

Image enhancement through conditioning of Vertical component data in OBC survey - A case study

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Abstract

The receiver ghost for ocean bottom recording, unlike a towed streamer ghost, generates notches in the seismic pass band. Fortunately, the positioning of dual sensors on the sea bottom presents an opportunity for removing the receiver ghost and reverberation sequence whilst producing a single combined output from the hydrophone and geophone. The basic principle is that the hydrophone measures a scalar pressure response, which is unaffected by the direction of propagation, whereas the vertical geophone measures a vector response, giving a polarity change between up and down going energy. The vertical component of the geophone OBCZ provides the major contribution to the improved OBC image. The OBC data have a lower level of multiple contaminations because of the contribution from the OBC Z component, together with an effective suppression of receiver-side water-column reverberations as a result of the combination of the OBC hydrophone and geophone traces, i.e. PZ combination. However, the dual sensor data is contaminated with Noise and /or imperfect receiver coupling. This paper dealt with the necessary pre-processing of the data before the summation to enhance the signal to noise ratio by eliminating the various noise viz. scholte wave, trapped energy etc.

From the result of the OBC data reprocessing in the study area, the dual-sensor summation has proved its effectiveness in providing broadband, high resolution reflection data without the potential contamination of water-column reverberations or ambient noise. This is evident from the preliminary 3D cube time slices generated, and the imaging is encouraging. The OBC dual-sensor technology is certainly an innovative technology for high resolution seismics.

Introduction

Dual sensor recording uses co-located hydrophones and geophones consequently, when traces from these are suitably combined, the receiver ghost tends to cancel, and the reverberation problem is attenuated. It can be seen that the two spectra are complementary - where there are notches in one, there are peaks in the other. Hence frequencies missing from the notch in the hydrophone spectrum are supplemented by a peak in the geophone spectrum. Summing the two signals removes the spectral notches yielding a much more desirable spectrum. The OBC method has the advantage of obtaining coverage in congested producing fields clustered with platforms, pipelines, and drilling rigs, where towed source vessel operations are difficult or impossible. It is also suited to shallow water, lakes, bays and rivers. It offers a range of benefits including higher signal bandwidth, high spatial resolution, low noise, minimum down-time, design flexibility, improved near surface solution, full coverage in obstructed areas, and virtually unlimited offsets. An additional benefit is wavelet stability. After removing the harmful effects of the receiver ghost, stable wavelet remains, which are independent of water depth and provides for much more detailed stratigraphic analysis. A main benefit of the dual-sensor is the improved frequency range, or bandwidth, achieved over other methods. Increasing bandwidth allows resolution of thinner beds. Marine streamers record a receiver ghost, which affects the higher frequency parts of

the spectrum, reducing bandwidth. Since the receivers are located on the water bottom, potentially all the water layer reverberations may be eliminated with the ancillary benefit of extracting the relative water bottom reflectivity. Having eliminated the ghost, the dual-sensor data can be richer in higher frequencies. The geophone contribution usually improves low-frequency content as well.

Many existing techniques for processing dual sensor data assume that the recorded data composed of noise free signals recorded by ideal hydrophones and

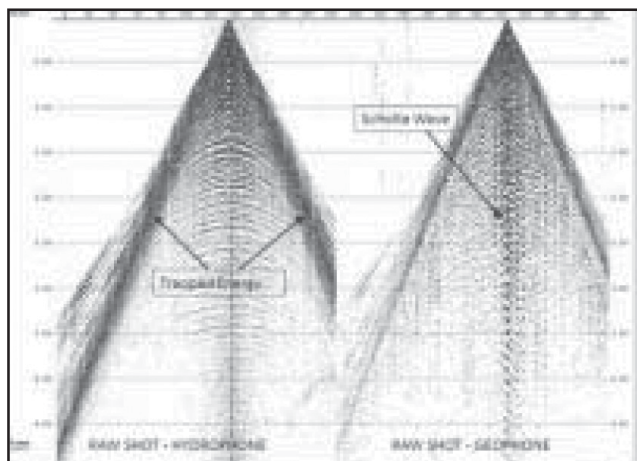


Fig. 1: Raw shot depicting various types of noises. Left- Hydrophone Right-Geophone

geophones well coupled to the sea floor. However, real seismic data are contaminated by source side reverberation as well as both random and coherent noises. Geophones are particularly susceptible to noises such as converted and cable noises (Fig.1). These noises may represent a significant portion of the total recorded geophone energy and can deteriorate the summing process. Ocean floor coupling of the geophone may also vary significantly due to local conditions, causing wide variation in the amplitude of recorded signal and noise. Direct implementation of summing theory is difficult unless these noises are correctly accounted for.

An attempt was made to remove such noises of an OBC data of Western Offshore Basin, ONGC, India. To achieve this, various noises eliminating process had been applied to hydrophone data and geophone data separately which yielded a better reservoir characterisation in comparison to vintage data. The results are very encouraging as is evident from the time slices generated through 3D cube as well as in sections. (Fig. 7, 8, 9, 11, 12).

Conditioning of Data

Various types of coherent and random noises are present in both hydrophone data and geophone data as stated earlier. These include Scholte Wave, trapped guided wave, noise bursts, spikes etc. Some of the noises are dominant in vertical component data especially random

noise which obscures the hyperbolic events, separate processing methodology was adopted to pressure (hydrophone) and vertical (geophone) component data. After navigational data merging, hydrophone and geophone data were separated based on their phone_id. Following table shows the processing sequence applied to the data to achieve better summation.

Each of the noises present in the data were handled separately. After removing the random noises and coherent noises from hydrophone and geophone, the data was summed. Three set of dataset was prepared from CDP sorting onwards. The three datasets were a) Hydrophone data b) Geophone data and c) Summed data. Each dataset processed with identical processing parameters after cdp sorting. The steps involved were minimum phase conversion of the data, spherical divergence correction, tau-p deconvolution, interpolation of the missing offsets and initial velocity analysis on hydrophone data. PSTM was carried out on all the three data type viz. Hydrophone, Geophone and Summed data using horizon based velocity and kept all the parameters identical.

Results

Processing the hydrophone and geophone data separately gives a very good quality of data which can be treated as noise free data and their summation removes water column reverberation effectively. Fig.2 shows the output of fx-dip filtering and median filter application. These filters very efficiently removed the random noise part and thus enhanced the continuity in hyperbolic events especially in geophone data (compare to Fig.1).

1.	REFORMATING (SEGD to Internal format)
2.	SPS MERGE, DELAY CORRECTION, EDITING
3.	SEPARATION OF HYDROPHONE AND GEOPHONE DATA
4.	FX-DIP BASED FILTERING IN SHOT DOMAIN
5.	TIME FREQUENCY BASED NOISE REMOVAL
6.	NOISE BURST ELIMINATION
7.	ENSEMBLE EQUALISATION
8.	RANDOM NOISE ATTENUATION
9.	SUMMATION OF HYDROPH, & GEOPHONE IN SHOT DOMAIN
10.	CDP SORT
11.	MINIMUM PHASE CONVERSION
12.	SPHERICAL DIVERGENCE CORRECTION ($T^{*1.5}$)
13.	TAU-P DECONVOLUTION (PD= 12, OL 300ms)
14.	XLINE OFFSET INTERPOLATION
15.	HORIZON BASED VELOCITY ANALYSIS
16.	PSTM (KIRCHOFF'S EIKONAL); APER 6KM X 6KM
17.	RADON DEMULTIPLE
18.	MUTE
19.	STACK
20.	SIGNAL ENHANCEMENT (SLANT APPROACH)
21.	TVF 0-1200 ms: 5-10-80-100 Hz, 1400 2500 ms: 4-8-70-90 Hz, 3000 5000 ms: 3-6-60-80 Hz

Table 1 Processing sequence applied to OBC data

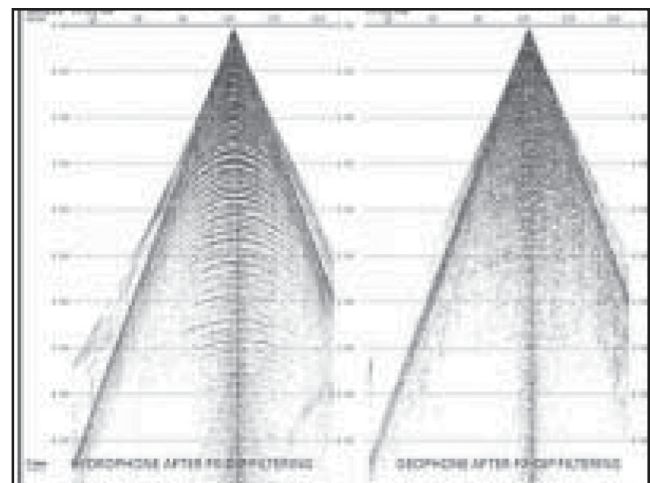


Fig. 2: After application of fx-dip and median filter on the same shot shown in fig.1.

Since, OBC recorded data always shows a strong trapped guided waves, it is utmost important to attenuate such energy before summation otherwise it spoils the calibration in summation.

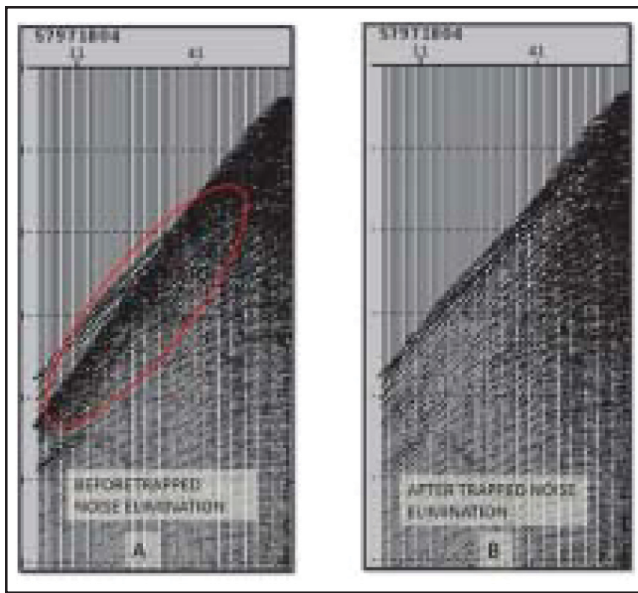


Fig. 3: Reduction of trapped energy in time frequency domain. A – before and B- after

This is very efficiently achieved through noise reduction in time frequency domain (Fig. 3).

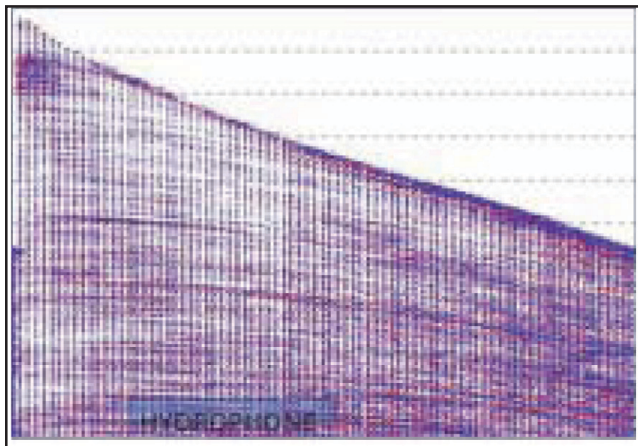


Fig. 4: Final CDP gather- hydrophone only

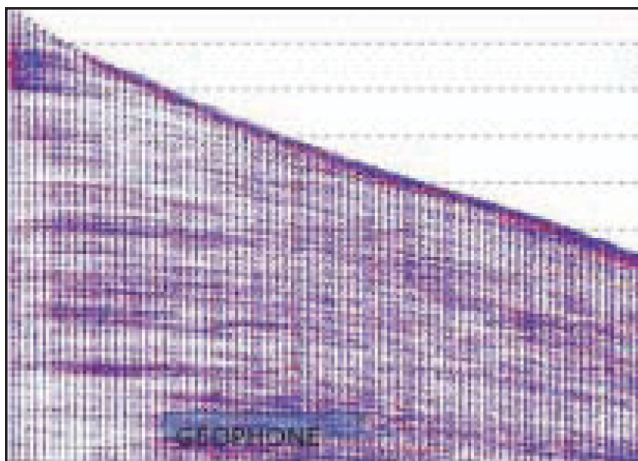


Fig. 5: Final CDP gather- geophone only

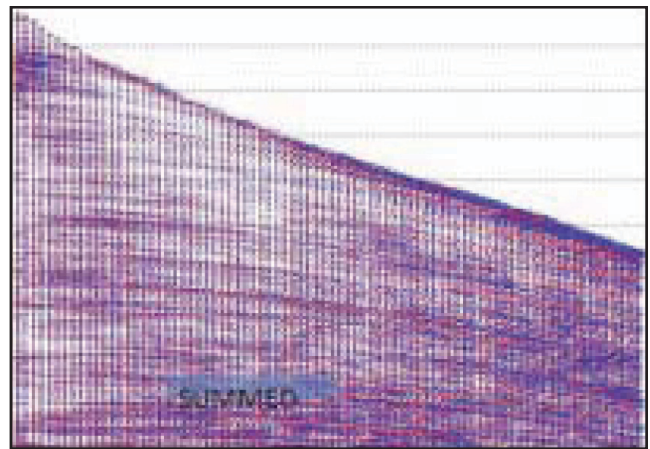


Fig. 6: Final CDP gather- summed

Fig.4 to 6 shows the results of one cdp gather each from hydrophone, geophone and summed data respectively after application of various noise elimination processes and tau-p deconvolution.

All datasets were subjected to PSTM separately and their results were shown in Fig. 7, 8, 9 as time slices. It was observed that both hydrophone and geophone data has some reverberation present in the data which depicts that their wavelets are not distinctly resolved.

Geophone data is fairly good at lower frequency part while hydrophone data is at higher frequency end (Fig. 10). Residual notches in frequency due to water column reverberation were handled fairly well through deconvolution for these noise free datasets. The summed output shows best resolution and hence corresponding amplitude anomaly distribution. The reprocessed PSTM section is comparatively noise free and shows more clarity in

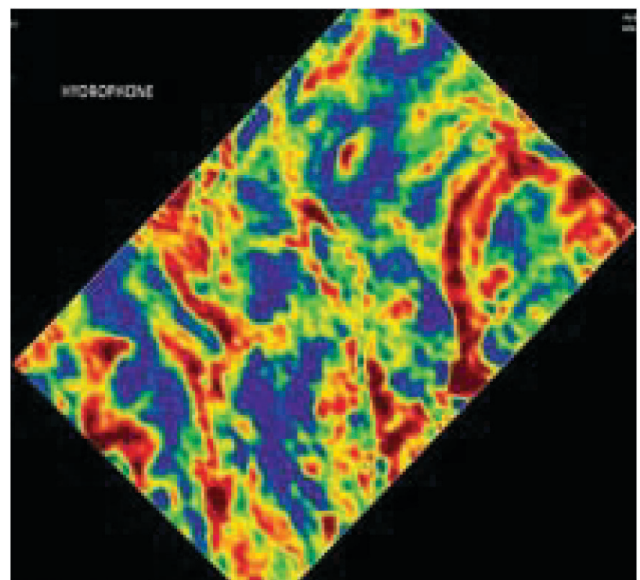


Fig. 7: Time Slice at 2200ms from PSTM-hydrophone cube alone

Conclusion

There is not a single algorithm that can remove all types of noise in seismic gathers according to our analysis. It is rather the combination of a number of different techniques, each adapted to the specific problem will lead to optimal de-noising results. The result after de-noising hydrophone and geophone data separately for all possible noises and then summing the data has tremendously improved the signal to noise ratio in the gather and thus helps in pre-stack attributes generation for modelling in reservoir characterisation.

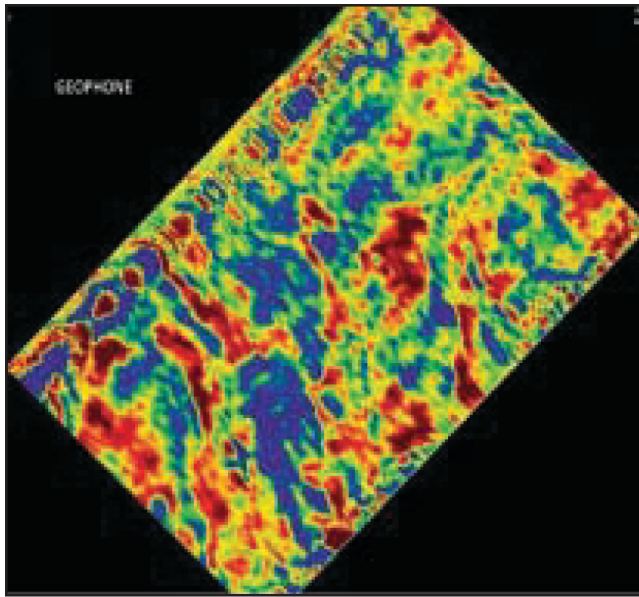


Fig. 8: Time Slice at 2200ms from PSTM-geophone cube alone

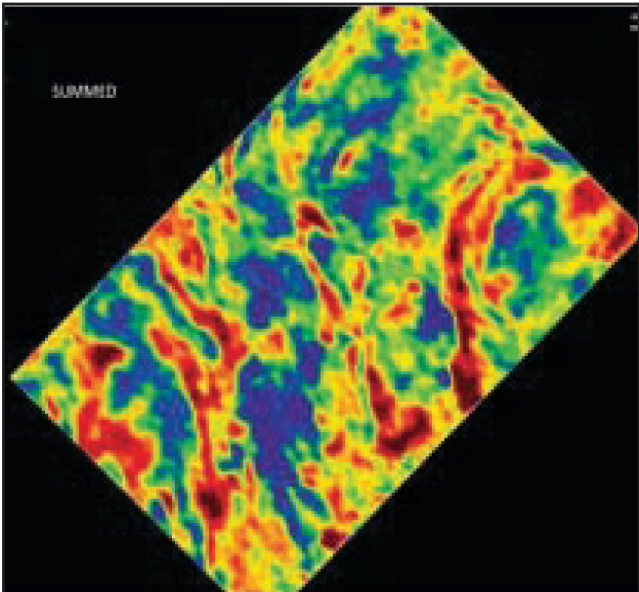


Fig. 9: Time Slice at 2200ms from PSTM-summed data cube

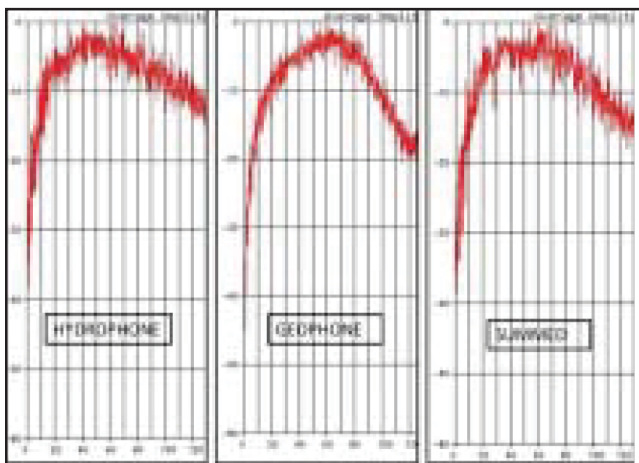


Fig. 10: Frequency spectrum from PSTM data of Hydroph. (left), Geoph. (centre), Summed(right)

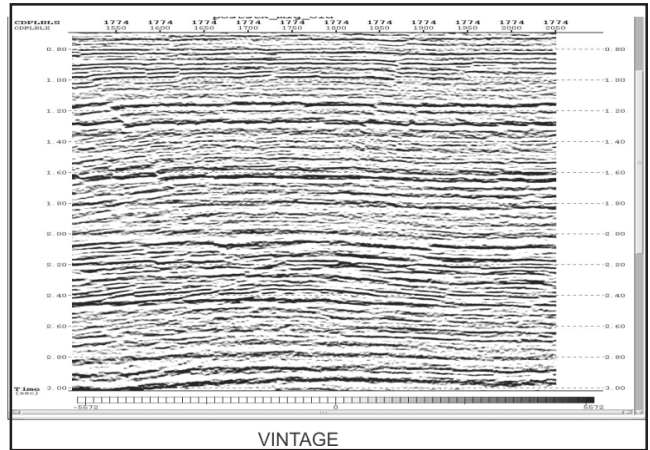


Fig. 11: PSTM-section from vintage processed

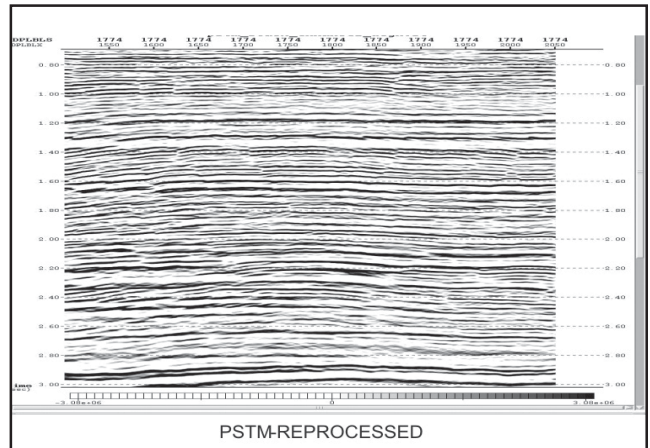


Fig. 12: PSTM section reprocessed

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References

- Ball, V. and Corrigan, D., 1996, Dual-sensor summation of noisy ocean-bottom data: 66th Annual Internat. Mtg., Soc.Expl. Geophys., Expanded Abstracts, 28-31.
- Barr, F.J. and Sanders, J.I. 1989. "Attenuation of Water Column Reverberations Using Pressure and Velocity Detectors in a Water-Bottom Cable". Presented at the 59th Annual meeting of the Society of Exploration Geophysicists (Dallas) Texas.
- Richard Bale, 1998, Plane Wave Deghosting of Hydrophone and Geophone OBC Data: 68th Annual Internat. Mtg., Soc.Expl. Geophys., Expanded Abstracts.
- Yilmaz, O. 1987. Seismic Data Processing. SEG: Tulsa.