GEOPHYSICS PAPER 22

4D SEISMIC ANALYSIS OF RESERVOIR SANDS OVERLYING A SALT STRUCTURE

Haziqah Othman, Shuhadah Basaharudin, Salbiah M Sahad, Salbiah Isa, MK Sengupta & M Firdaus A Halim

PETRONAS Research Sdn Bhd, Lot 3288 & 3289, Kawasan Institusi Bangi, 43000 Kajang, Selangor, Malaysia

PETRONAS Research has recently embarked on a study to determine and understand pressure-saturation variations in a field through the use of 4D seismic technology. Changes in hydrocarbon pressure and saturation due to production produce noticeable changes in amplitude response. 4D seismic or the use of repeated time-lapse 2D/3D seismic surveys enables detection of 4D signal indicative of pressure or saturation changes.

The C field is located some 80 km due east of the coastline of West Africa. Water depth ranges from 739.3 to 823.6 m with area of 60km2. The oil and gas in the field are trapped in Early to Mid-Miocene reservoir sands above a faulted dome caused by underlying salt intrusion. The dome is faulted by low angle (45-60°) radial faults. A dominant east-west fault set subdivides the structure into an uplifted area in the north and a downthrown area to the south, which is itself separated into east and west fault blocks by a large north-south fault. Hence, the faults compartmentalize the field and hydrocarbons into three main fault blocks. The reservoir represents mid-slope turbidites which consist of a series of fining upwards sequences.

Conducting 4D seismic analysis and understanding pressure-saturation variations involve integrating several geophysical technologies. These technologies include well-synthetic-seismic correlation, Rock Physics, Production Scenario Seismic Modeling at selected injector/producer wells, 2D/3D seismic modeling, 4D AVO Modelling/Interpretation and correlating seismic attributes with engineering data, pressure history and saturation measurements.

Figure 1 shows the earth model of the reservoir sand that lies over a salt structure in the C field. The seismic synthetics generated from ray tracing are compared to the seismic section passing through the structure. Figure 2 top panel shows the well-seismic correlation at a selected well in the C field displaying the correlation at the main reservoirs. The bottom panel shows the rock physics analysis in C field.

Figure 3 shows the salt model with three reflectors and the OWC between first and second reflectors. The seismic modelling was conducted using the acoustic elastic finite difference wavefield modeling tool with seismic acquisition parameters applied on the C field. The wave simulation at time 2.1 sec shows the OWC at depth approximately 2000m. This simulation matches with the model where the wave hits the OWC. The generated raw and AGC shot gathers, in the bottom panels, at the source location of distance 1500m shows the three reflectors (R1, R2 and R3) at depth approximately 3200m until 3600m. Figure 4 shows the AVO modeling conducted at a selected well in C field showing a comparison analysis between In situ conditions and after Fluid Replacement Modeling.

Figure 5 shows the Base 1999 and Monitor 2007 RMS Amplitude and Difference Amplitude attribute maps. Yellow color on the RMS Amplitude attribute map indicates high RMS amplitude value. The difference (Monitor – Base) amplitude displays yellow color for high negative and purple for high positive difference amplitude values. Seismic attributes extracted within the major reservoir sands were generated for prediction of hydrocarbon. These attributes and difference maps can be correlated and integrated with pressure and saturation maps for interpretation of the 4D effects.

Figure 6 shows the 3D Inversion Amplitude Envelope attribute map. Orange color indicates high amplitude envelope value indicative of the reservoir hydrocarbon accumulation. The

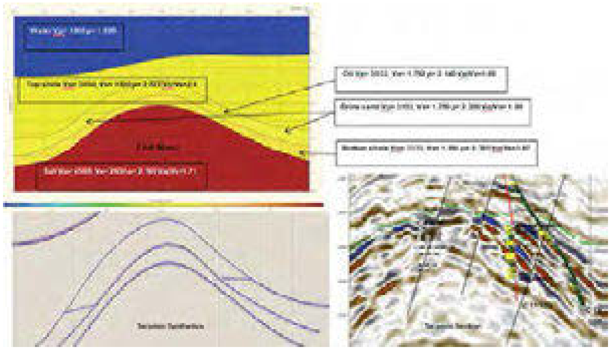

Figure 1: Seismic modeling ray tracing results compared with seismic section in C field.

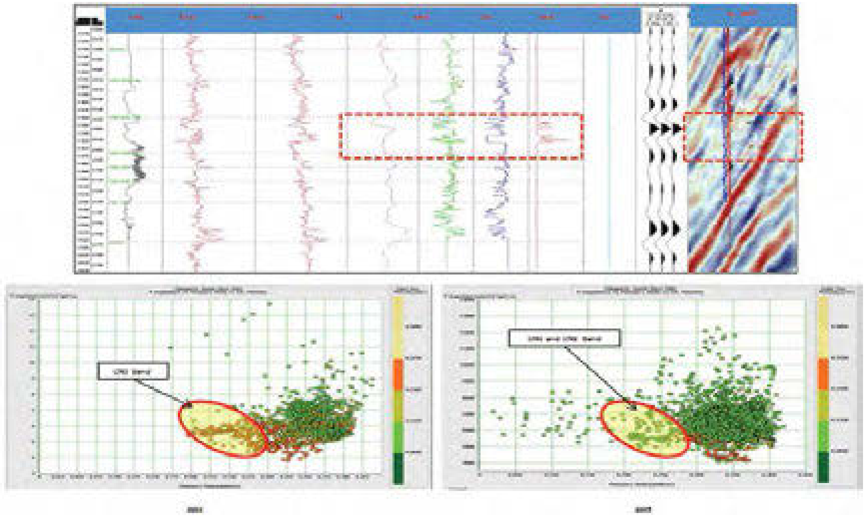

Figure 2: Well-seismic correlation and rock physics analysis in C field.

difference (Base-Monitor) amplitude between base and monitor is most anomalous within the south west region. Purple color indicates small changes in amplitude envelope difference value while yellow color indicates high changes. The 3D Inversion extraction attribute maps can be used for integration with production data.

Improving reservoir monitoring through the effective use of 4D Seismic analysis methods will enable us to more accurately locate bypassed oil and therefore, increase reserves. In addition, 4D seismic can be used to minimize costs by optimally locating development wells even in complex structures.

ACKNOWLEDGEMENT

We would like to thank the management of PETRONAS, PETRONAS Carigali Sdn Bhd and PETRONAS Research Sdn Bhd, for their support and permission. We are grateful to Liau Min Hoe, Lee Chun Ren, Nurhidayah Hutamin and En Abdullah Embong of PCSB, for their support and expert technical advice.

REFERENCES

TURA and LUMLEY, 1999. Cross plotting and constrained inversion method of P wave and S wave impedances. Geophysics. pp. 1655-1658.

LANDRO, 2001. Time-lapse AVO Intercept and gradient method. Geophysics. pp 66,
836-844.

FLORICICH, MACBETH and STAPLES, 2005. An engineering-driven approach without the need for rock physics. SEG 2005, Houston.

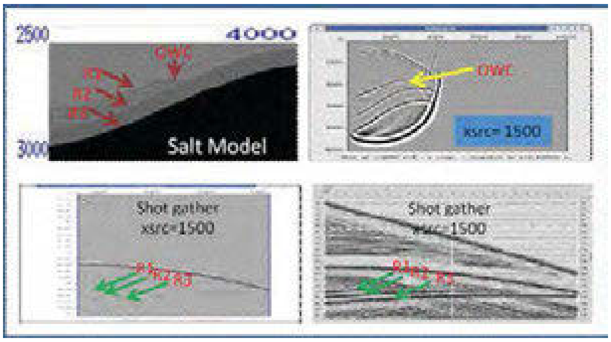

Figure 3: Finite Difference seismic modeling analysis and results.

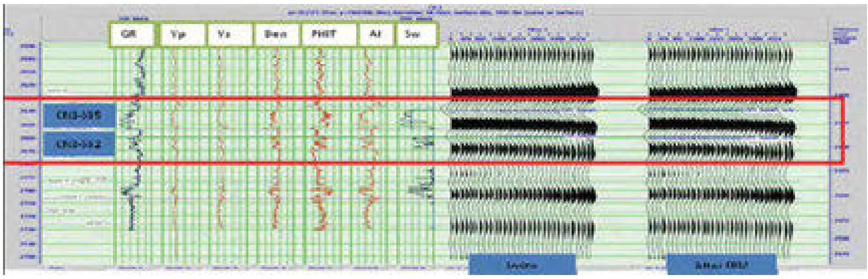

Figure 4: AVO modeling at reservoir sands.

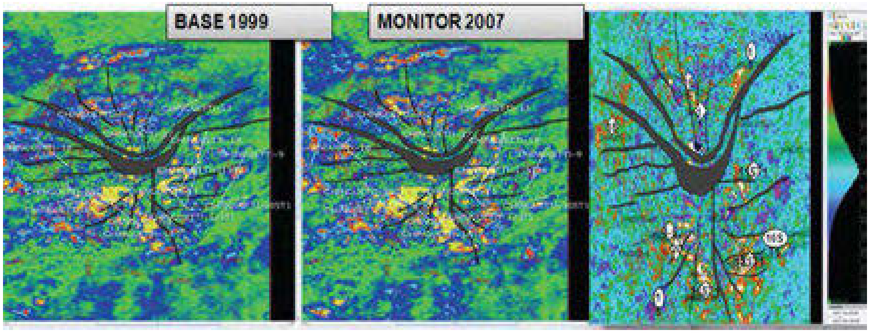

Figure 5: Seismic RMS Amplitude attributes of seismic surveys in 1999 and 2007. Right panel shows the difference amplitude map.

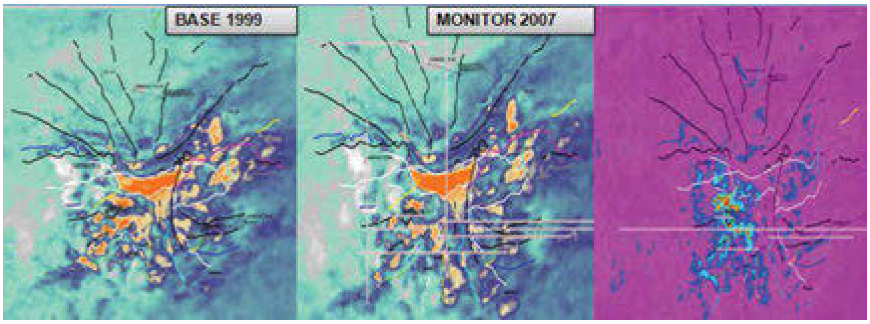

Figure 6: 3D AI Inversion Amplitude Envelope maps of seismic surveys in 1999 and 2007. The difference map is shown in the right panel indicating highest difference amplitudes observed in the southwest region.