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How can we integrate geological knowledge into 3-D structural models? A Bayesian perspective on multiply constrained geomodelling

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he construction of meaningful 3-D structural models for complex mineral systems demands the best possible integration of all available geological and geophysical data, combined with the knowledge about the evolution of a system in time and space. The formal integration of all of this information into one model is challenging and commonly contains subjective decisions, as the geological and geophysical data sets can contain a high degree of uncertainty, and the formal integration of the evolutionary context is often based on previous experience and knowledge of the geologist constructing the model. These models are therefore often not reproducible, and it is difficult to communicate how accurate they are.

We present here an approach to integrate both aspects of this challenge, the consideration of uncertain input data, and the integration of specific aspects derived from the geological history, into an automated modelling framework. The core of our approach is that we aim to formalise specific aspects of the geological history so that they are automatically testable in a constructed model, to validate a model against history. We then combine this evaluation step with a stochastic structural modelling method. This combination enables us to generate model realisations that are in accordance to the constraints imposed by geological history, and probable given uncertainties in the input data.

We derive two important outcomes from this integration into a Bayesian framework: (1) We obtain an ensemble of structural models and can use these models for subsequent uncertainty analysis, and (2) we can analyse the posterior distribution of the input data sets to derive a deeper insight into the parameters uncertainties and correlations. Both aspects are important steps towards uncertainty identification and reduction for meaningful structural geological models.