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DFN Generator

A new tool for dynamic fracture modelling

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Understanding fluid flow in the subsurface requires accurate characterisation of the natural fracture networks in the rocks. This is important for applications such as geothermal energy, carbon capture and storage, pollution and groundwater monitoring, waste disposal as well as oil and gas production. The fractures must be included in computer models of the subsurface. But they cannot be seen directly on geophysical data – they are too small. The traditional approach is to build fracture models stochastically – fractures are placed at random and there is little constraint on length and connectivity, so the models often give poor results.

Therefore we launched the DFN Generator project – a new approach to build fracture models by simulating the nucleation and growth of the fractures, based on geomechanical principles and geological knowledge. This should generate much more realistic fracture models which honour the geology. The first version of DFN Generator, modelling layer-bound fracture networks, was released as a Petrel plug-in in 2019, and has been used successfully to model fractures in Kraka, Gorm, Skjold, Svend and Valdemar, in collaboration with TEPDK and Noreco geologists and engineers.

We are currently working on a multilayer version of the software, to predict fracture connectivity across barrier layers in mechanically layered strata. The algorithm has been developed, and we are running calibration and sensitivity studies. We hope to develop a beta version of the software soon to start testing.

Both the current single-layer and future multilayer versions of DFN Generator have important applications in the energy transition, including:

- Modelling topseal integrity and risk of leakage through fractures for CCS prospects
- Modelling the fracture networks that are essential in tight geothermal reservoirs
- Groundwater flow and pollution monitoring, for underground waste storage
- Mining for rare earth metals and other elements hosted in veins and fractured rock

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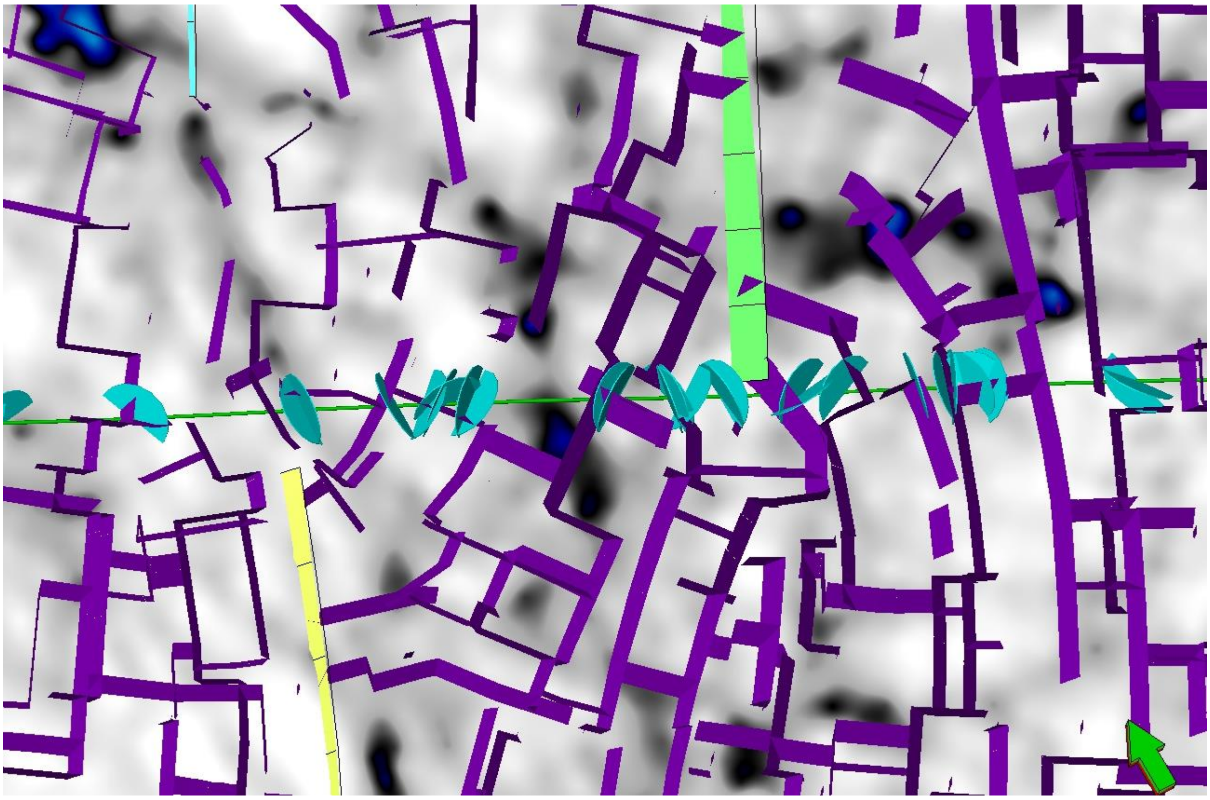

Fracture model from the Kraka field, and comparison with fractures observed on borehole image data

Conventional stochastic models	DFN Generator
Accuracy: Since they are calibrated against limited and incomplete data, conventional tools often generate geologically unrealistic fracture models, with a high level of uncertainty in the results.	**Accuracy:** Since it simulates the physical processes of fracture nucleation and propagation, the model output will automatically honour the geology, geomechanical properties and structural evolution of the reservoir.
Ease of use: Since there is very little constraint on the input parameters, "trial and error" approach with a lot of tweaking is required to get reasonable results, which is time consuming.	**Ease of use:** Since this is a deterministic model it is easy to set up and run. A first pass model can be generated in c.½ day, and then refined with additional data when it becomes available.
Uncertainty and risk analysis: Since the input parameters are poorly constrained, it is difficult to systematically generate multiple realistic realisations, or to rank them in likelihood.	**Uncertainty and risk analysis:** Since it simulates fracture growth, it automatically generates multiple realisations at different stages of fracture development, which can be used for uncertainty analysis.
Usefulness: Since the output from the models is limited, and often merely reflects the input data put into the models, they are only able to provide limited input into quantifying parameters of interest (e.g. connected fracture volume, permeability anisotropy etc.).	**Usefulness:** The model outputs many parameters and properties (e.g. fracture size distributions, fracture connectivity) that are required for complex flow modelling calculations. These properties come out of the simulation, and cannot be calculated directly from the model inputs.

Advantages of dynamic fracture modelling compared with conventional stochastic modelling