

Geoscientific Studies in the Mizunami Underground Research Laboratory -A method for evaluating uncertainty of fault distribution-

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The geological environment in fractured crystalline rock such as granite has a heterogeneity caused by faults and joints which have the potential to act as water conduits. Since it is impossible to directly observe the 3D subsurface structures, knowledge instead must be obtained from a combination of indirect sources (e.g., geophysical measurements, lineaments) and limited direct observations (e.g., surface exposure, boreholes etc). Therefore, the geological models will have a level of uncertainty. It is important to develop methodology for evaluation of the uncertainty in order to select geological features considered essential for geological characterisation.

Here we address this uncertainty by developing and applying a novel statistical and Bayesian approach to model subsurface fault distribution in the Mizunami Underground Research Laboratory (MIU). Multiple sets of information are combined in a quantitative fashion to predict heterogeneous structure with documented uncertainties; and to reduce those uncertainties through an iterative approach. Essentially, two main steps are performed yielding an a posteriori estimate. The first or fundamental step is to make a prediction based solely on existing information (e.g., lineament analysis, published geological maps etc), seismic reflection survey and geological mapping of faults, creating an a priori estimate. The a priori assumption or expert judgment here is never perfect and is usually quite vague. The second step is to update or modify the a priori assumptions by incorporating information that is likely to be indicative of the locations of faulting. This new information, obtained here from core description, geophysical logging and VSP survey of an existing borehole (500m depth) and from core description and geophysical logging of four shallow (100-200m depth) boreholes, is used to modify the a priori estimate to form an a posteriori estimate of the location of faults. Due to the abundance of data, the MIU allows us to evaluate our model using data from new boreholes and construction of MIU.

In the a priori analysis, the probability of fault existence ranges from 0 (does not exist) to 1 (definitely exists) and fault location uncertainty is proportional to a scaling parameter (standard deviation). We find that the uncertainty of fault location is negligible near outcrops but increases with depth (as well as horizontal distance between outcrops). Typically faults have a location uncertainty of up to plus or minus 25m at 0m depth (Sea level) increasing to plus or minus 50m at 500m depth. In the a posteriori analysis, uncertainties are reduced to negligible levels for faults that intersect near the boreholes. By assessing the number of fault uncertainties that are improved by the borehole data in this analysis, we make estimates of how large an area a single well can be used to reduce surrounding fault uncertainty.