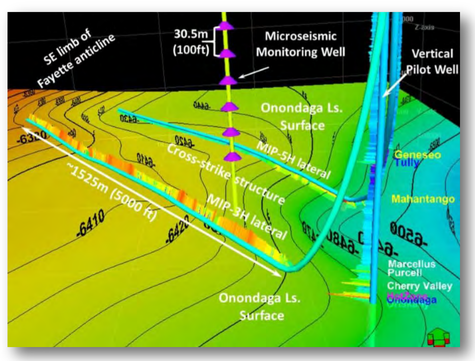
New Methods for Processing Fiber-Optic DAS and DTS Data

Payam Kavousi Ghahfarokhi and **Timothy R. Carr**
West Virginia University, Morgantown, WV, USA

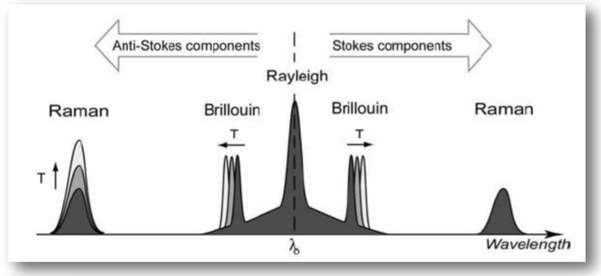
Abstract

Oil and gas companies have started to invest on fiber optic technology to remotely monitor subsurface response to stimulation especially in shale reservoirs. Distributed Acoustic Sensing (DAS) and Distributed Temperature Sensing (DTS) are two fiber technologies that record vibration and temperature around the fiber, respectively. One issue is how to process and interpret the extremely large amounts of data acquired at every stage and cluster. We introduce improved work flows and new attributes to provide increased insights into stimulation efficiency during hydraulic fracture stimulation and subsequent production efficiencies. The DAS and DTS data covers the entire 28 stimulated stages of the shale gas lateral MIP-3H well near Morgantown, WV, which is part of the Marcellus Energy and Environment Laboratory (MSEEL). The DAS data was used to calculate energy and instantaneous frequency attributes for the DAS data along with low frequency energy events with duration of several hundred seconds, which are interpreted as long period long duration (LPLD) events. The proposed approaches to DAS data increases resolution and better illustrates changes in stimulation efficacy across individual clusters in a single stage and cross-stage fluid communication. Analysis of DTS data indicates that in areas of significant preexisting fractures stimulation fluid is transferred cross-stage during hydraulic fracturing between stages. DTS attributes through the production history can help explain stage by stage variations in gas and water production and the relationship to stimulation and geologic variations in the Marcellus Shale.
Research funded through the U.S.DOE National Energy Technology Lab (DOE Award No.: DE-FE0024297).

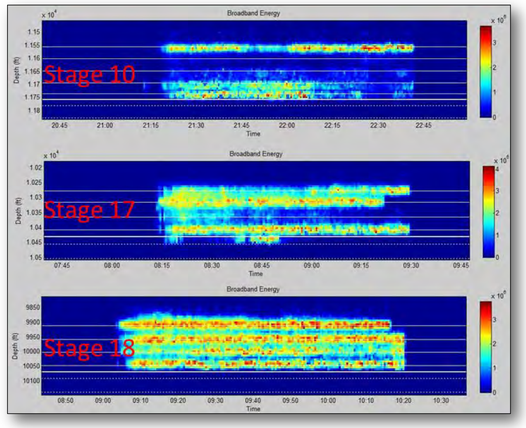
Marcellus Shale Energy and Environment Laboratory (MSEEL) just outside Morgantown, West Virginia, USA. The MSEEL site consists of four horizontal production wells operated by Northeast Natural Energy LLC. (MIP-3H, MIP-4H, MIP-5H, MIP-6H), two pilot holes (MIP-3 and MIP-4), a microseismic observation well (MIP-SW), and a grid of five surface seismometers (triangles).



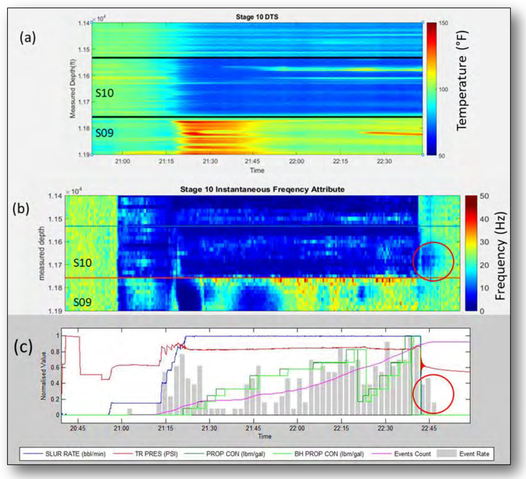
3D view of wells located in the study area. DAS data were collected in the MIP-3H. Contours on the top of the Onondaga Limestone (Base of Marcellus Shale) are in feet subsea. Gamma ray log responses are shown in the vertical pilot well and the two horizontal wells. Geophone locations are shown in the lower part of the microseismic monitoring well



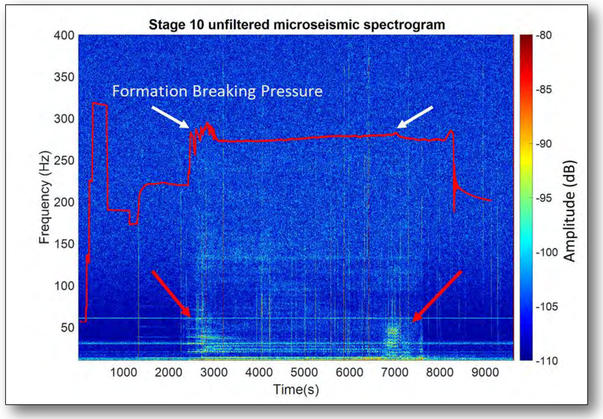
The incident laser is backscattered in different wavelength Raman and Brillouin waves; however, a majority of the incident laser is backscattered with the same wavelength as the incident laser through Rayleigh scattering. An increase in temperature (T) results in movement of the Brillouin waves and an increase in the Anti-Stokes components of Raman waves



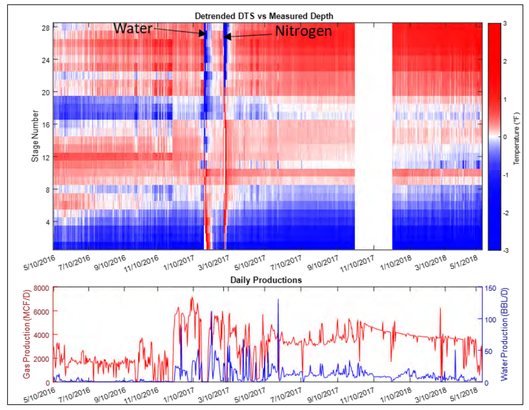
DAS energy attributes of three stages of the MIP-3H show variations in stimulation efficiency across clusters. Note that DAS energy attribute has no unit.



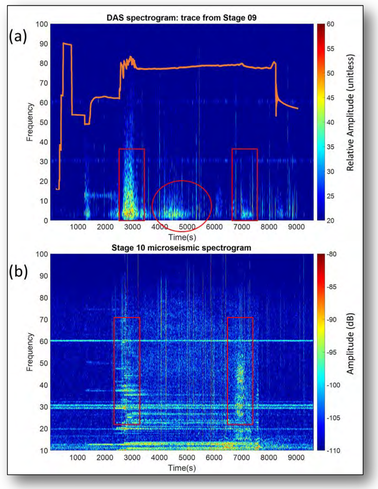
a) The DTS data for stimulation of Stage 10. The warmer color (arrows) shows higher temperature in stage 9. b) Instantaneous frequency attribute showing low frequency time intervals observed in the Stage 9 (S09) during stimulation of Stage 10. Note the leak-off period marked by a circle. c) Normalized pumping data of the Stage 10 stimulation are shown. The bar histogram shows the microseismic events recorded in the borehole geophones of the monitoring well. The circle shows the microseismic activities during the leakoff period.



The raw unfiltered microseismic spectrogram of the Stage 10. The red curve shows the normalized treatment pressure. Low frequency time intervals are during the initial period of high treatment pressure and during another smaller pressure increase. LPLD events release one to two orders of magnitude more energy than observed microseismic events and may contribute much more to reservoir stimulation than that associated with observed microseismicity.



De-trended DTS attribute averaged to the stage scale. The arrows show the time that MIP-3H was washed with water and then with nitrogen foam prior to production logging. DTS attribute data is interpreted to represent relative production. Note Stage 10, which displayed low completion efficiency and affected Stage 9 have relative poor production that continues to the present.



The presence of long-period long-duration (LPLD) events, similar in appearance to tectonic tremors, is documented in the borehole geophone data of one of the MIP-3H stimulated stages. LPLD events are generally overlooked during the conventional processing of microseismic data, but they represent significant non-brittle deformation produced during hydraulic fracture stimulation. a) Stage 10 stimulation causes low frequency time intervals in DAS trace#371, which is in Stage 9. The orange curve shows the treatment pressure b) Spectrogram of sum of the z-components of Stage 10 microseismic.

Conclusions

- Fiber-optic DAS and DTS Data can be processed and displayed using FIBPRO to improve display and analysis of the typically large data.
- DAS energy and attributes can show stimulation efficiency across different cluster in a stage and cross-flow between stages
- DTS attributes can be used to better understand cross-flow between stages and variation in production through time along the horizontal wellbore.
- Slip along preexisting fractures and small faults running at non-optimal orientations to Sh_{max} strongly influence stimulation and subsequent production.
- The presence of long-period long-duration (LPLD) events is documented in the borehole geophone data of one of the MIP-3H stimulated stages. LPLD events are generally overlooked during the conventional processing of microseismic data, but they represent significant non-brittle deformation produced during hydraulic fracture stimulation.
- Application of machine learning algorithms have proven to be significantly useful for multi-scale big data analytics.