Analysis of the Teal South, Gulf of Mexico, 3D-4C seismic survey

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Summary

Preliminary results of a 3D-4C seismic processing are presented. Reasonable hydrophone and vertical element sections are obtained. The radial component data, after horizontal reorientation, asymptotic binning, and correction for large receiver statics, produced section with continuous events. Shooting direction apparently caused acquisition footprint. The three cable-deployment methods used (trench, tape, sandbag) produced similar results for the P-wave sections. Initial results indicate that the taped deployment (unburied with no sandbags) worked better for the radial. There appear to be some contamination of S-wave energy on the vertical channel, but little P-wave energy on the horizontal channel. The survey provides very promising results for P and P-S analysis.

Introduction

The Teal South 4C-4D seismic project is an initiative to investigate the use of multicomponent seismic data to assist in monitoring reservoir fluid movements. The Energy Research Clearing House (ERCH) and Texaco are coordinating the project. Texaco is the operator of the Teal South field, on Eugene Island Block 354, in the Gulf of Mexico. Texaco acquired a first 4C-3D in July 1997, using four ocean bottom cables (Ebrom et al., 1998). This report summarizes the acquisition and presents some processing results for the second 4C-3D, acquired in April 1999.

Seismic data acquisition

Fig. 1 shows the shot points and receiver positions. Seven ocean bottom cables (OBC) were used in a fixed configuration. Four cables, each cable with 6 receivers spaced 200 m, were laid along the E-W direction; the distance between cables was 400 m – this is a receiver pattern close to the one used in the first 3-D survey at Teal South. Three additional cables (each cable having 4 receivers spaced at 400 m) were laid in an N-S direction, spaced 100 m apart (Fig. 1). The shot point grid was 25 x 25 m, over an area of approximately 4 x 3 km^2. In total, there are about 19,200 shots. The raw data were recorded on tape, located in four different buoys spread in the area. The costs were diminished by the use of analogue sensors and light cables on the sea floor and placing more expensive recording equipment on the buoys (Baker Hughes/Western Geophysical, 1999).

One objective of the Teal South project is to analyze how different ways of cable laying on the sea floor impacts the recorded data. For this reason, five cables were buried (trenched) 1 m under the sea floor, one cable laid on the sea floor with receivers taped to it and another cable was laid on sea floor with receivers taped and sandbagged (Fig. 1). The sandbag technique is presented in Sullivan (1995).

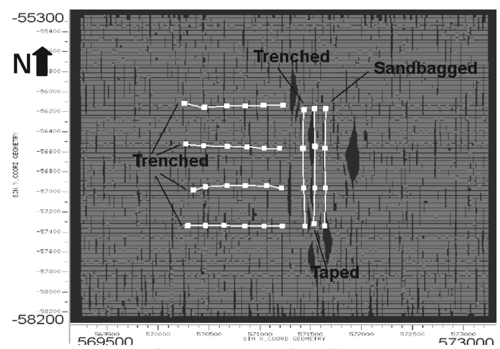

Fig. 1 – Map view of shot points (gray) and receivers (white) positions. Observe shot gaps (due to obstacles), four receiver cables along E-W (with six units), and three cables along N-S (four units/cable). Distances in metres.

Pre-processing and quality control

As expected from the high number of shots, a high and homogenous fold is present for vertical and hydrophone components. For the horizontal components, the maximum folds after asymptotic (ACCP) binning more than doubled, but the distribution is more heterogeneous and a smaller area is imaged.

To use the concepts of 'radial' and 'transverse' receiver orientation, the original horizontal components have to be rotated to a new set of orthogonal axis. The radial direction of the new axis is given by the maximum energy alignment (hodogram analyses) and the transverse by the orthogonal to this direction. The source-receiver energy alignment obtained was very good. We also correct for reversal polarity on horizontal components.

A dominant frequency per trace analysis showed that the hydrophone records the highest dominant frequency (around 40 Hz) and the vertical and horizontal components have almost the same dominant frequency (20 Hz). The lower value for the horizontal components is expected, but not for the vertical. A possible reason for this lower dominant frequency (close to the horizontal component value) is contamination of shear-wave energy on the vertical component.

Vertical and hydrophone components

On CDP gathers, the hydrophone data seems to have more continuity in the events and a higher frequency content, than the vertical elements. Average amplitude spectra for the two components are shown in Fig. 2. The hydrophone data have strong notches, at frequencies close to the ones expected from the water depth in the area (85 m). The absence of notches on the vertical component may be due to presence of shear-wave energy. This is supported by coherent energy when a P-S processing flow is applied in vertical component data (Fig. 9).

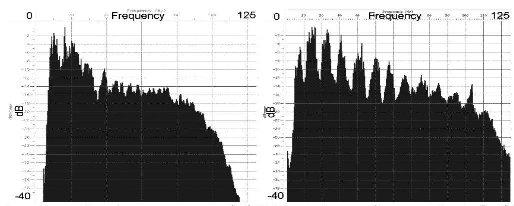

Fig. 2 – Amplitude spectra of CDP gathers for vertical (left) and hydrophone (right) components.

After source, receiver, and CDP statics, DMO was applied to the data. A new velocity analysis was performed after DMO, and the data from the two components stacked and (finite-difference) migrated. The results are shown in Fig. 3. The hydrophone section seems better than the vertical below 2.0 s.

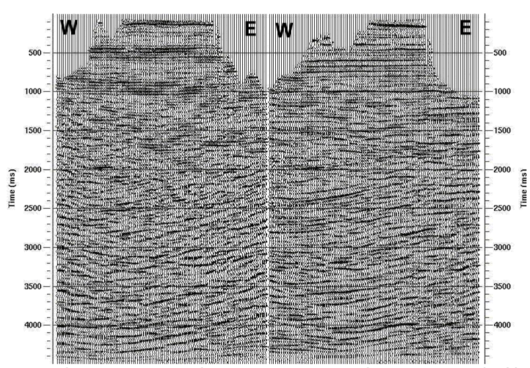

Fig. 3 – Comparison of migrated data for vertical (left) and hydrophone (right) components. Trace distance 25m

Radial and transverse components

After reorientation, a sequence similar to the one applied to vertical and hydrophone was applied to radial and transverse components. The most notable difference is the use of asymptotic common-conversion-point (ACCP) binning.

Fig. 4 presents hand (structural) and residual receiver statics for radial component. Hand statics are 4 to 8 times higher in the radial than in the vertical and hydrophone components. The picture also shows that after three interactions the residual statics become very small. After all statics were obtained, a new velocity analysis was performed and the data stacked. Fig. 5 shows a comparison between radial and transverse components. The radial component has more continuous reflections.

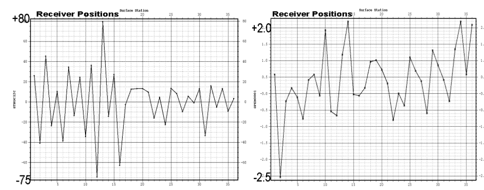

Fig. 4 – First hand (left) and third residual (right) radial component receiver statics.

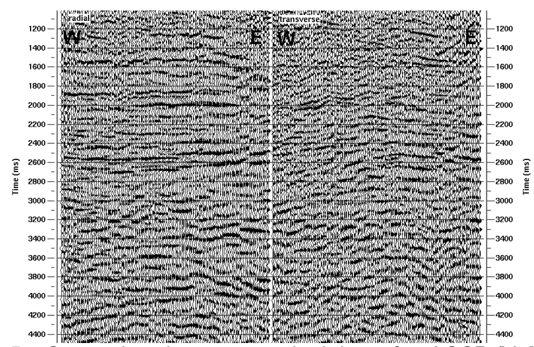

Fig. 5 – Comparison between stacked data after ACCP (V_P/V_S = 2.0) binning from radial (left) and transverse (right) components. Trace interval 25 m.

Comparison of cable deployment techniques

As one purpose of the Teal South project is to analyze which – if any – ocean cable deployment technique is superior, a comparison of the three cable deployment methods – trenched, taped, and taped and sandbagged – was undertaken. It was assumed that, due to the small distances (around 100 m) between the analyzed cables, geological changes could be neglected in the comparison. The cables compared are the ones in the N-S direction, located in easternmost part of the survey (Fig. 1). The same processing parameters (statics, velocities, etc) were used for all cables; the hydrophone and radial components were used in the analyses.

Fig. 6 shows the comparison. For the hydrophone, the results are quite similar. Nevertheless, it appears, based on reflection continuity, that the trenched cable data and the taped only receivers are a little better than the sandbagged units. For the radial, the difference in data acquired in each deployment is larger. The taped system seems to have more event continuity Fig. 7 shows amplitude spectrum of the stacked sections presented above. For the radial component, although the differences are not extreme, the taped data seems to have frequency content slightly better than the two other methods (between 10 and 20 Hz and around 30 Hz); the trenched data seems to have lower energy content from 10 to 20 Hz.

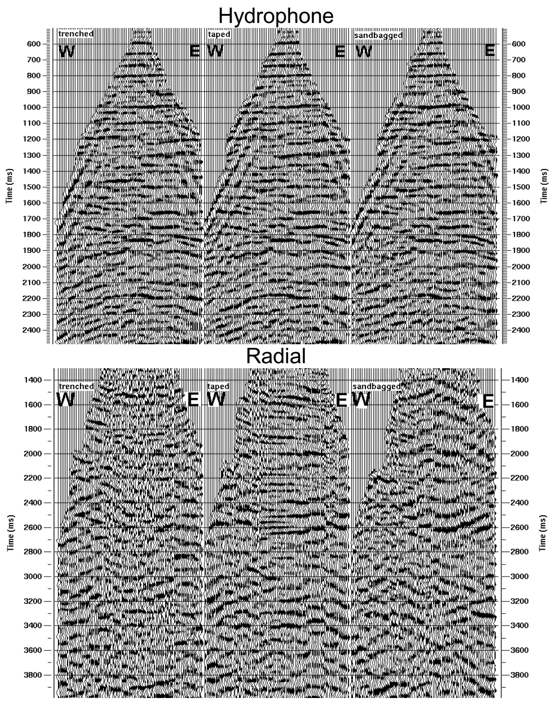

Fig. 6 – Comparison between data collected using cable trenched 1 m below sea bottom (left), cable with taped receivers (middle) and cable with receivers taped and sandbagged (right). Hydrophone at top and radial at bottom. Trace distance 25 m.

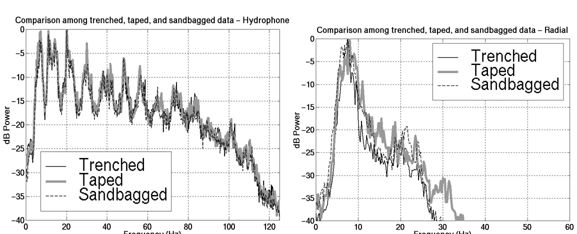

Fig. 7 – Amplitude spectra of stacked section for hydrophone (left) and radial (right) component data.

P-S energy on vertical component, P-P on radial

To consider the possibilities of P-wave energy on the radial component, the vertical component processing flow and its parameters (statics, velocities, etc.) were applied to the radial component data after reorientation. We see that almost no coherent events are obtained (Fig. 8). This suggests that little P-P energy is present on the radial component, perhaps because the compressional energy is arriving at the sea bottom with an emergency angle close to zero or there is little mechanical instability on the radial element.

In a similar way, the presence of shear wave energy on the vertical component was observed by applying the radial component flow to the vertical component data. One can see (Fig. 9) that many events are present, showing that the vertical data appears to be highly contaminated with converted-wave (P-S) energy. Indications of this leakage have already been presented in this report – namely, the lower frequency content and the absence of receiver ghost in the vertical component in comparison to the hydrophone.

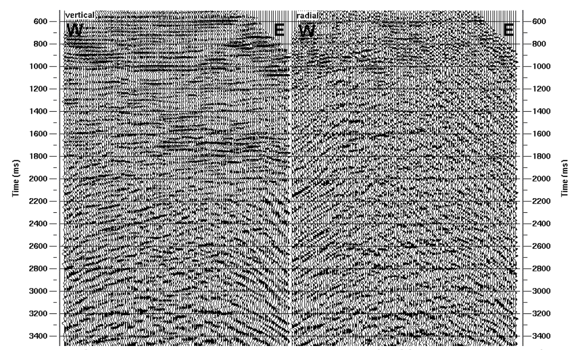

Fig. 8 – Comparison between vertical (left) and radial (right) component data processed with P-P flow.

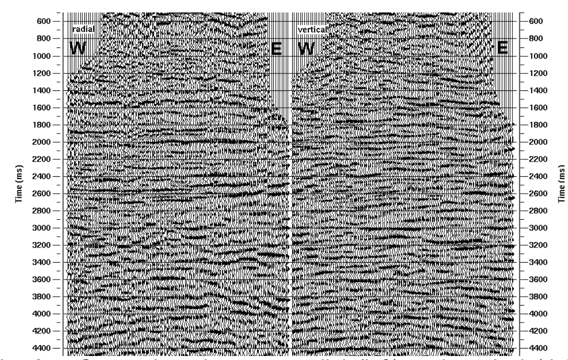

Fig. 9 – Comparison between radial (left) and vertical (right) component data processed with P-S flow. The presence of S-wave energy in the vertical component is clear.

Two possible explanations for the presence of shear-wave energy in the vertical component are 1) S- to P-conversion at sea-bottom, and/or 2) spurious mechanical coupling of energy on to the vertical component. Modeling (Rodriguez-Suarez et al., 2000) suggests that S-P conversion should not be a major factor.

Processing a 3D-4C from Teal South, Gulf of Mexico

Acquisition footprints

To consider the existence of possible acquisition footprints – caused by source and/or receiver survey orientation – time slices were analyzed in hydrophone and radial components. Fig. 10 presents a time-slice, at 2.0 s for hydrophone and 3.5 s for radial components. The north-south source vessel orientation (Fig. 1) can be clearly seen in the data, mainly in the radial component. In addition, there may be some receiver footprint.

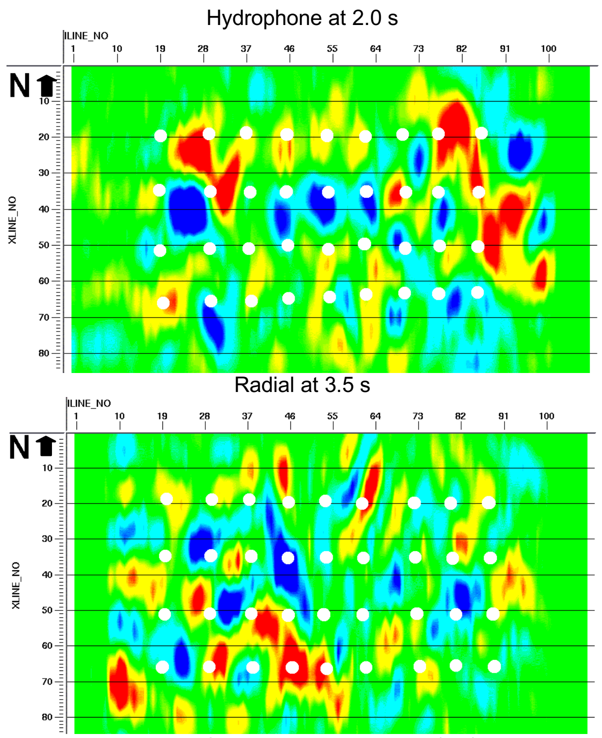

Fig. 10 – Time-slices for hydrophone at 2.0 s (top) and radial at 3.5 s (bottom). The shot point footprint (N-S direction) can be seen in both components. White dots indicate approximate receivers positions.

Additional analyses

Further processes applied in the radial component were converted-wave DMO, depth-variant stack and vertically transverse isotropic (VTI) stack. Converted-wave DMO (Harrison, 1992) intends to correct dip effects in converted (P-S) data. Depth-variant stack tries to consider the actual conversion point for different depths, using time and spatial variant V_P/V_S ratios. VTI stack, based on Thomsen (1998), uses the concept of effective V_P/V_S ratio (= γ^2_{NMO}/γ_0, γ_{NMO} V_P/V_S ratio from processing velocities and γ_0 vertical V_P/V_S ratio) to theoretically account for VTI effects. Initial depth-variant and VTI stack produced poor results, perhaps due to incorrect V_P/V_S values used in the calculation of the conversion point. Further values are being tried.

To search for the presence of anisotropy (for both P-P and P-S waves) in the Teal South area, hydrophone and radial component data were grouped and stacked by opposite range of azimuths. Differences were found for symmetric azimuth ranges in both components; a detailed comparison was prejudiced by low signal-to-noise ratio, especially in the radial component.

Conclusions

Source and receiver statics could be satisfactorily solved for hydrophone, vertical, and radial components. Reasonable P-P data quality was present on the hydrophone and vertical elements. From the three methods used on cable deployment (trenched, sandbagged, lain), these preliminary results suggest that no option is significantly better for P-P data. The taped deployment (no trenches, no sandbags) seems to have more event continuity in P-S sections. Little compressional wave energy was found in the radial component, but the vertical component is contaminated with converted-wave energy. This may be cause by S-P conversion at sea bottom or mechanical cross coupling related to acquisition problems. There is some smearing in the shot line direction plus possible receiver footprint. Both P and P-S data show considerable promise for further processing and analysis.

Acknowledgements

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