Combined Ocean Bottom Stations and Streamers

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Abstract

We propose to combine sparse multi-component (MC) seismic data with dense single component (1C) data. Such a combination provides the best of both: cost effective imaging and AVO analysis from the streamers, together with cost effective VP/VS ratio and MC AVO from the multi-component ocean bottom stations.

Introduction

MC seismic data have been acquired on the seabed for over a decade. Compared to surface towed streamers, such data are of higher cost but have the promise of additional value. The list of promises is long: imaging through gas clouds and mud volcanoes, multiple attenuation, imaging reflectors with low P impedance contrast and improved ability to characterize lithology and fractures. After over a decade we can point to some technical successes. However, MC technology is used marginally and the commercial viability of providing an MC service is a promise yet to be delivered. Why?

One problem with MC is data quality. Ocean bottom cable (OBC) data sometimes do not have the fidelity needed for detailed analysis. Another problem is lack of analysis methods. However, the main problem with seabed data is that streamer data are not only too cheap but also too good. Many of the promises of MC data can be delivered by long offset and wide azimuth 1C data. For example, low normal incidence P impedance reflectors can be imaged with long offset streamer data. In general, streamers give seabed seismic a good run for its money leaving too small a niche to be commercially viable.

In this paper we present an idea for a type of seismic service, which is currently not offered. Rather than attempting to replace streamers altogether, we propose to add sparse multi-component data to the streamer data.

Combined Ocean Bottom stations and Streamers (COBS) data example

Last year VeritasDGC acquired and processed such data in the North and the Norwegian Seas. The COBS surveys were carried out by the Veritas Vantage and the SeaBird (Figure 1). A score of self-landing and ascending SLA-OBS (Buttgenbach et al, 2002) were used. The SLA-OBS were deployed, serviced, and retrieved on the Sea Bird (Figure 2).

The data acquired was of high fidelity. Pressure and Vertical data (after 3C rotation) contain excellent PP data and no PS data (Figure 3). The horizontal radial and transverse components contain excellent converted waves PS data (Figure 4).

Figures 5-6 show stacks of the hydrophone P and vertical V data. These are overwhelmed by multiples. The P component and the V component data were combined to produce images from up-going and down-going waves (Figures 7-8). Further demultiple processing after the PV combination produced the migrated PP-wave image shown in Figure 9. The multiples are very much attenuated. The image from the streamer data (Figure 10) is superior, however. The lack of P and V components on the streamer data is more than compensated by higher fold.

Figure 11 shows a migrated image of the stack of the horizontal radial component.



Figure 1 The vessels doing the summer 2002 COBS surveys. The Veritas Vantage, a 93m, 8200 ton 3D seismic vessel (on her maiden voyage for the COBS survey) and the SeaBird, a 35m, 300 ton chase/hospital boat mobilized for OBS deployment, service, and retrieval.

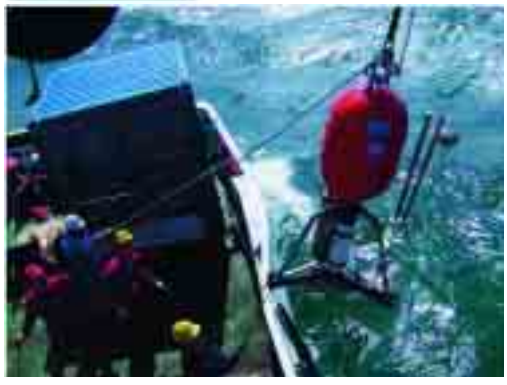


Figure 2 Deployment of an OBS in the North Sea from the SeaBird.

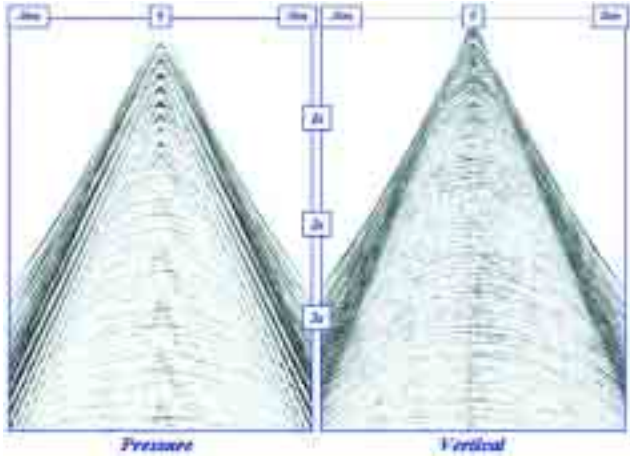


Figure 3 The two P-wave (PP) components. Pressure from the hydrophone and vertical velocity from the geophones. The vertical component is after rotation accounting for the deviation of the three-component geophone package from vertical. (Data from Quad 15 in the North Sea.)

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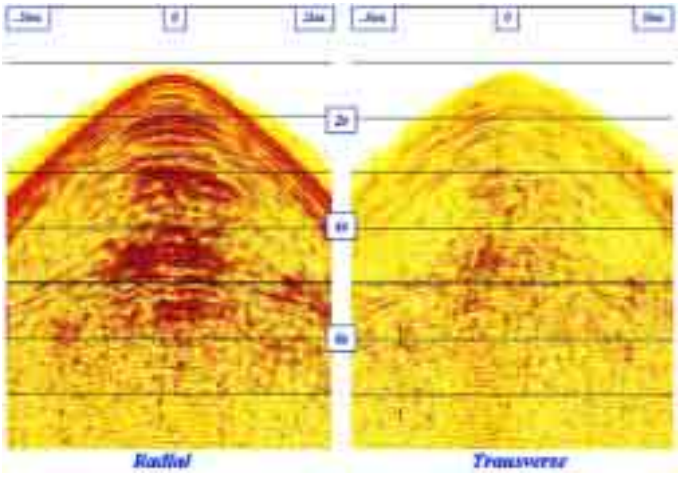


Figure 4 The two converted waves (PS) components. Data from the 3C geophone rotated into horizontal radial (left) and transverse (right) components. (Data from Quad 15 in the North Sea.)

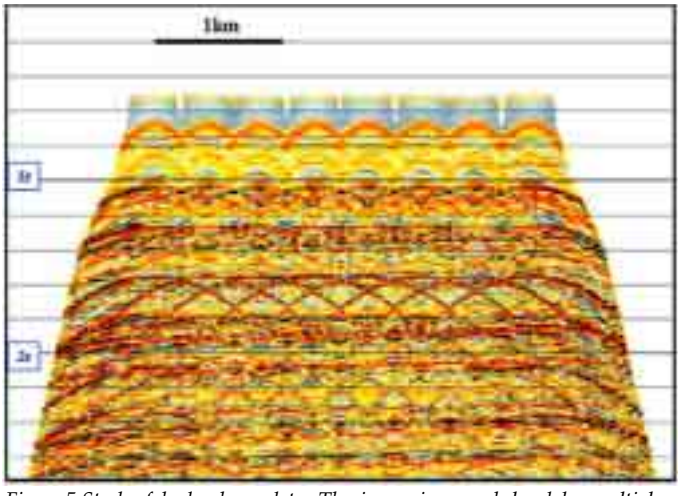


Figure 5 Stack of hydrophone data. The image is overwhelmed by multiples, which are easily recognizable due to their slow moveout, for example at 1.6 seconds. (Data from Utgard area in the Norwegian Sea.)

AVO analysis of streamer data depends on a priori VP/VS ratio, which is usually provided by well data. The sparse seabed data provide VP/VS ratio from moveout velocity analysis and from PP and PS event linking. Thus COBS provide an alternative to well data. In addition, the direct measurement of PP and PS AVO from the seabed data can be used for joint PP and PS inversion to validate and calibrate the 1C AVO. COBS can thus substitute for VSP and well log data to provide VP/VS ratio and calibration of the attributes generated from AVO and inversion of 1C surface seismic data.

The sparse MC data provide excellent Azimuthal Anisotropy analysis (Figure 12). Our analysis method I based on the observation of Garotta and Granger (1988) that the transverse component data flip sign on when the shot-receiver azimuth is in either of the S1 or S2 azimuthal anisotropy directions. This information is very valuable for fracture and lithological characterization and can be further enhanced by collecting streamer data in multiple azimuths.

After our North Sea operation in summer 2002, we learned that Rob Stewart (personal communication) was involved in a contemporary OBS operation in the east coast of Canada in the White Rose area. Stewart and ourselves predict and observe similar benefits.

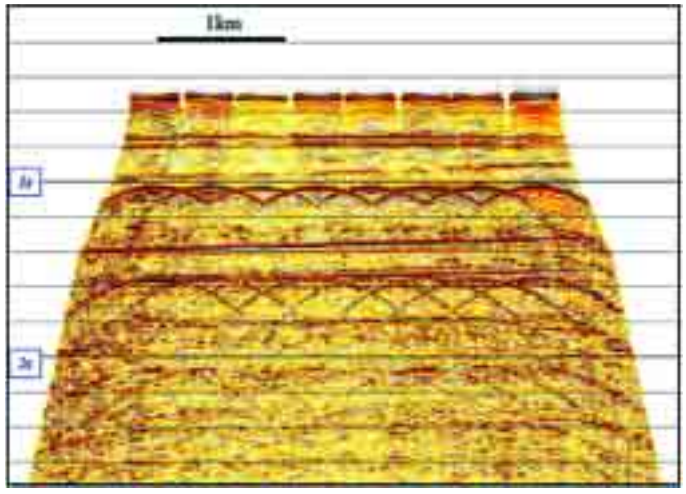


Figure 6 Stack of vertical geophone data. The multiples are not as strong as on the hydrophone stack (Figure 5) but this product is still not useful. (Data from Utgard area in the Norwegian Sea.)

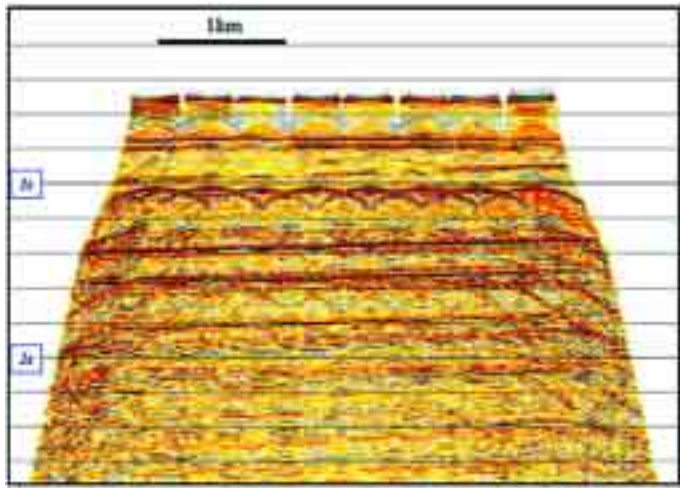


Figure 7 Stack of up-going waves. The pressure, P, and the vertical component, V, were combined to separate up and down going waves. The up-going waves do not contain one kind of multiples: the multiples, which have a bounce on the seabed on the receiver side. All other kinds of multiples, including peg-leg multiples on the source side are present in this PV combined image.

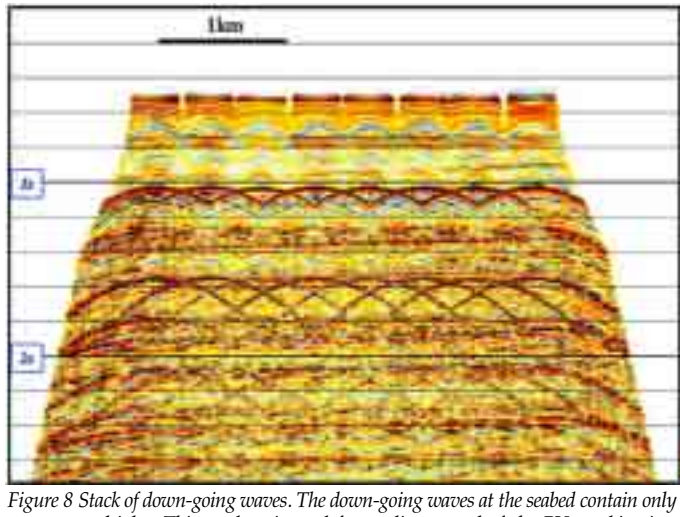


Figure 8 Stack of down-going waves. The down-going waves at the seabed contain only multiples. This product is used for quality control of the PV combination. Remnants of primaries, such as the very faint event at 1.3 seconds are mainly due to imperfect match between the geophone and the hydrophone.

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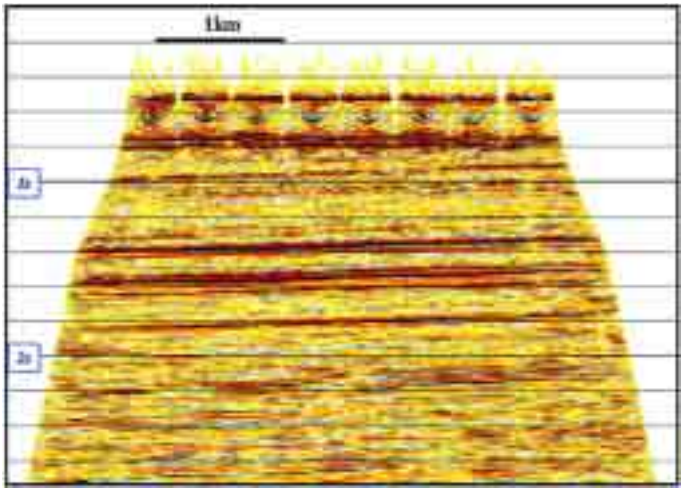


Figure 9 Migrated PP-wave image. The PV combined data were subject to further demultiple processing (compare to Fig 7). (Data from Utgard area in the Norwegian Sea.)

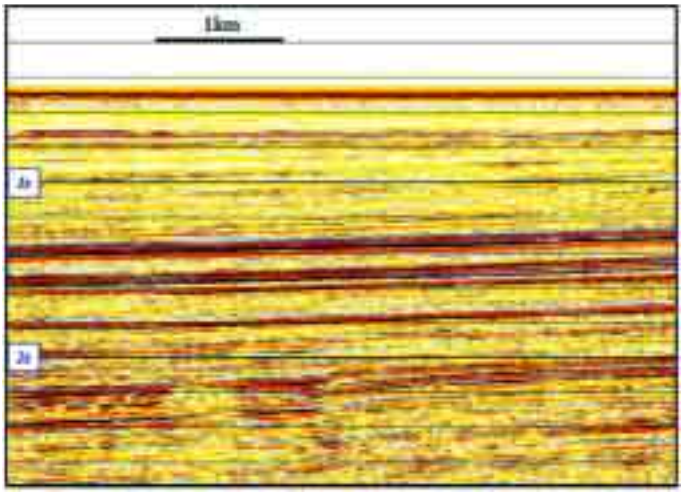


Figure 10 Stack of streamer data in the same locations of Figures 5-9. Compared to the final PV (Fig 9) the higher fold of the streamer data more than compensates for the lack of geophones on the streamer.

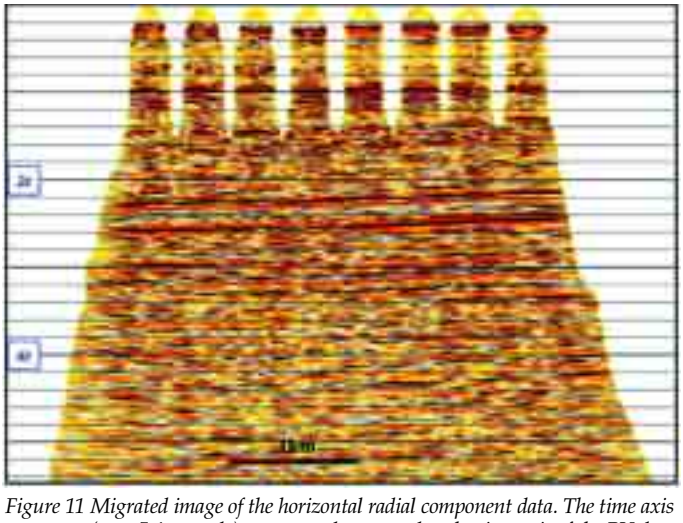


Figure 11 Migrated image of the horizontal radial component data. The time axis (max 5.4 seconds) compressed compared to the time axis of the PV data (max 2.6 seconds in Figures 5-10). (Data from Utgard area in the Norwegian Sea.)

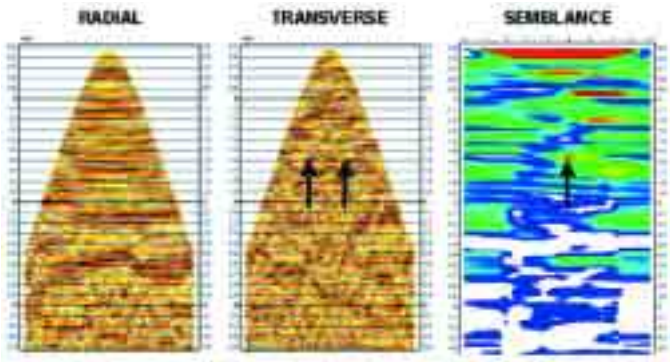


Figure 12 Azimuthal Anisotropy analysis picking the transverse component sign flips aided by semblance. (Data from Utgard area in the Norwegian Sea.)

Onshore?

There are no streamers and no ocean bottom onshore. However, the idea of combined multi-component and single component data is of course applicable there as well. The economy onshore is different; the price differential between single component and multi-component data (taking into account the permitting, surveying, and shooting) is much less than the price difference between streamers and seabed. However, it will be (at least) a few years before all land crews will be multi-component. Meanwhile, it is possible to add sparse multi-components elements into single component surveys. The main challenge is the combined data analysis and this challenge is common offshore and onshore.

Photographic Analogy

A 20 year old analogy attributed to Cam Wason, then head of GSI research is that single component data are like black and white photography; reliable, sharp, and cheap. Multi-component data were compared to colour photography; not as sharp, more expensive, but were going to replace black and white. There are many limitations to this simplistic analogy. However, we would like to conclude this paper with a photographic demonstration. (Figures 13-15).



Figure 13 Wason's analogy: Single component image is analogous to black and white photography.



Figure 14 Wason's analogy: Multi-component component image is analogous to color photography.



Figure 15 COBS data are analogous to black and white combined with some color patches.

Summary

COBS provide great additional value for a small additional cost of acquiring and analyzing 1C streamer data. They have a much higher added value per added cost compared to conventional MC data from OBC. The benefits include improved lithological, fluid, and fracture characterization, improved illumination sub salt/basalt, and multiple identification. R

References

Buttgenbach, T., Schleisiek, K., and Ronen, S., 2002, *Self-landing and ascending OBS: opportunity for commercial seismics in ultra deep sea: First Break*, 20, no 12, 770-772.

Garotta, R. and Granger, P. Y., 1988. *Acquisition and processing of 3C x 3-D data using converted waves*: SEG Annual Meeting Abstracts, Session S13.2.

Ronen, S., Ratcliffe, A., Nicholls, P., Mills, K., Leggott, R., Hawkins, K., and Scott, L., 2003. *Combined ocean bottom stations and surface towed streamers*. EAGE Annual Meeting. Paper C37.