PETEX 2010
From Volatility to Value

IMAGING SUB-BASALT PALAEOCENE, MESOZOIC AND PALAEOZOIC TARGETS IN THE DEEP WATER UKCS MARGIN: COMBINING EFFECTIVE REPROCESSING STRATEGIES WITH NEW DEEP TOWED ACQUISITION

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Introduction

In 2009 TGS acquired 2,947 km of 2D long-offset multi-client data in the Atlantic Margin across the far northeastern part of the Faroe-Shetland Basin (FSB) crossing into the southwestern Møre Basin as part of its continuing North Sea Renaissance (NSR) programme (figure 1). The new acquisition encompasses the under-explored area between the Lagavulin and Talisker prospects in the northernmost part of UKCS crossing into Norwegian territorial waters towards the Tulipan discovery. Extensively thick sequences of Palaeogene flood basalts associated with the opening of the proto North Atlantic Ocean dominate the area which strongly attenuate and scatter the high frequency components of the seismic signal. For this reason, the acquisition deviates from the NSR programme to date through the use of a much deeper towed streamer at 18 metres depth to concentrate on low frequencies. The principal objective was to improve imaging of prospective Palaeocene clastic sediments interbedded within the basaltic flows and the potentially prospective Mesozoic and Palaeozoic section concealed beneath. The deeper towed streamer also allows the acquisition of data in poor sea-states, resulting in less downtime and extension of the season.

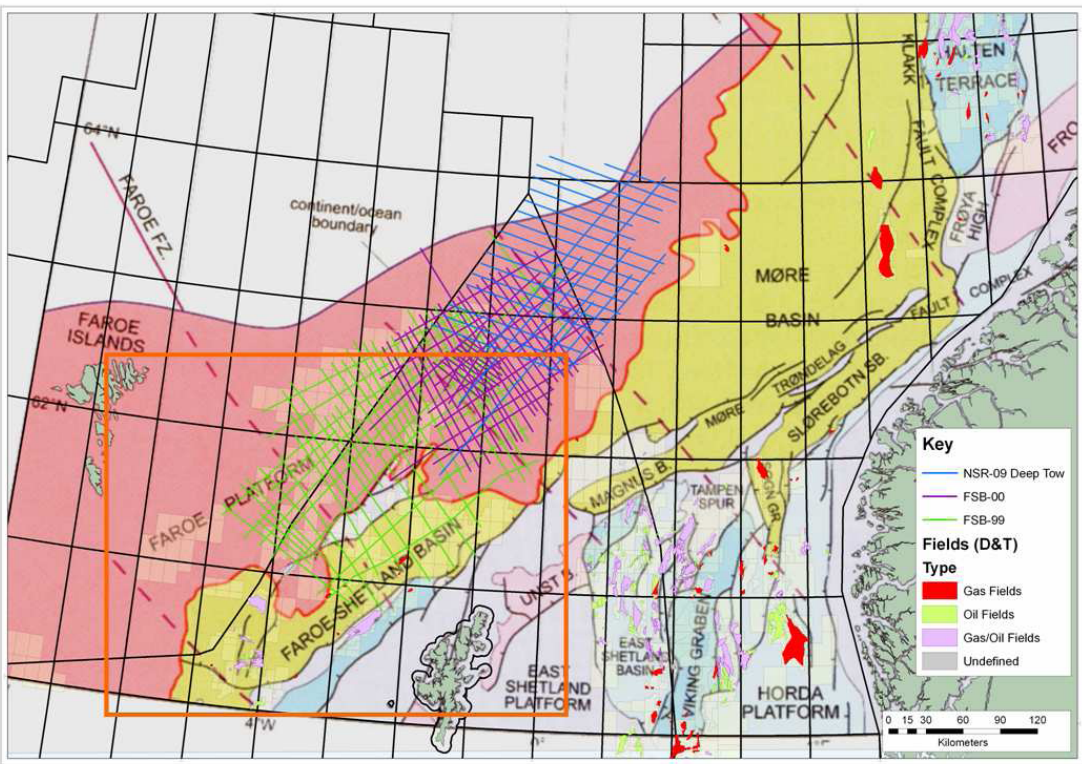

Figure 1: Location map showing the NSR 2009 lines acquired with a streamer towed at 18 metres depth and the reprocessed FSB 1999 and 2000 surveys overlain on regional structural elements from Mudge et al., (2007). Oil and gas discoveries and concessional blocks are also shown. The region shown in pink approximates the extent of widespread Palaeogene volcanism. The area highlighted in orange refers to the more detailed structural elements map of the Faroe-Shetland Basin shown in figure 2 with discoveries en-echelon to the southwest-northeast trend.

Alongside the acquisition of the deep towed NSR dataset, 9,779 km of 2D long offset data were reprocessed from the FSB 1999 and 2000 surveys which overlap to the southwest and were acquired with a more conventional 9 metre depth streamer. The FSB surveys sample a series of southwest-northeast orientated intra-basinal highs in Faroe-Shetland Basin, such as the Corona Ridge which hosts the Rosebank/Lochnager discovery at the southern end of the FSB 1999 survey (figure 2). The NSR deep towed acquisition follows the northward continuation of these features into deeper water along the structural trend of Caledonian inheritance which dominates the northwestern Atlantic margin of Europe.

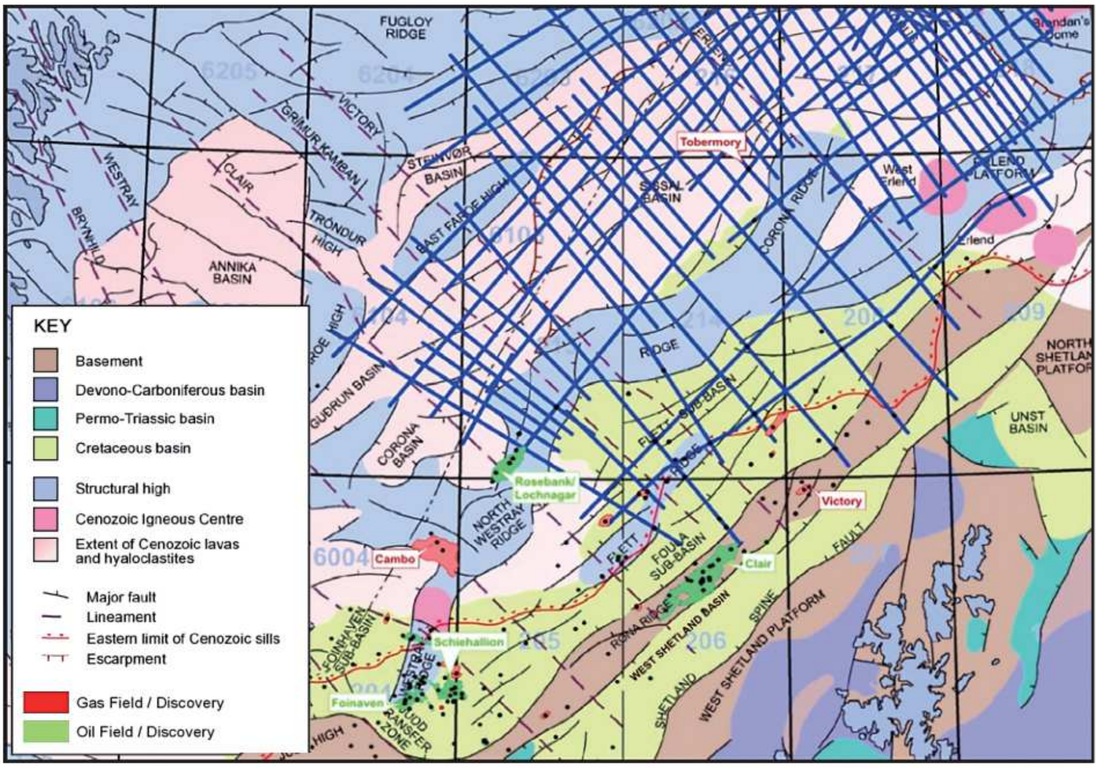

Figure 2: Tectonic elements map of the Faroe-Shetland Basin modified from Moy (2010) showing the reprocessed FSB 1999/2000 2D survey lines in dark blue, wells (in black) and oil/gas discoveries.

The FSB reprocessing campaign, completed in January 2010, incorporated a number of processing approaches which demonstrated a dramatic improvement over the original time image. Applicable components of the reprocessing sequence were then applied to the new deep towed acquisition. The overlap of data allows the comparison of the original FSB dataset with the reprocessed data and the new deep towed NSR acquisition through the intersection of 2D lines showing a stepwise improvement in the sub-basalt image.

Challenges in acquisition and processing

Imaging beneath thick basalt flows remains a challenge along the northwest European Atlantic Margin although many of the issues are now well understood. The strongly reflective top of the basalt and rugose nature of the flows, scatter much of the incident P-wave energy whilst interbed multiples generated within the basalt layers and surface multiples mask weaker sub-basalt reflections with similar moveout. The high velocity basalt layer absorbs and scatters the higher frequencies present in the source wavelet, not only limiting the effective resolution of the sub-basalt image, but large velocity discontinuities at top and base basalt interfaces result in significant ray-path distortion and multi-pathing. The key to improved imaging is therefore to generate and retain as much low frequency energy as possible in processing (e.g. Ziolkowski *et al*. 2001). Subsequently, more recent acquisition has seen the towing of cables and sources at increasingly greater depths using very large sources concentrating more of the available energy into the low frequency end of the amplitude spectrum through constructive interference of the free surface ghost.

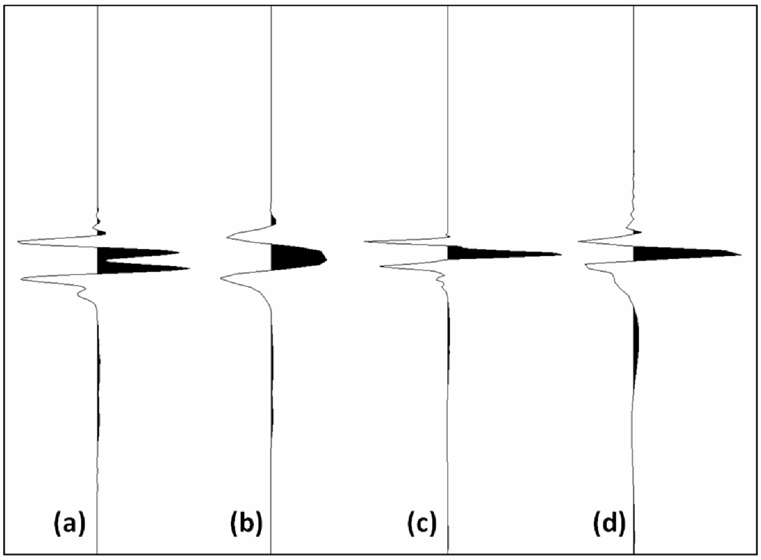

Figure 3: (a) Data derived wavelet from the NSR 2009 18m streamer and (b) after resample to 4ms and 42Hz 36dB/octave high-cut filter; (c) data derived wavelet from the FSB 1999 survey and (d) and spectral manipulation.

Figure 3(a) shows the data derived source wavelet for the 18 metre towed cable with a 7 metre source and figure 3(b) after the application of a 42 Hz high cut filter and 36 dB/octave taper. This compares with the same data derived wavelet for the FSB 1999 survey (figure 3(c)) acquired with a cabled towed at 9 metre depth and 7 metre source depth. The equivalent amplitude spectra are shown in figure 4. The NSR deep tow dataset demonstrates a broad receiver ghost at ~ 42Hz but a much richer response in the low end of the amplitude spectra when compared to the shallow towed configuration with a notch at ~ 82 Hz.

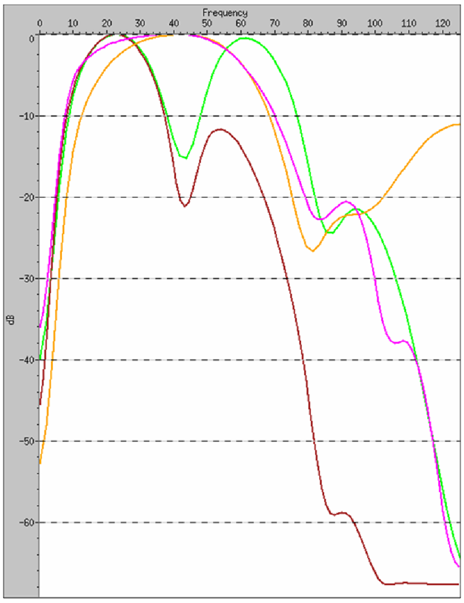

Figure 4: Normalised amplitude spectra of the data derived wavelets shown in figure 3. Green: raw NSR deep tow (fig. 3(a)); Brown: after filter (fig. 3(b)). Orange: FSB 1999 (fig. 3(c)); Pink: FSB 1999 after application of low frequency boosting operator (fig. 3(d)).

Sub-basalt data processing strategies

The FSB reprocessing utilised three key strategies which in combination produced a significant improvement in the sub-basalt image (Hardwick et al., 2010). These were (1) the enhancement of recorded low frequencies through spectral manipulation, (2) noise attenuation in multiple domains to maximise the signal-to-noise ratio and (3) ‘full-sequence migration multi-velocity analysis' adopting a strategy analogous to that used in pre-stack depth migration for updating velocity models in areas of complex structure. In the processing of the NSR deep towed data we adopt the same strategies with the omission of the low frequency boosting operator. Figure 3(d) shows the FSB 1999 data derived wavelet after application of this operator and the amplitude spectra in figure 4, showing a similar response to the NSR deep tow at the low end.

Results

Arbitrary intersecting lines allow the comparison of the NSR deep towed dataset with the original and reprocessed FSB dataset time image. Figure 5(a) shows such an intersection with the original time processing and figure 5(b) with the reprocessed image. Clearly the reprocessed FSB data shows a significant uplift in the sub-basalt image, but the deep towed data to a greater extent in the underlying Mesozoic and Palaeozoic section almost down to maximum recorded two-way-time (9 seconds). However the deep towed acquisition effectively limits the use of frequencies above the receiver ghost notch which compromises high frequencies in the overlying Tertiary section which were retained in the FSB reprocessing. The two datasets therefore need to be used in conjunction for regional evaluation.

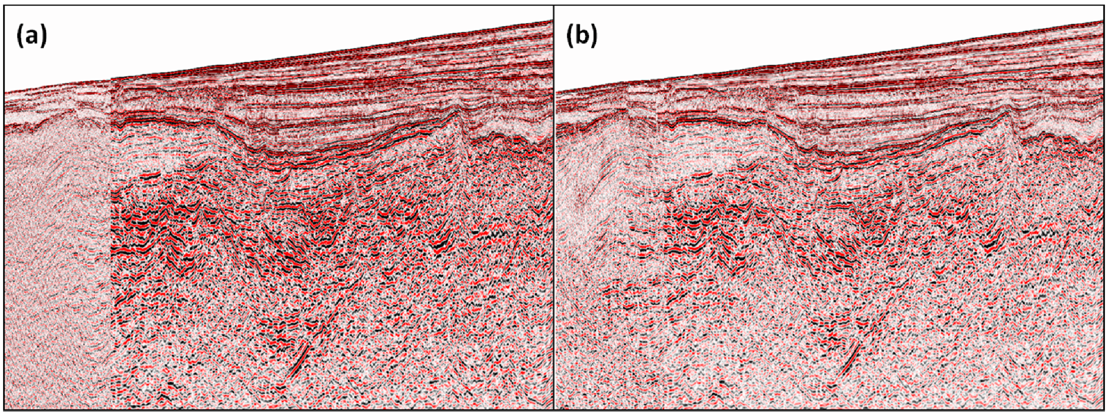

Figure 5: (a) Original FSB time migration at an intersection with the NSR 2009 deep towed time migration and (b), the FSB reprocessed time migration at the same intersection.

Conclusions

We show that combining effective approaches from the reprocessing of an overlapping dataset in the northern UKCS with new deep towed acquisition allows improved imaging of deep Mesozoic and Palaeozoic structure below Palaeogene flood basalts. The deeper towed acquisition may not be suitable for the critical assessment of stratigraphic plays in the Tertiary.

References

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