Dehydration of lawsonite in blueschist could directly trigger intermediate-depth earthquakes in subducting oceanic crust

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Intermediate-depth earthquakes in cold subduction zones (e.g., northeast Japan) are observed within the subducting oceanic crust, as well as the mantle. In contrast, intermediate-depth earthquakes in hot subduction zones (e.g., Cascadia and southwest Japan) predominantly occur just below the Moho. These observations have stimulated interest in relationships between seismicity and blueschist-facies metamorphism occurring typically at cold subduction zones, particularly through dehydration reactions involving lawsonite.
We conducted deformation experiments on lawsonite, while monitoring acoustic emissions (AE), in a Griggs-type deformation apparatus. Results were compared to experiments on antigorite serpentine, for which stable frictional behavior has been observed during dehydration at similar deformation conditions. Deformation was initiated at a confining pressure of 1.0 GPa, temperatures of 300 ^{o}C (for lawsonite) and 400 ^{o}C (for antigorite), and constant displacement rates of 0.16 to 0.016 μm/s (corresponding to equivalent strain rates of 8 $\times10^{-5}$ to 8 $\times10^{-6}$ s^{-1}). Samples were first loaded at conditions within the lawsonite/antigorite stability field. Next the temperature was increased to 600 ^{o}C for lawsonite and 700 ^{o}C for antigorite at temperature ramping rates of 0.5 to 0.05 ^{o}C/s to induce dehydration reactions while the samples continued to deform.
In contrast to similar tests on antigorite, rapid stress drops occurred during dehydration reactions in the lawsonite. Microstructural observations indicate that strain is highly localized along the fault (R_1 and B shears), and that the fault surface develops mirror-like slickensides. Cumulative AEs for the lawsonite sample continuously increase at temperatures >450^{o}C, indicating unstable microcrack growth during fault slip. In contrast, the AE signal for the antigorite sample is essentially the same as that observed from the control experiment using an aluminium sample. Rapid stress drops with unloading slopes similar to the apparatus stiffness at all experimental conditions (regardless of the strain rate and temperature ramping rate) indicate that unstable fault slip (i.e., stick-slip) occurred during the lawsonite experiments. The unloading slope for antigorite is primarily controlled by the effects of the dehydration reaction rate and the strain rate on the evolution of pore fluid pressure. A time-independent thermal-mechanical scaling factor for the experiments covers the range estimated for natural subduction zones, indicating the potential for unstable frictional sliding within natural lawsonite layers appropriate for intermediate-depth earthquakes.

Keywords: lawsonite, dehydration embrittlement, intermediate-depth earthquake

