AS SEEN IN
FEBRUARY 2011
E&P

Advanced microseismics optimize unconventional development

Microseismic analysis is moving beyond the mapping of single fractures, providing a wealth of information about complex reservoirs.

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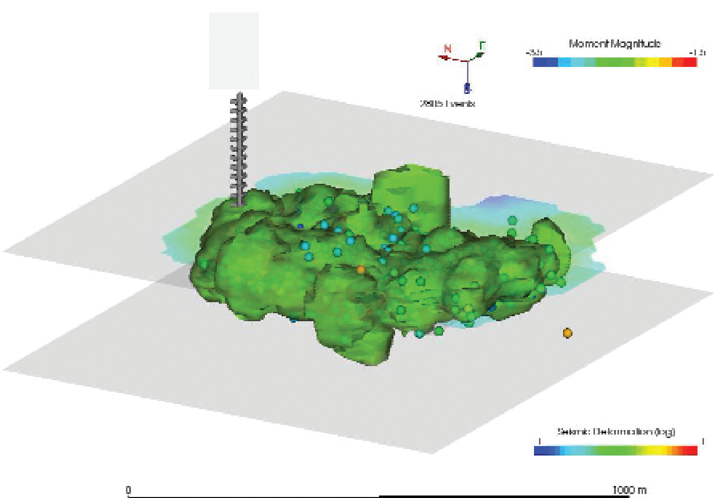
The global emergence of the unconventional gas boom created significant buzz within the energy industry in 2010. Often referred to as a "game-changer," gas-rich shale plays have transformed the dynamics of the energy industry across North America. The unconventional gas phenomenon appears to be going global, with Europe, the Middle East, India, and China clamoring to develop their own shale or tight gas resources.

Unconventional resources are not, however, limited solely to gas. Indeed, in the next 10 to 20 years, as conventional oil production begins to flatten (and even starts to decline), unconventional oil production from heavy oils and oil-bearing shales will become an increasingly important source of supply.

Microseismic (sometimes referred to as passive seismic) monitoring has received great attention in recent years for its ability to provide images of subsurface hydraulic fractures. Event locations associated with each fracture are mapped in real time, providing operators with 3-D images of fractures as they propagate through the formation. Engineers and geophysicists use this information to make real-time adjustments to the operations as well as to better plan future frac stages or well locations. However, microseismics can go far beyond merely identifying locations of individual fractures and can be applied across a wide array of unconventional resource applications.



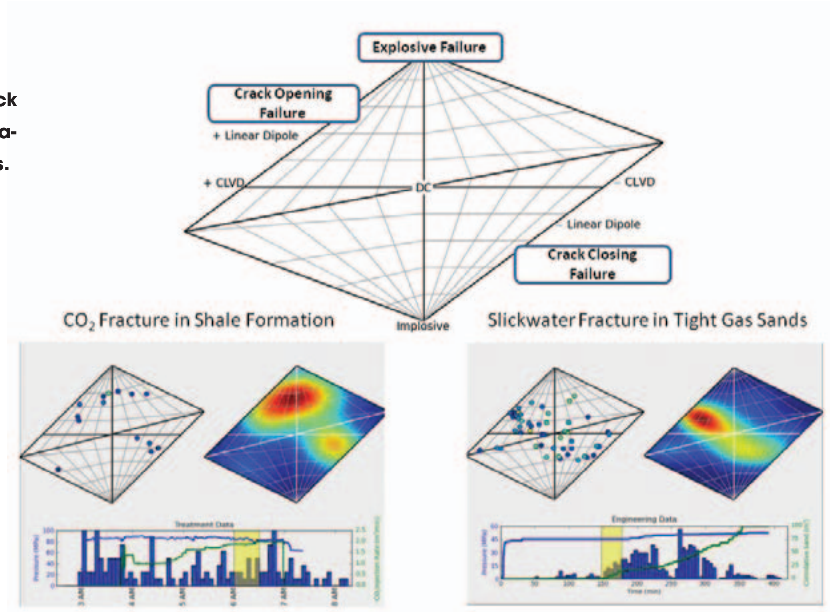
Combined with estimates of stimulated reservoir volume, operators can visualize regions of the reservoir that are effectively stimulated and are contributing to production. (Images courtesy of ESG Solutions)

Optimizing thermal, EOR operations

As one of the world's only designers of "microseismic-specific" instrumentation, ESG Solutions has been successful at transforming a short-term fracture mapping technique into a powerful, cost-effective reservoir monitoring technology. Heavy oil or partially depleted conventional reservoirs often require some form of stimulation to mobilize the oil. When steam is injected, it creates fractures and stress changes within the reservoir, which are manifested by a release of seismic energy. Multilevel sensor arrays of geophones or accelerometers can be deployed in a custom configuration both on the surface and in observation wells. These sensors are deployed strategically to detect and locate the seismic activity associated with the reservoir's response to the injection. Detected seismicity is digitized by microseismic data acquisition units attached to the sensors, and the microseismic data are relayed back to a central onsite location, where they can be processed in real time.

Microseismic reservoir monitoring systems are used to optimize thermal recovery or enhanced oil recovery (EOR) operations. The events associated with the steaming injections are mapped in time and space to allow reservoir engineers to visualize where the steam migrates and how it is moving through the reservoir. Steam chamber growth can be mapped, and adjustments can be made to steaming programs to target any identified regions of bypassed oil. Operators can use the data combined with estimates of stimulated reservoir volume to visualize regions of the reservoir that are effectively stimulated and are contributing to production.

Microseismic reservoir monitoring also can be used for reservoir characterization and environmental monitor-



k-T plots are used to identify the manner in which the rock is fracturing as well as the influence that different stimulation programs could have on unconventional formations.

ing. Pre-existing fault and fracture networks might influence EOR or thermal injections, causing potential leakage or serving as fluid-flow pathways. Microseismic monitoring can be used to identify the reactivation of networks or structures that could cause the injection to migrate away from its target zone.

Similarly, microseismic systems installed in the reservoir can be used to monitor caprock or seal integrity, providing engineers with advanced warning of a breakout if the injection is observed to migrate vertically toward the surface.

Many producers have adopted microseismic monitoring to reduce the risk of blowouts caused by casing failures. Higher pressure steam injections often cause the reservoir to undergo periods of dilation and compaction, subjecting well casings to considerable tensile stresses. The frequency characteristics of a well casing shear can be characterized, enabling operators to react immediately to potentially hazardous events.

The future of microseismics

Now that the energy industry generally has accepted the benefits of microseismic analysis (particularly in the shale gas application), it is important to further develop the value that advanced microseismic analysis can offer. The next logical steps are to move beyond the idea of simply plotting individual event locations and instead focus on groups of microseismic events and look at how they can describe the behavior of a complex unconventional reservoir. Advanced geophysical analysis such as seismic moment tensor inversion (SMTI) can characterize microseismic events by their specific failure type, allowing engineers and geophysicists to learn exactly how the reservoir rock is breaking. By understanding which fractures within the reservoir are shearing (non-opening) versus those that are isotropic (fractures that open up the rockmass and create volume-related changes), producers can better understand which areas of the stimulation are enhancing permeability and will contribute positively to increased resource production. SMTI analysis gives operators the ability to create 3-D maps of "open" fracture networks and determine reservoir permeability.

Advanced microseismic analysis should not, however, be used in isolation. The key to unlocking true value through microseismics is to integrate the technology with other available information such as engineering and geological data. For example, SMTI analysis can be integrated with pumping, pressure rates, and other treatment information to understand how different stimulations are affecting the reservoir.

By examining k-T plots, information about fracture growth and fracture failure mechanisms related to the pumping program can be obtained, and the influence that different fluid packages have on different formations can be observed. For example, the results of a slickwater fracture conducted in a tight gas play in Western Canada can be illustrated by a k-T plot. In this example, as the sand is introduced into the fracture, the events dominantly represent opening failures, suggesting that the proppant is being successfully introduced into the fracture. Another k-T plot depicts an energized CO_2 fracture conducted in a shale play in Western Canada. As the CO_2 injection rate reaches 2 cu m per minute, the k-T plot displays a dominance of explosive failures, indicating that a substantial volumetric change has occurred and complex fracturing likely is taking place. These are examples of how different unconventional formations might react to different treatments. The microseismic analysis can be used to validate the engineering process and calibrate geomechanical models that can be used to forecast reservoir response to subsequent stimulation programs.

Microseismic science continues to evolve as the industry moves into a new era of examining the technology as more than simple event locations on a map. The use of microseismics in different applications and different contexts will be instrumental in helping to gain insight into how to optimize production from complex but important unconventional resources. E&P