"Drop & Pop" 3C submersed floating OBN for cost-effective marine seismic acquisition

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Introduction

Ocean Bottom Node (OBN) systems have become an established technology for providing extended azimuthal illumination of subsurface targets and for recording long offsets diving waves. Most of the OBN 4C systems on the market are equipped with a hydrophone and 3-component geophones (or accelerometers) for PP and PS imaging capability.

It is well accepted, amongst the seabed seismic community, that a key prerequisite for high quality 4C OBN data is an effective coupling of the sensors with the seabed. This paradigm has guided the way OBN devices are designed and constructed as well as their deployment in the field. The most common deployment method in shallow water is the Node-On-A-Rope approach (NOAR) and in deep water, ROVs are utilized to accurately place the nodes onto the seabed, thereby guaranteeing an optimum coupling, especially for the directional geophones. These deployment requirements can make the OBN acquisitions expensive.

More recently, the widespread adoption of FWI technologies for velocity model building and imaging have increased the demand for OBN style acquisitions in a context of 3D exploration and 4D reservoir monitoring.

In this paper we present an innovative node design and deployment method that challenges the coupling paradigm discussed above and relaxes some of the traditional 3D/4D OBN survey design constrains.

The project was motivated by two simple questions: Can we make seabed sensor acquisition more cost effective by reducing the number of components and simplifying the deployment method? What will be the implication of such changes for 3D VMB/imaging using FWI and 4D reservoir monitoring?

The submersed floating node design and the "Drop&Pop" deployment concept

The effective deployment of multicomponent streamers, about 15 years ago, have shown that immersed geophones/motion sensors are able to record valuable information of the emitted seismic wavefield. It is therefore plausible that the same would be true if we would place a geophone into an autonomous seabed recording system, but instead of placing the unit on the seabed it would be tethered to an anchor line and floating just above the seabed. The imagined recording system is composed of two hydrophones separated by 1 meter and a geophone placed in between, facilitating two pressure measurements and the recording of vertical particle velocity using the natural gimble system (Figure 1). The three sensors are integrated into a short vertical array. The immersed system sits above the seabed and the positioning is maintained using an "organic anchor". The vertical stand is ensured by a positive buoyancy of the array using the Archimedes principle.

Note that the system doesn't include any horizontal component measurements (Vx, Vy) which means that PS imaging is not an option in our case. Most of today's OBN imaging projects use a combination of the recording of the pressure field (P) and a measurement of the vertical particle velocity (Vvertical) allowing to perform the wavefield separation into P-Up and P-Down, required for various imaging steps such as deghosting, up-down deconvolution, mirror imaging, etc.

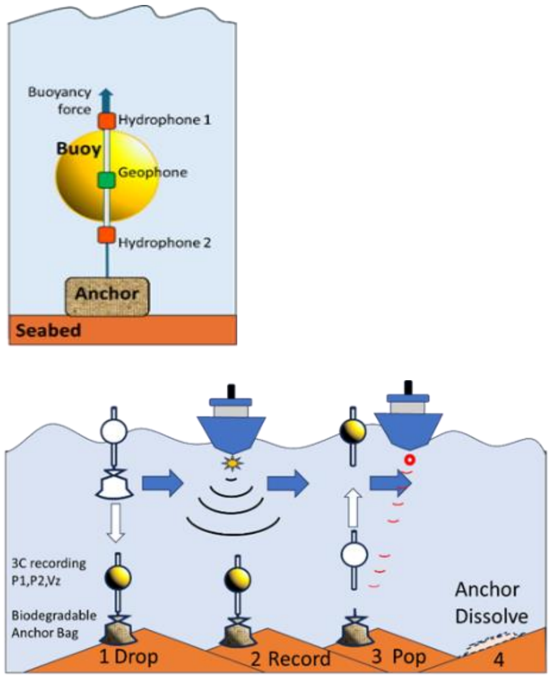

***Figure 1** The submersed floating node design and "Drop&Pop" deployment concept*

In our case, the pressure field P is given by the average of the two hydrophone measurements and Vvertical can be extracted either from the hydrophone differential or the built-in vertical geophone. We will analysing the various wavefield separation methodologies in a practical manner with real data from a field test.

Given the novel design of the 3C recording unit, a "Drop&Pop" node deployment is appropriate as it takes advantage of the absence of any coupling requirement. The deployment *modus operandi* consists of dropping the free-fall node from the sea-surface at a predetermined location. The biodegradable sandbags weight ensures the descent and the anchoring to the seabed. Once the survey is completed, a release mechanism, using a transponder, is triggered from the retrieval vessel. The recording unit is then released from the anchor, comes up and floats at the sea surface where it will be recovered. The "organic" anchor is left in the seafloor and will dissolve through the contact with sea water. The simplicity of the free-fall system makes the node deployment very cost effective as the rate of deployment is only limited by the operational vessel speed.

3D hybrid streamer/sparse OBN exploration acquisition

Because effective coupling is not a pre-requisite for arranging this seabed recording system, it makes the "Drop&Pop" deployment very efficient, from an operational point of view, for large sparse OBN surveys. Hybrid seismic exploration acquisition generally mixes towed streamers for imaging and sparse OBN for FWI velocity model building; the non-utilization of ROV for the OBN deployment/recovery will significantly reduce the operational time (and cost), especially in a deep-water context. The spatial sampling between OBN receivers can be relaxed when the main technology in use is FWI at low frequencies to effectively recover geological features, such as salt bodies. More than 1000 m OBN separation has been shown to be typically adequate for exploration velocity model resolution. The resulting high resolution FWI model is then used to image with the towed streamer data.

4D monitoring OBN acquisition

For any reservoir monitoring study, even with sparse OBN, it is important to ensure a good repeatability of the recorded wavefields outside the reservoir target. Heterogeneities in the shallow overburden are often responsible for generating non repeatable noise, often referred to "Vz noise" in the literature (Paffenholz *et al*., 2006). In fact, large variations of shear wave velocity near the seafloor generate surface wave perturbation which present a real challenge for 4D OBN imaging. By placing the recording instrumentation just above the seafloor, the impact of surface wave and shear wave noise on the recorded data is limited (Figure 2).

Consequently, the Vvertical raw data, recorded with the "floating" geophone, are cleaner, and the positioning repeatability constrains can be relaxed. Combined with advanced imaging technology such as 4D Least-Squares (LS) Imaging with multiples, the precise repeated pre-plot positioning becomes less critical.

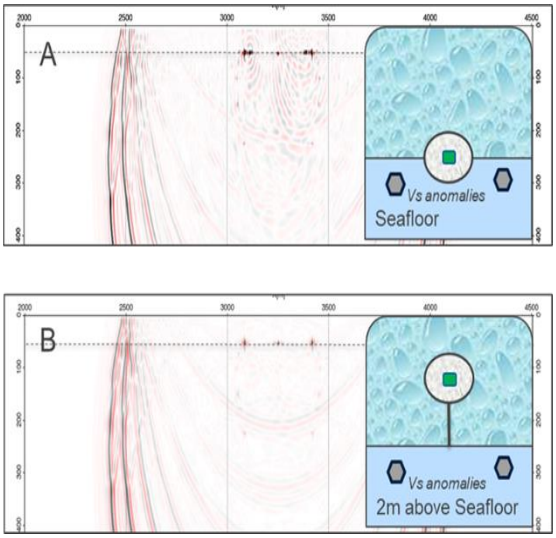

***Figure 2** 4D shear wave noise modelling for seabed coupled and non-coupled geophone. The shear wave noise is modelled by inclusion of Vs anomalies just below the seafloor (Paffenholz* et al*., 2006). The recording instrument positioned above the seafloor (B) is less sensitive to the overburden Vs artefacts.*

Data from the preliminary field test

Two prototypes of the floating nodes recording units have been built and tested during a multi-client steamer acquisition. Both systems recorded 3C data during several sail lines of a multisensor streamer survey where a triple source configuration was used (Figure 3).

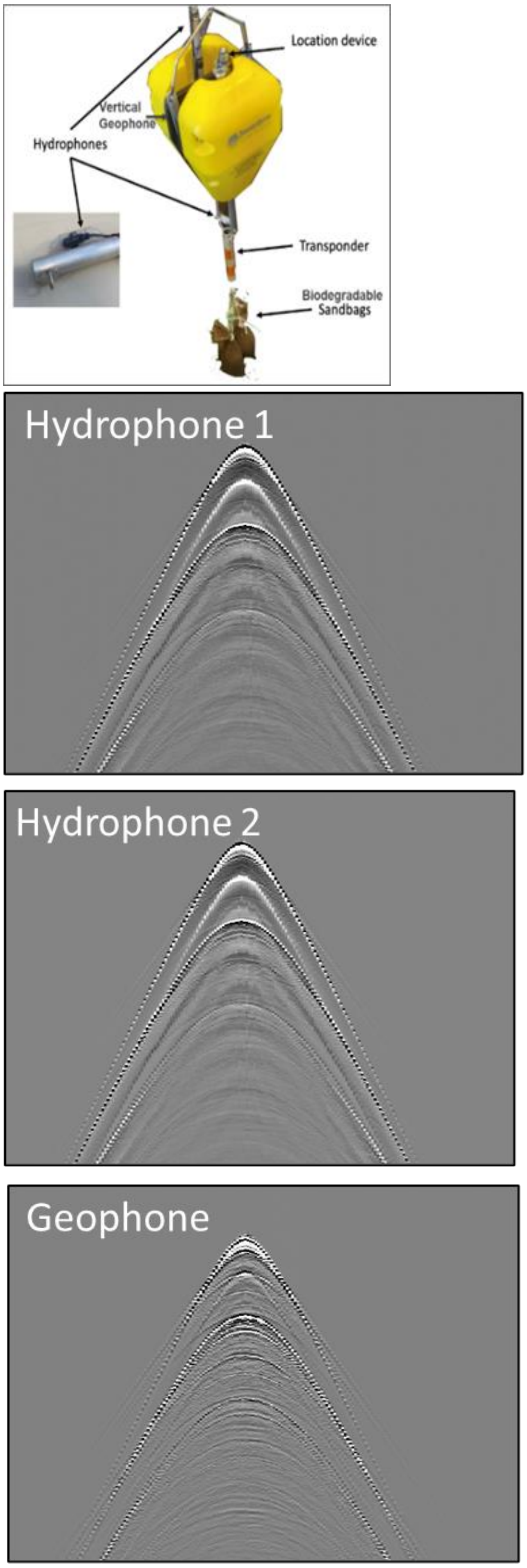

***Figure 3**: The submersed floating OBS prototype tested during a multi-client streamer survey. The 3 components data recorded by the submersed floating OBS*

Figure 4 shows the recording of the vertical geophone after some initial signal processing with a 5.5 km/s linear move out (LMO) applied. Clean reflected energy can be seen on the near offsets without any visible presence of shear wave noise. As for the far offset, fast diving wave energy can be observed all the way out to 25 km offsets.

Conclusion

We present an innovative submersed floating 3C recording system that has been designed for easy and cost-effective deployment to record high-quality (near) seabed data. The objective is to target sparse OBN acquisition in the context of 3D hybrid streamer/OBN exploration or reservoir monitoring. In 4D case, the floating nodes anchoring principle has demonstrable advantages by suppressing the non-repeatable coupling noise. The initial field test has shown some promising results with good quality reflected event and reliable refracted energy being recorded by the geophone sensor out to very long offsets. These preliminary results encourage application of such technology for sparse recording system either for large exploration objective or for reservoir monitoring using combination of 4D FWI and 4D FWM (imaging with multiples).

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References

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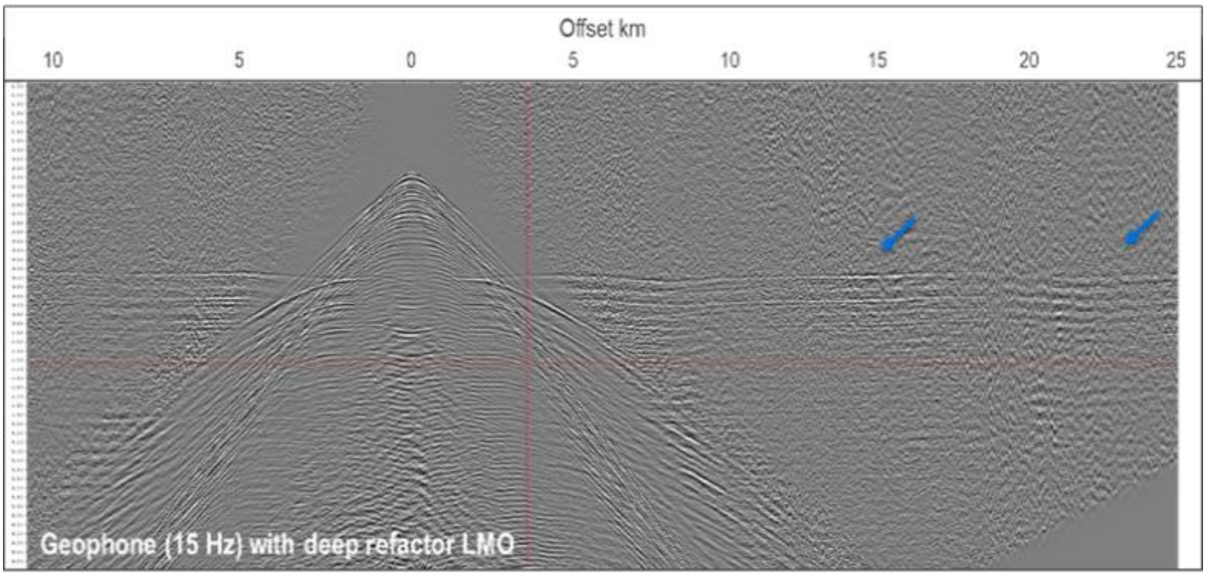

Figure 4: *Record of the vertical geophone along a sail line with a 5.5 km/s LMO. Deep Diving wave are pointed by the blue arrows.*