PETEX 2010
From Volatility to Value

Processing Challenges from Arctic Latitudes: Attenuation of Diffraction Multiples from Ice-scouring Tracks

Introduction

Over the past 10 years TGS has built up a substantial geophysical database offshore Greenland. This includes over 64,000km of 2D seismic, much of which contains multiples of primary diffractions, generated from seabed scatterers, especially in latitudes north of 70°.

These 'diffraction multiples' often have relatively strong amplitudes compared to the underlying primary signal, and are particularly resistant to attenuation using conventional processing. For example, conventional 2D SRME generally predicts the specular component of multiples while the nonspecular component related to multiple diffractions is often not adequately predicted (Zhou *et al*, 2005).

Several authors have described techniques for removal of diffraction multiples (Brittan *et al*, 2004; N Hargreaves *et al*, 2005; Zhou *et al*, 2005; Bekara *et al*, 2010) that are adaptable to 2D seismic; however the most successful examples are showcased in deep water datasets. Here we describe the diffraction multiple problem and a method for suppression, with examples from the continental shelf offshore western Greenland.

Diffraction Multiples: a problem for data acquired in 'high-latitudes'

Diffraction multiples are inherently 3D in nature. The source of these seabed scatterers is, therefore, difficult to determine from a 2D seismic dataset. To answer this question we have evaluated recordings from a recent TGS 3D survey acquired in the Barents Sea (N Norway).

Figure 1(a) provides a seismic-amplitude time-slice through the seabed reflector in a portion of this current 3D survey. An unmistakable NE to SW trend of iceberg drift tracks is evident. These scouring tracks can, in a lot of cases, be resolved as channels on inline/crossline images (fig. 1(b)). A judgement can therefore be made regarding the size of the features.

The vertical threshold for resolution is ¼ of the dominant wavelength, λ:

$$\lambda / 4 = v / 4f \qquad (1)$$

Therefore, for a typical dominant frequency f = 45Hz, and velocity, v, of water = 1500m/s, the minimum size of a channel that can be vertically resolved would be 8.33m. Of course, channels can be bigger than this (and more easily resolved in the seismic) or smaller than this – the presence of which would be inferred by using diffractions. It should be noted the scatterers can also take the form of glacial debris deposited on the sea floor.

Study of the *Fresnel* zone concept provides insight into the lateral resolution and relative seismic amplitude of these seabed scatterers. As the radius of the scatterer increases the amplitude begins to build up until it reaches the radius of the *Fresnel* zone, r:

$$r = \frac{v}{2}\sqrt{\frac{t_0}{f}} \qquad (2)$$

Again, using the Hoop-3D survey as an example, where the seabed two-way time t_0 ~ 600ms, the radius of the *Fresnel* zone is ~86m.

Figure 1(c) shows a near-offset trace image from a sample 2D line in Baffin-Bay situated at ~73° N. The seabed reflector in this image is similar in character to that of the seabed in the Hoop-3D data. Whilst this evidence is not conclusive it is suggested the source of seabed-scattering offshore W-Greenland to be a result of iceberg drift scouring tracks and deposited glacial debris.

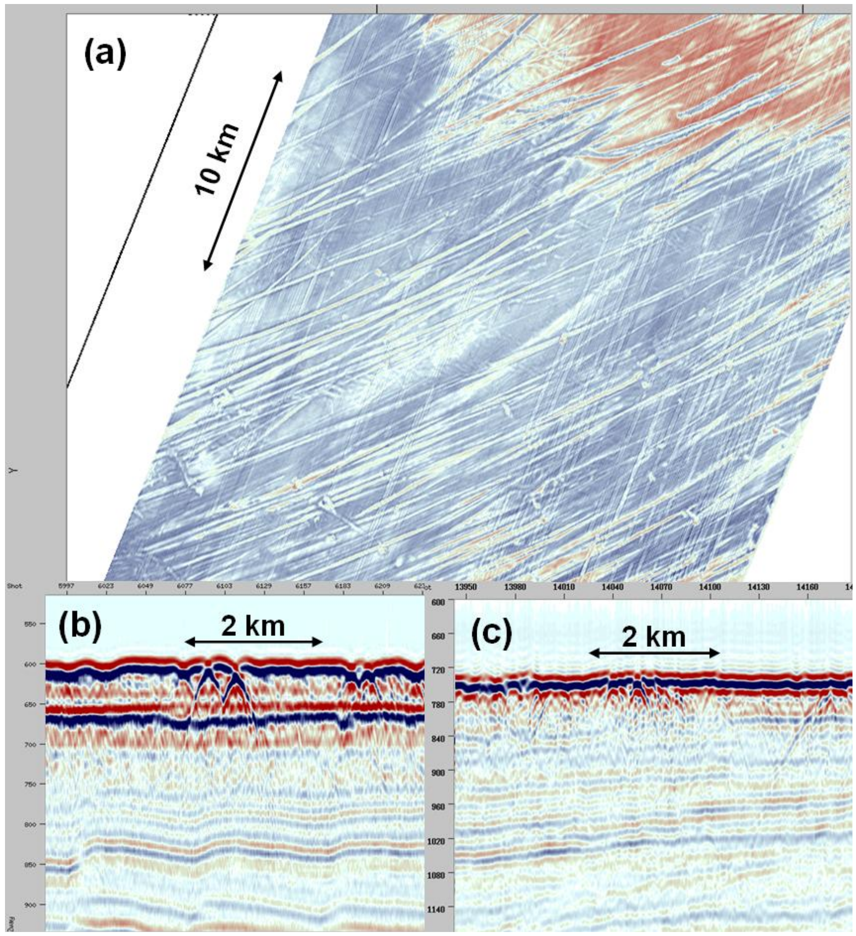

Figure 1 *(a) Seismic-amplitude time-slice through the seabed – from the TGS Hoop-3D survey (taken from an early processing stage). (b) Sample subsurface inline stack from the same data volume. (c) Near-offset trace image of 2D-line BB09-50265 from offshore Greenland (Baffin Bay)*

Synthetic data examples

Evaluation of synthetic data demonstrates that pre-stack travel-time recordings of diffraction multiples vary in character depending on depth to seabed-scatterer (fig. 2(a) & 2(b)). The diffraction multiples split into a pair, and one of the shot or receiver side multiple reflections will appear almost flat in CMP gathers offset from the position of the scatterer. But this situation is apparent only where the scatterer is at a depth to seabed <600m.

To understand this concept it is worth considering the travel-time surface of a diffractor/scatterer in line with the seismic line. This will form a pyramid in (t,x_m,x_o) space (Vermeer, 1990). This pyramid will act as an asymptotic boundary condition for any in-line scatterer at the seabed at any depth. Therefore, the resulting primary and diffraction multiples will appear flat in CMP 'slices' with midpoint positions off to the side of the scatterer, but only when the depth to the scatterer is small (fig. 2(c)).

The apex shifted nature of the deeper-water diffractions can be dealt with through processes such as apex-shifted radon where the transform can adequately separate primaries and multiples of scatterers (Hargreaves *et al*, 2003). However, this approach is expensive and may be harmful to primary amplitude preservation primaries (Abma *et al*, 2002). Furthermore – in shallower water – these synthetic data suggest the character of the recorded diffraction multiples diverge from the assumptions that apex-shifted radon is based upon (fig. 2(a)).

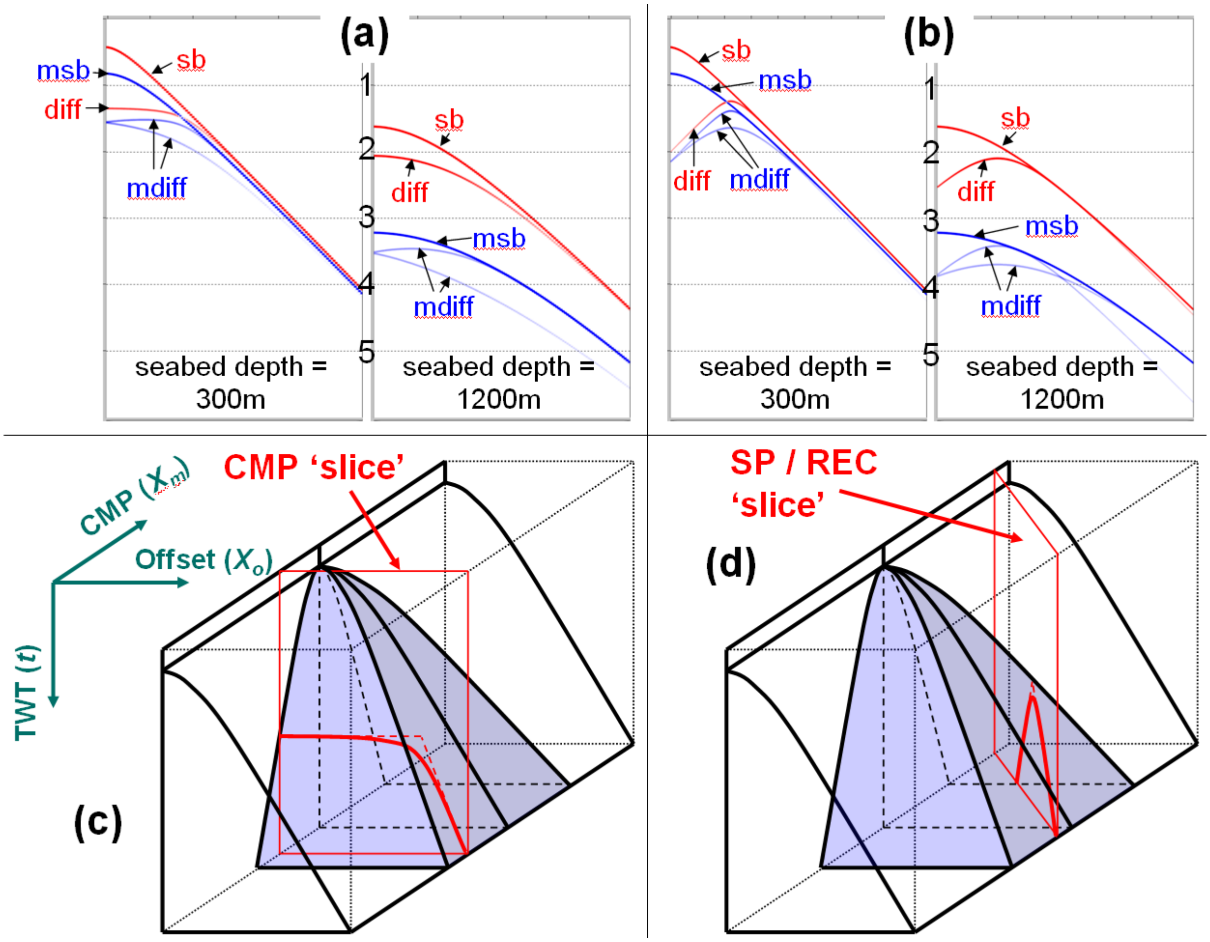

Figure 2 *Synthetic seismic gathers, generated from a flat seabed and single in-line seabed point-source scatterer, with diagrammatic explanation of travel-times. (a) Synthetic CMP gathers at contrasting depths to seabed. In-line distance between midpoint position and scatterer = 1km. KEY: sb=seabed; msb=multiple of seabed; diff=diffraction; mdiff=multiple diffractions. (b) Synthetic SP gathers.(c) Travel-time surfaces of the seabed (uncolored curved sheet) and of the diffractor (purple pyramid). CMP slice indicates approximate position of the synthetic gathers in (a). (d) The same travel-time surfaces but showing the approximate position of the synthetic shot gathers.*

Diffraction Multiple Attenuation: examples from offshore Greenland (Baffin Bay)

Hargreaves *et al* (2005) describe how the *pre-stack kinematics* of diffraction multiples can be used as a key to suppression of the events in final stack images. It is worth emphasising, however, the very characteristics used to isolate diffraction multiples in, say, the shot and receiver domains are also exhibited by steeply dipping primary reflections. Suppression techniques that work only on the basis of isolation in the shot and/or receiver domains may attenuate dipping primary energy.

Satisfactory attenuation was achieved on the BB09 survey by developing a two-step approach:

1. This first process isolates the diffraction multiple energy based on amplitude and frequency character in NMO-corrected CMP gathers. It assumes the well-behaved (i.e. hyperbolic) specular portions of the diffraction multiple have already been removed by earlier 'conventional' processing techniques such as 2D-SRME and high-resolution radon filtering. A noise model from this process is then passed on to the next stage.
2. Step two refines the diffraction multiple noise model via a process of dip-based event discrimination in the shot and receiver domains. This refined noise model is then subtracted from the input CMP gathers.

It is important to stress this technique worked only when the two steps were combined in the order described. Furthermore, neither of these processes when used individually were found to isolate the diffraction multiple noise from primary signal in data from the BB09 survey.

Figure 3 provides a display of a stack section and some sample CMP-gathers from offshore Greenland (Baffin Bay). After conventional demultiple processing (fig. 3(a)) residual diffraction multiples are still evident in the stack image and CMP-gathers. When this is combined with successful application of the diffraction multiple attenuation (DMA) technique (fig. 3(b)), these multiples are suppressed.

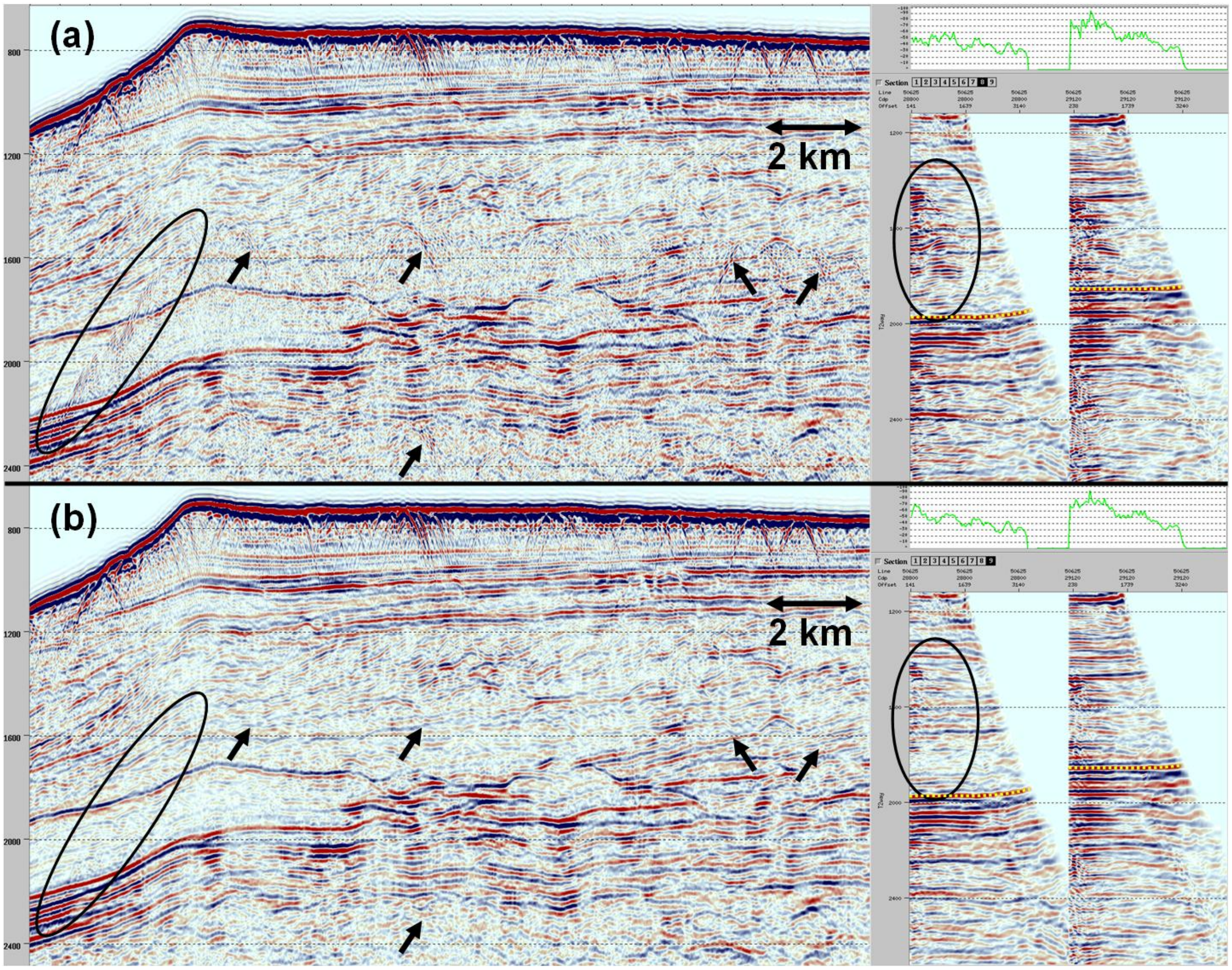

Figure 3 *Stack section (before migration) and sample CMP-gathers from line BB09-50625, offshore W-Greenland. (a) After conventional demultiple processing. (b) After conventional demultiple processing and diffraction multiple attenuation (DMA). Amplitude plots, displayed above gathers, are calculated along the primary reflections highlighted by the yellow dashed lines.*

Conclusions

Seismic data acquired at latitudes north of 70° may contain multiple diffractions generated by iceberg drift scouring tracks and glacial debris, which act as scatterers on the present-day sea-floor. The travel-time surfaces of these events display different characteristics depending on the depth to the seabed, as shown in synthetic data This paper illustrates the use of an amplitude/frequency isolation technique in the CMP domain followed by an event discrimination procedure in the shot and receiver domains, which can generate a noise-model for the successful suppression of diffracted multiple energy.

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References

Abma, R., Kabir, N., Matson, K., Shaw, S., McLain, B., and Michell, S., 2002, Comparisons of adaptive subtraction techniques for multiple attenuation: 72nd SEG International Ann. Mtg, Expanded Abstracts, **21**, 2186.

Bekara, M., Sedhom, M., Wigner, A., 2010, Methodology for Diffracted Multiple Reduction: 72nd EAGE Conf & Exhibition, Expanded Abstracts P417

Brittan, J, and Wrench, A., 2004, Attenuation of multiple diffractions using a cascaded noise removal sequence: First Break, **22**(8), 71-74

Hargreaves, N.D., VerWest, B.J., Wombell, R., and Trad, D., 2003, Multiple attenuation using an apex-shifted Radon transform: 73rd SEG International Ann. Mtg, Expanded Abstracts **22**, 1929.

Hargreaves, N.D., Wombell, R., 2005, Multiple diffractions and coherent noise in marine seismic data: First Break, **23**(9), 67-73

Veermeer, G.J.O., 1990, Seismic wavefield sampling: Society of Exploration Geophysicists

Yu, Z., Kabir, N., Matson, K., 2005, Diffracted multiple attenuation using wavelet filter in the focused domain: 75th SEG International Ann. Mtg, Expanded Abstracts **24**, 2072

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