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Tomostatics applications for basalt-outcrop land and OBC multi-component surveys

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SUMMARY

Tomostatics have been recently applied to two types of data sets. The first is from the Middle East region where the near surface layer is exhibiting high-velocity basalt outcrops and the second is a multi-component (4C) OBC data set containing low-velocity gas clouds. Near-surface velocities estimated from turning-ray tomography provide useful information for geologic interpretation and structural imaging. Tomostatics have shown advantages over traditional refraction statics in regions where (1) no refractors can be easily identified, and (2) high velocity materials (e.g. basalt) are overlaid on top of the low velocity sediments immediately below the topography.

P-wave velocities estimated from turning-ray tomography can be used to calculate the traveltime contours. Correlating P-wave and converted-wave traveltimes would allow us to estimate Vp/Vs ratios, leading to a practical approach for converted-wave long-wavelength statics solution.

INTRODUCTION

Seismic exploration in the Middle East usually suffers from near-surface effects, especially in areas with high-velocity basalt outcrop. These near-surface velocity anomalies will not only result in poor stack images in processing, but also will introduce long-wavelength misleading structures for interpretation. Recently, Tomostatics (Zhu et al., 1992; Stefani, 1995) were applied employing turning-ray tomography in order to estimate shallow velocity anomalies. The estimated near-surface velocity field was subsequently used to remove the long-wavelength statics anomalies caused by high-velocity basalt pull-ups. Consequently, the improved images have reduced the seismic exploration risk in basalt-outcrop regions.

Ocean-bottom-cable (OBC) surveys, on the other hand, have been widely used today for recording 4-component (4C) seismic data. OBC multi-component data has been successfully used to image structures beneath gas clouds. If the gas clouds are relatively shallow, we can use turning-ray tomography to estimate P-wave velocities and the associated long-wavelength statics in order to improve P-wave and converted wave images. This is especially important when both shot and receiver time delays are affected by the lateral extent of the gas clouds.

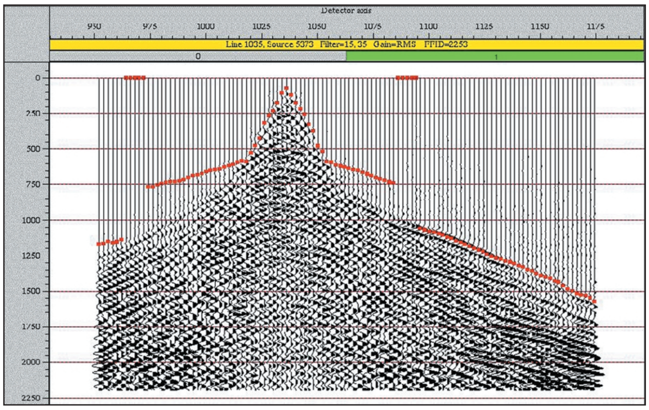

Fig. 1. Representative shot record and picked first arrivals from a basalt-outcrop land survey.

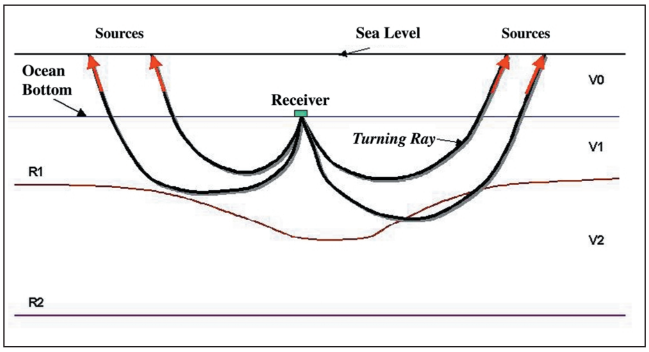

Fig. 2. First arrivals picked from common-receiver gathers for ocean-bottom-cable (OBC) turning-ray tomography, using reciprocity principle.

METHOD AND RESULTS

Tomostatics stands for turning-ray tomography plus statics corrections (Zhu et al., 1992). In turning-ray tomography, first-arrival travel times (Figure 1) are picked as input. The solution involves minimization of the difference between the observed traveltimes and those predicted by ray tracing through an initial model. The solution is iterative and contains five steps: (1) picking of first arrivals, (2) ray tracing through an initial estimate of the velocity model, (3) segmenting raypaths into the portion contained in each cell of the velocity model, (4) computing the differences between the observed and predicted traveltimes for each ray, and (5) iteratively back projecting the time differences to produce velocity-model updates. Velocity update is performed by a simultaneous iterative reconstruction technique (SIRT), that is, the velocity is updated once after all rays pass through a cell, using an average correction for the update. Usually an initial velocity model can be estimated from slopes and intercept times on the shot records, or

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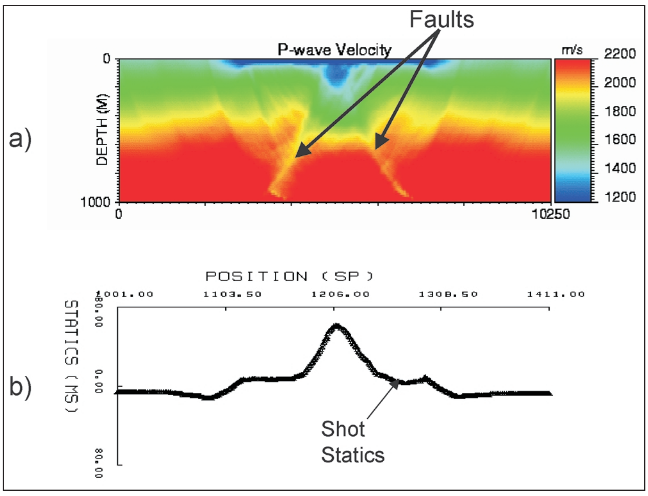

Fig. 3. Estimated near Ocean-bottom velocities and Statics. a) P-wave velocities estimated from turning-ray tomography; b) Shot statics calculated from the velocity image (a).

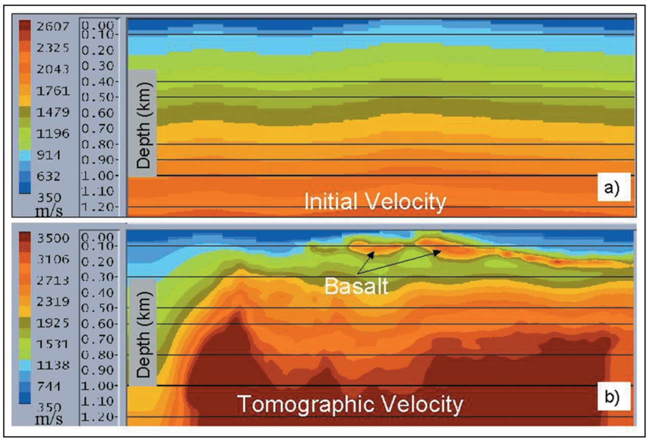

Fig. 4. Velocity models from a basalt-outcrop land survey. a) Initial velocities estimated from regional geologic information; b) Tomographic velocities. Tomostatics for both shots and receivers are calculated from b).

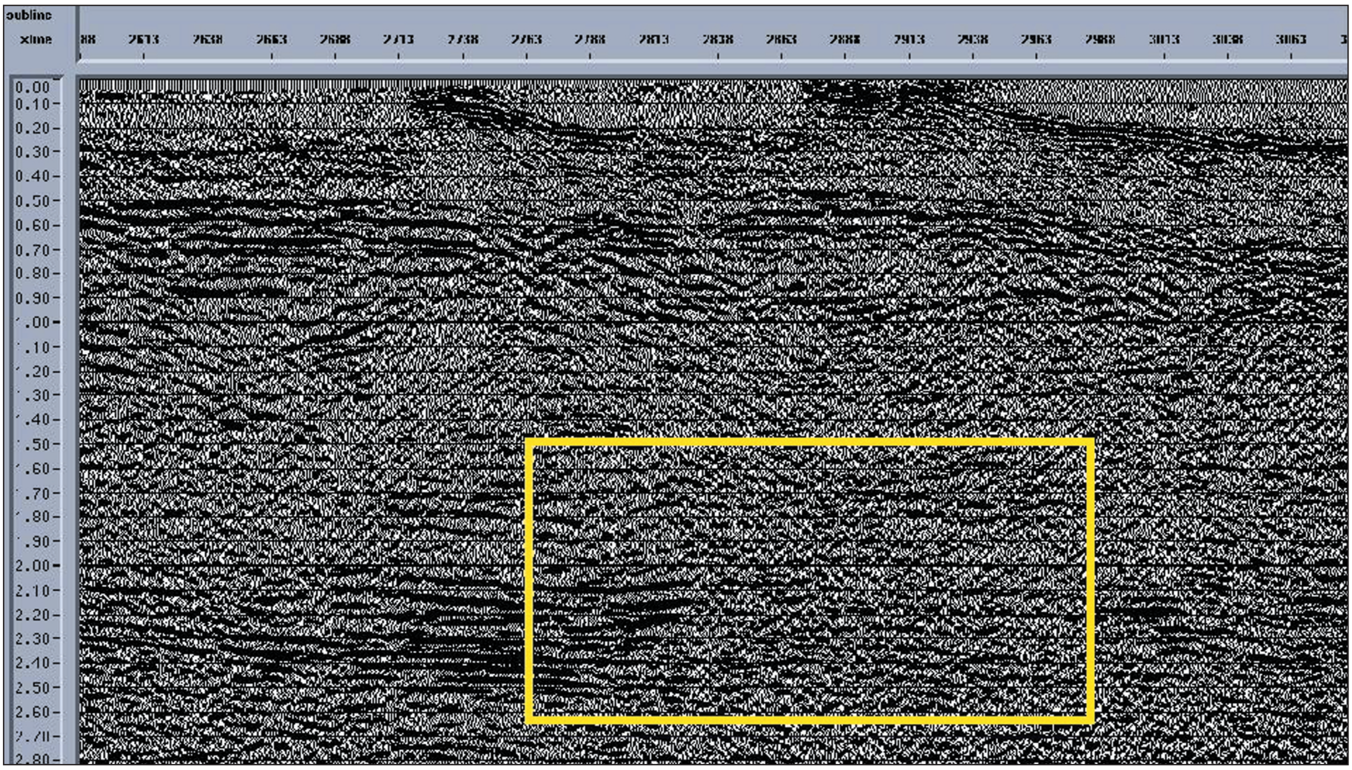

Fig. 5a. Stack section with elevation and residual statics.

from regional geologic information. In static corrections, shot and receiver statics are calculated vertically from the surface to a downward continuation datum (or pseudo datum) using the computed near-surface velocity field. The main advantage of Tomostatics over conventional refraction statics is that Tomostatics could produce better structural images in areas where the first arrivals cannot be modelled by head waves or refractions.

For OBC surveys, we usually have more shots than receivers. Using the reciprocity principle (Figure 2), we can easily pick first arrivals from common-receiver gathers as input for turning-ray tomography.

Figure 3 shows the P-wave velocity image estimated from turning-ray tomography and shot statics calculated from the velocity image from an OBC 3D4C survey in a gas-cloud area. Seeping gas from the deep formation along the faults is clearly visible on the tomographic image.

P-wave velocities derived from turning-ray tomography could be used to calculate the P-wave traveltime contours. By correlating P-wave and converted-wave traveltimes, we can estimate Vp/Vs ratios. Once Vp and Vp/Vs ratios are estimated, we can get both shot and receiver statics for the converted waves. This works for areas with or without gas clouds.

Figures 4 and 5 show a high-velocity basalt-outcrop land example. Figure 4a depicts an initial velocity model provided by regional geologic information. Figure 4b displays the final velocity model obtained via turning-ray tomography after 5 non-linear iterations (ray-tracings) with 15 linear iterations for each ray tracing. High and low velocity anomalies are clearly visible at the

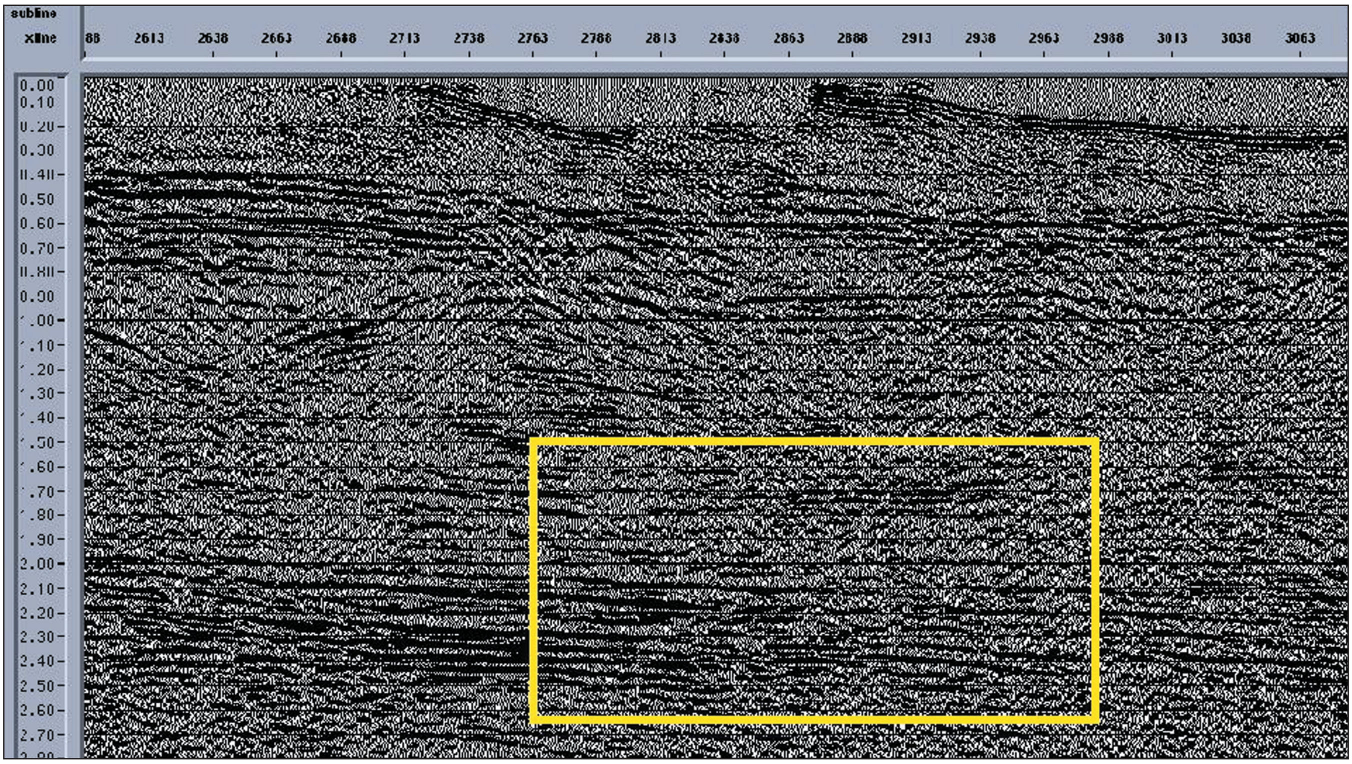

Fig. 5b. Stack section with Tomostatics and residual statics.

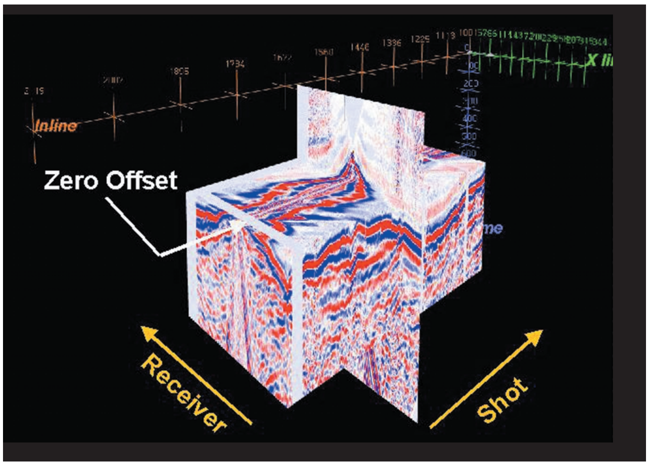

Fig. 6a. A 2D seismic line loaded into a virtual reality system as a seismic cub.

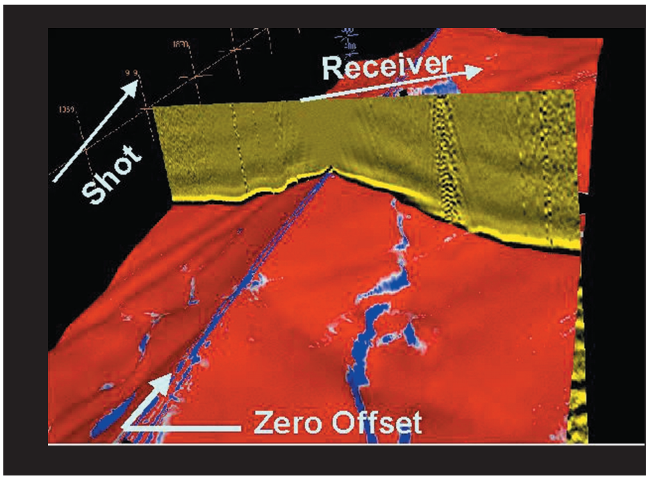

Fig. 6b. First arrivals picked in three dimensions.

shallow part, which cause both short and long wavelength static problems in stacking (Figure 5a). After the application of the computed tomostatics, events at both shallow and deep parts are better imaged and more easily interpreted (Figure 5b).

CONCLUSIONS AND DISCUSSIONS

We have shown with field data examples that tomostatics is enhancing interpretation and is applicable in the Middle East region and is adequate for OBC multi-component acquisition surveys. One of the challenges is how to pick the first breaks in production processing, which is especially true for 3D surveys. The efficiency and accuracy of the first-break picking can be improved by utilizing a virtual reality system. In the virtual reality system, a 2D line can be formed as a cube (Figure 6a) and the first arrivals are picked automatically to form a three dimensional sheet (Figure 6b). Several numbers of control points may be required, depending upon the complexity of the first arrivals. Given 200,000 traces of a 2D seismic line from Rocky Mountains, it only takes less than 10 minutes to pick the first arrivals with 14 control points. It is easy to pick, QC and edit the first arrivals using the virtual reality system. Yet another area to be further investigated is how to utilize the reliable near-surface velocity model estimated from turning-ray tomography for prestack depth migration.

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