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Grain size reduction during metamorphic reactions as trigger for deep earthquakes

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Due to nucleation depths of 50-700 km in Earth's lower crust and mantle, deep earthquakes cannot be explained by Byerlee friction as it is the case for their shallow counterparts. However seismic relocation and field observations clearly demonstrate embrittlement of Earth's crust and mantle even under elevated pressure-temperature conditions. The observation that those events coincide with areas in which metamorphic reactions are expected to occur (e.g. eclogitization of oceanic crust during subduction or of continental crust during orogeny) lead to the hypothesis that mineral reactions could weaken the rock to enable brittle failure. The fact that deep earthquakes are recorded in various rock types in different geological settings points to a common weakening mechanism that is independent of rock's mineralogical composition. To experimentally investigate this hypothesis, deformation experiments using a D-DIA apparatus were performed under eclogite-facies conditions on either hydrous lawsonite-bearing blueschist, representing the oceanic crust (cold subduction), or on nominally anhydrous mafic granulite as representative for the lower continental crust (continent-continent-collision). Experiments were conducted at either P= 1.5-3.5 GPa, T= 583-1121 K (blueschist samples) or at P=2.5-3 GPa, T= 1023-1225 K (granulite samples) and a strain rate of around $5 \times 10^{-5} s^{-1}$. The experimental results demonstrate faulting in both rock types accompanied by the record of acoustic emissions. Micro- and nanostructural observations reveal a link between the growth of nanocrystalline eclogite-facies minerals and strain localization. Based on our experimental results on crustal rocks in combination with previous experimental studies on the olivine-spinel transition, we suggest that shear localization due to grain size reduction during metamorphic reactions act as a viable common mechanism to trigger deep earthquakes.