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Mode I Opening Orthogonal Fracture Networks: Can They Be Used as Analogue Fracture Networks for Subsurface Models?

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ABSTRACT

Natural fracture networks play an important role in the effective permeability and therefore fluid flow in tight reservoirs. These network patterns are rarely randomly orientated or distributed, and often show systematic relations with respect to the orientation of the principal stresses, the type of fracturing and layer boundaries. An example of such an arranged network is an orthogonal fracture network. These networks are comprised out of mode I opening fractures and show systematic fractures perpendicular to the regional (far field) σ’h and smaller cross fractures perpendicular to σ’H. The goal of this study is to establish how distinctive and unique the required stress state and elastic material properties are, regarding orthogonal network configurations. Previous mechanical models have shown how the opening of fractures greatly reduces the local effective tensional stresses perpendicular to the fracture plane. Due to this local effective stress reduction, the simultaneous development of multiple closely spaced fractures must occur under sub critical stress conditions. This implies that the crack tip will not rupture but will slowly develop over time. In this study, we will combine the theory of sub critical crack growth and linear elastic fracture mechanics, in order to assess the development of layer- bounded mode I fracture networks. This will be done using a static finite element code in combination with the empirical relations describing sub critical crack growth rocks. The results show that an orthogonal fracture network can only develop whilst both horizontal principal stresses are in effective tension. The required effective horizontal tensional stress ratios (σ’H/ σ’h) depend on the material parameters of modelled material. In general, a stress ratio of: σ’H/ σ’h = 0.5, is required in order to develop an orthogonal micro perturbation in the presence of larger systematic fractures. Furthermore, the modelling results indicate that the final geometry of an orthogonal network is highly dependent on the applied effective principal stress ratio. This implies that when the stress ratio ≥ 0.85, a nested geometry will develop, whereas lower stress ratios will result in a ladder-like pattern. Finally, our models show that the simultaneous development of a orthogonal network must occur under a, in terms of geology, unique regional stress state and that the final network geometry is highly dependent on small changes in the regional stress state.