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Modeling of slow crack propagation in heterogeneous rocks

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Crack propagation in heterogeneous media is a rich problem which involves the interplay of various physical processes. The problem has been intensively investigated theoretically, numerically, and experimentally, but a unifying model capturing all the experimental features has not been entirely achieved despite its broad range of implications in Earth sciences problems. The slow propagation of a crack front where long range elastic interactions are dominant, is of crucial importance to fill the gap between experiments and models. Several theoretical and numerical works have been devoted to quasi-static models. Such models give rise to an intermittent local activity characterized by a depinning transition and can be viewed as a critical phenomenon. However these models fail to reproduce all experimental conditions, notably the front morphology does not display any cross-over length with two different roughness exponents above and below the cross-over as observed experimentally.

Here, we compare experimental observations of a slow interfacial crack propagation along an heterogeneous interface to numerical simulations from a cantilever fiber bundle model. The model consists of a planar set of brittle fibers between an elastic half-space and a rigid square root shaped plate which loads the system in a cantilever configuration. The latter is shown to provide an improved opening and stress field in the process zone around the crack tip. The model shares a similar scale invariant roughening of the crack front both at small and large scales and a similar power law distribution of the local velocity of the crack front to experiments.

Implications for induced seismicity at the brittle-creep transition are discussed. We show that a creep route for induced seismicity is possible when heterogeneities exist along the fault. Indeed, seismic event occurrences in time and space are in strong relation with the development of the aseismic motion recorded during the experiment and the model. We also infer the statistical properties of the organization of the seismicity that shows strong space-time clustering. We conclude that aseismic processes might drive seismicity in the brittle-creep regime.