Summary

A novel model-based procedure for sub-basalt analysis has been proposed [1]. The procedure puts certain constraints on the offset coverage because early arrivals from very long offsets are exploited. The results demonstrate that early arrival reflection data contains information about the sub-basalt sediments, and can be used for imaging. Comparisons with conventional processing techniques are made.

Introduction

The continental break up of Northern Europe and Greenland during Paleocene was associated with transient, massive volcanism. As a consequence many of the sedimentary sequences of highest hydrocarbon potential are overlaid by lava-deltas.

Even though the basalts covers large areas of sedimentary sequences of the highest hydrocarbon potential, these areas are still not explored for oil. The main reason being lack of technology to map the sediments underlaying the basalts.

The basalts themselves often act as high velocity - high impedance contrast bodies. Irregular interfaces of the basalts will cause significant scattering of the seismic wave field. The high impedance contrasts cause penetration problems, strong multiples, and mode conversions of the seismic waves. All of these factors make reliable analysis and seismic imaging very challenging.

To handle these challenges conventional acquisition and processing methods are inadequate, so new acquisition and processing methods have to be developed.

Results from applying the novel procedure to a long offset (~ 12 km) seismic survey will be presented. With this method a seismic model is built as part of the analysis and offers to identify the different wave-modes in the observations and to drive the model-consistent imaging.

Acquisition

Data from two surveys acquired offshore the Faroes Iceland are analysed. One survey using a two-boat acquisition geometry with conventional streamer technology (6 km), giving synthetic aperture up to 18 km. A second survey was acquired using a single boat with new long streamer technology and a total aperture of 11.4 km.

Two boat versus single boat configuration

The two-boat acquisition geometry has despite its ability to give us long offsets, some fundamental limitations. The long recording length needed (12 – 17s) limits the density of the shot sampling and thereby the cmp offset sampling. To avoid aliasing problems during multiple
removal several stages of interpolation has to be carried out. This is both costly and complicated because of streamer feathering. The longest offsets contains reflections from sub-basalt events traveling through the high velocity basalt layer and comes in earlier than the overburden reflections. However, the void area in the super shot gather of the two-boat geometry complicates the analysis of the early arrivals, since reflections cannot be mapped to normal incident along a continuous offset range.

**Model-based processing**

The measured reflection response from the sub-basalt events are complicated by strong multiple energy, refractions and mode conversions. The velocity model built as part of the model-based processing, help to understand the nature of the sub-basalt reflections. Rays traced in the model are overlayed the pre-stack seismic and used to identify the observed response. Travel time curves picked on pre-stack data might be depth migrated assuming a given mode (pp, pssp, etc). This procedure gives an improved understanding of the sensitivity and the non-uniqueness of the inversion problem.

Both the moveout and the sorting are predicted by the model and is used in the model-based stacking. The early arrival reflection data are mapped model consistent to normal incident using this approach (Figure 1). Despite the lower frequencies obtained, mainly due to NMO stretching and attenuation loss, sedimentary reflection events can be observed (Figure 2). Since these events are not influenced by the strong multiple energy, valuable information about the sub-basalt sedimentary reflections can be extracted. Angle band stacks of early arrivals have a good potential for mapping faults below the basalt (Figure 2). The velocity model is also used as input to pre-stack depth migration (PSDM Figure 2).

**Conclusions.**

The model-based approach proves to be very useful when analysing pre-stack data from a basaltic area. Seismic modeling helps identifying which wave modes are present in the observed wave field. Further it allows to discriminate between multiples generated in the overburden, and primary sub-basalt reflections. In our case the pp-wave energy, the fastest traveling mode, was also the most energetic. Model-predicted travel-time curves can be used to map long offset early arrival reflection data with high accuracy to normal incident, giving reliable imaging of these wave modes. The symmetric mode-converted sub-basalt reflections traveling with lower velocities are superimposed with shallow reflection events. This makes reliable imaging of these modes difficult.

Comparing the two surveys the single boat long-streamer configuration is favorable compared to a two boat geometry, both economically and in terms of data quality. The improved image of the single boat configuration is attributed to better multiple attenuation and velocity analysis. Also, with the continuous streamer the long offset reflection data can more easily be understood and mapped to normal incident, since both cmp and shot gathers thus are continuous. The quality of the image below top basalt is improved when extending the offset range from 0-6 km to 0-12 km. Intra-basalt reflections, the base of the basalt and sub-basalt reflections are improved and more continuous when including longer offsets.

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References


Figure 1: Shot gather showing early arrival sub-basalt reflections with modeled traveltime curves overlayed. Offsets from 3000 – 8600 meter are shown.
Figure 2: Comparing sub-basalt imaging results, pp-wave mode.
Top: Conventional time domain processing (0-11.4 km offset)
Center: PSDM converted to time (0-11.4 km offset)
Bottom: Early arrival model consistent imaging (5-11.4 km offset)