Introduction

Subsalt velocity updating (Wang et al., 2004, 2006) can be categorized into two approaches: 1) Data-driven subsalt tomography based on residual moveouts; and 2) interpretation-driven subsalt WEM scans (Wang et al., 2006). When subsalt reflections are well defined and their reflection angle range is broad, subsalt tomography works just as well as suprasalt tomography. On the other hand, if subsalt reflections are not well defined or the range of reflection angle is limited, as is often the case, we may have to rely on a more brute force approach such as subsalt WEM scan.

Although subsalt WEM scan is effective, the cost of generating migration scans is still comparatively high. To generate a set of WEM scans, multiple passes of wave equation migration are performed for each of the scaled velocity models. The number of wave equation migrations needed is linearly proportional to the number of scans to be produced. Because of the cost issues, the number of WEM scans produced is typically limited to 7 to 9 scans. To address the cost issue, Wang et al., (2005, 2006) proposed an alternative subsalt scanning technique using DIT scan based on focusing analysis (MacKay and Abma, 1992). With DIT scan, only one-pass of wave-equation migration is performed, but multiple images are produced by applying zero-time imaging condition as well as non-zero imaging condition (Sava and Formel, 2006).

Due to the fact that the cost of applying an imaging condition is just a small fraction of wave-equation migration (about 5%), we can afford to generate very dense DIT scans (for example, 21 DIT scans). This greater density of scans allows more precise picking and better resolution for the resulting velocity update.

With the more expensive Reverse Time Migration (RTM) gradually becoming a routine migration tool, the standard subsalt scan approach, becomes impractical. On the other hand, the alternative DIT scan becomes more attractive, because the cost of computing wave propagation for RTM is comparatively even more expensive than applying an imaging condition.

Another benefit of performing RTM-based DIT scan is that picking is based on scan image quality of RTM, therefore the velocity model derived is more consistent with the final RTM image (Jones et al., 2007), and therefore gives a better chance to create a better focused final RTM image.

RTM-based DIT scan

We have developed a new methodology of subsalt velocity updating using RTM-based DIT scan, which consists of the following main components: 1) Generating subsalt RTM-based DIT scan; 2) Picking DIT values by comparing different RTM-based DIT scan images; 3) updating subsalt velocity using the picked DIT values.

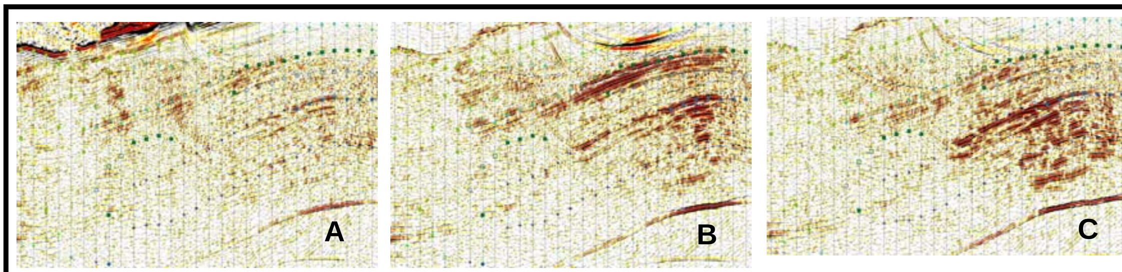

Figure 1. *An example of DIT scan panels with delayed imaging time: A) 0 ms; B) - 300 ms; C) - 500 ms*

To be able to generate RTM-based DIT scan, any existing RTM program can be easily modified to be able to apply zero-time as well as non-zero-time imaging condition. The picking tool for DIT scan is very similar to those originally designed for regular WEM-scan picking (Wang et. al., 2006); but instead of using velocity scaling factor, now the picked value is time-shift (such as -100 ms, or +200 ms). Both stacked section form and gather form are used for picking. To facilitate picking, a gather is also converted to pseudo-semblance. Figure 1 shows an example of DIT scan panels. Clearly, for this example, with increasing negative time-shift, the deeper events are much better focused.

Composite RTM image based DIT scan picking

One benefit of performing DIT scan analysis is the ability to produce a better focused composite image. In order to be able to produce the composite image, we first convert each time-shifted DIT scan image to a pseudo-depth domain by applying the following steps: 1) depth to time conversion; 2) compensate the time-shift applied during the time-shift imaging condition; 3) time to depth conversion. The composite image can be generated interactively during the picking process to evaluate the validity of the picks.

Figure 2 is an example of the composite image after the DIT scan picking using the BP synthetic data set. Comparing with the regular RTM image (Figure 2B), this composite image (Figure 2C) is much better focused and subsalt events are more coherent. This indicates the trend of the updated picks is correct. The composite image also more closely matches the true model (Figure 2A)

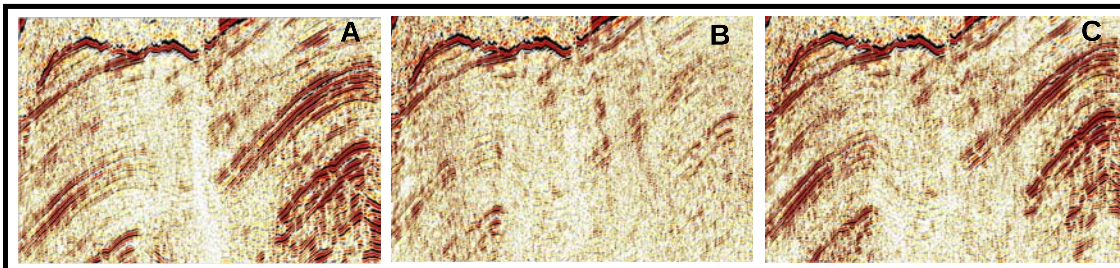

***Figure 2**. A) RTM image using true velocity model; B) Regular RTM image using initial velocity model; C) Composite RTM image using the same initial velocity model as Figure B, after DIT scan*

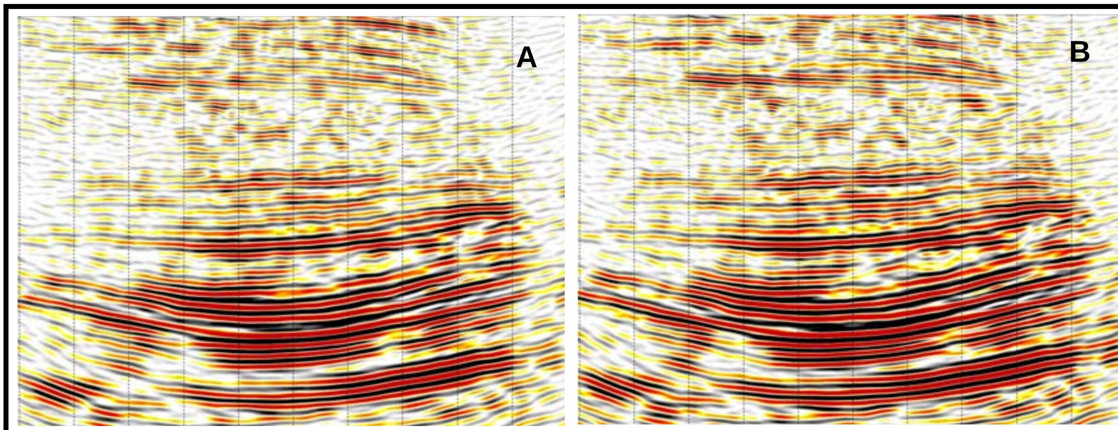

***Figure 3.** A) Regular final anisotropic RTM image; B) Composite RTM image after anisotropic RTM DIT scan*

The composite image can serve two purposes: 1) QC the DIT scan picking; 2) produce the final best focused image. The composite image must be equal or better in quality as compared with the regular image corresponding to DIT equal to zero. Any degradation of the composite image in any part of image indicates picking errors.

DIT scan and the DIT picking can also be used to produce the best final image. Figure 3 is a 3D real data example performing anisotropic RTM. The composite image (Figure 3B) based on DIT scan picking is better focused and more coherent as compared with the regular anisotropic RTM image (Figure 3A). This allows further improvement of the final image that was limited by the inevitable inaccuracies in the velocity model.

Subsalt velocity update using RTM-based DIT scan

The complete subsalt velocity update flow has been successfully tested using the BP 2D synthetic data set. The picked DIT values can be used either for tomographic velocity updating (Wang et al, 2005), or vertical update.

This new RTM-based DIT-scan subsalt velocity update has been successfully applied to a real 3D data set from Gulf of Mexico (GOM) in the area of Green Canyon and Walker Ridge.

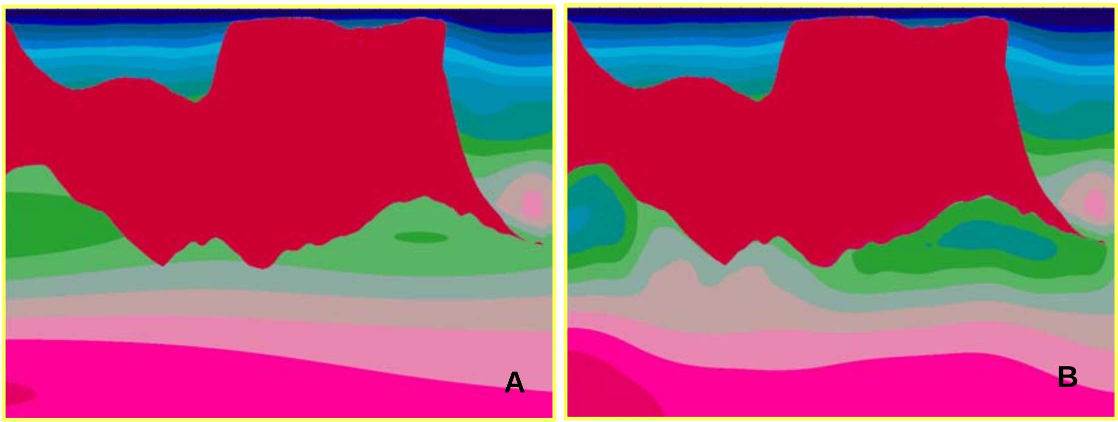

Figure 4. *A) Initial subsalt velocity model; B) Updated subsalt velocity model after RTM-based DIT scan*

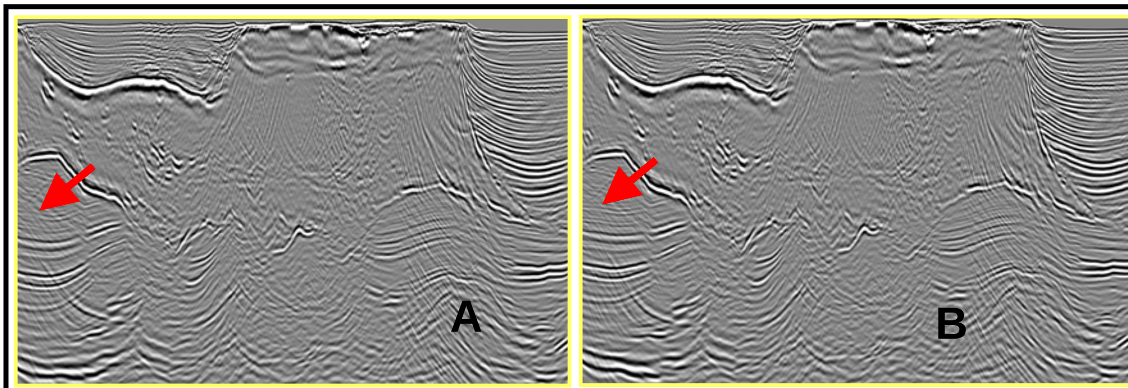

Figure 5. RTM images: A) Using initial subsalt velocity model; B) Using updated

Figure 4 shows the subsalt velocity models before and after the RTM-based subsalt DIT scan. For this example, a total of 21 RTM-based DIT scan images are produced. The initial velocity model is already responsibly well for most part after our initial depth processing. Using our subsalt scan picking tool, delayed imaging times are picked by comparing scan panels (stacked images) as well as gather display, which is similar to the WEM scan picking (Wang, et al. 2008). After the subsalt velocity update, as much as 10% velocity reduction is needed at left side right below the salt body.

Conclusions

We have developed a new methodology of subsalt velocity update using RTM-based DIT scan. As an efficient alternative to the standard subsalt migration scan, RTM-based DIT scan only needs to perform one-pass of RTM computation followed by multiple time-shifting imaging conditions. Both synthetic and real data testing demonstrate this new subsalt scan technique is practical and effective. In addition to velocity update, RTM-based DIT scan can also be used to produce a better focused final RTM image.

Acknowledgements

We would like to thank Frederic Billette of BP for generating the BP synthetic data set. We thank Kevin Bishop of BHP for his encouragement for this work and stimulating discussion. We also like to thank Xiansong Zeng, Huimin Guan, Wenlong Xu, Sampath Gajawada and Young Kim for help and discussion. Thanks to Laurie Geiger for help in proof-reading. We thank TGS-NOPEC management for permission to publish this paper.

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