The mechanics of intermediate and deep focus earthquakes: experimental evidences

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At least part of the subducting slab seismic activity could be triggered by phase transformations and mineral reactions. However, the way mineral reactions can modify the deformation regime of deep rocks, from ductile to brittle (embrittlement) is still poorly understood and remains one of the outstanding unsolved problems of geophysics and rock mechanics.Here, we provide experimental evidence that, under differential stress at high pressure and temperature conditions (3-5GPa/800-1000°C), shear fractures nucleate and propagate at the onset of the olivine -> spinel transition in the Mg_2GeO_4 analogue system. The propagation of these fractures is sufficiently rapid to radiate energy in the form of intense acoustic emissions (AEs). Using a similar set-up, a second set of experiments demonstrates that glaucophane and lawsonite mixtures, two of the principal mineral water carriers in the subducted oceanic crust, undergo dynamic fracture instabilities when deformed within the eclogite field (3GPa/400-800°C). This time, AEs are observed due respectively to the glaucophane breakdown into jadeite and talc under low temperature and lawsonite dehydration under higher temperature. Finally, deformation experiments performed on partially serpentinized peridotites at 2-4GPa, 500-700°C, demonstrate that 5% serpentine in sufficient to trigger dehydration embrittlement of the peridotite body. In this case, low serpentine contents may favor initiation of mechanical failure of the olivine “load bearing” network. In all these three cases, various post-mortem microstructural observations techniques (SEM, TEM, Raman, Microprobe, X-ray tomography) reveals that samples deformed under stress almost systematically present high presure (HP) faulting, to the contrary of samples transformed under isostatic conditions. In addition, AEs correspond to acoustic waves radiated by dynamic HP transformational faulting and follow the Gutenberg-Richter law over sometimes more than 4 orders of moment magnitudes.Put together, our observations provide strong experimental evidence of the role played by mineral reactions on earthquake triggering in mantle conditions, both in the Wadati-Benioff double plane of seismicity and the Earth mantle's transition zone.

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