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Assessing the Impact of Microseismic Location Uncertainties On Interpreted Fracture Geometries

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Abstract

Interpretation of fracture geometry is an important aspect of microseismic monitoring, especially for hydraulic fracture stimulations. The fracture geometry is often inferred directly from the microseismic locations, particularly by using the few events comprising the edges of the cloud of microseismic locations. These few events are frequently used to measure the fracture dimensions of height and length, as well as the width to interpret fracture complexity. In this paper, a synthetic dataset assuming different location uncertainties is constructed, to illustrate how location errors relate to uncertainties in the fracture dimensions. If the edges or extremities of the microseismic clouds are used to interpret the fracture extents, the synthetic data demonstrate that these locations are potentially statistical outliers of the microseismic uncertainties. Therefore, the extremities are shown to be biased towards measuring larger fracture dimensions, and potentially misinterpretation of fracture complexity associated with mislocated events. A technique termed compression is introduced which considers the probability density function to interpret the statistical spatial scatter of the microseisms, to enable an interpretation of the fracture dimensions ‘compressed’ away from the extremities of the cloud. The synthetic data is used to validate the technique, demonstrating that the resulting fracture geometries are more accurate and are less biased by the location uncertainty. The compression technique was applied to a hydraulic fracture image, for a dataset which was processed using automatic data processing and then reprocessed with a more accurate algorithm. For both the automatically processed and the refined locations, the compression technique results are similar, confirming the technique is relatively insensitive to the location errors. The refined image was sufficiently accurate to identify two discrete structures in the image.

Introduction

Microseismic imaging of hydraulic fractures is a common technique to map the geometry of fractures created by hydraulic stimulations^{1,2,3}. The hydraulic fracture process results in microseismic emissions, for which the hypocentral locations are computed resulting in a time-lapse image of the fracture growth. The event locations can be used to evaluate the azimuth, height and length of the fracture⁴. Simple, single fracture planes are typically too narrow for the width of the fracture to be assessed from the microseismicity. However, if a relatively wide fracture network is created, the wide seismically active zone can be used to infer the fracture network complexity in cases where the fracture spacing is comparable to the microseismic hypocentral accuracy. For example, microseismic monitoring of hydraulic stimulations in the Barnett shale often results in an image of a relatively complex fracture network. This complexity has been attributed to interaction of the stimulation with pre-existing fractures and also to a small degree of anisotropy between the horizontal stresses^{5,6,7,8}.

Microseismic hypocenters are generally computed by matching arrival times of the seismic waves, with predicted travel times from the hypocenter to the monitoring sensor array. Often, microseismic monitoring utilizes a single observation well, in which case seismic ray polarization analysis is used to help constrain the source locations¹. Uncertainties in the arrival times and polarization analysis lead to a location uncertainty ellipsoid, defining how predicted uncertainties vary with direction. Hypocenter determination requires the construction of a seismic velocity model to enable seismic forward-modeling techniques, usually involving ray tracing, to predict travel times from a specific source position. Uncertainties in the velocity model will result in systematic hypocenter uncertainties or mislocations, while the arrival time and polarization uncertainties are normally assumed to be random effects that result in random location uncertainties. Quantification of the systematic location effects of the velocity model uncertainties can be used directly to infer a potential systematic mislocation from the true position of the seismic sources⁹. This paper focuses on the fracture uncertainties resulting from random microseismic uncertainties.