Use of narrow azimuth data for enhanced Wavefield Extrapolation multiple prediction on a WAZ survey

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Summary

There has been a continually expanding interest in wide azimuth (WAZ) data in all its variations. We are now challenged to take full advantage of the additional information available with minimal compromise. It has been shown that the wider azimuths alone do not supply a dataset sufficient for the full range of processing that must be applied for quality imaging. The narrow azimuth (NAZ) portion of the data is also necessary for shallow imaging as well as multiple prediction and attenuation. Final imaging and both 3D Surface Related Multiple Elimination (SRME) and Wave Field Extrapolation (WFE) methods of demultiple benefit from the presence of near offset / narrow azimuth data. In this paper we present the use of narrow azimuth data from a pre-existing survey to enhance the overall azimuth and offset distribution in a wide azimuth survey with primary emphasis on better prediction of multiples with WFE method.

Introduction

It has been shown that WAZ data, despite its natural tendency to reduce multiples, still benefits from demultiple processing. Common methods of multiple attenuation for 3D data including 3D SRME and WFE require near offset data contribution for optimum results (Keggin et al, 2006). As described by Howard (2009), we find that this full cross-line offset data is lacking in some WAZ acquisition scenarios. In these programs the NAZ survey data can be used to fill the missing near cross-line offset content and improve demultiple and data regularity as well as the final image. We can also incorporate NAZ where we find loss of coverage in areas due to obstructions even in WAZ surveys that were designed to include narrow azimuth content.

We continue to find multiple attenuation to be one of the major challenges in seismic data processing. For this exercise we use the WFE process for multiple prediction which, being shot-based, is well suited to WAZ application. (Stork et al, 2006). The WFE method requires shot data, a velocity field and a depth migrated image as a reflectivity model. Surface related multiples can be considered an additional round trip from water surface to different reflectors that is added into the primary reflection events. The quality of the multiple prediction is very dependent upon the reflectivity model down to the deepest surface from which we expect multiple generation. We will show the value of using NAZ data to enhance the reflectivity model for the WAZ survey in the problem areas.

For this exercise we used a WAZ survey located in Mississippi Canyon, southeast of New Orleans in the Gulf of Mexico. Over the years this area has been and continues to be a source of significant hydrocarbon production and remains an active exploration area. As a result of this active production, there are numerous production facilities that prevent acquiring data close to the infrastructure. Since a major objective is to acquire data that has a full distribution of offset and azimuth, we are very interested in these coverage irregularities. In general there is minimal use of infill for WAZ acquisition, relying upon the higher density of the data and broader azimuth distribution to compensate for small areas of poor coverage.

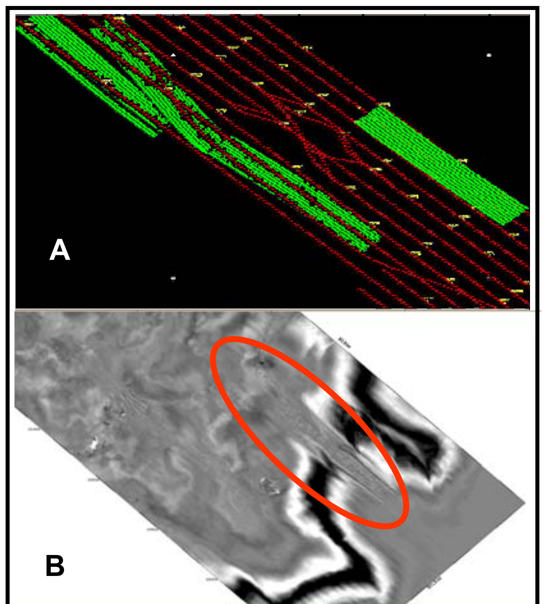

Fig. 1: A) Sail-line pattern in area of obstruction; B) Depth slice of migrated image at water bottom showing loss of signal due to missing data

The WAZ method naturally lends itself to undershooting obstructions to cover longer offsets and wider azimuths but it is at a disadvantage when acquiring near offset data near obstructions. Figure 1A shows the pattern of shots and cables in the area of production platforms from WAZ survey and Figure 1B shows the effect of the missing data on a depth slice that intersects the water bottom.

With most if not all cases of WAZ acquisition, there are pre-existing NAZ surveys that cover the same area. In this case we have a NAZ survey acquired in 1999-2000 that covers much of the new WAZ area. In the areas of obstructions, we find that with the 99/00 vintage data we have much better near offset/NAZ coverage. This could be due to different current conditions, changes in infrastructure, smaller acquisition footprint or tighter restrictions on acquisition access. Figures 2A and 2B show the coverage in the area of production platforms from WAZ and NAZ surveys respectively. By combining data from the two surveys, we are able to produce a more homogenous, higher resolution depth image that will be used as the WFE reflectivity model.

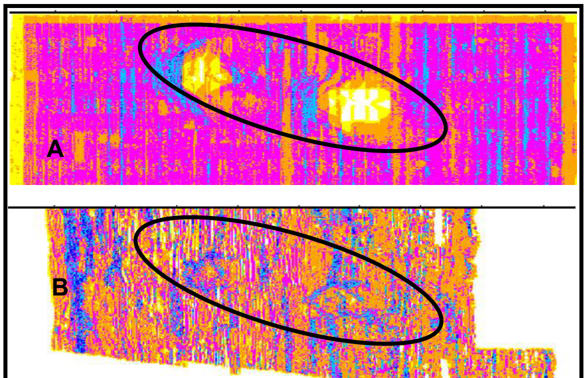

Figure 2: A) 200-2250m Offset coverage from WAZ survey in area of obstruction; B) Offset coverage from NAZ survey in same area

Generation of the Reflectivity Model

To generate the initial reflectivity model, we produce a stack concentrating on near offsets. This is a problem for the WAZ survey in areas of obstructions because some areas have no coverage within approximately 2.5 km of the infrastructure. As a result the stack must include farther than optimum offsets in order to prevent loss of coverage in the water bottom and shallow section. This results in a lower frequency stack with less definition and more noise. In the next step, we run a post-stack wave equation migration (WEM) which then becomes the reflectivity model. WFE only needs a shallow reflectivity model that includes major multiple generating interfaces. For most applications the post-stack WEM is sufficient to generate a quality image that includes the water bottom and top of salt (TOS) which are the most significant multiple generators.

As a secondary reflectivity model we supplement the WAZ pre-stack data with that from the NAZ survey. Preparation and merging of these datasets involves the following steps:

- Determine and extract the NAZ data contributing to area in question.
- Match amplitude, phase and frequency content of NAZ to WAZ data.
- Combine gathers using missing offsets extracted from the NAZ dataset and create stack volume.
- Run post-stack WEM for the reflectivity model.

Fold maps and survey analysis allow us to select the desired NAZ pre-stack data. Survey matching has become routine practice in many areas where multiple 3D surveys are merged to create a greater homogenous image. In order to maintain direct comparison, we used the same offset range for both stack volumes. Since the dataset containing the NAZ contribution includes more near offsets, we could also restrict the far offsets more resulting in an even better image.

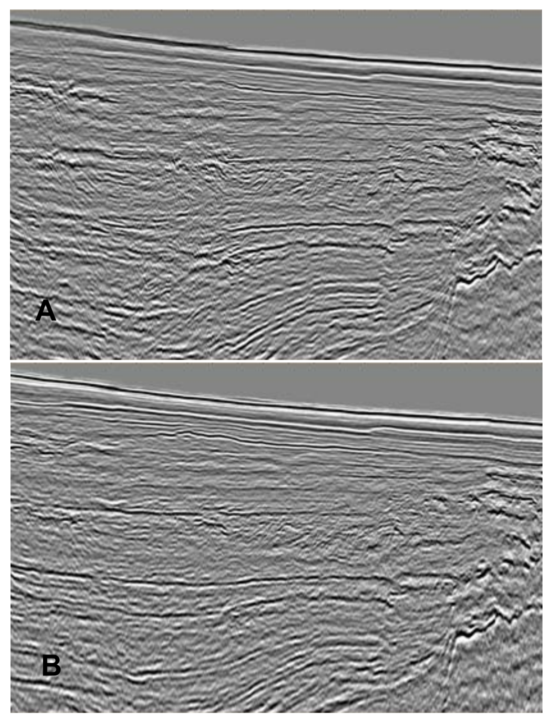

Figure 3: A) Post-stack WEM from WAZ survey in area of obstruction; B) Post-stack WEM merged WAZ / NAZ stacked data

The resulting stack volumes are input to the post-stack WEM to generate the reflectivity model for WFE multiple prediction. When comparing the two 3D migrated images we see significant improvement in continuity and resolution as well as a more stable wavelet in the shallow multiple generating section. All these enhancements will improve the ability of the WFE to predict the multiples. Figure 3A shows the reflectivity model created with the WAZ data input and Figure 3B shows the combined WAZ/NAZ data.

Multiple Prediction

For the WFE multiple prediction we input shot ordered data or in the case of this WAZ survey, data is gathered into supershots in which shots within a defined grid have the wavefield propagated as one. We can consider multiples as primaries with an additional round trip. This method has been described (Berryhill and Kim, 1986) and many variations offered subsequently (Kabir, 2004; Pica, 2005). The wavefield extrapolation from the reflectivity and velocity models allows us to model the multiples for the shot data.

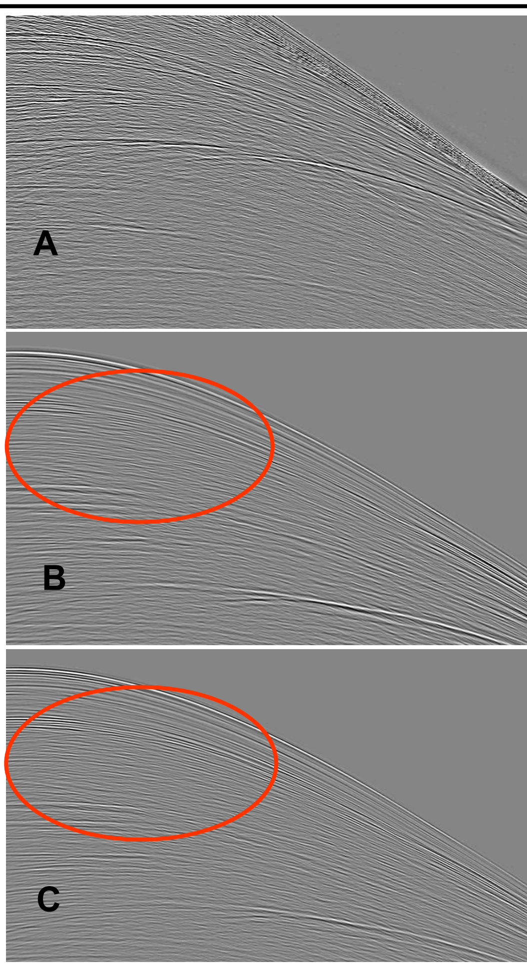

Figure 6: A) Input Data; B) Prediction 1; C) Prediction 2

The quality of the multiple prediction is largely dependent upon the integrity of the reflectivity model. We try to match as closely as possible the wavelet and resolution of the input shot data. This contributes to a better prediction and allows a more conservative approach to the subtraction which is less likely to adversely effect primary reflections.

Since the WFE method operates on a shot-by-shot basis, it is relatively easy to test and QC the results. The first QC is to compare the input shot data and the predicted multiples generated with both reflectivity models. In Figure 4A the input shot data is displayed, followed by predicted multiples in Figure 4B from the WAZ reflectivity model and the combined WAZ/NAZ reflectivity model in Figure 4C. The kinematics on both are similar but the amplitude content and wavelet from the WAZ/NAZ version matches that of the input data much more closely. When the predicted multiples are similar in character to the input shotpoint data we can expect better results in the adaptive subtraction step.

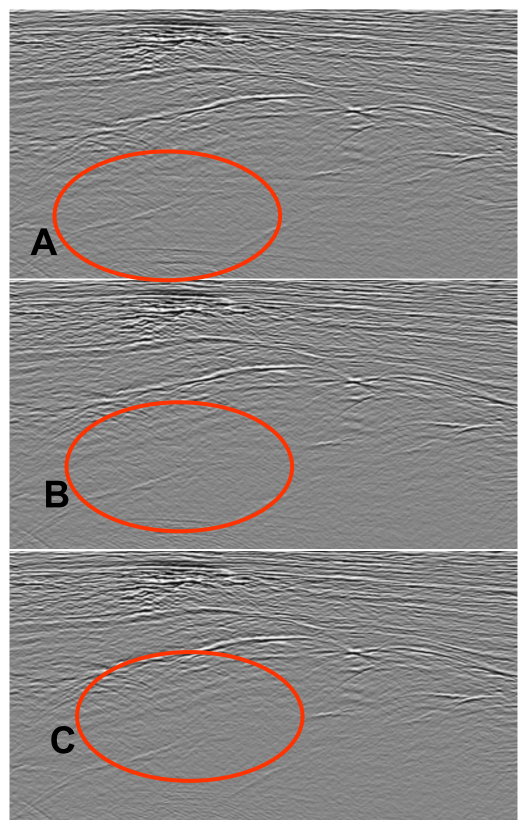

Figure 5: A) Input Stack; B) Stack from WAZ subtraction; C) Stack from WAZ/NAZ merged subtraction

Multiple Subtraction

Once a predicted multiple gather has been generated we can remove the multiples from the input data by means of adaptive subtraction. There are several variations on subtraction methods but we will use a least squares method and apply the same adaption parameters in order to make more direct comparison between the two output datasets.

This is, in fact, where we find the relative improvement with the enhanced reflectivity model. Initial QC is performed on shot data comparing input data and the subtraction results from both reflectivity models. In addition to shot data we stack the data for each subtracted volume and compare with the unprocessed stack.

In Figure 5A the stack section from the unprocessed data is displayed in the area of most dominant multiple contamination. In this illustration the multiples from the water bottom as well as those from other shallow reflections clearly dominates the deeper section. The stack from the initial WAZ-only model subtraction (Figure 5B) shows significant attenuation of the multiples but the merged WAZ/NAZ model is much more effective. In Figure 5C, we see the water bottom multiple is almost completely removed and multiple energy from other shallow high amplitude reflections are significantly reduced.

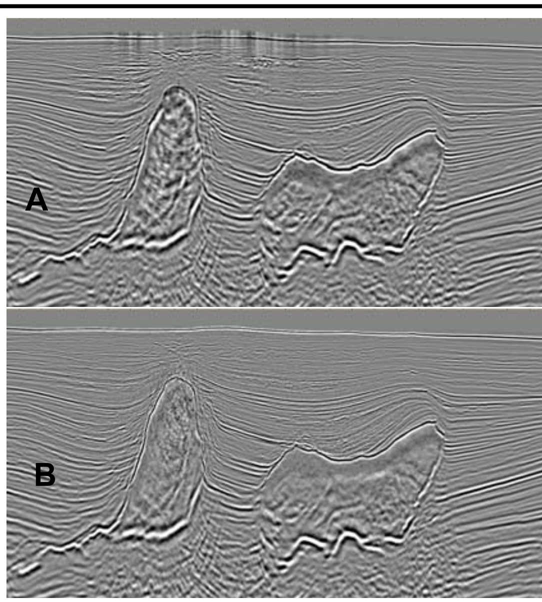

Figure 6: A) Kirchhoff Depth Migration WAZ only; B) Merged Kirchhoff Depth Migration

Other Applications for Merging NAZ Data

In addition to this WFE multiple prediction, the merging of the narrow azimuth data to the WAZ volume can be beneficial to other applications. The contribution of the NAZ data is useful for any flex binning or data regularization process and can take the place of missing infill data, especially in WAZ designs that do not include narrow azimuth data. An example of this is the BP Mad Dog survey which has a minimum cross-line offset of 325m (Threadgold et al, 2006). We also can use this narrow azimuth data to supplement the final image by merging either the pre-stack data or migrated images. An example of this can be seen in Figures 6A and 6B.

Conclusion

We have shown that a wide azimuth survey can be enhanced by including narrow azimuth data from prior vintage projects. The addition of this narrow azimuth data can be used to more fully cover the critical missing near cross-line offset content. This merged dataset can be used to enhance the reflectivity model used for WFE multiple prediction with the addition of NAZ data. The addition of this data is useful to supplement WAZ acquisition that inherently lacks the NAZ data or, as demonstrated in this paper, in areas of restricted acquisition access. We found that we can generate a higher resolution reflectivity model that results in improved multiple prediction. The improved prediction yields a more effective multiple attenuation with less risk of affecting primary reflections.

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EDITED REFERENCES

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