Interactive demultiple in the post-migration depth domain

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Summary

In efforts to further improve final migrated images we have developed a new methodology for post-migration multiple removal in the migration depth domain. The typical input for the prediction phase of this process is a 3D depth migration volume and the corresponding velocity field. A post-stack Wavefield Extrapolation (WFE) based multiple prediction is used to identify/confirm the multiple events in the migration depth domain. Once multiple events are identified, an effective and efficient demultiple procedure called interactive demultiple is applied to remove the residual multiple from the final migration. The key ingredient of this new interactive demultiple methodology is the attribute-based subtraction. We will describe the main steps of this methodology, and demonstrate its effectiveness by showing some field data applications.

Introduction

In spite of great advances in this area, multiple removal continues to be a challenging task in seismic data processing. Frequently there are noticeable residual multiple reflections remaining in the final migration image. There are numerous causes for these residual multiples and we will summarize a few of them. First, the predicted multiple models are not accurate enough because of insufficient data acquisition, or the data regularization does not generate the bounce points as needed. Second, subsequent subtraction techniques are too conservative in order to preserve weak primary reflections such as subsalt sediment events. Third, the prediction and removal of inter-bed multiples has not yet become routine. These types of residual multiples are commonly found in shallow marine or land data. Fourth, in the case of fast-track projects, there is often not enough time to apply the complex full blown 3D multiple removal techniques.

There are many good articles which discussed both surface-related and inter-bed multiple predictions. Among them, the papers of Verschuur et al. (1992), Weglein et al. (1997), Jakubowicz (1998), Berkhout (1999), Kelamis et al. (2002), Erez and Ikelle (2005), Matson and Xia (2007), Baunstein et al., (2006), Pica et al. (2005, 2008), and Dragoset et al. (2008) represent significant efforts in this area.

We have developed a new methodology for predicting and removing multiples in the migration depth domain. Our prediction technique is based on Wavefield Extrapolation (Pica et al., 2005; Stork et.al, 2006; Matson and Xia 2007), but our prediction is in post-stack mode and capable of predicting both surface-related multiples as well as inter-bed multiples (Wang et al., 2009). Last year (Wang et al., 2009), we presented how the post-stack WFE could be used as an aid for salt interpretation. In this paper, we focus on residual multiple removal by interactive demultiple procedure in the post-migration depth domain.

Unlike the typical multiple removal methodology, the predicted multiple model is not directly used for the subsequent subtraction. The post-stack WFE predicted multiple model is only used qualitatively to identify and confirm the residual multiple events in the final migration. Once multiple events are identified and confirmed, an interactive demultiple technique is applied to remove the residual multiple from the final migration volume. The key ingredient for this interactive demultiple is the attribute-based subtraction method (Guo et al., 2008). Application to both marine and land data have proven this new methodology to be very effective and efficient in enhancing the final image by reducing the residual multiples.

Post-stack WFE multiple prediction

The objective is to generate a multiple model prediction in the migration depth domain that can be compared with the migrated image. Since this multiple prediction method operates in post-stack mode, it is extremely efficient.

The input volumes for this method include the 3D migration image cube and the corresponding migration velocity model. The output is the predicted multiple model in the migration depth domain. The method consists of the following major steps:

1) Using the migration image (as the reflectivity model) and the migration velocity model, we perform a post-stack wave-equation based demigration to get the zero-offset (post-stack) wavefield (Wang et al., 2005).
2) Using the demigrated wavefield as input, and adding a round-trip forward wavefield extrapolation (WFE), we obtain the multiple model wavefield in the time domain.
3) Using the post-stack Wave-Equation Migration (WEM), we convert the predicted time domain multiple model to the multiple model in the migration depth domain with the same migration velocity model.

Figure 1 is a 3D data example from the Gulf of Mexico (GOM). Figure 1A is the migration velocity model. Figure 1B is the final migration image, which shows significant residual multiple left in the final image. Figure 1C shows the well predicted multiples in the migration image domain.

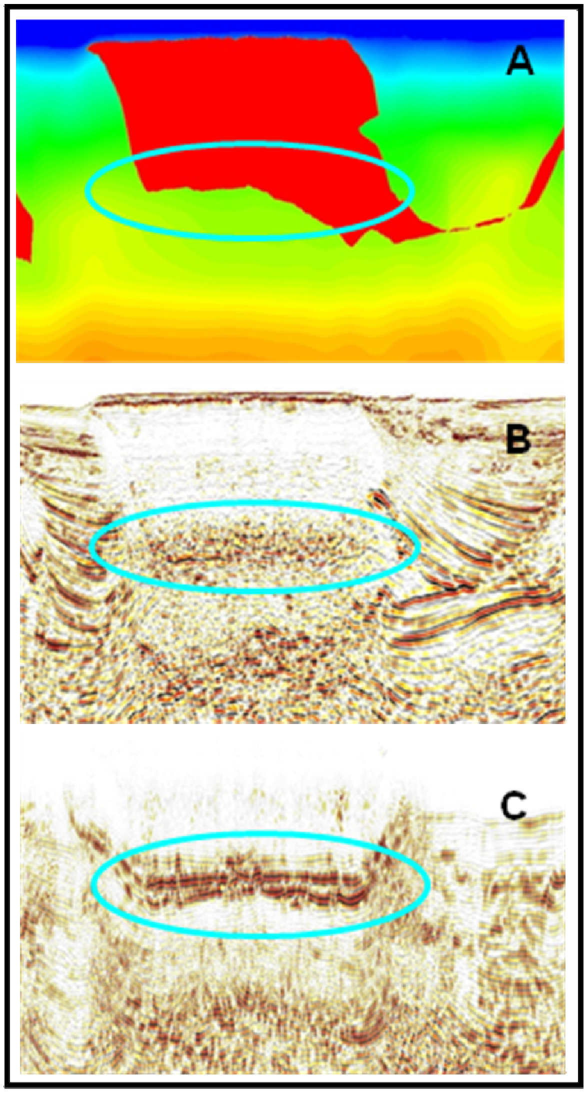

Figure 1 A) Migration velocity model; B) Final migration image; C) Multiple model predicted by post-stack WFE.

As an alternative, if some key interpretation horizons from the depth-migrated volume are available, such as water bottom or top of salt (TOS), then we can use these horizons instead of the seismic migration volume to predict multiples in horizon form. Figure 2 shows an example. This post-stack WFE is also capable of predicting inter-bed multiples, details of which are given in Wang et al. (2009).

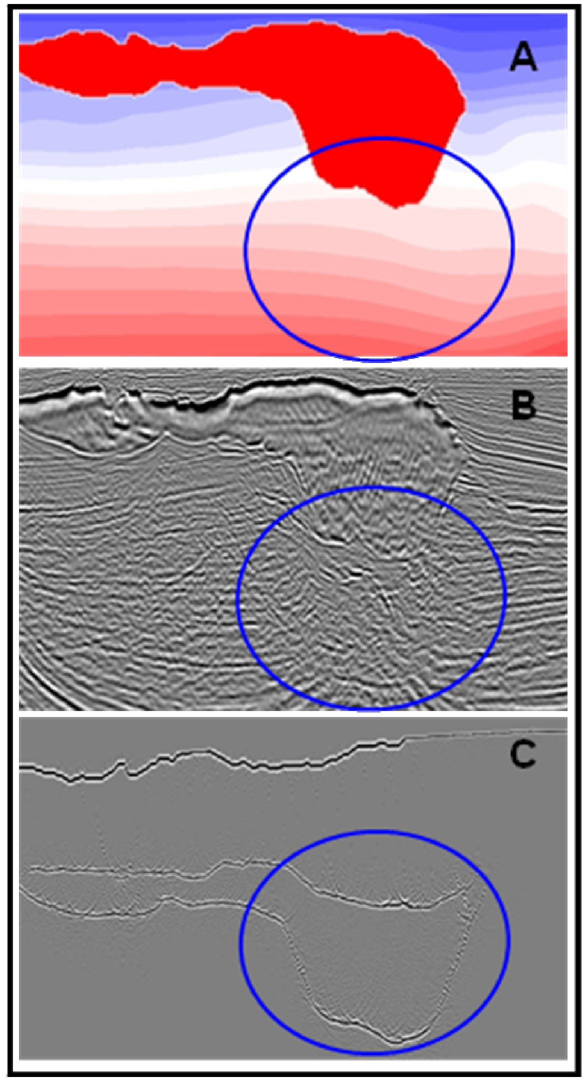

Figure 2 Migration velocity model; B) Final migration image; C) Multiple model predicted by post-stack WFE using horizons as reflectivity model.

Interactive demultiple in the migration depth domain

In contrast to typical multiple removal procedure, the multiple model predicted by the post-stack WFE is not directly used in the subsequent subtraction step such as adaptive subtraction. One of the reasons is that the wavelet shape and frequency content of WFE predicted multiples are significantly different from multiples existing in the data, and this makes adaptive subtraction very difficult.

In our new methodology, once the multiple events are identified and confirmed, they are qualitatively used to guide the so-called interactive demultiple procedure to remove the residual multiples from the migration volume. The key ingredient of this methodology is the use of attribute-based multiple subtraction techniques, which compares the seismic attributes (such as event-dip, frequency content, and absolute amplitude, etc.) of the multiple model with the final migration image. The details of this procedure are given in Guo et al. (2008).

There are two main steps for our interactive demultiple methodology:

1) Mild demultiple using F-K filtering
2) Attribute-based multiple subtraction

For the F-K filtering step, we first define a 3D surface which follows the main dipping trend of the multiples (Figure 3B). We use the picked surface to flatten the multiple events, a gentle F-K filter is applied to mildly remove the multiple. In the F-K domain, energy from multiple is separated by its flat dip (after flattening) and relatively higher frequency.

After the F-K filtering step, the majority of multiples are removed, and the data is ready for the second attribute-based subtraction step. The following are the key steps for the attribute-based subtraction:

1) The mildly demultipled migration volume is used to compute the dip field of primary events
2) The primary dip field and original migration volume are used to construct the major primary events
3) The constructed major primary events from step 2 are subtracted from the input data, outputting the multiple events plus some weak residual primary events
4) Construct multiple model using multiple dip field and the volume produced by step 3
5) Direct subtraction of the multiple model constructed from step 4 from the original migration volume, to give the final demultipled migration volume.

Though the input volumes are 3D, the interactive demultiple process operates in the 2D line-by-line mode, therefore it is extremely efficient. For better dip separation, sometimes we also sort the migration volume to the crossline direction before the interactive demultiple. Figure 3 shows an example of this interactive demultiple methodology.

Figure 3C is the final migration volume, which is contaminated by residual multiple events. Figure 3A is an example from the corresponding 3D migration velocity volume. Figure 3B is the multiple model predicted by the post-stack WFE. As shown in Figure 3B, the red curve shows the interpreted surface which follows the dip-trend of multiple events. Figure 3D is the result after applying the interactive demultiple procedure just described.

Figure 4 shows an example of how effectively the interactive demultiple is able to remove the residual multiples in the final migration image. The flattish residual multiples in the original migration image are very evident in Figure 4A. Figure 4B shows the results after the interactive demultiple technique is applied on the migrated image. Figure 5 shows another example of residual multiple removal from the final migration image by the interactive demultiple technique. The water bottom peg-legs of TOS and BOS multiples are effectively removed. Primary reflectors are well behaved after the multiple removal.

Application to OBC and land field data also has shown great promise.

Conclusions

We have developed a new and efficient multiple removal methodology called interactive demultiple. It operates in the post-stack mode in the migration depth domain. Unlike other typical multiple removal techniques, the post-stack WFE predicted multiple model is not directly used for subtraction. Instead it is only used to identify, confirm, and interpret a multiple model.

In our interactive demultiple procedure, the F-K filtering step takes advantage of the dip and frequency separation between primary and multiple events. The F-K filtering step makes the subsequent dip field computation of the primary events more accurate. The step of constructing major primary events by using the primary dip field is an important step to better preserve the primary events in this whole demultiple methodology.

The attribute-based subtraction technique is a key ingredient of this interactive demultiple methodology and takes advantage of dip, frequency, and amplitude to distinguish multiples from primaries. Applications to several field data projects demonstrate its effectiveness.

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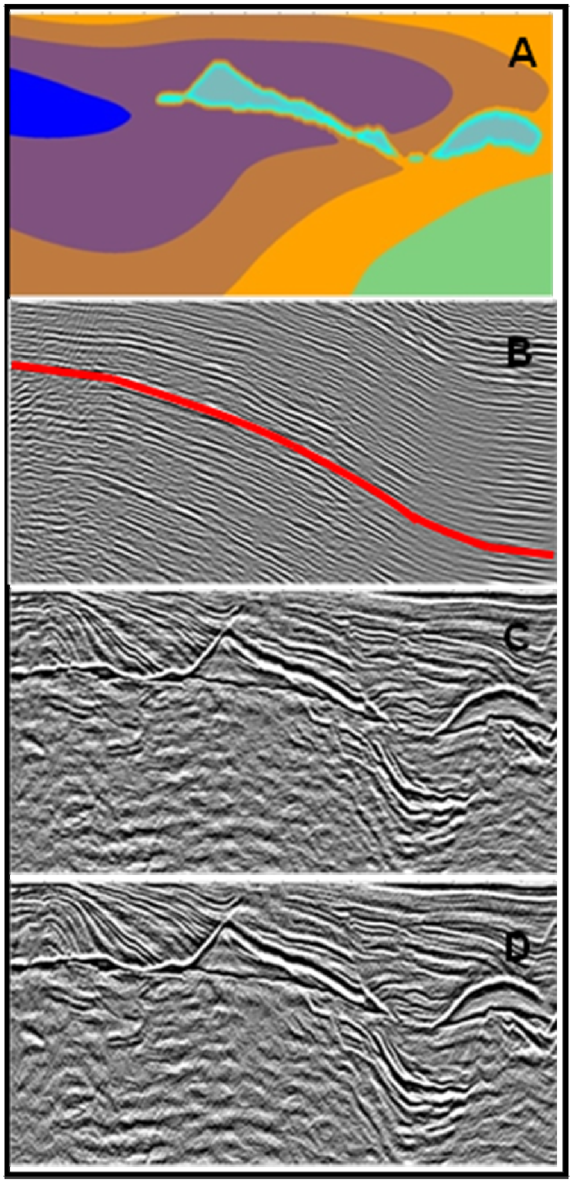

Figure 3 Migration velocity model; B) Multiple model; C) Before interactive demultiple; D) After interactive demultiple.

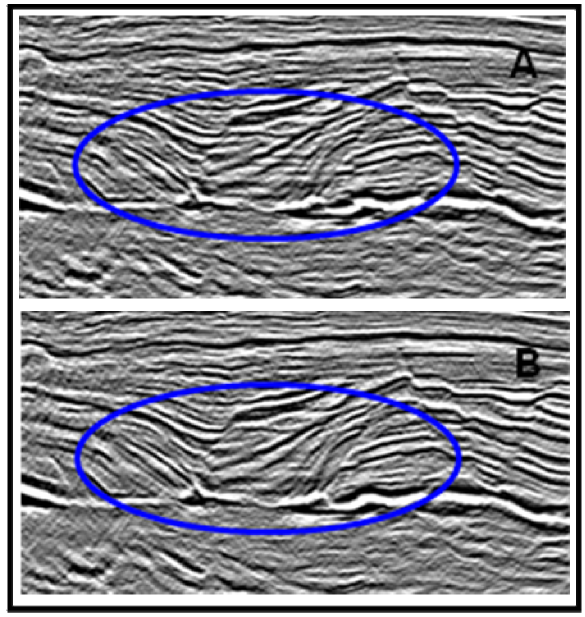

Figure 4 A) Original migration image; B) Migration image after interactive demultiple.

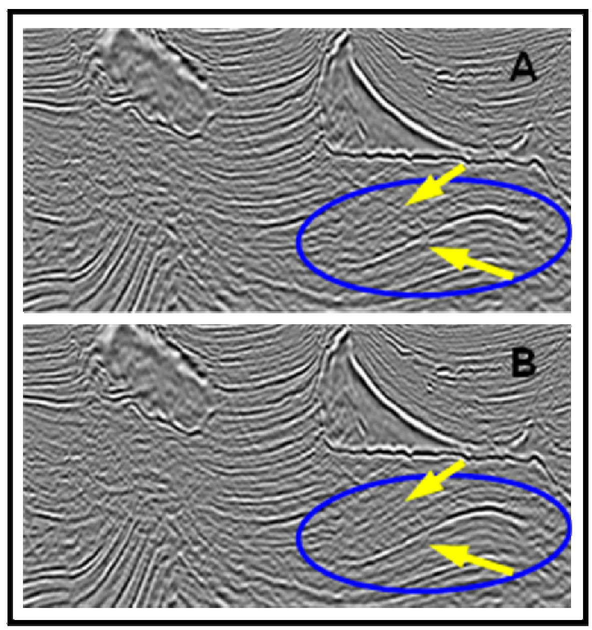

Figure 5 A) Original migration image; B) Migration image after interactive demultiple.

EDITED REFERENCES

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