OBS comes of age

From its beginnings as a low-budget niche solution, ocean bottom seismic is evolving into an important multicomponent and time-lapse tool.

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Anyone who has traveled through the Gulf of Mexico at night cannot help but be astonished by the lights that stretch from horizon to horizon, seeming as numerous as the stars. They shine in silent testimony to the success of the search for oil and gas at sea: a search that has been long typified by large seismic vessels.

Today, these seismic vessels tow a number of streamer cables as much as 5 miles to 6 miles (8 km to 10 km) long, and these may spread out for half a mile laterally behind the ship. With on-board computing power and high-speed satellite communications that were undreamed of only a few years ago, these vessels have evolved into floating seismic factories, collecting and processing huge swaths of data simultaneously.

That incredible productivity, however, depends upon seas essentially free from obstructions. The rigs, platforms, buoys and tender vessels that provide the source of the light are hazards for streamer operations. But by using small boats to lay seismic cables directly onto the seabed and then using a separate vessel to provide the seismic source, a practical method was developed for obtaining seismic data in such congested areas. Starting as low-budget "niche" operations restricted to shallow water, the early ocean bottom seismic (OBS) equipment was derived from marine seismic equipment, and the acquisition operational techniques were modeled on land seismic surveys.

Early development

An early technological improvement in OBS was the introduction of "dual sensors," in which a hydrophone and a geophone are co-located to record both particle velocity and pressure. Combining the data from both sensor types removes the effect of notches in the spectrum from surface reflection interference, and the result is data that can be significantly better than that collected by either hydrophones or geophones alone. OBS sensors have further evolved with the addition of two horizontal geophones, in-line and cross-line to the cable axis. Thus, four data components are now recorded for each receiver point: pressure, vertical particle velocity from the compression wave, and in-line and cross-line particle velocity from shear-wave data. And, for the past 5 years or so, OBS systems have been available that have permitted operations down to 650 ft (200 m) water depth, thus extending the area served to almost the entire worldwide continental shelf. OBS surveys have been used in almost all active marine seismic areas of the world, including the Gulf of Mexico, North Sea, Mediterranean, West Africa, Red Sea, Persian Gulf, India, China and Southeast Asia.

On streamer vessels the seismic source is at the front of the streamers, and geophysical targets are illuminated with a limited range of azimuths. In OBS operations the source vessel moves across the survey area in preset patterns that illuminate the targets with azimuths from around the compass. And the shear-wave data recording that is possible only with four-component phones allows the direct measurement of some rock properties such as Poisson's ratio. Together these provide a superior geophysical visualization of structures that can be critical for management of a field over its life. OBS has come of age.

A new generation

The OBS cable systems of today were designed with the signal conditioning and digitization electronics in high-strength modules that provide protection against the harsh environment and against handling damage. These modules are placed between cable sections, and each sensor's signal is carried to the electronics modules on individual wire pairs. The number of analog wire pairs that can be placed in a cable, and the number of seismic channels in a module, limit the length of cable sections and ultimately the length of the cables. These long analog signal wires are particularly susceptible to electrical leakage caused by water intrusion into a section. With OBS technology finding increasing applicability, such limitations have become more and more significant. A new generation of OBS cable systems has been developed to address these issues. An example is shown in Figure 1.

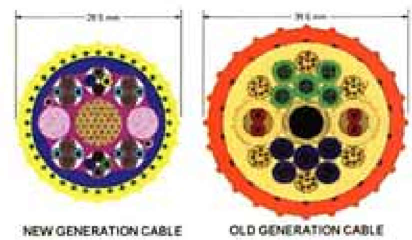

Figure 1. This diagram compares traditional OBS cables, right, with newer, smaller-diameter cables, left.

The new cable shown in Figure 1 has a much smaller diameter than that of the older-generation cable, but it may be routinely used in water depths of 1,000 ft (300 m) and even to 1,600 ft (500 m) in some circumstances, whereas the older cable is limited to water depths of 650 ft (200 m).

This improvement is possible in part because semiconductor components with higher levels

Figure 2. An OBS cable is squirter-tested to replicate cable retrieval forces from maximum depth.

of integration and significantly lowered power consumption are now available. Thus, architectures are possible in which the electronics are moved directly into the receiver points on the cable, eliminating the signal wires in the cable completely. Thinner cables are lighter, easier to handle and more flexible. They may also improve signal fidelity by reducing noise coupling from the cable.

But modern electronics alone are not sufficient to assure system performance. The working environment for OBS equipment is among the harshest anywhere. Not only will the cables be deployed and retrieved from the seabed hundreds of times in rough weather as well as in good, but speed of operations will dictate that these will generally occur at or near maximum loading. Further, they may be pulled from the mud, dragged over the bottom, banged into the hull, dropped onto the deck and so on. Nevertheless, geophysical operators rightfully expect that their investments in OBS equipment will provide them many years of useful service, even under these conditions.

Ensuring that OBS equipment is fit-for-purpose requires a good understanding of how that equipment will be used, in particular of the handling equipment and handling methods. Mathematical models, improved by years of empirical information, can then predict with reasonable accuracy the types of loading that the cables will experience. This serves two purposes: first, to establish design requirements; and second, to develop test equipment and methods that simulate field usage and loads. Such accelerated-life-testing is needed to ensure the cables will survive and perform well under the specified operating conditions. It includes tensile testing, drop testing and flexural testing as well as survival over overboarding sheaves and through traction engines, and the pressure on storage drums. Figure 2 shows a cable being tested with a squirter and with tensile back-loading set to replicate cable retrieval forces from maximum depth.

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Equipment reliability is paramount in achieving required productivity and cost-effectiveness. The inherent system reliability can be further enhanced by introduction of redundant power distribution and data telemetry. This is made practical by the removal of the analog signal wiring from the cables. This means the system will still be fully operational in the event that a power line fails and that data can be rerouted from path to path in the event of a telemetry failure. Such schemes can increase system reliability by a factor of 10.

Figure 3. Loop-back redundancy helps improve reliability in deep water.

New architectures have also made it possible to increase the number of channels in a cable, allowing much longer cables to be deployed, and the number of cables that can be deployed and managed from the same recording unit has also been increased. This allows seismic companies greater flexibility in designing their surveys to improve their logistics and shooting efficiency.

What next?

As production of hydrocarbon reserves moves further offshore into ever-deeper waters, field costs become enormous, and operators need improved means to maximize recovery from their fields. One of the most promising appears to be installation of a permanent seismic-receiver array that would remain in-situ and be used to provide seismic data for the life of the field. Such receiver arrays could be buried or trenched in the mud by means of remotely operated vehicles (ROVs). Installations in water depths of 6,500 ft to 10,000 ft (2,000 m to 3,000 m) are likely to occur in the not-too-distant future. The expense of deploying, positioning and burying these cables and the need for them to remain operational for 10 or more years will make extreme equipment reliability mandatory. The improvement in system reliability that can be achieved using critical redundancy has already been discussed. However, connecting the individual cables in loops as shown for the deepwater cables in Figure 3 can make further improvements in system-level reliability.

By connecting the cable ends together in this manner, protection against data loss can be obtained even if a cable is completely severed. Thus, overall system reliability can be improved by more than one hundred-fold over that of a system with no redundancy.

Deployment and retrieval strategies for laying cables at these depths will almost certainly be different from that used by conventional OBS crews in shallower water. Although all components must withstand the tremendous sea pressures at these depths, the forces exerted by the handling during deployment and retrieval may dominate the design approach. Once buried in the mud, however, the cables will be in a relatively benign environment for long-term survival.

Looking further ahead, there are other emerging technologies with promise. One is all-optical cables with optical hydrophones and optical geophones. At this time it is uncertain if such a system could match the performance of electronic systems; much has yet to be accomplished. However, if such systems were ever to be deployed, the OBS wheel would have turned completely 360° to its beginnings with an all-analog solution. To paraphrase Yogi Berra, it would be "déja vu all over again." E&P