Characterizing Stress Sensitive Fracture Apertures in Discrete Fracture Network Representations: A Stress Based Method to Represent Fracture Aperture Heterogeneity as an Input for Fluid Flow from Realistic, Outcrop Derived DFN Fracture Representations*

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Abstract

Carbonate reservoirs contain nearly 60 percent of the world’s conventional oil and gas reserves. Subsurface data and outcroppings indicate that they are intensely fractured. The subsurface distribution of natural fractures is often unknown due to their sub-seismic size and owing to difficulties in extrapolating 1D fracture information from available well data to 3D reservoir geomodels. Outcrop analogues is a method that one can resort to for constraining the 3D architecture of fracture networks. Outcrops represent a local snap shot of the current multiscale state of fracturing which is perhaps a net result of multiple events of stress reversals, burial and / or exhumation and tectonics. Outcrop data is still useful to calibrate mechanical and fluid flow models to predict the impact of fractures on storage and flow in the subsurface. The outcrop fracture data is used in building a Discrete Fracture Network (DFN) representation in which multiscale fractures are represented explicitly and hence honors the fracture intensity and topology. DFN representations can be used as input for flow and geomechanics numerical models.

In this work we utilize a combined outcrop based and numerical approach to characterize fracture patterns, fracture apertures and fluid flow sensitivities using a folded ‘box-type’ anticlinal structure example from the Pag Island, Croatia. Fractured folds often form prolific reservoirs owing to the structural closure they afford and the additional porosity and permeability due to the fold related fracturing. The fracture patterns are of specific interest owing to the complex geometries associated with folding. A 3D model of the Pag Island is created with slices of multiscale fracture traces which are interpreted and digitized from drone photogrammetry. We use 2D finite element modeling to quantify a stress sensitive fracture aperture and by incorporating these apertures into a conformal discrete fracture and matrix reservoir simulation model we can quantify the effect of stressed aperture on fluid flow. Our results indicate that the fluid flow behavior is variable spatially owing to the aperture heterogeneity across the area of the fractured fold.
References Cited


**ABSTRACT**

**SAMPLING DFN FROM REGIONS OF FOLD**

**APERTURE HETEROGENEITY VARIATION WITH STRESS**

**FRACUTRED RESERVOIR FLUID FLOW MODEL**

**COMPARISON OF FLUID FLOW RESPONSE**

**CONCLUSIONS**

**WORKFLOW**

**FROM PHOTOGRAMMETRY TO DIGITIZED DISCRETE FRACTURE NETWORK**

**CHARACTERIZING STRESS SENSITIVE FRACTURE APERTURES IN DISCRETE FRACTURE NETWORK REPRESENTATIONS**

A stress based method to represent fracture aperture heterogeneity as an input for fluid flow from realistic, outcrop derived DFN fracture representations.

The authors would like to acknowledge the Stanford University Petroleum Research Institute for Reservoir Simulation (SUPRI-B) program for the permission to use their research and data.

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**DIMENSIONS**

- **Page dimensions:** 1361.0x1772.0
- **Element count:** 120
- **Node count:** 6922
- **Element type:** Mesh of tri-elements around fractures

**Unstructured Mesh for Simulation**

**Digital Elevation Model**

**Mesh Generator**

**Unstructured Conforming**

**Station Scales Measures**

**Fracture Density**

**Discrete Fracture Network**

**DFM Fluid Flow Model**

**Unstructured Conforming**

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**REFERENCES**

**GEOLOGICAL SETTING AND DEFORMATION STYLE**

The External Dinarides are a fold and thrust belt characterized by general SW vergence [e.g., Tari, 2002]. The Pag anticline involves about 1 km of Cenomanian-Santonian rudist-bearing limestones overlain, through an unconformity, with transgressive Foraminiferal limestones of Eocene age [Korbar, 2009]. At the km-scale, the fold is continuous along-axis for ca. 30 km between the NW and SE periclinal terminations. In cross section, the fold has box geometry, with sub-vertical to overturned forelimb and a gently undulating hinge zone (1c). The fold is crosscut by minor thrust faults verging both to NE and SW, and by sub-vertical strike-slip faults striking either NS or EW. Thrust and strike-slip faults determine local increases in fracture intensity (1d, 1e).

**REFERENCES**


In 2D fracture networks, the fractures may be considered to be a system of branches and nodes (Sanderson & Nixon, 2015). Fracture topology refers to the relationship between the elements of the network. The behavior of the fracture network to flow and stress depends not only upon the geometrical features of the fractures but also upon these connecting relationships. The nodes may be divided into isolated (I) nodes, abutting or terminating (T) or (Y) nodes and crossing (X) nodes. The proportion of these nodes define the topology (Manzocchi, 2002; Mäkel, 2007) and can be used to characterize the fracture system. We perform such a topological analysis of the nodes and derive the node metrics for the Pag fracture network.

The proportion of nodes may be represented on a ternary plot. Sanderson and Zhang (1999) compared three natural fracture networks with stochastic line simulations (fig below). The Pag system is juxtaposed on this ternary plot and it has an isolated topological character for the system as a whole.