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Breakthrough of Internal Multiple Attenuation with XIMP Technology in Tarim Basin

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SUMMARY

Internal multiples, which mainly contaminate land datasets, are more difficult to address than surface-related multiples. Internal multiples generally appear to be very similar to the primaries because of their comparable velocities; they are therefore difficult to differentiate, especially in areas with relatively flat geology. In northern Tarim basin of China, most surveys have this type of flat geology and internal multiple problem. Traditional event discrimination methods, such as multi-channel dip filter, Radon transform, and inside mute, have failed to effectively remove the multiples. We show recent results using a prediction based framework using the extended internal multiple prediction (XIMP) followed by adaptive subtraction, where encouraging results show a clear removal of internal multiples in Northern Tarim basin.
Summary

Internal multiples, which mainly contaminate land datasets, are more difficult to address than surface-related multiples. Internal multiples generally appear to be very similar to the primaries because of their comparable velocities; they are therefore difficult to differentiate, especially in areas with relatively flat geology. In northern Tarim basin of China, most surveys have this type of flat geology and internal multiple problem. Traditional event discrimination methods, such as multi-channel dip filter, Radon transform, and inside mute, have failed to effectively remove the multiples. We show recent results using a prediction based framework using the extended internal multiple prediction (XIMP) followed by adaptive subtraction, where encouraging results show a clear removal of internal multiples in Northern Tarim basin.

Introduction

The Tarim basin is located in the Xinjiang Province in northwest China and it is the biggest inland basin and petroleum-bearing sedimentary basin in the country.

In most seismic surveys from middle and northern Tarim basin, the internal multiple problems have been known as one of the top challenging geophysical problems which are still awaiting the advent of a good solution.

The reservoir targets in Tarim are usually either in the Ordovician carbonate caves buried in a depth of 6 to 7 km, or in slightly shallower Carboniferous-Permian clastic rocks. These are very deeper targets if compared to many other land basins. As a consequence, primary events are normally weaker in amplitude. Besides, in deep zone of 6~7km depth, the internal multiples usually have similar velocity and moveout as the primary reflection and this makes identification and separation of primaries and multiple become even more difficult.

Figure 1 shows a typical depth migrated section in the Madong survey in Tarim basin. From top to bottom are seven key horizons interpreted from the legacy depth migration dataset: Horizon 1 - the Top of Standard Carbonate, Horizon 2 - Bottom of Carboniferous, Horizon 3 - Top of Ordovician Carbonate, Horizon 4 - Bottom of Yingshan formation, Horizon 5 - Bottom of Upper Cambrian, Horizon 6 – Bottom of Middle Cambrian, and Horizon 7 - Bottom of Cambrian.

However, the interpreters suspect that the Yingshan Formation in the Ordovician is contaminated with strong multiples from overburden layers. The interpreters guess that if the multiples could be removed better, then maybe the results could become much easier to interpret.

In recent years the most common methods for demultiple in this region were based on deconvolution in early stage of the processing workflow followed by a Radon residual multiple attenuation after pre-stack migration.

Due to the large period between multiples and their primaries, deconvolution has not been very effective. Likewise, due to little velocity discrimination between primaries and multiples, Radon transform is not effective either. Figure 2 shows a typical pre-stack time migration (PrSTM) section and common reflection point (CRP) gather before and after Radon. We can see that Radon has not changed the look of the section, although it makes the gather look flatter and cleaner. So for this region the multiple problem needs a completely different approach.
Figure 1 Depth migration section from the Madong survey and the seven interpreted horizons based on this result.

Figure 2 CRP gather before (top right) and after (bottom right) Radon Demultiple and the stack sections, which shows that even though Radon demultiple makes gather look cleaner and it does not improve the stack response.

Method

Extended Inter-bed Multiple Prediction (XIMP) is one complete new method for internal multiple attenuation. The algorithm is true-azimuth 3D algorithm based on the method described by Jakubowicz (1998). Wu et al. (2011) gives a more detail description on how XIMP works.
XIMP handles this challenge by generating an internal multiple model that can be removed using various adaptive subtraction techniques. XIMP is able to handle any acquisition geometry, and predicts multiples at true azimuth. This is particularly important for rich-azimuth land acquisition. When used in conjunction with 3D surface demultiple techniques, the result is a much better representation of the primary energy.

The procedure of applying XIMP on the Madong survey can be described in the following four steps:

First, we need to precondition the data to make input data has enough signal-to-noise ratio and also well sampled. To achieve this, for this specific dataset we applied 5D Matching Pursuit Fourier Transformation (5D MPFI) to regularize the data and also to clean the data.

Second, the main internal multiple generators need to be identified and interpreted. Although the XIMP has minimum requirement of a priori information and it can work well without explicitly interpreted horizons, accurate identification and interpretation can still do good to more efficient multiple model prediction. Therefore, after careful analysis of the legacy migration results, we concluded that there are seven horizons that could be the most important multiple generators in this survey, as shown in figure 3. It is important to stress that the deepest multiple generator – MG7 in figure 3 roughly corresponds to the horizon 1- the top of Standard Carbonate. This means most internal multiple in the target Yingshan formation are reflections from these or deeper interfaces, which are then further downward reflected once or more by the 7 interfaces.

The third step is the computing-intensive step of generating the multiple model prediction. All predicted models are output in to the raw model files in one go during this step.

In the fourth step, we applied adaptive subtraction of the raw multiple models from the input dataset, in a cascaded flow, in Offset Vector Tile (OVT) domain.

![Figure 3 The seven multiple generators in Madong survey.](image_url)

### Results

Figure 4 shows the PrSTM section of data without XIMP applied and with XIMP applied. Compared to the result shown in figure 2, we now see that XIMP has done a much better job of removing the
internal multiples in the Yingshan formation target zone. On the migration section after applying the XIMP workflow, the reflection events now become clearer, simpler and easier to interpret.

From the interpreter’s point of view, the previously interpreted ‘Bottom of Carboniferous’ - the horizon 2 in figure 1, based on the legacy data, is now recognised through XIMP as being a multiple. Furthermore, the top of the Ordovician carbonate - the horizon 3, is now much clearer (red arrow) on the result of XIMP. At the level of deeper Cambrian around 4 seconds TWT, the use of XIMP has almost completely removed the ‘Bottom of Mid-Cambrian’ event previously interpreted from the legacy data and processing.

**Figure 4** The PrSTM section of before (left) and after applying XIMP (right).

**Conclusions**

The internal multiples have been a very challenging geophysical problem in the seismic data of Tarim Basin. Traditional methods failed to successfully remove the internal multiples and uncover the true primaries in the deep target zone.

The successful application of XIMP technology in the Madong data is a breakthrough in solving this problem. By removing the strong internal multiples with XIMP, we are now able to make dramatically different interpretations.

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**References**
