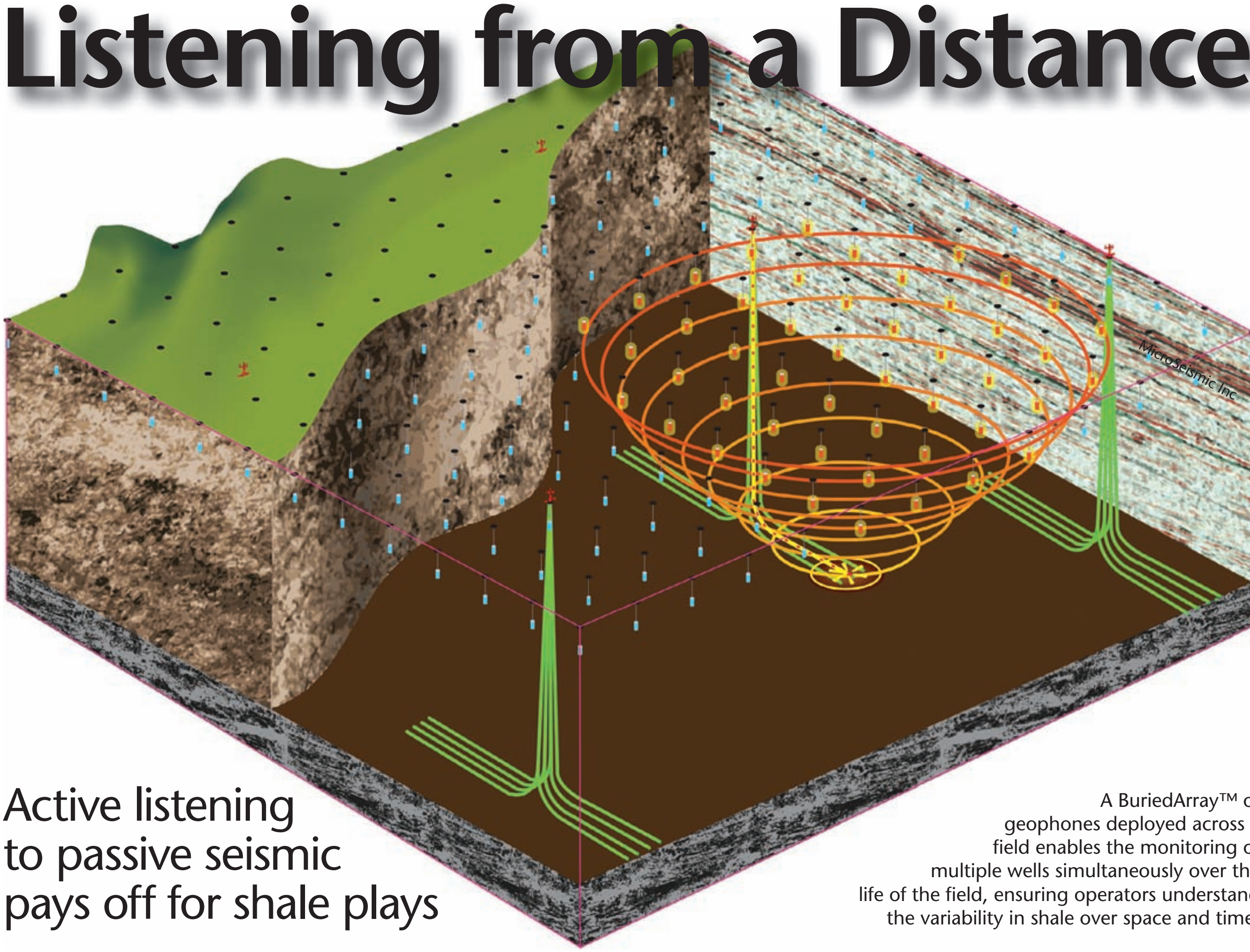
Listening from a Distance



Active listening to passive seismic pays off for shale plays

A BuriedArray™ of geophones deployed across a field enables the monitoring of multiple wells simultaneously over the life of the field, ensuring operators understand the variability in shale over space and time.

TED MOON

The past decade has seen a major transformation in gas production in the United States, driven mainly by the development of shale gas plays. According to the US Energy Information Administration (EIA), the proliferation of activity into new shale plays has increased shale gas production from 0.39 Tcf in 2000 to 4.87 Tcf in 2010, or 23% of US dry gas production. By 2035, EIA expects shale gas to represent 46% of US natural gas production.

This expansive growth in shale gas development, seen from the Barnett to the Marcellus, would not have been possible without the combined technology revolutions of advanced horizontal drilling techniques and hydraulic fracturing. These techniques have opened access to previously inaccessible, low-permeability shale gas reservoirs, allowing companies to profitably produce natural gas from these reservoirs for the first time.

However, this incredible opportunity has brought with it closer public scrutiny and increased environmental concerns, particularly the fear that hydraulic fracturing techniques, and the fracturing fluids used, may have long-term detrimental effects on the water table and nearby communities. Therefore, meeting the dual drivers of commercial and environmental sustainability has prompted the development of innovative techniques for monitoring and mapping fractures in the shale.

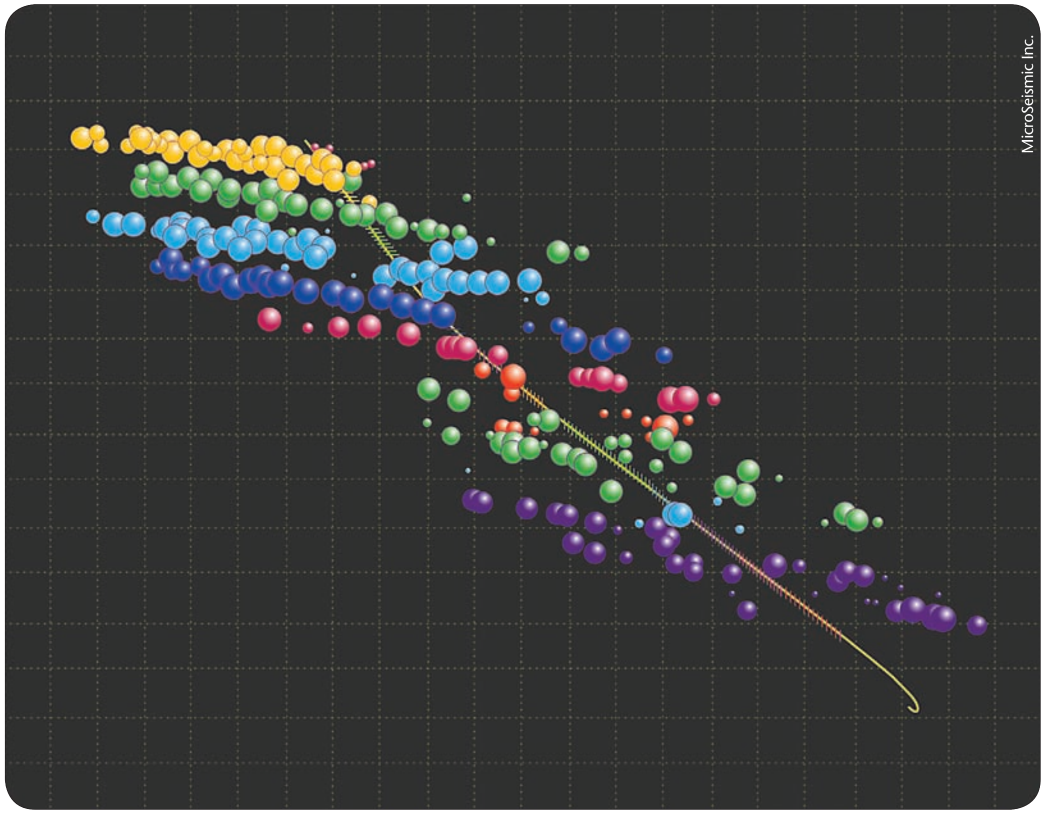
This is where MicroSeismic Inc. (MicroSeismic) has made a significant impact in a relatively short time. The company has pioneered a unique process in which the low-energy passive seismic, or microseismic, events that take place during drilling, stimulation and production are recorded and then analyzed for their impact on the reservoir. Armed with this information, reservoir engineers can optimize well placement and completions for maximum hydrocarbon recovery at reduced cost.

Unique System

While microseismic monitoring methods are becoming more common, MicroSeismic's technique is unique in the way in which it is deployed, according to MicroSeismic President and CEO Peter Duncan. "Unlike conventional microseismic recording techniques that monitor from a single point downhole, our technique deploys an array of passive seismic monitoring instruments – geophones – laid out in a grid at or just below the surface. This data acquisition method not only delivers higher quality data, it avoids many of the monitoring difficulties common to downhole methods."

Drilling a dedicated monitoring well is expensive, costing some US$2–4 million per well. In addition, there are temperature limitations on the tools that can be deployed downhole, and the recording instruments can only map a relatively small area around the well. "Because of this, reservoir engineers do not gain the full picture of where fractures are occurring during stimulation, which hampers their ability to optimize completion and production strategies for the reservoir," Duncan says.

MicroSeismic's array of geophones placed on or near the surface dispenses with the need for most borehole monitoring and covers a much wider area. In addition, the seismic recording devices use subsurface noise from the production operation as the energy source, eliminating the need for separate sources such as dynamite or vibrators.

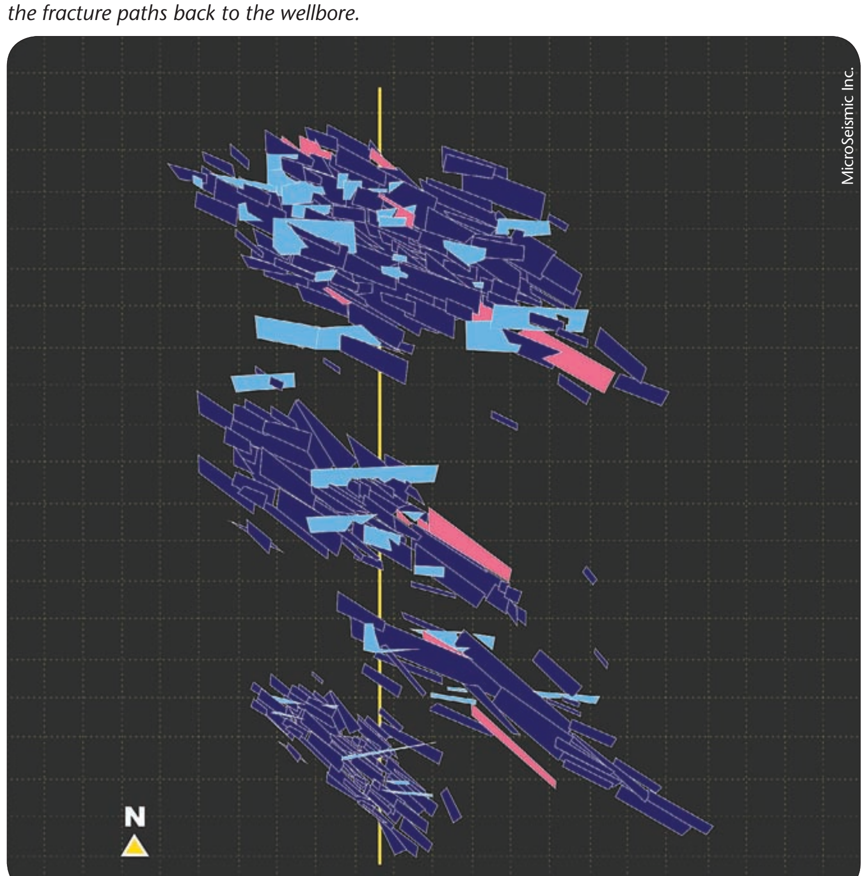


Frac monitoring results using MicroSeismic's PSET® imaging technology indicate good wellbore azimuth and frac spacing. The spheres represent seismic events sized by amplitude and are colored by stage. Operators use this information to optimize well and frac spacing.

Duncan admits that when MicroSeismic began in 2003, the concept of microseismic monitoring from a near-surface geophone array was met with a healthy dose of scepticism in the industry. "The conventional thinking was that the microseismic signals were too weak and our geophones were too far away from the source to be effective. However, we have proven that we don't need to be as close to the event as conventional monitoring, because we are using the collective listening power of an array of hundreds or thousands of geophones to create something akin to a parabolic dish microphone that can simultaneously detect multiple microseismic events over an entire field," he says.

The individual geophones are linked by MicroSeismic's Passive Seismic Emission Tomography (PSET) mapping and analysis program, which serves as a focusing algorithm that allows the engineer to use the dense array of geophones to 'beam steer', or sum the output of the entire array. In this way, microseismic events can be detected and located with a high degree of accuracy. PSET also overcomes the issue of signal attenuation by the overburden, which hinders the effectiveness

Frac monitoring results are used to generate a Discrete Fracture Network (DFN) Model indicating the fracture paths back to the wellbore.

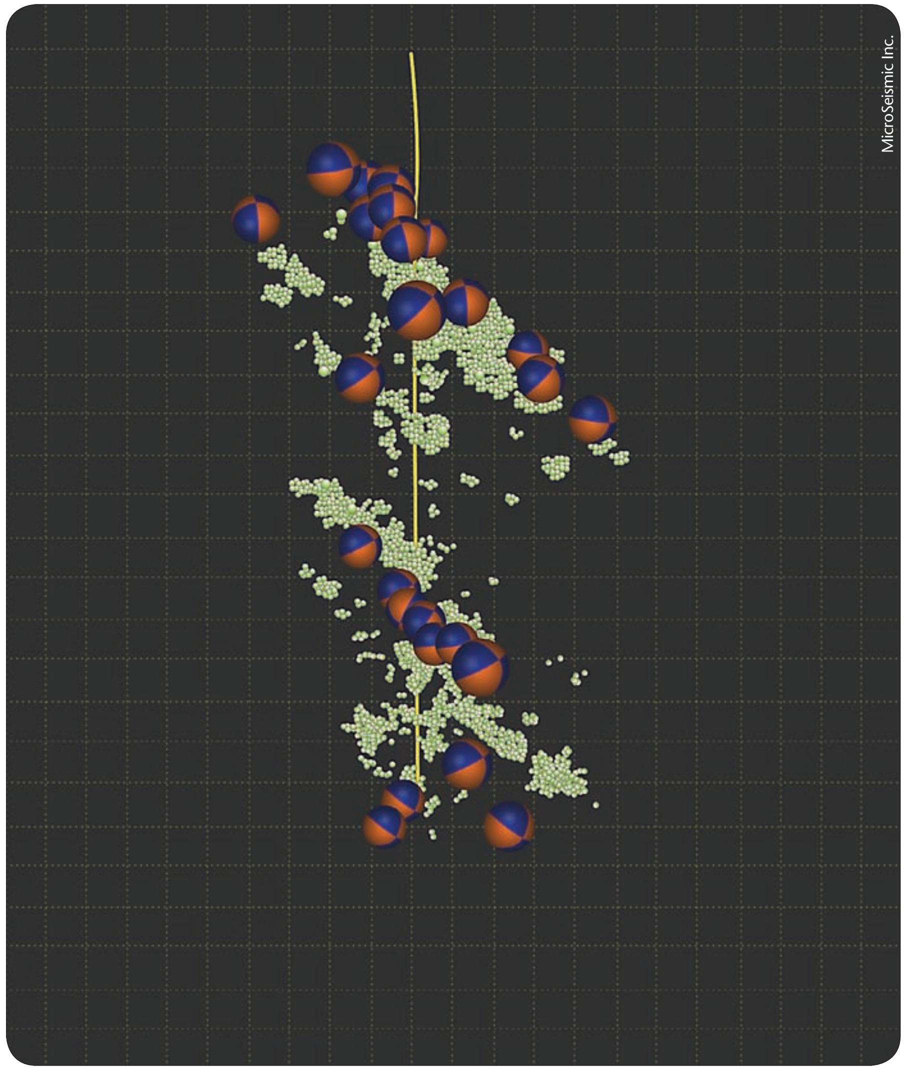


of conventional seismological earthquake location techniques.

Duncan likens his company's monitoring solution to a common medical procedure. "We are like doctors placing a stethoscope on a patient's chest. In our case, the patient is the reservoir. By listening for the almost imperceptible microseismic events and then diagnosing what these events might mean for the reservoir, engineers can take immediate steps to maintain the health of their production process."

The non-invasive monitoring technique helps ensure the long-term vitality of a shale gas reservoir by allowing operators to properly space their wells such that hydrocarbons are not bypassed and money is not wasted drilling unnecessary wells. In addition, mapping of a stimulation treatment helps ensure that the fracture path does not penetrate into environmentally sensitive subsurface areas such as water conduits.

The geophone array can also be used as an early-warning system for wellbore or casing stability problems. "Not only can we identify if there is an integrity problem downhole, but we can very accurately pinpoint the location and source, allowing for earlier and more effective intervention," Duncan says.



PSET® processing and imaging technology identifies source mechanisms that help geologists understand how the rock is breaking during fraccing. Operators use this information to optimize their completions and field development strategies.

Real-time Monitoring

Over the past 7 years, MicroSeismic's monitoring technique has been steadily adopted by shale gas operators across North America, who are experiencing more efficient and increased production, while drilling fewer wells and with less impact on the environment. The company has advanced its monitoring expertise to the point that it is now monitoring multiple wells and simultaneous fracturing operations in real-time, from one installation over an area encompassing 1,300 km^2.

"Our technology gives operators a holistic view of their fields, allowing them to track interactions between wells and well-to-well variability over time," Duncan says. "This ability to monitor all wells over time is a powerful tool that lets operators adjust their completions and field-development strategies for enhanced long-term productivity."

MicroSeismic offers both temporary and life-of-field monitoring options. The company's FracStar design uses a removable surface-located array of geophones arranged in a hub-and-spoke pattern to monitor long laterals and pad drilling over a large area. The array's large 2D aperture and PSET-based microseismic monitoring images how the stimulation-induced fractures interact with a reservoir's natural fracture networks.

For longer term monitoring, MicroSeismic's BuriedArray system deploys an array of geophones permanently installed and buried at a depth of 100 m for those operators who need to monitor multiple wells over a long period of time for strategic planning and development purposes. This service drives down the cost of monitoring with each well drilled, making it a cost effective, long-term monitoring option. To date, MicroSeismic has installed 25 buried arrays and monitored over 3,000 frac stages for clients covering a total area of nearly 700 square miles. Another 3-4 projects are slated for installation before the end of the year.

"Whichever option is chosen, the bottom line is that companies can gather more real-time data for less cost and with a much smaller environmental footprint," Duncan says. "This adds up to better informed decisions about future stimulation to optimize field production and recovery."

Increasingly, operators that originally installed a monitoring array to detect microseismic only during a fracturing job have begun to see the array as a long-term, cost-effective way to monitor the movement of fluids out of their reservoir during production, or into their reservoir during enhanced oil recovery operations.

According to Duncan, this shift to using microseismic detection as a long-term production-monitoring tool is largely due to the growing influence of the Digital Oil Field concept. "One popular idea within the Digital Oil Field is to turn a field's production into a process that can be monitored and tuned in real time as conditions change," he says. "This can only be accomplished with information about the reservoir's status between the wells, in addition to the information at the wells. Our technique provides both."

Further Applications Abound

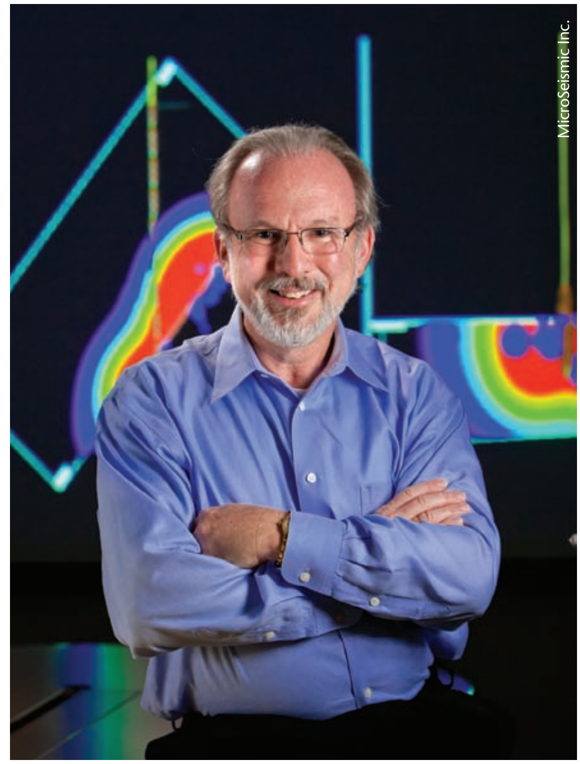
Going forward, Duncan sees MicroSeismic's technique as an effective tool for monitoring everything from steam injection in oilsands projects in his native Canada to carbon sequestration and enhanced geothermal systems. For now, he is excited to be developing a technology that promises to hasten the emergence of efficient and environmentally sustainable production of unconventional gas around the world.

To that end, the company has used a recent capital investment of more than US$100 million to further develop its technology and expand its service internationally, including into Poland, where it has set up an office. An April 2011 report by the US EIA estimates Poland's potential shale gas reserves to be 792 Tcf of risked shale gas-in-place, from the Baltic Basin (514 Tcf), Lublin Basin (222 Tcf) and the Podlasie Basin (56 Tcf). If recovered, this sizable resource would keep the country supplied with natural gas for the next 200 years, delivering an enormous boost to the nation's economy and helping to reduce its dependence on imported gas from Russia.

The promise of such an economic windfall for Poland puts pressure on the geoscience and engineering communities to first verify that the shale gas resources exist in these quantities and are technically recoverable. This will be accomplished over the next 18 months with a series of 30–40 drill tests by various companies to more accurately determine the existence and commercial viability of Poland's shale gas.

If these tests confirm the potential, then operators will have to ensure that their exploration and production activities pose no risk to the safety or environment of local communities, and regulatory authorities will need to be satisfied that fears expressed over contamination to water supplies are unfounded.

These issues are mainly technical in nature, and Duncan is confident that MicroSeismic's technology is uniquely qualified to provide the answers. "Once they are familiar with the value our technology offers, we believe that governments and local communities in Poland and elsewhere will welcome the benefits it can bring in terms of responsible production and management of their unconventional oil and gas reservoirs." ■



Dr. Peter Duncan began his career with Shell, and worked for a number of geophysical companies before becoming founding President of MicroSeismic in 2003. He was President of the Society of Exploration Geophysicists 2004 – 2004