APPLICATION OF BEAM MIGRATION TECHNIQUES TO THE EVALUATION OF AN EXPLORATION PROSPECT (BALVENIE): A CASE HISTORY FROM THE UKCS NORTHERN NORTH SEA

L Ben-Brahim¹, S. Varley¹, O. Michaud¹, P. Buffet¹
S. Hollingworth², A. Woodcock², C. Purcell²

¹ Total E & P UK.
² CGGV, Crawley, UK

Summary
Over the Northern North Sea the hydrocarbons trapping mechanism in the pre-BCU interval is mostly structural and relies on favourable lithology juxtaposition across faults and to a lesser extent on fault seal properties. Refining the quality of depth migrated data to improve focusing and reduce multiple content, is critical to the proper assessment of prospects risks and volumetrics and thus economics.

Over a block operated by Total E&P UK (100%), improved risks evaluation of a fault trap prospect was achieved through the use of Controlled Beam Migration (CBM), a specialized form of the beam algorithm.

Controlled Beam migration is suited for structural imaging. It improves the signal to noise ratio and enhances steep dips. It is also possible to achieve some discrimination between primary and multiple energy during the imaging process.

Over Balvenie, the CBM dataset has improved imaging of the faults and clarity of data for interpretation, thanks to a significant reduction in multiple content and better focusing of dipping events.
Introduction
Total E&P UK operates, with 100% working interest, the so-called Alwyn Core area (Fig. 1) located over part of Quad 3 (UKCS). The Alwyn field is used as a hub for either large fields developed from a platform (Dunbar) or smaller accumulations developed subsea (Forvie North, Jura, Islay). The exploration of the area continues with leads and prospects located within a few kms of subsea connections.

Figure 1: Location map for Alwyn area

Regional Geology
The Balvenie prospect (Fig. 2, 3) is located on the western margin of the Viking Graben in an area characterized by a North-South trending high at BCU (Fig. 2). Fault patterns are complex and reliable trap definition relies on good quality 3D PSDM.

The most prolific reservoir is the Middle Jurassic Brent deposited as part of major prograding (Rannoch/Etive/Lower Ness) and retrograding (Upper Ness/Tarbert and Balta) sequences (Jourdan et al, 1987 and Brown et al, 1987). Sourcing is provided by marine source rocks (Heather and Kimmeridge clays) of Upper Jurassic age.

The Balvenie panel is located downdip from Grant and Forvie North, two producing fields.

Structural Framework
The Alwyn and Forvie-Jura areas are located over an intermediate deep terrace between the East Shetland Platform to the West and the Viking Graben to the east. The Jurassic tilted blocks and faults’ geometries are a result of extensional movements along the underlying ramp-flat decollement surface associated to the opening of the Viking Graben.

The movements are mainly Callovian-Oxfordian in age. Seismic resolution is low (typically an 18Hz average peak frequency at Brent level) and does not allow refined intra-Brent interpretation.

Detailed structural work has revealed (Fig. 2 and 3) the importance of the numerous NW-SE dextral transfer zones offsetting the North-South normal faults (generated by the overall gliding of the Mesozoic series towards the Viking Graben).
Data Processing
The 3D survey was acquired in 2003 with dense parameters (single source, 18.75m crossline bin size). A first anisotropic PSDM3D was carried in 2004 and was used to locate the Jura well discovery (Barber et al, 2007). The continued evaluation of the area has resulted in the identification of the Balvenie prospect. This prospect is fault bounded on 3 sides (Fig. 3) thus fault location and cross-fault juxtaposition were identified as critical parameters for the de-risking of the prospect. Also, as over most parts of Viking Graben, multiple contamination (water layer and long period internal multiples) hinders locally detailed picking of the events of interest.

To address these concerns, a quick turnaround project was launched to assess the sensitivity of fault locations to migration velocities, improve the 2004 velocity model (below BCU) and attenuate multiples. Controlled beam migration (CBM) was used in this project. Hill (2001) describes the theory and application of pre-stack depth beam migration. Beam migration can be formulated in the common-offset, common-azimuth domain. Consequently, it is well suited for application to standard narrow azimuth marine acquisition typical of the North Sea. The method is based on rays which are formulated into beams. These provide the kinematics and the amplitude weights of the migration. The migration itself is performed in the ray parameter domain which facilitates the imaging of multi-pathed seismic energy. As it is a ray-traced method, like Kirchhoff, it doesn’t have any difficulty in imaging steep dips. This makes it an attractive proposition for application in the North Sea where salt diapirs provide both steeply dipping events and complex geology. Recent papers (eg., Gray, 2004; Notfors et al., 2006) have advocated beam migration as a practical alternative to Kirchhoff...
migration. Recent developments have resulted in a specialized form of beam migration designed for structural imaging which improves the signal to noise ratio of images and enhances steep dips. It is also possible to achieve some discrimination between primary and multiple energy during the imaging process.

Prospect evaluation
Balvenie tilted fault block evaluation has been improved (Fig. 4) through quality imaging of the bounding faults, facilitating the construction of fault juxtaposition diagrams. The general improvement of the signal to noise ratio (see blue box in Figure 4) and the reduction in multiple content (Fig. 6), in particular in the vicinity of the BCU, has provided further insight into the tectonic evolution of the panel with well defined truncations at BCU level (Fig. 5).

Figure. 4 (above): Comparison between 2004 Kirchhoff PSDM3D and 2008 CBM PSDM3D
Figure 5 (below): zoom of above figure. Dotted red line is the first BCU seabed multiple.
Figure 6: Comparison between CBM and CBM with dedicated anti-multiple process. Blue arrows indicate location of some of the multiples.

Conclusions
In a structurally complex area of the Northern North Sea, CBM migration techniques were applied successfully to assess fault location sensitivity to migration velocities, improve the pre-BCU velocity field, fault imaging and attenuate multiples. Main risks for this prospect were better evaluated, providing greater confidence in computed risks and volumes.

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References