Downhole Monitoring with EventPick™ technology provides an independent evaluation of well stimulation results in areas less suitable for surface-based microseismic acquisition. Final results, determined using the proprietary EventPick processing technology can be delivered within a month of the acquisition. The solution provides operators with the fracture geometry and azimuth, discrete fracture network characterization, estimations of stimulated reservoir volume, and recommendations for completions optimization.

The results help operators determine well spacing, improve fluid and proppant selection, alter pressure pumping schedules, avoid geohazards, and delineate reservoir boundaries. The Downhole Monitoring product can be combined with MicroSeismic surface acquisition products like FracStar™ and BuriedArray™ and patented PSET™ processing to provide the leading technology for combined downhole + surface acquisition.
Downhole Acquisition

Acquisition is performed using 15Hz 3C geophones, with 10 to 40 or more levels for large aperture acquisition, spaced 20 - 50 feet apart. Coupling is preferred to ensure stability of the instruments in the observation well. The data is recorded continuously in standard SEGd or SEGy format, starting both before and after the treatment. The data can be processed in the field for real time operations. Typically, two field days are required for deployment.

Optimal acquisition method is determined by the MicroSeismic Array Design Group based on modeling customer needs and field and operational constraints. Acquisition approaches include a single monitoring well, multi-monitoring well, monitoring within a multi-lateral, and surface and downhole combinations.

Downhole Processing & Interpretation

MicroSeismic uses the earthquake seismology derived technique of p-wave and s-wave first arrival picking for processing microseismic events acquired via downhole geophone arrays.

Before monitoring can begin, instrument calibration is performed. To determine true north, geophone rotation is performed using a string shot or perforation shot provided by the operator in a nearby well. To ensure proper location, a deviation survey is needed for the monitoring well, and for the treatment well if the perforation shot or instrument string is located in a deviated section.

Next, velocity calibration is performed relying on the same string shots or perforation shots. The velocity model is derived using existing sonic logs or pre-existing velocity models. Local velocity anisotropy must be accounted for to determine good locational accuracy. Vertical Transverse Isotropy (VTI) corrections are made using Thomsen’s parameters, epsilon and delta, to account for the faster arrival of waves parallel to the bedding plane. In addition, stage by stage velocity calibration is performed.

After acquisition, the raw data is converted from SEGd to SEGy format. The first step in the processing technique applies a de bias filter (where applicable). Next, a band pass filter is used to eliminate high and low frequency noise. The frequency range of the final waveform is between 10Hz to 250Hz.

The proprietary EventPick processing software is used to provide automated triggering on microseismic events. These triggers, however, identify not just fracture deformation events but also false positives like tube waves, electrical spikes, pumping noise and other cultural noise. As a result, a team of experienced processors manually validates each trigger to identify the events of interest. Processors are trained to detect false positives as well account for other complex

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waveform arrivals, such as faster travelling head waves resulting from high velocity contrast layers. Arrivals are picked and located, with positional accuracy typically within 20 to 60 ft. in the x, y and z directions. Positional accuracy is dependent on SNR and velocity calibration.

For every microseismic event the x, y and z location and origin time is defined. Additional attributes generated include amplitudes for picked events, back azimuth of the event in relation to the monitoring well, and event magnitude. Event magnitude is defined using the moment magnitude scale (Hanks & Kanamory, 1979). Magnitude is calibrated using a large reference event. Lower magnitudes are estimated using the relationship between the amplitudes of the reference event and the smaller events. Detection thresholds can go down to -4.0 magnitudes depending on SNR and distance to observed microseismicity.

Inherent to the downhole processing approach is positional uncertainty dependent on the distance to the events. The optimal event detectability range is between 200m and 1000m. Distances closer than this range lose spatial resolution in p- and s-wave arrivals. Distances larger than this range create problems in back azimuth detection to properly locate the event. Back azimuth calculations are made using hodogram analysis. As a result, it is important that the monitoring well be proximal to the fracturing activity.

Where the monitoring well location is sub-optimally located, detectability can be improved through the use of multi-well downhole acquisition. Through the use of 3 downhole arrays, where such additional monitoring wells are available, locations can be more confidently determined. In some cases, MicroSeismic can apply its unique PSET™ 3C imaging technique to identify events. This evolving technique uses reflection seismology approaches to automatically calculate event locations without the need for manual picking. This technology, which incorporates multi-component seismic data, is distinct from the PSET surface processing used by MicroSeismic for the FracStar™ and BuriedArray™ products.

An advantage of the more azimuthally varied acquisition in the multi-well scenario is the ability to calculate focal mechanisms. The focal mechanisms describe the dip, strike and rake of the mechanical failure occurring due to stimulation. This information helps understand the local stress orientation and geology and track how the horizontal maximum stress is changing over the field. In addition, more refined discrete fracture network models can be created.

A further refinement can be made through the combination of surface and downhole acquisition to provide a more comprehensive view of the fracture network. The wide aperture of the surface array minimizes positional error in the x and y directions and provides for more reliable source mechanism detection. The z direction resolution is improved by stage to stage velocity calibration. The downhole array provides for a lower threshold of event magnitude detectability and, when the array is deployed at target depth, the z direction positional error can be better constrained. The positional error in the x and y direction will depend on the proximity of the monitoring instruments to the fracturing activity.
Customer Deliverables

The service will include:

- Real-time detection of events where needed.
- Microseismic hypocenter event position X, Y, Z, DATE, TIME and AMP (amplitude) in ASCII CSV format.
- The original waveforms of the detected events are provided for additional verification by customer. Delivered in SEGY format for the triggered and located event waveforms and ASCII for the picks. The EventPick - Viewer version - software is also provided to load and check the data.
- Focal mechanisms in multi-well acquisition scenarios.
- Geology context including digital elevation map (DEM), surface faulting (if available), stress map and descriptive interpretation.
- Where appropriate mechanism data is available, single run of discrete fracture network (DFN) model and geocellular modeled fracture permeability.
- Estimation of stimulated reservoir volume (SRV); performed for each well if pad based, multi-well project.
- Final report in PowerPoint format.
- One copy of raw field data in native field format (usually SEGd or SEGY) delivered via formal transmittal with confirmation.
- Final Observer logs (Excel).
- Array geometry file (final postplot SPI file).

Pricing & Availability

Cost and availability depend on configurations and timelines that differ across customers. Please contact worldwide.sales@microseismic.com or 1.866.593.0032 for a custom proposal or additional details.

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