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Process-Based Natural Fracture Predictions Using Geomechanics

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ABSTRACT

Naturally fractured reservoirs are often challenging to produce efficiently due to a host of issues. A key uncertainty in most fractured reservoirs continues to be the lack of predictability of fracture locations, geometry and apertures. The ability to predict fractures, despite decades of work across academia and industry, is a first order constraint for the successful development of fractured reservoirs. There have been significant improvements in fracture characterization techniques, primarily from well-based data sources, but also in remote sensing, in flow simulation capabilities and refinements in statistical modeling of fracture populations. The solution to improved accuracy in subsurface prediction of fracture intensity, physical dimensions and connectivity away from wells, however, remains elusive. To address natural fracture prediction, we utilized a sophisticated first-principles geomechanical modeling approach, calibrated to subsurface data when available, to reduce uncertainty. Leveraging the concepts that stress heterogeneity and degree of effective tensile stress control the formation of opening mode fractures, we model the development and evolution of stress in a reservoir over time as the basis for our predictions. Natural fractures nucleate in the numerical models due to tensile failure induced by changes in the boundary conditions, initial conditions and mechanical stratigraphy over time that reproduce a particular reservoir burial and deformation history. The new modeling capability uses extended finite elements to accurately model 3D natural fracture nucleation, growth and interactions under a range of settings. The approach is useful to predict natural fractures formed through a variety of fracturing mechanisms. In particular, where the processes responsible for fracture formation can be identified, such as variations in mechanical stratigraphic stacking or bending due to folding, numerical models can reproduce the stress history responsible for fracturing. The utility of this approach is demonstrated using case studies of reservoirs fractured under a range of strain histories. One illustrates the prediction of fractures in low strain settings where mechanical stratigraphic stacking and burial/exhumation history controls the locations and degree of fracturing. Another shows how natural fractures due to folding can be predicted in high strain settings through forward modeling of fold evolution.