Beyond dots in a box

The big players in the development of microseismic monitoring are now focusing on interpreting the data

By R.P. Stastny

At trade shows just five years ago, Shan Jhamandas spent most of his time explaining what microseismic monitoring is. Today, the marketing manager of ESG Solutions, a leading microseismic provider based in Kingston, Ont., finds he's mostly talking about what makes his company different from the competition, what's new in microseismics and where the technology is heading.

"That's largely due to the rise of shale gas plays," Jhamandas says. "Microseismics is really a great science for providing feedback on fractures in these reservoirs and helping to optimize shale gas development."

Alongside the shale gas, another driver is the oilsands. Since ESG first put microseismics to work at Shell Canada Limited's Peace River cyclic steam stimulation project in 2002, it has developed a strong steaming group. Further branching out into the monitoring of depleted conventional reservoirs has rounded out ESG's expertise and allowed it to take its technology global.

RIVALRY

"We're in the process of finalizing what will be the largest permanent downhole microseismic monitoring program in the world," Jhamandas says. "It's in Oman. We have about 26 monitoring wells monitoring in two fields, so it's complete field-wide monitoring."

ESG has also just completed a record-setting frac-monitoring microseismic job in the Horn River Basin for Nexen Inc., monitoring 143 fracture stages over 43 days. But don't tell that to Peter Duncan, founder and president of Houston-based MicroSeismic, Inc., because that will spur him to tell you about his company's microseismic program south of the border.

"We actually put in a permanent array on the Whiting Sanish Field in North Dakota in the Williston basin, which we turned on March 1 last year and [which] has been recording data 24-7. We have a 152-square-mile permanent array in that field that's recorded an average eight wells per month and an average of 25 stages per well, so I think we have surpassed—at least in stage count, and certainly by number of hours of recording—ESG's numbers," he says.

You'll have to forgive Duncan's one-upmanship, but there's a kerfuffle going on between downhole and surface microseismic providers. Duncan's a surface guy. Jhamandas is mostly a downhole guy. Both are jockeying for advantage as the oil and gas industry tries to figure out which is better at understanding what's happening underground.

As in most debates with rapidly evolving technology, the answer is all but clear. The common perception is that downhole

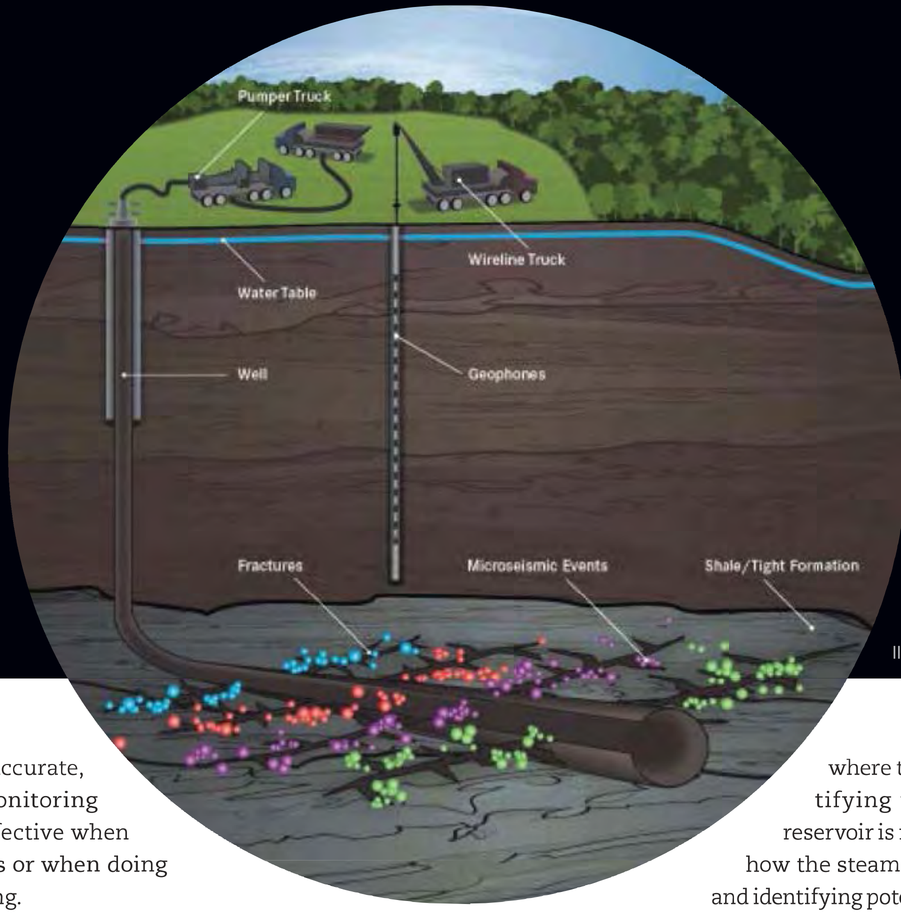


Illustration: MicroSeismic Inc.

monitoring is more accurate, but that surface monitoring can be more cost effective when tracking many wells or when doing field-wide monitoring.

The surface guys, like Peter Duncan, are passionate about correcting industry views on surface seismic accuracy—or the lack of it. Originally from New Brunswick, Duncan went to Houston for a three-year work tour that turned into 30 years. During that time, he launched three companies including MicroSeismic, which brought surface microseismic monitoring to the market.

"It's a common perception that downhole microseismic is more accurate," he says. "If you're monitoring within a few hundred feet, say up to 1,000 feet, of a monitoring well, the downhole data are likely to have better positioning accuracy than surface—but not always, as Mother Nature can be tricky. Beyond that, for reasonable signal-to-noise conditions, surface monitoring is every bit as accurate."

BENEFITS

What both surface and downhole microseismic providers seems to agree on, though, is a long list of benefits and applications for microseismic monitoring, from frac mapping to long-term reservoir monitoring.

"You can watch in real-time what's happening subsurface during a frac to avoid things going wrong mechanically," Duncan says. "For example, a ball that doesn't seat properly in a sliding sleeve, resulting in treating the same zone twice."

Microseismics can help detect a bad cement job that's allowing fluids to run up behind pipe. Or identify a fault that's become a thief zone, stealing proppant and fluid instead of cracking rock. Or if there's an aquifer below the target, like the Ellenberger below the Barnett that needs to be avoided to not lose the well, you can watch the progress in real time, push the limits, harvest all the gas and not water out your well.

Beyond this mechanical dimension, microseismic allows you to understand the length, width and height of a frac. How big an area was cracked? Was it uniform all the way down the well? Knowing this can inform the placement of the next well. Less guesswork, better results.

In the oilsands, microseismic is an important tool for monitoring caprock integrity, but it also has value in better understanding where the steam is going, identifying in real time how the reservoir is responding to steaming, how the steam chamber is developing and identifying potential leakage pathways.

Microseismic also has limitations, the main one being that in fracture stimulations, it monitors the fluid, not the proppant. That is, it can see the fluid fracturing rock but not the sand that goes in after to hold open the fractures.

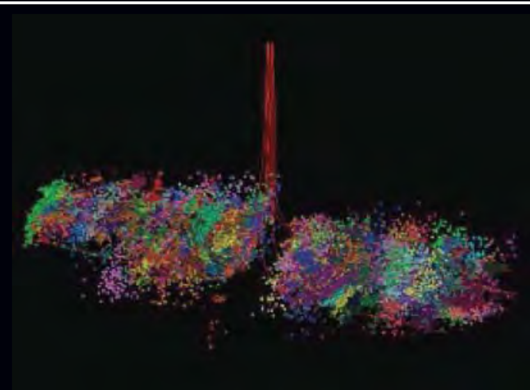
"Microseismic is a tremendously valuable tool in determining what the fracs look like," says Dan Themig, president of Packers Plus, a pioneer of multistage fracture systems. "But you have to have a real clear understanding that you're looking at fluid moving out and not proppant. I think if, as an industry, we could ever get to where we could see how far the sand is moving into the formation, the benefits would be multiplied tremendously."

Duncan essentially agrees with this assessment. Monitoring the movement of proppant with microseismics is a fertile area of research, which he believes will yield new capabilities in about two years' time.

THE RISE OF SURFACE MONITORING

All microseismic monitoring is essentially done with the same technology *(con't pg 29)*

Geneology



CGI image: ESG Solutions

Oil and gas microseismic monitoring traces its roots to geothermal and mining

The idea of using microseismic, which is essentially the same technology that's used to detect and locate earthquakes, in monitoring oil and gas activities goes back to the late 1960s and early 1970s.

"The patent in the U.S. on using microseismic monitoring in hydrofracking was awarded in 1973," says Peter Duncan, founder and president of MicroSeismic, Inc. "But the technology required [a] quality of downhole seismic receivers that really didn't exist back then, so microseismic monitoring didn't really become practical until much later."

In the meantime, the technology lived in the mining community where it was used for safety. It was also used in the geothermal community to detect underground geysers, which were harvested for their heat for electricity generation.

There was enhanced geothermal work under something called the "hot-dry rock experiments," Duncan says. Sponsored by various governments, they consisted of drilling into deep granitic bodies and hydrofracking them to create a heat exchanger. Cold water was pumped into these hot zones, where it was heated and the hot water was brought back to surface to run electricity-generating turbines.

A core of today's microseismic providers came out of these hot-dry rock experiments and the mining world. In the 1980s, northern Ontario mines were experiencing increased seismic activity. Then in 1984, a large rock-burst killed four miners in Sudbury, Ont. In response, a consortium of mining companies with government support wanted to determine if monitoring microseismic activity could have prevented this tragedy.

The research lab at Queen's University set out to develop instrumentation, software and processing routines to locate the source of microseismic activity in mines. When the lab disbanded in the early 1990s, ESG Solutions was founded and continued this work in a commercial capacity.

By the late 1990s, some oil and gas companies and the U.S. Geological Survey decided to test microseismic monitoring in the oilpatch. As shale gas development got off the ground with horizontal drilling and hydrofracking, microseismics came to life.

"When they started to do hydrofrac monitoring in the late 90s, they started to see how complex and how different from their predictions these fracs really were," Duncan says. "That drove the use of microseismic monitoring."

One of the early leaders in microseismic monitoring was Pinnacle Technologies, Inc., a group of U.S. hydrofrac engineers. It wanted to track hydrofracking and steam injections in California's oil deposits and originally was using tilt meters.

"When water or steam is pumped into the ground, the surface actually swells very slightly," Duncan explains. "So if you had a really accurate carpenter's level, which is what a tilt meter is, you could detect that swelling."

The Pinnacle guys got introduced to microseismic monitoring in the mid-1990s when they participated in a "turkey shoot." "That's where an oil company has several contractors come in to monitor a hydrofrac," Ducan says. "The Pinnacle guys saw what you could do with microseismics and they jumped in with both feet."

On account of its engineering contacts, Pinnacle quickly took the market lead in microseismic mon itoring. They were eventually bought by a proppant company called CARBO Ceramics Inc., which was then bought by Halliburton.

Photo: ESG Solutions

A wireline and monitoring truck on location at a microseismic collection project.

utilized in earthquake detection and location. There are microseismic monitoring stations all around the world. In the event of an earthquake, those stations make an estimate of the direction to the source. Through a process triangulation, where those vectors cross is identified as the epicentre of the earthquake.

In an oil and gas application, the average microseismic event gives off very little energy, about the same as dropping a can of pop from the height of a person's hip. So the technology developed around the idea of putting the geophone downhole closer to the events.

"Makes sense, right?" Duncan says. "The problem is if you think about triangulation, you need to have points all around the event as it occurs so that you can triangulate in. But it's expensive to drill a bunch of monitoring wells, so you typically have one well with a bunch of geophones on a long string. It's not quite as good. I guess you'd call it, 'bi-angulation.'"

Duncan's background is in more conventional 3-D seismic, which relies on essentially the same equipment and processes. It's the sum of all the geophones laid out on the surface, he explains, that amplifies microseismic events sufficiently to map.

"So now surface microseismic is replacing downhole microseismic for a number of reasons," he says. Cost is one reason. Drilling even a single monitor well is expensive. If a well is already available, the production casing still needs to be pulled and cleaned. If it's a producing well, it means lost revenue.

Another factor that has driven people to surface monitoring is the length of some horizontal wells. A 3,000-metre lateral can be a challenge to monitor from a single well—and ideally you want more monitoring wells in order to triangulate.

Some plays, like the Haynesville, are also very hot. At 3,000 metres below surface, temperatures can be 150-170 degrees Celsius, which can overheat some downhole equipment.

In many cases, surface monitoring can overcome the limitations of downhole monitoring.

"I've got some clients that monitor 100 per cent of their wells," Duncan says. "By putting a permanent array over the entire field, I can drive the cost down from what used to be $20,000 or $30,000 per frac stage to $2,000 or $3,000 per frac stage."

FUTURE

Both ESG and MicroSeismic have taken their technology global. MicroSeismic is happy to ride on the coattails of the shale gas revolution as it spreads to Europe, China and the rest of the world. ESG has opened sales offices on every continent except for Antarctica. (Its services target more than just oil and gas, and include geothermal and mining clients.)

Both surface and downhole microseismic providers say the quality of monitoring equipment will continue to evolve and providers will continue to experiment with configuration, driving down costs and reducing the number of people needed to set up and maintain the systems, but all that progress will be linear compared to the revolution underway in the interpretation of microseismic data.

"There are opportunities for making real strides in the interpretation of data, pushing the technology towards more accurate, more predictive models. So far, microseismic is only at the beginning of this journey," Duncan says.

By replacing the data "dots with little fracture planes that have a sense of motion to them," for example, a lot more information about the reservoir and the geology can be plugged into the reservoir simulator and linked with all the other seismic data.

ESG's Jhamandas talks a lot about integration, seeing microseismic as just one piece of the puzzle, and integrating it with engineering and geo-mechanical modelling to create a more robust picture of how fractures develop and how the reservoir is behaving.

"How is the rock failing? Is it an isotropic volumetric failure? Where is it going to create a channel of permeability?" Jhamandas says. "That's important for us to identify as opposed to just identifying a shearing event, which is a rock failure but isn't necessarily going to create a channel of enhanced permeability by which the gas can flow to the well and provide increased production."

Duncan adds that with all this microseismic equipment already in the field, there are opportunities to listen between the fracs and hear what other kind of noise is coming from the reservoir. Deciphering that could lead to a better understanding of how oil and gas is moving within the reservoir, which could be used to improve production. ■