Paradigm®

Subsalt Imaging using 3D Pre-stack Depth Migration in the UK Southern North Sea

The Challenge

For a reservoir in an area containing one of the largest salt structures in the Southern North Sea, accurate depth mapping was vital for the assessment of potential gas prospectivity. Previous seismic processing studies had failed to produce a reliable subsalt image.

The Assessment

The target reservoir is located in an area that contains one of the largest salt structures in the UK Southern North Sea. Accurate depth mapping of this reservoir below the salt structure is vital for the assessment of potential gas prospectivity. Previous seismic processing, that included 3D post-stack time and depth migration, showed large distorted zones below the main salt body and flanks. Strong lateral and vertical velocity variations associated with the complex salt structure led to non-hyperbolic seismic reflections, and therefore to a general deterioration in seismic stack quality. This explained the failure of post-stack migration methods to deliver a reliable subsalt image.

The state-of-the-art Paradigm™ GeoDepth® 3D pre-stack depth migration software was selected to produce and validate a more robust subsalt depth image.

The Solution

Initial velocity/depth model building

The first stage of the project entailed building an initial velocity-depth model. The horizons for the earth model were established based on major geological surfaces coupled with the available well logs. Layer cake interval velocities were estimated from the pre-stack data using stacking velocity analysis followed by a ray tracing-based 3D stacking velocity inversion. The obtained interval velocity maps were used to convert the original time migrated surfaces to depth domain using image ray map migration. These were extrapolated across the salt wall prior to depth conversion, to produce a continuous overburden (no salt) velocity/depth model.

Velocity/depth model update and validation

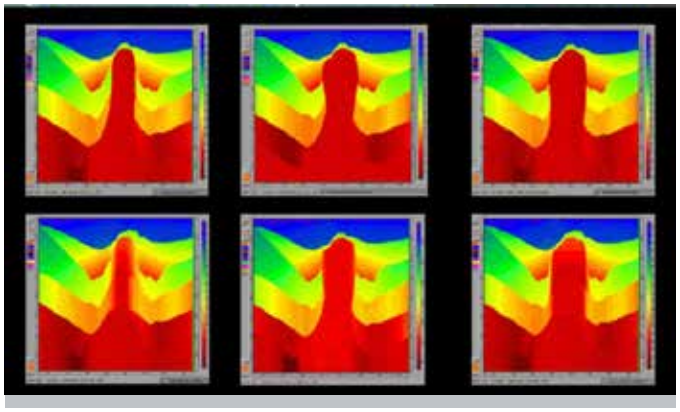
In the next stage, the velocity/depth model was updated separately for the overburden and the salt body.

Modeling of the overburden

3D pre-stack depth migration using the initial velocity/depth model generated depth image gathers along velocity lines. The residual depth move-outs were used to update the model, by means of horizon-based 3D tomography. The update resulted in improved imaging quality with better gather flatness. Seismic interpretation of these images was used for the final adjustment of the overburden horizons.

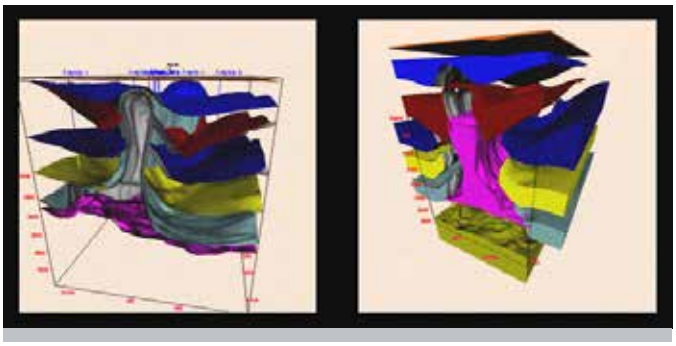
Modeling of the salt structure

The overburden model was used for full volume 3D post-stack depth migration and 3D target-oriented pre-stack depth migration of velocity lines. Both of these migrations were used to make an initial interpretation of the salt geometry. Different models were built to investigate the sensitivity of the sub-salt image to salt



▲ Salt sensitivity study

shape and velocity, and identify the best model. Velocity-wise, the sharp contrast on the salt boundary gave better results than gradual velocity transition. Sensitivity tests were performed with



▲ Structural model

thin and thick salt shapes, which were then assembled, based on the optimal seismic image in depth, to form the final salt model.

Full volume depth migration, post-migration processing and calibration

The final velocity/depth model was used to perform full volume 3D pre-stack depth migration using the Kirchhoff algorithm.

Residual depth move-out corrections were applied to the depth gathers to improve the depth stack image. The image was scaled to vertical time; further wavelet processing consisted of the time variant frequency filter and automatic gain control on the time scaled volume.

Depth horizons showed misties with depth picks at the well locations. These misties were due to a natural difference between seismic and well velocities (velocity anisotropy). This bias was estimated using cross-plotting techniques and removed from the velocity model, which was then used to convert scaled time images from vertical time back to depth. Calibration reduced depth misties to less than 1%.

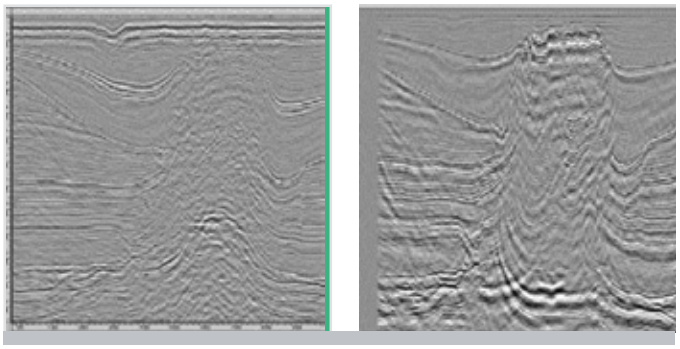
Imaging Results

A final interpretation of the sub-salt target was carried out on the calibrated depth volume. The significant improvement in the sub-salt seismic image and geologically plausible geometry of reflections in depth domain enabled the client to interpret the primary energy, and to confidently tie it to the well data. The new sub-salt depth interpretation also showed a fault pattern and displacement that matched the regional geological scenario.

These results enabled the previous drilling results in the area to be explained. Furthermore, the client was able to make a better assessment of the future prospectivity of this part of the Southern Gas Basin.

Benefits

Paradigm's advanced technology provided a highly accurate image of the subsurface, enabling the clients to reconcile seismic interpretation with available well data, and produce reliable depth maps of the reservoir.



▲ Post-stack time migration vs. pre-stack depth migration

Paradigm's advanced technology provided a highly accurate image of the subsurface, enabling the clients to proceed confidently with their drilling plans.

Paradigm wishes to thank Agip UK and Total for their permission to use their data.