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Imaging of Fractures and Faults Inside Granite Basement Using Controlled Beam Migration

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Summary

In this paper, we present a reprocessing case study that applied the latest processing technologies to improve the seismic imaging inside the granite basement reservoir. The highlight of this effort is the application of the latest Controlled Beam Migration (CBM) technology, and a stack sweep method for updating velocity inside the basement.

Key words: *Migration. CBM. Stack sweep.*

Introduction

The current study area is in the Cuu Long Basin, offshore Vietnam. In this area, the fractured granite basement forms an excellent reservoir rock, and is the main target of exploration and development activities (Nguyen and Hung, 2004). It is therefore important to image the granite basement with its fractures using seismic methods. However, past effort of imaging has met with difficulties. Two of the main challenges are the poor signal-to-noise ratio inside the basement and the imaging of the steeply dipping fractures. In 2002, a study was carried out in the area using Kirchhoff prestack depth migration, which included horizon-based model building up to the basement and constant velocity sweep below the top of basement. Even with this effort, it was difficult to interpret because the image was contaminated with noise. In particular, it was hard to distinguish the vaguely visible steeply dipping fractures from Kirchhoff migration artefacts.

With recent advances in imaging technology and velocity model building tools, we reprocessed the same data through prestack depth migration, and achieved significant improvements in signal-to-noise ratio and steep dip imaging inside the basement. We present the methodology and results in this abstract.

Methodology

Data preparation

Prior to migration, the acquired seismic data was processed through linear noise removal, demultiple, and fold and offset regularization. It is extremely important to preserve dipping primary energy in data preparation, especially at the stage of linear noise removal.

Velocity model building and update

Figure 1 shows the lithology and velocity structure of the study area, based on the available information at the start of the project. Water bottom is shallow, approximately 50 meters. For convenience of description, we divide the lithology into three groups. Group one is clastic layers having mostly gradient based velocity, except for a thin layer of velocity inversion that is detectable in sonic logs. Group two is the E sequence, which is also clastic but has a faster velocity. As a consequence, there is a high velocity contrast between group one and group two. Group three is granite. The depth of the top of the granite basement ranges from 2.4 km to 6 km. Sonic log measurements show the granite matrix velocity to be between 5500-6000m/sec. However, the 2002 imaging study found that a velocity of 4600m/sec was more applicable for the migration and stack response of the intra-granite fractures. The initial velocity model was built with the above information in mind.

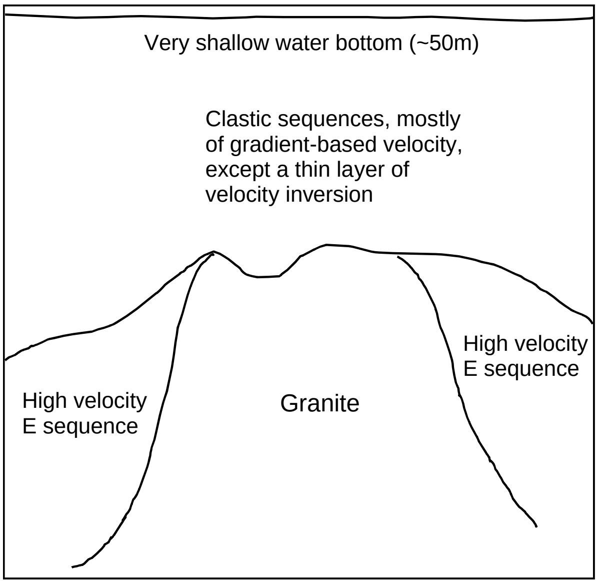

Figure 1 Schematic illustration of lithology and velocity structure.

The velocity update was carried out using tomography that is based on residual curvature analysis (RCA) of Common Image Gathers, in a top-down approach. The method was successful in group one, but met with difficulty on reaching the E sequence. There were two issues. The first was remnant multiples. As the primary reflection was weak below top E, the multiples appeared strong and were the dominant energy (Figure 2). It was therefore impossible to pick the residual curvature correctly. The second issue was in the limitation of RCA tomography itself. The residual curvature of CIG is less sensitive to velocity perturbation at deeper depth.

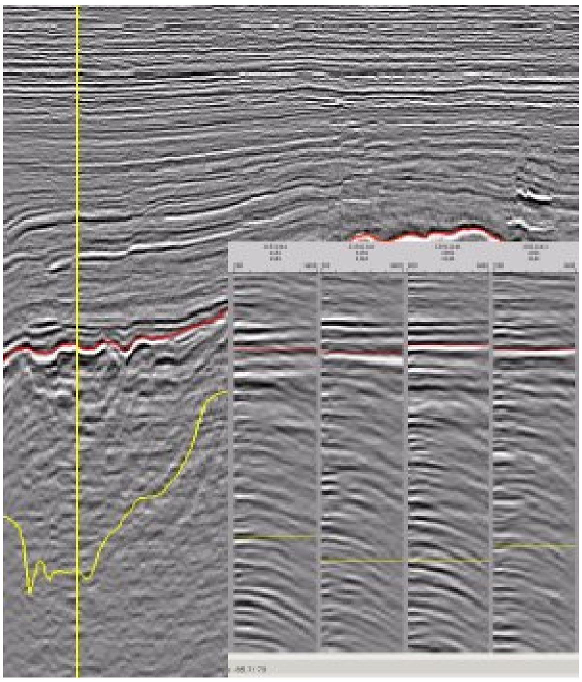

Figure 2. A stack section and some common image gathers (CIG) near a highlighted location. Red: top E. Yellow: top of the basement. The multiples are stronger than primaries below top E.

To continue the velocity update into the E sequence and the granite basement, we resorted to a stack sweep method that was developed for sub-salt velocity update in the Gulf of Mexico. We took the top E horizon as the upper boundary of the stack sweep (Figure 3). The velocity below top E was smoothed and used as the reference velocity, or 100% velocity. Six other velocities were generated by scaling the reference velocity below top E with 83.5%, 89%, 94.5%, 105.5%, 110% and 116.5%, respectively. The seven velocities were used to generate seven CBM (to be introduced later) stacks. We then swept through the seven stacks at each location and depth, and picked the preferred stack (Figure 4). The criterion for picking was based on both the quality of the signal and the geologic plausibility of the structure, so it was necessary to be done by or with the help of an interpreter. After all locations were picked, the picks were smoothed, and then fed into a 3-D tomography program to compute the final velocity (Figure 5).

Migration

Both Kirchhoff and Controlled Beam Migration (CBM) were used in the final migration. Kirchhoff migration was run to image shallow sections and to facilitate the AVO analysis, while CBM was used to image the top of the basement and the fractures inside the basement.

CBM has an advantage of enhancing signal-to-noise ratios and imaging steeply dipping events. In a medium of complex velocity, a subsurface point may have multi-arrivals. A conventional Kirchhoff migration is a single-arrival migration algorithm, representing a high-frequency approximation to the acoustic wave equation. When multi-arrivals occur, it has to select one of the arrivals depending on the specified criteria. This can result in poor imaging. Wave Equation Migration does not use ray paths to represent the propagation of wave fronts, and thus accounts for all arrivals. It produces cleaner images; but it does not image steeply dipping events well. CBM has the advantage of Kirchhoff migration and Wave Equation Migration. It handles multi-arrivals, resulting in a cleaner image than Kirchhoff migration, and preserves the steep dips.

Results and Discussion

The Kirchhoff migration image in the current study is better than the 2002 Kirchhoff image. However, for basement imaging, the major improvement came from CBM. A comparison of 2002 Kirchhoff migration and the current (2006) CBM migration is shown in Figures 6 to 8. The fractures that were barely visible in Kirchhoff migration were clearly imaged with CBM. The top of the basement is also better focused with CBM.

Conclusions

We have presented a case study using Controlled Beam Migration (CBM) to image the top of the basement and the fractures inside the basement. The image quality of CBM is superior to that of Kirchhoff migration.

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References

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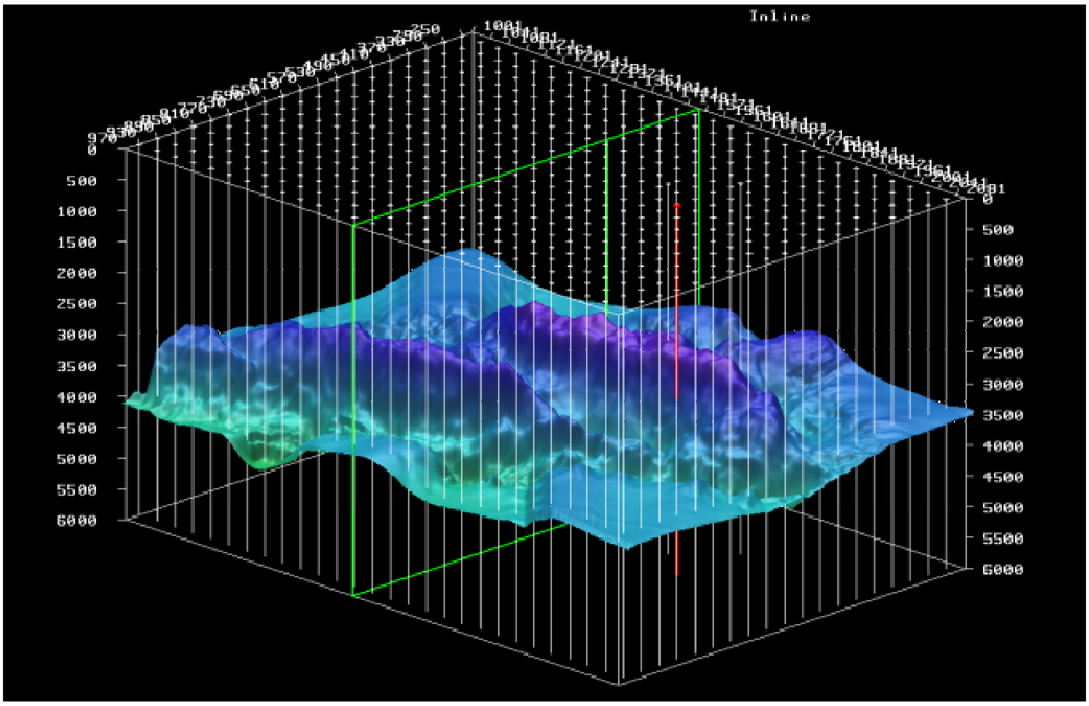

Figure 3. 3D view of the Top E horizon. Stack sweep starts below the top E horizon

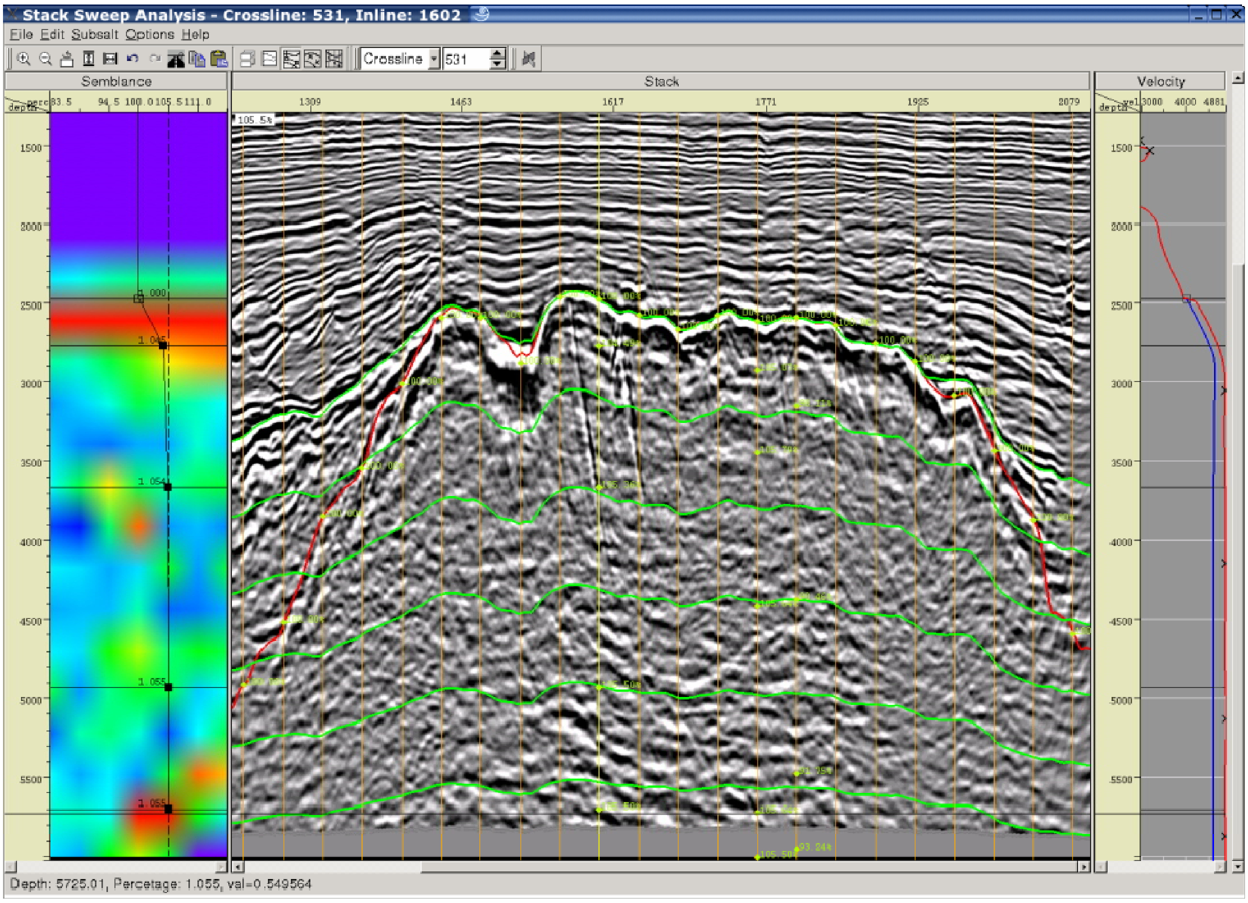

Figure 4. A snap shot of the stack sweep window.

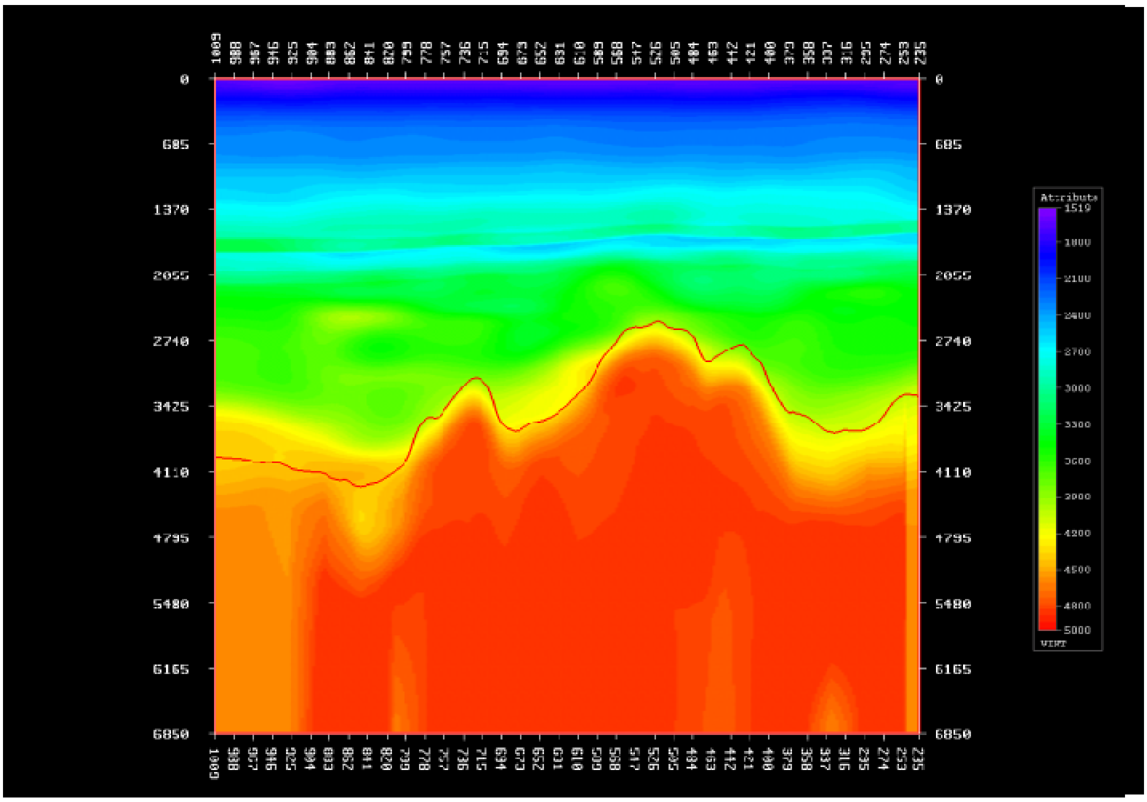

Figure 5. A section of the final velocity model, after stack sweep velocity update.

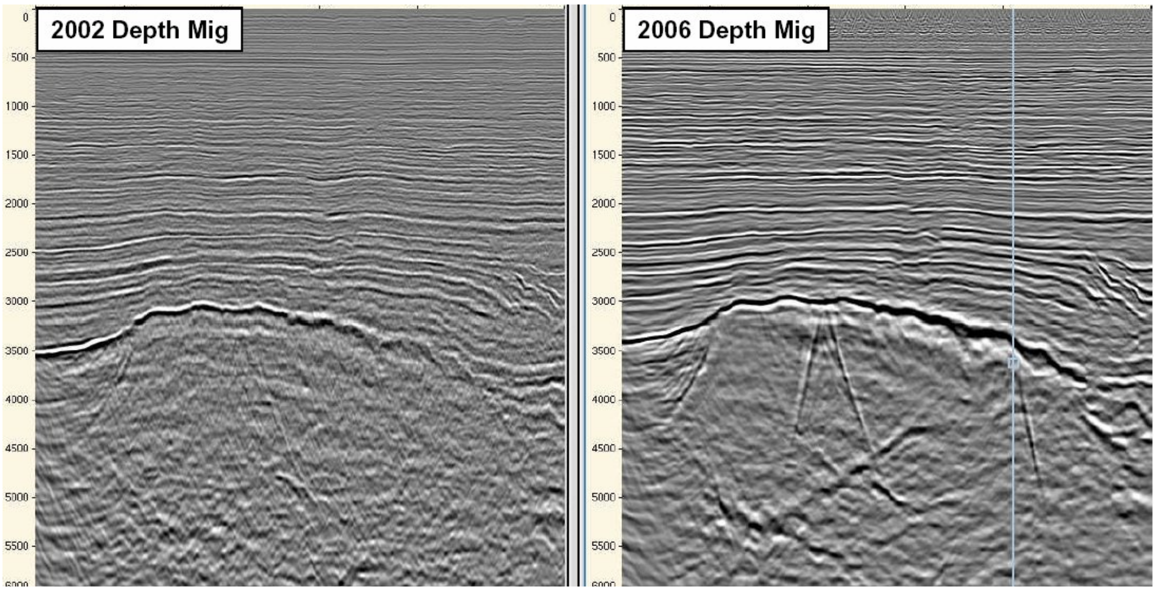

Figure 6. Comparison of 2002 and 2006 depth migration on a vertical section

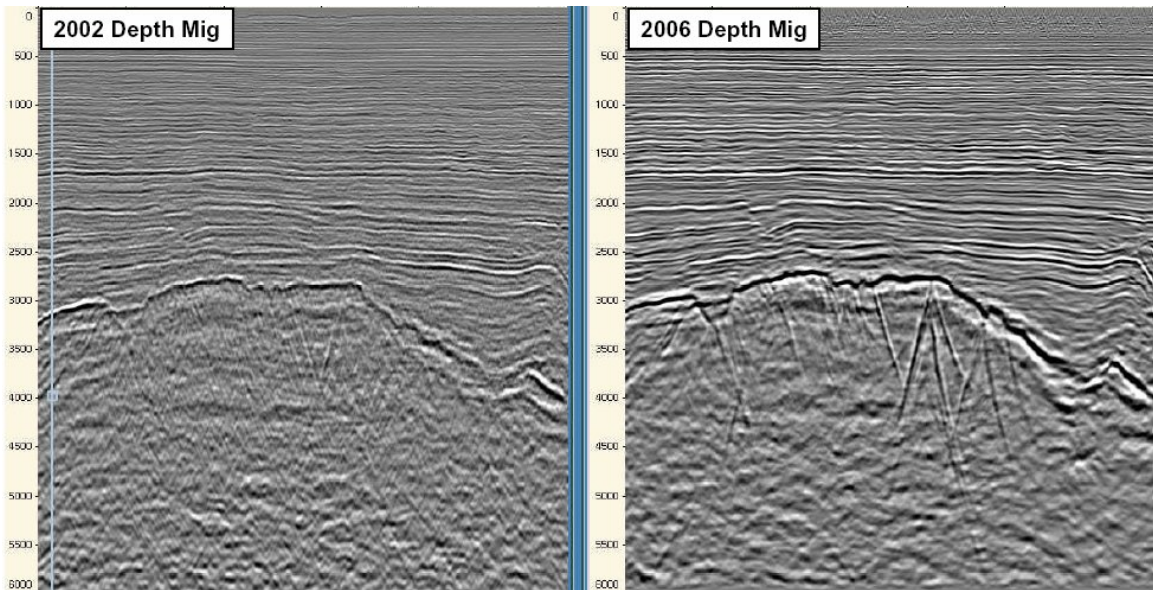

Figure 7. Comparison of 2002 and 2006 depth migration on a vertical section.

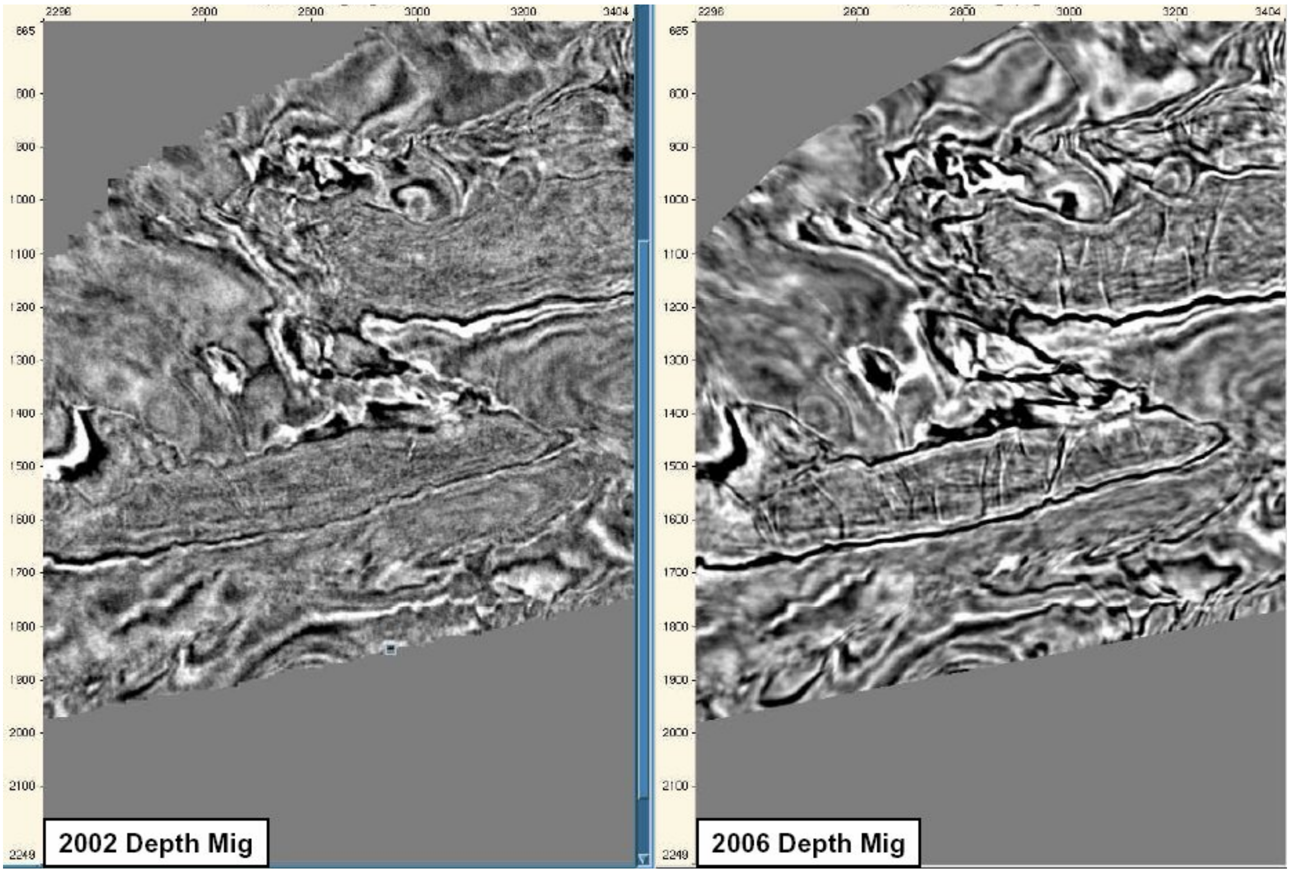

Figure 8. Comparison of 2002 and 2006 depth migration on time slices.