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Using Microseismic Events to Constrain Fracture Network Models and Implications for Generating Fracture Flow Properties for Reservoir Simulation

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Abstract

Microseismic monitoring of hydraulic fracture stimulation treatments has done much to diminish the expectation of engineers and geoscientists that symmetrical bi-wing fractures extending away from the well bore from as a result of the treatment. Mapping of microseismic event locations indicates that more often, zones of high complexity form which suggest multiple rock failure mechanisms could be in play during the stimulation treatment. The complexity of the failure is further complicated, or perhaps explained, by the interaction of the perturbed stresses with existing fractures in the reservoir relative to the unperturbed stress state of the reservoir. Existing fracture planes favorably oriented for shear will fail at lower stresses than are required to create new fractures. Geologic mapping and regional to local in-situ stress information will allow informed interpretation of the resulting microseismicity patterns as well as providing predictive capability for fracturing patterns of treatments in subsequent area wells and production planning. Correlative to the improved fracture mapping is the use of the fracture interpretation as input to fractured reservoir modeling and fractured reservoir simulation. Utilizing microseismicity data not only to constrain location of fractures, but also fracture size, shape and orientation allows creation of improved fractured reservoir models based on geologic concepts and supported by the real time data.

In this paper two examples are presented from a hydraulic stimulation of North American mid-continent wells that were monitored with a surface-based geophone array. The resulting microseismicity patterns in both wells show that the fracture development was strongly influenced by pre-existing discontinuities (fractures or faults), which are easily explained by geologic and in-situ stress analysis. The fracture interpretation and microseismicity data from one example is used to generate a discrete fracture network from which fracture flow properties are created in a geocellular model. The resulting model provides a quantitative framework for production history mapping and reservoir behavior, with hard constraints for the behavior of the dominant fractures in the fracture network.

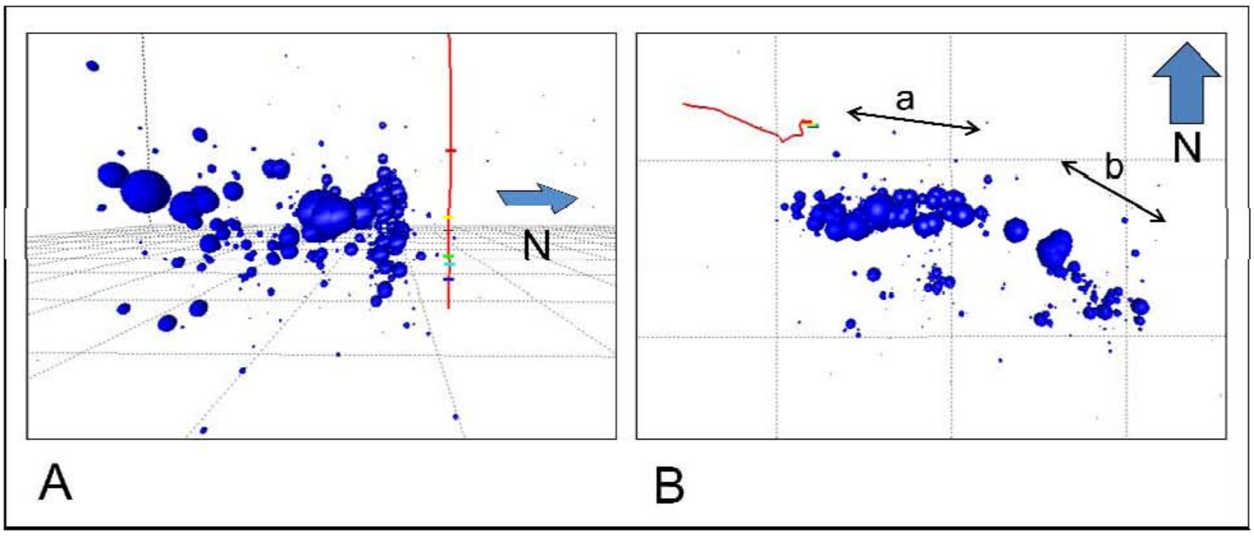

Figure 1. Microseismic events sized by relative amplitude. A. Cross sectional view of reservoir showing relationship of vertical well to events. Orientation of the view is parallel to the trend of events lined up along east-west. Distance between the well and the vertical plane defined by the events is approximately 80 meters. B. Map view, looking down into the reservoir with the vertical well in the upper left of the figure. Two event trends are clearly visible, one oriented east-west closest to the well which abruptly bends to the southeast away from the well. The arrows marked a and b show the orientations of the intrinsic fast shear wave direction (parallel to fractures) and the stress induced fast shear wave direction, respectively.

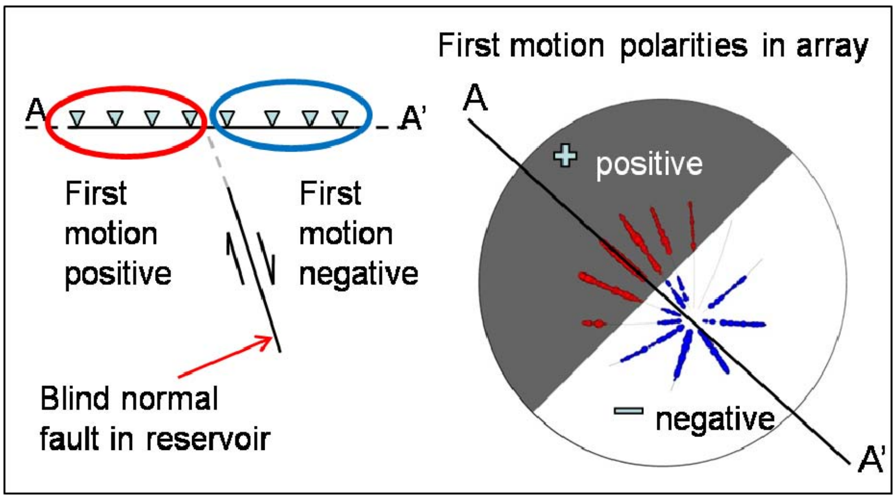

Figure 2. Diagram showing schematic microseismic surface array and relationship of nodal plane between events with positive and negative first motions as detected by array.

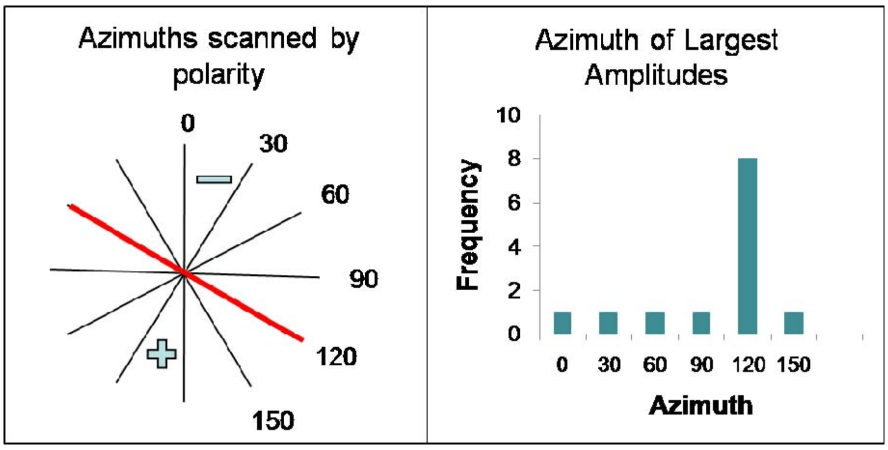

Figure 3. Relationship between number of events and azimuth of the polarity change for example data shown in Figure 1. Events at 120o azimuth have the largest amplitudes.

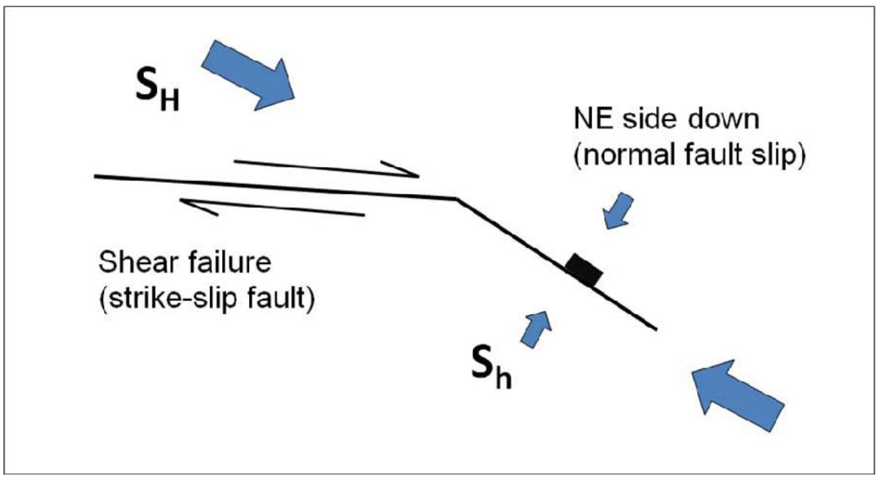

Figure 4. Geologic interpretation of event trends shown in figure 1. The strong azimuth dependence of the event amplitudes for the southeast trend is interpreted to come from dip-slip motion parallel to that trend.

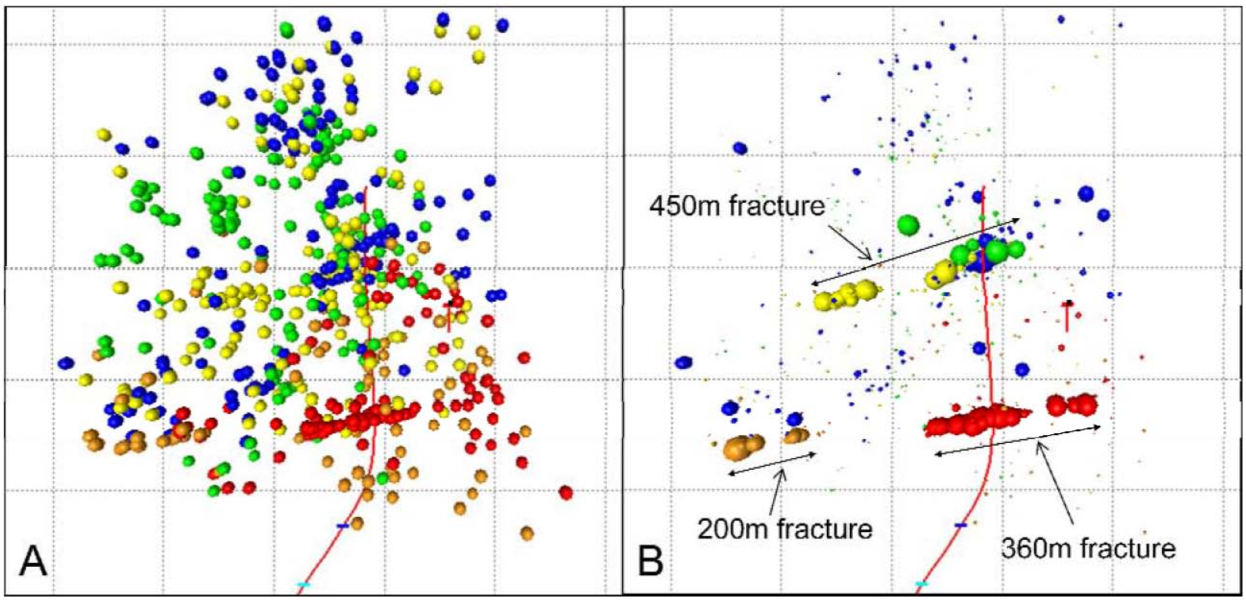

Figure 5. Two views of the microseismicity imaged from a hydraulic fracture treatment of a horizontal well. A. shows the event locations colored by stages: stage 1 = blue, 2 = green, 3 = yellow, 4 = orange, 5 = red. B. The same events sized by relative amplitude showing more clearly the fracture trends outlined by the strongest events.

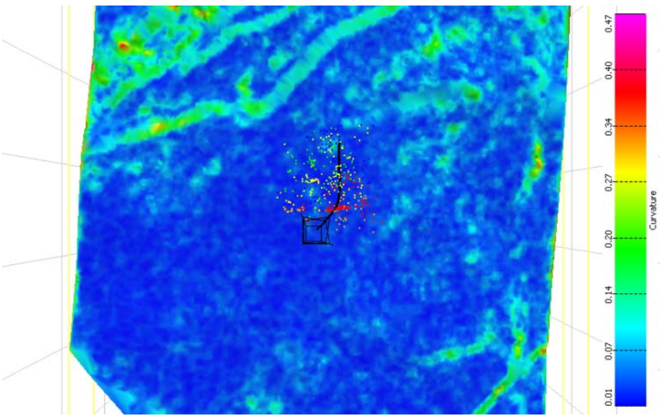

Figure 6. Top of the reservoir horizon colored by curvature (dip) Showing trend of major normal faulting north of the reservoir. The 80° stimulation treatment fracture trend is visible just to the north of the well derrick symbol, outlined by red dots.

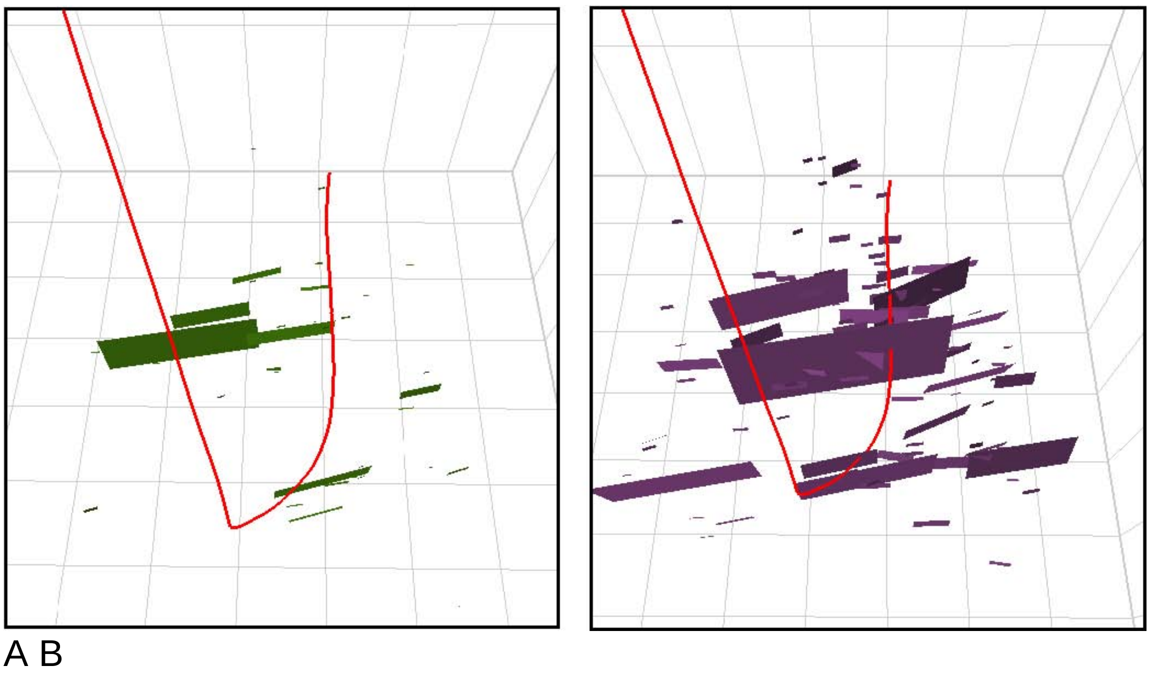

Figure 7. Discrete fracture model generated from the microseismic event locations. Event amplitude was used to control fracture location by using it as an intensity measure, and fracture sizes were controlled by the relationship between the amplitude and the seismic moment.

A. fracture intensity = event amplitude. B. fracture intensity = square root(event amplitude).