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Integration of near-deterministic and stochastic discrete fracture network (DFN) models for fractured rock mass property estimation

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It has long been recognized that natural fracture systems impart mechanical and permeability anisotropy within the upper crust. Consequently, generating numerical representations of fracture and fault networks in order to predict rock mass stability, geomechanical behavior and fluid transport properties has considerable application within the geosciences, being pertinent to a number of fields (e.g. hydrogeology, petroleum geoscience and rock mechanics). In practice, it is common to represent fracture networks using a statistical representation of the discontinuity array, whereby each individual fracture is modelled explicitly as a polyhedron located using stochastic point processes, with discontinuity orientation and size randomly drawn from pre-defined parametric distributions discrete fracture networks / DFN models). Determining distributions of fracture orientation, size and intensity for conventional DFN modelling often requires the use of outcrop datasets, both for direct applications (i.e. rock mass stability studies for excavations) and analogue studies (i.e. naturally fractured reservoir and aquifer studies). Historically, these datasets are acquired using manual outcrop surveys or image interpretation, superseded more recently by acquisition from 3D mesh or point cloud based models of rock exposures (digital outcrop models).
Recent advances in structural data extraction and modelling from digital outcrop models now enable quasi-deterministic DFN models to be generated, constrained to 3D trace maps extracted from tetrahedral meshes. These near-deterministic structural models enable key fractured rock mass statistical properties to be determined in a holistic manner, and allow their spatial quantification across the outcrop sampling domain. Building upon this framework, this presentation will demonstrate the integration and co-conditioning of quasi-deterministic discrete fracture networks and conventional stochastic DFN models, conditioned to discontinuity intensity (P32) property grids. Utilizing examples of outcrop analogues of Middle Eastern naturally fractured reservoirs, this modelling framework is used to estimate higher order fractured rock mass volumetric properties (representative elementary volume and equivalent fractured rock mass permeability).