Automatic RTM-based DIT scan picking for enhanced salt interpretation

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Summary

Delayed Imaging Time (DIT) scans based on Reverse Time Migration (RTM) are often used in production to update velocity models, particularly in subsalt or other low signal-to-noise (S/N) areas (Wang et_al, 2009). This approach has been recently enhanced in two ways. Firstly, an automated model building approach has been developed which enhances the quality of the resulting velocity model update with significant reduction in turnaround time. Secondly, the automated approach is used as an effective tool for improving the salt interpretation process. This ability is enhanced by use of properly relaxed constraints. In this paper, we first briefly describe the automated RTM-based DIT scan methodology and then show real data examples which demonstrate the effectiveness of DIT scans for building better salt models in complex areas.

Introduction

Subsalt reflections are often not well defined and the range of reflection angles is quite limited. For these reasons, velocity updating below salt sometimes requires a brute force approach such as subsalt migration scanning. While subsalt velocity perturbation scans (Wang et al., 2006) are often effective, the cost of generating migration scans is proportional to the number of scan images generated, since each image requires a complete RTM imaging run. Typically at least seven to nine scans are required making the cost roughly an order of magnitude more expensive than a standard RTM run. To reduce the cost, Wang et al. (2009) proposed an alternative subsalt scanning technique using Delayed Imaging Time (DIT) scans based on focusing analysis (DeVries and Berkhout, 1984; Faye and Jeannot, 1986; MacKay and Abma, 1992; Audebert and Diet, 1993; Nemeth, 1995; Wang et al., 1995, 1998). By applying several non-zero-time imaging conditions, in addition to the standard zero-time imaging condition, multiple migration images can be produced from a single migration (DeVries and Berkhout, 1984; Wang et al., 1995, 1998; Sava and Fomel, 2006).

RTM-based DIT scans (Wang et al., 2009) have been developed and successfully applied to many real-data 3D projects. Previous DIT scan picking was a horizon-driven, manual interpretation process requiring great care and typically a few months of project time. We recently have been able to reduce project cycle time after we developed a set of tools to automate the DIT scan picking process. The automation process improves the resulting robustness and quality of the picks and the model updating process is reduced to a few days. The automatic picker utilizes a volumetric structure based approach to enhance S/N and reasonability of the resulting model update. During the course of applying RTM-based DIT scans to many real-data 3D projects, it has become clear that the DIT scanning technique is effective for subsalt velocity updating and has a strong potential to identify interpretation errors in the low S/N areas. In this paper we illustrate how RTM-based DIT scans can be utilized to identify salt interpretation errors and thereby improve the resultant salt velocity model.

Automatic DIT scans picking process

The automatic DIT scan picking is performed in the DIT gather domain. Twenty-one scan images are typically produced during the RTM DIT scan stage, by applying different delays to the source wavefield before applying the imaging condition with the receiver wavefield. Gathers are formed by sorting the images to Common Image Point (CIP) domain, where each gather is 21 fold, with each gather trace corresponding to a different delay time image. A DIT gather looks similar to CIP gathers used for migration based tomographic velocity updates. However, unlike a CIP gather, the horizontal axis of a DIT gather represents imaging time delay (Wang et al., 2009) instead of offset or reflection angle, and each trace is a complete migration stack image rather than a partial image of single offset or single angle.

To help in the picking and comparison among different DIT scan images, each scan image is redepthed (Wang et al., 2009) to match the zero-delay image. One of the challenges of automatic picking is to avoid picking noise. To enhance the S/N ratio, some preconditioning of gathers is necessary before automatic picking. One of the most effective DIT preconditioning steps is to form a super-gather by grouping a few adjacent DIT gathers together such that structural dips are taken into account. Figure 1 shows a comparison of a DIT gather before and after the gather conditioning process. After gather conditioning, the DIT gathers are then converted to a semblance-like attribute before automatic picking is performed (Figure 2).

Automatic picking is performed volumetrically and densely in the resultant 4D cube of semblance samples, where the dimension to be picked is imaging time delay. Picking is done densely on every sample utilizing structural constraints, interval velocity constraints and smoothness constraints such that the output picks are as close to the final result as possible. In addition to improving S/N, the volumetric approach to autopicking enhances the quality of the resulting picks because it helps take into account the movement of dipping energy as a function of velocity which would otherwise bias the picks. As an example of this type of bias, a simple gather by gather autopicker tends to speed up around the edges of swings and stretches them laterally across the image as it attempts to maximize local image energy. A volumetric approach has less of a tendency toward this undesirable behavior. To ensure that the subsequent subsalt velocity update is structurally consistent, the structural constraints are based on dense subsalt horizons. To reduce the human effort required to generate the surfaces, we have developed a tool for automatic horizon generation based on dip fields. Figure 3 shows an example of the automatically generated horizons. This new automated DIT scan methodology dramatically reduces the project turnaround time by reducing the work time of DIT-based subsalt velocity updates from a few months to a few days while producing notably better results.

DIT scans used directly for salt interpretation

It is well-known that pre-stack depth migration is very sensitive to the accuracy of the velocity model. Due to the high velocity contrast between typically low velocity sediments and the high velocity of salt, the accuracy of the salt geometry has a first order impact on subsalt imaging quality.

DIT scans have been used routinely in our production projects to update the subsalt sediment velocities. During the update we sometimes observe that subsalt sediment velocity changes are merely trying to compensate for salt interpretation errors introduced in the prior salt model building stage. In this way, DIT scanning has proved to be an excellent tool for identifying salt interpretation errors that are otherwise difficult to identify.

There are two ways that DIT scans can be used for identifying salt geometry errors in a salt velocity model. The first way is described in this section, which is by comparing the DIT scan RTM images with the regular RTM image with a delay time of zero. Figure 4 shows one example of a DIT scan for a 3D Wide Azimuth (WAZ) data set from the Gulf of Mexico (GOM). Figure 4a is the migration velocity model, Figure 4b is the regular RTM image and Figure 4c is one of the scan images with a positive delay time of 300 ms. The basic purpose of DIT scans is to emulate velocity perturbation scanning (Wang et al, 2006), where positive delays represent an increase in velocity and negative delays represent a decrease in velocity. In this case, it is apparent that with a positive delay time, not only is the Base of Salt (BOS) in the highlighted area much better imaged, the nearby subsalt events are much better focused and more coherent. By looking back at the salt velocity model, it can be seen that the original interpretation of the BOS is too shallow, and therefore a positive change in the velocity (positive delay time) is needed to compensate for the missing piece of salt. Figure 5 shows another 3D narrow azimuth (NAZ) example from GOM where flipping through the 21 RTM-based scan images, the BOS image clearly pops up with a negative delay time of 225 ms, whereas in the conventional zero time delay image it is not well defined. This could be indicative of an intra-salt sediment inclusion or a Top of Salt (TOS) that is too shallow.

DIT scan velocity update for salt interpretation

Another way to identify a salt geometry error is shown in Figure 6. First, an automated DIT scan picking and velocity update procedure is performed. Figure 6a is the delta velocity field produced by the automated DIT scan velocity update process. Figure 6b is the initial velocity model which was used to produce the RTM image shown in Figure 6d. Comparing Figure 6a to Figure 6b we can see there is a significant positive delta velocity right below the BOS in the two highlighted areas. It should be noted that due to limited spatial resolution, the delta velocity is merely an indicator of salt geometry problems in the vicinity that must be further investigated. Looking at the RTM image (Figure 6d), the BOS is not well imaged in the RTM image used to build the initial salt velocity model (Figure 6b).

Based on this new information, we built a new salt velocity model with a modified salt geometry and an updated subsalt velocity model, as shown in Figure 6c. Figure 6e is the RTM image using the new updated velocity model (Figure 6c). Comparing Figure 6e and Figure 6d, the image using the DIT-scan updated velocity model has much better quality. The new migration shows that by extending the salt deeper in the model, the BOS is better imaged and more subsalt events show up clearly in the area near the newly added salt. Subsalt velocity is also improved, which results in better subsalt images with enhanced coherency.

Conclusions

Automation of RTM-based DIT scans has resulted in a significant reduction in project turnaround time. A new application of DIT scans for refining salt interpretation and building a better salt velocity model has proven to be very effective. Two ways of using DIT scans for salt geometry refinement are identified. First, by comparing the 21 scan images, the salt boundaries, especially the BOS, may image better in the scan with a non-zero time delay than it does in the original zero-delay image. Second, by comparing the delta velocity field produced by the automated DIT scan to the RTM image, we can obtain information on how to modify the salt model. If there is a large positive delta velocity right below a BOS, which is not well defined in the RTM image, this is a strong indication that more salt needs to be added to the BOS. Conversely, a large negative delta velocity may be indicative of too much salt or dirty salt. While DIT is a useful tool for subsalt velocity model updating, it has also shown itself to be a valuable tool for obtaining more accurate salt geometry which is critical for enhanced subsalt imaging.

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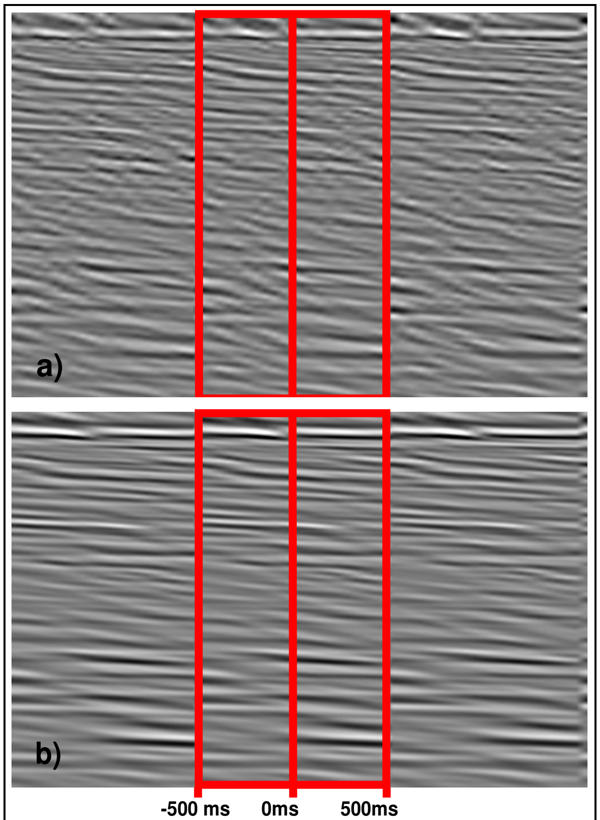

Figure 1. Example of DIT gathers: a) raw DIT gathers; b) DIT gathers after gather conditioning.

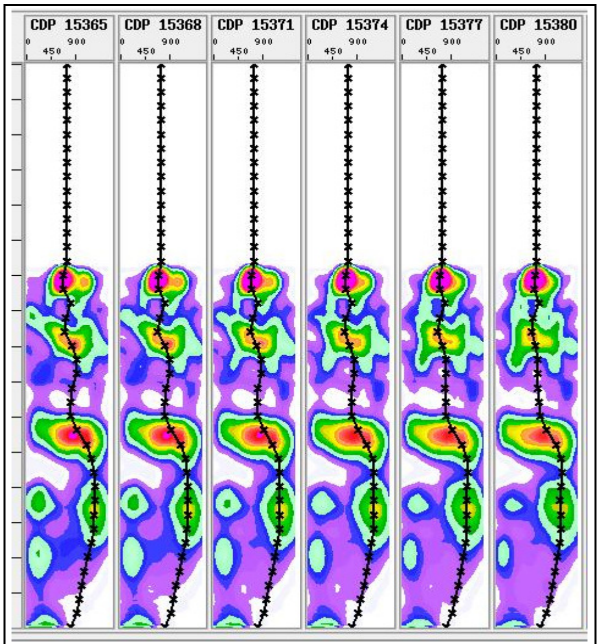

Figure 2. Automatic DIT picking on semblance-like attribute.

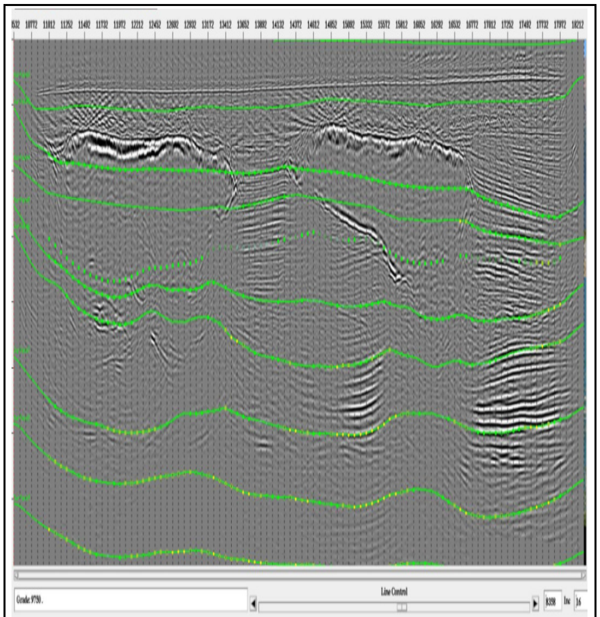

Figure 3. Automatic surface creation using dip fields.

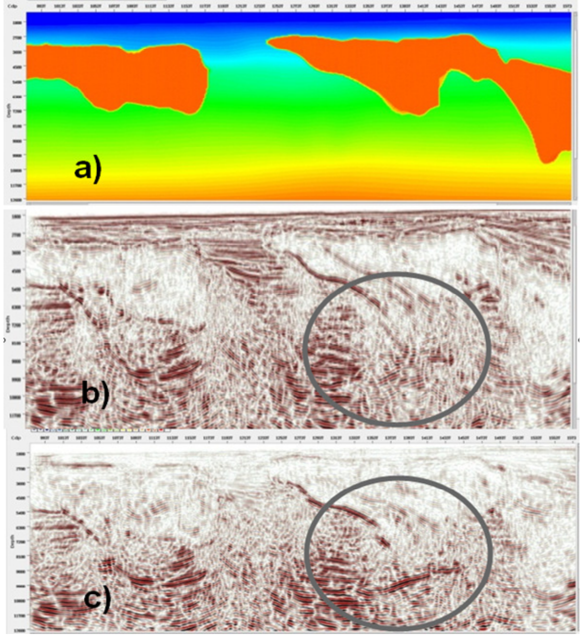

Figure 4. DIT scans for salt interpretations: a) initial salt velocity model; b) regular RTM image; c) RTM image with delay time of positive 300 ms.

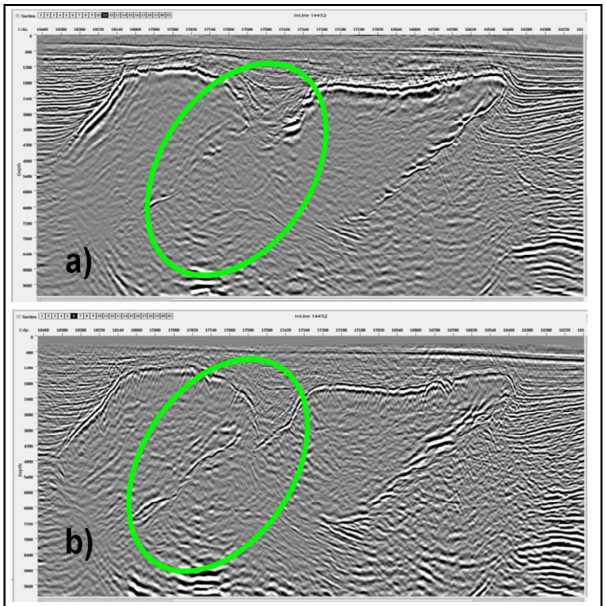

Figure 5. DIT scans for salt interpretation: a) regular RTM image; b) RTM image with delay time of negative 225 ms.

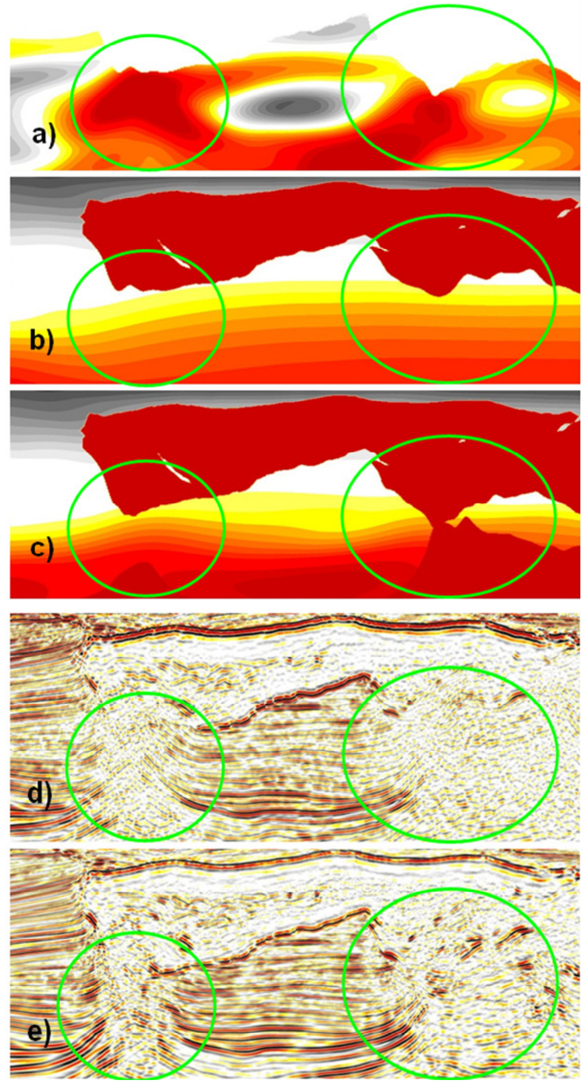

Figure 6: a) delta velocity model derived by DIT scans; b) initial velocity model; c) updated velocity model; d) RTM image using the initial velocity model; e) RTM image using the updated velocity model.

EDITED REFERENCES

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