Automated RTM-based DIT scans for salt interpretation and model building

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Summary

Reverse Time Migration (RTM) based Delayed Imaging Time (DIT) scans have been used routinely in production to update velocity models in subsalt or low signal to noise areas. Recently, this approach has been enhanced in two areas. Firstly, an automated methodology has been developed that both enhances the quality of the analysis and significantly reduces project turnaround time. Secondly, the automated method is used as an effective tool to help salt velocity model building. In this paper we first describe briefly the automated RTM-based DIT scan methodology; we then show real data examples that demonstrate the effectiveness of DIT scans for better salt model building in complex areas.

Introduction

Due to the fact that subsalt reflections are often not well defined or the range of reflection angle is limited, velocity updating beneath salt sometimes has to rely on a brute force approach such as a subsalt migration scanning. Subsalt velocity perturbation scans (Wang et al., 2006) can be effective, but the cost of generating migration scans is linearly proportional to the number of scans, since one migration must be performed for each of the scaled velocity models. Constrained by the computation cost and run time the number of velocity perturbation scans produced is typically between seven and nine scans. 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. However, previously DIT scan picking was a horizon-driven, manual interpretation process and typically required a few months of project time. To reduce the project cycle time we recently developed a set of tools to automate the DIT scan picking process. Automation enables us to reduce down to a few days the time required to perform a subsalt scan based model update. In order to make the subsequent velocity update more accurate and robust, the new DIT scan picking approach uses an automatic and volumetric picking tool to speed up the process and enable dense picking. 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 salt interpretation errors in the low S/N areas. In this paper we illustrate how RTM-based DIT scans can be used to identify salt interpretation errors thereby improving the salt velocity model.

Automatic DIT scans picking process

Our new automatic DIT scan picking is performed in the DIT gather domain. Typically, a total of 21 scan images are produced during the RTM DIT scan stage. A DIT gather looks similar to the Common Image Point (CIP) gathers used for migration based tomographic velocity updates. Each DIT gather typically consists of 21 traces corresponding to the 21 DIT scan images. However, unlike a CIP gather, the horizontal axis of a DIT gather represents the 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.

To help in the picking and comparison between 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. Some preconditioning of DIT gathers is required before the automatic picking. One of the most effective DIT gather preconditioning steps is to form a super-gather by grouping a few adjacent DIT gathers together and taking into account the local structural dips. Figure 1 shows a comparison of a DIT gather before and after gather conditioning. After gather conditioning DIT gathers are converted to a semblance-like attribute before the automatic picking is performed (Figure 2). Automatic picking is performed on every DIT gather and every depth sample is picked to obtain dense, volumetric picks. To ensure the subsequent subsalt velocity update is structurally consistent subsalt horizons are generated. To reduce the human effort required we have developed a tool for automatic horizon generation based on dip fields. Figure 3 is an example of horizons automatically generated using dip fields. 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.

DIT scans for salt interpretation

It is well-known that prestack depth migration is very sensitive to the accuracy of the velocity model.

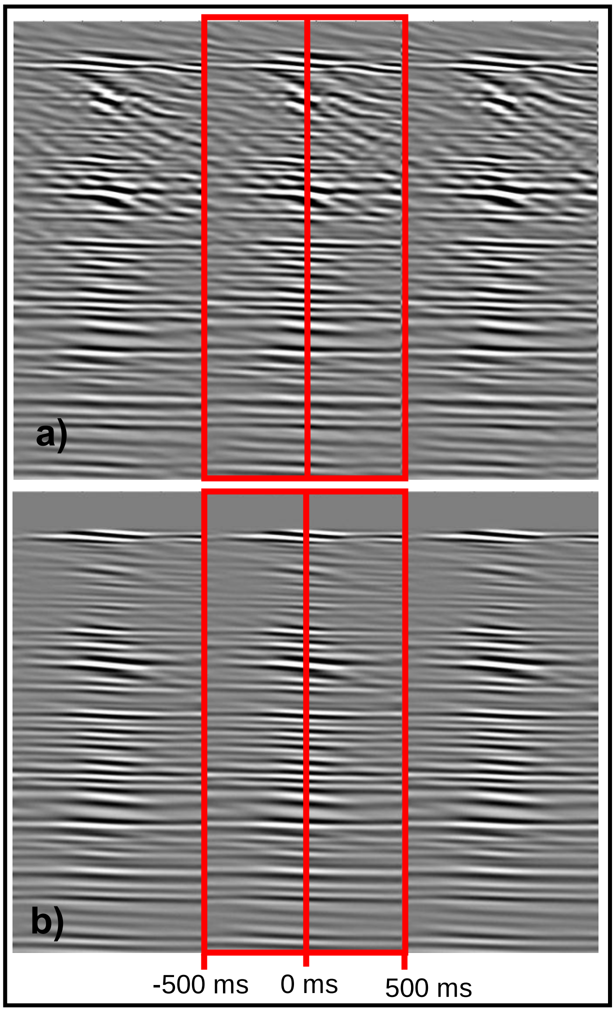

Figure 1. *Example of DIT gathers: a) raw DIT gathers; b) DIT gathers after gather conditioning.*

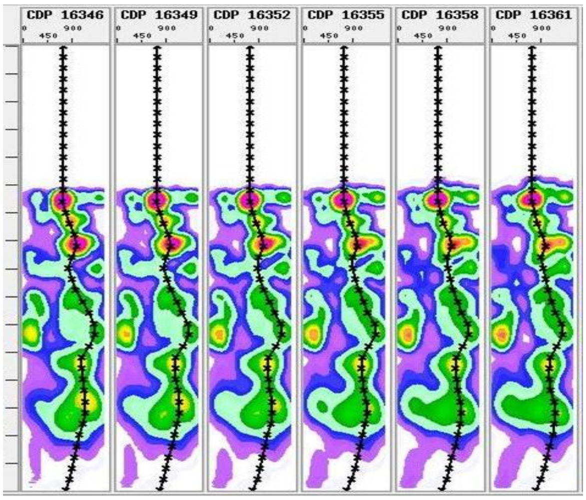

Figure 2*. Automatic DIT picking on semblance-like attribute.*

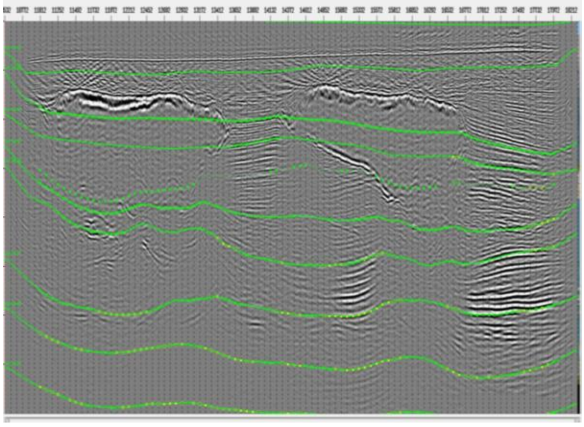

Figure 3*. Automatic surface creation using dip fields.*

Due to the high velocity contrast between the typically low velocity sediments and the high velocity 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 velocity. During the update we sometimes observe that the subsalt sediment velocity changes are merely compensating for salt interpretation errors introduced earlier in the salt model building stage. DIT scanning has proved to be an excellent tool for identifying interpretation errors in the salt picking.

There are two ways DIT scans can be used for identifying salt geometry errors in a salt velocity model. This section describes the first way, which is by comparing the DIT scan RTM images with the regular RTM image that corresponds to 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. Simply put, the purpose of DIT scans is to emulate velocity perturbation scans (Wang et al, 2006), where positive delays represent an increase in velocity. Clearly, with a positive delay time, not only is the base of salt (BOS) in the highlighted area much better imaged, but also the nearby subsalt events are much better focused and more coherent. Looking back at the salt velocity model it is clear that the original interpretation of the BOS is too shallow, therefore a positive delta velocity (positive delay time) is needed to compensate for the missing piece of the salt body at the BOS. Figure 5 is another 3D narrow azimuth (NAZ) example from GOM where by scanning through the 21 RTM-based scan image, the BOS image is clearly popped up at a negative delay time of 225 ms, though in the regular RTM image (corresponding to zero delay time) the BOS is not well defined.

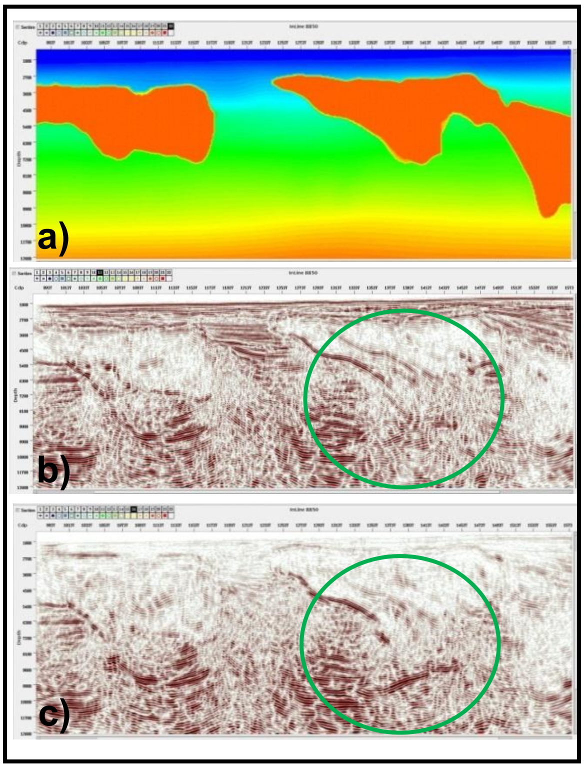

***Figure 4**. DIT scans for salt interpretation: a) initial salt velocity model; b) regular RTM image; c) RTM image with delay time of positive 300 ms.*

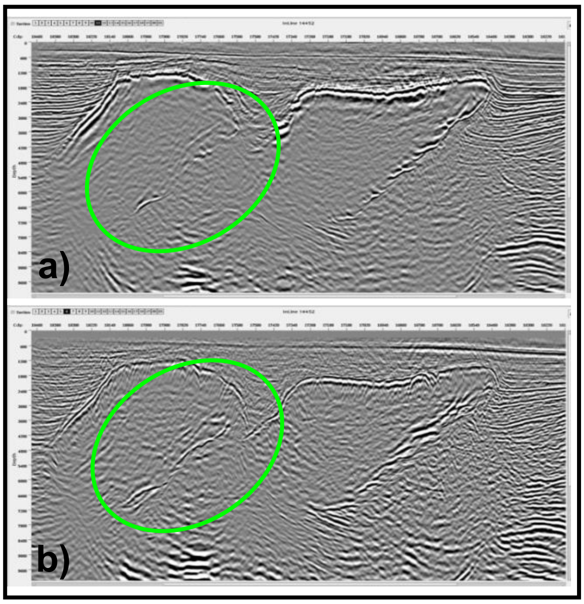

***Figure 5**. DIT scans for salt interpretation: a) regular RTM image; b) RTM image with delay time of negative 225 ms.*

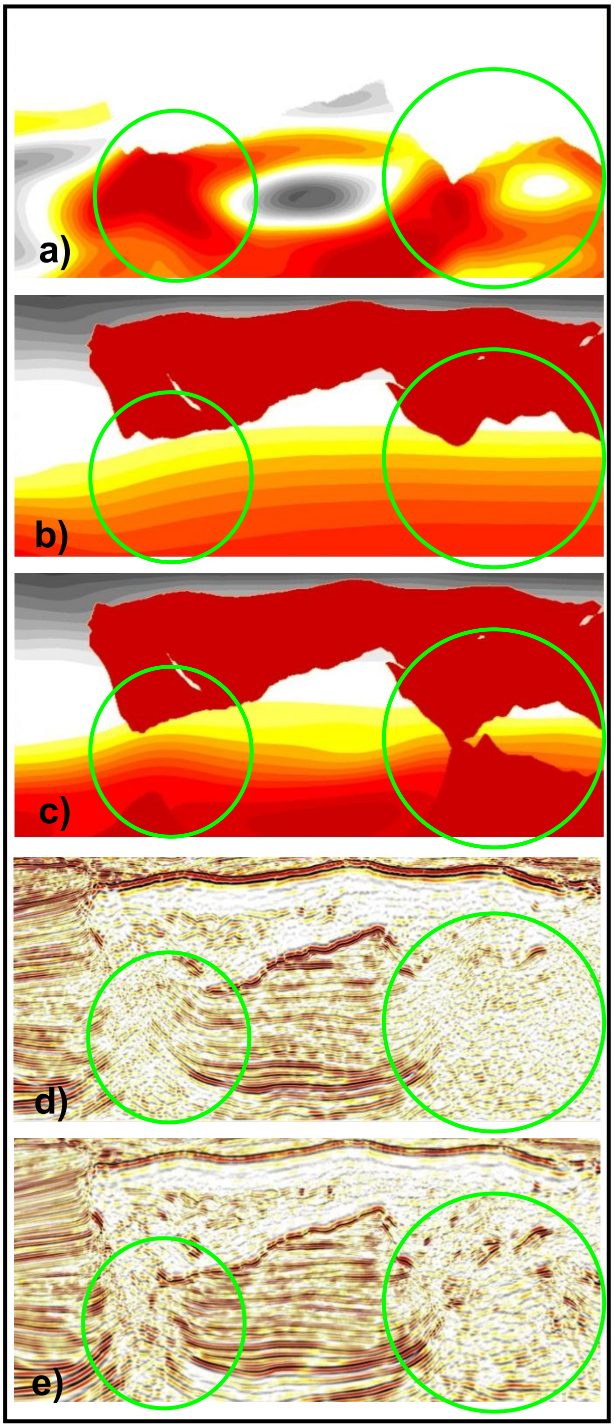

***Figure 6**: a) delta velocity model derived by DIT scans; b) initial velocity model; c) updated velocity model; d) RTM image using the initial velocity model; e) RTM image using the updated velocity model.*

DIT scans for salt velocity model building

Another way to identify a salt geometry error is illustrated 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 that there is a significant positive delta velocity right below the BOS in the two highlighted areas. 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 of 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, it is a strong indication that more salt needs to be added to the BOS.

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