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The Development of Reliable Earth Models

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Abstract

This presentation summarizes more than forty years experience in the installation and operation of microseismic monitoring systems for the geomechanical, oil and gas, and mining industries. In the majority of cases these systems are intended to be permanent, Life of Field, LOF installations designed to provide the reservoir operator with a monitoring system which will define the location, magnitude and type of microseismic event with a precision appropriate to his needs. With the rapid growth of hydraulic fracturing in unconventional reservoirs, the location and growth of induced fractures, both in the reservoir, and in adjacent deposits, becomes a parameter of critical importance.

It is clear that the installation of microseismic monitoring arrays, either surface, downhole or hybrid systems, without the prior development of a valid earth model, leads to unreliable data and disappointed end users. For this reason our presentation focuses on some of the initial processes which must be completed before valid information can be derived from the field investigations.

The primary objective of all the preliminary studies is to generate a three-dimensional earth model for the ground which may be affected by the fracking. As a very general rule of thumb this can be taken as the volume of ground encompassed by a series of 45º planes originating at the boundaries of the proposed subsurface development.

The model must be built, and then progressively refined, so that the travel time data from the fracking induced microseismic events can be converted into event locations. With this information in hand the time-dependent growth of the fractures between the initial source and the sensor can be monitored and mitigated in real-time.

The earth model construction incorporates a number of separate phases, the major ones are:

- Production of a representative stratigraph and structural model.
- Derivation of the major rock properties based upon well log data, and their distribution with depth. These parameters included density, porosity, shear and compressional wave velocities, quality factor, shale volume, and the degree and type of anisotropy.
- Understanding the regional stress distribution at shallow depths (i.e. <8,000 ft.) and its influence on the fracking process and anisotropy of the rocks.
- Calculation of uncertainty associated with the target rock properties and the identification of uncertainty propagation paths in the earth model derivation.
- Interpretation of any reflection seismic data which may be available for velocity model validation.

With this basic information in hand it is possible to develop the following parameters which are used for both the design of the microseismic fracture event monitoring sensor arrays, and the refinement of the seismic event detection and location algorithms.

- Distribution of the major rock properties vs. depth can be calculated. These form the earth model, which is used for the microseismic monitoring array design, and seismic source location algorithm.
- An estimate of the extent and type of rock anisotropy type can be obtained. Information about regional stress distribution allows for a better understanding of crack propagation processes and crack-related anisotropy.
- Seismic reflection data shows major reflection interfaces. This allows the calculation of average velocities, which are used as a cross check of the velocity profile from the well log data.
- Uncertainty propagation paths can be identified, starting from the process of depth-averaging well log parameters to earth model variables. Uncertainties are calculated in terms of the coefficients of variation and variances for all rock properties as a function of depth.

In conclusion, the application of a methodical approach to the development of the earth model greatly enhances the reliability of the derived data and its valve to those responsible operating the reservoir.