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Integrating Laboratory Compaction Data With Numerical Fault Models: a Bayesian Framework

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When analyzing rock deformation experimental data, one deals with both uncertainty and complexity. 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 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 (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 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. We focus on one rather general, though experimentally derived, model of a compaction law, with a stress exponent, an apparent activation energy, and a porosity term as main parameters. We will first describe the method and show how it can help define the number and the duration of the experiments, as well as the range of conditions that would lead to a good determination of the physical parameters. We will then present an application to the Niemeijer et al (EPSL2002) data on quartz. Finally we will show how such creep laws can be implemented in direct models of pore pressure evolution using graphical models as a guide to propagate the uncertainties.