HEAVY hitters

BY SUSAN EATON

IT'S THE MERCEDES-BENZ of the seismic recording industry.

Elegantly engineered to generate a seismic wave source, the Explorer 860 is a Mercedes-Benz farm tractor that has been retrofitted with a 2,600-pound weight drop system on the rear of the vehicle. When the hydraulically operated hammer strikes a base plate that's positioned on the ground, it delivers up to 860,000 pounds of force, sending sound waves deep into the subsurface. Equipped with an array of lights and an onboard global positioning system, the Explorer 860 is capable of working 24 hours a day — and that's an important feature for Jim Ross, a geophysicist with Apache Canada Limited, who faces the logistical challenges of shooting seismic during a narrow window each winter when the muskeg is frozen at Zama in northern Alberta.

Developed in partnership between Apache Corporation and Polaris Explorer Limited of Calgary, the Explorer 860 represents the modern-day version of the original "thumper" or weight drop source used by the industry 30 years ago. The Explorer 860 offers a cost effective alternative to the dynamite and vibroseis seismic sources currently used in the field by the geophysical industry.

Apache, Polaris Team Up To Develop New Weight Drop Source For Seismic Operations

COLLABORATION. Thirty years ago, it was commonplace for large oil companies to finance in-house research and development laboratories and machine shops where scientists and technicians spent their days developing new technologies and gadgets designed to discover — and extract — oil and gas. Those days are gone. Although the oil and gas service sector has stepped in to fill the R&D void, it has often worked in isolation from its industry clients. In today's competitive business environment, however, industry leaders such as Apache Corporation have formed value added, strategic alliances with seismic technology vendors and seismic contractors, and are reaping the benefits in terms of better subsurface seismic imaging of geological formations, and substantial cost reductions of seismic data acquisition.

During the past year, Houston-based Apache and its wholly-owned subsidiary, Apache Canada Limited, have struck strategic alliances with three seismic contractors: Polaris Explorer Limited and Trace Energy Services Limited, both of Calgary, and Input/Output Inc. of Houston (see sidebar). Leveraging on Apache's significant financial assistance, Polaris has spent in excess of $1 million to test and build three Explorer 860 units that were deployed this winter at Zama.

"We went from design blueprints to seismic data acquisition in half a season which was amazing," says Ross of the construction of the three Explorer 860 units.

Prior to beginning field production, Polaris brought in an independent testing company from Great Britain to put the Explorer 860 through its paces. Using accelerometers and other testing equipment, the company measured the system's 860,000 pounds of peak force and 450 hertz frequencies at the base plate — at a minimum. According to Polaris, the company's instruments couldn't measure values any higher. Testing suggested accuracies of timing on the order of microseconds.

Because the weight (hammer) can be raised up to 24 inches — and the stroke length and the hydraulic force adjusted — unique force outputs can be created, as required. The base plate is gimbaled, ensuring that the mass always hits it perpendicularly, even if the base plate is deployed on uneven ground. Airbags are used to create a floating base plate — seven degrees off horizontal — to compensate for an uneven ground surface. According to Polaris, the weight drop system results in very little surface damage, and no long-term surface compaction. With its large, high impact tires, the Explorer 860 offers an environmentally attractive alternative to other seismic sources.

Using the Explorer 860, Apache acquired 485 square kilometers of seismic data at Zama, comprised of three 3-D surveys and about 80,000 shots. Ross estimates that the Explorer 860 reduced his seismic shooting costs by 17% to 20%. The weight drop source, he says, eliminated costs associated with the drilling of shot holes, the purchase of explosives and the front-end surveying of source lines, as the Explorer 860s are equipped with global positioning satellite systems for navigation.

According to Ross, the Explorer 860 is versatile, and can acquire shots more quickly along source (or shooting) lines than can be achieved by detonating dynamite, shot by shot, or by using three or four vibroseis units shaking the ground in tandem.

Peak production at Zama — based on two Explorer 860 units working — averaged about 1,500 shots daily. That's a whopping five times greater than daily production using conventional seismic sources. Additional production was achieved at night while the Explorer 860s navigated down source lines that had been staked, but not surveyed. "We acquired up to 900 shots overnight, plus the daily production, which is huge," says Ross.

He also experimented with using the three Explorer 860s, in a "ping-pong" pattern, to speed up production — in a game of Leap Frog: The first unit dropped its weight on the ground, while a second unit on a second source line was already in position, with its base plate on the ground, ready to shoot, and a third unit was moving along a third source line to its next shot. Based on three Explorer 860 units working 24 hours a day, Ross had several record-breaking production days of 2,500 to 2,800 shots.

With seismic recording crews at Zama costing around $50,000 a day, the old adage, time is money, became Ross's mantra.

According to Mike Bahorich, Apache Corporation's Houston-based vice-president of exploration and production technology, the company has saved $4.5 million (U.S.) by using weight drop seismic sources during the last couple of years. "Apache is a company that recognizes that there is significant value in technology," says Bahorich.

PICTURE PERFECT. But cost savings may not be the most attractive feature of the Explorer 860. The weight drop source produces subsurface images of the geological formations that are superior, in many ways, to data acquired by other seismic sources. "You get a much better near surface image than vibroseis because the Explorer 860 is an impulsive source," says Bahorich. "Therefore, your first breaks are much sharper, which enables you to create a high quality velocity model of the near surface for calculating statics."

According to Bahorich, vibroseis source arrays normally sweep the ground for a period of 12 to 16 seconds, causing the first breaks to be averaged, or blurred. First breaks represent the first recorded signal attributed to the seismic wave travelling from the source. Determination of near-surface velocities, especially in the low-velocity weathering layer, is critical for the processing of the seismic data.

In order to properly image subsurface geological features, geophysicists need to acquire seismic data with the highest seismic fold and frequencies, and the best signal-to-noise ratios. The geophysical term "fold" refers to how many times the same point is sampled in the subsurface. Comparisons of weight drop seismic with dynamite are favourable, from both a frequency and signal-to-noise perspective.

Polaris and Apache have conducted several production tests to compare dynamite and the Explorer 860 sources. With the weight drop system, they noted that the higher frequencies trailed off slightly with increasing depth. On the flip side, they noted that the Explorer 860's capability to dramatically increase fold compensated for the slightly lower frequencies.

Increased fold leads to improved velocities for processing of the data, and better signal-to-noise ratios. At no extra cost, the Explorer 860 can acquire closely spaced shots, on the average of 20 metres apart, creating very high fold seismic data. "For less money you can acquire three to five times the fold," explains Bahorich.

Zama's prolific oil producing Keg River reefs sit at about 2 000 metres in the subsurface. With a typical dynamite crew, Ross can afford to acquire a 40-fold image of the Keg River reef — using the Explorer 860, he can obtain a 140-fold image of his exploration target. In the shallower geological section, well above the Keg River reefs, Ross has also benefited from the higher fold seismic data. For the first time, he believes that he can image and map unconsolidated glacial channels that could contain natural gas in the Zama area (see Ground Currents, New Technology Magazine, Oct/Nov 2003).

"Personally, I think that this technology has a chance of changing how we shoot seismic, because there's no way we could shoot 140-fold dynamite data," says Ross.

Jeff Hislop, a geophysicist with Polaris, concurs with Ross's assessment. Hislop says the Explorer 860 system has redefined the way he designs 3-D surveys for field acquisition. With more tightly spaced shots, Hislop has developed efficiencies in survey design: decreased shot point and source line intervals, and increased receiver (recording) line intervals. Hislop has also been able to decrease the size of the recording patch, or the number of geophones that must

● Improving The P-Wave

Multi-Component Seismic Helps Extract More Information From Data

IN AN ATTEMPT to extract more information from seismic data, Apache Corporation has invested in the acquisition of three-component or "full wave" seismic imaging.

"Multi-component seismic helps with fluid and lithology [rock type] issues, versus structural issues," says Mike Bahorich, Apache's Houston-based vice-president of exploration and production technology. "With new, low-cost digital systems, multi-component seismic acquisition will increase."

Additional information, such as the density and orientation of fractures, is sometimes available through the interpretation of multi-component seismic. Bahorich is looking to multi-component data to fine-tune Apache's exploration, development and reservoir management programs in Western Canada and around the world.

IMPROVING THE IMAGE A crew prepares a System Four VectorSeis Cable recording system for seismic acquisition in Alberta last winter. The "full wave" Input/Output system was brought to Canada by Trace Energy Services under contract to Apache Corporation.

Predicated on work commitments from Apache, Trace Energy Services Limited invested more than $6 million (U.S.) to assemble a field crew and to purchase a System Four VectorSeis Cable (VC) recording system from Input/Output (I/O) of Houston.

The VC system, with 3,000 sensors and 9,000 channels, was shipped to Alberta in time for this winter's seismic recording season. The system is capable of acquiring three components of seismic data in the field — primary or compressional wave (P-wave) and two shear wave (S-wave) vectors.

Jim Hollis, I/O's Houston-based vice-president of the land imaging systems division, says he posed a simple question to Apache: "Where are your imaging problems around the world, and how can we be relevant?"

The resulting discussions led to the three-way partnership between Apache, I/O and Trace.

Hollis is encouraged by the producer's commitment to embrace new technologies. "It's a refreshing partnership that I'm really excited about," he says. "For years, seismic was a commodity business, and the subsurface image suffered."

With I/O's multi-component system, explains Hollis, "You can get a much better P-wave, which is what everyone uses to map structures." The two S-wave vectors, according to Hollis, are used to improve the P-wave image. "It's not just about the S-waves," he says. "It's about getting the best P-wave."

The VC system consists of a network-based

be laid out to record the seismic data.

Ross describes the Explorer 860 as the "third generation of weight drop machines" that Apache has tested with Polaris during the past several years. The original focus of Apache's R&D efforts at Zama was to experiment with weight drop sources jettisoned from helicopters at high altitudes.

Bill Mooney, the president of Polaris, was involved in the airborne weight drop program several years ago. "Apache is not afraid to try stuff," he says. "They're always open to innovation."

Mooney describes the aerial weights as "drill collar missiles."

Explorer 860

"We cut them into different lengths, put round noses on them, and then dropped them in 500 foot increments, up to 2,500 feet altitude." While the missiles produced an excellent seismic source upon impact, Apache conceded the airborne sources were more appropriate for wildcat exploration areas away from infrastructure and pipelines.

Following this, experiments continued to develop a safe seismic source that could navigate between the maze of oil wells and pipelines that dotted the field. The use of dynamite sources created gaps in 3-D programs, as regulations require dynamite shots be placed between 32 and 255 metres from high pressure pipelines and oil or gas wells. With the Explorer 860, that distance can be cut down to 15 metres.

According to Ross, the various R&D field tests conducted at Zama focused on establishing reliability, repeatability and control of the source. "How do you basically build a better mousetrap," he says of their various efforts. They tested an elastic weight drop machine that acted like a huge slingshot, propelling a weight to the ground with great force; they also imported Digipulse machines from the United States that employed impulsive weight drop systems. ntm

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cable telemetry system. The ground electronics feature fast deployment and wakeup, automatic testing capabilities and redundant power distribution. The VC uses three-component digital accelerometers. The accelerometers or "sensors" — the equivalent to analog geophones on a conventional seismic recording system — are high fidelity instruments, measuring about two inches by two inches.

Analog geophones are comprised of a spring with a suspended mass that measures vibrations or velocity in the vertical or "Z" direction. For this reason, analog geophones must be planted vertically, to ensure good data acquisition. In contrast, digital accelerometers record changes in the full seismic wave — two horizontal directions in addition to the "Z" direction. I/O's sensors measure the acceleration of the apparent gravity field for each of the three vector's axes. Because the sensors work on any plane, they are not sensitive to deployment in the field.

"The accelerometers use the Earth's gravity field to figure which way is up," explains Hollis. He describes field crews using plaster of Paris to cement the sensors to outcropping limestone for a recent shoot in Texas. At Apache's 3-D program in Coronation, Alberta, the accelerometers were planted six to eight inches into the ground, using an auger to get through the snow.

A two-person team plants the accelerometers — the driller places the sensor in the ground, and the aligner follows behind, equipped with a sight glass and a compass to steer the sensors toward the azimuth that has been selected for the seismic shoot.

Brett Cameron, Trace's operations manager, has adopted a new terminology to describe the accelerometers — he refers to each sensor as a "station" because each sensor acquires three channels of data. Cameron describes this winter's shooting season as a steep learning curve. "We shoot at a high (daily production) rate in Canada, compared to anywhere else in the world," he says. "It's the first system of its size working in real time in North America."

However, he says Trace quickly realized logistical efficiencies in deploying the VC system in the field. "There's only one sensor per station to move, compared to six geophones per array for analog systems," he explains. "The equipment is lighter, and we can move at least 20% more equipment by helicopter per day."

Kelly Hrabi, a geophysicist with Apache Canada, used the VC system to shoot the 80 square kilometre, 12,000 shot 3-D survey at Coronation this winter. Hrabi's program employed two crews to facilitate shooting 24 hours a day.

Hrabi's exploration target is a gas bearing Manville channel sand that sits at about 1 000 metres in the subsurface. "We can track the channel fairway," he says. "But, when we get into the channel, it's fooling us."

"We're finding conflicting seismic character anomalies, so we're pushing the technology to predict lithology." Apache's channel sand fairway trends 80 kilometres; the difference between a good well and a bad well is three

mmcf per day versus 50 mcf per day. Although the seismic data are still being processed, Hrabi says that he's seeing "amazing frequencies" in the data, up to 180 hertz.

In the future, Hrabi would like to benefit from the cost savings that Jim Ross achieved at Zama with the Explorer 860. He believes that his focus area would be a prime candidate to marry the two technologies — the VC system and the Explorer 860.

With large parts of northern Canada inaccessible for seismic data acquisition during the summer season, Trace's I/O VC system has headed south of the border, to acquire multi-component seismic data for Apache Corporation. ntm

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