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Estimating Primary and Secondary Production by Considering the Collective Behaviour of Microseismicty

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Summary

Conceptually, conventional static microseismic interpretations, such as event location and relative position/timing to the perforations and injection data are used to identify processes related to the dynamic expansion of a fracture network during hydraulic fracture stimulations. We know that disturbances in the rock trigger inelastic deformation as stress and fluid transfer through the rock mass, thereby suggesting that this deformation can be considered as flow. These characteristics of flow are mirrored in the seismicity and large fluctuations in stress in the reservoir comprise turbulence in this flow and lead to finite and macroscopic deformation. Through the application of statistical mechanical approaches to the collective spatial-temporal growth of events and their properties within different formations, it is possible to extract additional information on the rock mass response to injection such as the direction and rate of seismic activity and associated stress transfer, the susceptibility of a rock mass to fracturing, where seismic flow is hindered by fracture complexity, the ease with which the reservoir deforms, and the proportion of available strain energy which is radiated as seismic waves. In this study we consider how we can characterize volumes of interest, ie.,how we define pay, out-of-pay growth, define the volume of deformability related to the producing fracture network, Our intent is to arrive at better decisions on volumes that directly can be attributed to both primary and secondary production volumes.

Here, we present a case study of a hydraulic fracture treatment in the Permian Basin. Cluster-based microseismic parameters ("dynamic parameters") are compared to petrophysical log data acquired during drilling of the treatment well. The advantage of this cluster-based approach is that there is an inherent accounting of temporal and spatial variations in the microseismicity as well as looking at aggregate deformation and stress release parameters. As we illustrate in figure 1, the response of the rock can be decomposed into the competing forces of anelastic deformation (Plasticity Index), stress-induced fracturing (Stress Index), and diffusion of seismicity into the reservoir (Diffusion Index). Through this lens, we observe two distinct behaviours (figure 2), one close to the treatment well and one further from the well, that offers a path into better understanding of fluid-induced seismicity. We consider that the observed distributions may represent primary production and areas of secondary or less well-connected production (figure 3). Inherently, the collective behaviour of microseismicity provides a methodology to differentiate deformation behavior leading to time-based production or drainage. Based on these observations we suggest that these approaches can provide constraint of Rate-Transient Analysis models for the prediction of decline curves and accurate estimation of the effectively stimulated fracture lengths relative to fracture lengths based on locations alone (figure 4).

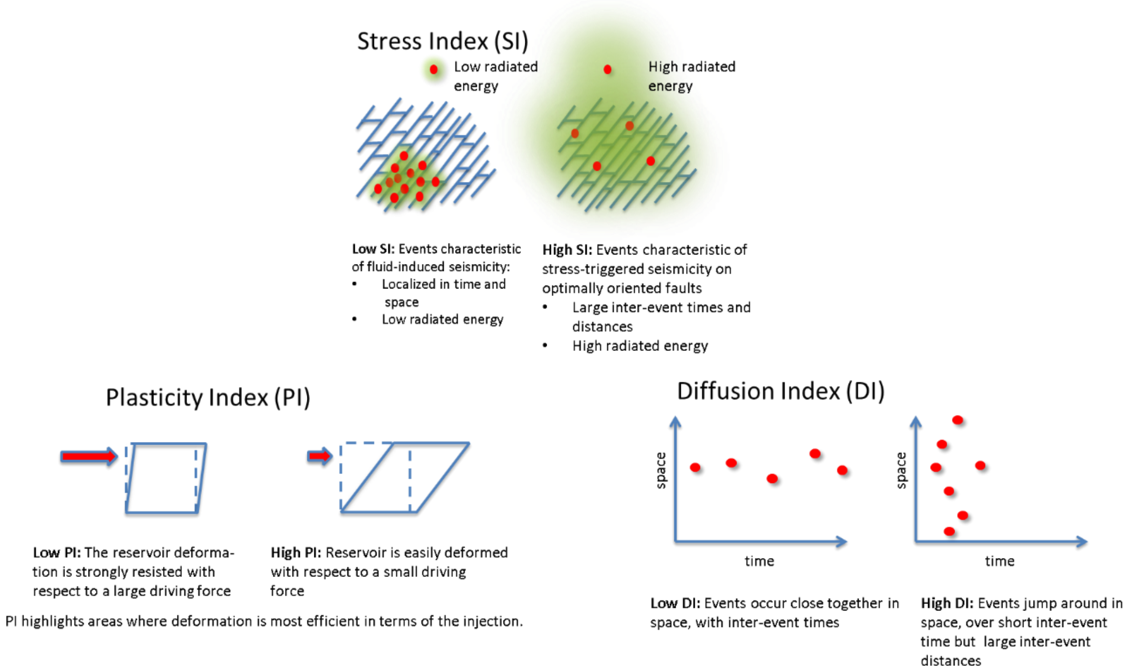

Figure 1. The concept of collective behaviour is reflected in the dynamic parameters depicted above. The images reflect end points in behaviour.

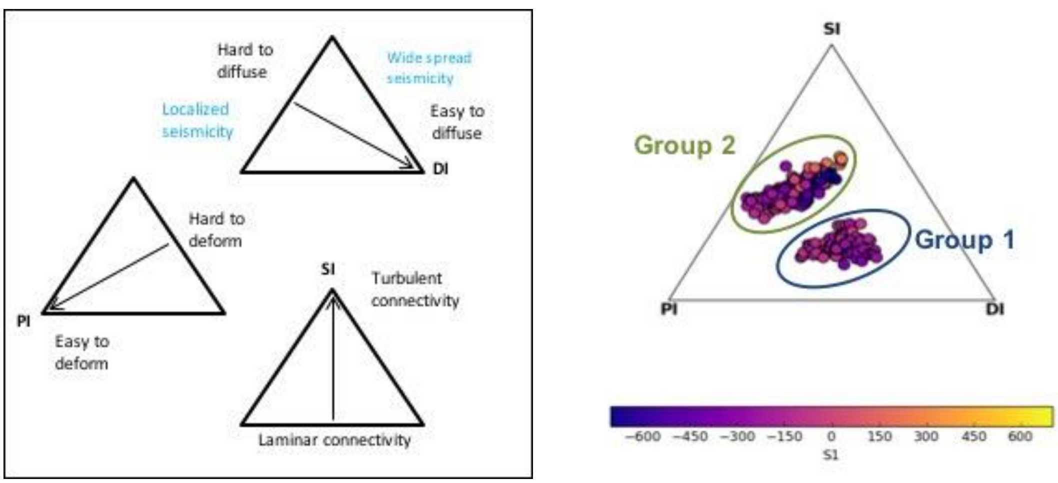

Figure 2. Ternary representation of dynamic parameters. For the data set considered, event clusters fall into two distinct groups as influenced by the collective changes primarily in Diffusion Index and Stress Index.

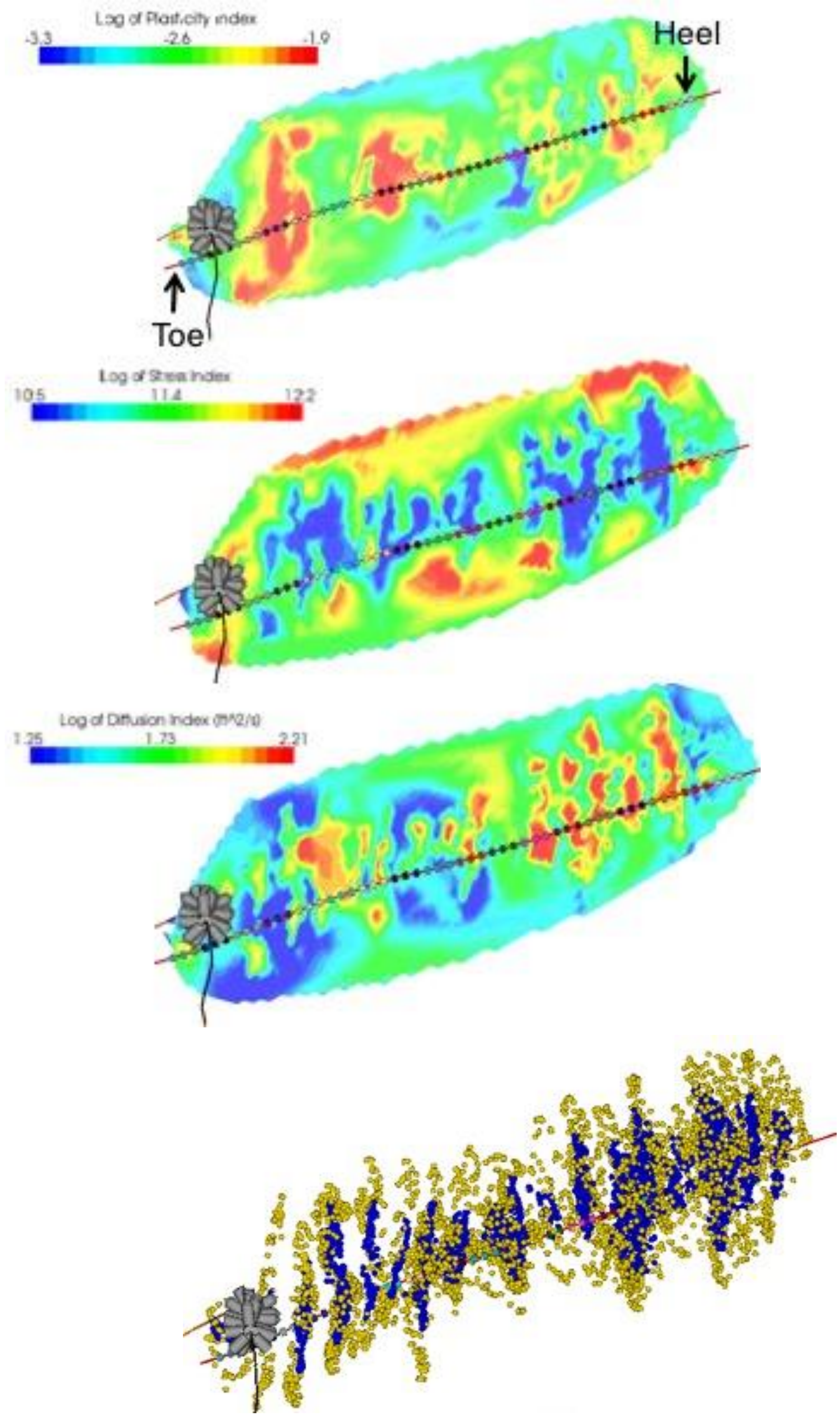

Figure 3. Spatial representation of the individual dynamic parameters for the treatment well (top three contour plots) and as identified through observed ternary interactions of the dynamic parameters (bottom plot). The ternary based groupings show a well-defined volume close to the treatment well (blue) enveloped by a secondary volume (yellow).

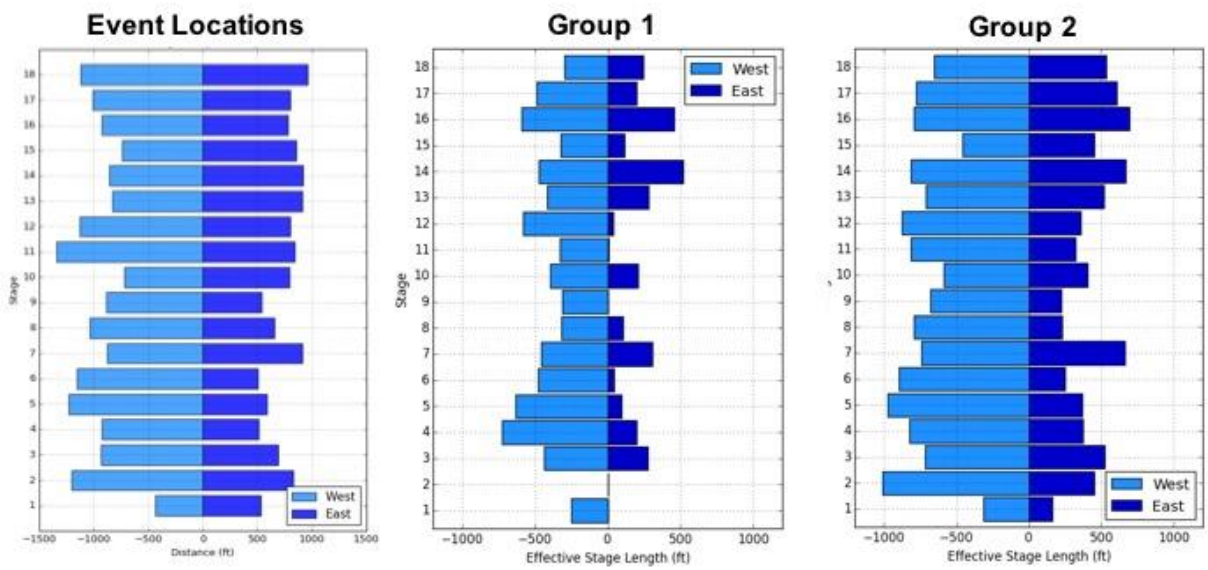

Figure 4. Comparisons of the interpretive fracture lengths based on the locations of all events (left), group 1 events close to the well bore (middle), and group 2 events diffused around the wellbore. For all stages dimensions based on events alone overestimate the potential volume of production. Group 1 represents the dimensions associated with primary production whereas Group 2 outlines The potential for secondary production.