Multi Azimuth Imaging of an Oil-bearing Faulted Sandstone Reservoir: A Nigeria deep offshore Case study

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Introduction

The first depth velocity model over the field was created in 2011, using data acquired in 2008 as part of a high definition (HD) survey collected on a 6.25 x 12.5 binning grid with relatively shallow streamer and gun depths (5 m and 6 m respectively) aimed at maximizing the signal bandwidth and spatial resolution of the faulted sandstone reservoir. Here we present further work updating the 2011 model by combining the 2008 HD survey with an earlier 1997 regional survey to achieve a dual azimuth reprocessing.

The reprocessing effort for these two surveys focused on delivering two closely matched orthogonal input surveys that would be used in a dual azimuth tomographic model building process that would improve on existing processing and resulting velocity model. The combination of the two azimuths should potentially enhance the interpretability of the data. The reprocessing itself focused primarily on de-ghosting and multiple suppression: the field sits below 1100m of water with the water-bottom multiple sitting just below the reservoir interval – with the risk of multiple energy migrating into the reservoir interval as noise if not fully removed.

Our previous velocity model building over this and adjacent fields identified shallow velocity variations throughout the area. Hence, in this new work, introducing this small detail into the model was critical. The other challenge was that of establishing a realistic anisotropy component where the well information was detailed but not widespread. This was critical in correctly placing the reflectors seen on the flanks of the structure and the many fault plane reflections throughout the reservoir interval.

Method

Initial velocity modeling updates took the existing archived preprocessing and aimed at comparing the existing single azimuth historical velocity with an update using the two surveys. As a starting point it was necessary to reduce the detail in the historical model – to start from a "smooth background" – allowing the two datasets to contribute to this update without the bias of the historical view. The historical model did not conform particularly well to the seismic structure and improving on the correlation between seismic and velocity structure was an objective for the initial update.

Work to improve the structural trends in the model was then undertaken. Having the second survey with richer low frequency gave more data to the tomography – also incorporating structural constraints within the tomography helped in achieving this aim. At the conclusion of the first phase of model update both datasets were migrated onto a common grid to give two images of the reservoir. These were then combined with the aim of extracting the best elements and benefit from each individual image.

The second phase of model building used the two data vintages after the full re-processing – with both datasets being better matched with source and receiver ghosts removed. The aim for this phase was to add detail to the velocity model and better define the anisotropy to optimize the image of each survey, thus provide a single high-resolution coherent image volume for the asset team's interpretation.

Examples

The Migration of data from the two different pre-processing routes gave datasets which, as expected, were richer in low frequencies for the de-ghosted 1997 deep tow data and predominantly richer in high frequencies in the case of the later HD 2008 non-de-ghosted data. It was found that to merge the resulting individual migrations it was necessary to weight data prior to combining to take the best of both datasets –this gave an overall good combined result. This merge took a 90-10 blend of the data at low frequencies favoring the 1997 data, while the high frequencies reversed this weighting taking a 10-90 weighting favoring the HD 2008 survey. This approach proved to be superior to a simple averaging of both datasets.

Following the new full reprocessing, wherein both vintages of data had a full de-ghosting sequence applied, the spectra from both surveys were extended and more importantly were better matched. Figure 1 shows the respective spectra before and after the deghosting and wavelet processing.

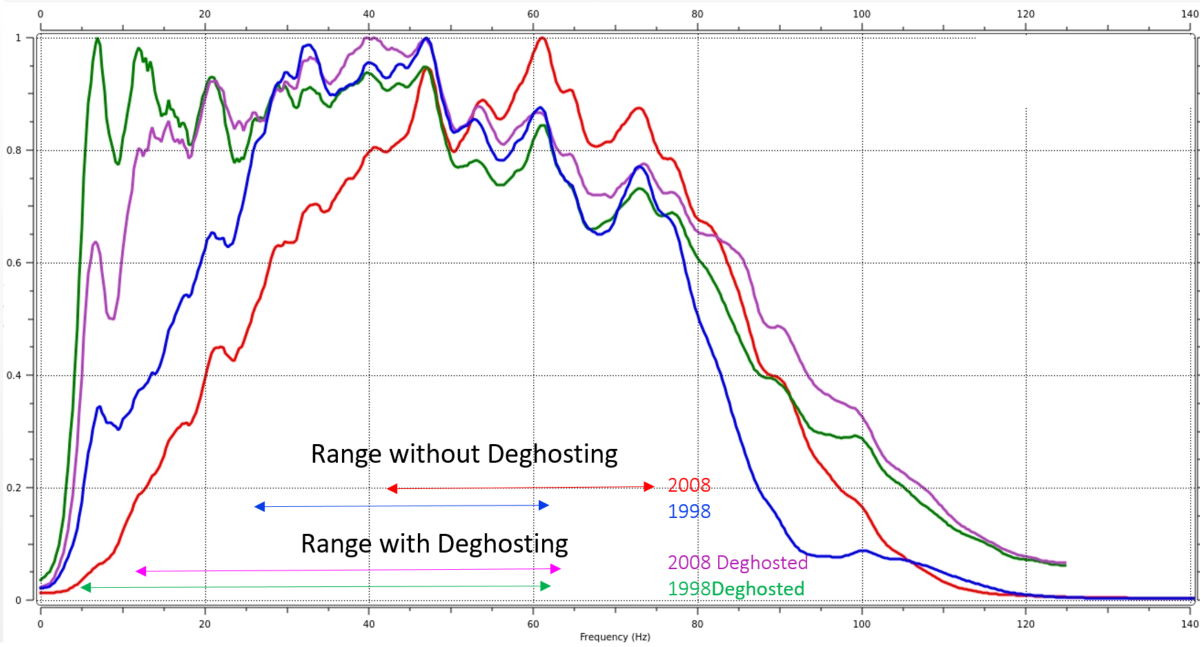

Figure 1: Extension of Spectra – with Deghosting

On migrating the newly processed data, the combined image was formed by merging the two volume equally across the full frequency range – there being no need to weight different parts of the frequency range differently to optimize the merge.

Now having two datasets with matched spectra, it was possible to deal with getting detail into the model. Figures 2 and 3 show the migrated data with velocity model overlay for both the 2011 and 2018 products respectively. Improvements are clear throughout the image in the 2018 results, especially in the vicinity of the heavily faulted reservoir (~2450 m) and also deeper on the flanks of the structure were faults are much more clearly defined (denoted by the yellow circle).

To achieve the desired detail in the 2018 model, it was necessary to reduce the ray tracing cell size so as to capture the detail in the ray tracing for Kirchhoff migration feeding the tomography. The optimum cell size to capture the fine structural detail was found to be 125x125x50 m. The model with this fine cell sampling produced a better alignment of velocity with the structure, and also resulting in a general lowering of velocities over the reservoir. In comparison, the 2011 model more or less simply follows the seabed geometry: in other words, represents a compaction trend model.

Figures 4 shows an inline section denoting the top of the structure, whilst figure 5 shows the amplitude map associated with this horizon for the vintage and new processing results: The new 2018 processing shows a much more coherent amplitude response, well bounded by faults.

Conclusions

Two separate data volumes and a merged combined data volume from a high resolution TTI tomographic model building route were delivered to the interpretation team for studies towards production development plan. In addition to the benefit of increased resolution and clarity at the reservoir level resulting from low frequency content of the de-ghosted data, these new images also facilitated a better understanding of the overall reservoir architecture, and thus better reservoir model.

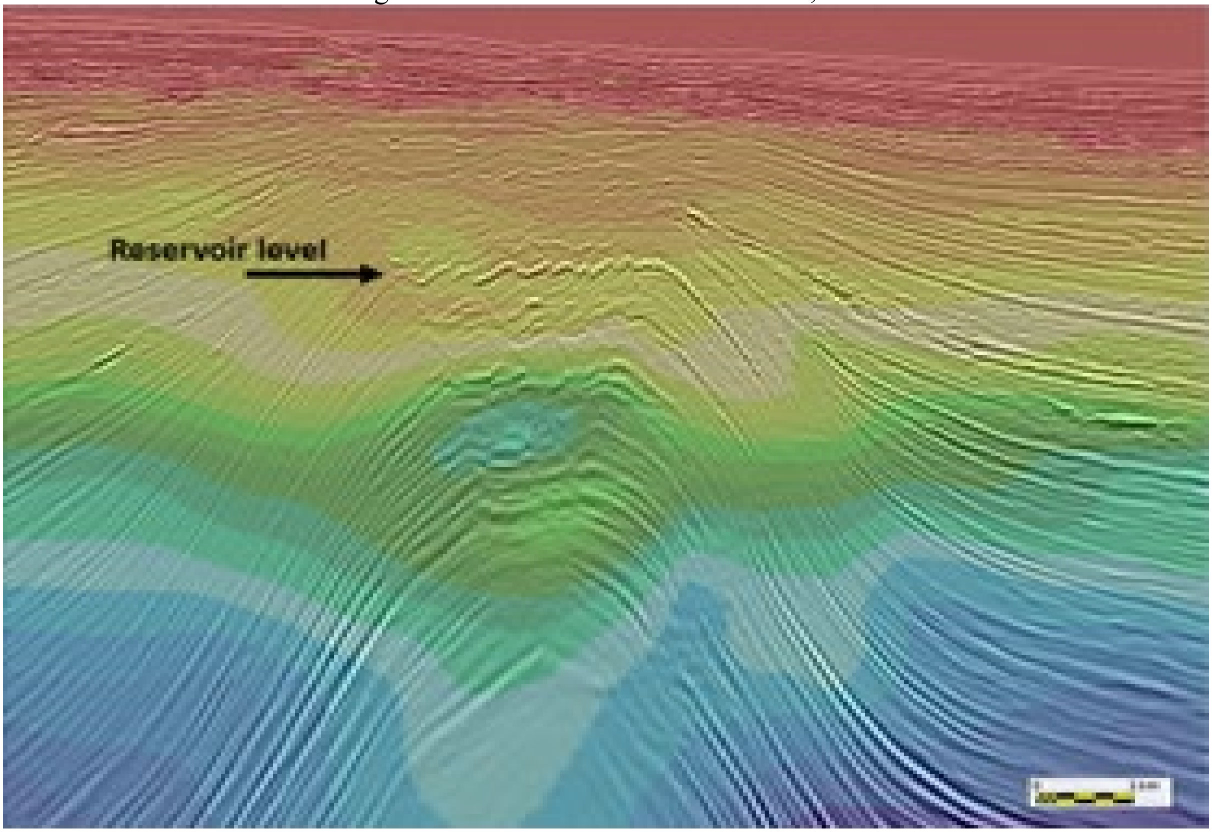

Figure 2. Kirchhoff preSDM images with model overlay for the 2011 results.

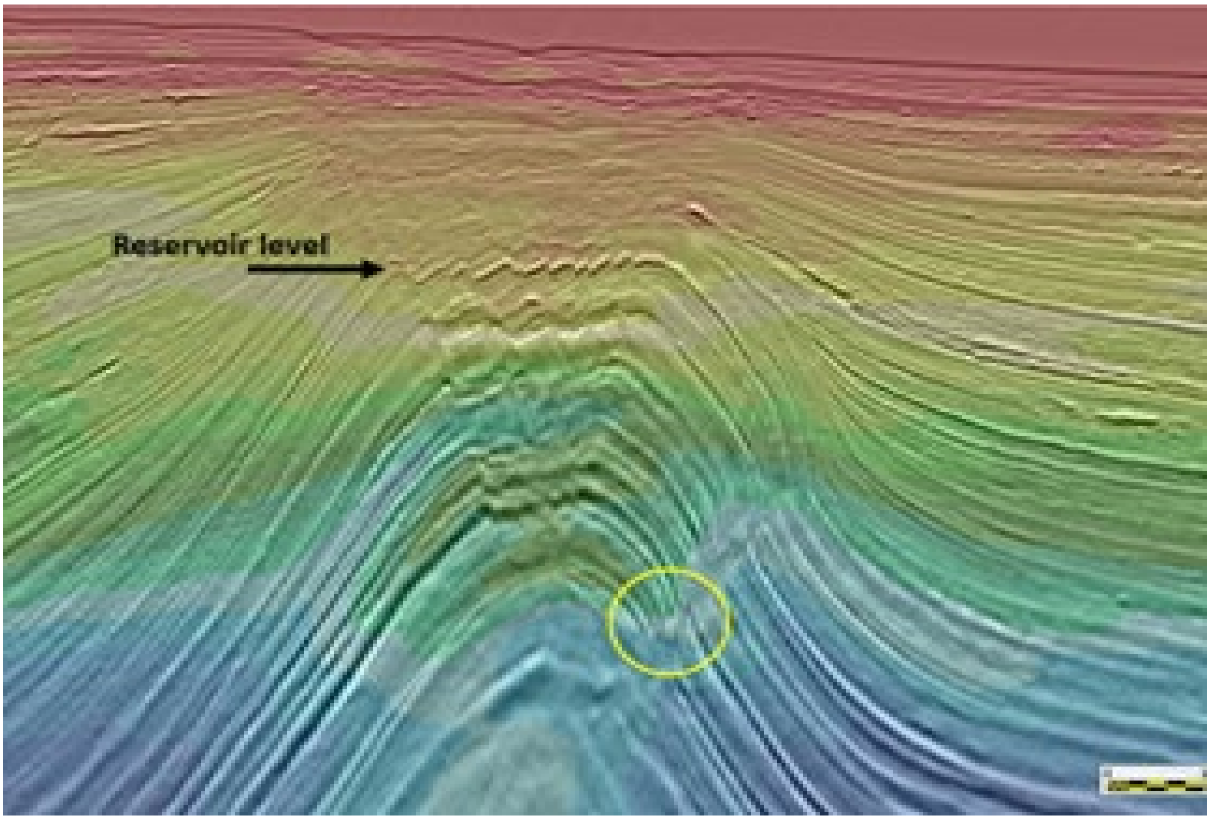

Figure 3. Kirchhoff preSDM images with model overlay for the 2018 results. Improvements are clear throughout the section, especially in the deep section were faults are clearly defined (e.g. yellow circle). The depth of the one of the reservoirs is indicated.

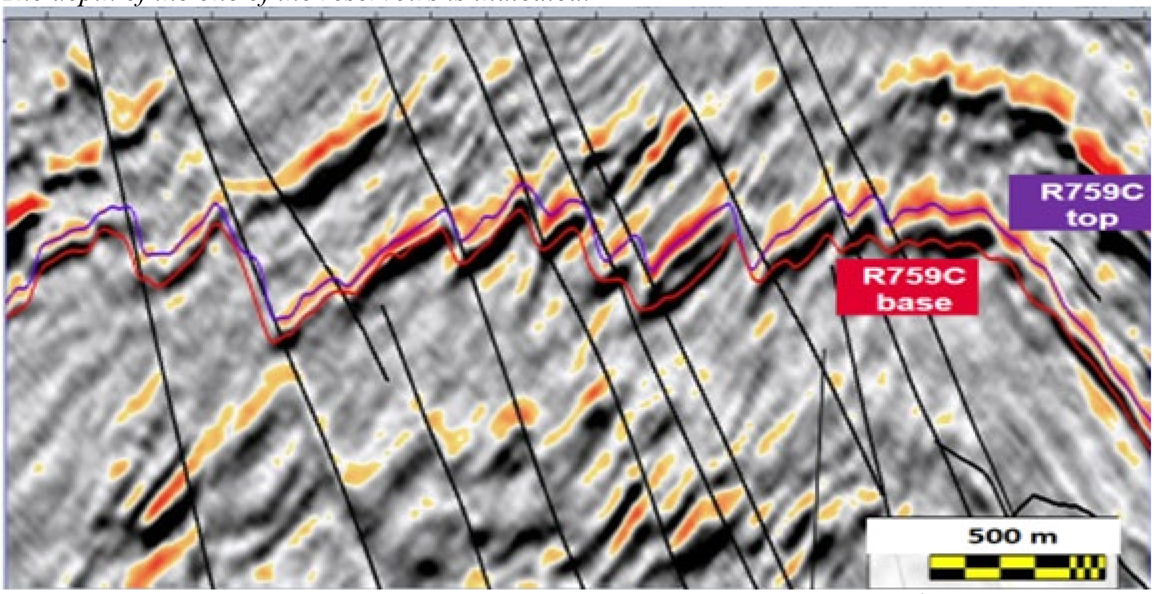

Figure 4. Zoom of structure at reservoir level for the far offset stack (30 – 42^0). The interpretations in purple and red denote the top and base of the reservoir unit, respectively.

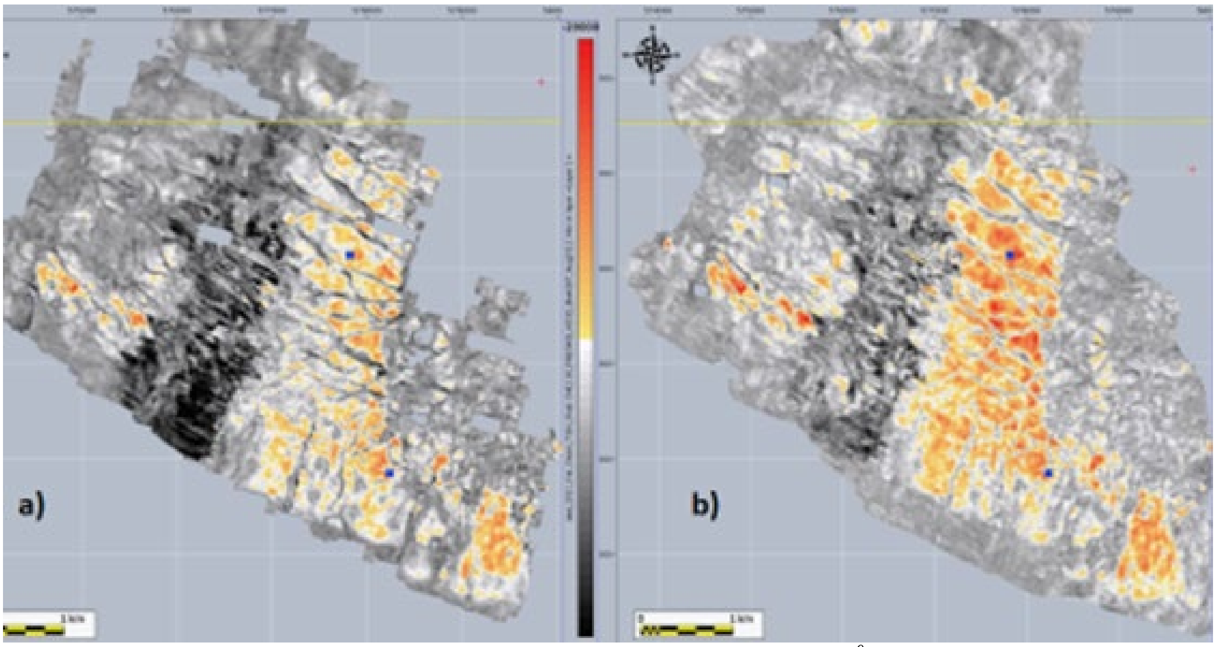

Figure 5. Amplitude map at reservoir level for far offset stacks (30 – 42^0) for the minimum amplitude, for the 2011 results (a) and the new 2018 results (b). The new 2018 processing shows a much more coherent amplitude response, well bounded by faults.

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