

IMPROVED SIHIL IMAGE FROM 4C FULL AZIMUTH NODE DATA

Marco Vázquez García¹, Dr. Gorgonio Garcia Molina¹, Francisco Maya², Carlos Federico Ruiz Torres², Eivind W. Berg³, Claude Vuillermoz³, Atle Fyhn³
¹Pemex, CNPS, Villahermosa, ²Pemex Exploración y Producción, Región Marina Noreste, Ciudad del Carmen, Mexico, ³SeaBed Geophysical, Trondheim, Norway.

Summary

A large 4C OBS seismic program was acquired for Pemex over the Cantarell field offshore Mexico to improve the structural definition of the deeper Sihil field underlying the giant Akal field. The acquisition was made using autonomous receivers planted with accurate positioning on a regular grid in the seabed. The data is acquired with a regular and full azimuth/offset distribution. High quality data was recorded. The PP and PS data is time processed with migration before stack. Better resolution of the top of the Sihil under the overthrust of Akal is obtained. The converted wave has a better resolution for the shallower data.

Introduction

November 2003 Seabed Geophysical deployed the CASE (node) system for a large scale offshore program on the giant Cantarell field. It proves the industrial reliability to acquire high quality, high vector-fidelity seismic data. The node recording system is an autonomous ocean bottom seismic (OBS) which is cost effective, flexible and provides higher data-quality than existing systems. Each node consists of three geophones and one hydrophone and is accurately positioned and planted in the seabed by an ROV (Remotely Operated Vehicle). During this operation tilt and direction are monitored.

The Sihil discovery is part of the Cantarell complex with water depth ranging between 40 m and 50 m. To cover the area of interest a total of over 1500 receiver units were deployed into seven swaths in a 400 x 400m grid for a total of 230 km². Both compressional wave (P wave) and converted shear wave data (C wave) were processed by CGG with a full 3D Kirchhoff pre-stack time migration approach.

The Field

Cantarell, offshore Campeche, Mexico, (figure 1) is a mature giant field, which produces mostly from the Akal fault block (90% of the field reserve). The Akal block has a WNW-ESE orientation and overthrusts the Sihil block. The structural complexity has been a great challenge for the seismic interpretation (J. Garcia et al, 2005). Both structures are cut off to the west by a N-NW almost vertical right lateral strike-slip fault. Production comes from 2 carbonate rocks: the

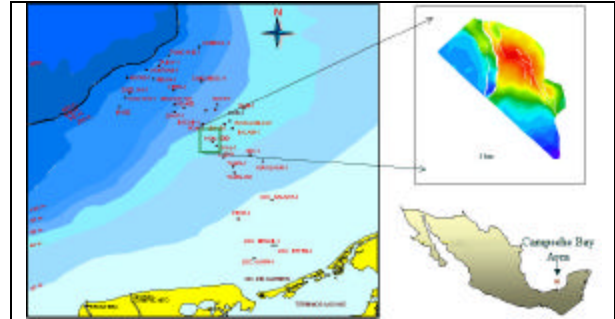
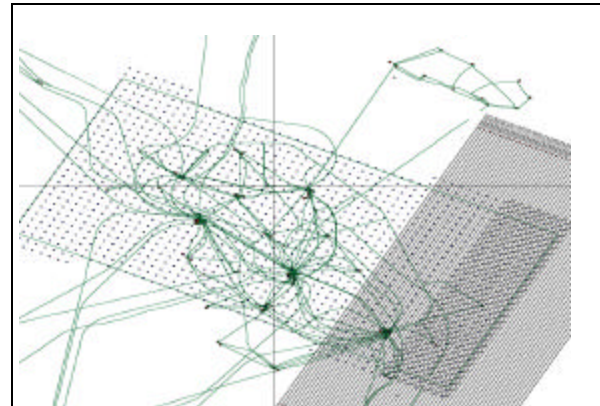


Figure 1: Cantarell-Sihil structural setting



Swath 6 - Configuration

Total number of Nodes (29x8):	232 Nodes
Receiver area (11,2 x 2.8):	32,36km ²
Node spacing:	400m
Inline shooting offset:	3,4km
Crossline shooting offset:	3km
Shooting area (18km x 8.8km):	158,4km ²
Shot spacing (flip-flop):	50m
Shot line spacing:	75m

Figure 2: Swath six is shown with its proper shooting area of 158 km². Note the dense infrastructure of this mature field.

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Paleocene Upper Cretaceous (dolomitized breccia) and Lower Cretaceous (dolomitized plus fractured limestone).

Modeling

The survey design was done by modeling based on the interpreted horizons from prior OBC. The objective was to illuminate the top and edges of the Sihil reservoir as well as its extension. The hit count in the modeling for both P and converted wave was made at that level.

4C-3D acquisition with sparse grid receivers

The nodes deployed were autonomous units comprising of an instrument-housing and a node. The instrument-housing contains a CPU, A/D, data storage, clock and battery and the node contains 3 orthogonal geophones, a hydrophone and tilt meters. Each unit is deployed and positioned by crane from the support vessel and the node is planted and positioned accurately by the ROV.

Careful sensor design and controlled planting with the ROV manipulator arm provides excellent coupling and high vector fidelity; the sensors are placed at the water-seabed interface, well coupled and in a known orientation. A hydro-acoustic communication system allows data transmission to a surface vessel.

The 232 nodes per swath are deployed in a sparse grid with a 400m spacing and covers 35km² (figure 2). The total receiver area of the 7 swaths covers 230 km².

The 520 km² of shot area with a grid of 75x50m was made of 1100 km² including the overlap of swaths. The survey provided full regular azimuths and offsets up to 8000m with regular fold coverage of over 100. The shooting area is close to 160 km² for each swath. Sail line interval is 150 m with dual source shooting flip flop every 50m.

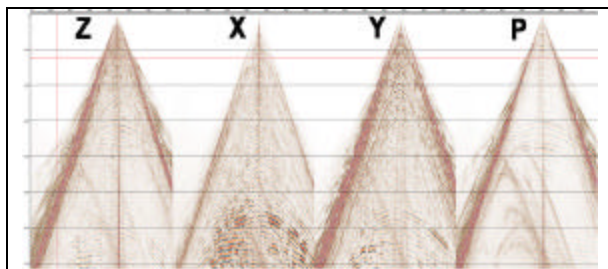


Figure 3: Raw 4Cnode data

QC was done on board and the activity of the nodes was monitored. On board processing generated 2D sailing line stacks and 3D preliminary P wave stacks for QC.

The operations started on November 4th and were completed in 134 days only. Average production rate was 1,7 km² a day, with high quality records obtained (Figure 3)

Sihil processing of P wave

The important steps of the processing of the P wave flow included.

- 3-component rotation of the geophones and QC to insure the verticality of the Z geophone.
- PZ summation, a calibration of dual sensors is applied in order to combine the measurements of the hydrophone and geophone. The wavelet of the geophone was converted to that of the hydrophone. The successful merge of hydrophone and vertical geophone act as water layer demultiple (Soubarras 1996).
- Industrial noise was very severe and intelligent suppression was applied on the hydrophone prior to the PZ summation.
- Further noise removal was done by full 3D FK in node receiver domain (figure 4)
- Radon demultiple
- Full 3D pre stack Kirchhoff time migration (PSTM) velocity analysis and picking
- Full 3D pre stack Kirchhoff time migration with imaged anelliptical migrated gathers. Then residual analysis and correction prior to final stack of pre stack migrated gathers.

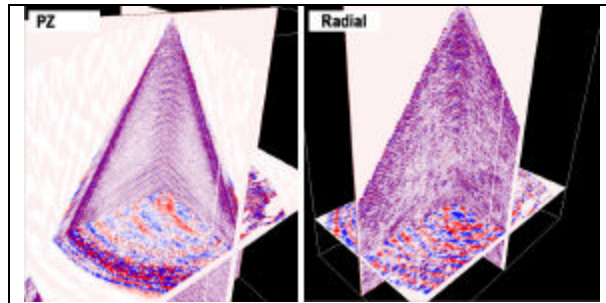


Figure 4. PZ and Radial components after 3DFK filtering

Good imaging was obtained with high frequency data. The 3D shape of the structures are well defined (Figure 5) without influence of the direction of acquisition as compared to previous seismic. The top of the Sihil is well imaged though no specific processing taking advantage of the full azimuth acquisition geometry was done at this stage. A DMO stack and post stack migration with PSTM velocity was also made for comparison. (Figure 6)

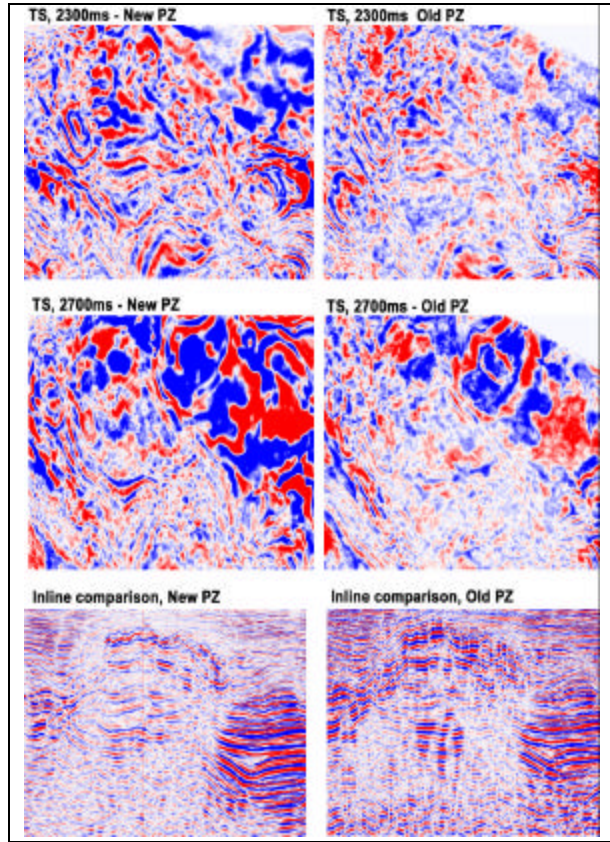


Figure 5: Time slice and inline comparisons with new node data and old OBC data

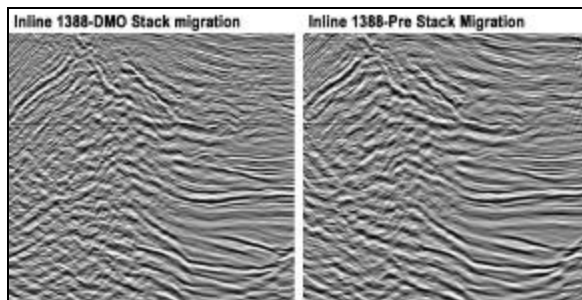


Figure 6 Comparison between DMO -post stack migration and PSTM.

Sihil processing of C wave

The processing workflow for the converted wave (C wave) included

- QC of the orientation of the geophones, the 3-trace rotation using the tilt, toss, heading from the acquisition is adjusted with the one measured from the data.
- horizontal components rotation from acquisition to radial (figure 3)(source to receiver direction) and transverse coordinates. The whole further processing was carried out with the radial component only as at this stage no energy was seen on the transverse in the overburden.
- noise editing and a 3DFK per node was a major step
- The main static corrections were modeled from receiver, offset limited stacks modeled from the P shallow horizons brought to PS time in the proper VP/VS ratio.
- Velocity and a first analysis of effective V_p/V_s (η_{eff}) was done and a C wave post stack migrated volume was generated. The slow velocity of shear waves results in improved separation between reflectors in time and when compressed to P time this separation translates to shorter wavelengths and more detail than in the P wave section. (figure 7)
- PSTM is a suitable tool to process C waves as it performs at the same time accurate CCP binning and non hyperbolic moveout in regions with moderate lateral velocity variations.

Generating the velocity models in processing C waves is a crucial step. The difficulty comes from the velocity parameters required to obtain flat accurate common conversion gathers. In vertically heterogeneous VTI media a route for C-wave velocity analysis is provided by the pre stack time migration (PSTM), as it achieves a correct conversion point location for finite offsets and dipping reflectors. Four parameters control the accuracy of the final image C wave. RMS velocity, V_c , Vertical P to S wave velocity ratio (η_0), effective P to S wave velocity ratio (η_{eff}), effective anisotropy (ϵ). C wave migration velocity analysis makes use of the hyperbolic double square root equation, and only 2 parameters are scanned: V_c and η_{eff} . Gerea et al. (2001), Gresillaud et al. (2003) and Boëlle et al.(2003). C wave velocity analysis is performed independently of the P-wave velocity analysis. η_{eff} governs the symmetry of the image gather, V_c governs the flatness of the image gather. η_{eff} can be globally estimated by a lateral correlation criterion (Granger et al.1991)

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The processing approach was the usual determination of θ_{eff} that attempts to measure the lateral shift of CCP location versus offset, and was expected to be efficient here in the present situation of Akal/Sihil

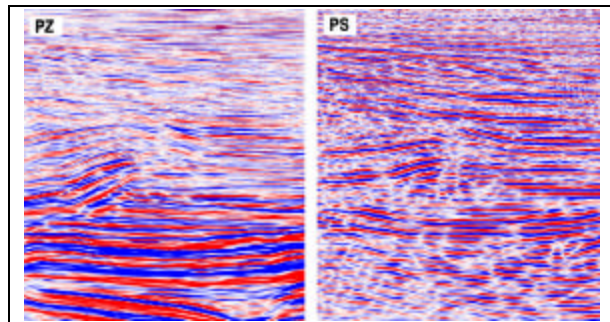


Figure 7. Enlargement of a comparison of the PZ DMO post stack migration and the Converted wave PS. A much better character and resolution is obtained in the Tertiary.

Conclusion

The large 4C OBS successfully acquired for Pemex Exploration y Produccion offshore Mexico makes possible a better structural definition of the deeper Sihil field underlying the giant Akal field. This acquisition was made using autonomous receivers planted on a regular grid 400 x 400 m in the seabed with a regular and full azimuth/offset distribution. High quality data was recorded. The processed compressional wave (PP) with prestack time migration has a better resolution and more accurate imaging of the top of the Sihil than previously acquired data. The processed converted wave (PS) also with prestack time migration has a better resolution for the shallower data and confirms the main structural features of the field.

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