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Reconstructing the 3D fracture distribution model from core –10 cm– to lineament –10 km– scales

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Considering the role of fractures in hydraulic flow, the knowledge of the 3D spatial distribution of fractures is a basic concern for any hydrogeology-related study (potential leakages in waste repository, aquifer management, . . .). Unfortunately geophysical imagery is quite blind with regard to fractures, and only the largest one are generally detected, if they are. Actually most of the information has to be derived from statistical models whose parameters are defined in a few sparse sampling areas, such as wells, outcrops, or lineament maps. How these observations obtained at different scales can be linked to each others is a critical point, which directly addresses the issue of the fracture scaling.

This statistical description of fracture networks through scale still remains a concern for geologists, considering the complexity of fracture networks. A challenging task of the last 20-year studies has been to find a solid and rectifiable rationale to the trivial observation that fractures exist everywhere and at all sizes. The emergence of fractal models and power-law distributions quantifies this fact, and postulates in some ways that small-scale fractures are genetically linked to their larger-scale relatives. But the validation of these scaling concepts still remains an issue considering the unreachable amount of information that would be necessary with regards to the complexity of natural fracture networks.

In this study, we use one of the most important dataset that ever been collected for characterizing fracture networks. It was collected by the Swedish company SKB for their research program on deep repository for radioactive waste, and consists of large-scale lineament maps covering about 100 km^2, several outcrops of several hundreds

of m^2 mapped with a fracture trace length resolution down to 0.50 m, and a series of 1000m-deep cored boreholes where both fracture orientations and fracture intensities were carefully recorded. Boreholes are an essential complement to surface outcrops as they allow the sampling of horizontal fracture planes that, generally, are severely undersampled in subhorizontal outcrops. Outcrops, on the other hand, provide information on fracture sizes which is not possible to address from core information alone. However linking outcrop and boreholes is not straightforward: the sampling scale is obviously different and some scaling rules have to be applied to relate both fracture distributions; outcrops are 2D planes while boreholes are mostly 1D record; outcrops can be affected by superficial fracturing processes that are not representative of the fracturing at depth.

In this presentation, we present the stereology methods for calculating the 3D distribution model from both outcrop and well fracturing observations, and we discuss the consistency between the along-core fracturing intensity profile, the outcrop fracture traces, and the lineament maps. In the Forsmark site investigated by SKB, we conclude that the power-law distribution model is statistically consistent from core scale (80 mm) to outcrop scale ($\sim$10 m); the consistency with the lineament scale (10 km) is still questionable. An important subhorizontal fracturing exists at shallow depth, but it does not seems to affect the statistics of highly dipping fractures.