Geophysical Research Abstracts
Vol. 16, EGU2014-16505, 2014
EGU General Assembly 2014

Evolution of damage during deformation in porous granular materials (Louis Néel Medal Lecture)

Ian Main
School of GeoSciences, University of Edinburgh, Edinburgh, UK

‘Crackling noise’ occurs in a wide variety of systems that respond to external forcing in an intermittent way, leading to sudden bursts of energy release similar to those heard when crunching up a piece of paper or listening to a fire. In mineral magnetism (‘Barkhausen’) crackling noise occurs due to sudden changes in the size and orientation of microscopic ferromagnetic domains when the external magnetic field is changed. In rock physics sudden changes in internal stress associated with microscopically brittle failure events lead to acoustic emissions that can be recorded on the sample boundary, and used to infer the state of internal damage. Crackling noise is inherently stochastic, but the population of events often exhibits remarkably robust scaling properties, in terms of the source area, duration, energy, and in the waiting time between events. Here I describe how these scaling properties emerge and evolve spontaneously in a fully-dynamic discrete element model of sedimentary rocks subject to uniaxial compression at a constant strain rate. The discrete elements have structural disorder similar to that of a real rock, and this is the only source of heterogeneity. Despite the stationary loading and the lack of any time-dependent weakening processes, the results are all characterized by emergent power law distributions over a broad range of scales, in agreement with experimental observation. As deformation evolves, the scaling exponents change systematically in a way that is similar to the evolution of damage in experiments on real sedimentary rocks. The potential for real-time failure forecasting is examined by using synthetic and real data from laboratory tests and prior to volcanic eruptions. The combination of non-linearity and an irreducible stochastic component leads to significant variations in the precision and accuracy of the forecast failure time, leading to a significant proportion of ‘false alarms’ (forecast too early) and ‘missed events’ (forecast too late), as well as an over-optimistic assessments of forecasting power and quality when the failure time is known (the ‘benefit of hindsight’). The evolution becomes progressively more complex, and the forecasting power diminishes, in going from ideal synthetics to controlled laboratory tests to open natural systems at larger scales in space and time.