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New methods in sub-basalt imaging using wide-angle seismic and reflection seismic data

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One of the main achievements of the Atlantic Margins Project has been to successfully develop and test new strategies for the enhancement of sub-basalt imaging. In recent years the use of OBS (Ocean Bottom Seismographs) as an exploration tool has become increasingly viable with the development of large numbers of small reliable instruments. Even so, the processing of these data is still in its infancy compared to conventional reflection seismic data. We present new methods which have greatly improved the processing and interpretation of wide-angle refraction and reflection data, including picking of refracted energy from shot gathers from a 12 km seismic streamer, waveform deconvolution of wide-angle seismic data, multiple suppression in ocean bottom seismometer data using the vertical geophone and hydrophone channels and enhancement of data quality by stacking of several channels of a vertical seismic array on the sea-floor.

Long seismic streamers

Over the past several years the development of cheaper and smaller OBS has meant several tens of instruments are routinely deployed along a single profile. This has greatly increased the ray coverage and resolution of the resulting seismic velocity model but gaps still exist where the model is less well constrained. Typically OBS will be positioned 5-10 km apart and even with this close spacing the velocity of the uppermost sedimentary layers will be poorly constrained. The problem is further compounded by any instrument losses. Accurately modelling the uppermost layers has a knock-on effect for the deeper regions of the velocity model, as all rays must pass through the upper layers. The AMP have collected coincident OBS and streamer data using 10 km OBS spacing and a cable length of 10 km. Such long cable data contains a vast amount of useful information in the form of refracted arrivals occurring ahead of the reflected water-wave cone. In conventional reflection processing these arrivals are typically muted out. However, we show here that picking and modelling the travel-times of these refracted arrivals allows the derivation of high-resolution velocity models for the top 0-4 km of the subsurface. The arrivals may be either forward modelled using ray-tracing, or inverted to provide a smooth tomographic velocity model. The resulting velocity model can then be merged seamlessly with the velocity model for deeper regions derived from the OBS. Using this approach the OBS spacing need only be as close as the length of the streamer, and OBS losses have a less detrimental effect on the overall dataset. The final velocity models provide excellent control for both migration and depth conversion of the coincident reflection sections.

Waveform deconvolution

A new development is the use of known source wavelets as a processing aid to the identification and picking of arrivals on OBS data. The source wavelet is recorded shot-by-shot, then used as a deterministic filter for the associated record on the OBS. This offers two major advantages: firstly, the filter removes the long bubble pulse coda typical of air-gun arrays tuned for low-frequency and hence enables more confident identification of second arrivals; secondly, the filtered wavelet has zero-phase so rather than trying to pick the onset time of the energy that is emergent from the background noise, the pick is now centred on the maximum of the filtered pulse which may significantly reduce picking uncertainty.

Multiple suppression in wide-angle seismic data

Multiples of sea-surface reflected events in wide-angle marine seismic datasets can complicate their interpretation in two ways: (a) Phase indentification can be complicated when the traveltime difference between secondary arrivals and multiples is small, and (b) strong multiple arrivals sometimes obscure weaker first arrivals. Through stacking of the vertical geophone data and the data from the hydrophone the multiple energy can be eliminated making phase identification easier and allowing additional arrivals to be interpreted. A third advantage of this method is the increase of the

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signal/noise ratio as commonly is found for multichannel seismic reflection data. We present examples of the multiple attenuation from OBS record sections from the NE-Rockall Trough (figure 1).

Vertical array

Progress in the development of wide-angle seismic instruments has been slower than that of reflection seismic data acquisition, where today streamers of several kilometers length and several hundreds of hydrophones are commonly being used. Stacking of several channels can enhance the data quality of wide-angle seismic data similar to reflection seismic data processing. The instrument provides an increased coverage, because hydrophones at the top of the array record rays that have travelled a different path from those recorded by hydrophones at the bottom of the array. We present results from apparent velocity analyses and stacking of data from a 16 channel vertical seismic array moored on the seafloor.

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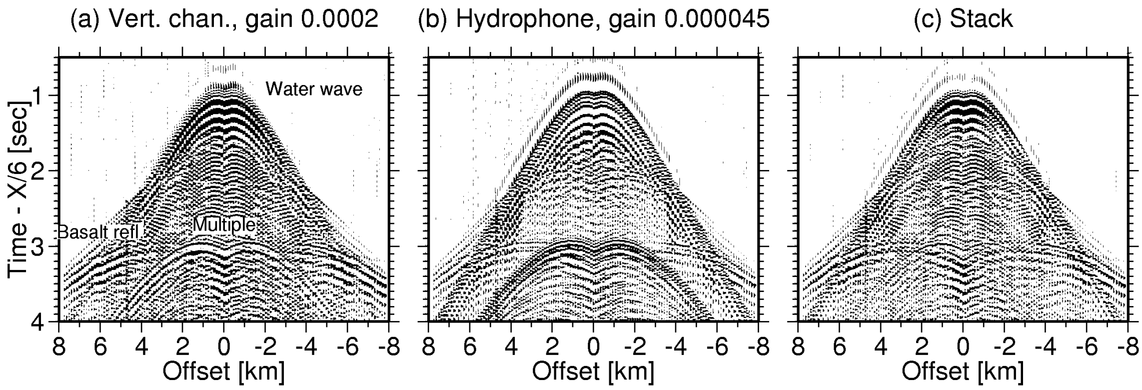

Figure 1: Vertical geophone, hydrophone, and combined stacked data of trace 1601 (30 km offset) of an OBS in the Rockall Trough between -8 and 8 km offset. (a) Vertical channel data from an OBS in the NE Rockall Trough. The strong direct waterwave multiple overlies the reflections originating from a basaltic layer, making picking difficult. (b) Hydrophone section (c) Stacked data section. The reflection from the basaltic layer is visible underneath the strongly attenuated water multiple.