Modelling and Removing WAZ OBC Interbed Multiples

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SUMMARY

Interbed (or internal) multiples, caused by ringing between strong reflectors, can play havoc with the interpretation of primary reflections deeper within a seismic section, and have been historically difficult to suppress. True wide-azimuth, relatively sparsely acquired 3D data (like OBC) add to the complexity of this problem.

For this case study, we present our testing and on-going developments on interbed multiple suppression. Two methods are shown. The first is an interpretive pattern-recognition technique applied after migration. The second, applied to unmigrated data, is a new version of wavefield modelling that attempts to predict interbed multiples without any knowledge of the actual multiple generators. A well-constrained adaptive subtraction methodology is required, and the testing and development of a new 3D subtraction algorithm is reviewed. Both methods have been shown to perform well.

Key words: Interbed, internal, multiple, prediction, modelling

INTRODUCTION

Surface-related multiples, even complex 3D ones, are now routinely handled by SRME algorithms or by newer hybrid techniques for shallow water conditions. However, interbed (or internal) multiples, caused by ringing between strong reflectors deeper within the section, have been historically difficult to suppress. These can have periods of milliseconds to seconds, and can interfere with the interpretation of the primary reflections. Conventional separation methods, based on multiple periodicity or residual moveout, can be difficult. Very short-period multiples can be tackled via a deconvolution approach (although this can damage the signature and any parallel bedding), and radon demultiple can often take care of longer period multiples, but those are the easy exceptions. In a worst case scenario (seen by one of the authors), interbed multiples from limestone packages can have a faster apparent moveout velocity than the real primaries! Different techniques have to be used in these situations.

One recent and promising approach (based on modified inverse scattering) is currently only suited for the typical narrow azimuth marine acquisition. The case study here involves a recent 3D Ocean Bottom Cable (OBC) seismic survey orthogonally shot over a reef zone. For this survey, unfortunately, we need something other than the inverse scattering approach to handle the wide azimuth acquisition. The "ghosts" and water-bottom multiples (typical issues with OBC data) were well-controlled by the chosen pre-processing flows. However, strong, layered events in the upper sections produce interbed multiples below, with very little normal-moveout discrimination in the gathers. Two demultiple approaches were tried. The first is an interpretive one. The second is a new variation on a method that can predict all interbed multiples without any knowledge of the multiple generators, or of the mechanisms involved.

Below is a cartoon drawing of typical interbed multiples, followed by a psdm section showing their impact on our OBC data:

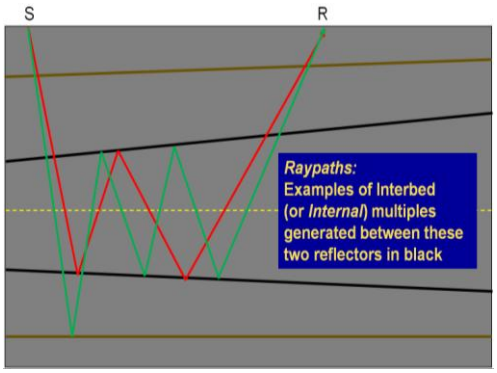

Figure 1. Interbed multiple raypath example.

-The interbed multiples between the black arrows below are interfering w/ the deeper primary image and are generated from the layers above the red marker:

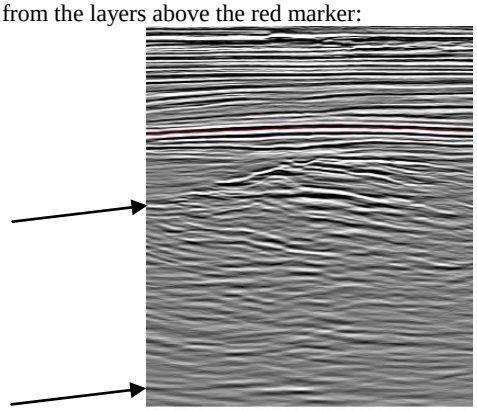

Figure 2. Example of Interbed multiples in the real world.

SOLUTIONS

1) A Practical Approach to Interbed Demultiple

Dariu Doicin and Simon Spitz created a pattern-recognition algorithm in 1991 that can be used to model surface and pegleg multiples quite successfully. SPLAT (Specified PegLeg ATtenuation) uses a maximum likelihood approach to remove any piece of data that exactly fits to the shape of a modelled multiple. This has long since been extrapolated to a 3D algorithm. By carefully digitising horizons to produce a model, we can adapt this method to remove interbeds that might have only subtle dip differences to primaries. In addition, the algorithm can handle lateral amplitude and frequency variations (unlike, say, FK or other dip filters), and even various time shifts. We can easily apply this algorithm post-migration (here, after a pre-stack orthorhombic depth migration) on our migrated Common Offset Vector (COV) gathers.

In our case, some of the worst interbed multiples do cut across the underlying primary structures, interfering with interpretation (and QI analyses). Results after "SPLAT" are quite good, but it's an interpretive approach: we are limited to our interpretation of what are the multiples and their potential generators. In this case, we are limited in this survey to the removal of simple "flattish" multiples, and cannot predict the more complex interbed peglegs throughout the volume. In addition, we are manually "tuning in" the program's discrimination between local primary and multiple shapes for best result. SPLAT was applied after 3D PSDM on gathers to remove some of the obvious interbed multiples. Results were quite acceptable as seen below, and were carried through for final production on this OBC survey.

Results of a pre-stack pattern-recognition technique on interbed multiple suppression (PSDM stack):

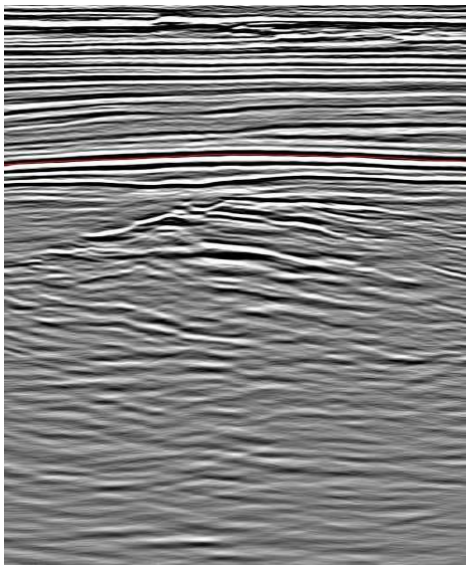

Figure 3. *Before* pattern-recognition demultiple

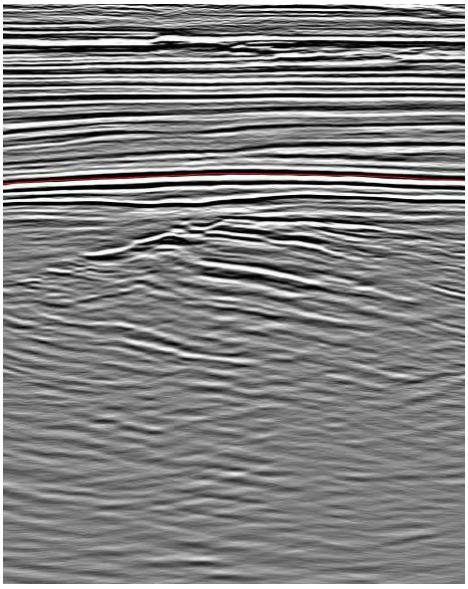

Figure 4. *After* pattern-recognition demultiple

2) 3D Interbed removal by Wavefield Modelling

This method is based on Antonio Pica's (non-convolutional) 3D SRME algorithm first introduced in 2005. "MOMUL" requires a migrated volume as an auxiliary input to act as a reflectivity series, and can model multiples of pre-stack data. Normally, this would be run on typical NAZ (or MAZ) marine shot records for surface multiple modelling (followed by a subtraction).

In our case, we have a wide azimuth survey that has been processed through a 5D simultaneous interpolation. Instead of shots, the input data will be a dense set of individual (unmigrated) Common Offset Vector volumes, to be used as 3D areal sources. The data is propagated and reverberated within the reflectivity volume using one way wave equation to create a 3D multiple model in the COV domain. In the original interbed implementation, the output multiple model traces would be synthesized by modelling the wave fronts travelling between specific reflectors situated under and over a given horizon. Any multiples generated outside of this window won't be modelled (as in the Figures 5 and 6 below).

Wavefield Interbed Multiple Prediction of pre-stack data through a reflectivity series:

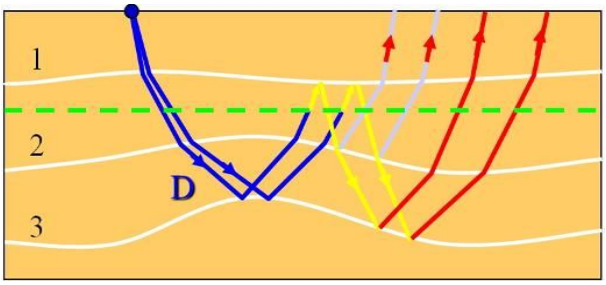

Figure 5. All interbed multiples modelled between horizons 1 and 3

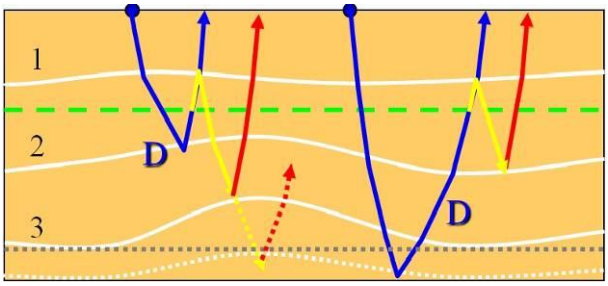

Figure 6. Interbed multiples that are generated from the reflectors *below* our analysis window (black dots) are not seen and cannot be modelled.

To get around the limitations depicted in Figure 6, we are using a new approach whereby we run the program repeatedly over many overlapping windows to model all possible interbed multiples arriving at our target zone(s). In this way, no a priori information of the multiple generator details is needed.

These models then have to be adaptively subtracted simultaneously from the input data to remove our interbed multiples. There are several problems associated with this. "Normal" marine surface-related multiples are generally much stronger than the primaries (there is relatively little attenuation in water compared to bedrock), making it easy to safely perform the "adapting" using stock algorithms in the market. Unfortunately, interbed multiples are often weaker than primaries and, in addition, interbeds and primaries can sit nearly on top of one another. Lastly, we might have ten or more multiple models to subtract, over the same target window.

A new adaptive subtraction program was developed: AMS3D. It is a fully 3D program using 3D operators, thus we can better discriminate its fitting over a 3D volume (unlike the usual 1D or 2D versions). It has also been designed to adapt more than twenty models simultaneously, and subtract them in one step. It was tested on our OBC survey with promising results, but we still needed better constraints. A newly developed curvelet–domain algorithm is now available. It has excellent "shape" discrimination, but unfortunately cannot handle the many input multiple models we have here. We designed a new constraint specifically for our interbed case: the output of the subtraction must have the same smoothed amplitude spectrum as the input. This additional cost function will act as an added control where primaries and multiples have equal amplitudes, and would have weighting from zero to one. For our project we have instead incorporated this concept as a two-pass process. After the last step, we now have "automatic", deterministic results that address our interbed trains generated by the complex 3D structures.

The new demultipled gathers were carried through a 3D pre-stack time migration to compare with the original data. The original gathers show the internal multiples have some move-out discrimination but not enough for a radon technique. The wavefield modelling approach used for our test here did a surprisingly good job at suppressing the multiples that sit right on top of primaries. This approach shows good promise, is a straightforward technique and has the benefit of being applicable to any type of seismic data (2D, 3D land, marine, OBC). Results of interbed multiple suppression are shown in Figures 7-10 below.

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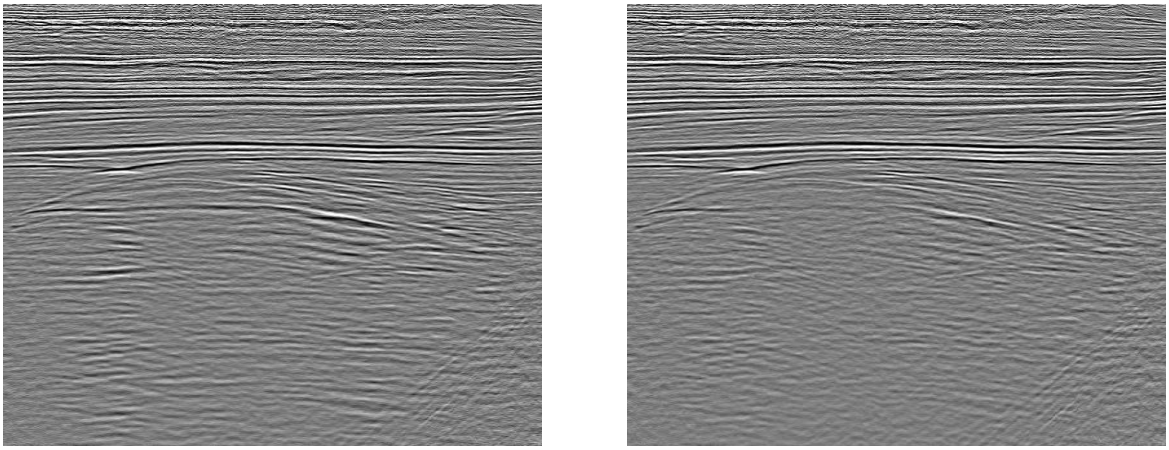

Figure 7. Results of wave-equation interbed suppression (pre-migration *stack*).
Left: before ***Right: after***

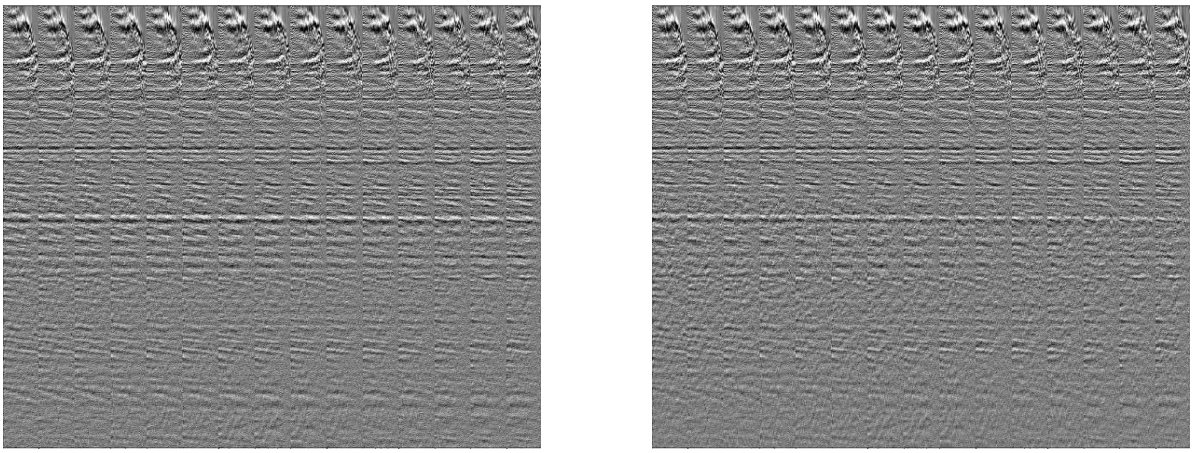

Figure 8. Results of wave-equation interbed suppression (pre-migration *gathers*).
Left: before ***Right: after.***

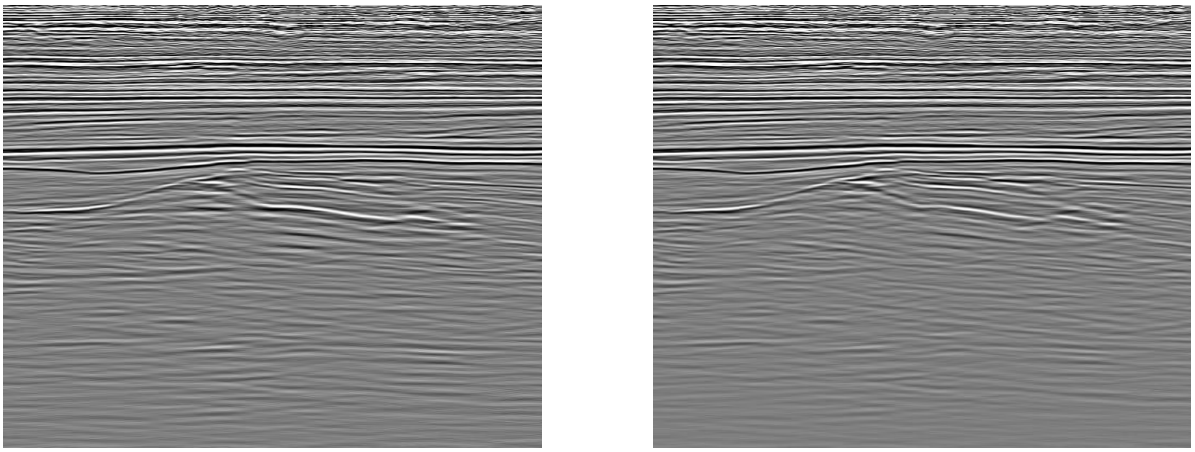

Figure 9. Results of wave-equation interbed suppression (*stacks* after Pre-Stack Time Migration).
Left: before ***Right: after.***

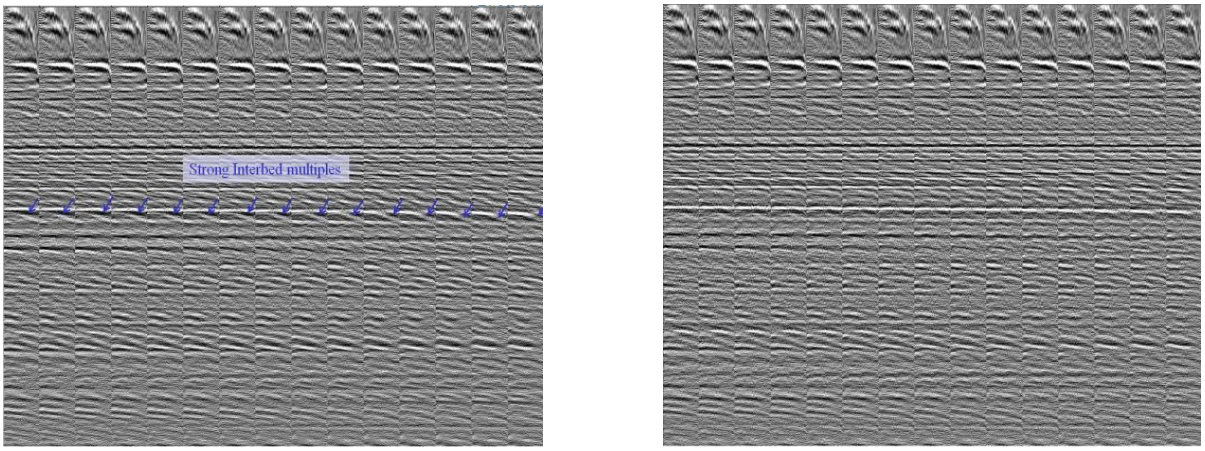

Figure 10. Results of wave-equation interbed suppression (*gathers* after PSTM).
Left: before ***Right: after.***