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DECIPHERING THE ARCTIC’S DEPTHS

Mapping Uncertainty
Using geostatistics to analyze reservoirs
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By Maurice Smith

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Though much of the activity has been under the radar, arctic exploration is quietly heating up again, as new technologies not available in previous rounds of exploration are put to the test in still largely unexplored basins.
BP Exploration Co. Limited committed a record $1.18 billion in June, 2008 for a 202,000 hectare parcel in the Canadian Beaufort Sea, topping Imperial Oil Limited and ExxonMobil Canada’s earlier record-setting $585 million 205,000-hectare exploration lease in the same area won in 2007. In addition to three 611,000-hectare leases awarded to BP last year, two other parcels went to ConocoPhillips Canada Resources Corp. and a consortium of ConocoPhillips, MGM Energy and Phillips Petroleum Canada Ltd.

This after Devon broke a 20-year offshore drilling drought in 2005-06 with the Paktoa well, described as a major oil discovery with recoverable reserves of 240 million barrels. Activity is also picking up in the U.S. Beaufort and Chukchi seas and in the icy waters surrounding Greenland.

Helping to drive the resurgence is Houston-based ION Geophysical Corporation (formerly known as I/O), which has undertaken three major “basin span” seismic surveys in recent years — in the Canadian Beaufort Sea, the U.S. Chukchi Sea and off northeast Greenland — that are providing new insights on a basin-wide scale.

Custom designed in collaboration with ION subsidiary GX Technology, and intended to trigger new ideas to drive exploration and discoveries for the future, SPAN projects are geologically inspired, basin-scale, ultra-deep seismic programs that allow exploration companies to evaluate the geologic evolution, deep basin architecture and depositional and structural histories of entire petroleum systems across a region, the company says. It is hoped they will determine where source rocks are most prevalent, where sediment fairways are located and where the most promising migration paths from source to reservoir exist.

“On a global basis ION has close to 250,000 line kilometres of SPAN data acquired around the globe. We have been instrumental in opening up new frontiers in a lot of places, non-arctic related as well as arctic-related. And I think we are continuing to build a very good reputation for delivering high-quality seismic data in frontier basins,” says Joe Gagliardi, ION program manager for ArcticSPAN surveys.

Its Beaufort survey, for instance, has shed new light on deeper and more northerly areas not yet drilled, opening up enticing exploration possibilities. “We believe that the BeaufortSPAN data can significantly aid in understanding the complex Beaufort-Mackenzie petroleum system,” says a company study. “Despite all the previous work that has taken place in the area, significant questions regarding the basin architecture and petroleum system, especially in water depths greater than 200 metres, remain.”

ION initiated its ArcticSPAN seismic data programs offshore Alaska and Canada in 2006. In July, it announced the launch of its third phase to study the deep crustal architecture offshore Greenland. Several of the world’s largest energy companies agreed to underwrite the basin-scale imaging project, recognizing the potential in the Arctic, which the U.S. Geological Survey estimates contains nearly 25% of the planet’s undiscovered oil and gas resources.

While the Greenland data is still undergoing processing, results from the Beaufort and Chukchi sea surveys have bolstered anticipation for major finds. The lightly explored Beaufort-Mackenzie basin — where offshore drilling has been concentrated in shallow, near shore waters — has already accounted for 48 significant discoveries representing an estimated 1.7 billion barrels of oil and 11.7 trillion cubic feet of natural gas.

The BeaufortSPAN found significant potential in deeper and less explored waters to the north. “I think some of the most exciting things that the BeaufortSPAN data has done is that it has expanded the knowledge base on the potential for both the deepwater Mackenzie Delta and, as we have been finding in the last couple of years, the potential for the Banks Island area; we find that to be very exciting as well,” says Gagliardi.

“We are seeing very deep sedimentary troughs, in and around 10 kilometres of sediments, off Banks Island that we think has been more influenced by sediment outflow from the Amundsen Gulf and McClure Strait than in the Mackenzie Delta, where we are looking more at river sediments.”

The Amundsen Gulf and McClure Strait,
which flow from the south and north of Banks Island, respectively, constitute arms of the
fabled Northwest Passage through the Canadian Arctic archipelago.

“Before we shot this survey, there was some data that was about 20 years old, but certainly
nothing on a regional context nor anything that actually tied the Banks Island margin to the
Mackenzie Delta,” Gagliardi says.

“That area, we think, is equally prospective [as the Mackenzie Delta]; however the fans off
of Banks Island may actually offer better reservoir quality. It is extremely unexplored, so what
we are talking about is not for the faint of heart. But at the same time, we believe it could be a
world-class province. It’s definitely untested, but has some very interesting potential.”

“We believe that the Banks Island offshore, part of Canada Passive Margin closest to the
Mackenzie Delta, has all the components of a potential major petroleum province and
therefore deserves serious attention from the oil and gas industry,” stated Menno Dinkel-
man, GX Technology’s chief geologist, and consultants Naresh Kumar and James Helwig in
a paper published in May.

They conclude: “It is hoped that the favourable indications for hydrocarbon accumulations
suggested in this paper would encourage the industry to carry out additional work and eventu-
ally to drill in the area, as lack of well control is the biggest obstacle to establishing the presence
of petroleum habitat along the Banks Island margin.”

According to the authors, the study is designed to image the entire basin architecture,
with seismic resolution allowing for imaging at the crustal level as well as exploration target

MAPING THE ARCTIC
With the recent completion of a marine seismic survey
off the northeast coast of Greenland, ION added some
6,500 kilometres of data to the 20,000 already collected
in similar ArcticSPAN surveys conducted in the Beaufort
and Chukchi seas.
depths — to reveal details of structural and stratigraphic features. Seismic data are interpreted together with simultaneously collected gravity and magnetic data to regionally map the ocean-continent boundary and the top of Moho discontinuity, the boundary between the Earth’s crust and the mantle. Data is also correlated to existing well data wherever possible to identify the major stratigraphic sequences.

Constituting a first ever look at the deep water in the Beaufort-Mackenzie Basin and of the Banks Island western margin, the BeaufortSPAN included more than 16,000 kilometres of two-dimensional long-offset reconnaissance seismic data collected over three seasons from 2006 to 2008. The acquisition is designed to image down to the base of the crust with a nine-kilometre long cable, 18-second recording and final depth processing to 40 kilometres using prestack depth migration.

Based on the data collected along with previously published data, the team describes the observations that led them to conclude the existence of traps, reservoirs, source rocks and timely maturation and migration in the never before drilled waters of the Banks Island margin.

With the exception of large scale folding observed in the Mackenzie Delta, “petroleum-system components conducive to hydrocarbon accumulations reliably exist in the area,” they say. They note the presence of possible source rocks in Upper Jurassic, Upper Cretaceous and Paleogene times, in multiple levels throughout Cretaceous and Tertiary periods, as well as an Arctic-wide “Azolla” source rock in the Paleogene time has been suggested by others, and say “the continuity of seismic markers from the Mackenzie Delta area suggest that suitable environments of deposition formed source rocks during multiple periods in an area much more extensive than just the Mackenzie Delta.”

As for reservoir, as in the case of source rocks, they say the continuity of seismic markers “suggests good probability of sand-rich intervals along the Banks Island among the various intervals that form known reservoirs in the Mackenzie Delta,” while ample possibilities for structural and stratigraphic trapping were also seen to exist.

Shale-rich sedimentary accumulations of 10 kilometres – less than the up to 15 kilometres thickness in the Mackenzie Delta, but considerably thicker than thought would be the case in an area 300 kilometres from the source of the majority of sediment, the Mackenzie River — would provide the seal for hydrocarbons accumulated in the intervening sands.

Gagliardi notes the presence of thick sediments is one of the key factors indicating a potential resource play. “But there are other parts to a working hydrocarbon system that still need to be proven, and that is why this is definitely a frontier exploration type of play. But at the same time we find it to be quite exciting.”

The company would like to expand the basin-wide concept further to learn more about the larger region, he adds. “We would like to be able to reconstruct the entire Canada Basin, which would run from the U.S. Chukchi through the U.S. Beaufort along through Canada and then up toward the Arctic Islands, so that you can eventually do the conjugate margin reconstruction from Alaska back along the Canadian Island margin.”

Chukchi Sea

Meanwhile, the company’s Chukchi Sea survey has also helped to stir new exploration interest — and accompanied rich lease sales in the past few years. The target of just five exploration wells, drilled between 1989 and 1991, one of which discovered a major gas accumulation at Burger, the Chukchi appears to be on the verge of a new round of exploratory drilling.

In 2008, in the first Chukchi Sea lease sale since 1991, Statoil was the high bidder on 16 leases, 14 of which were joint bids with ENI Petroleum. They are located 60 kilometres north of the Burger discovery in water depths from 20 to 80 metres. In November, Fugro-Geoteam was contracted to acquire 2,400 square kilometres of 3D marine seismic around the leases, all operated by Statoil. The $26 million survey is planned to take place from early August into October 2010. Royal Dutch Shell spent $2.1 billion acquiring leases in the Chukchi Sea, also in 2008, and recently said it remained committed to its exploration plans in the Chukchi and U.S. Beaufort Sea despite delays caused by challenges from environmental and Alaska native groups. In July, David Lawrence, Shell’s executive vice-president for exploration, said the company believes there is possibly more oil and gas in offshore Alaskan waters than there is remaining to be found in the Gulf of Mexico.

And ConocoPhillips said in November it was shifting its focus from onshore Alaska, where results have been disappointing, to the remote, frontier area that lies between northwestern Alaska and eastern Siberia. After investing some $500 million in Chukchi lease sales in 2008, the company said it plans to begin drilling in 2012. Among other things, the ChukchiSPAN found widespread evidence of gas chimneys, which indicate a column of natural gas seeping up from a deeper horizon. The results are also providing new insights into the formation of the entire Canada Basin. (ION collaborated with scientists from the Geological Survey of Canada on the Beaufort and Chukchi surveys to advance the understanding of the complexities of the Canada Basin’s history and tectonics.)

“We were mapping Moho at 38 kilometres in the Chukchi Basin, so we do look to do
as deep an imaging as we possibly can, because we are trying to understand the entire basin framework,” says Gagliardi.

“Our intention was to provide a regional framework that companies could use as a way to register their prospects in various locations in the basin across one single uniform dataset. I think it was fit-for-purpose when it came out, and has provided some interesting insights into the Chukchi. In the end, I think we reconfirmed everyone’s excitement that the Chukchi appears to be very prolific basin and supported the work that was done 20 years ago. I believe the survey continues to demonstrate the resource potential that exists there.”

The technology

The company’s Intelligent Acquisition (IA) Arctic Solution plays an integral part of the ArcticSPAN surveys. It integrates traditionally stand-alone navigation, positioning, acquisition, streamer control and source systems. At its heart is the Orca intelligent command and control system, designed to assess and optimize acquisition in real-time.

Orca provides the latest software and positioning technologies involved in seismic data acquisition and navigation to vessel operators. Using data from on-vessel systems, in-water equipment as well as environmental factors, Orca positions the streamer spread to optimum parameters. Centralized control also allows for such capabilities as precise streamer steering, line prioritization, obstruction modelling, current prediction and coverage assessments.

Among the proprietary technologies incorporated into IA Arctic Solution are the DigiSTREAMER solid cable system, designed to provide continuous acquisition in an extended weather window using low noise, solid streamer technology; DigiFIN lateral streamer control technology to provide spread stability and denser spatial sampling by maintaining tighter,
more uniform cable separation along the entire length of the streamer cable; and the DigiBIRD depth control system, used to maintain streamers at predefined target depths to optimize the bandwidth of acquired seismic data for increased resolution and repeatability.

**Under ice seismic**

Putting the portfolio of technologies to work in ice-plagued Greenland waters presented challenges that impacted all aspects of the seismic workflow, necessitating a custom-designed, integrated solution, Gagliardi says. ION used lessons learned in the Beaufort and Chukchi BasinSPANs, which skirted the ice but never penetrated into it, to design its first ever under-ice program for the just completed GreenlandSPAN program.

Acquisition of this latest phase of the ArcticSPAN program, which added 6,500 kilometres of data now being imaged by the GX Technology subsidiary, was undertaken by the Octio Group, a subsidiary of Norway’s GC Rieber Shipping, utilizing ION’s IA streamer technologies, specially adapted to ice-prone conditions. The isolated, desolate region is considered one of the harshest on the planet to obtain a marine survey, with up to 5,000 cubic kilometres of pack ice flowing through annually.

“For this project, ION’s IA streamer portfolio was the only suitable technology solution,” noted Bjarte Fageras, Octio Group CEO. He says Octio purchased ION’s DigiSTREAMER due to its unique continuous recording capability and environmentally friendly, low-noise cable, and that Octio deployed DigiFIN, DigiBIRD and the Orca command and control system “to actively steer around and beneath any ice we encounter.”

ION had spent three years in the Beaufort, from 2006 to 2008, honing its skills in operating in the Arctic, explains Gagliardi, “in what is considered to be open water, meaning you go and shoot your surveys when Mother Nature gives you a hole in the ice to do so. The Beaufort was a way for us to learn enough about what we would need to alter to allow us to successfully make the transition, in one season, from shooting near ice to shooting in the ice. We did a fairly good job of getting the experience base with ice management, [dealing with] the operational issues associated with working in a near-ice environment. And in 2009 we used that experience base to conduct the under-ice marine streamer survey off of northeast Greenland.

“ION has a competitive advantage in that we have a sister group within the ION umbrella of companies which is a marine seismic imaging equipment manufacturing group and we were able to combine our arctic exploration expertise from our integrated seismic solutions group with the equipment manufacturing group to really go back and look at, from a process by process standpoint, all of the different components of a normal seismic program that would require an upgrade in order to operate in an under-ice environment,” he says.

Although a Polar Class icebreaker was used to clear a channel through which the seismic vessel could pass, crews and equipment were still faced with chunks of ice left in its wake, necessitating equipment alterations. “If you are going to shoot in an ice environment you have to figure out how you are going to get all that equipment below the ice, and that’s what requires the major modifications,” says Gagliardi.

Solid streamer cables, for example, were used due to their higher tolerance to freezing water and better buoyancy below the water surface, while high-declination compasses were used to compensate for proximity to the magnetic North Pole. Provision also had to be made to keep streamers within the corridor created through the ice. Along with use of streamer steering capabilities, a special towing procedure was created to help deflect slabs of ice from interfering with streamers.

“And, in addition, because you are working in and around the ice, you have different types of noise or interference on the seismic data; you need to figure out how you are going to handle that as well. That's more of a data processing solution. We combined high-end data processing, along with the modifications to existing seismic equipment to allow it to work in that environment.

“What we came up with basically allowed us to acquire data along a pre-plotted line rather than waiting to get what Mother Nature allows you to get with regard to open water around ice. And that made a difference for us. We had an extremely successful season in a very challenging ice environment.”

Though final results are months away, Gagliardi says early indications are that another high-quality dataset has been acquired, opening the door to more programs in future. “We have interim products that we have looked at that we find to be very encouraging from a technology validation standpoint. So for us we are excited about this technology and we have some plans for it in 2010.”

**CONTACT FOR MORE INFORMATION**

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