Wide angle screen method applied to pre-stack migration of a 2D syn thetic salt-like model

Franck Cyril Mignet and Xiao-Bi Xie, Institute of Tectonics, University of California, Santa Cruz CA 95064, F. Mignet is also Elf-Aquitaine.

Summary

The wide-angle screen propagator can be used for fast and accurate depth migration. In this study, we applied the method to the prestack depth migration of a complex 2D model. The model shows a number of challenging features to migration algorithms, e.g., strong velocity contrast and steep structures. Our results show that the wide angle algorithm gives good results in a complex model. We also studied the image from selected reflectors and artifacts using a shot versus position method. It reveals that the noise is mostly generated by the spreading of wave energy in the complex upper part of the salt body. We also suggest that the acquisition geometry share the responsability for imaging quality. The small aperture of shot-receiver combination prevented the wave traveling through the right part of the model to compensate that traveling through the salt.

Introduction

Fast and accurate imaging methods are crucial to today's oil and gas exploration. The phase screen (split-step Fourier) method (Stoffa *et al.*, 1990) provides an efficient migration propagator. Many of its modifications, e.g., the PSPI method (Gazdag and Sguazzero, 1984), Fourier finite-diference method (Ristow and Ruhl, 1994), wide angle improvement method (Xie and Wu, 1998) and the modified pseudo screen method (Jin et al. 1998) improved the accuracy of screen method especially for large velocity contrast and at wide scattering angles. They provided efficient and accurate algorithms for prestack depth migration in complex velocity structures such as salt domes. In this paper, the modified pseudo screen method by Jin et al. (1998) is used for migration test.

To evaluate capabilities of various migration methods on complex structures, the Institut Français du Petrole (I.F.P.), Elf-Aquitaine and C.G.G. jointly generated a challenging model and the corresponding synthetic data set. We will work on the data set for both testing the migration method and investigating the possible configrations of data aquisation that may improve the quality of the imaging.

Description of the model

Features of the velocity model. Elf-Aquitaine, I.F.P. and C.G.G. jointly generated a 2D-velocity model and data set for prestack migration, which will be used in this study. Shown in Figure 1 is the velocity model. The model is 13.1 km in horizontal and 5 km in depth. The number of grid is 524 point in horizontal by 200 in vertical, and both with a 25 m spacing. The model simulates a typical salt dome in North Sea. It shows many features challenging migration algorithms. The most obvious difficulty is the strong velocity contrast (ratio up to 2). Sharp interfaces exist on sides of the salt dome as well as between layers. Another challenging feature is the extremly complex zone at the top of the salt structure. The wall of the salt body are particularly interesting: almost vertical in zone 1 Figure 1. This pattern is especially challenging, since the standard phase screen operator is valid only for small scattering angles and small velocity perturbations. There is a hanging wall on the right hand side of the dome, of which we can expect a 'shadow zone' (zone 2, Fig.1). On the left side of the salt body, note narrow angle junctions between horizontal interfaces and the wall (zone 3, Fig. 1).

The data set. The data were generated by I.F.P. using a finite difference method which is second order in both time and space. 127 traces were computed for each of 261 shots. The source is on the left hand side of the receiver array. The receiver space is 25 m and the shot space is 50m. The minimum and maximum offsets for the receiver array are 200 m and 3350 m, respectively. Record length is 5 s with a 4 ms sampling interval. The data set has been preprocessed including mute, antimultiple and cylindrical geometrical spreading correction.

Preliminary results

Parameters. Shown in Figure 2 is the migrated image obtained with optimized parameters. We use 370 frequencies in computation ranging from 5Hz to 50Hz. For each shot, a sliding window of 256 points is used. The window is approximately half the model size. In order to process the whole data set, we extended the velocity model at both ends following a reasonable' assumption of laterally invariance. The receiver array is centered in the window. The CPU time is 196s per shot on a SUN ULTRA 1 workstation. 47% of the CPU time is spent in the wide angle correction.

Interpretation First we see that most of features of the model are correctly reconstructed, especially on the uppermost part of the salt dome. The staircases on the second layer boundary (left of the salt body, Figure 2, zone 1) are perfectly reconstructed. This gives us a good idea on the horizontal resolution in the shallow part. As for the vertical resolution we observe that the third and fourth layers are distinctly imaged (zone 2). On the left wall, we see clearly the horizontal interfaces joining the wall without crossing it (zone 3). The hanging wall of the salt dome is also imaged although somewhat discontinuously (zone 4). Regarding the steepness of the salt body, it is not well imaged. The upper part of the wall goes down too deep but the lower part, although light, is located at the right position. The stronger and less dipping upper part concealed the lower and more dipping part. The reflectors on the right side of the salt bottom (zone 5) are hidden in the migration noise and can not be seen. We will investigate the noise in the next section.

Noise study

Method As indicated in the previous section, migration noise concealed the image in the lower right part of the salt dome, where we previously pointed out as a potential shadow zone. In order to find the origin of the noise and possibly a way to eliminate it, we selected some typical reflectors and artifacts from the image. Then looked at the contributions from individual shot to these images. This method is similar to the so-called coherence panel study. It is equivalent to look at the result in the shots versus curvilinear abscissa along the selected images. We chose five objects shown in Figure 3 a to e. The first two are reflectors located on the upper and lower part of the right flank of the salt body. The third one is a typical migration-related artifact. The fourth one is the image of the top salt reflector and the last one is the left flank of the salt dome. Figure 4 gives the image distributions, where a to e correspond to that marked in Figure 3. The horizontal coordinate is shot and the vertical coordinate is the location along the marked line in Figure 3.

Interpretation Comparing the results it appears clearly that energies that compose image d and e, located on the upper left side of the dome, are much more coherent than the rest of images. For each well-imaged point on a reflector, the energy comes from less than 15 shots, and their contributions are coherent. On the other hand, the energy composing the hanging wall (Fig. 4a and 4b) spreads over more than 30 shots for each point. Contributions from one shot to another sometimes show opposite signs which resulting in an incoherent summation for the image. For image c, which does not correspond to any existing reflector, we found that the main contribution comes from less shots but the image oscillate strongly from positive to negative, which shows the inconsistency of arrivals from different shots. Note that the energy in this area comes from the same shots which imaged the upper part of the salt dome.

This lead us to two conclusions. First, the energy imaging the hanging wall passed through the complex top of the salt body. The strong velocity contrast and the narrow edge in this area play a major role in dispersing the energy. This process may lower the resolution in the deeper part of the model. Second, a wider receiver array together with the information coming from the right part of the model may improve the final image. Backpropagated energy coming from the right side would then compensate the noise. Note also that the energy show a trend to shift to the most right source position when the point move to left on the reflector for the upper part of the hanging wall (fig 4a) indicating that we pass the focusing point.

Conclusions

In this paper, we present some tests that apply the wide angle phase screen migration method to a 2D-synthetic salt model. This model shows every challenging features for a migration algorithm and may be used later as a standard test for future improvement. The results are good even for strongly dipping reflectors which are well-positioned without crossing boundaries. The extremely complex top part of the model is well imaged in both horizontal and vertical directions. The hanging wall of the salt dome is partially imaged. However the near vertical section is practically absent. On the right side of the salt body, some migration noise appears and contaminated the image. This noise comes mostly from the complex and high contrast zone in the shallow part of the model. We also suggest that a small shot-receiver aperture may lost part of the energy that will compensate and eliminate the noise.

Acknowledgments

We thank Dr. Shengwen Jin for providing the prestack migration program. This work is supported by the WTOPI (Wavelet Transform On Propagation and Imaging for seismic exploration) project at UCSC. We are grateful to the sponsors. We thank Elf-Aquitaine, I.F.P. and C.G.G. for providing us with the model and data set here used. The facility support from the W. M. Keck Foundation is also acknowledged.

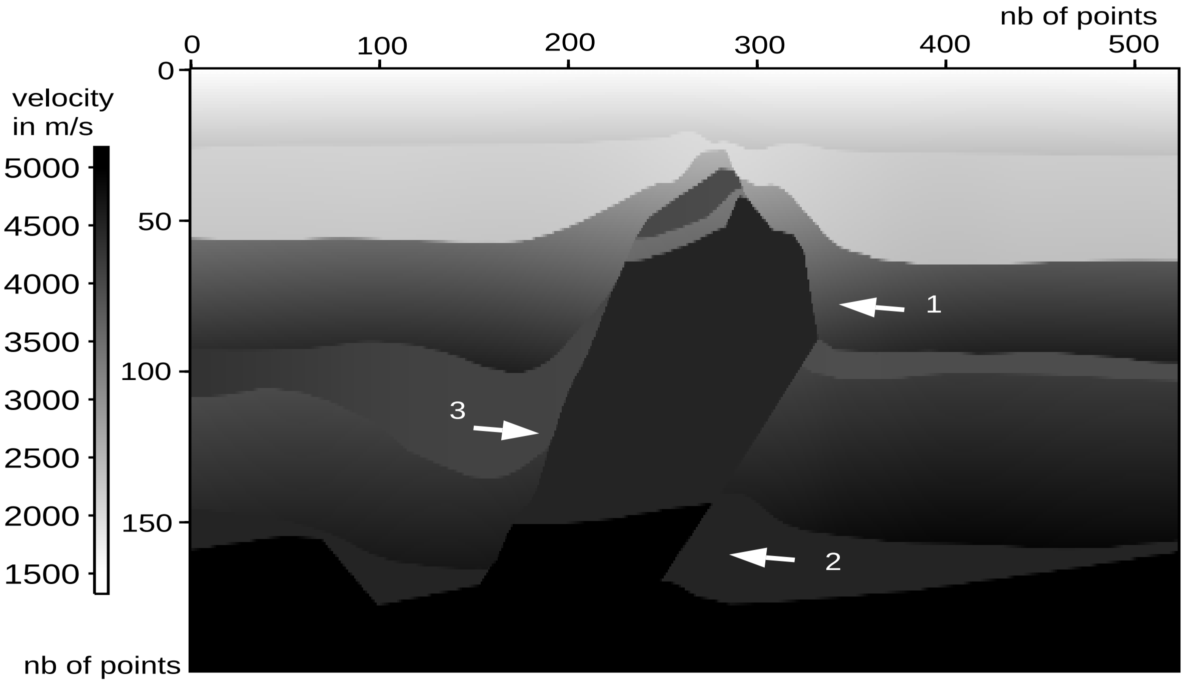

Figure 1: The velocity model.

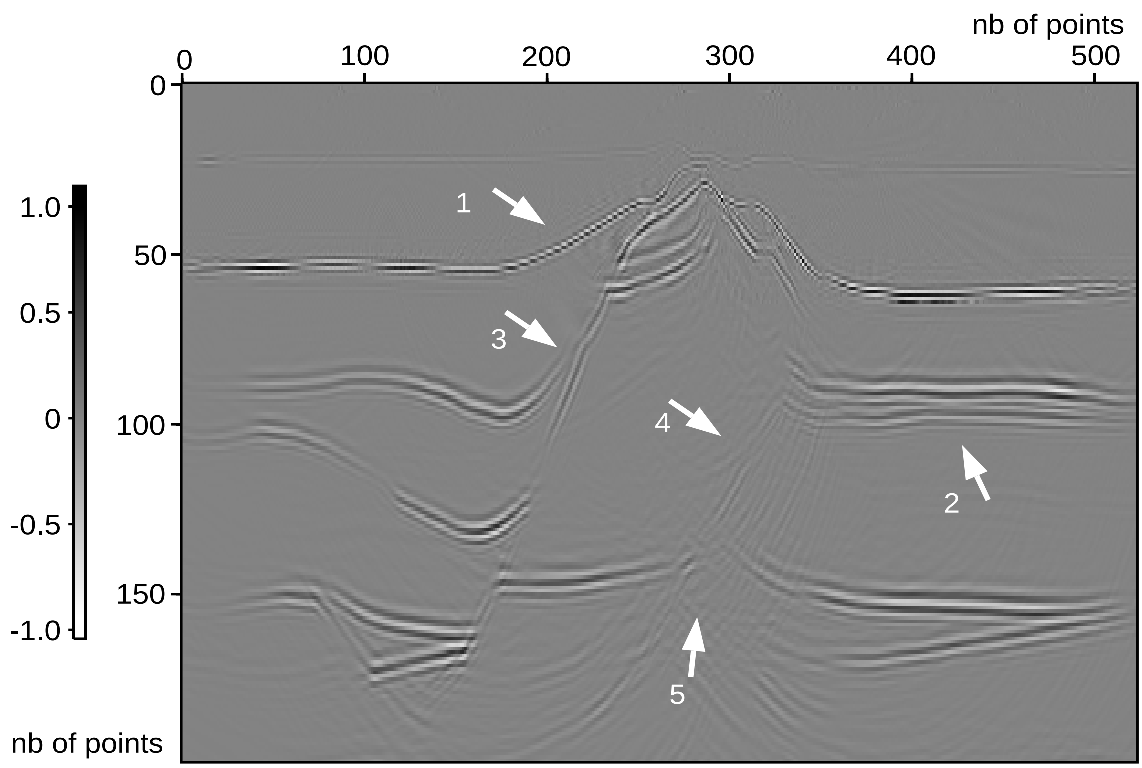

Figure 2: The wide-angle migration result.

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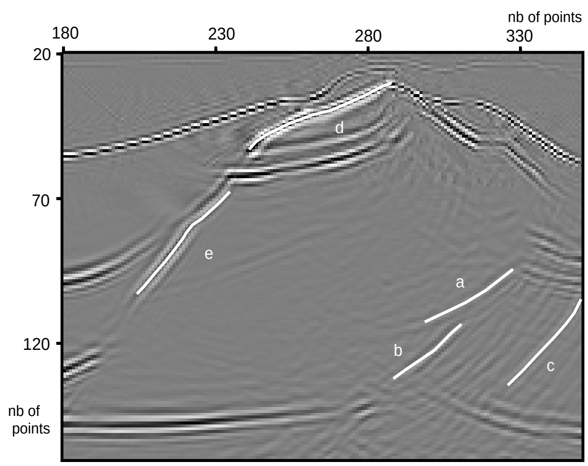

Figure 3: Selected artifacts and reflectors used for the investigation in Fig.4.

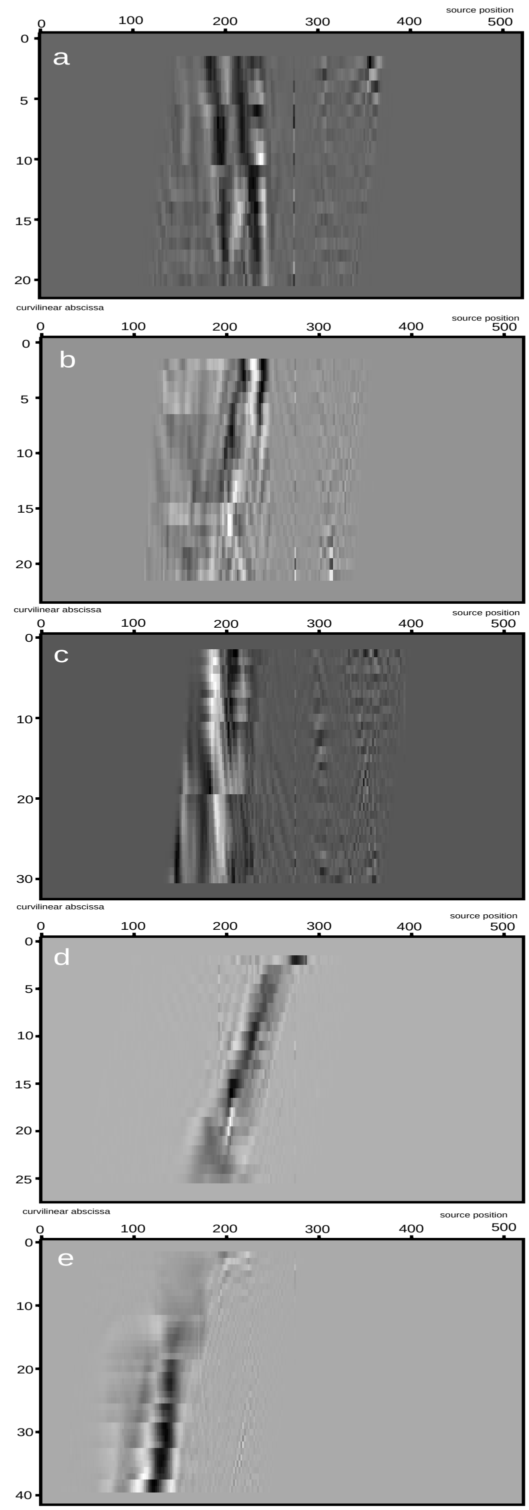

Figure 4: Results in shot versus curvilinear abscissa along images shown in Fig. 3. a-e correspond to that in Fig. 3.