E Fracture Generation

The techniques presented in this board illustrate a method of generating stochastic, geologically realistic fracture networks that can form the precursor to simulations of flow through fractured rock. The key benefit of using the method presented here is that a model's deformation history can be used as a key constraint to fracture growth.

Fractures can be generated: a) using active geological controls; b) at any stage in the evolution of the reservoir and c) in response to inversion or changes in stress as well as tectonic strain.

Multiple layer−bounded sets can be generated at the same time (9). Seeds are points of stress concentration that can trigger failure and generate a fracture (10). If the seed probability is set to be constant then everywhere on the surface has an equal probability of receiving a randomly dropped seed.

Attribute maps, such as those generated from geometric analysis, can be used to control the seeding of fractures. The number of seeds dropped in on each iteration can be controlled and a multiplier applied. A low multiplier makes the rate of increase in fracturing decrease with progressive deformation.

The propagation potential determines how far and in what direction the fracture will propagate (11). The step length dictates how far each fracture will propagate in a given iteration. The multiplier controls how that step length varies through time. If the multiplier is below 1 the fracture will propagate by shorter and shorter steps, as it grows longer. Orientation map can be used to control the propagation azimuth of the fracture, i.e. the strike of the actual fracture.

Spatial impedance is how effective the rock is going to be at stopping a fracture from growing (12). In addition, if a fracture is shut it will be invisible to other fractures and will exert zero fracture impedance. If the fracture is fully open the approaching fracture will hit a free surface and stop. The open fracture therefore has total impedance. The spatial impedance again can be defined with a constant value across the model or with a map.

The forbidden zone (FZ) simulates the area of stress relief around an active fracture (13). Aspect ratio gives the length/width relationship and defines the general shape. The maximum width stops the FZ spreading an unrealistic distance from the fracture. This will be a function of rock properties and how far stress and stress relief can be transmitted through a rock.

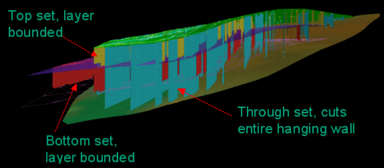
The projection distance defines the end zones, which are a function of fracture length and the tip angle. The projection length gives the distance ahead of the fracture tip that the stress relief (FZ) extends and the tip angle give the angle of the FZ boundary and the projection line. It defines how rapidly the tip wedge reaches the full FZ width. This will control how far fractures can overlap before the FZs interact and stop a fractur from growing.

Generated fracture networks can be attached as objects and exported to other software to be used as input for fracture/matrix simulation (14).

• *Upper and Lower bounding beds*

Each fracture set is named and coloured using the *Edit Fracture Set* options. The set is activated using the red toggle.

The upper and lower beds are selected for each fracture set individually. This allows multiple layer bounded fracture sets to be grown at the same time

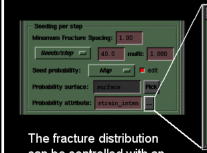


9 Fractures generated between beds

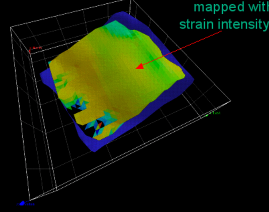
• *Seeding potential*

The number of potential fracture points can be set and a multiplier applied to control the change in fracture initiation with time.

The seeding potential for a fracture set can be constant or spatially variable. This variability is controlled by an attribute map. This allows fracture density to vary across an area.



The fracture distribution can be controlled with an attribute map. Use *Pick* to select one of the bounding surfaces, and selecting an attribute using the selection box.

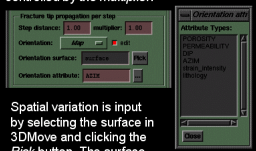


10 Fracture growth controlled by numerical seeds

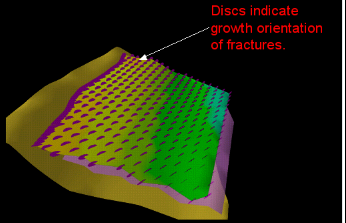
• *Speed and Direction of Propagation*

The fracture growth is set in the *Step Distance* box and growth rate through time is controlled by the *multiplier*.

A propagation distance in metres is set for fracture growth. This can be multiplied to change growth behaviour through time. The orientation can have a constant azimuth or a spatially varying map.



Spatial variation is input by selecting the surface in 3DMove and clicking the *Pick* button. The surface attribute is selected, through the grey toggle in the *Orientation attribute* box

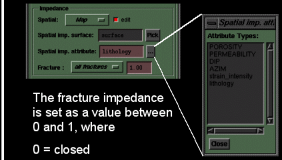


11 Control of fracture propogation

• *Spatial and Fracture Impedance*

The spatial impedance is set by picking the attribute surface and the specific attribute attached.

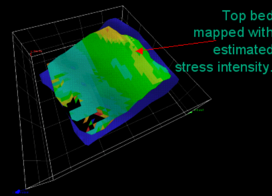
Spatial impedance allows the volume around the fracture to be assigned a resistance to failure. Fracture impedance allows a fracture to be assigned a value ranging between open and closed. This will affect the intersection behaviour of fracture sets.



The fracture impedance is set as a value between 0 and 1, where

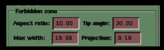
0 = closed

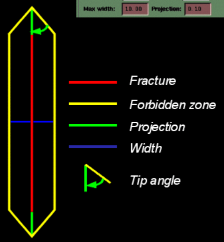
1 = open



12 Control of fracture impedance

• *Forbidden Zone Geometry*





- The forbidden zone tip geometry is defined by the projection and tip angle.
- The total shape is further defined by the maximum zone width.
- Together they approximate the ellipsoidal stress relief envelope proposed to exist around fractures

13 Control of stress release ellipsoid shape

• *Apply and attach*

Apply saves the initial input of fracture set parameters and allows syn-propagational changes to be effected on active fractures.

Apply and reactivate allows an entire fracture set to be reactivated.

Run initiates a modelling run of a given number of steps. At each step the program will reassess the local attribute values controlling fracture growth.

Evolutionary changes in growth style and reactivation of fracture networks can be modelled.

Apply allows active fractures to change behaviour, within a single deformation phase.

Apply and Reactivate affects all fractures and simulates a second phase of deformation. Using these two functions temporal as well as spatial variation in fracture growth can be simulated.

Fractures are only visualised during model runs. This allows very rapid and interactive modification of models.

Attaching creates the fractures as surfaces within the model allowing them to be manipulated and mapped with attributes.

14 Fractures available to be deformed

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