D005

PP/PS PSDM, AVO and Joint Inversion Applied to a Virgin Exploration Area in the North Sea

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SUMMARY

Wintershall Norge ASA have identified a Palaeocene seismic amplitude anomaly in blocks 33/5 & 6 in the North Sea. The anomaly is located in a virgin area for Palaeocene exploration and there is no analogous anomaly that has been described or drilled within this or adjacent parts of the North Sea (Hughes et al, 2010). Multi component seismic (OBC) was acquired in the summer of 2009 in order to de-risk the prospect. The combination of converted wave (PS) and compressional wave (PP) data can be used to de-risk a prospect before drilling in order to distinguish between lithology and fluid fill.

The OBC data were processed by CGGVeritas in the autumn of 2009. A complex 4 component (4C) processing sequence was implemented and imaged through anisotropic PP- and PS-wave pre-stack depth migrations (PSDM). The resulting PS images are of high quality and we demonstrate successful applications of PS AVO analyses and joint PP/PS inversion.
**Introduction**

An amplitude anomaly has been mapped on 3D seismic which is most evident on the far stack. The anomaly shows strong AVO Class III characteristics (Rutherford and Williams 1989), and differs from other anomalies observed on the 3D data at the same level which are of opposite polarity and exhibit no significant AVO anomaly.

Wintershall contracted RXT (Reservoir Exploration Technology) to acquire two intersecting 2D lines (15 and 18 km) of multi-component ocean bottom seismic over the anomaly. The two lines intersect at a well which was drilled outside of the prospect.

We combined PP and PS data through amplitude friendly processing and imaging to yield high quality angle gathers and stacks. The PS angle gathers were subject to AVO analysis whereas the PP and PS stacks were jointly inverted.

**Data processing, velocity model building and imaging**

Wintershall contracted CGGVeritas to perform the data processing. The multi-component processing sequence included zero phasing, integration of the geophone data, 3C rotations (to vertical, horizontal inline and crossline components), 4C wavefield separations, de-noise, de-multiple and regularization prior to PSDM velocity model building and imaging.

An earth property model was built based on well matching, time migration velocities and some key horizons provided by Wintershall. The well log data used included sonic, gamma ray, caliper and density. The velocity models were updated based on the observed RMO and event registration. Each layer in the model contains a description of P- & S-velocities, epsilon & delta (Thomsen, 1986).

The 2 lines were 2D PP and PS Kirchhoff pre-stack depth migrated (Figure 1). Post migration processing included RMO correction, demultiple, angle mutes and de-noise. Angle mutes were computed through ray tracing in the depth domain and yielded incidence P-angles for both the PP and the PS data (Figure 2).

**PS AVO**

Common image point (CIP) gathers were transformed from offset to angle domain based on ray tracing in the depth migration velocity models. Both incident P- and departing S-angles were estimated. The AVO analysis was performed on CIP (incidence P-angle) gathers after RMO and radon demultiple had been applied (Figure 3).

Several PS AVO quantities were generated: PS AVO fitting parameters from two-term fits, PS to PP amplitude ratio, SS zero offset from PS stack, and the extreme amplitude $R_{PS}(\theta) = \text{max}$ and the corresponding angle value $\theta_{max}$ (Figure 4). The latter appeared to be the most robust of these attributes. The extreme position can be shown to be a function of the $vp/vs$ ratio, whereas the extreme amplitude is a non-linear function of the $vp/vs$ ratio and the shear wave zero offset reflectivity (Wei and Li 2009).

**Joint PP/PS inversion**

To extend the amplitude analysis joint simultaneous PP/PS inversion was performed on the migrated stacked PP and PS seismic volumes. The inversion process in this case used a two term form of the Fatti (1994) equation together with multi-component forms by Stewart (1990) and Larson (1999). One well is available in the area but does not penetrate the anomaly and shear wave log data was not recorded. A generated curve, using Greenberg-Castagna (1992), was provided. This well, together with PP and PS interpretations, provided the low frequency information for the initial model.

The derived P-impedance and $Vp/Vs$ volumes show the anomaly as low in both P-impedance and $Vp/Vs$ (Figure 5). This is encouraging as hydrocarbon sands are commonly associated with such a response. The anomaly is better defined when viewed in Lambda-Mu-Rho space (Figure 6).
Conclusions
The OBC data yield high quality PS angle gathers and stacked images, with excellent PP/PS event matches. For PP imaging, the streamer seismic data is better than the OBC data, probably due to the 3D acquisition geometry of the streamer data. Successful application of PS imaging, PS AVO and joint PP/PS inversion has been obtained.

The multi component seismic survey has helped de-risked the prospect. Wintershall is currently finalizing the evaluation of the processed data.

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References
Figure 1: Comparison of 3D streamer PSTM PP stack (top, with anomaly inside circled area) and PS PSDM stack (bottom).

Figure 2: PS PSDM CIP gather (offset) incidence P-angle overlay. Ten degrees per colour change.

Figure 3: PS PSDM CIP gathers transformed from offset to angle domain (0-50 degrees). Left gather inside and right gather outside of amplitude anomaly (target level indicated by arrows).
**Figure 4:** Maximum PS amplitude angle value, \( \sin(\theta) \). The amplitude anomaly area in the PP-data is within the circled area.

**Figure 5:** Joint PP/PS inversion P-impedance and \( V_p/V_s \) ratio.

**Figure 6:** Lambda-Mu-Rho transform of impedance volumes. Highlighted area corresponds to anomaly.