INTEGRATING LABORATORY COMPACTION DATA WITH SEISMOGENESIS MODELS: A BAYESIAN FRAMEWORK

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Abstract

When analyzing rock deformation experimental data, one deals with both uncertainty (due to data aquisition and to the choice of a model) and complexity. Though each part of the problem might be simple, the relationships between them, stochastic or deterministic, can form a complex system. This often leads to partial or only qualitative data analyses from the experimental rock mechanics community, which limits the impact of these studies in other communities (e.g., modelling). However, it is a perfect case study for directed graphical models.

We present here a Bayesian framework that can be used both to infer the parameters of a constitutive model from rock compaction data, and to generate porosity reduction within direct fault models from a known (e.g. lab-derived) constitutive relationship, and still keep track of all the uncertainties. This latter step is crucial if we are to go toward process-based seismic hazard assessment. Indeed, the rate of effective stress build-up [1] (namely due to fault compaction) as well as the recovery of fault strength determine how long it will take for different parts of the previously ruptured fault to reach failure again, thus controlling both the timing and the size of the next rupture. But deterministic models need a measure of their robustness (due to "epistemic" and "aleatory" uncertainties) to become process-based earthquake-rupture forecast models. It is therefore important to work within a framework able to assess model validity as well as use data uncertainties.

Our approach involves a hierarchical inference scheme using several steps of marginalization. Existing experimental data are rarely adequate to completely define a single constitutive relationship for given physical fault material parameters over temperature and effective confining pressures of relevance to actual fault zones. We therefore focus on one rather general, though experimentally derived, compaction law, and emphasize how applying the proposed inference scheme on simulated data first can help better plan the actual experiments (e.g., number of experiments needed with different temperature and pressure conditions) for a good determination of the creep law parameters (small covariance).

Key Words: Bayesian inference, marginalization, rock physics

[1] Effective stress = normal stress minus pore pressure. Its variations can come from tectonic stress transfer projected perpendicular to the fault strike, or from pore pressure changes.