Z-99 Fast-Track, Data-Driven Interbed Multiple Removal: A North Sea Data Example

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Summary

Removal of multiples from seismic reflection data is an essential pre-processing step before seismic imaging in many marine environments. Surface-Related Multiple Elimination (SRME) has proven to be a valuable tool to remove multiples that have been generated by the free-surface. This paper discusses the application of SRME where, instead of free-surface multiples, multiples generated by *internal* surfaces are removed. Particular attention is paid to the implementation issues. The proposed implementation requires limited user-interaction, and is comparable in performance and speed to 'standard' SRME. Application to a data set from the North Sea leads to satisfactory results.

Introduction

Although free-surface multiples usually exhibit stronger amplitudes than interbed multiples, strong impedance contrast at *internal* reflectors (such as top / base of salt or chalk, unconformities, disconformities etc.) may still create a complicated set of interbed multiples that can easily obscure primary reflections from relatively weak sedimentary reflectors.

Similar to the removal of free-surface multiples, there are two generic strategies to tackle interbed multiples: *model-driven methods*, that make use of statistical assumptions and/or a priori information about the subsurface (such as a local 1D assumption, detailed velocity- and/or reflector information), and *data-driven methods*, that use the measured data itself to predict and subtract interbed multiples.

Although model-driven approaches have been applied successfully, the reliability of the inherent assumptions and the user-provided priori information, as well as the level of user-interaction required makes these methods less suitable for efficient, 3D production processing.

Surface Related Multiple Elimination (SRME) removes all multiples that are introduced by a particular surface in the Earth. In order to remove these multiples, some form of a priori information from this surface (such as the geometry, and the reflection coefficients) is required. Since this information is readily available for the water surface, it is possible to remove *all* multiples that have been generated by the water surface, without using any additional information about the *sub*surface. This application is fully data driven, meaning that only the data itself is used to predict the multiples. Because user interaction is minimised, SRME has been successfully applied to remove free-surface related multiples in production processing environments, in most geological regions (see, for example, Van Borselen et al. (1997), King et al. (2000), Long et al. (2000)).

This abstract discusses the application of SRME to remove multiples generated by an *internal* surface. The approach followed is based on work proposed by Verschuur and Berkhout (1997) and Jacubowitz (1998), and requires only the identification (i.e. picking) of the multiple generator, or the identification of a *pseudo boundary* along which internal multiples have crossed during wavefield propagation.

Methodology

The application of SRME to remove interbed multiples has been discussed by various authors. In Berkhout (1982), it is described that by means of downward continuation of both the source- and receiver wavefield to the multiple generator, interbed multiples can be predicted using the well-known feedback loop. Later, in Verschuur and Berkhout (1997), this approach was reformulated making use of common focus point gathers. Also, an extension of the method was presented that allowed for the prediction of all multiples that crossed a particular boundary. In Matson et al. (1999), a method based on inverse scattering is presented that is not interface specific and attenuates all interbed multiples of a given order at once. In Jakubowicz (1998), it was shown that the process of downward continuation could be circumvented by decomposing interbed multiples into three wavefield constituents that can be obtained from the measured data via a simple muting procedure. Figure 1a shows how an arbitrary interbed multiple (generated by the reflector indicated by the arrow) can be composed by cross-correlating a wavefield from reflectors below the multiple generator with the primary of the multiple generator (indicated by the convolution with the complex conjugate operator), followed by a convolution of this result with the wavefield from reflectors below the multiple generator. It is noted that the convolution of two wavefield establishes the linking (or 'addition') of raypaths, whereas the cross-correlation establishes the'subtraction' of raypaths. Also note that the *–1* sign corrects for the polarity reversal introduced by the linking of the wavefield constituents. In Jakubowicz (1998), it is also shown how this method can be extended to sequences of multiple reflections, rather than just individual events. Using this approach, all internal multiples generated by the chosen boundary are predicted.

Figures 1b show that this procedure can also be used to remove interbed multiples that have crossed a *pseudo-boundary* that is chosen to lie between two strong internal reflectors (indicated by arrow). By cross-correlating the wavefield from reflectors *below* the *pseudo boundary* with the wavefield from *above* the multiple generator, and convolving this result with the wavefield from reflectors *below* the multiple generator, interbed multiples that have crossed this pseudo boundary during wavefield propagation can be removed.

It is remarked that ISRME must be applied in a top-down fashion to prevent 'leakage'. Leakage occurs when internal multiples generated by a reflector above the chosen multiple generator are mistaken for primary events, and generate during the prediction process non-physical events. Figure 1c shows an example of an erroneous event, predicted not using a top-down approach. Alternatively, multiple may be predicted kinematically correctly, but with reversed polarity (Note the *+1* sign in Figure 1d).

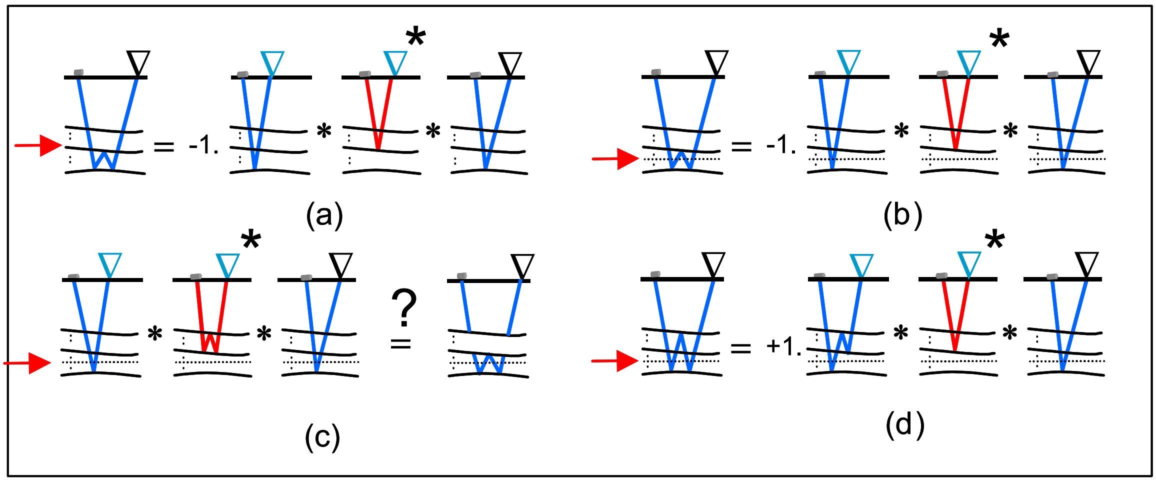

Figure 1: a) The prediction of an arbitrary interbed multiple generated by the indicated reflector, b) The prediction an arbitrary interbed multiple that has crossed the indicated *pseudo-boundary*, c) The prediction of an erroneous event via a non top-down approach, d) The prediction of an event with correct kinematics but reversed polarity from using a non top-down approach.

Implementation Issues

Cost and turnaround time continue to play an important role in production processing of large 3D seismic data sets. In the proposed processing flow, the application of Internal Surface-Related Multiple Elimination (ISRME) is preceded by the removal of all non-physical noise, regularisation of the measured data to obtain a constant grid of sources and receivers, the interpolation of missing near- and intermediate offsets and missing shots, removal of the direct wave and its surface reflection, and the removal of all free-surface related multiples, using 'standard' SRME.

As shown in the previous section, the identification of either the internal multiple generating boundary, or a pseudo boundary is crucial. Only by minimizing the user interaction in the process of boundary identification and muting, "production processing" of larger 3D data volumes becomes feasible. New visualization techniques, and sophisticated automatic horizon pickers play a crucial role in the reflector identification process and quality-control (Figure 2). Once the relevant reflector information is retrieved, muted shot- and receiver gathers are generated automatically, after which the interbed multiples are generated through temporal and spatial convolutions of these gathers. Finally, the predicted interbed multiples are subtracted from the input data, using the minimum energy criterion, which states that, after the subtraction of the multiples, the total energy in the seismogram should be minimized.

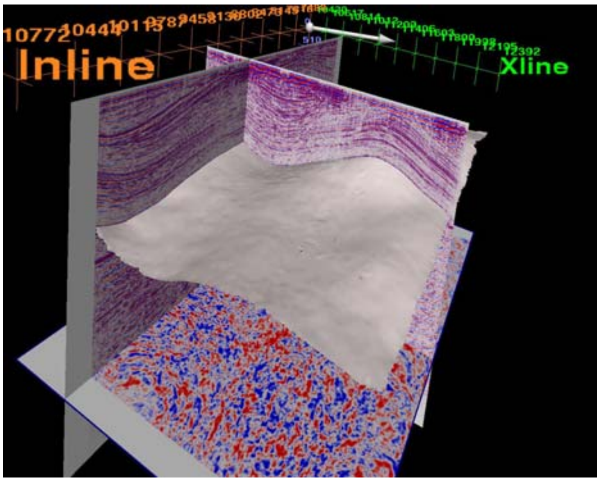

Figure 2: New interactive visualization techniques are used for the identification of the interbed multiple generating boundary.

North Sea Field Data Example

Large areas of the North Sea suffer severe multiple problems, which are particularly frustrating when combined with the low reflectivity of the prospective Cretaceous section. Figure 3 shows an example from the Jæren High Ula North area. The water bottom in the survey area is relatively shallow (125 m), resulting in a strong train of short-period, free-surface multiples. In addition, the presence of strong internal reflectors, such as the top- and base of Chalk, generate interbed multiples that are masking dipping primary reflectors. Removal of multiple energy remains the foremost obstacle to successful seismic imaging in this part of the world.

Figures 3a shows the stacked section of the raw data. Figure 3b shows the result after the removal of free-surface multiple using 'standard' SRME. Note the significant reduction of multiples in areas indicated by the white arrows. Next, the top of chalk was chosen as reflector from which to remove the corresponding interbed multiples. Figure 3c shows the result after the application of ISRME. Note the additional reduction of multiple energy, especially beneath the crest and along the flanks of the structure. Figure 3d shows the true-amplitude difference between figures 3b and 3c. It is noted that hardly any primary energy can be detected, indicating that primaries remained unaffected.

Conclusions

Surface-related multiple elimination has successfully been applied to remove interbed multiples from a North Sea data set. It has been shown that an optimized processing flow leads to an efficient removal of either interbed multiples that are generated by a (chosen) internal reflector, or interbed multiples that have crossed a (chosen) pseudo boundary during wavefield propagation.

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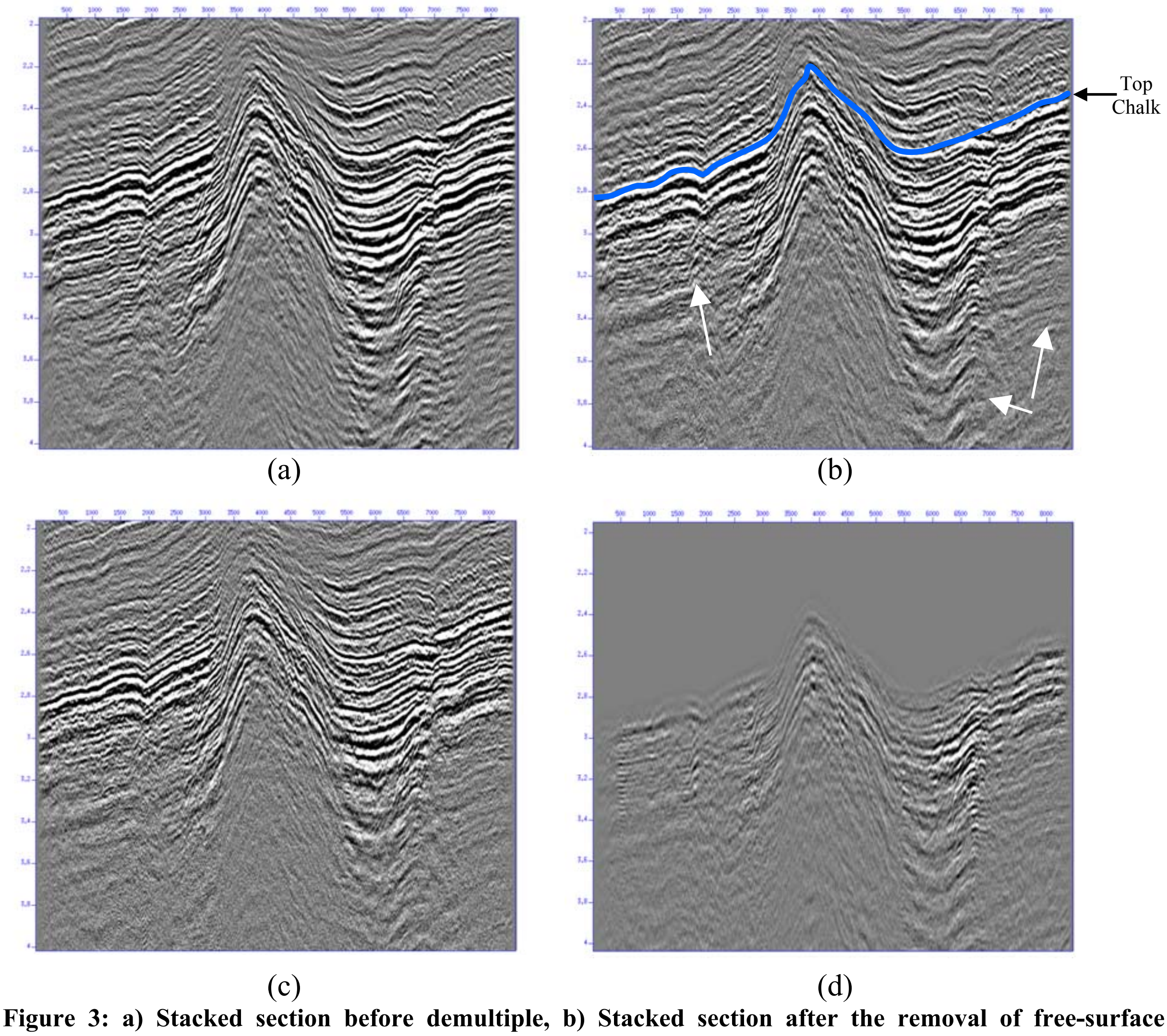

Figure 3: a) Stacked section before demultiple, b) Stacked section after the removal of free-surface multiples, c) Stacked section after the removal of interbed multiples that were generated by the top of Chalk, d) Difference between before and after interbed multiple removal using ISRME.