Geomechanical Explanations of Microseismic Images in Shale Plays

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Microseismic mapping is routinely used to estimate hydraulic fracture characteristics such as geometry, location, and complexity. Currently, this type of mapping is used to provide a visual representation of these characteristics, which is used to calibrate fracture and reservoir models. This paper describes the application of geomechanics to provide mechanical explanations of microseismic events.

The net effect of hydraulic fracturing is the opening of tensile fractures. However, microseismic mapping generally captures shear events, caused by geomechanical deformation. The event maps typically provided by microseismic surveys thus do not directly measure fracture geometry.

Nevertheless, visually-observed trends are often used to infer mechanical behavior. For example, broad clouds of events are assumed to represent "complexity", i.e., the development of a complex fracture network. Commonly, this is thought to involve the linking of natural fractures, exposing more rock surface and thus enhancing production compared to that obtained from "simple" conventional bi-wing fractures.

Similarly, if a series of events occurs some distance from those around the main fracture zone, it may be inferred that movement has occurred on a natural feature such as a fault or formation boundary. Geophysical statistics such as frequency-magnitude plots are used to discriminate between these events and those closer to the fractured zone.

This paper describes three major applications of geomechanics to hydraulic fracturing in shale plays.

First, new complex fracture propagation models provide insight into the development of complexity. These models simulate the development of complex fracture networks, based on the mechanical properties, stress regime and hydraulic fracture pumping schedule. The results of these simulations are correlated with observed microseismic events to determine the most likely locations and spacing of both induced fractures and opened natural fractures.

The next evolution in interpretation involves using geomechanical concepts to provide a mechanical explanation of the event patterns. The locations of potential slip on natural planes of weakness, as well as the failure of intact rock, can be accurately identified using three-dimensional geomechanical simulations of the stresses and strains induced by hydraulic fracturing. In these simulations, hydraulic fracturing induces irreversible plastic strains (Figure 1), which can be used to predict the location of microseismic events. Comparison of these predictions with observed microseismic events is used to explain the physical mechanisms of the observed events.

Finally, geomechanics is used to improve production predictions in two ways. By identifying events associated with conductive features, as opposed to unconnected regions, more accurate estimates of fracture dimensions are provided. In addition, strain induced by hydraulic fracturing can result in changes in both matrix permeability and fracture conductivity, clearly impacting production (Figure 2).

AAPG Search and Discovery Article #90122©2011 AAPG Hedberg Conference, December 5-10, 2010, Austin, Texas.

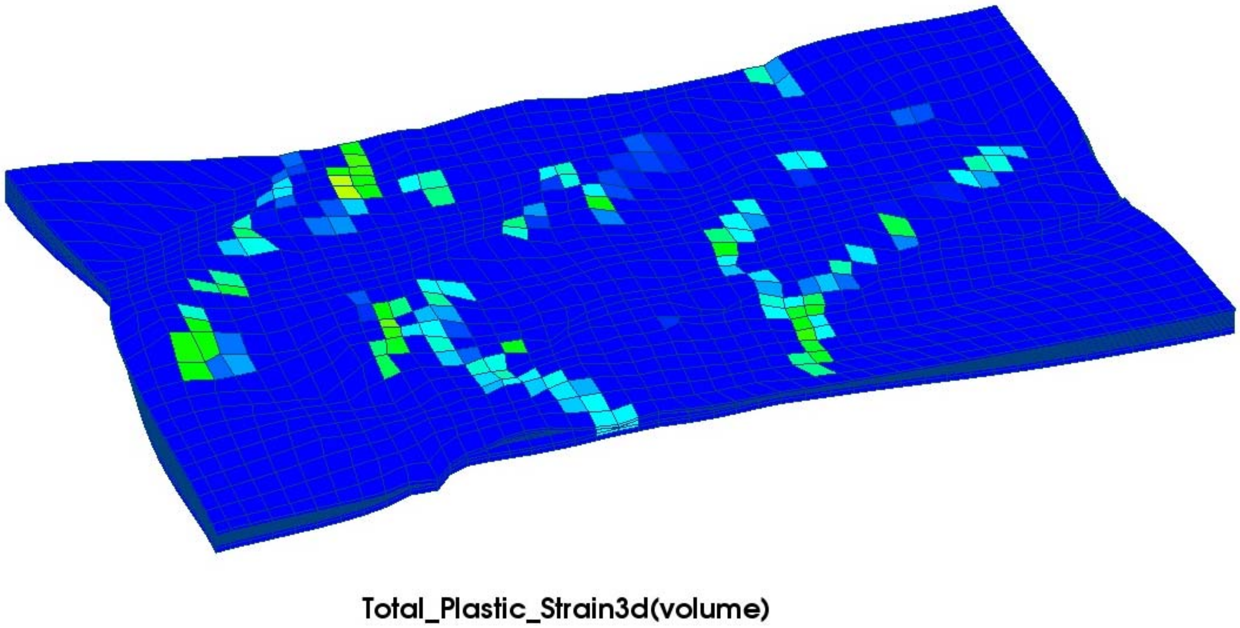

Figure 1 Total Plastic Strain in a small section of a full geomechanical model

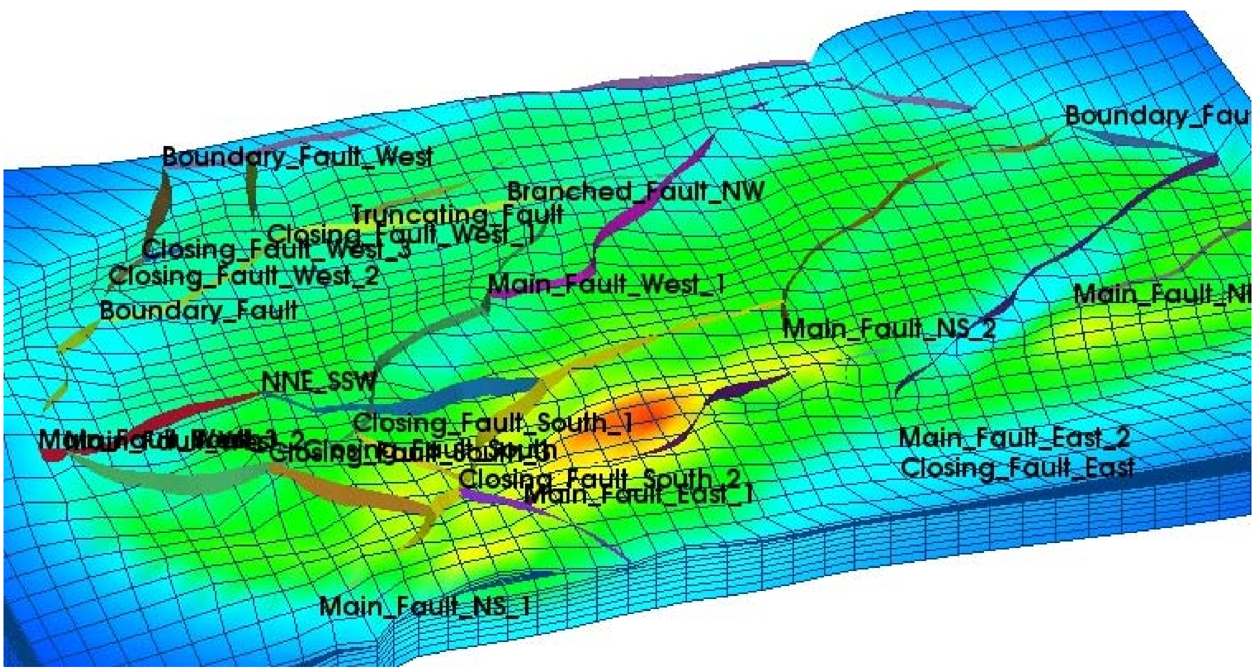

Figure 2 Displacement after production