The Brenda Field Development: A Multi-Disciplinary Approach

Ian F. Jones[1*], Rod Christensen[2], Jamie Haynes[3], John Faragher[1], Ika Novianti[1], Henry Morris[3], Giles Pickering[4]
[1]GX Technology,
[2]Oilexco North Sea Ltd.,
[3]IKON Science Ltd.,
[4]TROY-IKODA Ltd, ,

Summary

Recent initiatives in the North Sea and UKCS such as the introduction of the ‘Fallow Field’ initiative and offering of ‘Promote’ licenses have started to generate real activity by attracting active new entrants who can provide new capital and new ideas to focus on exploration and appraisal. Fields which had been abandoned, or considered of insufficient commercial interest have been offered a new lease of life by allowing proactive companies to identify and exploit latent commercial prospects by tying in to existing infrastructure.

Here we showcase one such recent discovery, made by Oilexco, where a multi-disciplinary approach was taken to identify potential targets using state-of-the-art pre-processing and high resolution pre-stack imaging, combined with detailed calibrated reservoir attribute analysis (based on elastic impedance inversion).

We will present the pre-processing strategy, the velocity model building and preSDM approach, as well as the elastic impedance inversion results, describing the attribute responses of neighbouring fields and their relation to the new discovery.

Introduction

Oilexco’s UK North Sea drilling program on License P1042 (Block 15/25b) in the Outer Moray Firth, targeted oil in the Paleocene Forties Sandstone. Initially 3 wells were proposed: two on a channel sand feature, whose prospectivity was indicated by an anomalously low elastic impedance response on the far-offset stack, and one on a structural high with classic four-way closure.

The surface location of the first new well, 15/25b-6 is approximately 150 meters west of Conoco’s 15/25b-3 undeveloped discovery, which tested 2,690 bbl/d of 39 degrees oil from the Forties Sandstone from 20 feet of net pay in 1990. This could be considered as an appraisal re-drill of the old undeveloped discovery.

The 15/25b-6 well targeted the channel sand, and encountered the “Brenda” oil find announced by Oilexco on January 26 2004. The well intersected a series of oil-bearing Paleocene Forties sands, the thickest of which has 26 feet of high quality oil pay. In addition to this sand, several other thin bedded oil bearing sands were also intersected. The thickest sand tested 40 degrees API oil from the Forties Sandstone at an average rate of 2,980 bbl/d, over an 18-hour test under stable flowing conditions, from 56 feet of perforations (evaluated with open-hole wire-line logs and formation fluid sampling tools). Associated natural gas flowed at an average rate of 600 Mcf/d throughout the test. No water or sand was produced during the test period.

The second well targeting this Paleocene sand (15/25b-8) tested 40 degree API oil at an average flow rate of 4785 bbl/d, from 69 feet of clean sand. This well was targeted on a specific elastic impedance anomaly indicated by the new data-processing.

Geological setting and drilling program

During the Paleocene, the East Shetland and Orkney Platforms were sites of deltaic outbuilding. These platforms were uplifted by significant thermal bulging. The uplifting and over-steepening of the delta and shelf slope systems caused instability and failure resulting in a direct supply of sands and sediments to the basin within density flows. Confined density flows of sand-rich sediment started with erosional scour channels, that were not overwhelmed by the volume of sediment supply. These distinct channel fairways mark the sand transport paths. Sands within these meandering channels are characterized as massive sandstones with planar and laminated sandstones and occasional load and dish structures. This type of density flow is common in the later Paleocene (Thanetian to Ypresian) and can generally be recognized by seismic data due to the contrast between the laterally equivalent shales and claystones.

The depositional profile was demonstrated in a Conoco core display at the 2003 Petroleum Geology Conference, which utilized the 15/12-1 well as illustrative of the shelf. The Balmoral-age sands were deposited in a sand (wave dominated) delta with clean, winnowed sand building up during a highstand. As the delta front was oversteepened, periodic failure occurred which triggered debris flows that traveled up to 25 kilometers. This provided the sand reservoirs at MacCulloch and beyond. The cores from the Conoco MacCulloch wells are indicative of sand-rich debris/density flows, similar to the sands Oilexco is seeing within the Forties Member in the 15/25b Block. Some of these sand types are described, by Conoco, as upper medium-grained, feldspathic, massive sandstone with very rare faint laminations, oil-saturated, friable to uncemented, very high porosity estimated to 30%, permeability measured from 1 to 2 darcies.

Oilexco interpreted that the Paleocene Forties "density flow" sand was only partially encountered by the Conoco 15/25b-3 well. The channel was nearly 50 feet thick at the nearby Sun Glamis 16/21a-6 well. In the other direction, the 15/24b-6 well in the down-dip portion of the McCulloch Field contains over 120 feet of the Forties Sandstone Member. The 15/25b-3 well encountered only 22 feet of sand. This sand was fine to medium grained, moderately sorted, and friable. The sedimentary structures of this sand were massive with planar laminations and good visible porosity. The entire sand down to the scour was oil stained with uniform yellow fluorescence and fast streaming cut. Core examination of the Conoco 15/25b-3 well allowed Oilexco to question whether or not the oil was trapped structurally or stratigraphically. An oil/water contact was not evident in the Forties sand in this core and a possible stratigraphic trapping mechanism was suspected.

Seismic data pre-processing

The main aim of the pre-processing work was to optimally prepare the gathers for imaging, focussing attention through the chalk interval. It was imperative that amplitudes be preserved through the processing sequence, since AVO techniques would be integral in identifying key prospects. Short period water bottom multiples contaminated the data, so great effort was expected in finding the optimum methodology to suppress them.

Due to the intrinsic limitations of velocities picked prior to migration, it was considered preferable to aim for a pre-migration demultiple method which was non-velocity driven, reducing the risk of attenuation of primary energy to a minimum. A surface related multiple attenuation (SRME) approach was therefore tested. This method is a two step process, the first step being the creation of a multiple estimate of the data, and the second being the matching and subtraction of this from the input data.

Following SRME the data was found to contain a certain amount of residual (interbed) multiple energy which was successfully attenuated by application of deconvolution in Tau-P space. As dip filtering was required in Tau-P space to remove the strum noise, the transform was designed to model only the desired dip ranges.

Velocity model building & Pre-Stack Depth Migration

The main focus of the imaging work was to accurately resolve the intricate faulting and small structures around the top chalk marker. Considerable care was taken in determining a detailed velocity model, through gridded tomography techniques, that would honour structural and stratigraphic variations (Hardy, 2003). Correct estimation of the overburden and chalk velocities were central to accurate preserved amplitude imaging of the targets.

The initial depth interval velocity was built from the time-RMS stacking velocity and converted to depth interval velocity. The water bottom was picked and gridded, based on an initial migration to create the water layer in the depth interval velocity model.

Following this step, we proceeded to three iterations of gridded tomographic update (Sugrue et al, 2003). Each iteration of our tomographic velocity model update consists of two steps:

1. Dense continuous automatic picking of the migrated seismic gathers to determine the residual moveout correction representative of the velocity perturbation
2. Depth domain tomographic inversion to update the velocity model based on the residual moveout velocity and the local dip-field estimated during the auto-picking.

Reservoir characterisation

On the MacCulloch field, 12 km NW of Brenda, Conoco have noted that the seismic event representing the top of the reservoir illustrates that this event is characterized by a “Class III” (weak trough – near offset, strong trough – far offset) AVO anomaly (Scorer, et al, 2003). Scorer claims that this technique has been a good “oil indicator” with an oil/water contact evident. Oil production and hence the substitution of oil for water “hardens” the top reservoir response with time-lapse effects being most marked on the far offset data. They note that structural closure does not explain the trap at the MacCulloch Field, and that the field trapping mechanism is stratigraphic. The evidence of a stratigraphic trap is demonstrated with their AVO impedance maps that illustrate where the “oil effect” terminates. This is the same type of anomaly that Oilexco is following in the “Brenda” area.

Average absolute amplitude maps were made over an interval 50ms to 200ms below the Top Balder. The main channel meandering SE from MacCulloch shows up well on both near and far stack data. On the far stack data parts of the two producing fields (MacCulloch and Blenheim) show up as bright anomalies. Also shown up as bright anomalies are parts of the main channel, in particular the section to the West and South of 15/25b-3. These far stack anomalies are illustrated by the example seismic line shown in Figures 1 & 2 for the Blenheim field and Brenda discovery, for the near and far offset stacks.

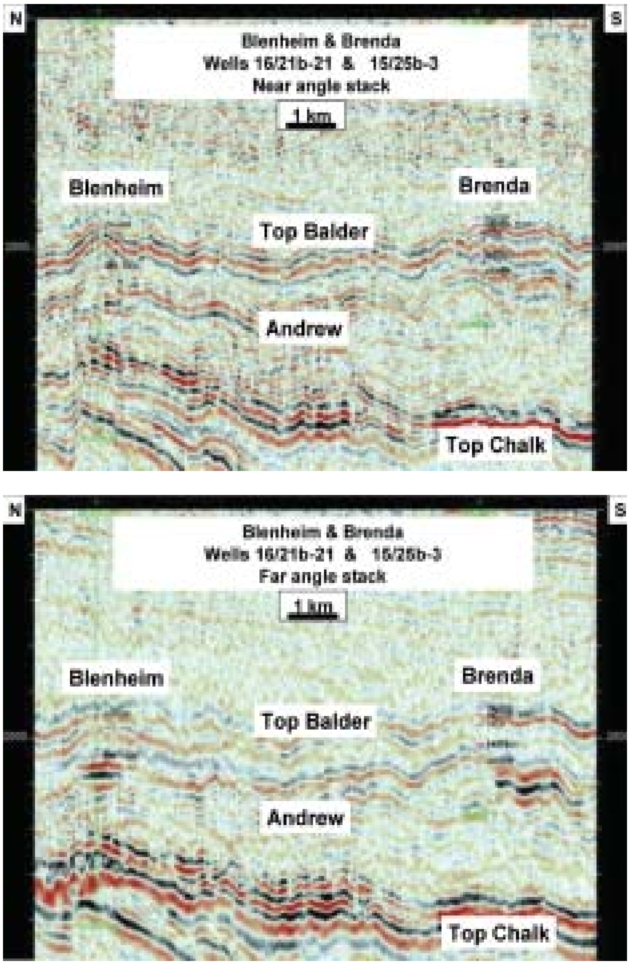

Fig. 1 & 2 Near and Far offset stacks showing the existing Blenheim field, and the new Brenda discovery.

Inversion results

As the known hydrocarbon occurrences and other anomalies are most easily seen on the far impedance volume and given the potential problems of the AVO Impedance volume due to inaccuracies in the near stack volume, the interpretation effort focussed on the far impedance.

Figures 3 & 4 show the EI38 results at the new 15/25b-6 location. (Note that the time interval of the seismic has been reduced to the zone around the known reservoirs to assist in the interpretation and visualization). It is clear that the old 15/25b-3 well is offset from the main hydrocarbon indicator response. The position of the new 15/25b-6 well, some 150m from 15/25b-3, was designed to target this hydrocarbon indicator..

Analysing the results with a 3D visualization package permits an aerial perspective of those parts of the channel sand system with hydrocarbon potential. “Turning-off” all the voxels with elastic impedance values greater than 525 (figure 5) shows these low EI38 bodies for the area. The major elements are clearly the large series of bodies lying along the channel trend SE of the 15/25a-2 well (SE of the MacCulloch field), and the presence of a body representing the Blenheim field. The presence of the Blenheim body is important, as this constitutes a “blind-test” of the method, as no well data from this field was used in this project. Both the MacCulloch and Blenheim fields show up as having low values of AVO Impedance, demonstrating that this is an indicator of oil-bearing sand. The AVO impedance of the remaining bodies varies from being indicative of oil, to some values that are more indicative of water sands, as anticipated from the relative levels of EI15 and EI38 noted above. However, this could be due to the difficulty in reliably estimating EI15, or a thinning of the sands, rather than a real change difference in fluid content. Clearly, further improving the resolution

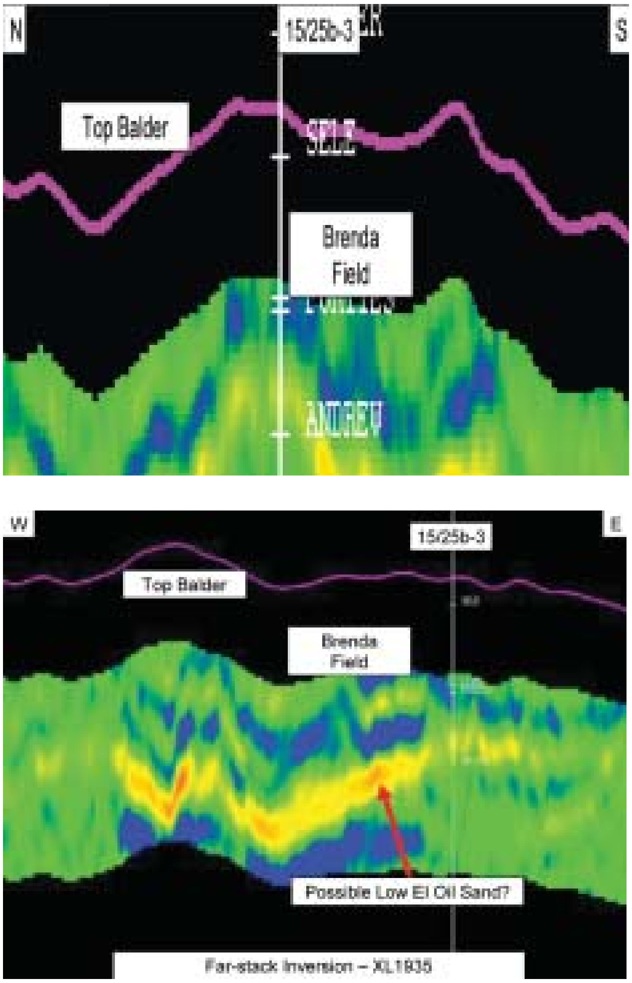

Fig. 3 & 4 Far-stack elastic impedance results for a N-S line and a W-E crossline over the Brenda Discovery.

of the data would reduce the uncertainty due to sand thickness, and integrating the results of the planned drilling programme would also improve the characterisation of the sands within the block.

Conclusions

Careful pre-processing to remove noise and multiple contamination, followed by high fidelity 3D pre-stack depth imaging has yielded a data volume suitable for accurate AVO and EI analysis.

Rock physics modelling on the oil-bearing well 15/25b-3 suggests that AVO and elastic inversion analysis should assist in the location of hydrocarbon-bearing Palaeocene sandstones.

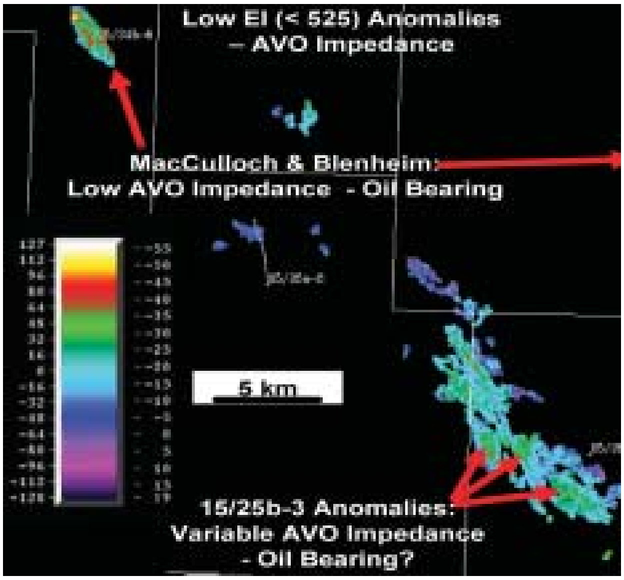

Fig. 5 Horizon slice of the elastic impedance clipped so as to outline the areas showing a clear hydrocarbon response

The analysis results are unusually unambiguous because of the excellent well control, calibration at MacCulloch and Blenheim fields and the good quality of the seismic data. Therefore it seems unlikely that the low EI38 bodies are not indicating oil bearing sands, however this requires that a stratigraphic trapping mechanism must exist for many of the bodies identified.

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Background Reading

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