**IMAGING BENEATH BASALT USING CONVERTED WAVES IN MARINE SEISMIC DATA**

Xiang-Yang Li and Colin MacBeth

*Edinburgh Anisotropy Project, British Geological Survey, Edinburgh UK*

**Introduction:** When a $P$-wave is incident upon the top of a high-velocity basalt layer, little $P$-wave energy is transmitted into the basalt layer. However, beyond a certain critical angle, an efficient conversion can occur from the incident $P$-wave to an $S$-wave travelling inside the basalt layer, with a strong reconversion to the $P$-wave at the bottom of the basalt layer. When this converted wave reflects at an interface beneath the basalt and impinges upon the bottom of the basalt from below, the conversion and reconversion occur again. This wave, according to its raypath, can be referred to as a PSSP, or PSPPSP, wave, and is studied here for imaging beneath basalt. The use of converted waves for sub-basaltic imaging was first tested in laboratory experiments by Purnell (1992). This technique was subsequently adapted for imaging structure inside salt bodies by Wang et al. (1994). Despite this, there appear to be few, if any, field and numerical modelling studies. Here we fill this gap using seismic data from the North Atlantic Margin.

**Converted-waves in marine seismic data:** A 2D seismic line from the North Atlantic Margin with a 6000m streamer length is selected for testing the concept. In the study area, the thickness of the sediments between the seabed and the basalt remains roughly constant at 900m, and the water depth varies between 600-1300m. The long streamer provides the requisite incidences to record intra-basaltic converted waves.

The primary $P$-wave reflections from beneath the basalt are very weak, and the data are dominated by multiples (Figure 1). At far offsets, there exists a wavetrain ahead of the primary seabed reflection. The first arrival within this wavetrain is a refracted wave from the basalt, and has an apparent velocity of 4200 m/s. Subsequent arrivals are weaker, but contain reflections/refractions (PSPPSPs) from layers beneath the basalt identified through moveout analysis. More detailed examination reveals that the PSSP from the bottom of the basalt has an rms velocity of 1708m/s, and a critical (onset) offset of 1075m.

The shot record in Figure 1 is modelled using full-wave reflectivity techniques (Taylor 1991). Major PP arrivals, such as those from the seabed, PP(1), and the sediments, PP(2), and the behaviour of the PSSPs and PSPPSPs agree and match the real data. At the far offset, the PSPPSP(4), and PSPPSP(5) cross over the seabed reflection, indicating that for better separation of these events, the recording offset should be longer than 6000m. A 10000m offset may be more appropriate, as revealed by subsequent modelling. It has been indicated that the basalt is highly variable and anisotropic (Kiorboe and Petersen 1995). Consequently, it is vital to determine whether the PSPPSPs are specific to the study area or more generally applicable. For this we calculated synthetics for several different scenarios.

**Test processing and conclusion:** It is important to understand the behaviour of different wavetypes, particularly, those associated with the basalt. For this, detailed velocity analysis and modelling was carried out, and special care was taken to preserve the far-offset arrivals. The final results have revealed sediments below the basalt, and improved the definition of the basement.

We conclude that the field data examined show clear reflected and refracted arrivals which consist of raypaths with $S$-wave segments through the basalt. Numerical modelling confirms these observations and reveals that use of converted waves is likely to be most productive where water depths are shallow, streamer lengths are long, and the $S$-wave velocity of the basalt is similar to the $P$-wave velocity of the adjacent sediments. Processing tests based on the PSPPSP waves has improved the structural imaging below the basalt. The processing also indicates that converted wavefield extrapolation and separation, and multiple suppression will be key issues for fully utilizing the PSPPSP arrivals at all offsets.
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References

Figure 1. Data characteristics of the original shot record from the test line in the study area. At near offset, no primary reflections can be seen beneath the basalt. At far offset, the converted wavetrain is ahead of the reflections and free-surface and basalt multiples.

Figure 2. (a) Simplified model of the North Atlantic Margin; (b) the synthetic record for (a); (c) the same as in (b) except that the elastic basalt in (a) is replaced by an acoustic basalt so that S-wave propagation within the basalt is prevented. No PSPPSP arrivals can be observed in (c). Numbers, such as (3.0/1.0/1.5), (5.8/2.9/2.9), within each layer are P-wave velocity, S-wave velocity and density, respectively. The bracketed numbers on the right of (a) mark the sequence of the interfaces. The dashed lines in (b) and (c) are ray-tracing travel time curves for the marked wavetypes from the corresponding interface.