

# “Off the Shelf” Seismic Data Processing

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## Summary

Seismic reflection data offshore Eastern Canada are heavily contaminated with complex water-bottom multiples, caused by a hard and irregularly shaped sea floor. In addition, some target reservoir intervals require imaging of steeply dipping structures in an environment influenced by salt tectonics. This paper discusses the use of free surface multiple suppression techniques and Kirchhoff pre-stack time migration methods and compares results with more conventional multiple suppression and imaging techniques.

## Introduction

Briefly, the structural styles offshore Nova Scotia have been controlled by the high sedimentation rates associated with the progradation of the late Jurassic to early Cretaceous Sable Delta complex. This sedimentary loading propagated a series of large, down-to-basin, listric faults, as well as initiating the movement of deeply buried Triassic salt. The latter accentuated the growth of syndepositional faults and the formation of numerous localised sedimentary basins (CNSOPB, 1997).

Much of the current hydrocarbon exploration interest in this region is in the transition zone from shallow (~30 m) to deep (~3 km) water, or off the continental shelf. Associated with this large change in water depth are deep channels in the sea floor, created by turbidite flows, carrying sediments from the shallower regions down the continental slope to the deep ocean floor.

This combination of structurally complex geology and a highly irregular water bottom is not friendly towards standard "off-the-shelf" processing methods. The main problems are complex water bottom multiples and seismic velocity fields that have a high degree of lateral variability. While standard post-stack time migrations and Radon de-multiple techniques provide a first-pass solution, more sophisticated techniques are required to unravel the structural complexity and better suppress the water-bottom multiples.

## Free Surface Multiple Elimination

Numerous publications on the subject of surface related multiple elimination (SRME) exist (e.g. Verschuur, 1992). The method itself requires no knowledge of velocities, or where the multiples are generated. It does, however, require very regular geometry, with a shot at every receiver location and all offsets from zero to the maximum offset to be present. SRME will, in theory, model any multiples with a reflection point at the free surface (i.e. it will not attack inter-bed multiples). Since the multiple model that SRME produces is based on a spatial convolution of the data with itself, the source signature must be estimated and removed from the model before its subtraction from the input data.

In practice, a simple subtraction of the source-signature-deconvolved multiple model from the input data does not work! An adaptive subtraction process must be used, consisting of residual matching filters to apply minor phase and time shifts to the multiple model prior to subtraction (e.g. Nekut and Verschuur, 1998). These residual differences between the multiple model and input data result from errors in estimating the source signature and from 3D effects. Offshore Eastern Canada, where the sea floor topography can be very complex, it is the 3D effects that really cause the problems. Extension of the 2D version of SRME to 3D (van Dedem and Verschuur, 1998; van Dedem *et al.*, 1999; Nekut, 1999) requires a significant increase in computational effort and is still in the experimental stage (i.e. large scale 3D applications of the technique have yet to be published).

An inverse scattering formulation of free surface multiple elimination has been used for the results in this paper. This differs from SRME in that it models the source as a monopole, rather than a vertical dipole in the water (Weglein, 1999). This more correct modelling of the source can give better results for steeply dipping multiples compared with SRME.

Source spacing:	25 m
Receiver spacing:	12.5 m
Source to near trace distance:	196 m
Number of receivers:	576
CMP spacing:	6.25 m
CMP fold:	144

Table 1: 2D line acquisition parameters

The data example presented here is a 2D line from offshore Nova Scotia. It was acquired parallel to the continental shelf, thus cutting across a number of channels created by turbidite flows. The acquisition parameters are given in Table 1.

Figure 1 shows a stack of the line, with a Radon de-multiple applied, specifically directed towards removing the water-bottom multiple. While this technique works well where the water bottom is regular, it is less successful below where the water bottom contains changes in dip.

Inverse Scattering Multiple Attenuation (ISMA) was applied to the line by first summing adjacent receivers, so the receiver and shot spacing were the same. Next, the data were extrapolated to zero offset using a Hyperbolic Radon Transform applied in the CMP domain. The data were then sorted back to shot domain for ISMA to be applied. After estimation and removal of the source signature, a residual matching process was carried out. This is the most problematic and subjective part of the process. Allowing too much freedom to match the multiple model with the input data results in primaries being removed. Too little freedom, and artefacts can be introduced by the multiple model.

Figure 2: shows the ISMA de-multipled stack (no additional multiple suppression has been used). This shows that in the areas below water-bottom channels and where the water bottom is dipping, ISMA does a better job of suppressing the more complex multiples than the Radon transform.

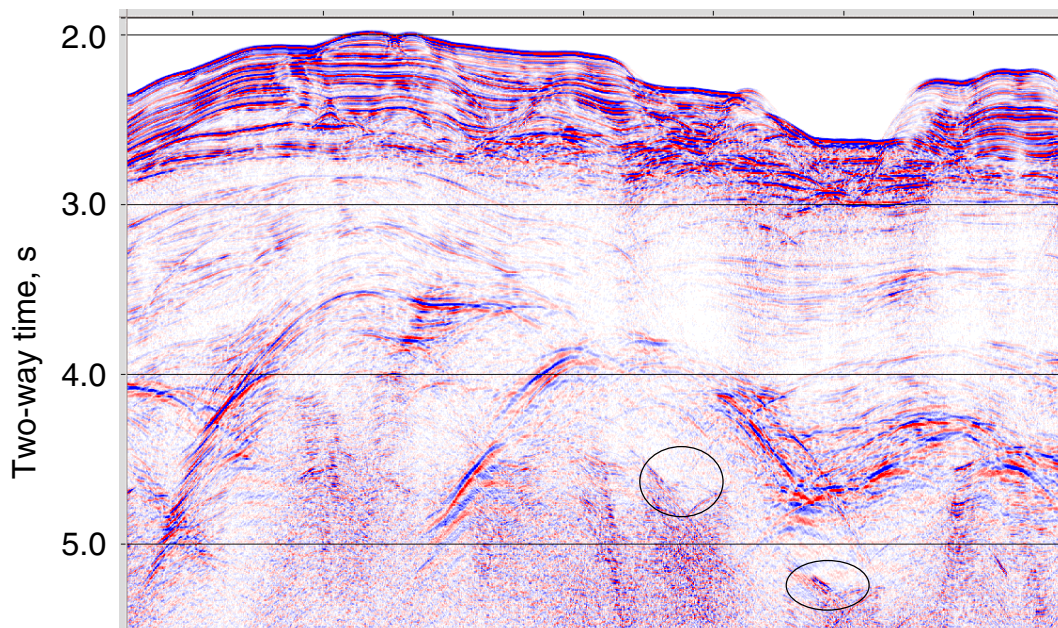


Figure 1: Stack with Radon de-multiple. The multiples generated from the relatively flat water bottom have been suppressed. The circled areas show residual multiples from below the water bottom with steeper dips.

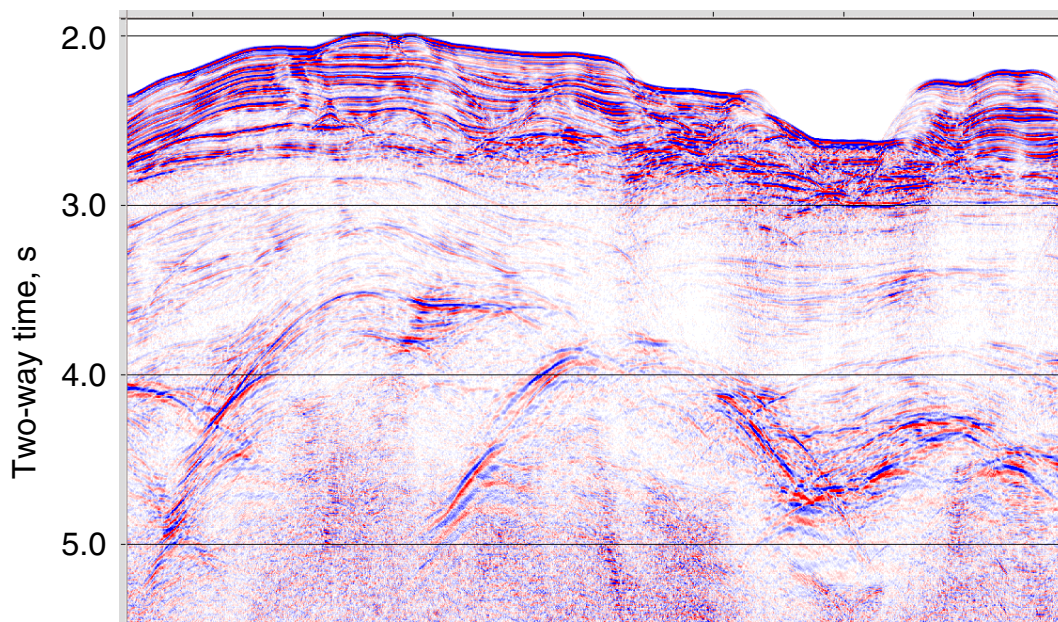


Figure 2: Stack with ISMA. Multiples from below the water bottom with steeper dips have been suppressed relative to the Radon de-multiple stack.

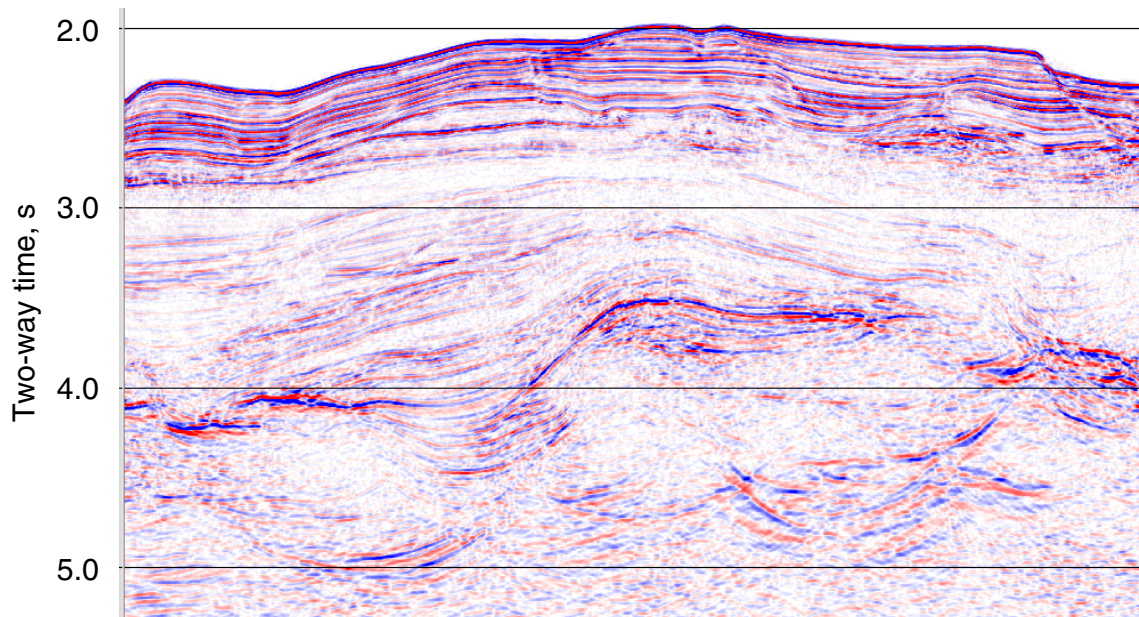
#### Imaging methods

Generally speaking, post-stack time migration is not a good imaging method for East Coast Canada data. Figure 3 shows a post-stack time migration from a portion of the line shown in Figures 1 and 2. This is supposed to show a salt upheaval below the Base Cretaceous. However, steep dips are poorly, if at all, imaged and there are migration "smiles" between 4 and 5 seconds.

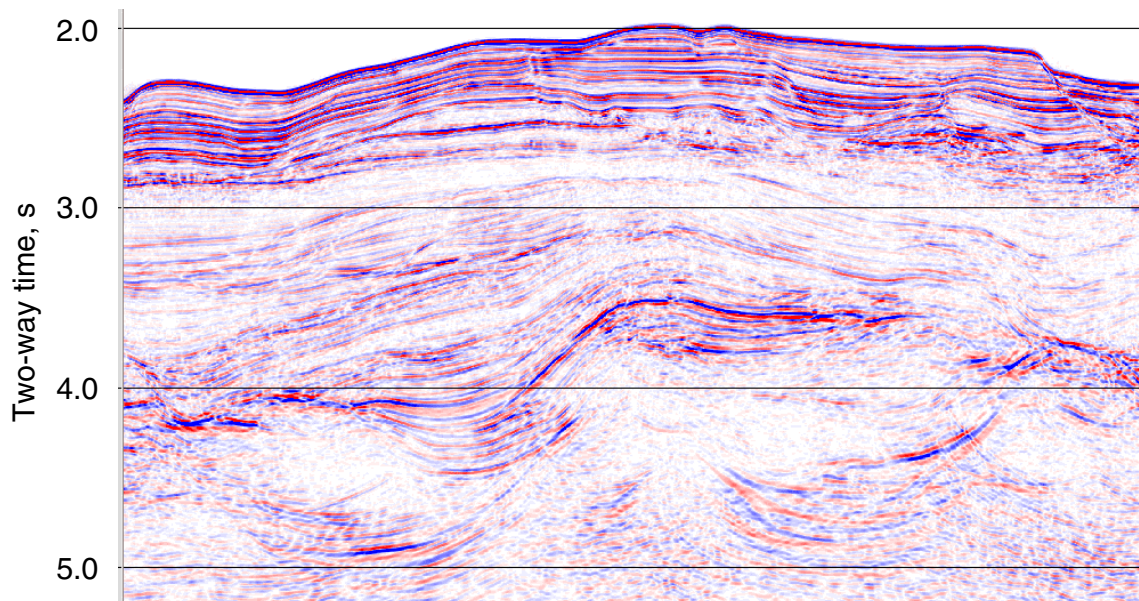
Pre-stack time migration (PreSTM) was performed on the line using two different methods. First, Common Offset Time Migration (COTiM) was performed using all 144 offsets. This form of PreSTM has been widely used in the industry (i.e. MOVES from Veritas DGC, as well as COTiM from WesternGeco). The final COTiM migration is shown in Figure 4 and shows a generally "cleaner" image compared with the post-stack time migration, with less evidence of migration "smiles".

Kirchhoff migration was used for the second PreSTM method, the results of which are shown in Figure 5. Comparing Figures 4 and 5, it is clear that the Kirchhoff migration has imaged the steep dips significantly better than COTiM. There are still some conflicting dips in the image (on the left flank of the salt upheaval), but these are likely to be out-of-plane (3D) effects.

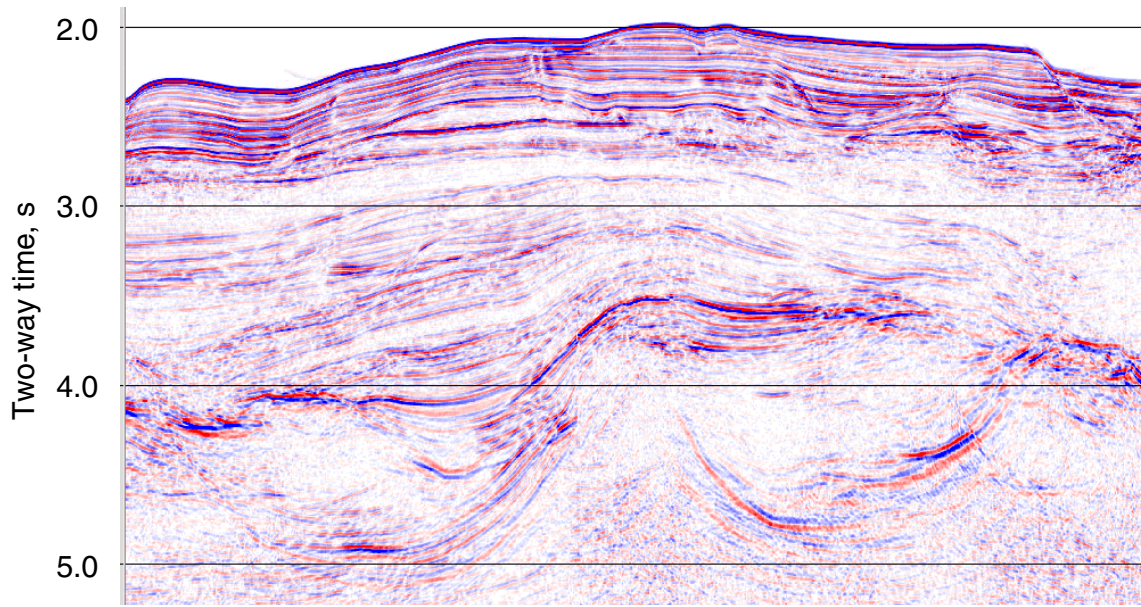
Kirchhoff migration uses a double square root (DSR), which is a description of the offset term, in the design of the migration operator. Although the migration part of COTiM is zero offset (single square root), the combination of NMO, DMO and zero-offset migration is attempting to mimic the DSR. In general, Kirchhoff is a more expensive method of PreSTM compared with the COTiM approach, but with increasing computer power, more efficient algorithms and a better looking final image, it is becoming an increasingly attractive option.



**Figure 3:** Post-stack time migration



**Figure 4:** COTiM pre-stack time migration (144 offset slots)



**Figure 5:** Kirchhoff pre-stack time migration

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**References**

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