Case Study

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Understanding Vertical Fracture Growth in the Marcellus Shale using Advanced Microseismic Methods

ESG acquired, processed and analyzed microseismic data for a hydraulic fracture stimulation in the Marcellus Shale. Advanced analysis was performed to evaluate disparity in vertical growth behaviour between stages. Using Seismic Moment Tensor Inversion, ESG found that stages exhibiting vertical fracture growth appeared to activate moderately dipping joint sets and could be related to stress induced by a buckling anticline.

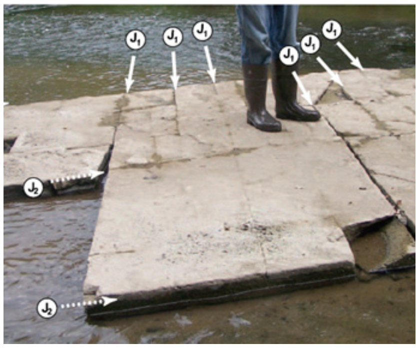

Fig 1: Visible joint sets in the Marcellus Shale (Engelder et al., 2009)

The Marcellus Shale is found in the northern Appalachian basin of North America and spans across a number of US states including New York, Pennsylvania, West Virginia and Ohio, covering an estimated 95,000 square miles. The shale can be found at depths ranging from 4,000-8,500 ft and averages in thickness from 50-200 ft. Due to its size and close proximity to natural gas markets in the Northeastern USA, the Marcellus is a very attractive formation for unconventional oil and gas producers.

Background

As a naturally fractured shale, the Marcellus incorporates two regional joint sets (J1 and J2) as observed in outcrops, cores and borehole images (Fig 1). In general, the layered sedimentary nature of shale seems to restrict vertical fracture growth in these formations, however the natural fracture networks within the Marcellus shale

ESG Solutions
20 Hyperion Court, Kingston, ON, Canada K7K 7K2
Tel: +1.613.548.8287 Fax: +1.613.548.8917
www.esgsolutions.com sales@esgsolutions.com

introduce complexity in the geology and many operators use microseismic monitoring to better understand this complex fracture growth behaviour.

Challenge

During a multi-well horizontal hydraulic fracture stimulation in the Marcellus shale, varying fracture growth behaviour was observed in two wells on the same pad. Figures 2 and 3 illustrate a cross-sectional view of microseismic events for a total of 4 stages on two wells (Well A and B, respectively), where the red and grey surfaces represent the top and bottom of the Marcellus shale. A greater understanding of local geology and fracture behaviour is a key element to optimizing hydraulic fracture stimulations, therefore ESG performed advanced microseismic analysis to investigate why fractures migrated vertically in Well A but were contained in Well B.

ESG Solution

Using patent-pending Seismic Moment Tensor Inversion (SMTI) methods, ESG developed discrete fracture networks (DFN) to describe fracture behaviour on both wells. SMTI analysis provides information about the failure mechanisms responsible for generating seismicity. Careful interpretation of these mechanisms can determine the style of failure as well as the fracture plane, allowing for the determination of the dominant fracture sets that a treatment is activating,

A stereographic projection is used in Figure 4 to describe the dominant fracture planes observed in stages 1 and 2 on both wells. The natural joint sets J1 and J2 are highlighted as green planes on the projections, while the dominant induced fracture families (F1 and F2) observed in the DFN are shown as white planes.

In Well A, the orientations of the fractures generated during the fracture stimulation closely match the natural joint sets J1 and J2, suggesting that natural fractures are activated by the treatment. In contrast, the fractures induced in Well B, which is located just on the other side of the same pad, exhibits a sub-horizontal fracture set, suggesting that fractures are controlled by natural bedding planes in the formation.

A comparison of the fracture plane orientations with the depth distribution of events reveals that greater vertical growth is associated with activation of natural joint sets than bedding planes. This evaluation implies the existence of a local control on the stress conditions (such as an anticline) promoting the jointed fracture network in Well A, whereas the natural preference is to activate bedding planes as in Well B.

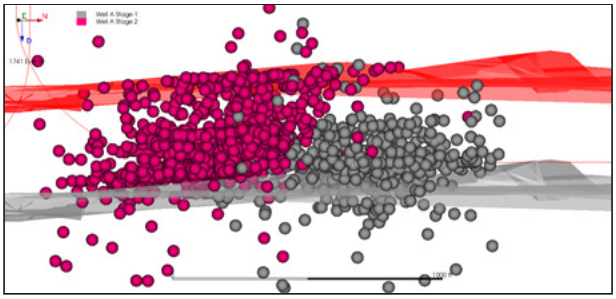

Fig 2: Cross-sectional view of microsiesmic events from 2 stages in Well A exhibiting significant vertical growth. The red and grey surfaces represent the top and bottom of the Marcellus, respectively.

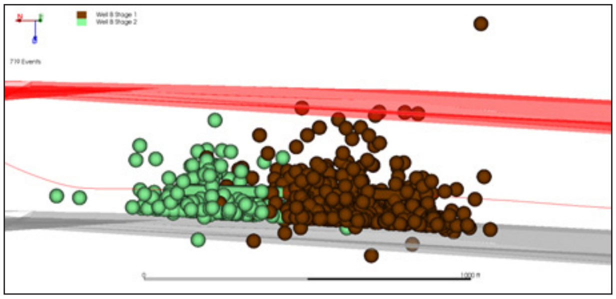

Fig 3: Cross-sectional view of microsiesmic events from 2 stages in Well B exhibiting vertical containment. The red and grey surfaces represent the top and bottom of the Marcellus, respectively.

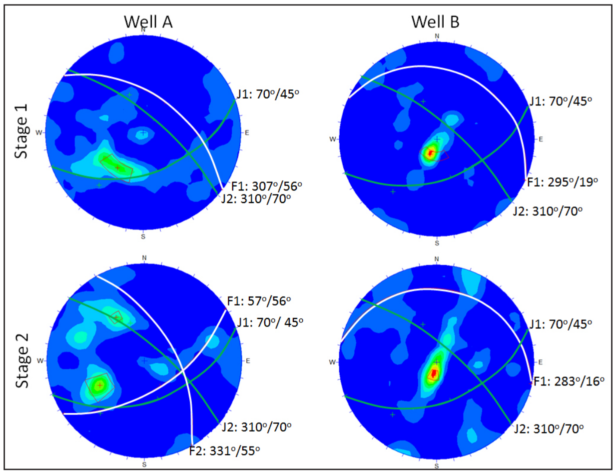

Figure 4: Lower stereographic projections of the poles to the SMTI-derived fracture planes in stages 1 and 2 of wells A and B respectively. These fracture planes are compared against the orientations of the dominant joint sets for the Marcellus described by Engelder et al. (2009).

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20 Hyperion Court, Kingston, ON, Canada K7K 7K2
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www.esgsolutions.com sales@esgsolutions.com