X027

Derisking Hild Field Development Through Wide-azimuth OBC and Multi-azimuth Streamer Depth Imaging

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SUMMARY

The development of the Hild field in the North Sea has been left stranded for 30 years as a consequence of both structural complexity and a very poor imaging of the target Jurassic reservoirs. Today, an appraisal and development scheme has been worked out based on a fully integrated seismic processing project that started in 2005 with the acquisition of wide-azimuth 3D-4C OBC survey. In this paper, we present the different milestones of this work which consisted in the integration of all seismic datasets acquired on the area, three multi-azimuth streamer and OBC, into one pre-stack depth migrated volume. To start with, we show the details of the depth imaging project. Following a fast-track OBC PSDM, a new VTI velocity model has been constructed with all azimuth information available from the 4 datasets. The latter is further used to depth-migrate all datasets and stack them into a combined volume for interpretation. The resulting uplift of the reservoir imaging is then discussed and its consequence on the field understanding and appraisal strategy is detailed.

Introduction

The Hild field is one of the largest un-developed gas discovery in the North Sea. Discovered 30 years ago, and today operated by Total E&P Norge AS, the field consists of several faulted and segmented gas accumulations in the mid-Jurassic Brent Group.
Despite being attractive, the Hild resources have been left stranded for many years for several reasons. Firstly, the structural complexity creates intense fracturing and faulting, together with different fluid contacts and pressure regimes. Secondly, drilling is very challenging due to an HPHT regime and a narrow mud weight window. Last but not least, seismic imaging of the Jurassic series in the main accumulation is extremely complicated due to both multiple energy and a seismic obscured area caused by gas dis-migration into the overlying Cretaceous.
Nevertheless, the last five years have seen a key step change in the improvement of the structural interpretation and field understanding by way of several seismic acquisitions and associated processing projects. These projects, utilising the latest seismic technologies, have led to a much improved reservoir image, and hence a completely new development strategy has been conceived.
We present here the workflow and challenges of the full seismic dataset imaging project including wide-azimuth high density Ocean Bottom Cable data and their impact on the field structural interpretation and development strategy.

Multi-azimuth 3D streamer and wide-azimuth OBC depth imaging

- **Fast-track imaging**

The fast-track anisotropic pre-stack depth migration of the Q-Seabed PZ OBC dataset was performed by WesternGeco using a legacy VTI depth velocity model that had been built by Total several years earlier (Kravik 2006). This model was derived from only a single azimuth streamer acquisition, but had been used for the migration of multi-azimuth streamer surveys, which provided an image improvement that inspired the work described here.

- **New velocity model building**

All azimuth information available from the multi-azimuth streamer data, and the wide azimuth OBC data was used by WesternGeco to build one new common VTI velocity model for all the surveys. Using hybrid grid-based tomography in a layer stripping manner, the gridded tomography resolved velocity anomalies and variations within ten hybrid layers which defined the major velocity breaks, and were calibrated to markers in up to seven wells. Prior to the model building process, the streamer datasets were matched in both phase and amplitude to the spectrally enhanced, deterministically zero-phased OBC data, with a procedure typically used for the matching of 4D datasets.

Six azimuth directions were used in the model building, consisting of three differently oriented streamer surveys and the OBC data which was split into three equal azimuth sectors, as shown in figure 1.

The OBC data with its higher fold, better azimuth distribution, and longer offsets, helped to produce a more accurate velocity model, with improved seismic-well ties and anisotropy estimations in the gas affected areas. Modeling of the shallowest velocity variations, where OBC coverage is typically reduced by a large cable spacing was particularly improved by the use of densely migrated streamer gathers in combination with the OBC gathers.

The PS data used for Vs modeling was pre-processed with a correction for shallow shear-wave splitting, and filtering of full 3D PS receiver gathers was performed in the 3D TauP domain. Vs modeling was performed after Vp modeling, and not concurrently, due to scheduling requirements. Updating the Vp model was not part of the Vs modeling work, although the superior imaging of the converted waves through the gas obscured area suggests a refined PZ interpretation, which could be used in a future joint anisotropic Vp/Vs update to improve the entire model further. Hybrid grid-based tomography, with PZ/PS event matching constraints was used to update the Vs model in a layer stripping manner. The Epsilon field taken from the prior PZ modeling work was further improved using input from the PS data.

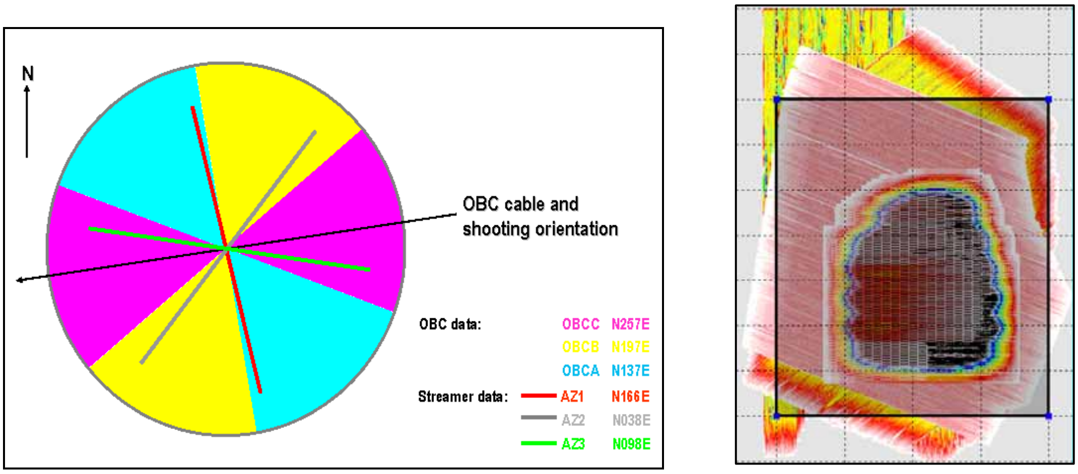

Figure 1 *Left: The three OBC model building azimuth sectors are displayed relative to the cable and shooting direction. The directions of the three streamer surveys are overlaid. Right: The OBC survey overlaid on the three streamer surveys, displayed on an inline/crossline grid. The output migration area is overlaid.*

- **OBC PZ, streamer, and OBC PS pre-stack depth migrations**

The OBC PZ data, and the three streamer surveys were each separately Kirchhoff pre-stack depth migrated using the new velocity model. Post migration processing included residual moveout corrections specific to each survey, followed by radon demultiple, trim static corrections, and other advanced processing techniques. In addition to each survey being delivered separately, the surveys were merged into a combined volume, after alignment with WesternGeco's Non-Rigid Matching technique. The PS dataset was also Kirchhoff pre-stack depth migrated using the new velocity model.

Impact on structural interpretation and field development strategy

The full Hild processing project has been a long process that started in 2005 with the OBC acquisition (Kravik, 2006) and ended up in 2008 with the final PS imaging. The initial schedule favoured a fast-track PZ pre-stack depth migration immediately following the time processing of the OBC dataset in order to speed up decision making on the field development (Vaxelaire, 2007). Figure 2 shows an example of the different outputs of this project.

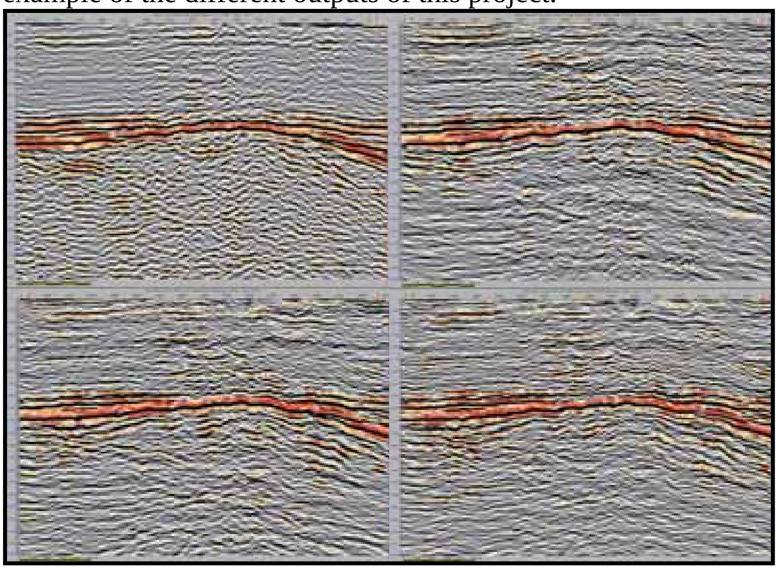

Figure 2 *Example of the 4 seismic datasets. Upper left: 2004 multi-azimuth streamer PSDM, Upper right: 2007 Fast-track OBC PSDM, Lower left: 2008 Final OBC PSDM, Lower right: 2008 Final combined Streamer-OBC PSDM.*

- **Fast-track pre-stack depth migration**

In 2007, the interpretation of the fast-track PSDM led to a completely new structural framework over the main Hild-East accumulation. More continuity of the seismic markers enabled a simplification of the fault pattern as compared to 2005 (Figure 3). In addition, due to improved deeper imaging quality, the fault interpretation was extended down to the Triassic, improving the confidence of the interpretation. The uplift of the image quality was particularly noticeable outside the seismic obscured area, but also inside to a lesser extent. As a result a new volumetric evaluation was carried out, and new reserves and economic figures were issued. Attached to that, an appraisal scenario was built, consisting of drilling a pilot well and a drain to de-risk the dynamic uncertainties associated to the fault pattern. Eventually, the fast-track processing and interpretation led to the go-ahead of the licence partnership for a rig commitment.

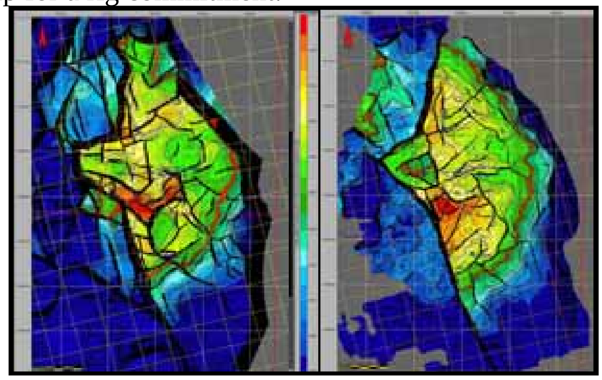

Figure 3 *Comparison between 2005 multi-azimuth streamer PSDM interpretation (left) and 2007 Fast-track OBC PSDM interpretation (right).*

- **Final combined PZ OBC and streamer pre-stack depth migration**

Following the fast-track imaging, the final version of the OBC PZ and streamer data pre-stack depth migration was delivered to interpreters mid-2008. This image benefited from an innovative true wide-azimuth pre-processing sequence (Boelle, 2008) that provided noise-attenuated OBC gathers as input to the final migration. Thanks to these gathers and to the brand new velocity model, resolution and imaging were further improved as compared to the fast-track PSDM (Figure 2). The seismic interpretation was revisited on the final PSDM volume primarily to de-risk the well panel imaging but in addition, the uncertain parts of the fast-track interpretation were partly de-risked with these newer datasets: despite the overall fault pattern of Hild-East remaining similar to the fast-track version, some of the faults trends were modified (Figure 4).

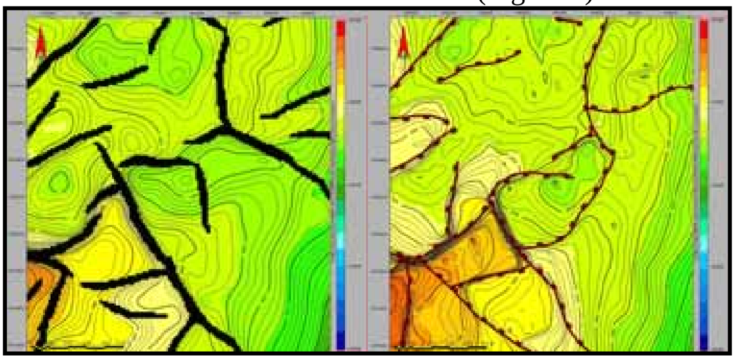

Figure 4 *Close-up of fault interpretation. Left: 2007 fast-track interpretation; Right: 2008 final interpretation.*

The new seismic interpretation was then used to challenge the initial appraisal well location in order to fine-tune and de-risk the well trajectory.

- **Final PS pre-stack depth migration**

The completion of the PS imaging project occurred at the end of 2008 and its interpretation is ongoing. However, the added value of the converted waves, despite lower resolution than the compressional waves, is already visible in the gas cloud area as the continuity of the pre-Cretaceous series overlying the Brent reservoir is noticeably improved, giving rise to coherent signal in the seismic obscured area below the Base Cretaceous Unconformity (Figure 5).

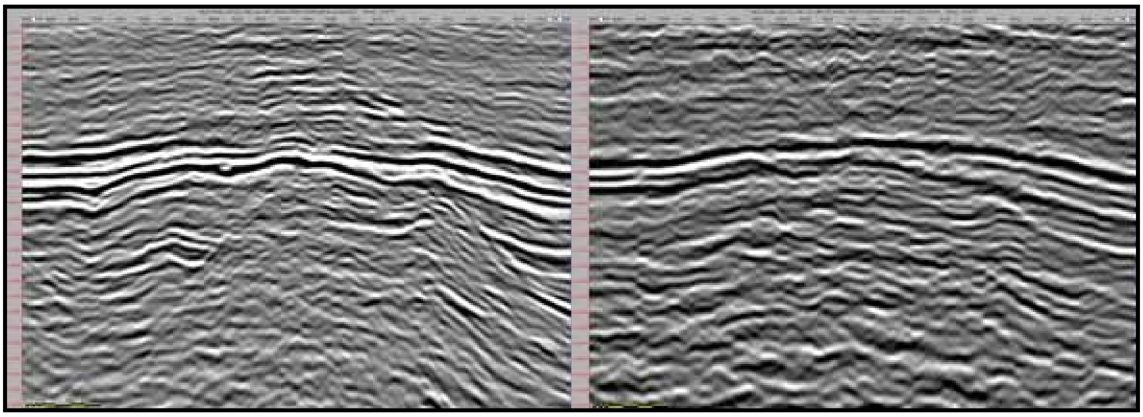

Figure 5 *Comparison between PZ (left) and PS (right) final PSDM in the Jurassic series.*

This PS dataset will probably further de-risk some of the Hild-East fault panels that have been primarily excluded in the reserves estimate as being too uncertain.

Conclusions

The joined Total E&P Norge/WesternGeco Hild processing project has enabled a step improvement in the imaging and comprehension of not only the main accumulation Hild-East but also of the surrounding prospectivity of Hild. The key reason is of course the wide-azimuth OBC dataset that proved to be the appropriate dataset to unlock the imaging through the gas obscured area. But, it is also the integration of all seismic datasets, three multi-azimuth streamer and OBC, into the construction of a single velocity model that provided a combined migrated stack to the interpreters. This integrated project enabled Total to completely reassess the stakes of the Hild field and to propose a new appraisal and development way forward. Still, some remaining uncertainties exist that will be partly de-risked by the first appraisal well. The latter will also provide valuable information as input to an update of the imaging project.

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