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Slow, delayed and aseismic failure in the laboratory: the problem of seismic efficiency

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Two triaxial compression experiments were performed on Carrara marble at high confining pressure under wet and dry conditions respectively. Marbles were chosen because they provide an excellent analog in the understanding of intermediate and deep fault gouges since they can undergo brittle-ductile transition at easily attainable pressures and temperatures. When deformed in the ductile regime, aseismic damage accumulation was observed thanks to elastic wave velocity monitoring. Reducing the normal stress induced aseismic episodes of exponential increases in axial strain, similar in nature to what is generally described as "creep events" in the field and intrepreted as the sudden aseismic growth of microcracks. This eventually led to criticality and delayed failure nucleation for crack densities close to one. Rupture propagation was slow and silent (60 - 200 seconds), although accompanied by stress drops of the order of 150 MPa and millimetric slips. During slip, acoustic energy started being radiated only for slip velocities larger than 0.1-1 mm/s. Our microstructural analysis highlighted the strong interactions existing at the intragranular scale between plastic (twinning and dislocation glide) and brittle (cracking) processes, which resulted in an aseismic (or ductile) macro-crack growth.

These experiments provide a clear experimental case of silent, slow localized failure in rocks as a result of an interplay between intragranular plasticity and microcracking. They highlight the role of fluid redistributions (and thus normal stress variations) during both aseismic and seismic deformation. The observation of a fast aseismic slip (up to mm/s) seems to raise some issues about the seismic efficiency in the early stage of rupture propagation at depth. There, minerals prevalent are predicted to behave in a similar fashion as calcite does at room temperature.