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Integrating Acoustic Emission Cloud Characteristics with Individual Event Source Parameters: What Can We Learn from Observed AE Throughout a Hydraulic Fracturing Process?

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Abstract

Observing the hydraulic fracturing process through microseismic sensing provides extremely valuable information regarding fracture evolution and the altered reservoir. Many individual microseismic events make up a large, and often times scattered, cloud of source locations of rock slippage and fractures. Traditionally, the cloud of three-dimensional source locations is used in order to understand the volume of rock that has been stimulated during a fracturing treatment, or stimulated reservoir volume (SRV). Using the location data and time, many procedures exist to estimate the volume of rock stimulated using clustering, shrink-wrapping, binning and other temporal techniques. Although these methods are elegant, many of them are just best guesses to what the fracture network looks like at great depths and do not take into account the numerous other data types gained from microseismic sensing. Additionally, validation of such techniques is minimal due to the inability to image fractures beneath the surface of the earth.

In many cases, the volume of rock that has been stimulated according to these techniques is not the volume of rock that is draining into the fracture which contributes to production. Hydraulic fracturing is performed in ultra-tight rock with extremely low permeability and very small and irregular pore structure, especially kerogen pore structure. Using existing techniques to determine a volume of stimulated rock or a volume of producible rock introduces the falsity that hydrocarbons can be drained from multiple inches or feet away from the fracture face without connecting these pores through microfractures to the main fracture in an economically feasible manner. The observed production is more closely related to draining the pore structure that has been directly connected to the wellbore through the main fracture or secondary microfractures from stress concentrations along a fracture face. This in turn means that extremely large volumes of predicted SRV are theoretically incorrect, and leave much of the source rock production potential behind, especially when fracture stage spacing is determined from the SRV cloud thickness.

Because of these concepts, efforts in validation and obtaining and using multiple other microseismic parameters for fracture network characterization must be made. Many of the current procedures can be confined or improved using the individual microcrack source parameters. Laboratory testing is necessary to understand fracture evolution and microseismic response, while providing an immediate validation of fracture location and damage. In this study, a single laboratory scale hydraulic fracture experiment is discussed while monitoring acoustic emissions (AE), which are synonymous with microseismic. Multiple methods for understanding the fracture network are used

including AE fracture cloud characteristics, AE confined cloud characteristics using source parameters, and individual AE microcrack analysis which helps provide additional information into reservoir alterations. A single vertical wellbore is placed in an ultra-high strength and low permeability granite block. The block is subjected to true triaxial stress state and hydraulic fracturing is performed through an openhole injection interval using gear oil at a flow rate of 0.1 mL/min. The acoustic emissions observed throughout the hydraulic fracturing process, seen in Figure 1, showed a very dense cloud of activity propagating in the direction longitudinal to the wellbore and towards the maximum principle stress and contained a general cloud width of approximately 50-75 mm. The individual event colors represent correlation coefficient, or location accuracy, with red showing highest correlation, blue showing lowest correlation and a gradient between. The sizes of the circles are directly proportional to the amplitude of each AE event. Determining the stimulated volume from a dense cloud such as this appeared intuitive, but post-test analysis showed that the main hydraulic fractures were no more than 0.15 mm in width. This meant that many of the observed AE events were very far from the wellbore connected network. Additional analysis was performed including moment tensor inversion for microcrack source mechanisms. From the moment tensor results, mode of failure was determined as well as orientation and direction of crack displacement vectors and crack face normal vectors and individual relative volumetric deformation of microcrack events. Initial cloud density plots were generated showing where the highest fracture damage was created inside of the fracture network, as shown in Figure 2. Combining the individual microcrack analysis and the AE cloud density analysis proved to confine the cloud results to a specific area of high damage and possibly highest likelihood of wellbore connected reservoir. Initial results from laboratory experiments showed that incorporating individual microcrack source parameters into the cloud and fracture network characterization proved to confine the results.

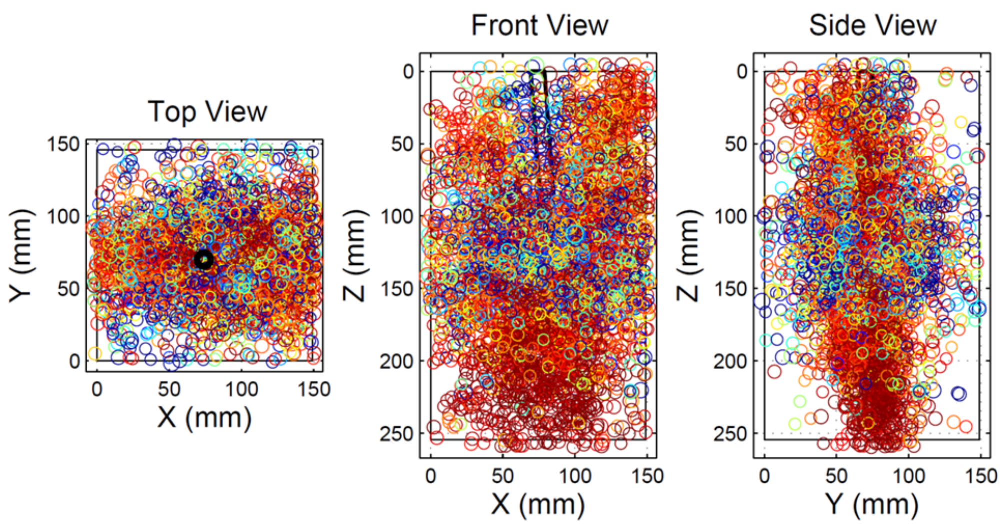

Figure 1 – Raw AE event source location data showing extremely large, dense cloud of AE events.

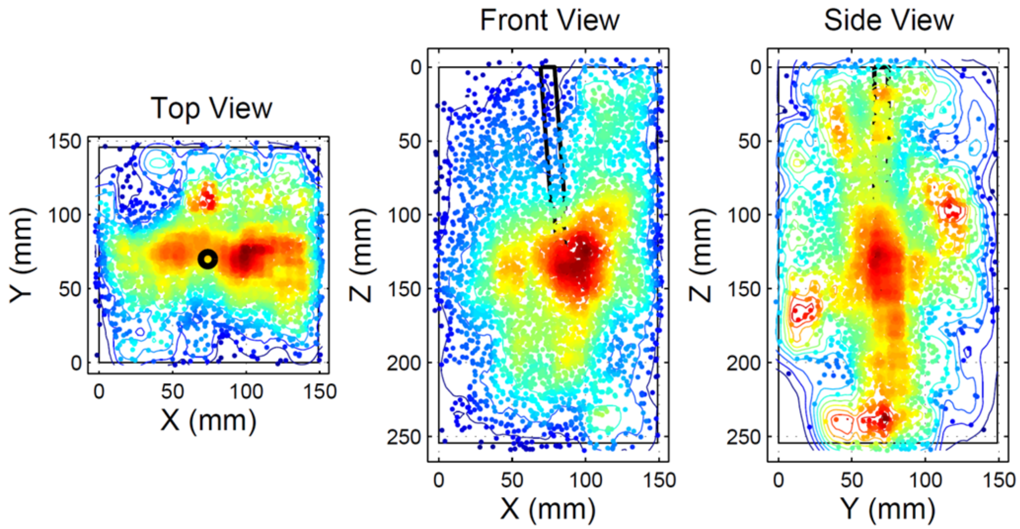

Figure 2 – AE cloud density using only three dimensional AE event locations shows possibility of multiple highly damaged regions.