Offshore

Seafloor seismic acquisition coming of age

Offshore Magazine Feb. 1, 2007

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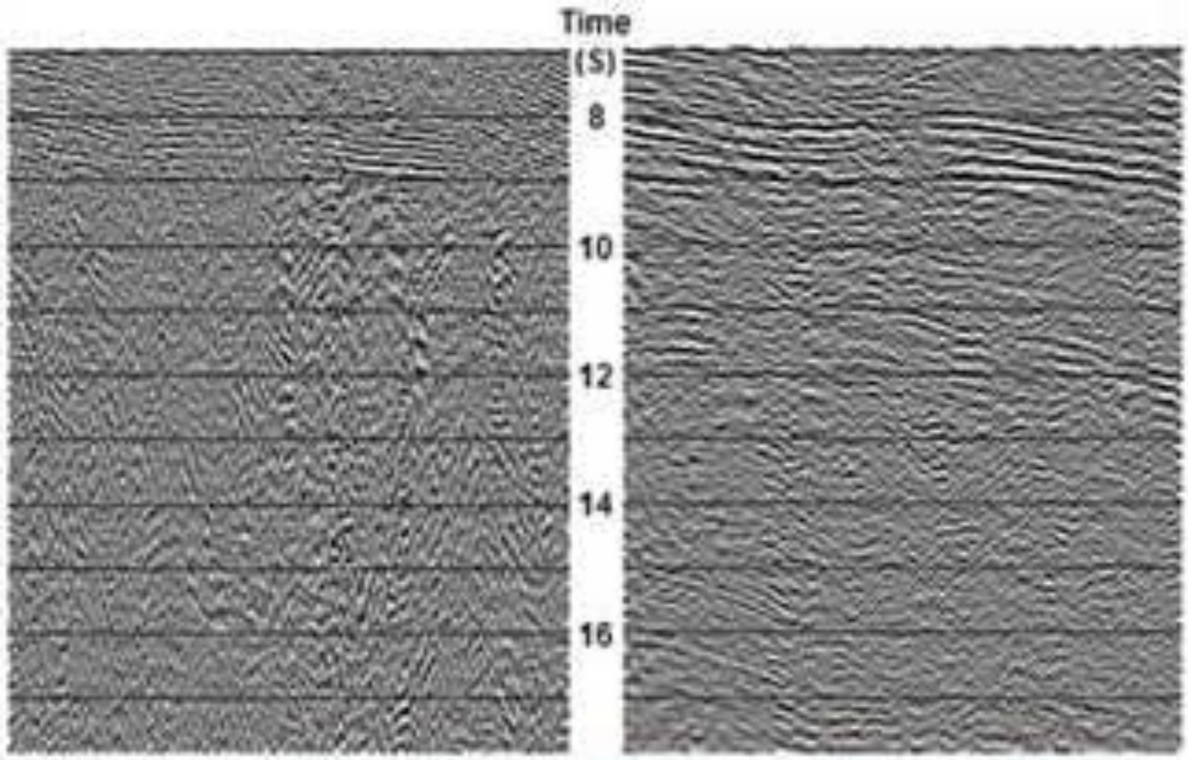
Ocean-bottom cable (OBC) seismic data acquisition is coming of age rapidly. Two things in particular are feeding this maturation. One is the interest in the advantage of wide-azimuth/rich azimuth surveys, and the other is the interest in “seeing” deeper into the target such as for subsalt imaging. Along with these have come advances in sensor isolation and in understanding of how OBC systems operate. Current circumstances from an operations viewpoint have contributed, too. The worldwide demand for vessels and the resulting run-up in day rates has benefited OBC because the method can eliminate the need for a recording vessel.

“A lot of what was talked about a year ago in terms of OBC benefits, we now are seeing,” says Tim Rigsby, senior vice president of Seabed Solutions at I/O. “One area is operational advantages in inaccessible areas such as shallow water and areas of extensive infrastructure like platforms and shipping lanes. Those circumstances are ones in which seafloor seismic methods are used commonly.”



Deep data returns. With bandpass filter applied (1-3-6-9 Hz) VSO reveals deep Gulf of Mexico

structures not visible on towed streamer image. Towed streamer returns are at left,

VectorSeis Ocean OBC returns are on the right.

The other area, and the one showing the most interest in the last year, is in the geophysical applications of OBC.

“You get the full wave recording and imaging with the converted wave,” says Rigsby. “You get the much broader bandwidth - much lower lows and much higher highs. You also have the opportunity for wide-azimuth and multi-azimuth designs. That actually plays into the strengths of a bottom cable system because it is much like a land system. You have a lot of flexibility in how you place your receiver arrays relative to your source arrays. Multiple vessels and multiple passes are not required with OBC in order to acquire wide azimuth data.”

“When you look at some of the exotic streamer acquisition methods, the cost per square kilometer is as high or higher in some cases than OBC,” says Felix Bircher, seabed systems product manager for I/O. “Companies are showing an increased willingness to pay that extra money to get that extra data quality. OBC is inherently wide-azimuth with the way it is collected.”

“The VSO (I-O’s VectorSeis Ocean OBC system) can be laid out in any fashion. We’re not restricted by what a boat can pull or by having to use multiple vessels. We can lay out a survey and have a full azimuth distribution around it,” says ***Peter Stewart,*** *senior geophysical advisor for GX Technology Corp*.

Technical advantages

In recent months, it is the broad bandwidth acquisition available with seabed seismic methods that has created the most interest.

“Things we talked about last year we have demonstrated this year. With VSO we have recorded signal down to 2 or 3 Hz which has enabled us to image deeper data with better resolution. We also have done some tests on the VSO OBC system that have shown exceptional improvements in the vector fidelity of the Vectorseis sensors relative to older OBC systems that used gimbled geophones,” says Rigsby.

VSO data is recorded in acceleration form rather than the usual velocity form. The data can be converted easily, if there is a benefit to doing so.

“You’re actually getting an apparently higher frequency from the acceleration,” says ***Stewart.*** “A conventional geophone measures a velocity movement and these geophones, however, measure a rate of change in the velocity. What we noticed is that the data had a huge bandwidth ... very good at the low end and a very good high end.”

This bandwidth benefit is seen when recording with both the hydrophone and geophone, and with the correct summations. The summations remove the inherent spectral notches.

“You get an upcoming wave that you record on the cable, and then a wave comes down from the sea/air interface to interfere with that particular wavelength and cancels out those frequencies,” says ***Stewart.*** “With the ocean bottom system when you’re recording both the hydrophone and geophone, you can eliminate that if you combine those in the correct fashion.”

A new element starting to come more into play with OBC is the horizontal component.

“We use the horizontal components to record converted waves,” says ***Stewart***. “That is data that is propagated down as a pressure wave and at some point reflects back as a sheer wave. These are picked up on horizontal phones. We are able to make images. There are properties associated with those, particularly when combined with P-waves, that are going to give direct hydrocarbon indications.

“We did a small 3D survey and processed it with the P-wave and then the C-wave, and in this area there were known hydrocarbons that were bright amplitudes on the Ps. The same reflectors on the converted waves did not have the bright amplitudes, and that is an indicator that those bright amplitudes are hydrocarbons and nothing else.”

It was known that OBC seismic was able to better penetrate gas clouds. Continued investigation indicated that this was related to P-waves, also. “Another property of P-waves is that they’re able to get through gas saturated areas, gas clouds, and providing you acquire the data correctly with a wide-azimuth you have the potential for analyzing for fractures and using shear wave splitting processing technique,” says ***Stewart.***

“When you combine wide-azimuth with converted waves, you have a huge new amount of information.”

Reservoirs are found in fracture formations in many areas of the world. In a fractured environment, seismic waves have different velocities depending on their attitude toward the fracture. So, the velocity in the direction in the fractures will be different, and usually faster, than the 90° to that when you’re cutting through the fractures. Hydrocarbons that fill the fractures would create that difference in velocity.

Subsalt applications

Another application where growing interest is being shown to OBC is in imaging subsalt, particularly where there are illumination problems with streamer data. This is where the multi- and wide-azimuth seismic runs have been popular. With OBC, the contractor can lay multiple cables over the salt mass and run the source boat. The offsets and azimuths are going to be recorded in a uniform distribution. The range of frequencies that can be collected with OBC also is a benefit in this application.

I/O also has implemented a new method for isolating the sensor package from the steel armored cable using a series of Kevlar ropes as part of the cable/sensor attachment. This new sensor attachment device allows the sensor nodes to be mounted in-line with the cable for ease of cable handling but eliminates some of the side effects associated with the cable/sensor systems deployed under tension.

“This simple but effective device works like a railroad car coupler in that the cable is under stress when it is being laid out, but once it is deployed, the sensor package has the ability to relax. This detensioning device allows the sensor package to couple well to the seafloor and eliminates strumming noise that can be an issue with OBC systems that use steel armored cables deployed under tension. We have seen data that show this is a very effective device.”

Without this flexible coupling, strumming noise could be caused by the cable vibrating under tension. Also, because the sensor package is under tension without the coupling, relief in the seafloor could prevent proper coupling of the sensor package to the ocean bottom, making the pickup of returns a problem.

Detection technology

The MEMS (micro electric mechanical sensor) used in VSO is one of the core technological differences in the system. MEMS is a digital sensor which replaces moving coils in the conventional seismic sensor.

“The MEMS has been used onshore for a long time,” says Bircher, “and has a very good reputation for delivery of a very high quality signal. We have a mode in VSO where the hydrophone data is collected in a derivative mode. We can collect a derivative of the pressure signal. The characteristic of the hydrophone signal matches the VectorSeis sensor in a way which gives better sensor matching and effectively better bandwidth.”

Fixed system

Permanent installations of seabed seismic hardware are part of the “e-field” technological development. For this purpose, OBC use is used as a time-lapse tool. The operator can image the reservoir over time to get indications of hydrocarbon movement in order to make decisions regarding best practices to extend field life and recover the maximum reserves. Operators still are determining how to apply available tools to e-fields, particularly regarding the initial expense.

Operational advancements

The operational advantages to OBC acquisition are in the way signals can be acquired. The VSO system from I/O is buoy-based. This omits the requirement for a recording vessel and crew. The recording is done in the buoy at one end of each seabed cable. The buoys communicate with a shipboard system via radio links. There is no need for a physical connection from a vessel to the receivers, so the communications hardware can be on the source vessel, for instance. Another advantage of this radio link is in the time required to access the receiver data.

There is another advantage to not needing a dedicated recording vessel. Because the cable is on a reel and requires little by way of handling equipment, it is possible to not only have a one-boat operation, but also to use a vessel of opportunity. The VSO equipment can be shipped anywhere and installed on any suitable vessel. There is no requirement for streamer handling or data acquisition to be built into a vessel.

OBC does not require ROV involvement for placement or retrieval, either. In this case, I/O used acoustic positioning devices. That, coupled with dynamic positioning capability on the installation vessel, means the end of the cable can be put down and positioned, and the remainder of the cable unspooled under some tension in order to get a straight line with the cable. Then, the cable can be monitored with the acoustic devices during operation. Once the seismic run is complete, the operator only has to retrieve the buoys and reel in the cable.

System application

Reservoir Exploration Technology (RXT) completely rethought the OBC end of the business," says Larry Wagner, vice president. "We started with 'a clean sheet of paper.' We looked at how we handle equipment and how we operate equipment. What came out of that were some unique and proprietary handling systems. So we not only have better data, but we have an operations mode that is fundamentally different."

The handling system is not the only difference. With VSO, everything is recorded in buoys. Prior to that, the operator used a cable connected to a recording vessel. With the recorder in a buoy, one less vessel is required. That, of course, favorably impacts economics.

"We've been operating steadily for 2 1/2 years in the Gulf of Mexico," says Wagner. "Our second crew began life in the North Sea last year, and we've just been awarded work in the Caspian Sea. Plus, we have the initial plans for a fourth crew. Each one of these geographic areas is different in terms of the application.

"In the GoM, it's much more exploration. Even though it is a 4C system, people are looking at it as a 3D survey. In the North Sea, people really are looking at it from a true 4C response. So, the systems and equipment operate a little different in an operations sense in that we're trying to get true 4C coverage over an active oilfield.

One aspect of a distributed system is that the shots and receivers are separate. They are not tied together and so do not move at the same time. This means the operator can set up the geometry however necessary for the best coverage.

"We've been operating bottom-cable with the idea that it needs to match up with streamer geometry," says Wagner, "so what we've been doing for many years with OBC is playing to the strength of a streamer crew. Now you find that streamer crews are trying to do the very thing that distributed systems can give you automatically."

Cable handling

The way RXT now handles the cable aboard the vessel has improved, too."We used to 'dog pile' cable on the deck of the cable handling boat," says Wagner. "One of the problems you get into is once you had a problem with the cable, the first thing you had to do was get people into that pile of cable and start pulling pieces out to find what module and what section needed to be checked. It was a manually intensive operation."

"If you look at the back deck of our crews now at RXT, the one thing you see is that it looks very much like a streamer crew because everything is operated mechanically." The cables are stored on reels. The reels have level-winders and de-tensioners. These vessels pick up and deploy cable and the crew almost never touches any cable. This minimizes the number of people required on the back deck and greatly reduces the HSE risk."

That process of automated cable handling allows the operator to integrate more of the systems.

“In our cable-handling vessels, for instance, we have the cable handling system connected to the DP system, that’s connected to the controller for all of the mechanically operated equipment that is automated,” says Wagner.

This means it is possible to program into the navigation system a point on the cable where the operator wants to stop. The navigation system knows how much cable has been played out and communicates with the DP system and the mechanical operation. The boat slows and the equipment slows, then the boat stops and the DP goes onto hold.

“That translates into efficiency,” says Wagner.

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