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Image Quality Enhancement Using Volumetric Q-tomography and Q-PSDM - Martin Linge Case Study

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SUMMARY

The compensation of absorption loss inside the imaging process using attenuation models estimated by Q-tomography is now widely accepted and used in the industry. This technology becomes even more important in the case of a complex dataset. For the Martin Linge field, characterized by a strong presence of faults and gas clouds, the multi-azimuth broadband acquisition involving a variable-depth streamer has helped to improve the quality of the data. High-end processing and imaging so far provided an image with enhanced resolution compared to legacy data mainly with regard to faulting in the deeper area. Nevertheless, imaging remained poor in the deeper part of the section because of a seismic obscured area (SOA) caused by gas clouds. In this paper we now illustrate how we managed to enhance the resolution under this SOA zone using volumetric Q-tomography and Q-prestack depth migration (Q-PSDM). In other words, we show that multi-azimuth broadband acquisition combined with Q-tomography/Q-PSDM techniques can provide an improved final image in the case of a complex data with a SOA.

Introduction

In recent years, there has been tremendous progress in resolution and accuracy of seismic images. Broadband seismic acquisition involving a variable-depth streamer (Soubaras and Dowle, 2010) is one of the tools that have helped us to obtain such improved seismic images. However, while a broad bandwidth is required for resolution, high frequencies decay rapidly with depth, i.e., amplitude spectra of deep events are dominated by low frequencies and bandwidth becomes limited. This is even more the case in the presence of strong absorption in the overburden, such as shallow gas. These phenomena should be characterised and compensated for, and the analysis required also provides additional information such as the location of attenuating bodies, for instance gas pockets and unconsolidated sediments.

In the Martin Linge broadband dataset the imaging is challenging due to a highly faulted complex structural setting with a seismic obscured area (SOA) caused by gas migration into the overlying Cretaceous interval (Morante-Gout *et al*., 2015). The resolution of the final image is very poor if we do not compensate for the absorption in the SOA.

For this challenging processing project, we applied a workflow that uses volumetric Q-tomography for converting volumetric, effective Q-measurements made on prestack data into a 3D interval Q-model. To compute the effective Q-volume in the prestack domain, we use a method based on the frequency peak shift (Gamar *et al*., 2015). The absorption effects can be accurately compensated within the imaging process (Xie *et al*., 2009) thanks to an interval Q-model computed by tomography (Xin *et al*., 2008, Cavalca *et al*., 2011, Gamar *et al*., 2015).

Volumetric Q-tomography

Our approach consists of calculating a prestack dense effective Q-volume in four dimensions (time, inline, crossline, offset), using the shift of the frequency peak (Gamar *et al*., 2015). The picking of the frequency peak is done on amplitude spectra computed around the maximum of the autocorrelation of the data. The use of the autocorrelation on short time windows increases the signal-to-noise ratio, making the frequency picking more accurate and the obtained result more precise. The effective Q-volume estimated from the frequency peaks is used as input to interval Q-tomography (Guillaume *et al*., 2011). The most interesting point here is that the workflow succeeds in automatically detecting the gas cloud anomaly responsible for the SOA without any a priori information of its position.

Martin Linge data example

The processing workflow for the 3D multi-azimuth Martin Linge broadband dataset involves dedicated preprocessing (deghosting, denoising, and demultiple), tilted transverse isotropy velocity model building combining both tomography and full waveform inversion (supported by valuable additional low frequencies offered by broadband acquisition), and PSDM.

In order to improve the structural understanding of the area and reduce the main structural uncertainties caused by the gas cloud, a Q-PSDM imaging step using a volumetric interval Q-model was added to the initial processing flow.

We converted PSDM common image gathers (CIGs) to the time domain and then destretched them. A dedicated structural denoising process was applied to increase the signal-to-noise ratio necessary for precise frequency peak picking. Following the approach described in the previous section, volumetric Q-values were measured for all offsets and for the three available azimuths.
These values were used in a tomographic inversion to provide a geologically consistent 3D interval Q-model. The right side of Figure 1 shows the result of the inversion overlaid on seismic (PSDM) for a depth slice (top right) and a stack section (bottom right). On the depth slice (top right), the Q anomaly matches quite well the suspected SOA zone, highlighted in brown in the top-left of Figure 1, despite the complexity of the geology.

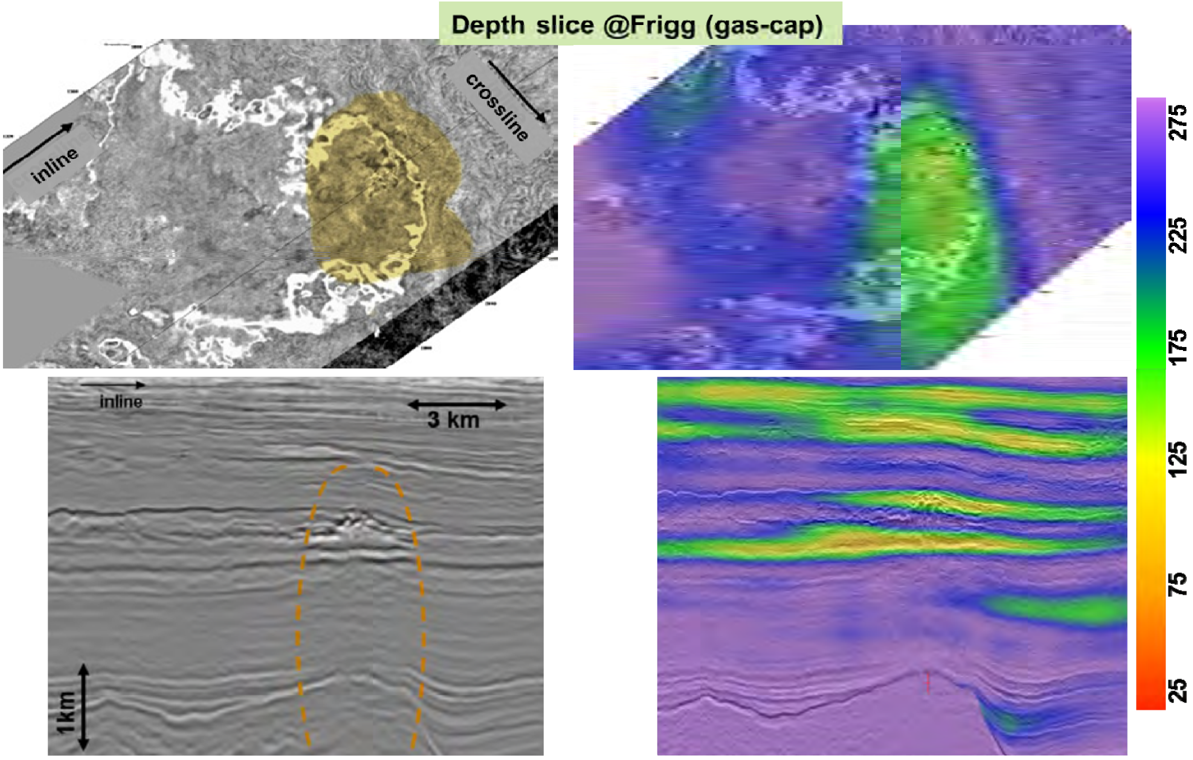

Figure 1 *Martin Linge SOA zone: Top) depth slices (at 2km) with left) the SOA marked in brown, suspected to be responsible for attenuation effects, and right) the inverted Q-model automatically determined. Bottom) inline section left) PSDM with SOA marked by brown dashed line and right) inverted Q-model overlaid on the PSDM section. Low Q-values on the depth slice (top right) fit quite well the SOA zone (top left) corresponding to the gas cloud area.*

The volumetric Q-field is consistent with the geological structures, with a strong absorption (Q ~ 25) identified within the SOA zone. Besides clearly picking out the gas cap, the Q-tomography model also highlights shallow anomalies corresponding to the Oligocene injectite areas. These anomalies occur over brighter packages which appear to be sandier channels above the target. These channels trap gas leaking from the main reservoir.

The resulting 3D interval Q-model (Figure 1, right column) was then used in Q-PSDM to compensate for dispersion and amplitude attenuation caused by the absorption along the actual wave-path. Figures 2 and 3 show the results of using the Q-tomography model in the imaging process. On the stack section (Figure 2), the resolution is improved and many events become more visible, thus increasing our ability to interpret structures inside the SOA. The migrated wavelets shown in Figure 2 (middle) are better balanced and symmetric for the Q-PSDM result (Figure 2, middle right) and events are well separated. The RMS amplitude computed at base Cretaceous unconformity (BCU) shown in Figure 3 illustrates the fact that Q-PSDM data show a much better definition of some events, giving more details (highlighted by yellow arrows) for interpretation. The Q-PSDM result also provides broader and flatter spectra (Figure 2, bottom) showing a real uplift in amplitude recovery for shallow and deeper parts of the seismic section. Figure 4 shows a zoom on the target area. On the Q-PSDM result, we can see improvement in the imaging of the deeper part of the section with a better imaging in the highly faulted area (see yellow ellipse) and slightly better continuity for events highlighted by yellow arrows.

Conclusions

In this case study, we have shown that volumetric Q-tomography succeeded in automatically identifying the absorption anomaly that was causing a SOA in imaging. Using Q-PSDM with the Q-model inverted from our volumetric Q-tomography can increase seismic resolution by recovering high frequencies, producing images with clearer horizon definition and better continuity.

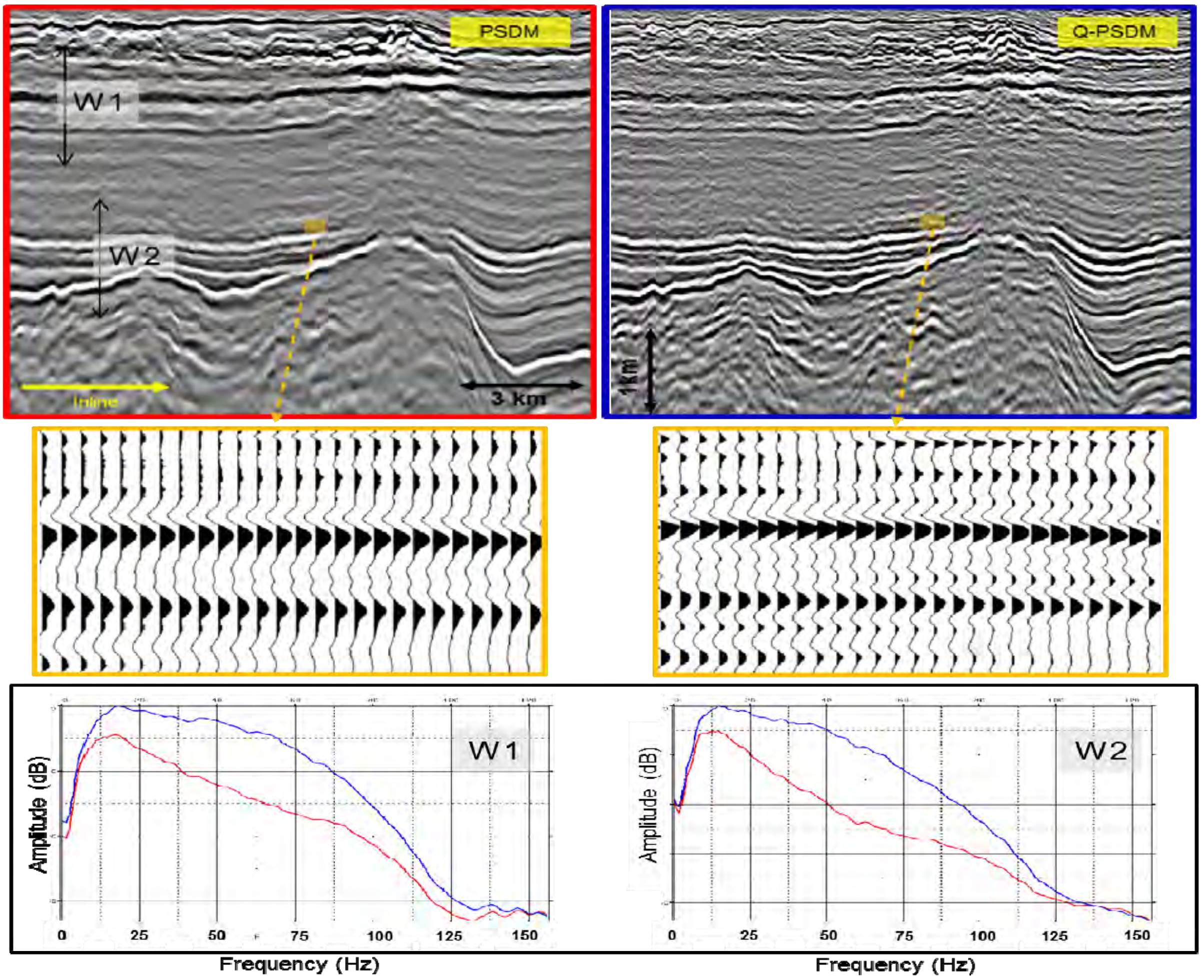

***Figure 2** PSDM (red box, left) and Q-PSDM (blue box, right) comparison for the stack section (top), migrated wavelets (middle) corresponding to the area highlighted by the yellow square on the stack section, and amplitude spectra (bottom) computed for shallow time window (W1) and deeper time window (W2).*

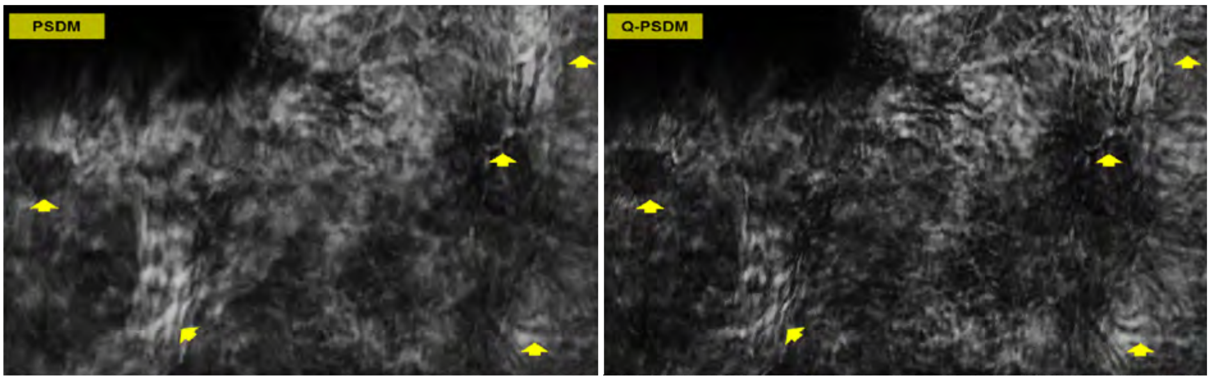

***Figure 3** PSDM (left) and Q-PSDM (right) comparison for near-stack RMS amplitude computed at the BCU. More details are visible on the Q-PSDM section (highlighted by yellow arrows).*

Acknowledgments

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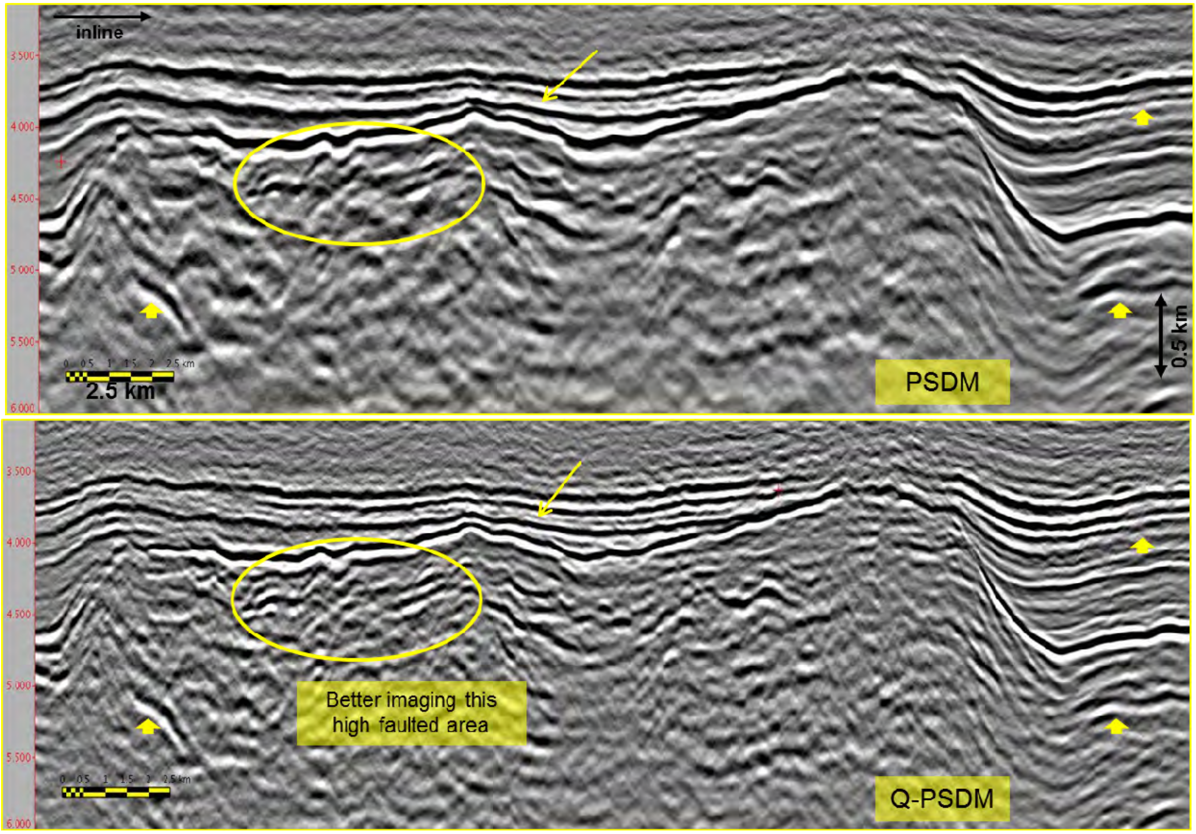

***Figure 4** Comparison of Martin Linge PSDM (top) and Q-tomography/Q-PSDM (bottom) results for a deeper part of the section: zoom on the improvement in the imaging of the Q-PSDM using the volumetric Q-model.*

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