Journal of Conference Abstracts
Volume 7(2), 176

An effective way to get rid of interface scattering

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Introduction

Internal and interface heterogeneity are believed to be amongst the major causes of low quality seismic data in basaltic areas.

In heterogeneous media, scattering occurs due to interactions of seismic waves with spatial variations in the material properties of the medium, variations that range in size from several seismic wavelengths to a small fraction of the wavelength. The scattering regime depends upon the relationship between the propagating wavelength and the scale of the heterogeneity. Scattering by heterogeneities affects a number of seismic observables, including amplitudes, traveltimes, spectra and waveforms.

Interface scattering

It is generally known that basalt boundary surfaces are not smooth. The scale of corrugations with respect to incident wavelength is the important factor when considering their effect in terms of scattering. From previous work it has been shown that basalt interfaces, like most natural topographies, are band-limited fractals. Therefore they contain roughness over a broad scale range including the seismic wavelength. The effects of irregular interfaces on wave propagation are well known.

Both internal and interface scattering contribute substantially to the sub-basalt imaging problem, one or the other being the dominant factor according to a balance between different parameters, such as basalt layer thickness, nature of the interfaces and seismic wavelength. However, even in the presence of thick heterogeneous layers, our modelling has shown that if irregular boundaries between layers are also present, interface scattering is most likely to be the dominant source of contamination of lower structures.

Wave-equation datuming in sub-basalt imaging

As a possible solution to the detrimental effect that interface scattering can have on deeper reflector imaging and continuity, a wave equation based pre-stack datuming has been tested on seismic data.

Re-datuming is a computational process that transforms seismic data to a datum plane different from the original acquisition plane. This process is based on the elimination of propagation effects between the surface and the new datum, predicting the effect of moving sources and detectors to a plane below the interfaces that are causing major contamination effects.

The procedure is graphically summarised in figure 1.

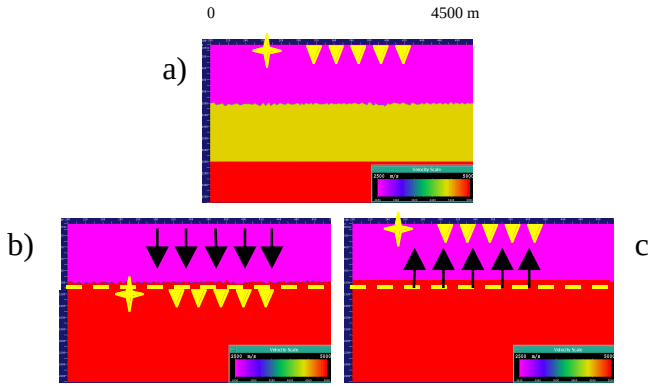

Figure 1: a) Original acquisition level is at the surface; b) Using the wave equation, pre-stack wave equation datuming moves sources and receivers to a datum plane, in this case chosen below the lowest topographic variations of the rugose interface. No information on the velocity structure at depth is necessary; c) Sources and receivers are moved back to the original acquisition level removing the topographic effect.

The application of this technique to synthetic finite difference (acoustic and elastic) and real data has improved, considerably, the image of sub-basalt reflectors. A synthetic acoustic finite difference shot gather (generated using the model in figure 1 (a)) before (a) and after (b) the application of the procedure is shown in figure 2.

The target reflector (interface between the second and third layer in the model in figure 1 (a)) is clearly evident in the shot gather after the datuming (1200 ms zero offset).

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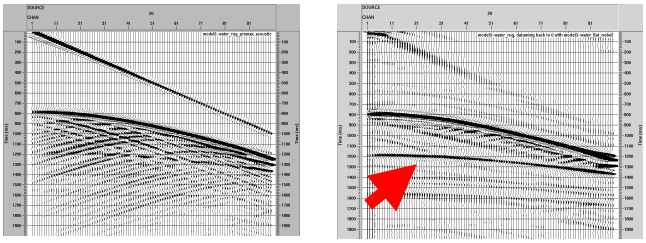

Figure 2: shot gather before (left) and after (right) the application of the pre-stack datuming procedure. The shot was generated on the model shown in Figure 1(a). Imaging of the target reflector (1200 ms zero offset) has considerably improved.

Real data example: NE Atlantic margin

We have tested the application of the wave equation based re-datuming, on a real dataset from the NE Atlantic Margin.

The dataset consists of a thin basalt layer, which is smooth for part of the seismic line and rugous in another part. Where the basalt layer is smooth, clear reflections are visible below the basalt layer in a conventionally processed section. On the other hand, where the layer has irregular topography, a large amount of scattering is generated and this completely contaminates any arrival from below (figure 3).

This represents the perfect dataset for testing the datuming procedure, giving a form on control on the results.

Also, as the basalt layer is very thin (a few tens of meters), the scattered waves can be related with great confidence to interface scattering effects, as there are not enough wavelengths propagating into the basalt layer to generate significant amounts of body wave scattering.

On the part of the line where topography is present in the basalt layer, resulting in lack of sub-basalt reflectors, a few reflectors "appeared" in the re-datumed stack final section (figure 4). These 'new' arrivals can be confidently correlated with the original arrivals on the right had side of the section

Conclusions

A tool to improve processed image quality affected by interface scattering contamination has been tested. The technique is shown to be reliable and can yield significant improvement in sub-basalt reflector clarity.

Having the same aim as pre-stack depth migration, wave equation pre-stack datuming has the great advantage that it requires knowledge of the velocity field up to the basalt layer and of the interface, as opposed to the entire velocity-depth model. It is also less expensive as extrapolation of the wavefield is in fact necessary only to the datum plane, rather than through the entire sub-surface data volume.

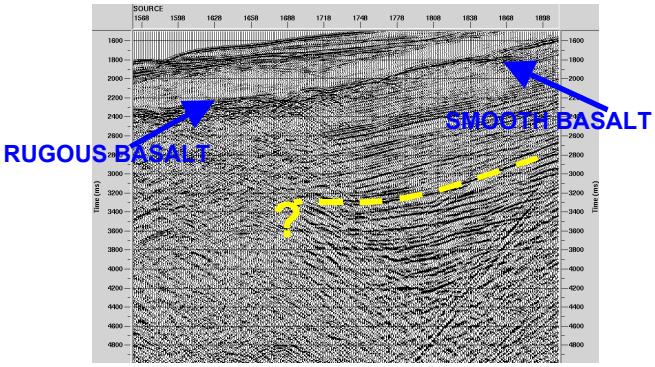

Figure 3: Part of the seismic line from the NE Atlantic margin object of the application of the datuming technique. This represents a very good dataset to test the technique, as where the basalt layer is smooth sub-basalt reflectors are visible, giving a form of control on the results.

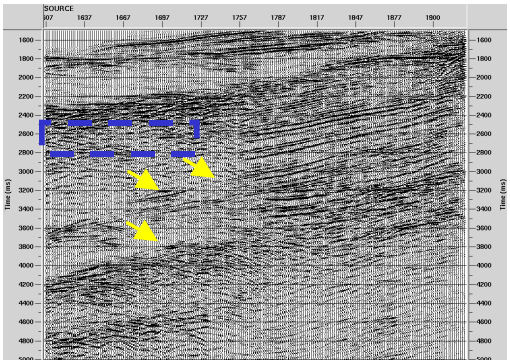

Figure 4: Section after re-datuming.

Acknowledgements

The authors would like to thank Phillips Petroleum and Agip UK for providing and giving permission to show the real data. This work was sponsored by the PIP RSG Project 97/21.