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Probabilistic Geomodeling and Scenario Testing in a Bayesian Framework

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Geological models often provide an important basis for subsequent subsurface investigations. As these models are generally built with a limited amount of information, they can contain significant uncertainties and it is reasonable to assume that these uncertainties can potentially influence subsequent model use, for example as input to process simulations, or decisions, for example concerning further exploration. However, the investigation of uncertainties in geological models is not straightforward and, even though significant advances have been made in the field, there is yet no out-of-the-box implementation to analyse and quantify uncertainties.

We present here results of recent developments to address this problem with an efficient implementation of a geological modelling method for complex structural models, integrated in an efficient probabilistic programming framework. The implemented geological modelling approach is based on a full 3-D implicit interpolation that directly respects interface positions and orientation measurements, as well as the influence of faults and fault networks. In combination, the approach allows us to generate ensembles of geological model realizations, constrained by additional information in the form of likelihood functions to ensure consistency with additional geological aspects such as sequence continuity, topology, or fault network consistency.

This approach has been applied successfully in several case studies. However, it is important to acknowledge that *the range of generated models is never a sound estimate of all possible realizations*, and we therefore cannot interpret a suite of obtained model realizations as a complete estimation of subsurface uncertainty. But even with this restriction, the analysis and quantification of spatial uncertainties, for example with measures from information theory, provides an insight into the distribution of uncertainties with respect to a specific model, the assigned input parameters, and any additional information that has been used to constrain it. We also emphasize that we have the best chance to learn about a model if it *does not* fit all data and assumptions and propose that a probabilistic framework provides a suitable way to efficiently test and compare different geometric interpretations. The developed methods therefore provide a range of possibilities to systematically investigate geological models, the underlying assumptions, and the associated uncertainties - providing insights that are not apparent when only a single deterministic model is constructed and analyzed.