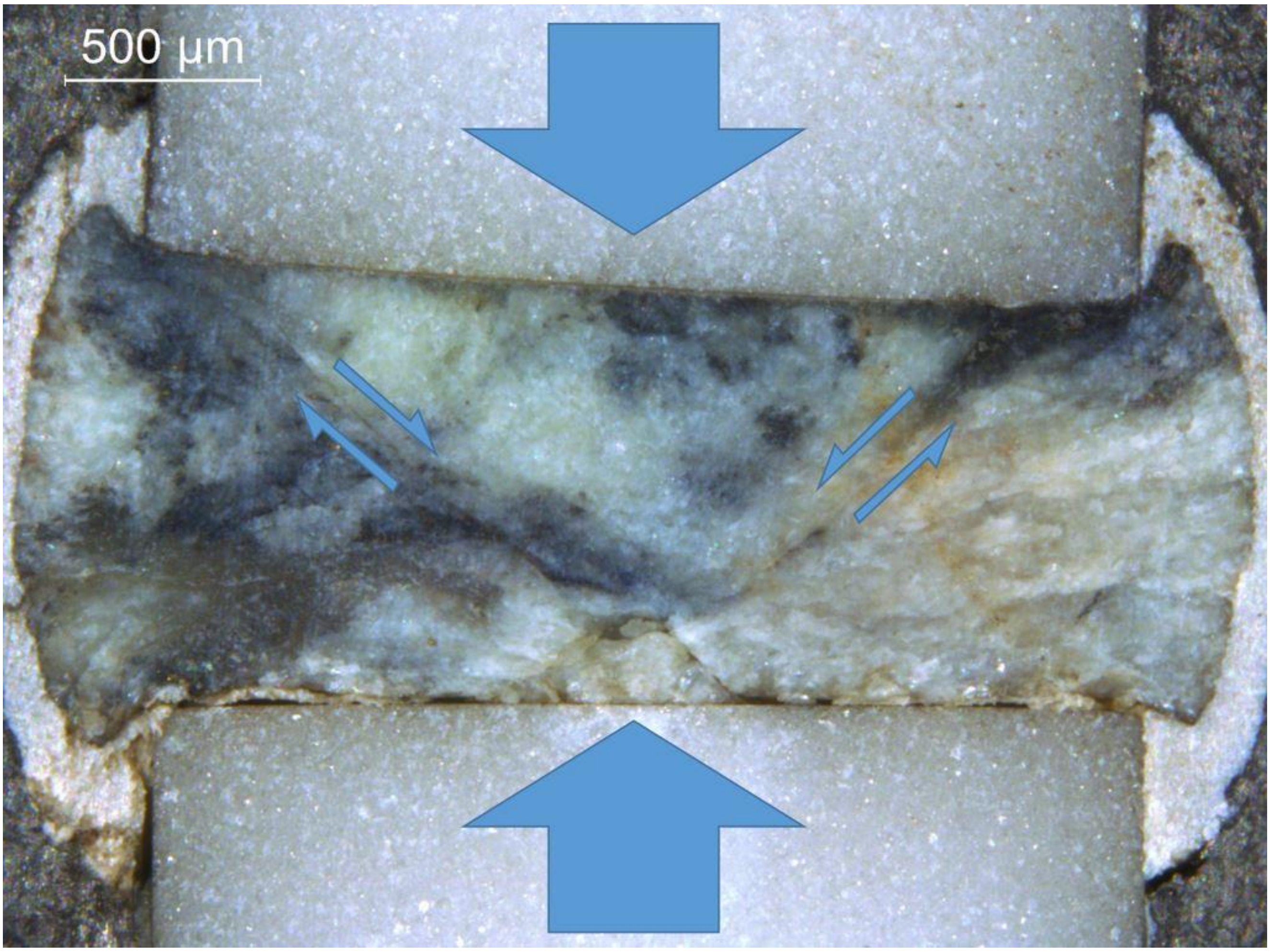
The origin of intermediate-depth earthquakes, which occur at depths of 60-300 km along subducting slabs, remains somehow enigmatic. In the pressure and temperature conditions involved, rocks should indeed deform in a ductile fashion. Dehydration embrittlement, due to serpentine breakdown, was long considered a good candidate to explain lower Wadati-Benioff plane seismicity. However, unlike in the classic dehydration embrittlement theory, dehydration induced volume changes are negative at such depths and cannot trigger instabilities via pore pressure buildup. Accordingly, some experimental studies have shown that faulting of serpentinites related to dehydration, occurs in a stable and aseismic way (Chernak and Hirth, 2011; Gasc et al., 2011). Nevertheless, tremendous progress was recently made in understanding the mechanics of intermediate earthquakes, notably thanks to the combination of high pressure deformation experiments and in-situ synchrotron techniques. In order to assess the seismic potential of serpentinites, micro-seismicity was monitored during high pressure experiments by recording Acoustic Emissions (AE’s) –or labquakes. A D-DIA apparatus was used to deform natural antigorite-rich samples at pressures of 1-5 GPa, both within and outside antigorite’s stability field.

Below 400°C, the deformation of fully hydrated serpentinite samples involves aseismic ductile cataclastic flow. Above 600°C, despite conditions propitious to dehydration embrittlement (i.e., with fast strain rates and reaction kinetics), joint deformation and dehydration also lead to ductile shear, without generation of AE’s. However, samples show a brittle temperature window around 500°C that seems to correlate with the very onset of the mineral’s breakdown, and is therefore not associated to significant release of water. In this latter case, AE’s are consistently collected upon faulting and extremely sharp strain localization is observed (Gasc et al., 2017). In addition, brittle faulting of partly hydrated samples (a mixture of olivine and antigorite) can also occur with minor amounts of antigorite, due to stress percolation upon antigorite breakdown. Unlike for low-pressure dehydration embrittlement, faulting is also enabled here by the metastability of the solid phase rather than by fluid overpressure and dynamic fault propagation occurs concomitantly with the appearance of pseudotachylites along the fault plane (Ferrand et al., 2017).
Both brittle failure mechanisms identified in these studies share major similarities with the now-classic concept of transformational faulting (Burnley et al., 1991), often invoked for deep-focus earthquakes, and both may be a source of seismicity in subducting slabs. We provide evidence that destabilizing antigorite at mantle depths can initiate faulting and thus be involved in intermediate-depth earthquakes. However, analysis of the acoustic signal shows that it is relatively weaker than its real-earth counterpart, once scaled relative to standard brittle faulting. This suggests that other mechanisms are responsible for large intermediate-depth earthquakes, which may reflect fault propagation in the adjacent peridotitic mantle.

Keywords: intermediate-depth earthquakes, serpentinite, high pressure, deformation experiments, acoustic emissions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