

Technology and economy of ocean bottom nodes on the first anniversary of the first 5C crew

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Summary

Ocean bottom seismometers and surface towed streamers are known methods. They each have well understood advantages and disadvantages. The most significant advantage of the streamers is their efficiency in covering large areas at a low cost per km square. While data quality and the usefulness of wide azimuth, demultiple, and shear waves is field specific and is often debated, a clear advantage of ocean bottom seismometers is our ability to use them in obstructed areas such as active oilfields. Nodes are better than cables in the presence of seabed obstructions. Streamers and ocean bottom seismometers therefore complement each other. If one adds a streamer element to an ocean bottom node crew, one can provide the two methods at the same time as a seismic monitoring snapshot. The point of this paper is to share the experience of a crew with both nodes and a streamer on its first anniversary.

Introduction

As oil companies' spend and demand for seismic services is gradually shifting from exploration to development and production, the seismic industry has been able to comply with this shift with surprisingly small changes to the methods. In particular, the same surface towed streamers are used for exploration and for reservoir characterization and monitoring. A typical seismic crew can complete a ten thousand km sq (3D) exploration survey, transit to an oil field, redeploy its streamers and sources with few changes and acquire a (4D) reservoir monitoring survey. The surprise is how few the changes are. Improvements such as solid streamers and more accurate streamer control and positioning are applicable for both the exploration and the development and production market segments. 15 years ago the pundits (as well as the authors of this paper who were too young to be considered pundits) believed that seismic reservoir surveillance would be very different from seismic exploratory surveillance. Namely, we believed multi-component receivers permanently deployed on the seabed would play a larger role.

Streamers, however, proved to be surprisingly adaptable, and the permanent seabed receivers revolution has not happened, at least not yet. In this paper we will review where streamers succeeded beyond expectation and where they did not. We will review a few ways in which the methods and the business may develop. We will focus on one method, which we call 5C that achieves, in our view, the best combination.

What is wrong with streamers?

A decade ago, pundits predicted that a few things would put streamers at a disadvantage compared to seabed sensors:

- (1) Streamers would not be possible in obstructed fields. Especially when the same vessels with many towed streamers utilized to cover large exploration areas is used for a reservoir project.
- (2) The repeatability of streamers data would be significantly inferior to that of permanent seabed receivers.
- (3) Streamers would not be able to provide the shear waves, which are useful for lithology and fracture characterization and for differentiating between fluid replacement and pressure effects in reservoir monitoring.
- (4) Images from streamers data would suffer from multiples significantly more than images from seabed receivers, which enable separation of up and down going waves.
- (5) Streamers are doomed to have narrow azimuths.
- (6) Repeated surveys in the same place would be less economical than permanent receivers.

We would like to offer our opinion where the pundits were right, and where it seems to us they were wrong

- (1) **Obstructions.** The pundits were partially right. It is of course true that multi-streamer vessels cannot and must not be used to close to surface obstructions. However, the typical oilfield is obstructed only partially. Most important are deep-water fields in which a single FPSO (plus an offloading buoy) and a few moving drilling ships, obstruct a small part of the field. Typically, a deep-water field would require a few hundred km sq of seismic data including so called migration aperture. The obstructed area, which is inaccessible for streamers, would typically be only a few tens of km sq. Moreover, vessel with one or two streamers can access more of the obstructed area than vessels with a greater number of streamers.
- (2) **Repeatability.** Streamers proved to be more repeatable than expected, and methods such as overlapping the most external cables have been developed to improve their repeatability. Repeatability of raw streamer data seems poor because of the limited ability to repeat streamers positions accurately (even when they are steered because of limited ability and noise generated by the steering). However, data processing proved very able to compensate for reasonable positioning differences and provide

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- repeatable images with slightly different positions. Only gross differences in positions in the presence of a complex overburden cause poor repeatability. Overall the surprising repeatability of streamers has eroded much of the motivation to deploy sensors on the seabed. Moreover, seabed receivers proved to often have more problematic coupling than expected years ago. Cables and stations on the seabed with gravitational coupling proved to be problematic because they often provided poor shear data and shear induced noise on the vertical component. Even when cables are trenched into the seabed vector fidelity is often poor because trenching disturbs the seabed and the cables are not well coupled to the trench. Only well coupled seabed receivers that are planted individually by a remotely operated vehicle (ROV) have an advantage over surface towed streamers. In some fields this advantage can be significant.
- (3) **Shear waves.** Shear waves do not travel in water and therefore streamers cannot record them, even if the streamers have multi-component sensors. However, Amplitude vs. Offset (AVO) methods provide valuable attributes that enable estimation of shear properties and lithology using P waves alone. Also, the poor coupling of early seabed systems prevented full utilization of shear waves and it has not been clear whether OBC has been better than AVO for shear reflectivity and for lithology. Processing and interpretation methods have been slow to develop for shear waves. Partly because of challenges like P and S velocity and anisotropy model building, and partly because interpreters could get the information from AVO and found little reason to completely change their work flow and methods so they can interpret images which have a different vertical dimension due to the different arrival time of reflected P and S waves. With better coupling of individually planted nodes and with progress in data analysis methods and availability of software shear waves may become a significant factor in the near future.
- (4) **Multiples.** Ocean bottom sensors indeed provide separation between up and down going waves using addition and subtraction of hydrophone (P) and geophone (Z) data. PZ combination is very useful for multiple attenuation and for imaging with multiples on the receiver side. Often multiples arrive at the same time as primaries and this is a significant factor.
- (5) **Wide azimuth.** It was always known that if the streamer and the source vessels are separated wide azimuth is possible. However, the wide usage of wide azimuth towed streamers (WATS) was not predicted until it actually started to happen. So streamers are capable of providing wide azimuth data with the associated benefits of imaging under complex overburden (sub salt), multiple attenuation, and fracture characterization. WATS cost is higher than narrow azimuth because instead of a single vessel covering an area in a single pass, it requires a few vessels covering the same area again and again. For small areas it is likely that nodes are cheaper than WATS. However, WATS are limited to unobstructed areas.
- (6) **Cost.** This is always last and not least. A multi-streamer crew can cover a large area, up to 100 km sq in a single day. This is because the wide tow of multi-streamers allows the vessel to cover the area with a few passes separated by hundreds of meters. An ocean bottom survey, requires a wide azimuth shot carpet. It does not matter if the ocean bottom sensors (OBS) are permanent or redeployed. Early attempts of OBS surveys with sparse shots for example with cross spread geometry, have by and large found to provide insufficient data quality for reservoir characterization and monitoring. In the last few years most OBS surveys have been done with sparse receivers and dense shots. Compared to streamers, the difference in productivity between a streamer crew and a source boat is almost an order of magnitude and is larger than the difference in the daily rate of the two vessels. There is no way OBS can be more economical than streamers in unobstructed area. The economy of permanent vs. redeployed OBS requires further discussion. The cost of deploying and maintaining a permanent ocean bottom cable (OBC) is much larger than the cost of deploying ocean bottom nodes (OBN) once. When it comes to repeating the survey over and over again many times, the economy has to be considered more carefully. It seems like the cost of deploying a permanent OBC in a single field is comparable to the cost of getting together a new OBN crew. If you have \$150M to spend, would you invest in instrumenting a single field or would you mobilize a crew that can provide surveillance to the field you think you want to monitor plus some other fields?
- To summarize, not much is wrong with streamers. OBS have certain advantages, and probably the crucial one is accessibility to obstructed areas, but the advantages of streamers in providing a low risk and fast coverage are overwhelming and seem to warrant an attempt to continue to use them as much as possible.
- ### The five-component method
- OBS data are usually called 4C because they record the three components (XYZ) of the vector wave field, be it particle velocity or acceleration, and the scalar pressure. About one year ago, a special seismic crew was mobilized. This crew has some hundreds of nodes along with the ROV that deploys them and the seismic source that shoots into them. Most such 4C crews do not have a streamer element.

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However, as one client expressed it “it is a crime not to record the near offsets as we are doing the dense shooting”. The crew that started operating in summer 2008 has a surface towed ministreamer streamer. The streamer element, which is systematic in addition to the 4C, is of course the fifth component. The ministreamers provides near offset data that is missing with sparse receiver geometry. Although mirror imaging can substitute for the lack of near offset data, the streamer behind the source vessel provides a much wider area coverage because the shot carpet extends for a margin of a few km around the receiver patch. We think that the added value is worth the additional cost in having full-length streamer behind the source vessel.

A real time image from the streamer is also useful for quality control for noise and source.

To provide a dense shot carpet for the sparse nodes and at the same time a dense midpoint coverage from the streamers, the number of sources and the number of streamers on the source vessel has to match. For example if we use a typical exploration set up and deploy a wide tow of 10 streamers separated by 100 meters behind the source vessel then the distance between the source lines would be 500m—it will not be a shot carpet. In addition a 10-streamer vessel would not be able to make close passes near obstructions compared to a vessel with no or fewer streamers. In practice, the geometry can be dual source and dual streamers. Such dual-dual provides carpets of both shots and midpoints. It is possible to have a multi-streamer vessel on the crew and use her full capacity away from the nodes out of the margin required for the shot carpet (typically 3-5km away from the edge of the node patch). Then have all but two streamers pulled in as she is doing the shot carpet. And pull another streamer or the remaining two for close passes.

One of the problems of autonomous nodes is clock drift. There is no radio communication in water so the nodes cannot be told when to start recording. They are recording all the time and keep the time. Each one of them is keeping the time with its clock which drift compared to the GPS clock that the shots are using. Even the best clocks drift and over the period of months the clocks can drift a few milliseconds and more. We find the main problem is not technical but a natural obsession of clients with clock drift. In addition to measuring the drift and the clock frequency at deployment and at retrieval, the seismic shots themselves can be used to synchronize the clocks. This can be done even when the positions on the nodes and the shots must be corrected and in the presence of tide and water velocity variations.

Nodes enable coverage in the obstructed areas while the streamers enable economical coverage of the most of the

area, which is unobstructed. Of course we depend on data processing to provide seamless images and seismic attributes from the different modes: surface P waves, seabed up going P waves, seabed down going P waves (mirror imaging) and shear wave recorded on the seabed in the obstructed areas. The shear waves can be useful to calibrate the AVO from the streamers so that AVO attributes can be checked against shear waves reflectivity, and V_p/V_s ratio which are needed for generation of AVO attributes can be measured by registration of PP to PS events. Likewise the demultiple power of PZ combination can be useful to identification of multiples. The wide azimuth geometry in the node covered areas may be useful for identifying how fractures would look like on streamer data.

Conclusions

The 5C crew, whether an all in one boat concept or in two or more vessels, enables the best of both OBN and streamers methods. The economy of streamers over the majority of the area and the advantages of nodes in obstructed areas.

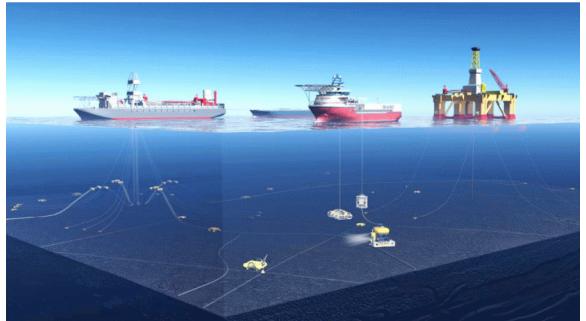


Figure 1: Simultaneous seismic, drilling, and production operation. The ships are from left to right, a floating production and offloading (FPSO), a tanker onloading crude from a buoy connected to the FPSO (the buoy is not shown), a seismic vessel deploying ocean bottom nodes (OBN) using a remotely operated vehicle (ROV) and a drilling rig.

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Figure 2 (left): A 5C seismic vessel shooting close to a production platform. This vessel also carries OBNs, an ROV (seen just left of the center) and a surface ministreamer

Figure 3 (below): A design for a 5C survey. The node patches around the obstruction are in yellow. The shot lines are in blue and purple according to their direction and the green lines are the turning tracks.

