Recent developments in microseismic monitoring

Introduction to the focus issue on Microseismic

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Increasingly widespread use of passive methods to monitor hydraulic fracture treatment programs is driving technological advances that are changing how microseismic data are acquired, processed and interpreted. This focus issue of the Recorder contains a series of 4 articles that deal with a variety of research topics varying from acquisition design of near-surface geophone arrays; the use of sophisticated processing strategies to achieve more reliable and accurate relative event locations; the value of analogues from geological observations in microseismic interpretation; to analysis of low-frequency tremor-like microseismic signals, possibly analogous to tectonic tremor on some earthquake systems, that may be indicative of aseismic deformation within a reservoir.

Given the inevitable tradeoffs between data quality, cost and logistical constraints, there are a number of open questions concerning optimal configuration of sensor arrays for microseismic monitoring. These issues are addressed in a case history by Snelling and Taylor, who document array-design considerations for several near-surface microseismic arrays installed in the Horn River basin. In 2011, a permanent array with 151 sensors was installed to a depth of 30m around an active treatment location. Factors considered in the design of the array included near-surface geology, access, and maintaining an array aperature and station density around the target zone to enable analysis such as stimulated reservoir volume (SRV). Lessons learned from the first installation, including decimation tests to evaluate array performance, were incorporated into the design of a second near-surface array. Although site-specific factors influence the final designs, the comprehensive approach used in this study provides valuable general insights.

Accurate and robust microseismic event locations are critical for interpretation of SRV, and more generally for linking microseismic observations to geomechanical processes that occur during hydraulic fracturing. Castellanos and van der Baan describe a microseismic processing workflow that includes cross-correlation analysis to measure waveform similarity between events, multiplet classification, traveltime refinement and double-difference relocation. The double-difference relocation method has been used extensively in earthquake seismology, and can significantly improve relative locations for an event cluster. The workflow provides a series of effective quality-control measures for time-picks and locations, It is applied to a vast number of triggered waveforms recorded using 28 3-component geophones in a mining environment and the resulting improved hypocentre locations facilitate geological interpretation of the results.

Natural fracture systems exposed in the Rocky Mountain Foothills provide a valuable field analog for fractured reservoirs in the subsurface. Using outcrop observations from a number of locations near Calgary, a multidisciplinary study by Pedersen and Eaton describes the influence of sedimentary facies on spacing and height of fractures. Their work shows that homogeneity of sedimentary facies leads to relatively large fracture heights, irrespective of sand/shale ratio. On the other hand, finely laminated zones within the same rock unit tend to contain fractures that are systematically smaller than massive facies. Appealing to magnitude-scaling relations derived from earthquake seismology, coupled with threshold magnitude considerations from microseismic surveys, Pedersen and Eaton propose that frac-induced deformation in reservoir regions where microseismicity appears to be sparse or absent ("stealth zones") could reflect variability in rock fabric. In this model, reservoir zones where fracture sizes tend to be small could produce microseisms that are below the detection threshold.

By analogy with non-volcanic tremor observed for some earthquake fault systems, unusual long-period long-duration events have been observed in the Barnett shale and interpreted as activation of "slow slip" deformation on pre-existing fracture systems (Das and Zoback, 2011). This increasing recognition of the potential significance of low-frequency (< 50 Hz) microseismic signals provided the motivation for a field experiment to monitor a multistage hydraulic fracture treatment in the Montney, reported by Eaton and others. The field deployment included an array of 4.5 Hz geophones installed in a deep borehole, as well as mini-arrays of broadband seismometers installed at the surface. Various low-frequency phenomena are described, including events that appear to be precursors to conventional high-frequency microseisms, and low-frequency tremor-like signals that persist over the duration of each treatment stage.

The range of topics in this special issue exemplifies the breadth of currently ongoing developments and research into best practices for acquisition, processing, and interpretation of microseismic data. As this area of geophysics matures, new questions arise that demand innovative solutions. A multidisciplinary approach that combines geophysics with geological insights and engineering constraints may hold the key to future progress. R

Reference

Das, I. and Zoback, M., 2011, *Long Period Long Duration Seismic Events During Hydraulic Stimulation of a Shale Gas Reservoir.* The Leading Edge, 30, 778-786.