Well Log and Synthetic Seismogram Analysis of the Kish Oil Field, Dorset, UK.

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ABSTRACT

Well logs from the Kish Oil Field were analyzed to determine the feasibility of a good seismic-to-well tie, and with it, the accuracy of the well ties. One of the major challenges in seismic interpretation is the uncertainty in picking the top reservoir; Sherwood sandstone, because of the gradational contact with the overlying Mercia mudstone, it appears on the seismic as a discontinuous reflector. However, this was minimized by shifting down the horizon of the top Mercia mudstone by 5 m to match zero crossing.

In this work a constant phase Ricker wavelet of bandwidth of 25 Hz was created and then convolved with the reflectivity series to generate a synthetic that will tie with the seismic data. The wavelet generated has an average phase of -125^0, the wavelet is then phase rotated to a zero phase wavelet (European polarity). The wavelet has been chosen for this analysis because it provided a good tie within the geological boundaries and also specifically within the reservoir intervals. It also has a phase error of <15^0 showing that the wavelet is in phase.

(Keywords: Kish oil field, Mercia mudstone, Ricker wavelet, Sherwood sandstone, zero phase wavelet)

INTRODUCTION

The Kish Oil Field is the largest of three producing oil fields in the Wessex Basin. The field is located beneath Poole Harbor (Figure 1) in Southeast Dorset, on the south coast of the UK (House, 1993). The data provided for this study assumes the oilfield is in an early stage of development with five wells; four onshore wells (Well K1-K4) and one offshore well (Well K-5).

Figure 2 outlines the location of the drilled appraisal wells. The increasing application of 3D seismic surveys and reservoir geophysics to reservoir management has emphasized the importance of seismic- to-well ties and, with it, the accuracy of well ties (White, 1980). A statement of well tie accuracy is essential to any attempt to quantify uncertainty in seismic lithological interpretation. The link between recorded seismic waveforms, the stratigraphy and rock properties of the subsurface is the seismic wavelet.

PETROLEUM SYSTEMS OVERVIEW

The reservoir is the 150 m Permo-Triassic continental red bed succession of the Sherwood Sandstone Group. The net reservoir is sandstone bar deposits which may be stacked laterally and horizontally. Floodplain deposits also provide a small volume of sand in Sheetflood sandstones but these are more important for their higher permeability and potential as a migration pathway (Underhill and Stoneley, 1998).

The Sherwood Sandstone Group has a gradational boundary with silty mudstones of the Upper Triassic Mercia Mudstone above. This mudstone is about 700 m thick and forms a reservoir-seal pair, both in the Wessex Basin and elsewhere in NW Europe.

Geochemical work (House, 1993) has identified the source rock as the 100 m thick organic shales of the Lower Lias (Lower Jurassic). Total organic carbon content up to 8% has been measured and is mostly algal material of Type II kerogen (Underhill and Stoneley, 1998).

The trapping structure is a tilted fault block which closes onto the net extensional West Field Fault. The trap requires the fault to be sealing (Figure 3).

Figure 1: The Location of the Kish Oil Field Relative to the Poole Harbor.

Figure 2: Reservoir Outline and Location of Wells at Reservoir Interval.

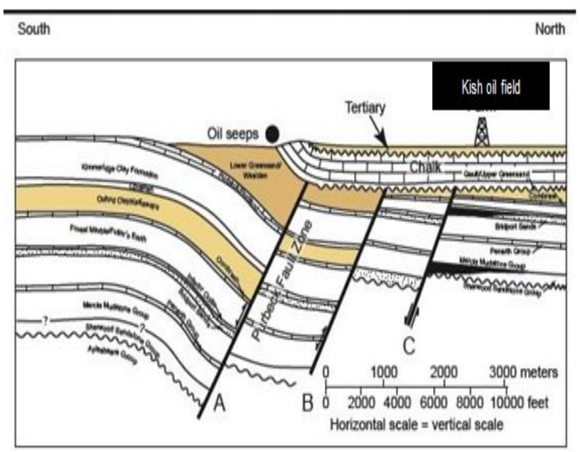

Figure 3: Structural Deformities Showing Reservoir and Seal Pair.

The Lower Lias shales are seen in outcrop at Charmouth but are only partially mature, although the presence of 'beef' (fibrous calcite) layers indicates burial to some depth prior to uplift to the surface. Published work indicates maturation occurred prior to the Tertiary inversion and is limited to a kitchen area south of the Purbeck-Isle of Wight disturbance (Underhill and Stoneley 1998). The Lower Lias has been identified as the source for the live oil seep in the Wealden beds in Mupe Bay (Cornford et al., 1988).

The reservoir and trap occurs to the north of the Isle of Wight-Purbeck disturbance so primary migration relied on leakage across the fault system to backfill the tilted fault block. This allows for the stratigrapically higher source to charge an older and lower reservoir.

Oil generation is reported to have begun in the Early Cretaceous with peak generation in the Middle to Late Cretaceous. The faults which acted as conduits for the backfilling of the reservoir must have then become sealing to allow for the accumulation of a thick oil column.

The majority of the deformation associated with the basin closure in the Tertiary is concentrated in the near vicinity of the Purbeck fault and in particular in the hanging wall to the south of the fault zone. Fault reactivation within the West oilfield does carry the risk of breaching the seal although all faults are still in net extension

METHODOLOGY

Synthetic seismograms are one-dimensional models. They are produced from interval transit time logs or sonic logs.

A quick synopsis of calculating synthetic is as follows:

- Develop a velocity log (RokDoc software converts a sonic log to a V_P logs automatically).

- The log can be combined with a density log, and a reflection coefficient versus time log can be calculated using this equation.

$$\frac{\rho 2V2 - \rho 1V1}{\rho 2V2 + \rho 1V1} - - - - - - - - (1)$$

Where ρ= density, v=velocity

- Convolve reflection coefficient logs with a preselected wavelet to obtain the synthetic seismogram. (Gadallah and Fisher, 2005).

This results in the development of a model taken from the well log, which closely resembles a seismic trace taken at the same location. The steps in estimating a seismic wavelet by matching a well log synthetic seismogram and Kish Field seismic data are explained as follows

Log Conditioning

A cross-plot of the density and velocity logs is carried out so as to reduce the effect of washout corrections; this could be seen from the Caliper log i.e. well bore rugosity, cycle skipping etc. This procedure involves a creating an inclusive polygon to despike the log from any of these listed corrections (Figure 4).

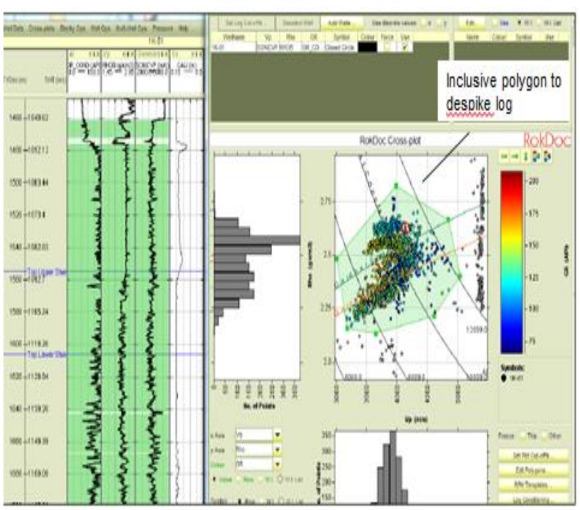

Figure 4: V_p-ρ crossplot for K-1 Well.

Calibration of Logs

This involves the correction between deviation from checkshots and Vp log, the Vp log is integrated to create a time-depth curve, which is then hung from a specific checkshot. The difference between the time-depth curve and the checkshot represents the drift as seen in Figure 5. The drift correction is then applied to the time-depth curve, which is then differentiated to give a calibrated Vp log.

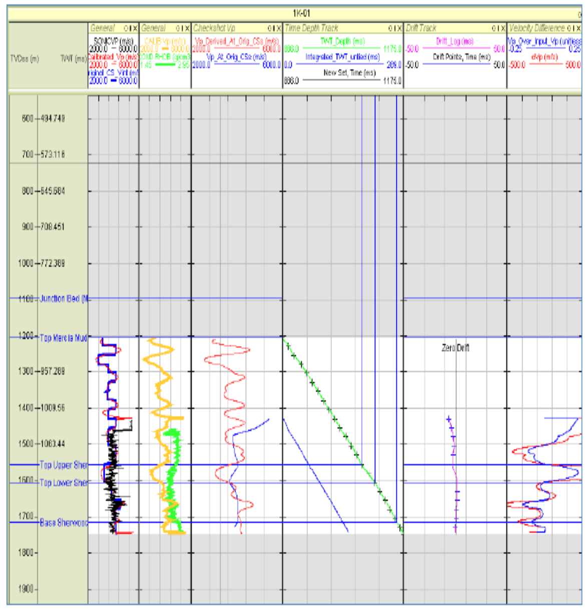

Figure 5: Calibrated V_p log for K-1 Well.

Wavelet Extraction

There are different methods of determining wavelet in data sets, but in the Kish Field data, the deterministic method of using a constant phase Ricker wavelet of sample interval of 2 ms with a bandwidth of 25Hz was created (White, 1980), this wavelet is convolved with the reflectivity series to generate a synthetic that will tie with the seismic as shown in Figure 7. This wavelet extraction is simply illustrated in Figure 6.

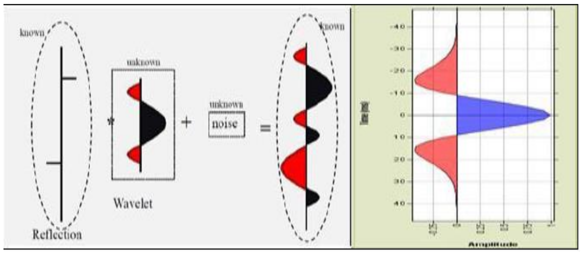

Figure 6: Ricker Wavelet used to Generate the Synthetic (White, 1980).

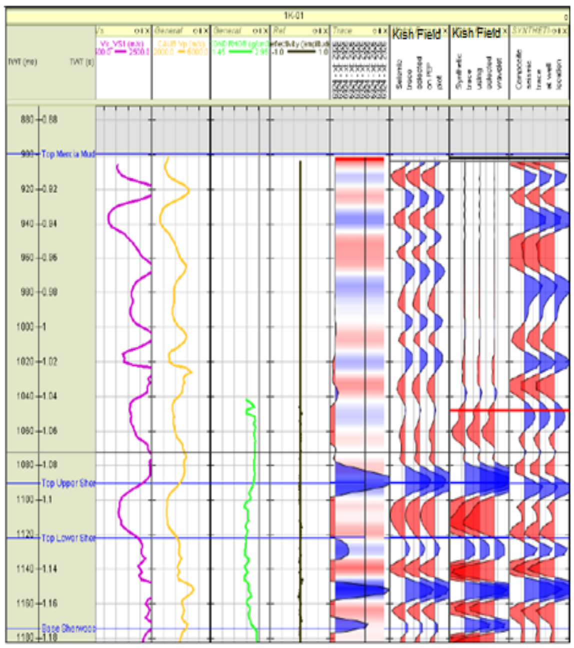

Figure 7: Model Synthetic Gather with the Seismic Data (a good match on reservoir interval) for K-1 Well.

<u>Phase Rotation</u>

The bandwidth of the seismic data provides a limit on resolution, and it is the product (i.e. multiplication) of the bandwidth of the earth's response and the bandwidth of the wavelet. Since the earth has relatively high-frequency variations (as it is evident in the logs), the main limitation on the data is the (bandwidth/amplitude spectrum of the) wavelet. This is why the wavelet bandwidth is important (White and Simm, 2003).

Phase rotation is important because the phase of the wavelet determines the time at which each reflection occurs. A zero-phase wavelet has no time delay, and allows events to be picked on peaks; it also has the maximum resolving power compared to any other phase. This is why we aim to have a zero-phase wavelet for interpretation.

The original wavelet in the Kish field data is not zero-phase, but its phase is nearly constant in the active bandwidth of the data. The corresponding value can then be found by comparing synthetics with actual data at the wells: the correct wavelet is the one that that makes the synthetics look most like the data. Subtracting this phase from the seismic data is known as phase rotation and it converts the data to zero-phase which in turn, allows easy picking on peaks.

RESULTS AND DISCUSSIONS

For a quick or first-look well tie it is often sufficient to filter the broadband synthetic seismogram with a wavelet having a passband corresponding to that of the seismic bandwidth and then apply a phase rotation that best matches the data. (Walden and White 1992).

The wavelet generated has to be broadband i.e. having a constant amplitude at all frequencies and also at a zero phase i.e. symmetrical in time, in this work an average phase of -125^0 was created, so the wavelet was rotated at a phase of -125^0 to a zero phase wavelet (European polarity), as shown in Figure 8.

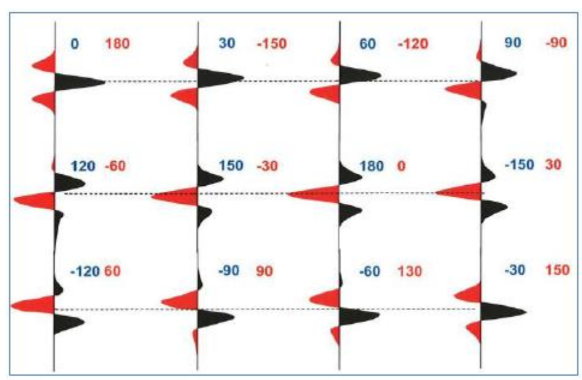

Figure 8: Phase Description Reference: SEG Standard +ve (shown above in blue) UKOOA (European) Normal Polarity (shown above in red) (Walden and White, 1984).

Figure 9 shows the wavelet extracted at the best fit location in the well K-1, this wavelet has been chosen for this analysis because it provided a good tie within the geological layer boundaries and also a specifically within the reservoir intervals and also having a phase error of < 15^0 showing that the wavelet is in phase.

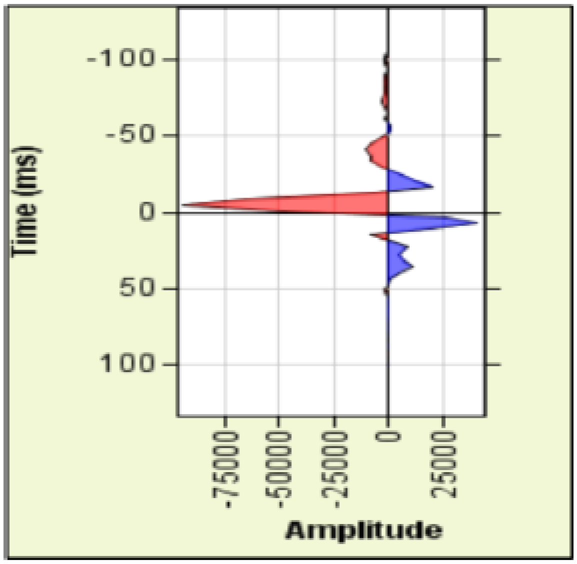

Figure 9: Extracted Wavelet at Well K-1.

Figures 10, 11, and 12 are the input parameters, data QC analysis (bT values, phase error and PEP plot) with the amplitude and phase spectra respectively, obtained from the K-1 well.

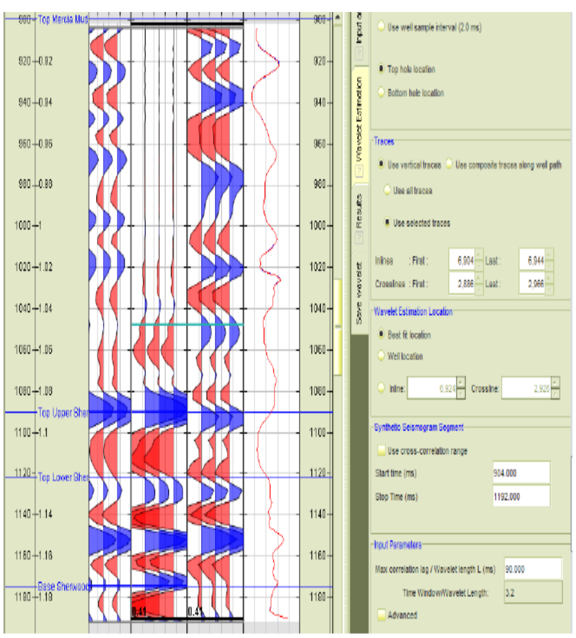

Figure 10: Input Parameters of the Estimated Wavelet.

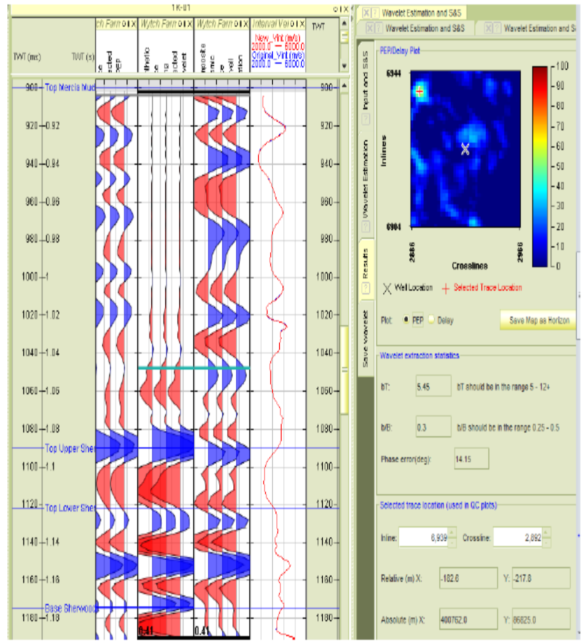

Figure 11: Data QC of the Estimated Wavelet.

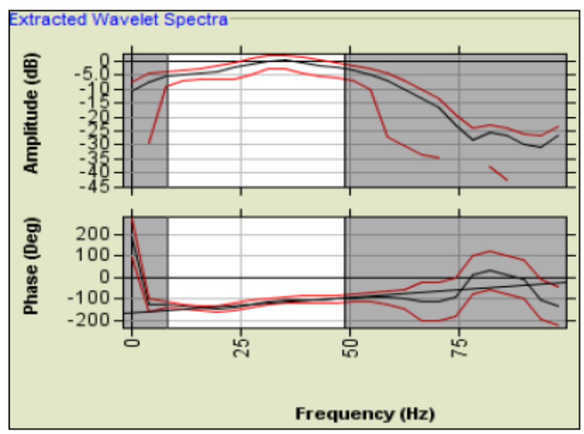

Figure 12: Amplitude and Phase Spectra of the Wavelet.

The shape of the wavelet is important for the results of seismic modelling, for example the wavelet has a negative peak (trough) at the top reservoir (Figure 13). The cut-out seismic section shows that understanding the polarity of the data is vital to identifying the loop which carries the amplitude information about the top reservoir. In this case the blue pick amplitude represents the trough.

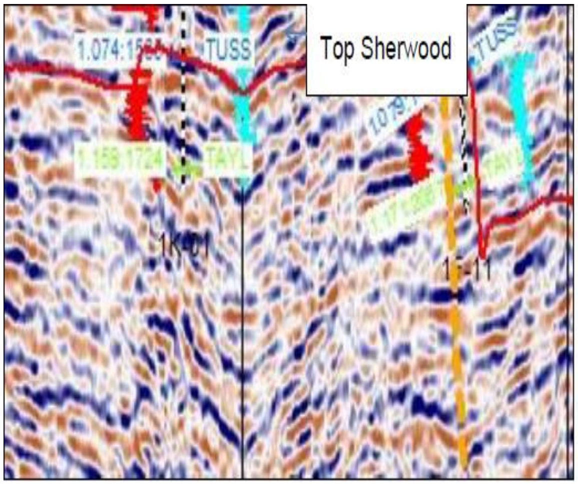

Figure 13: Cut-out Seismic Section of Top Sherwood.

CONCLUSION

A cross section of the phase rotated seismic (Figure 14) shows a zero difference across all wells in the key horizons between synthetic and original seismic in the top Sherwood sandstone. Horizon of top Mercia mudstone was shifted down by 5ms to match zero-crossing.

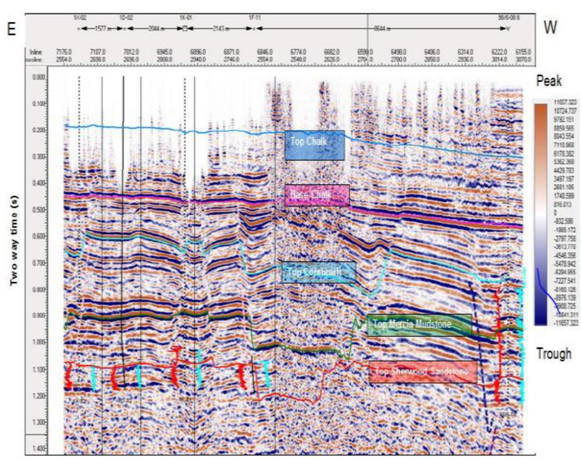

Figure 14: Cross Section (time) of Phase Rotated Seismic showing Wells, Faults, and Horizons.

Also results from the phase rotated seismic shows a negligible difference in horizon crossing against formation tops at wells and also reduced uncertainty in the horizon picking of the top Sherwood.

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