

Fracture Modelling in Move: Part 2. Evaluating fracture sets and creating a discrete fracture network (DFN)

The **Fracture Modelling** module allows users to construct discrete fracture networks (DFNs) based on structural evolution. Following August's feature on the prediction of fracture orientations and intensities using the **3D Kinematic module** and the **Strain Capture** tool, this feature will show how predicted fracture orientations can be evaluated and will illustrate the workflow steps to construct a DFN. As per part 1, this feature will use the East Kaibab monocline in Utah as an example dataset to demonstrate these tools.

Geological-based fracture prediction

Natural fracture systems can influence hydrocarbon recovery by creating conduits to flow or creating permeability anisotropies (Nelson, 2001; Warren and Root, 1963). To help quantify this, reservoir simulation studies commonly use DFNs to assist understanding subsurface fluid flow. The **Fracture Modelling** module in Move™ allows the construction of DFNs based on the available geological information, rather than providing a statistical extrapolation of measured fracture data. The module is used to create DFNs based on strain attributes from restorations or forward models. Multiple scenarios can be evaluated against available well and outcrop data prior to DFN creation. In this feature, a single fracture forming mechanism will be evaluated and a single deformation event will be considered to demonstrate the process.

The East Kaibab Monocline case study

The southern Utah portion of the East Kaibab monocline utilised in this study is shown in Figure 1. August's feature detailed the workflow to predict fracture orientations and intensities based on strain calculated from modelling the monocline's structural evolution. Orientations of joints, ϵ_2 -normal fractures, ϵ_3 -normal fractures and shear fractures were saved as attributes on the surface modelled in part 1. Before the creation of a DFN, the modelled fracture orientations must be compared to measured data to evaluate them and discern the dominant fracture type.

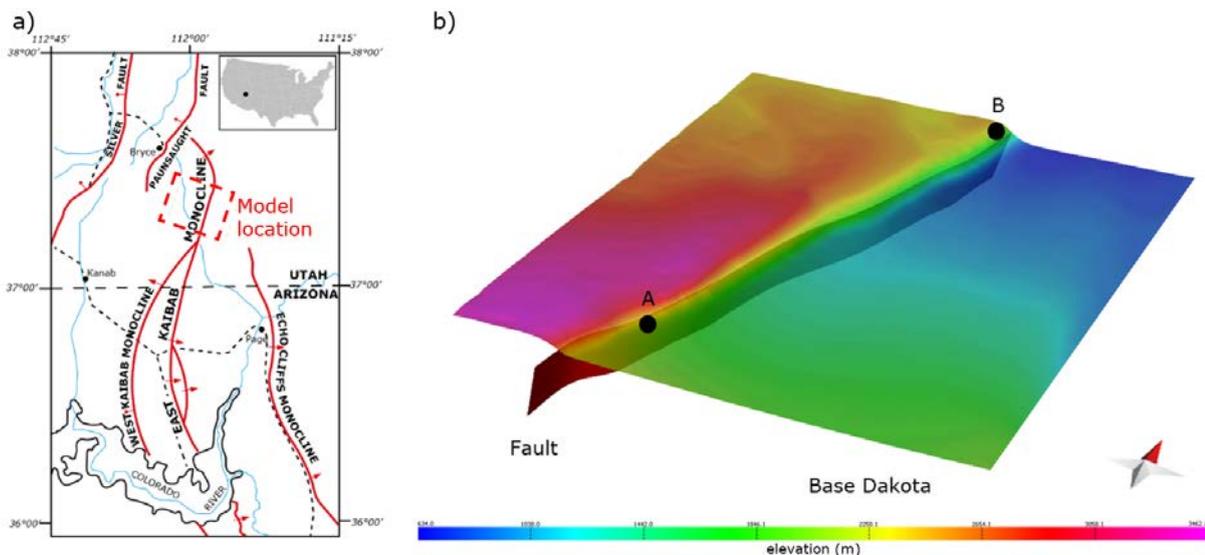


Figure 1. a) Location of the East Kaibab monocline and Move model; b) 3D model of the northern East Kaibab monocline, including the Base Dakota horizon (Upper Cretaceous), the main basement fault and two field sites with measured fracture data (A and B).

To validate the predicted fracture orientations, they were plotted as poles on a lower hemisphere equal area projection (stereonet plot) and visually compared to a stereonet plot displaying poles to fracture data measured in the field (see Figure 1b for locations of measured data). Visual comparison of predicted joint orientations (Figure 2a) to measured fractures (Figure 2b) showed comparable distributions which suggests that the modelled fracture-forming mechanism is valid and that joints are the dominant fracture type formed in this deformation event. More rigorously, a quantitative comparison could be carried out by calculating the angular misfit between the measured fractures and the predicted fracture orientations at the location of the measured data using the **Fault Response Modelling** module. For more information on the Fault Response Modelling module see the August 2016 monthly feature (accessible at [this link](#)).

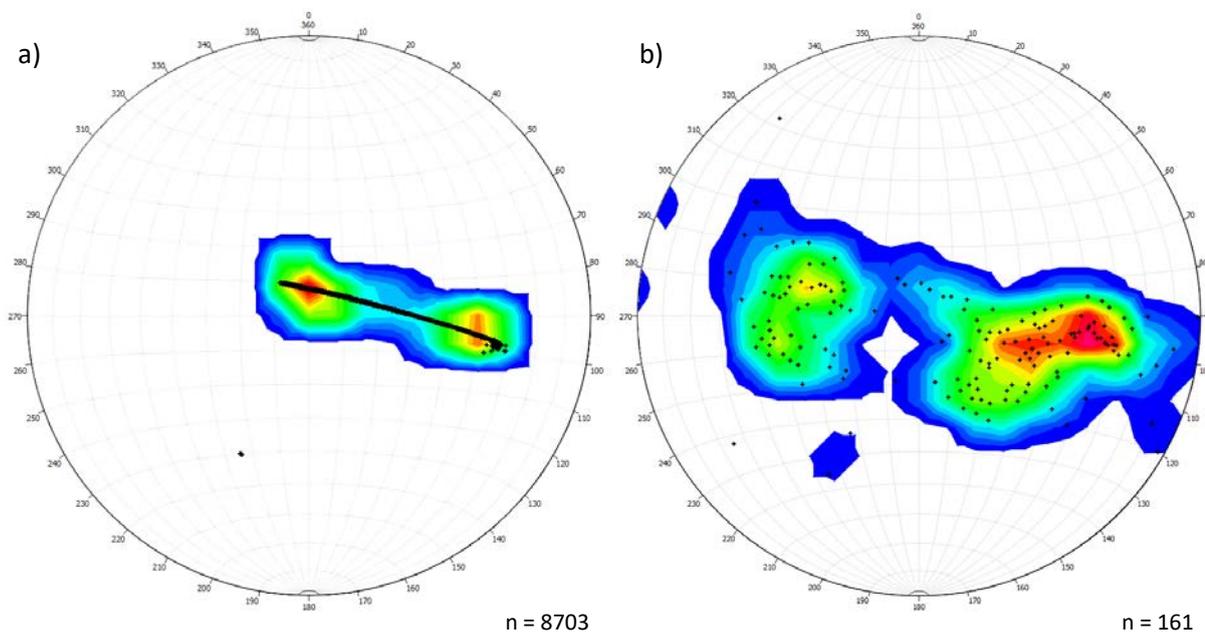


Figure 2. a) Lower hemisphere equal area projection of poles to modelled fracture orientations; b) Lower hemisphere equal area projection of poles to measured fracture orientations.

DFN creation

Prior to fracture set generation, a GeoCellular volume must be created within which, fractures will be predicted. This can be done simply by duplicating the surface of interest, moving the duplicate surface vertically down by a set amount using the **Basic Transform** tool and creating a GeoCellular volume between these two surfaces using the **Volume** tool. Any attributes that existed on the original surface are transferred to the cells of the volume (Figure 3).

The **Fracture Modelling** module (Figure 3) opens from the **Modules** tab in Move. The tool is easy to use, with a top-to-bottom workflow format (see Figure 3), prompting the user for required inputs.

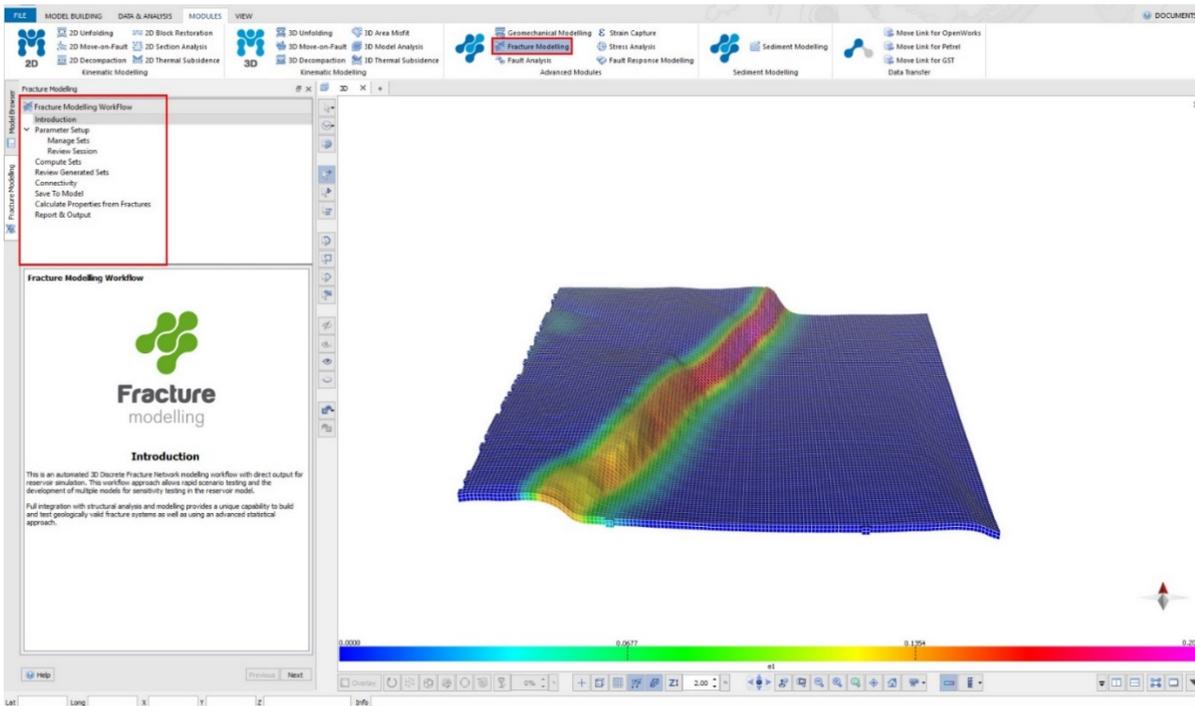


Figure 3. Fracture Modelling top-to-bottom workflow and GeoCellular volume used for DFN creation.

The following workflow steps outline the method to create a set of joints using a GeoCellular volume. The strain values calculated as part of August's feature will be used to model joint orientations and intensities. A similar workflow could be employed to create shear planes or other fracture sets identified from fracture evaluation.

1. On the **Parameter Setup** tab, create a new session and click **Next**.
2. Collect the GeoCellular volume in the **Select input GeoCellular Volume** box and add a fracture set (Figure 4). Multiple fracture sets can be added at this stage. These fracture sets will be populated with parameters from the GeoCellular volume. Click **Next**.
3. Next, parameters must be defined for each fracture set created in the tool. The first parameter to define is the region to create fractures within. If creating fractures throughout the entire volume is not required, regions can be set up prior to fracture modelling using the **GeoVol** tool (available from the Data & Analysis tab) and chosen here.
4. The following five tabs in the Parameter Setup section of the workflow prompt and guide the user to define the values that will be modelled to create the

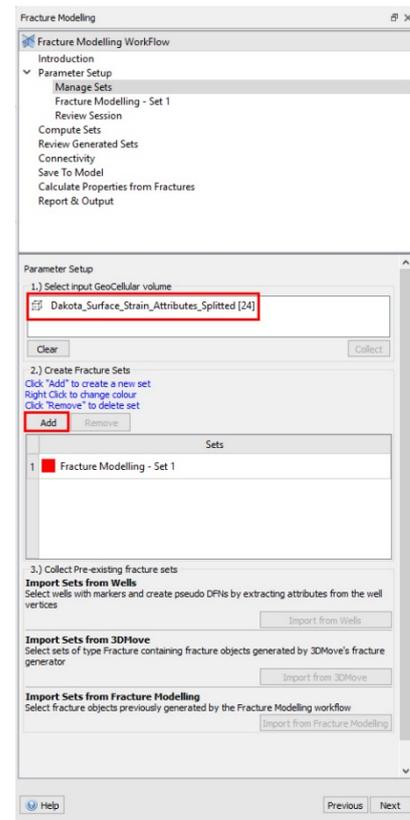


Figure 4. Parameter Setup in Fracture Modelling. The GeoCellular volume must be collected and fracture set(s) added (highlighted in red).

DFN. Strain values are saved on the grid; therefore, these will be used for the **Intensity** (e1, Figure 5) and **Orientation** (Joint Dip and azimuth, Figure 6) parameters. The **Orientation Distribution** parameter defines the degree of clustering of fracture orientations. A Fisher k-value can be measured from the measured data on the **Stereonet Plot** in the **Vertex Attributes Analyser** and entered here. **Length**, **Aspect Ratio** and **Aperture** can be defined based on outcrop or well measurements or from modelled or published values. When all the parameters have been set up, click Next and the tool will calculate the number of fractures that will be generated in the model. Click **Next** and then click **Run**.

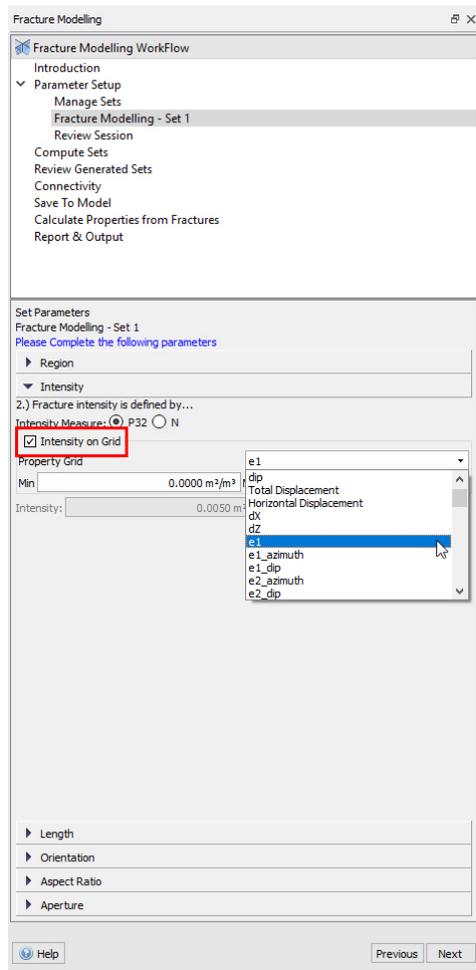


Figure 5. Defining fracture intensities based on strain intensity (e1).

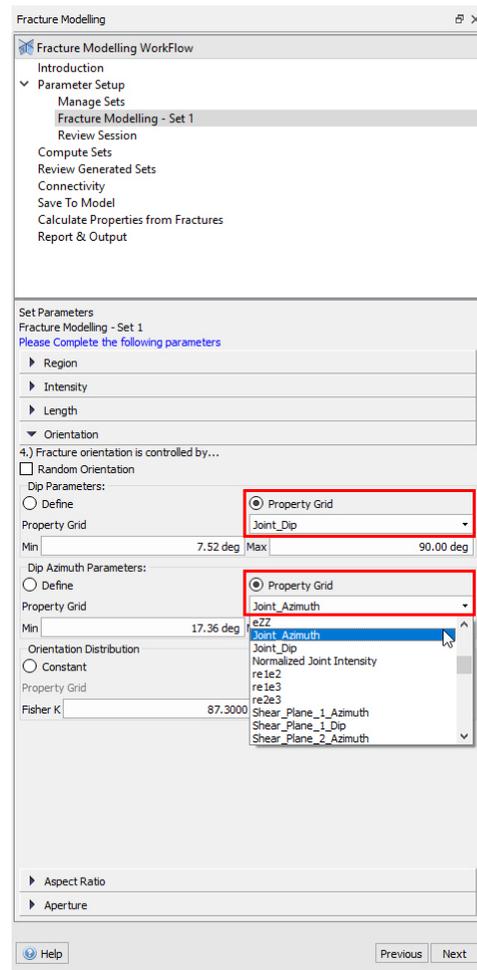


Figure 6. Defining Joint orientations as predicted by captured strain.

5. This will create the fractures and summarise the number of fractures, along with the runtime. Click **Next** again to visualize the fractures (**Review Generated Sets**, Figure 7).
6. The **Connectivity** tab permits the calculation of connectivity based on the modelled fractures without the need for full flow simulation. Connectivity can be calculated throughout the model or from/between wells if well data are available. This analysis can be valuable for planning injector and producer wells.

- If connectivity has been calculated, options will be available within the Connectivity Analysis tab for the display and saving of the resultant values. Click **Next** to proceed to the **Save to Model** step of the workflow.

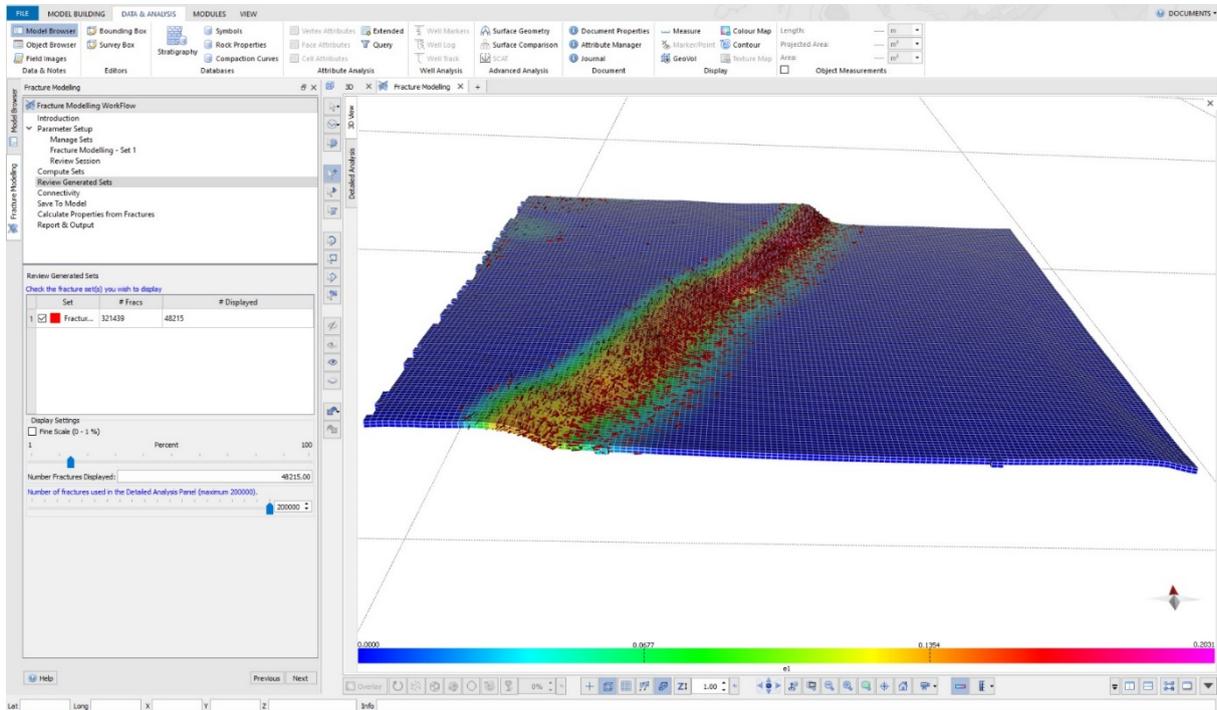


Figure 7. Reviewing the fracture sets generated in the Fracture Modelling workflow.

- Choose a percentage value of fractures to save. If the total number of fractures is excessively large (e.g. greater than 10 million), saving and visualizing the DFN may be computationally demanding. Choose to save the fractures to the model as a fracture set and click **Save** (Figure 8). This is a very important step because, up to this point, the modelled fractures only exist in the tool; they are not yet included in the model. When the fracture set has been saved, click **Next**.
- The **Calculate Properties from Fractures** tab can be used to calculate secondary porosity, secondary permeability, sigma and P32 for each cell in the GeoCellular volume, based on the DFN that has just been created. Choose the required properties to calculate and click **Calculate**, then click **Next**.

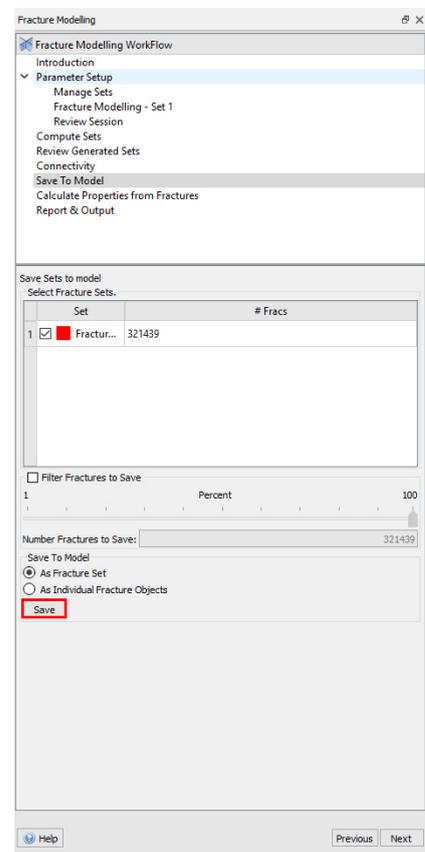


Figure 8. Saving the DFN as a Fracture Set

10. The **Report & Output** tab gives a summary of the DFN modelling carried out, including all the inputs defined, outputs generated and properties calculated, which can be saved by clicking on **Save to Journal**.

The fracture modelling window can then be closed and the DFN will exist as a fracture set in the Model Browser. The GeoCellular volume used will also be updated with the properties calculated during the fracture modelling workflow. Both the volume and the fracture set can be colour mapped for the attributes saved on them and visualized in the 3D View (e.g. Figure 9). This, for example, could help to identify drilling targets based on areas of increased porosity and permeability.

Many export formats are available if these objects are then required as inputs for more detailed flow modelling.

The results of the DFN modelling (Figure 9) show us that secondary-, or fracture-, porosity is higher at the northern end of the Kaibab Monocline. This may have implications for exploration and development of conventional and unconventional resources.

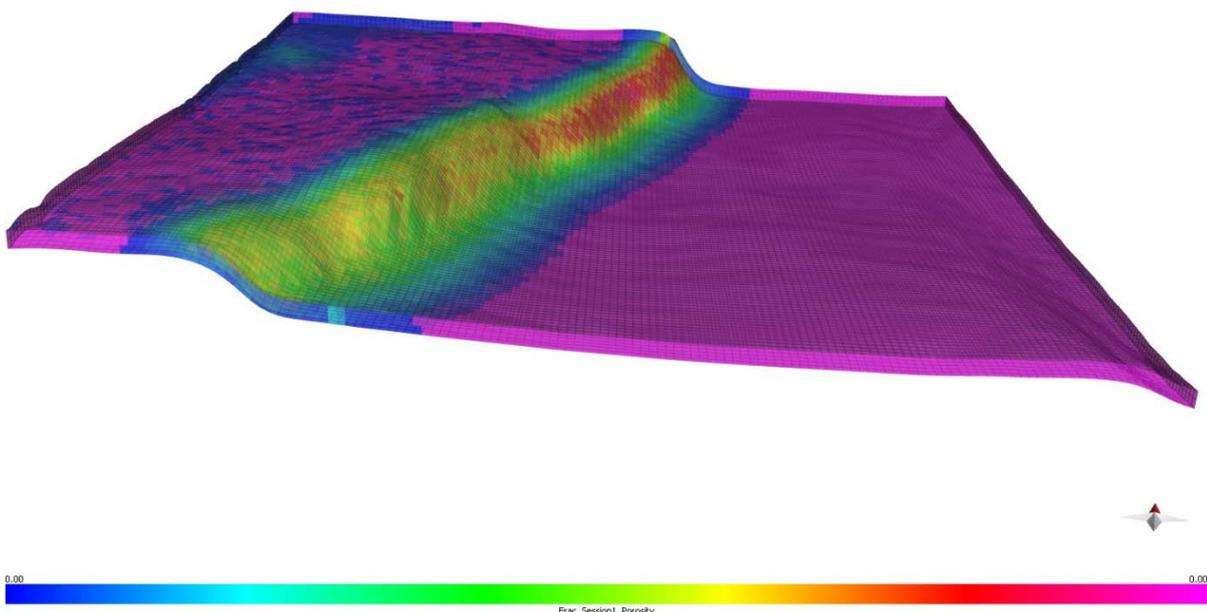


Figure 9. GeoCellular volume colour mapped for porosity, calculated during the Fracture Modelling workflow.

If you require any more information about Fracture Modelling, then please contact us by email: enquiries@mve.com or call: +44 (0)141 332 2681.

References:

Nelson, R. A., 2001, Geologic analysis of naturally fractured reservoirs, Gulf Professional Publishing, 332 p

Warren, J. E., and Root, P. J., The behaviour of naturally fractured reservoirs, *in* Proceedings Society of Petroleum Engineers Fall Meeting 1963, Volume SPE Paper 426.