Fluid contacts and net-pay identification in three phase reservoirs using seismic data

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Abstract

An integrated interpretation of 3D seismic attributes, spectral decomposition and pseudo impedances, led to the identification of fluid contacts within heavy oil reservoirs in Block II of the Uracoa Field, in Monagas Sur area, Eastern Venezuela. The study was run by Petrodelta, a PDVSA-Harvest Vinccler joint venture in Venezuela.

The final product is a breakthrough for Petrodelta development plan, result of a multidisciplinary interpretation and workstation capabilities. Those results led to setting two new drilling locations.

Introduction

The Uracoa Field is located in the Monagas Sur area, nearby the Orinoco Belt, Eastern Venezuela.

As a result of latest studies a PSTM processing was run for the 165 km2 seismic dataset in 2008 by Fusion Petroleum Technologies for Petrodelta. The field development plan (FDP) included a few more locations within the mature field, avoiding the shallower -drilled- free gas areas, and the deeper -modeled- water contact.

The challenge for the subsurface team was to reveal from old, reprocessed data, new evidence in order to determine where to drill horizontal wells in the oil bearing sandstones.

Further analysis of well-seismic calibrated data and several trials on different set of attributes and spectral decomposition started to reveal some subtle geological features and amplitude responses that led to forecast gas and heavy oil intervals. Seismic attributes and spectral decomposition interpretation were the key drivers to determine GOC and OWC, as well as the oil section to set new drilling locations.

Theory Background

The quest for the oil bearing interval in the reservoir was mainly based on recent investigation of seismic responses in presence of gas in heavy oils at high GOR (Han & Liu, 2008) where seismic velocity decreases. There is well data in Uracoa field that measured GOR > 24000 scf/bbl, which is very high at the local reservoir conditions.

In addition, gas-prone sands, drilled in previous campaigns, showed that there are a few areas in the field where free gas is located at the top of reservoirs. Such fact allow to consider seismic may detect the contrast between gas and oil.

A second investigation on heavy oil seismic responses was found (Wolf, Vanorio, et al, 2008) which suggests that if the sonic log shows elastic contrast, confirmed by S converted waves from near-to-far offset data, there is a chance to differentiate velocity and/or density changes on the seismic data. Log data available in Uracoa field confirmed acoustic/elastic changes that led the team to consider the possibility of mapping gas-oil contrast.

Workflow

The workflow was derived from the many trials on the datasets. It became a two steps flow:

1) First step of the analysis was to run spectral decomposition on the seismic horizons related to the top reservoirs. Gas-prone sandstones had been drilled in the area but the three phase fluids distribution had not been mapped either clearly understood in the reservoir..

The heavy oil reservoirs in the field have historically showed a water contact at the bottom. Seismic data was decomposed, in the quest for acoustic/elastic contrasts among the three fluid phases.

2) Second step was run in two phases: i) build a de-tuning curve to differentiate gas and non-gas amplitudes. ii) Pseudo impedances cube, interpretation to determine lateral sandstones distribution.

   Bounding stratigraphic features of the reservoir and the net-sand distribution within the GOC and OWC were identified and mapped.

By combining results of the two steps analysis the net-pay was determined, and two drilling locations set. Team interpretation improved the understanding of the today's reservoir performance, and served to update the dynamic model.

Test on data:

Well-Seismic data: The 50Hz cube showed to be useful for identifying the geological closures, free gas zones and the GOC of the reservoir.

Figure 1 shows a seismic section from the Spectral decomposition at 50Hz, across the Well-1. It is observed a high amplitude response at the top of the target reservoir. Higher amplitudes are interpreted to qualitatively represent the gas sand.

That well has a complete set of log, which confirmed gas presence in the interval. Figure 2 shows the gas bearing zone, interpreted in the Neutron-Density. The log data matched the 50 Hz seismic amplitudes. Next step was to check on the lateral continuity of the gas sands.

Lateral extension and GOC: Figure 3 is a spectral decomposition map, run to the top horizon after calibrated to Well-1. The amplitude response shows the lateral extension of the gas bearing sandstones and the GOC detected downdip to the North of the structure.

Production data match: The amplitude map shows the gas zone across two other wells that had not been revised: Well-2 and Well-3. Their production history was checked, and both wells had a very high GOR (>24000 scf/bbl) at the time the 3D seismic was acquired (1998). The GOR confirmed the amplitude was related to the gas distribution at the top of the reservoir.

At this stage the team was able to reliably map the gas presence, to be cased when drilling. It also mapped the oil column top. Next task was to map the net-sand distribution below the GOC and above the OWC.

De-tuning Curve: Amplitudes were extracted from top to bottom of the gas response. The detuning curve was generated using a Time vs. Amplitude curve to remove the high amplitudes, associated to gas.

Low impedances derived from calculated pseudo-acoustic impedance cubes showed to respond at sand distribution. Combining the detuned amplitudes and the derived impedance map allowed detecting the net sand below the GOC and above the OWC. Those sands became are interpreted to be oil bearing, and no well has ever targeted those.

Figure 4 shows the detuned curve and the impedance map where the lowest values, red in the scale, were interpreted as net sand distribution spots. Those spots, in figure 5, were selected as the drilling targets, and two locations were set in the 2009-2010 drilling sequence.

Conclusions:

Combining spectral decomposition data and pseudo impedances led to the identification of fluid contacts three phases reservoirs. Log data was used to calibrate the attributes at well locations and to forecast lateral continuity.

De-tuned amplitude maps and the pseudo impedance allowed to determined net-sand in the reservoir under the GOC and above OWC. Those sands became the drilling target.

Proposal for two drilling locations are the final product of a breakthrough interpretation workflow, adding value for the Petrodelta development plan.

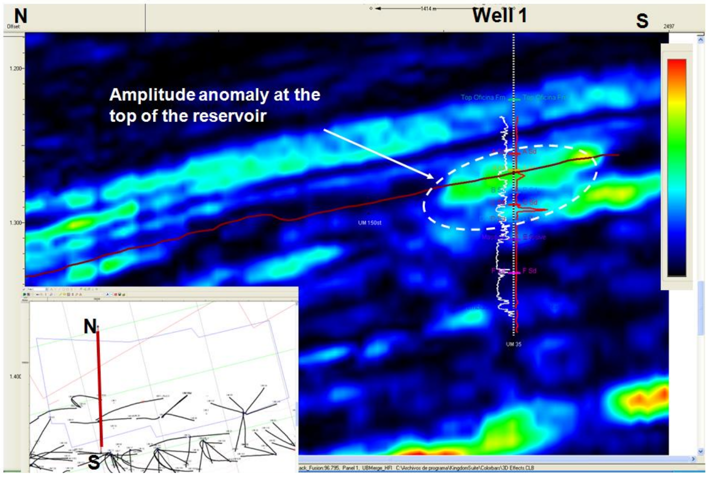


Figure 1. 50Hz Section across the Well-1. High amplitude response interpreted to qualitatively represent the gas sand

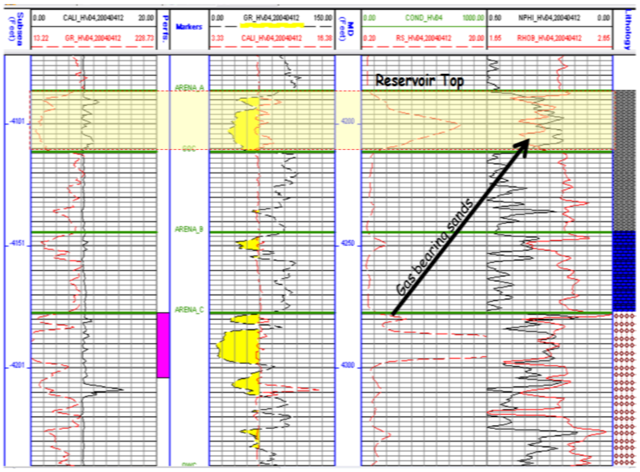


Figure 2. Neutron-Density confirmed gas bearing sands at Well1.

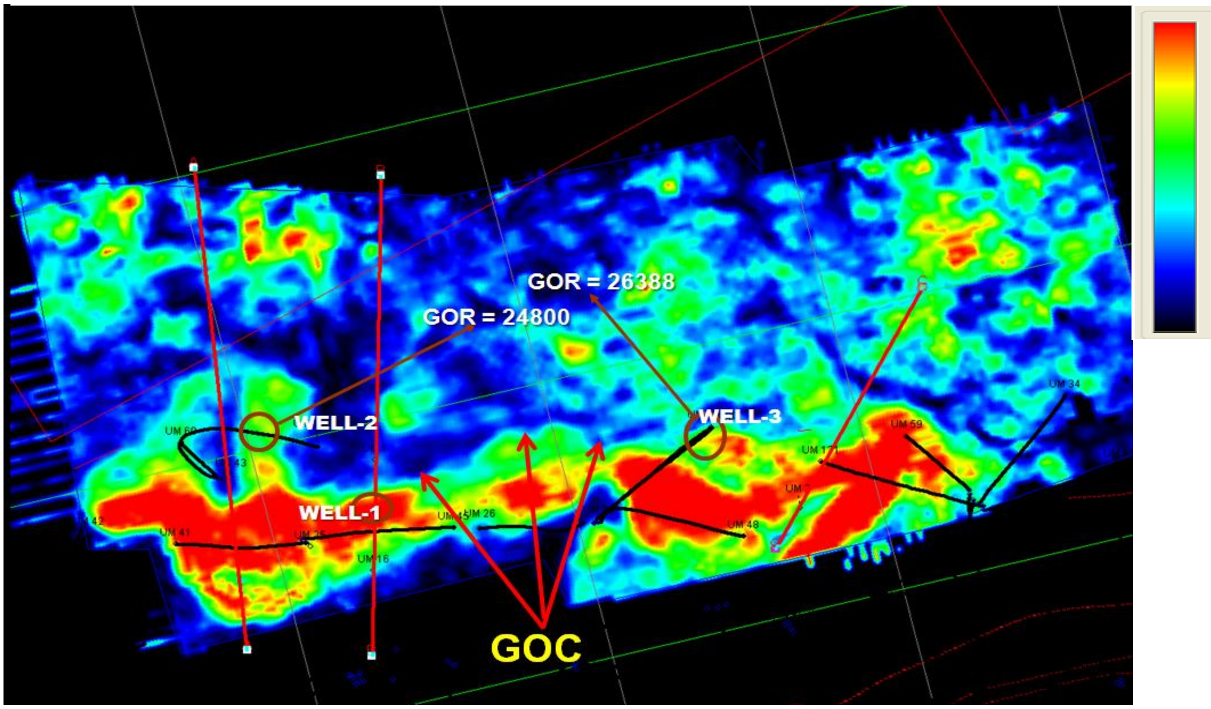


Figure 3. High amplitudes response interpreted to qualitatively represent the gas bearing sandstones. The GOC is observed to the North of the anomaly. An stratigraphic closure was interpreted to the South of the Well-a, while a NW-SE fault is the structural closure to the East. The high GOR of the wells 2 and 3 confirmed the seismic attribute and allowed to use it as prediction tool for the gas zones at the top of the reservoir.

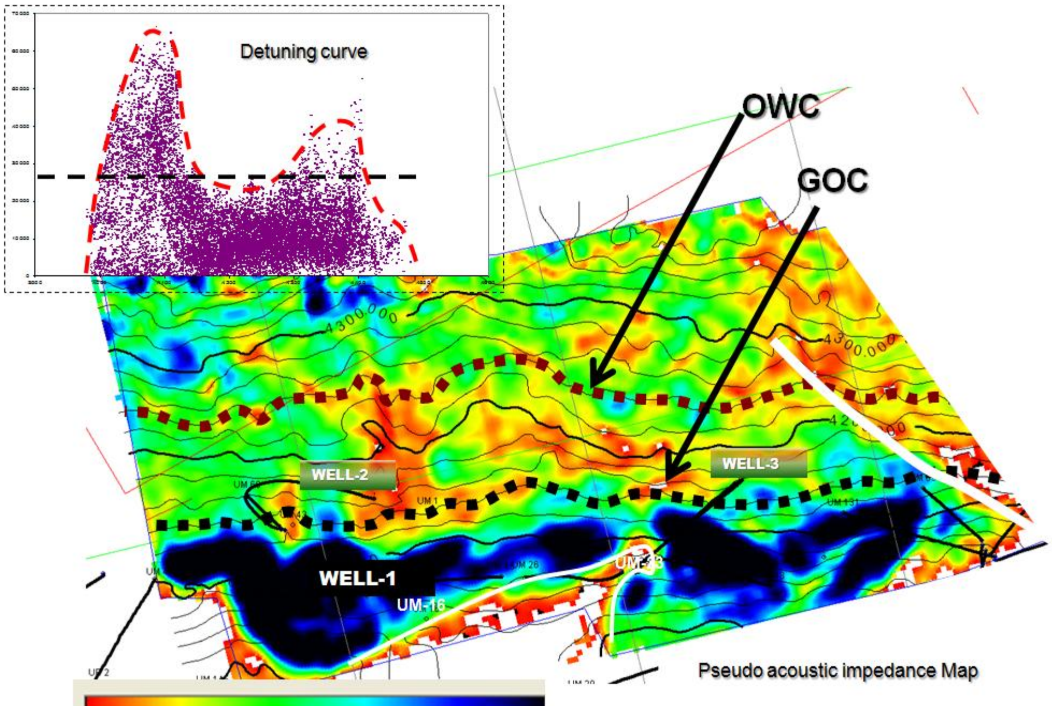
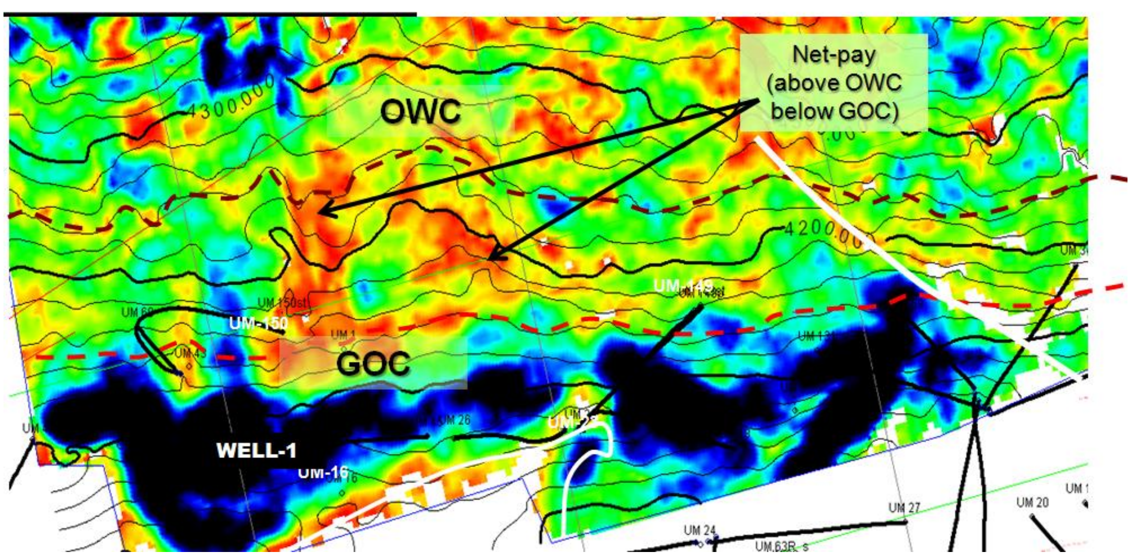


Figure 4. Time vs. Amplitude detuning curve shows the gas related high amplitudes. The impedance map shows dark blue and black areas of gas at the top of the reservoir interval. The lowest values, red in the scale, were interpreted as non-gas sandstones, distributed between the GOC and OWC.

Figure 5. Net-pay targets, selected for two new drilling locations, between the GOC and OWC.



EDITED REFERENCES

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