The Evolution of an OBS Node – From North Sea Tests to Final Design

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Summary

A new design of ocean-bottom seismometer (OBS) system has been developed and tested that can provide high quality data in challenging deep-marine exploration and production areas.

Each node records the pressure signal with a hydrophone and three components of seafloor motion using geophones. The new units are self-contained recording stations, and are deployed by a remotely operated vehicle (ROV). They record seismic data on the seafloor for an extended period while a source vessel shoots lines above. Because they are autonomous, there are no cables joining the stations together. The nodes are therefore well-suited to working in congested waters, even right up to, or perhaps under, production structures. They also render 4D surveys practical because the ROV can redeploy the units close to their previous sites to ensure a high level of repeatability.

The new nodes are differentiated from other types by improved levels of safety and efficiency; this is inherent in the compact, long-endurance, integrated modular design. The units also deliver high vector-fidelity thanks to excellent coupling to the seabed.

We discuss the considerations, compromises, development and testing of these new OBS units.

Introduction

The world demand for energy is accelerating, while its reserves of energy are diminishing. Producers are compelled to explore and produce in more challenging environments and to maximize recovery in existing reservoirs. Application of technology has always been a key to success in such situations.

New seismic technology in the shape of ocean bottom seismometers (OBS) or “nodes” aims at imaging the blind spots of conventional methods and offers new options for reservoir monitoring.

OBS nodes offer wide-azimuth geometry, important for imaging structures under complex overburden such as salt environments. By moving the receivers to the seabed and recording a dense shooting grid on the sea surface we can create a dataset that is well-populated in azimuth and offset, and provides optimum subsurface illumination. Conventional towed-streamer acquisition cannot provide this type of dataset because of the constraints imposed by the fixed source-receiver geometry. However, the Wide-Azimuth Towed-Streamer (WATS) method can, and is becoming a popular technique. The relative benefits of OBS and WATS depend on survey size. OBS surveys are more economic on smaller areas, up to about 400 sq.km. Furthermore, OBS data offer some advantages: up-going and down-going waves can be separated at the seabed for multiple attenuation or for imaging using the multiples, while shear waves can be used to provide information about lithology and fractures.

OBS nodes are deployed by an ROV, and can therefore be placed very accurately. This affords the opportunity for surveying right up to, within or even under production installations. Accurate redeployment is also possible making nodes an option for time-lapse recording.

Development

OBS systems have been used for many years by universities and oceanographic research groups. Academic OBS units are autonomous and deployed in small numbers along sparse 2D lines. They incorporate a releasable anchor weight to make them sink to the seabed. One such OBS has an external geophone mounted on an arm. On contacting the seabed the geophone is released and placed a short distance away from the main OBS unit. The unit then sits on the seabed continuously recording all seismic activity. At a pre-determined time, or by acoustic release, the anchor is detached,
and the OBS units ascend to the surface under their own buoyancy. They are then recovered from the water and the data extracted for analysis. Such units are termed self-landing and ascending (SLA) OBS.

Veritas tested one of the leading brands of SLA-OBS in the North Sea during 2002 (Figure 1). Excellent data were recorded on a number of tests. However it became clear that the SLA-OBS technology would not allow successful up-scaling to the thousands of nodes required for 3D surveys. The size, weight and shape of the units, and in particular the method of recovery, would not be viable for large numbers. Disposable anchors are also undesirable for both practical and environmental reasons. With this in mind, we decided in 2003 to develop a dedicated unit for 3D OBS operations.

Two consultant companies were engaged to assist in the design and development of the new unit: Carrack for the node chassis and SEND for the recorder electronics. Carrack has years of experience designing OBS units and had already designed the very successful remotely-deployed geophones used in the 2002 tests. SEND has a strong reputation and extensive experience in supplying OBS recorders. The design goals were set very stringently. We needed an integrated unit, without externally-deployed geophones; it also had to be compact, easy and safe to handle in large quantities. The recorder would have to use minimum power, be able to record and store data for an extended period (up to 3 months) and have an accurate reference clock.

The resulting chassis design incorporates symmetry and a low centre of gravity, since these optimize coupling to the seabed. In essence, the result consists of a disc-shaped case, and maintains all the key features and considerations of the remotely-deployed phones used in the academic SLA-OBS systems, for example base-plate grooves and ribbing (see below). However, it was not possible to simply upscale the SLA geophone design, since this would result in excessive weight and compromise the required pressure rating for operation at the maximum desired water depth (4000m). This was addressed by adopting a rigid circular base-plate on which three separate pressure cylinders are mounted symmetrically (Figure 2).
The three cylinders contain the recorder and two battery packs. In this design, the pressure cylinders as kept as small as possible, resulting in the smallest wall thickness to support the external pressure; this in turn results in considerable weight-reduction compared to larger cylinder designs.

A fourth pressure housing contains an external hydrophone together with a three-component Gal’Perin geophone; the latter is arranged so that it is consistent with the triangular symmetry of the unit. The housing penetrates the circular base-plate coaxially, and the upper surface of the node is streamlined by a cowling that avoids snagging internal cables. The centre of the cowling is closed by a flat top-plate to allow an ROV suction handling system to be used for deployment and retrieval. The underside of the base-plate (Figure 3) has a symmetric arrangement of ribs/grooves that is similar to that used on the SLA-OBS external geophone. These ribs/grooves have the additional advantage that they help in channelling liquid mud out from under the unit as it is deployed, thereby allowing the unit to sink a few centimetres into the sediment and contact more consolidated material. The end result is improved horizontal coupling. The base and cowl have holes for water ingress to allow free flooding of the unit. Only the pressure cylinders are sealed and water-tight.

The triangular symmetry of the design and operating environment led to the adoption of the name “Trilobit” for the new nodes.

A number of other companies have recently developed OBS nodes, notably Fairfield in co-operations with BP on their Atlantis project (Beaudoin and Michell, 2006; Mitchell and Grisham, 2006). While there are obvious superficial similarities among the models, (e.g. circular shape, yellow colour for visibility, handling method), each has been developed independently and the internal design details are quite different.

**Testing**

Development continued through 2004/5 with tests of three prototype recorders and chassis design in August and November of 2005. The first field tests of production units took place in May – July 2006. Twenty Trilobits were deployed within the area of a conventional transition-zone (TZ) project. The survey was in shallow water (2-3 m), over a salt dome in southern Louisiana. Data were recorded from some of the TZ dynamite shots (5 kg at 50 m). Nineteen Trilobits were based on the production design; while one other prototype unit had the internal geophone removed and was connected to an external Carrack phone of the type used in the SLA-OBS, (the same design that had provided good results in 2002). The objective was to compare the data from the new untested Trilobits to the data from the tried-and-tested external Carrack phone. There were two deployments (Figure 4): in the first the water bottom was muddy, while in the second it was covered with pond weed and mud.

The test was conducted alongside an exclusive proprietary survey and we thank the client for the permission to deploy the Trilobits and record data from the shots. The client prefers to remain anonymous, but we have permission to present un-stacked data without imaging and stacking.
A sample of the data from the production design Trilobits is shown in Figure 5, from a single shot line recorded into one common receiver. PP reflections are clearly seen on the vertical (Z) component and hydrophone, early in the record with faster move-out. Shear waves (PS) are visible on the two horizontal (X and Y) components, later in the record with slower move-out. Hodograms of a PP and a PS event are shown in Figure 6. As expected, the PS event is predominantly horizontally-polarized, while the PP event is dominantly vertical. Significantly, there is no leakage of shear waves into the vertical geophone components. This has been a problem with OBC and some other node systems.

The low velocity noise cone corresponds to surface waves in the lake bed and is strongest on the two horizontal components. Hodograms of this noise event (not shown) are predominantly horizontally-polarized.

**Figure 4** Deploying a node in shallow water.

**Figure 5** Test data from an OBS node, data rotated to vertical.
Conclusions

We have successfully developed an OBS node that incorporates the necessary features for commercial 3D deployment. Our tests demonstrate that the unit is capable of providing high-quality data containing clear primary (or pressure) P and secondary (or shear) S waves. Most importantly, the units show good coupling and do not appear to suffer from cross-coupling of energy and allow good separation of P and S signals.

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References
