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Diffraction Imaging in the North Sea, Case Study Over the Dutch Q16 Fields

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SUMMARY

In 2013 SGS Horizon, in combination with Z-Terra and Moser Geophysical Services, carried out a re-processing job for operator Oranje Nassau Energie which involved the merge of the offshore survey Q16 and onshore survey Monster. The pre-processing of the data was followed by pre-stack time and depth migration, all steps with amplitudes preserved because of fluid sensitivity of the reservoir. The velocity model involved estimation of anisotropy parameters and confirmed findings of a negative delta in the Tertiary as seen in other parts of the southern North Sea. The construction of a high-quality velocity model created the optimal conditions for subsequent diffraction imaging, which in turn provides high-resolution structural information.

Introduction

In 2013 SGS Horizon, in combination with Z-Terra and Moser Geophysical Services, carried out a re-processing job for operator Oranje Nassau Energie which involved the merger of the surveys Q16 and Monster. The pre-processing of the data was followed first by a pre-stack time migration and then a pre-stack depth migration. Pre-processing and subsequent pre-stack time- and depth-migration were amplitude preserved since the reservoirs are fluid sensitive. Velocity analysis during the PSDM phase was performed by tomography where three levels were considered: pre-Chalk, Chalk and post-Chalk. Depth migration was performed in anisotropic mode. The availability of a high-quality migration velocity and focusing of the depth image provided optimal conditions for subsequent diffraction imaging and deployment of diffraction imaging technology in the North Sea.

Q16

The working area is in the licences Q16a and Q16bc in the southern part of the Dutch North Sea (Figure 1). The primary target in the area comprises the Main Buntsandstein of the Q16A and Q16-Maas fields including their near-field exploration prospects. The depth range of this target is approximately from 1500–4000m. In addition, the Lower Cretaceous Vlieland Formation represents a secondary target. No sub-salt imaging is required as no movable Zechstein salt is present in subject area. The structural setting is defined by two key tectonic features: pre-Cretaceous block faulting (mainly caused by Jurassic rifting of the West Netherlands Basin) and Late Cretaceous to Early Tertiary basin inversion. The compressional inversion is relative mild in the Q16 area at the south-western edge of the West Netherlands Basin.

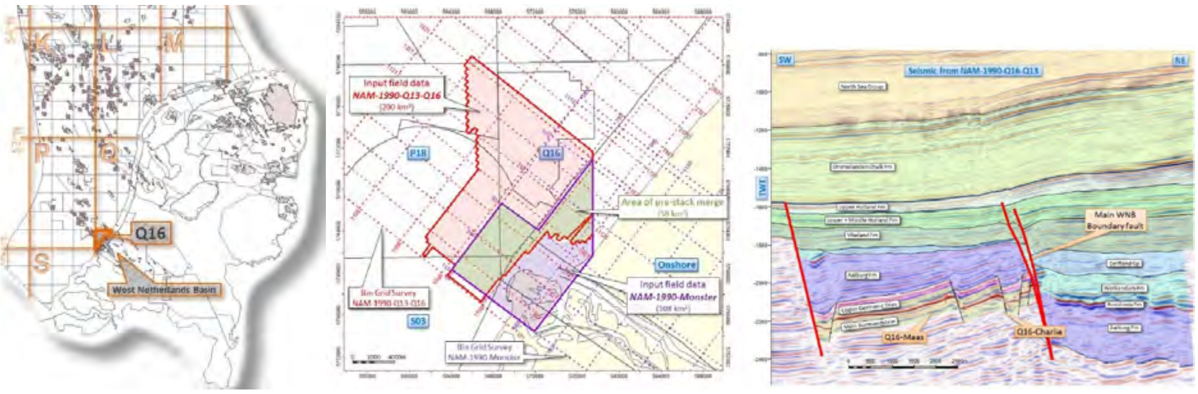

Figure 1 *Location of Q16 in the Dutch offshore.*

Preprocessing and depth imaging

The project involved merging the offshore survey Q16 and the onshore survey Monster. In particular the acquisition of Monster was rather complicated and several sources and receivers had to be used: dynamite, vibroseis and airgun as sources and geophones and bay-cable as receivers. So pre-processing on signature level was a first challenge on these low-fold and noisy surveys.

Noise suppression was another issue. Here the proprietary noise-suppression tool WIND was very successful. Figure 2 shows the results of this process where the strong noise in the shallower levels, severely affecting the deeper levels, was suppressed. WIND is based on LIFT proposed by Choo, Downton and Dewar (2004) and eliminates both random and organized noise.

The pre-stack depth migration was carried out in anisotropic mode. Table 1 lists the geological layers for which the anisotropy parameters were found to have distinct and almost constant values. In the same table the average values for those layers for delta and epsilon are listed.

One special aspect is highlighted here which is the negative sign of delta in the Tertiary. This negative sign is observed more often in the southern part of the Dutch North Sea, but although the possibility of a negative delta was reported already by Thomsen (1986) in his paper on weak elastic anisotropy, it is seldom applied. For some reason processors set a negative delta to zero when encountered. In this case it was decided to apply the negative delta anyway, since it was observed very clearly at the wells.

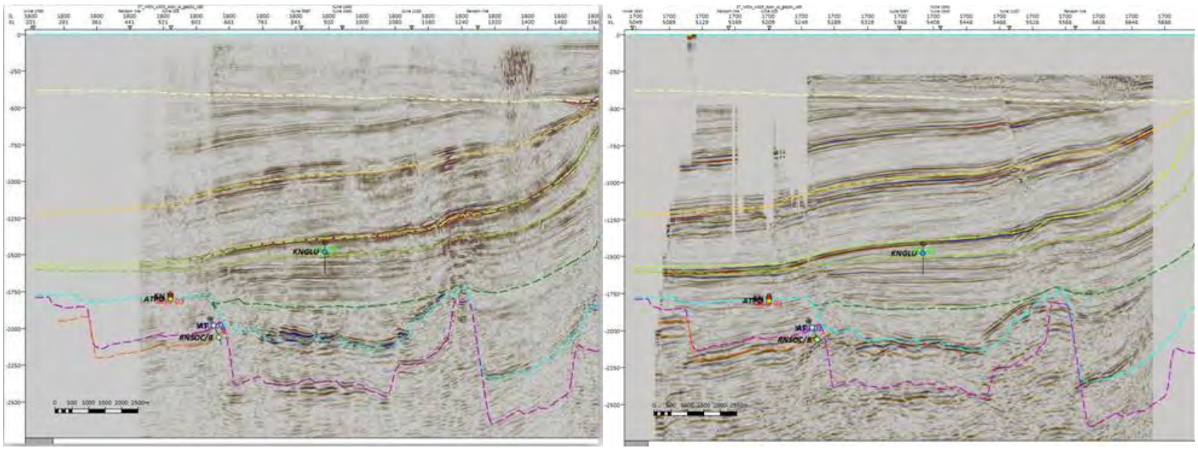

Figure 2 *WIND processing. Note the suppression of random and organized noise.*

Layer	Delta	Epsilon
Tertiary	-0.02	-0.04
Chalk	0.06	0.12
Lower Cretaceous	0.15	0.30
Jurassic	0.15	0.30
Triassic and below	0.15	0.30

Table 1 *Average VTI parameters for specific geological layers.*

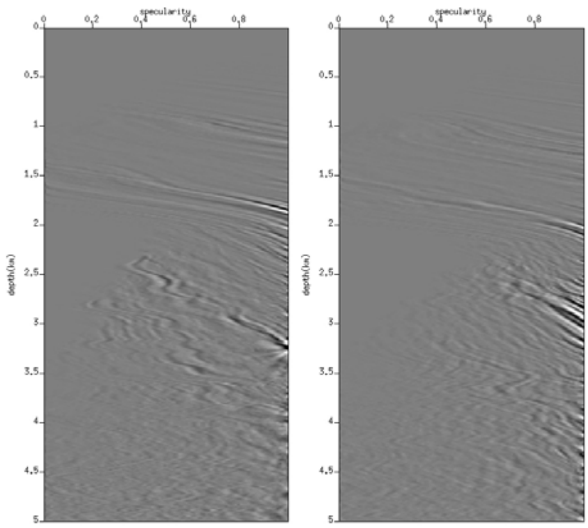

Figure 3 *Typical specularity gathers at two different locations. Specular reflected energy is concentrated along the right axis of the panels (specularity=1), non-specular diffracted energy is distributed over ranges with specularity smaller than one.*

Diffraction Imaging

Diffraction imaging has been carried over the Q16 area, following the work flow for diffraction imaging in depth outlined in Sturzu et al. (2013), where further references are found. Here, the diffraction imaging takes the standard (Kirchhoff) depth migration as a starting point. The basic assumption is that the migration velocity estimation and migration cycle has been finalized and has resulted in an optimal depth image with associated velocity model. As a first step in the work flow for diffraction imaging is to extract the reflector dip field from the standard migrated image. Using this information the depth migration is run again, but now with energy sorted according to specularity (defined as accordance with Snell's law, details see Sturzu et al., 2013). The specularity gathers are analysed with the purpose of designing an optimal specularity taper (suppressing reflection energy). Finally, the diffraction image is obtained by stacking over the tapered specularity gathers.

Typical specularity gathers are shown in Figure 3. Here, reflected energy is isolated at the right axis of the panels (corresponding to pure specular reflection) so that it can be effectively tapered out. Depth slices of diffraction images with various degrees of specularity tapering are shown in Figure 4. As can be seen from the displays in Figure 4cd, a different degree of specularity tapering results in different structural details being emphasized. In practice, it turns out to be useful to compare three options: the standard migrated image (i.e. no specularity tapering, Figure 4a), a diffraction image with very weak tapering (i.e. close to the standard image, Figure 4c) and one with strong tapering (showing diffractions only, Figure 4d). For comparison, Figure 4b shows a coherency depth slice.

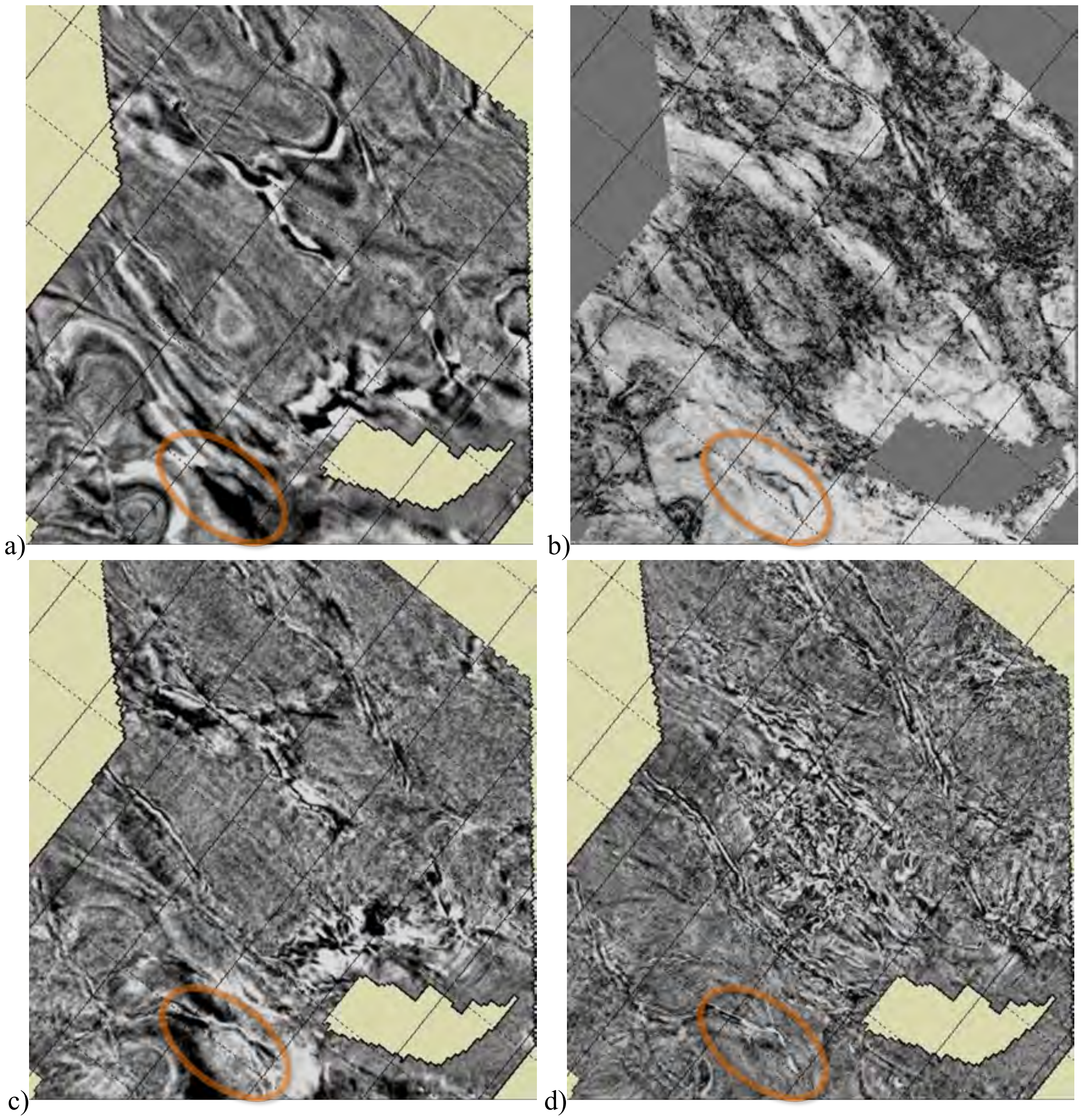

Figure 4 *Depth slices at 2930m of (a) standard depth image, (b) coherency and (c,d) diffraction images with increasing specularity taper. The Q16 Maas discovery is indicated by the ellipse. Note how increasing tapering brings up more structural detail in the diffraction image.*

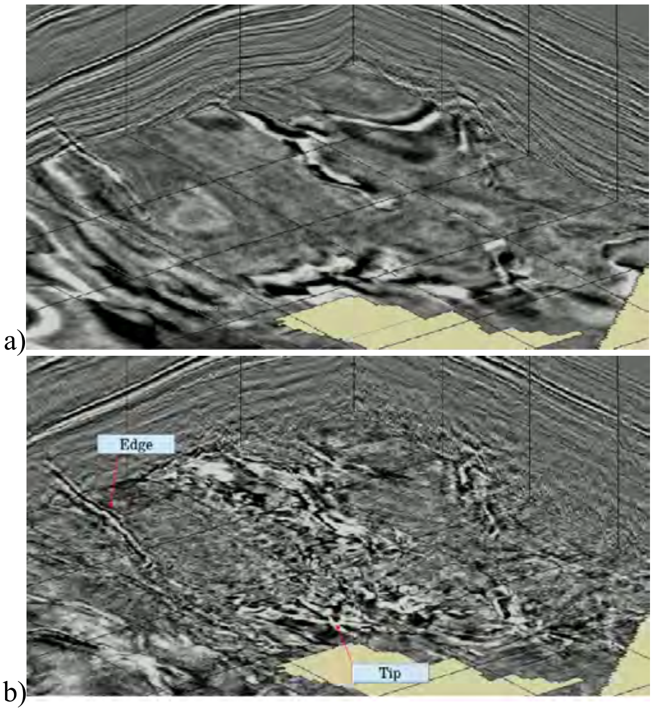

Figure 5 *Standard depth image and diffraction image (a/b). Zoom (in-/cross-line/depth) showing structural edge and tip diffractors.*

In Figure 5, a 3D view with inline, crossline and depth sections is shown for the standard depth migrated image and a diffraction image with optimal tapering. The diffraction image clearly shows the occurrence of edge and tip diffractors. As argued by Moser (2011), edge diffractions are only partly suppressed by the specularity tapering, since they still obey Snell's law in a direction along the edge. By contrast, tip diffractions are not affected at all by specularity tapering and therefore stand out in the diffraction image. Edges provide the structural skeleton, of which tips are the joints.

Conclusions

Pre-processing, PSTM and PSDM strongly improved the data with respect to former processing. WIND appears a powerful noise eliminator for both random and organised noise. Shallow levels in the southern Dutch North Sea often reveal negative delta, as confirmed by this study. Diffraction imaging is a powerful and attractive additional tool for fault delineation. During the study it was found and confirmed that keeping various vintages of diffraction imaging, differing in the degree of specularity tapering, is useful for interpretation purposes.

Acknowledgements

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