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Geomechanically Coupled Simulation of Flow in Fractured Reservoirs

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Capturing the necessary and sufficient detail of reservoir hydraulics to accurately evaluate reservoir behavior remains a significant challenge to the exploitation and management of fracture-dominated reservoirs. In low matrix permeability reservoirs, stimulation response is controlled largely by the properties of natural and induced fracture networks, which are in turn controlled by the *in situ* stresses, the fracture distribution and connectivity and the hydraulic behavior of the fractures. This complex interaction of fracture flow systems with the present-day stress field compounds the problem of developing an effective and efficient simulation to characterize, model and predict fractured reservoir performance. We discuss here a case study of the integration of geological, geophysical, geomechanical, and reservoir engineering data to characterize the *in situ* stresses, the natural fracture network and the controls on fracture permeability in geothermal reservoirs.

A 3D geomechanical reservoir model includes constraints on stress magnitudes and orientations, and constraints on mechanical rock properties and the fractures themselves. Such a model is essential to understanding reservoir response to stimulation and production in low matrix permeability, fracture-dominated reservoirs. The geomechanical model for this study was developed using petrophysical, drilling, and wellbore image data along with direct well test measurements and was mapped to a 3D structural grid to facilitate coupled simulation of the fractured reservoir. Wellbore image and stimulation test data were used along with microseismic data acquired during the test to determine the reservoir fracture architecture and to provide control points for a realistic inter-connected discrete fracture network.

As most fractures are stress-sensitive, their hydraulic conductivities will change with changes in bottomhole flowing and reservoir pressures, causing variations in production profiles between wells. More specifically, fractures can hydraulically open or close due to a decrease (caused by injection) or increase (caused by production) in the effective stress. Flow properties are a function of effective fracture aperture, so it is possible to predict reservoir behavior using the relationship between the mechanical behavior of natural fractures (in response to *in situ* stress and pore pressure changes) and their hydraulic properties. Low flow rate injection tests were used to characterize the hydraulic properties of the fractures, their width, stiffness and strength — properties that are often difficult to quantify, leading to large uncertainties in predicted response to stimulation of fractured reservoirs.

Flow through the individual fractures which form the connected network was explicitly modeled. Fracture stress sensitivity was coupled to the flow simulation through the DFN with dynamic adjustment of aperture to effective normal and shear stresses (after Moos and Barton 2008) and calibrated with microseismic data (positions and times of events) and injection data (rates and pressures). Available tracer test data were used to validate the flow simulation. The results highlight the importance of combining all available data, including microseismic, wellbore image, and flow and stimulation test data, to determine reservoir flow behavior and its response to stimulation.

References

Moos, D., and Barton, C. A. 2008, Modelling uncertainty in the permeability of stress-sensitive fractures. ARMA 08-312. 2008.