Subsalt Velocity Update Using RTM-based DT Scan

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Summary

Subsalt wave-equation based migration (WEM) scan is an effective way for subsalt velocity updating, and has become an industry standard practice; however, the cost of generating migration scan is still comparatively high. With the more expensive Reverse Time Migration (RTM) gradually becoming a routine migration tool, this standard subsalt scan approach, becomes impractical. In this paper, we propose a new methodology for updating subsalt velocity using RTM-based scan with a range of variable time imaging conditions (Delta-T or DT scan). The generation of the RTM-based DT scan requires only a single pass of RTM. We generate a set of RTM scan images by applying zero-time as well as non-zero time imaging condition. Synthetic and real data testing confirm the effectiveness of this new approach and suggest this DT scan approach could serve as an efficient alternative or even a replacement to the standard subsalt migration scan approach for RTM.

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 DT scan based on focusing analysis (MacKay and Abma, 1992). With DT 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 DT scan (for example, 21 DT 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 DT 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 DT 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 DT scan

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

To be able to generate RTM-based DT 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 DT scan is very similar to those originally designed for regular WEM-scan picking; but instead of using velocity scaling factor, now the picked value is time-shift (such as -100 ms, or +200 ms). Figure 1 shows tools used for DT scan picking. Both stacked section form and gather form are used for picking. To facilitate picking, a gather is also converted to pseudo-semblance as shown in Figure 1.

Figure 2 shows some examples of DT scans. Clearly, for this example, with increasing negative time-shift, the deeper events are much better focused.

Subsalt velocity update using RTM-based DT scan

To test the complete subsalt velocity update flow, BP 2D synthetic data set is used. To simplify the testing, only one out of four shots is used, and the offset is reduced to 8 km from the original 15 km. The initial subsalt velocity field is roughly a 1D model as shown in Figure 3B. Figure 2 shows some of the DT scans by performing RTM using the initial velocity model. The picked DT values can be used either for tomographic velocity updating (Wang et. al, 2005), or vertical update.

Comparing the initial velocity model (Figure 3B) with the true model (Figure 3A), it is expected that the initial subsalt velocity needs to be reduced in the middle and increased on both sides. Figure 3C shows the subsalt velocity update (DV field) after one iteration of subsalt DT scan. Figure 3D is the corresponding updated subsalt velocity model. Comparing with the true model (Figure 3A), the updated velocity model (Figure 3D) is able to capture all the major velocity anomalies after just one iteration of DT scan. This example clearly demonstrated that the DT scan is very effective to capture the major velocity anomalies.

Composite RTM image based DT scan picking

A side benefit of performing DT 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 DT 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 can be generated interactively during the picking process to evaluate the validity of the picks.

Figure 3C is an example of the composite image after the DT scan picking. Comparing with the regular RTM image, this composite image is much better focused and subsalt events are more coherent. This indicates the trend of the updated picks is correct.

The composite image can serve two purposes: 1) QC the DT 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 DT equal to zero. Any degradation of the composite image in any part of image indicates picking errors.

DT scan and the DT picking can also be used to produce the best final image. Figure 5 is a 3D real data RTM image. The composite image (Figure 5B) based on DT scan picking is better focused and more coherent as compared with the regular RTM image (Figure 5A). This allows further improvement of the final image that was limited by the inevitable inaccuracies in the velocity model.

Conclusions

We have developed a new methodology of subsalt velocity update using RTM-based DT scan. As an efficient alternative to the standard subsalt migration scan, RTM-based DT 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 DT scan can also be used to produce a better focused final RTM image.

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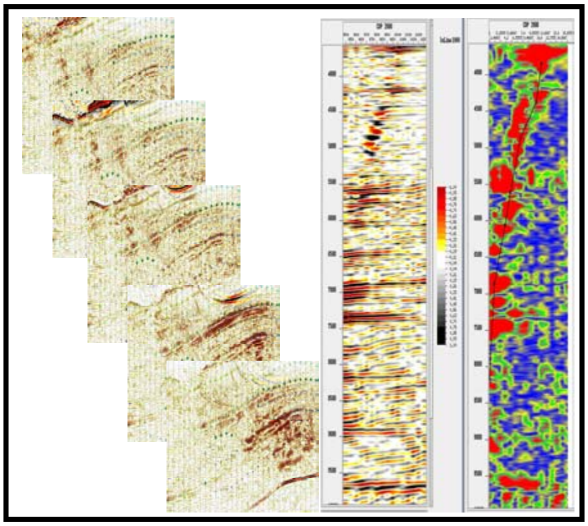

Figure 1. An example of RTM-based DT scan in section form (left), gather form (middle), and pseudo-semblance form (right).

RTM DT Scan

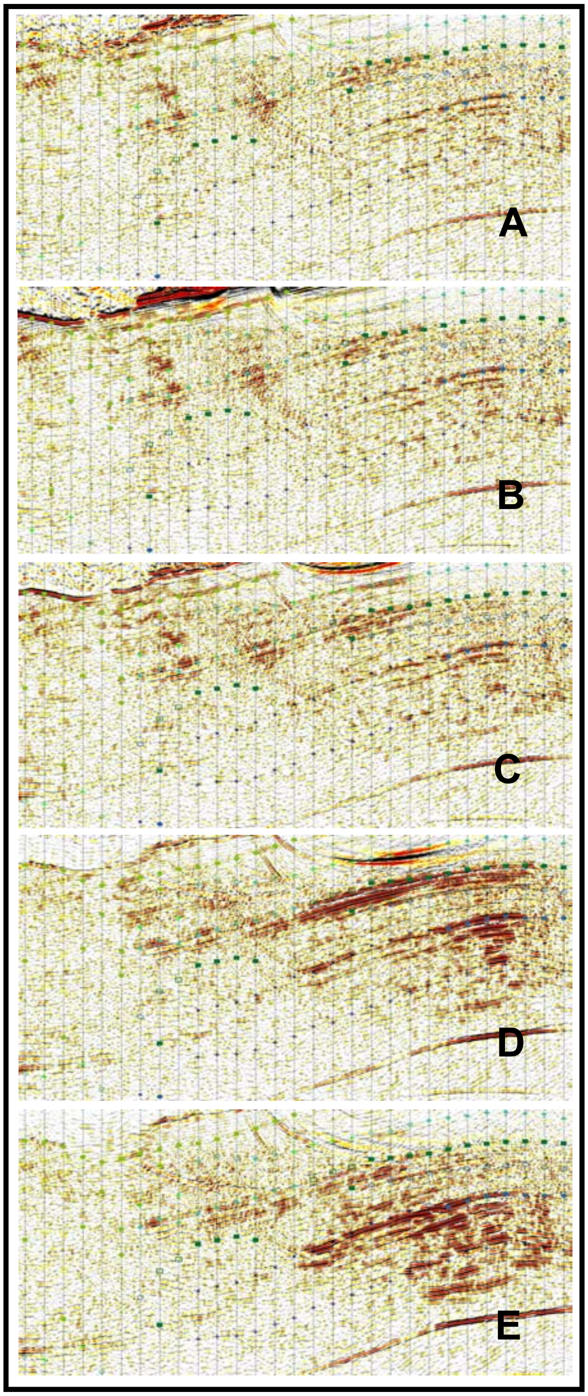

Figure 2. A selected RTM-based subsalt DT scan using BP synthetic testing data set: (a) +100 ms; (b) 0 ms; (c) -100 ms; (d) +300 ms; (e) +500 ms.

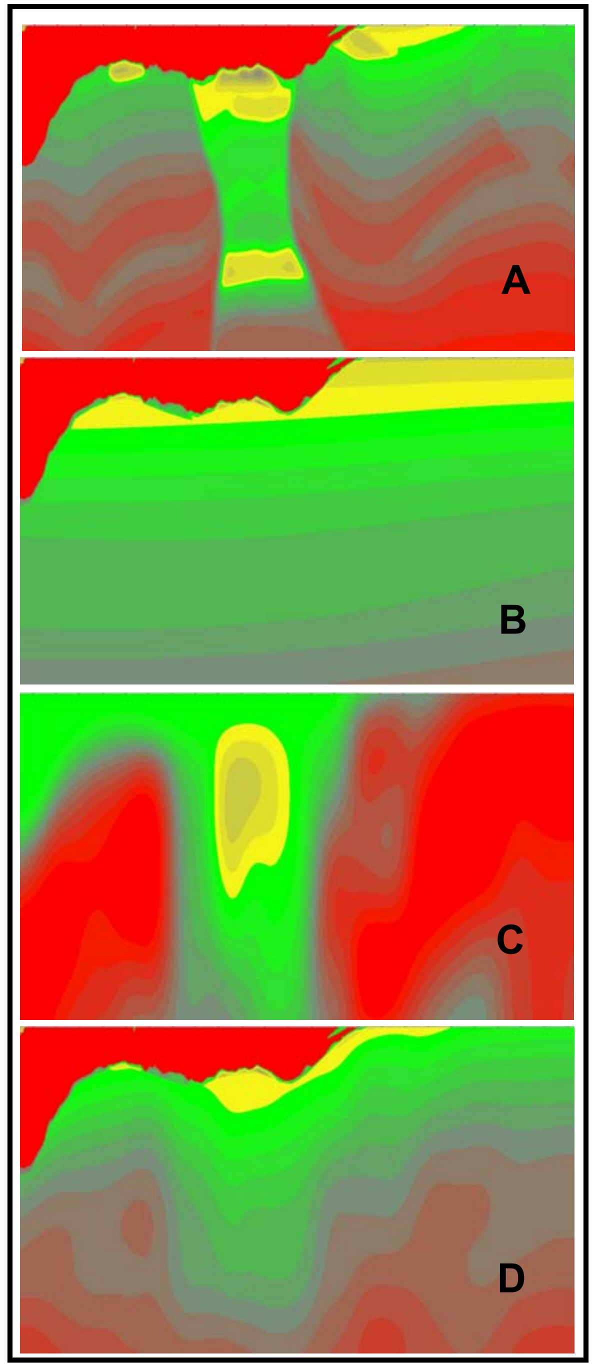

Figure 3. Velocity models: (a) True model; (b) Initial model; (c) updated DV field; (d) Model updated with RTM-scan method.

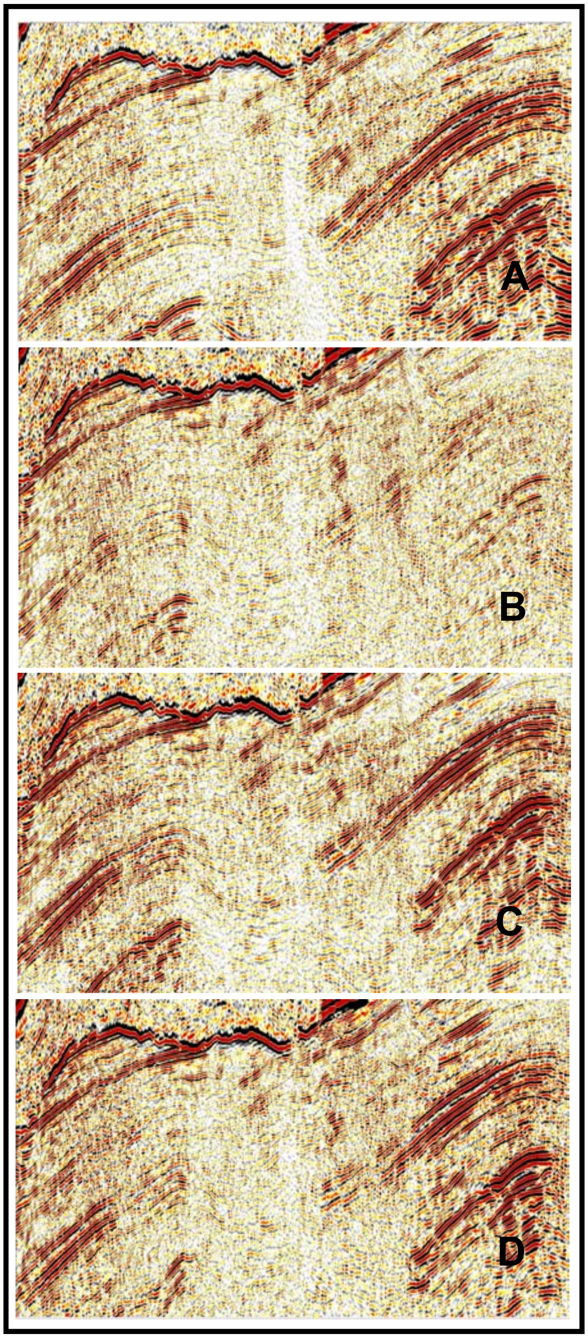

Figure 4. (a) RTM images: corresponding to true velocity model; (b) RTM images: corresponding to initial velocity model;(c) RTM composed on DT scan picking corresponding to true velocity model; (d) RTM images: corresponding to updated velocity model;

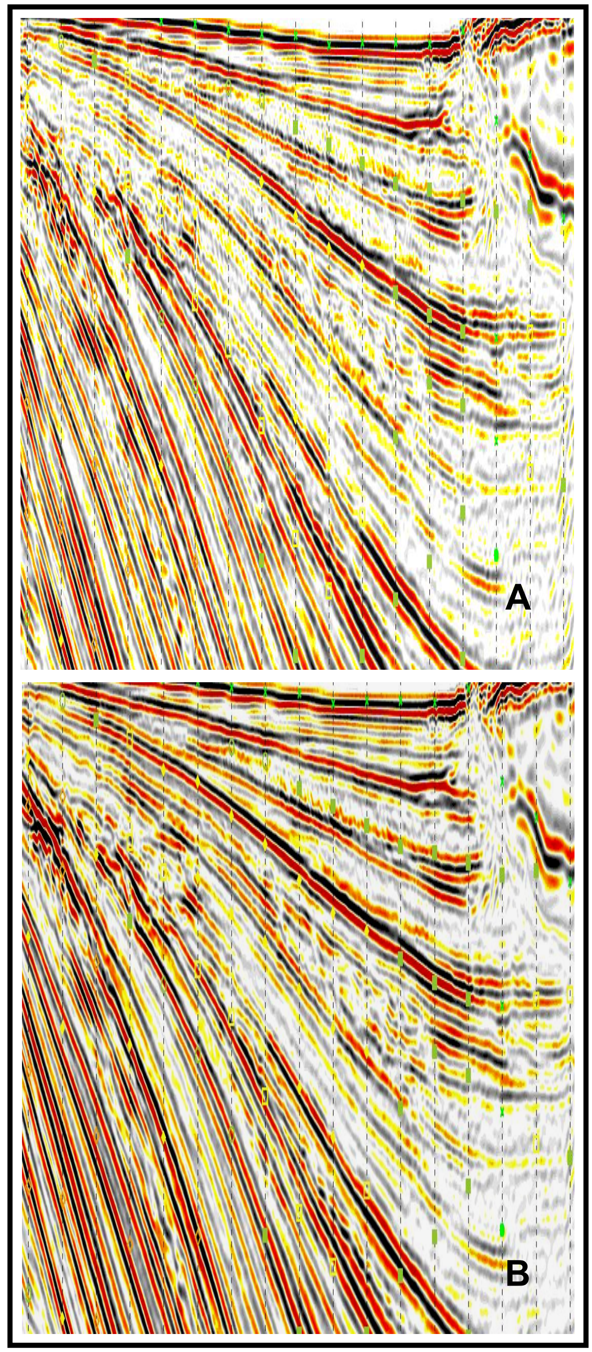

Figure 5. 3D real data example of composite RTM image based on DT scan picking. (a) Regular RTM image; (b) Composite image.

EDITED REFERENCES

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