3D SRME Application in the Gulf of Mexico
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Summary

The effective removal of surface multiples is critical for imaging subsalt structures in the deepwater Gulf of Mexico. The widely used 2D surface-related multiple elimination (SRME) is inadequate for rugose reflectors. We extend the SRME methodology to three dimensions through the construction of high density and wide azimuth data. We demonstrate the success of our method with results from a case study.

Introduction

Strong contamination from surface multiples is one of the major problems in imaging subsalt structures in the deepwater Gulf of Mexico. These surface multiples are predominately generated from water bottom and top and base of salt surfaces. Two-dimensional surface related multiple elimination (SRME) has been widely used to suppress the surface multiples. However, when one of the surfaces is highly undulating, surface multiples have a strong out-of-plane component that makes 2D SRME ineffective. It is then necessary to extend the SRME methodology to three dimensions.

To predict out-of-the-plane multiples, 3D SRME requires high density and wide azimuth data. The conventional steamer acquisition geometry that has sparse source locations and a narrow crossline aperture is far from satisfying the requirements. Due to the high cost of acquiring an ideal data for 3D SRME, we developed an alternative that allows us to utilize conventional streamer data for 3D SRME. Our approach is as follows: (1) construction high density and wide azimuth data from conventional streamer data, (2) perform 3D convolution for multiple prediction, and (3) apply adaptive subtraction schemes to remove multiples from data. We tested this method on several Gulf of Mexico datasets. It has proved to be a more effective tool in predicting coherent out-of-the-plane surface multiples. The predicted multiple models are better than 2D models in terms of timing, wavelet shape, and amplitude. With the improved multiple predictions, we are able to more effectively attenuate multiples, and thus improve subsalt images. Examples from Alaminos Canyon Perdido fold belt will be shown to demonstrate the benefits of 3D SRME.

Alaminos Canyon Perdido Fold Belt

The geology of the Alaminos Canyon Perdido fold belt includes extensive salt sheets. The intrusion of salt sheets creates rugose water bottom and top of salt. They are the brightest reflectors and the major multiple generators. Multiples from these two reflectors mask the major subsalt exploration targets. Figure 1 is a near offset section showing the multiple problem. On the right hand side of the section where the structures are simple and without salt, we expect 2D SRME to work well. But 3D SRME is needed in other areas.

The dataset we used was acquired with the conventional streamer geometry, which does not have a shot and a receiver on each of the surface grid points. To satisfy the 3D SRME requirements, we reconstruct a swath of data to form a perfect areal acquisition geometry for each output line. The output line is in the center of the swath. The width of the swath is determined by the crossline aperture. Figure 2 shows a reconstructed shot gather (on the right) to simulate a real shot gather (on the left). The seismic energy is mapped to the source and receiver locations in the real shot gather, traces of which are excluded in the reconstruction process. Major events are well reproduced. There are some artifacts in the far offsets and the deep section. This is one of the areas we are actively working on.

3D SRME predictions are done by summing related cross-convolutions over all surface reflection points. The summation is decomposed into inline and crossline directions. Summation along the inline direction is just like doing 2D SRME predictions. After the inline summation, a crossline gather is obtained for each output trace.

Selected crossline gathers are shown in figure 3. Crossline gathers are important for illustrating the need of 3D SRME and determining the crossline aperture. At the simple structures, the gather are symmetric, so the 2D prediction (the center trace) is adequate. For complex structures, the apexes shift to one side. This indicates that the 2D model is incorrect, and that 3D SRME is needed. The crossline aperture should be big enough to capture the apex of each event within the gather. This is one of the ways to determine the crossline aperture. The full aperture we used in this case is 2 km on the surface.

The crossline gathers are finally stacked to form 3D SRME predictions. Figure 4 shows the 3D SRME models compared with the input data and the 2D models. The pictures are zoomed in to the blue rectangle area in figure 1. Several conclusions can be drawn from the images: (1) the
3D models are much closer to the multiples in the data than the 2D models. (2) The 3D models are cleaner than the 2D models. (3) There are still diffracted multiples that are not predicted correctly in the 3D models.

The 2D and 3D models are adaptively subtracted from the input data. The conventional Delft adaptive subtraction method is used. Figure 5 shows PSDM sections after the subtraction. The image on the right is the PSDM section without de-multiple, the middle image is the PSDM section with 2D SRME, and the image on the left is the 3D SRME results. 2D SRME does clean up some multiples underneath the salt, but a lot of residual multiple smiles still interfere the sub-salt structures. 3D SRME cleans up more multiples, and helps to bring through some of the sub-salt events. Some multiple swings are still present in the data. These residual multiples are mainly diffracted multiples, which are not well predicted by our 3D SRME method.

Discussions

This case study shows 3D SRME produces better multiple models, and attenuate more out-of-the-plane multiples than 2D SRME. The final images with 3D SRME are consequently cleaner. One of the remaining challenges in 3D SRME is to suppress diffracted surface multiples. The diffracted surface multiples are usually aliased in the crossline direction and therefore poorly predicted by 3D SRME. The ability to de-alias the diffracted multiples is essential for further improvement in 3D SRME.

References


Figure 1: Input near offset section without de-multiple. The blue rectangle area is to be shown in figure 4.
Figure 2: A real shot gather (on the left) compared with its reconstructed one (on the right).

Figure 3: 3D SRME Crossline gathers for near offset multiples. They are selected from the corresponding locations in figure 1.
3D SRME Application in the Gulf of Mexico

Figure 4: Multiple predictions in the complex area highlighted in figure 1 with a blue rectangle. The image on the left is the input; the middle one is 2D SRME model; and the one on the right is 3D model.

Figure 5: PSDM Sections without de-multiple (on the right), with 2D SRME (in the middle), and with 3D SRME (on the left).