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The Influence of Mesh Size on Fracture Network Growth

John W. Crowley, Adam M. Baig, and Ted Urbancic
ESG Canada Inc

Summary

Microseismic analysis is used to determine event locations, event strength, stress and energy release, and relative fracture lengths. Additionally, fracture orientations are calculated using Seismic Moment Tensor Inversion. These microseismic observables are used together with the detailed hydraulic fracture treatment data to identify several dynamic changes in the growth of the discrete fracture network. In this study, we identify a preferred fracture set that is consistent with the regional stress and easily activated throughout the treatment program. A secondary fracture set is also observered but is only temporarily activated by increases in mesh size. Abrupt changes in event rate, fracture plane orientation, and proximity to the treatment zone are linked to changes in the treatment program, such as mesh size, providing insight into the role and effectiveness of both fluid and proppant on extending the connected discrete fracture network.

Introduction

Hydraulic fracturing aims to enhance pathways for gas and petroleum extraction by creating and reactivating pre-existing fractures through the injection of high-pressure fluids and proppant. The problem is complex and depends on the formation geology, the treatment plan (pumping pressure, fluid type, proppant size, etc.), the complexity of the stress field, and local variations in geology.

The dynamic behavior associated with Frac growth is inherently captured by recording microseismicity during the stimulation. Microseismic events are the response to the treatment program. It is well established that the event distribution alone is insufficient to identify and characterize the development of the underlying discrete fracture network (DFN) responsible for the propagation of the Frac. However, utilizing a multi-well multi-array monitoring configuration allows additional information about the fracture characteristics to be obtained.

This paper focuses on the role that proppant plays in the development of the fracture network. In addition to its primary purpose as a ‘prop’ to hold fractures open, proppant is also regarded as an efficient medium for effectively transferring stress throughout fractures and eroding and enlarging pre-existing fractures. In our examples, we discuss how Frac growth occurs through the activation of distinct fracture sets and show that the introduction of proppant appears to help in activiating more difficult fracture sets.

Method

By utilizing two down-hole arrays we determine event strength, stress and energy release, and relative fracture lengths. Additionally, we derive information about failure types (shear tensile failures), fracture orientation and the stress/strain conditions associated with the failures using a Seismic Moment Tensor Inversion (SMTI) approach.

Microseismic observable are compared to detailed treatment parameters (pressure, proppant concentration and proppant size) and distinct temporal patterns observed.

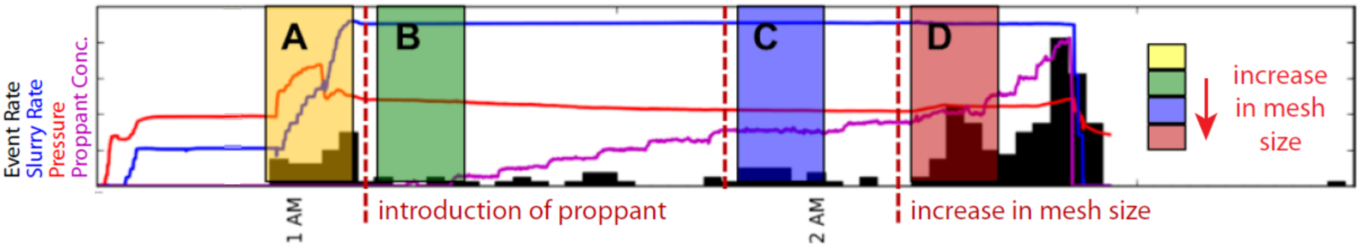

Figure 1: Treatment parameters and event rate as a function of time for the hydraulic fracturing of a single stage. Colored bars indicate time windows before the introduction of proppant (yellow), after the introduction of proppant (green), and following increases in the proppant mesh size (blue and red).

Examples

In our examples, we discuss how Frac growth, in the direction of the maximum horizontal stress, occurs through the activation of distinct fracture sets that are consistent with the known regional stress. Failure types vary with distance from the treatment zone as well as with treatment parameters and distinguish regions influenced by fluid from those affected indirectly by changes in local stress. This further allows for the identification of the connected DFN and assessment of the total Stimulated Reservoir Volume (SRV). Abrupt changes in failure type were linked to changes in the treatment program, such as mesh size, providing insight into the role and effectiveness of both fluid and proppant on extending the connected DFN. Finally, the spatiotemporal distribution of microseismic events indicates local variations in geology and/or stress that act as potential barriers to growth, reducing the overall effectiveness of the treatment program.

Figure 1 shows the event rate and treatment parameters for a single stage of a hydraulic fracture. The four panels of Figure 2 show the event positions and fracture plane orientations corresponding to the time windows indicated in Figure 1. Within the time window marked ‘A’ a large number of fractures form as pressure is increased in the initial stage of the treatment program. These events form on zone and the majority of the fractures follow a North-East trend. An increase in the number of distal events is observed upon the introduction of the proppant (time window ‘B’). In addition, fracture planes are found to be temporairly oriented along a North-South direction, indicating that a distinct fracture set has been activated.

Increasing in the proppant mesh size (between time windows ‘C’ and ‘D’) is found to have a similar effect and again activates a secondary fracture set.

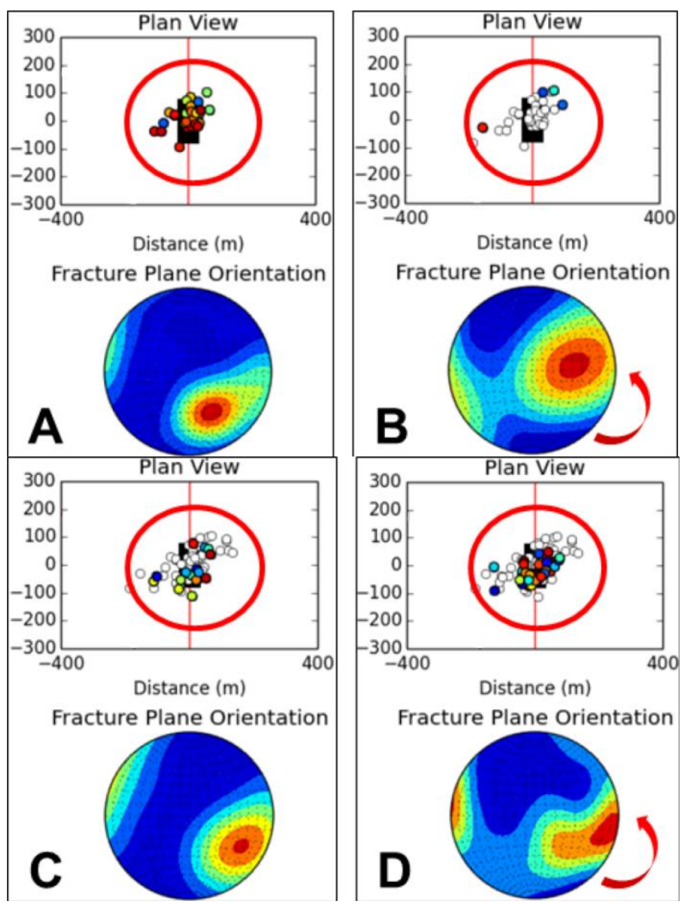

Figure 2: Event distribution and fracture plane orientations shown on a stereonet corresponding to the colored time windows in figure 1. Colored events are events produced within the time window while white events show the position of events recorded prior to the time window.

Conclusions

Combining advanced microseismic analysis with detailed treatment data reveals several important changes in the dynamic growth of the discrete fracture network and allows for the identification of the key treatment parameters responsible for them. Transient changes in fracture orientation and event distribution are observed in response to the change in proppant size and indicates that proppant may play an important role in helping to activate additional fracture sets, thereby increasing the connectivity and efficiency of the overall discrete fracture network.