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Sources of uncertainty when estimating the sample space of structures mapped in cored boreholes and its effects on discrete fracture network models

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Many applications in fractured crystalline rocks use measured orientations of structures mapped in boreholes as foundation, e.g. structural modelling and discrete fracture network (DFN) modelling. These measurements are afflicted with uncertainties stemming from a variety of sources. Commonly, such uncertainties involve instrument imprecision, external disturbances and human factors. Relying on the specification of instrument imprecision supplied by the manufacturer, and neglecting uncertainties from the other two sources, the orientation uncertainty is often assumed to be small. However, the different sources of uncertainty may conspire and result in an unexpectedly large uncertainty space.

The orientation of a structure mapped in a borehole, e.g. a fracture, can be calculated using four parameters: the bearing and inclination of the borehole together with two angles of the structure relative to the borehole, denoted α (dihedral angle to the borehole trajectory) and β (rotation angle around the borehole trajectory). Each parameter may be a result of one or several measurements with different magnitudes of uncertainty that have to be added. The aggregated uncertainty space depends on the uncertainty of each of the four constituents and shows as an area on a lower hemisphere stereonet.

The scope of the present work is to identify sources of uncertainty for each of the four constituents; to suggest methodology to estimate the uncertainties; to present the magnitudes of uncertainties arisen during the site investigations for a nuclear waste repository located in fractured crystalline rock in Sweden; and to demonstrate some implications of the uncertainties on DFN models.

During site investigations performed by SKB (The Swedish Nuclear Fuel and Waste Management Co.), the uncertainty for each of the four constituents were estimated using statistical analysis. While the two uncertainties coupled to the borehole orientation, i.e. the bearing and inclination uncertainties, were mostly affected by instrument imprecision, the uncertainties coupled to the relative angles, α and β, were largely affected both by instrument imprecision and human factors, and to a lesser extent by external disturbances. The uncertainty of both the α and β angle was shown to be correlated to the value of the α angle.

The implication of the orientation uncertainty is twofold: on the one hand it tends to blur and skew the interpretation of fracture orientation models towards less concentrated and erroneously spread sets, yet on the other hand, it might explain outliers that do not fit a conceptual model. In other words, the uncertainty should be exploited carefully and neither be underestimated nor overestimated.