# Improved Interpretability via Dual-sensor Towed Streamer 3D Seismic - A Case Study from East China Sea

S. Rongfu (CNOOC Shanghai), C. Hua (CNOOC Shanghai), W. Yun (CNOOC Shanghai), Z. Yabin (CNOOC Shanghai), M.T. Farouki* (PGS), D. Benfield (PGS), H. LeGluet (PGS) & P. Lee (PGS)

## SUMMARY

The geophysical objectives in the exploration for hydrocarbons in the East China Sea require 3D seismic data of sufficiently high quality to facilitate accurate structural and lithological interpretation of the deep reservoir plays (typically at a depth of 2.5 – 5.5 km). Conventional ‘narrow bandwidth’ 3D seismic which contains the sea surface ghost lacks the required resolution of seismic structure and penetration of signal in the deep section which is characteristic of broadband seismic obtained via an acquisition de-ghosting solution.

A 3D broadband seismic survey was commissioned in 2012 by the operator CNOOC using dual-sensor towed streamer acquisition system specifically designed to eliminate the sea surface receiver ghost. Comparison of data quality with an adjoining 3D conventional survey acquired in 2011 shows improved imaging of the highly developed fault systems, the associated deep reservoir plays, and basement. In particular, the more prominent amplitude response, and the better delineation of the different facies character, facilitates more accurate interpretation of the seismic data.

## Introduction

The East China Sea is a back-arc basin in the western margin of the North Pacific. The East China Sea Basin was formed through several phases of rifting, uplift and subsidence. The basin contains very thick accumulation of Tertiary sediments up to 10km thick and has the elements of a working petroleum system, where there are good source rocks in the syn-rift (lacustrine, fluvio-deltaic and coally sediments). Reservoir can be found in the fluvio-deltaic sediments, as well as in the marine sandstones and possibly basement. Both structural and stratigraphic traps can be considered.

The geophysical objectives in the exploration for hydrocarbons in the East China Sea require 3D seismic data of sufficiently high quality to facilitate accurate structural interpretation of the deep reservoir plays (typically at a depth of 2.5 – 5.5 Km). Conventional ‘narrow bandwidth’ 3D seismic which contains the sea surface ghost lacks the required resolution of seismic structure and penetration of signal in the deep section which is characteristic of broadband seismic obtained via an acquisition de-ghosting solution.

## Survey objectives

Figure 1 is a section from a conventional 3D survey and illustrates the exploration challenge in the Northern Kongqueting area of the East China Sea. Accurate structural imaging of the highly developed fault systems, better continuity of events at target level and of the basement reflector, and improved Signal-to-Noise-ratio (S/N) are all necessary criteria for a reliable interpretation of the seismic data. Additionally, robust amplitude and phase integrity in the pre-stack data is required for Angle-versus-Offset (AVO) and Direct Hydrocarbon Indication (DHI) studies.

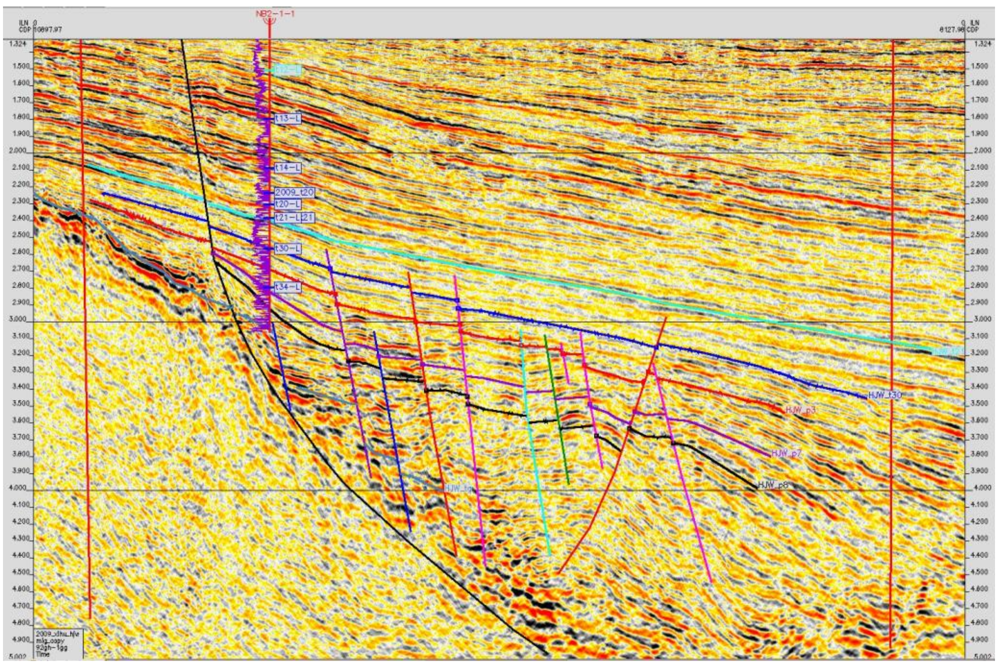


***Figure 1*** A section from conventional 3D seismic survey, from N. Kongqueting area, East China Sea.

## Broadband seismic via dual-sensor streamer acquisition

Conventional hydrophone-only streamers record the total pressure wavefield - a continuously interfering combination of the up-going wavefield (which is free of the ghost) and down-going wavefield (which *is* the ghost). The ghost recording introduces notches in the frequency spectrum of the recorded data, thereby negatively impacting the resolution of events, the return of signal in the deep section, and the general interpretability of the seismic data. Carlson et al (2007) describe an acquisition solution for broadband marine seismic via a dual-sensor towed streamer. Co-located hydrophones and velocity sensors contained in a single solid streamer record their sea surface ghosts respectively with different polarity, thus enabling wavefield separation into up- and down-going components, i.e., de-ghosting at the receiver side.

Significant benefits are realized when the receiver ghost is eliminated via an acquisition solution. Ghost free data is clearer, easier to interpret, and more closely ties earth's reflectivity. The increased bandwidth both at the low and high end of the spectrum results in improved resolution of seismic events and greater penetration of seismic signal in the deeper section.

**Data examples**

Legacy 2D data is clearly inadequate to meet the needs of the exploration objectives. In 2011, a 3D seismic survey in the region provided better imaging of the geology including basement. This survey was acquired with a point receiver streamer sytem, where receiver array forming in the streamer is performed in data processing subsequent to acquisition in order to gain an improvement in S/N in the field data. This difference aside, the 2011 survey can be considered to be a conventional survey in that the receiver ghost is present, together with the associated adverse effects on the recorded data.

In 2012 the operating company CNOOC conducted a 3D dual-sensor survey, in a bid to meet the exploration objectives discussed earlier. The 2011 and 2012 surveys are adjoined with a narrow section of overlap. Figure 2 shows the geographic location of the area, the extent of the two 3D surveys, and the location of comparison sections used to illustrate data quality.

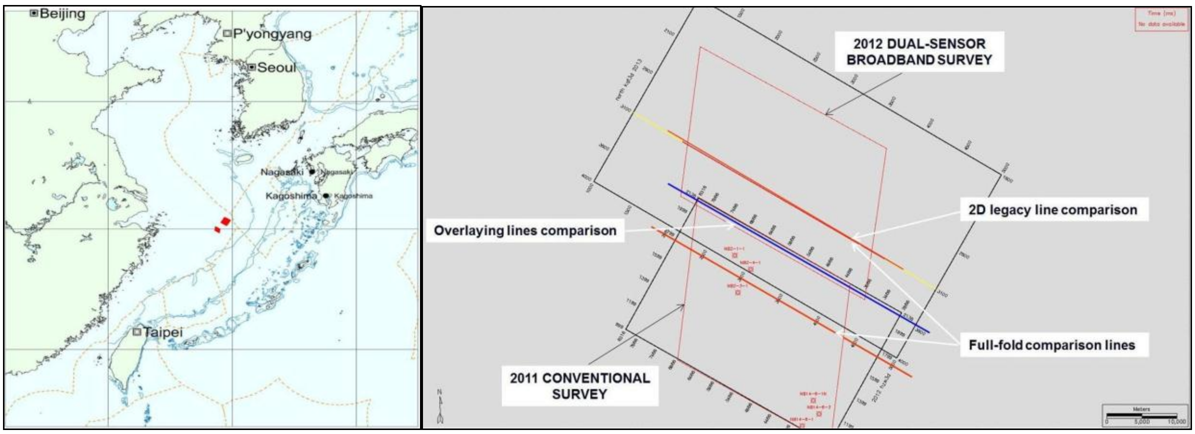


***Figure 2*** *Geographic location of exploration area (left), and 2011 and 2012 3D surveys (right).*

Figure 3 illustrates the limitation of the 2D seismic, where the basement reflector is poorly defined. By contrast, the 2012 3D dual-sensor survey provides a significant uplift in imaging of the subsurface, due certainly to the more robust imaging of 3D seismic, but also because of the ghost elimination and increased bandwidth.

Figure 4 shows a potential exploration play associated with a positive flower structure. We compare a Pre-Stack Time Migration inline from the conventional 2011 survey, with the corresponding inline from the 2012 broadband survey. The lines overlay each other where the two surveys overlap, but because the overlap zone is narrow neither of the lines is full fold. Nevertheless the comparison shows significant improvements in the dual-sensor data versus the conventional survey:

- More easily interpretable seismic due to elimination of the receiver ghost and increased S/N.
- Clearer correlation of primary events within the complex fault system.
- A much clearer basement reflector.

These uplifts can be attributed to, (a), the broader bandwidth of the dual-sensor data which results from de-ghosting via wavefield separation, and, (b), greater S/N in the dual-sensor acquisition as a result of the deeper towing depth of the streamer.

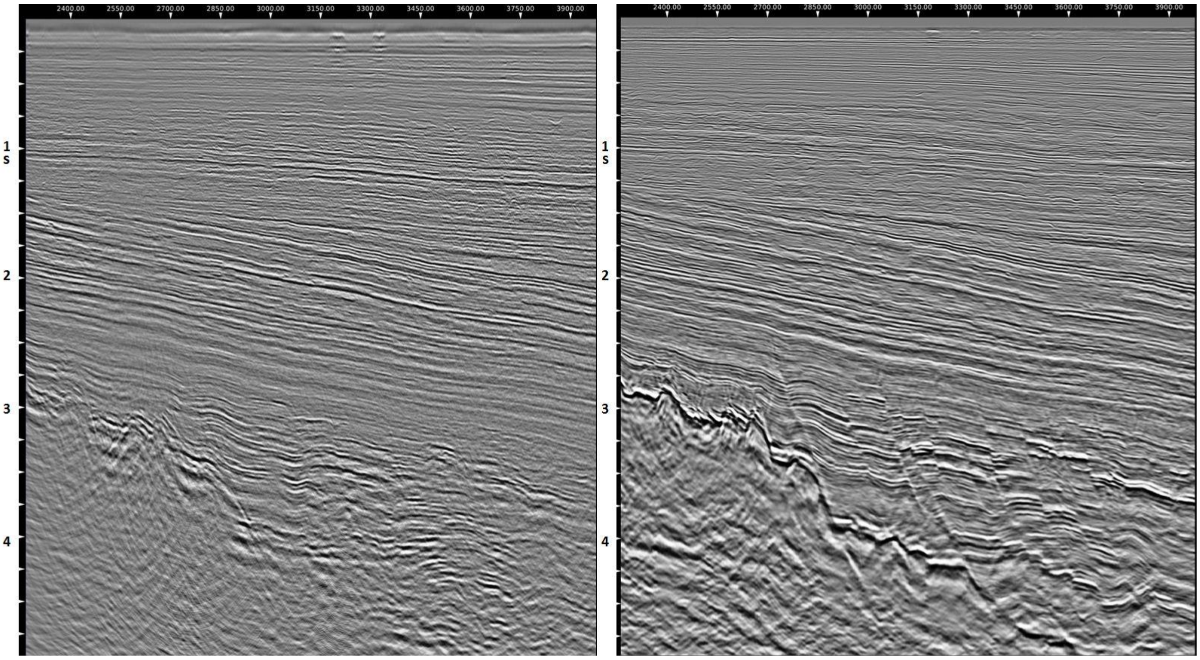


***Figure 3*** *Legacy 2D seismic (left) versus 2012 3D dual-sensor data (right)*

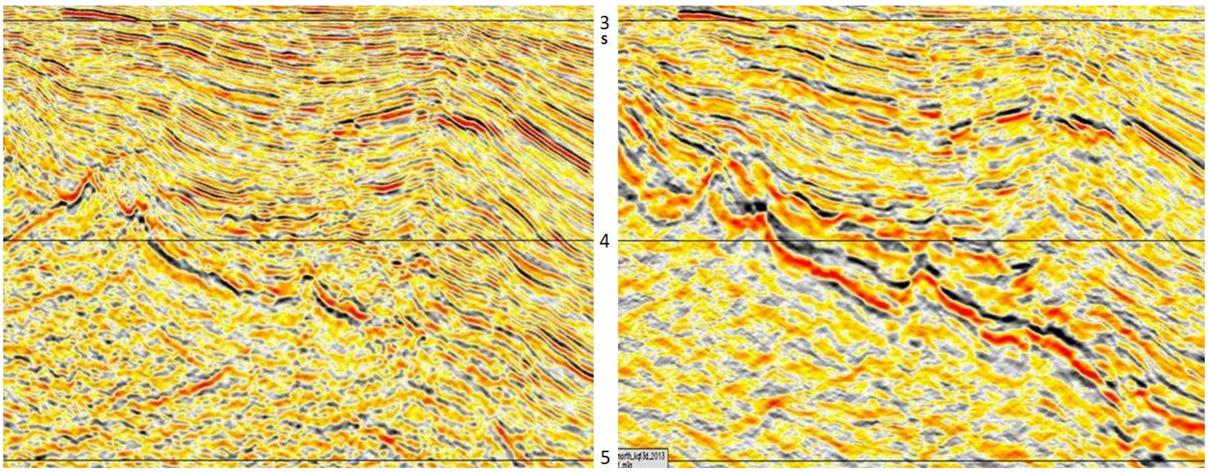


***Figure 4.*** *Overlaying lines: Left, 2011 conventional survey; Right, 2012 dual-sensor survey.*

It should be noted that whilst the acquisition parameters for the two 3D surveys are very comparable, they represent two very different technologies. The 2011 survey uses point receiver streamer technology for improved S/N but provides no mechanism for receiver de-ghosting. In contrast the 2012 dual-sensor system is designed specifically for receiver side de-ghosting. The dual-sensor system is towed deeper (15m) than the conventional system (8m) which provides an additional boost to S/N and low frequency content.

A final example is shown in Figure 5. Here we compare full fold lines from each of the surveys. The lines are not coincident – their locations are indicated in Figure 2 – so whilst we expect much difference in terms of structural content because of the separation in location, the geological setting is the same, and the uplift gained from the dual-sensor acquisition is clearly visible. Figure 6 illustrates the increase in bandwidth measured for the comparison lines in Figure 5; the improvement in bandwidth in the recorded dual-sensor data matches well the expected uplift in bandwidth predicted by modelling exercises during the survey design stage.

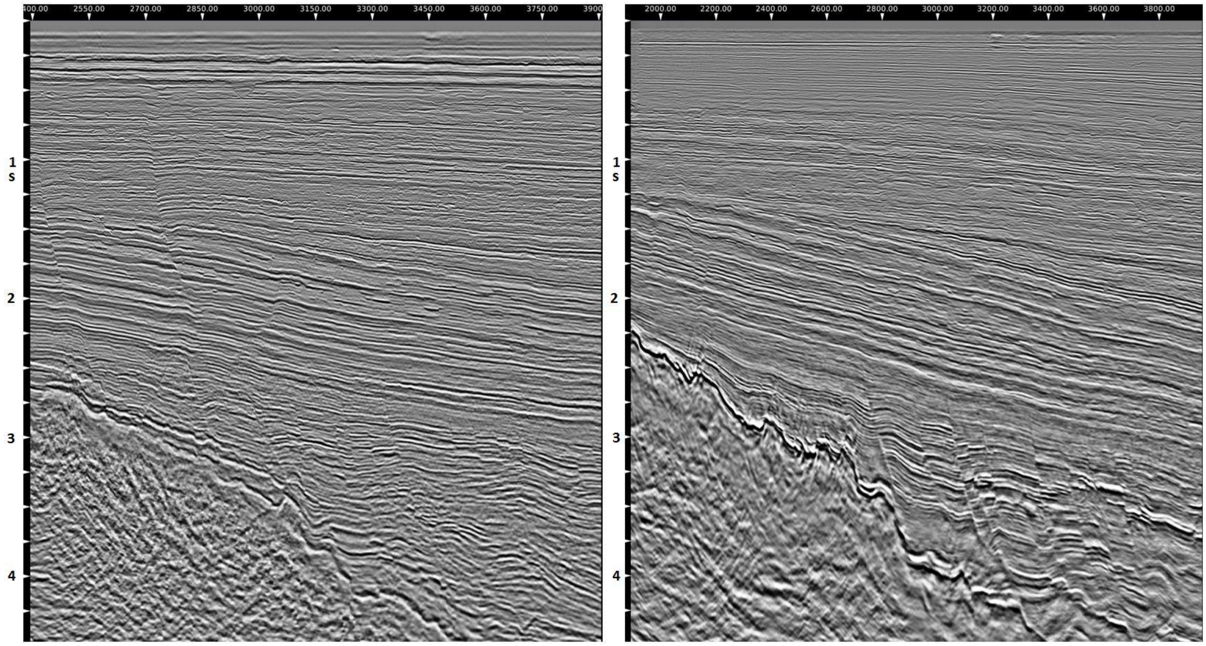


***Figure 5**. Full fold lines: Left, 2011 conventional survey; Right, 2012 dual-sensor survey.*

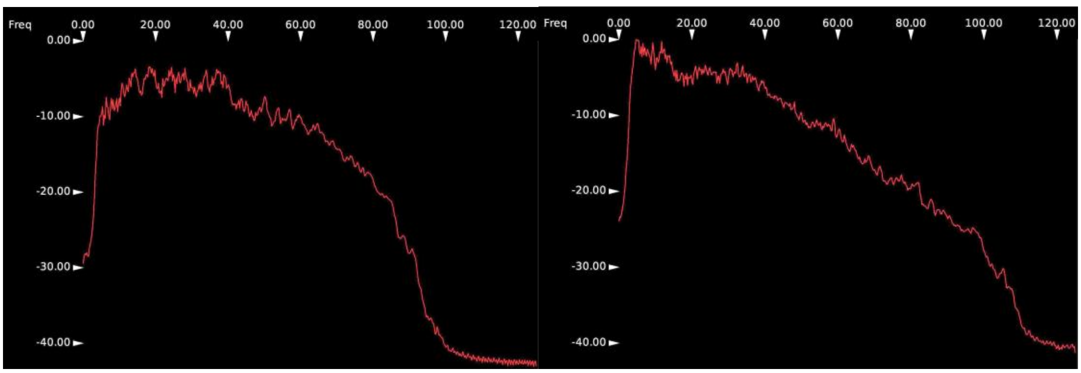


***Figure 6** Amplitude spectra for the data in Figure 5, window 500-4000ms:*
*Left, 2011 conventional survey; Right, 2012 dual-sensor survey*

## Conclusions

Receiver side de-ghosting via wavefield separation of dual-sensor recorded seismic data delivers a step change in data quality in comparison to conventional data which contains the ghost. The improvement in bandwidth which results from the de-ghosting and the deep tow of the streamer allows the geophysical objectives in a challenging exploration environment such as in the East China Sea to be realized. In particular, the more prominent amplitude response, and the better delineation of the different facies character, facilitates easier and more accurate interpretation of the seismic data.

## Acknowledgements

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## References

Carlson, D., Long, A., Söllner, W., Tabti, H., Tenghamn, R. and Lunde, N. [2007] Increased resolution and penetration from a towed dual-sensor streamer, First Break, **25**, 71–77.