9th Biennial International Conference
& Exposition on Petroleum Geophysics

"HYDERABAD 2012"

P-247

Sub-basalt Multiple and Noise Suppression Usinga Dense, Marine Wide-azimuth Recording Geometry

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Summary

A dense, wide-azimuth marine seismic line was recorded in the W. Shetland region of the Atlantic Margin starting in an area with no basalt and extending over an increasing thickness of basalt. Conventional seismic surveys have found difficulty in imaging beneath the basalt because of strong and complex multiple generation, scattering of energy and attenuation of signal frequencies above approximately 20Hz.The azimuthal diversity of a well sampled wide-azimuth stack provides an additional means of suppressing both multiples of dipping events and short wavelength scattered energy. The shot line spacing was 100m,with symmetrical inline offset sampling within CMP gathers. This is much denser than production wide azimuth surveys in the GOM. On-board stacks of the wide azimuth data show significant suppression of the multiples and noise compared to a 2D stack. Processing tests show that this is primarily caused by azimuthal diversity rather than increased fold or non-linear offset distribution.

Keywords*: Marine Acquisition, Wide Azimuth, Sub-Basalt*

Introduction

Exploration for hydrocarbons in both sub-basalt and intra-basalt environments has been attempted in a wide variety of locations around the world such as the Atlantic Margin of NW Europe and offshore India. Although there has been some success, progress has generally been limited by the poor quality of seismic images in many of these situations. It has been difficult to obtain even structural images of sufficient quality and reliability to identify drillable prospects. Amplitude analysis is usually even more difficult.

The major difficulties are caused by strong multiples and strong absorption within the basalt. The impedance of basalt usually gives rise to a strong reflection coefficient at top basalt and hence strong multiples. Seabed multiples and inter bed multiples between top basalt and the seabed may compound the complexity of the multiple energy. The basalt 'layer' may contain multiple flows with erosion and sedimentation occurring between the flows. This can lead to strong absorption within the basalt and also significant scattered energy with short spatial wavelengths.

The combination of strong, complex multiples, scattered energy and absorption of the primary gives rise to a poor signal to noise beneath and within the basalt. It is commonly accepted that only very low frequencies, perhaps below 20Hz, can be used for sub-basalt seismic imaging and even then multiples and scattered energy are problematic. Seismic imaging beneath structurally complex salt bodies in the Gulf of Mexico has been enhanced by the use of wide azimuth recording geometries. This has allowed enhanced illumination of sub-salt layers, particularly around the edges of discrete salt bodies, but also provided an uplift in multiple suppression. However, scattered energy is not usually generated within salt bodies to the same degree that we find within multiple basalt flows. Multi-azimuth techniques have been used offshore Egypt to improve sub-Messinian imaging and to improve signal to noise below a rugged surface. Furthermore, Keggin et al (2002) showed that a dense, wide-azimuth geometry significantly attenuated multiple diffracted energy from a rugose seabed offshore Norway; a dense cross-line sampling was necessary because of the short wavelength nature of the 'point' diffractors causing the multiple energy. This may be analogous to the scattered energy

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causing problems for sub-basalt signal to noise. Therefore, a dense, wide-azimuth experimental seismic survey was performed in the Atlantic Marginin August 2010 with the aim of improving attenuation of multiples and scattered energy and hence obtaining better imaging beneath the complex basalt layer.

Survey Design

The survey was designed using a '2D wide-azimuth' geometry following the method described by Keggin et al (2002). Unlike the Gulf of Mexico wide azimuth surveys, the primary concern was the ability to suppress both multiples and scattered energy; improved illumination is a secondary concern since the basalt flows are extensive and do not allow illumination around the edges of discrete bodies. Thus, the aim of the test geometry was not to allow a 3D migration but to test the ability of a wide-azimuth stack and other pre-stack de-multiple techniques to suppress the multiples and scattered energy.

A single CMP line crossing the UK-Faroes border of the Atlantic Margin was chosen from existing3D data. The line was chosen to intersect a Faroese well and to run from an area with no basalt in the SE into an area towards the NW with increasing thickness of basalt, to test if horizons identified away from the basalt could be tracked under the basalt and if so, whether they could be tracked further and with more reliability than with conventional narrow azimuth data.

The data was acquired with a single recording vessel with 8 streamers separated by 100m and a separate source vessel firing a single source every 25m as shown in figure 1. The streamer vessel wasal ways sailed along one side of the target CMP line and the source vessel on the opposite side, thus providing off-end shooting in the cross-line direction. The purpose of the multi-streamer configuration was to allow for feathering rather than to record more than one CMP line; 3D binning allows us to use data from whichever streamer has the right cross-line offset to 'hit' the CMP line.

The cable length used was 8km. However, since the top basalt is reasonably shallow at approximately2s two way time, the source vessel was moved back to be perpendicular to the mid-point of the cable.Given the 8km long streamers, this provided an in-line split spread configuration of +/- 4km offset which is sufficient for the typical stack mute to a reasonable depth below the basalt.

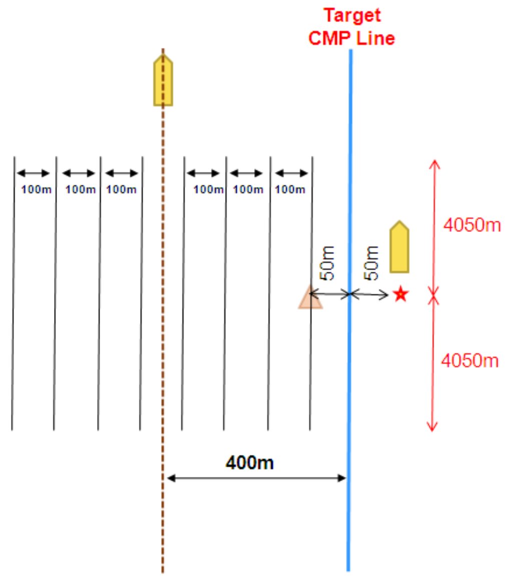

Figure 1. Planned 2 boat geometry for in-line split spread and cross-line off-end shooting

The cross-line offset spacing was 100m which is much denser than that typically used for Gulf of Mexico wide-azimuth recording. This was chosen since many previous studies in this area haveshown that inline offset sampling of 100m within CMP gathers is desirable for effective multiple suppression; wider spacing leads to aliasing that has not adequately been recovered with interpolation. In addition, the scattered energy is thought to have short spatial wavelengths and therefore needs dense sampling. This design provides symmetrical sampling of in-line of cross-line offsets within the CMPs.

A total of 11 passes of the 2 boat configuration were made with the shortest cross-line offset being 100m. An additional central 2D line was acquired by the streamer vessel using her own source and sailing along the CMP line. Thus, cross-line offsets from 0m to 1100m were recorded with 100mincrement.

Other survey parameters such as source depth (10m), cable depth (15m) and 4260cu. in. source were typical of previous surveys in the area.

Data Acquisition

In this area, it is known that currents can vary rapidly and are pre-dominantly from the SW towards the NE. Therefore, the source vessel was always positioned on the NE side of the line so that she could move away quickly if the cable feathering towards her increased quickly. The first pass of the vessels targeted a cross-line offset of 500m to allow the vessel crews to gain experience of steering with the designed configuration with a 'safe' separation between the source and the mid-points of the cables. The cross line offset was then reduced on successive passes by 100m. During the 300m cross-line offset pass, a rapid change in feathering meant that the source vessel had to steer away. Therefore, for the 200m and 100m passes, the source vessel was moved closer to the head of the streamer in order to reduce the risk from large feathering. For these passes, some split-spread in-line coverage was achieved but it was not symmetrical. The longer cross-line offset passes were recorded subsequently and with fully symmetrical split spread positioning. A typical CMP fold of coverage is shown in figure 2; the reduced split spread coverage of the in-line offset distribution can be clearly seen at the shorter cross-line offsets.

For the longer cross-line offsets, the receiver vessel was positioned so that in the case of no feathering, one of her central streamers provided the designated cross-line offset to the CMP line. Thus, when feathering occurs in either direction, one of her other cables should be correctly positioned to provide the necessary coverage for binning. However, at shorter offsets the outer cable shave to be targeted. For example, at the shortest cross-line offset of 100m (figure 1), the source was positioned 50m away from the CMP line and the outer cable steered to be 50m the other side. The multiplicity of cables then only allows for feathering in one direction (towards the source vessel) to be binned successfully.

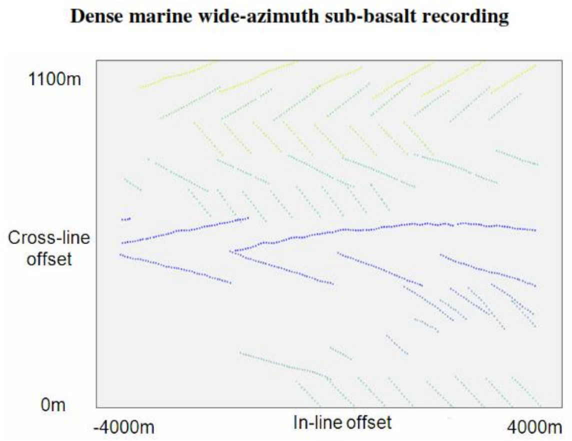

Figure 2. Offset distribution of the individual traces for a typical CMP. The split-spread in-line offsets range from -4000m to+4000m and the off-end cross-line offsets from 0m to 1100m.The different colours refer to different passes of the vessels.

Analysis and Results

Figure 3 shows the result of the onboard QC stack using a picked velocity field but no de-multiple other than the stack. The comparison between the 2D stack and the wide-azimuth stack shows a striking suppression of the water bottom multiple using a wide-azimuth stack. This can be understood by considering the multiple of a dipping event. During processing, we typically choose velocities and imaging tools to flatten the primary of that event within a CMP gather. However, the multiple will usually have residual moveout and this moveout will depend, amongst other things, on the dip of the event. Therefore, the residual moveout will also depend on the shot-receiver azimuth i.e. whether the trace is shot in the dip direction, the strike direction or another direction. Thus, azimuthal diversity will help to suppress multiples during the stack process by introducing an azimuth-dependent residual moveout. This effect can be seen clearly in the gathers in figure 4.

Full processing of the data, involving 3D Radon and inside muting, is necessary to attenuate deeper and more complicated multiples. It also reduces the difference of narrow azimuth versus wide-azimuth. However, there are still clear benefits from using wide-azimuth data.

There are other possible causes of the improvement in the stack. Firstly, the wide azimuth stack is much higher fold than the 2D stack. Secondly, a wide azimuth geometry on a regular grid in x and y introduces offset weighting in that

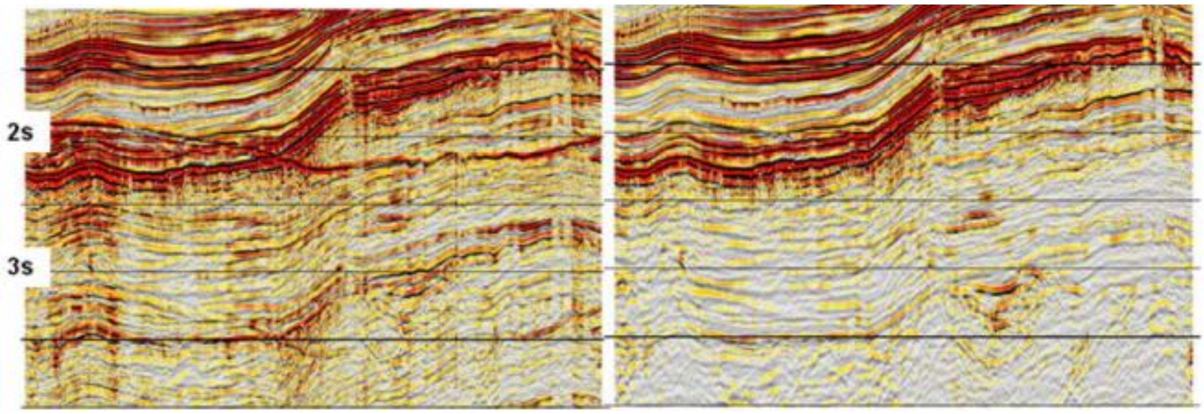

Figure 3. The 2D onboard QC stack is shown on the left and the wide-azimuth stack on the right. The water bottom multiple and other multiples are clearly suppressed in the wide-azimuth result

there are preferentially more traces with a mid offset. These effects can be tested during processing. The first effect was evaluated by producing a stack containing a full range of azimuths but a fold equal to that of the 2D. The second simulation involved applying an offset weighting to the 2D stack to match that of the wide azimuth stack. These simulations were performed on data that had been through the complete de-multiple sequence. In both cases, thebenefits of azimuthal diversity could not be matched, indicating that the dominant effect is that ofazimuthal diversity.

Conclusions

Wide-azimuth seismic has been shown to have benefits for multiple and noise suppression caused by azimuthal diversity within the stack process. This can begin to help to reveal clearer primariesalthough in this particular area there is still a need for further improvements in this regard.

References

Keggin J., Widmaier M., Hegna S.and Kjos E. [2002] Attenuation of multiple diffractions by multiazimuthstreamer acquisition. 64*th EAGE Conference and Exhibition,* Extended Abstracts, F39

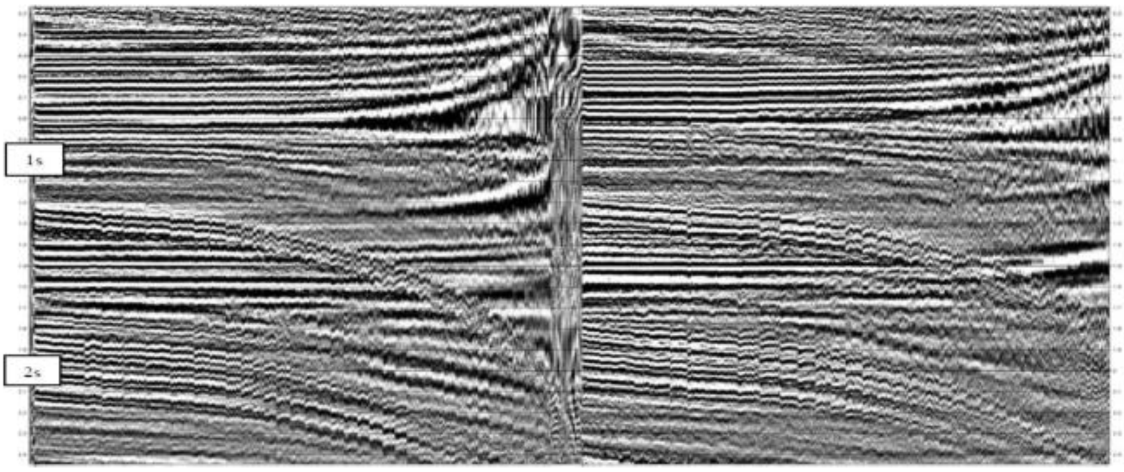

Figure 3. The 2D onboard QC stack is shown on the left and the wide-azimuth stack on the right. The water bottom multiple and other Figure 4. Selected time window from two wide-azimuth CMP gathers with traces sorted by in-line and then cross line offset. Notethe flat, continuous primaries and the "jitter" of the dipping multiple events. Within each group of traces in an inline offset class, the arrival time of the dipping multiples varies with azimuth and this effect becomes more pronounced as offset increases. multiples are clearly suppressed in the wide-azimuth result