ELASTIC PRESTACK, REVERSE-TIME MIGRATION

Yue Wang

ABSTRACT

Elastic prestack, reverse-time depth migration is applied to both synthetic data and four-component field data from the Valhall area. Reverse-time extrapolation of the recorded multi-component data is by 2-D elastic finite difference solution to the full wave equation. An eikonal solver is used to compute the acoustic travelt ime from the source to the image points. By using horizontal inline and vertical particle velocity components, the converted P-to-S reflections are imaged simultaneously with the primary P-wave reflections, shot by shot. Synthetic results showed that the elastic reverse-time migration gave better images of the subsurface structure than traditional Kirchhoff-like migration. Preliminary field data results show the feasibility to image the earth structure using the reverse-time migration.

INTRODUCTION

Reverse-time prestack migration has the advantage of imaging complex structures when strong lateral velocity variations and/or steep dips exist. It was also reported by Thomsen et al. (1997) that P-to-S converted waves recorded by a multi-component ocean-bottom survey could be used to improve the image quality when primary P-wave reflections fail to image the target’s reservoir overburden by gas seepage. Traditional multi-component data processing typically separates the P and S wavefields and then processes them separately. The success of the separation method depends on the knowledge of the sea-bottom’s elastic parameters, and the final separated P- and S- wavefields are still polluted with each other’s wave modes.

Elastic reverse-time prestack depth migration can be used to treat data in vector form. It also automatically images both the primary P-wave reflections and the
P-to-S converted reflections. As an example, Chang and McMechan (1994) applied 3-D elastic prestack, reverse-time depth migration to some synthetic data set. Computational resources still limited the elastic reverse time migration to small field data sets. Here we apply the 2-D elastic reverse time migration to both synthetic and field data set. We also discuss the possibility of decreasing the computational cost by using variable grid scheme (Wang and Ji, 1996) and phase-encoding technique (Morton and Ober, 1998).

IMPLEMENTATION

Reverse-time extrapolation

The reverse-time extrapolation algorithm is implemented using a staggered-grid finite-difference scheme with second-order accuracy in time and fourth-order accuracy in space. The process is applied to each shot gather, where recorded multi-component data are reversed in time order and applied at the corresponding receiver position as sources for reverse-time extrapolation.

Image condition

The algorithm starts from the final time $t_f$ and proceeds in reverse time. At one time $t_1 < t_f$, the image condition is:

$$t_p(x, x_s) = t_1; \quad (6.1)$$

where $t_p(x, x_s)$ is the one-way P-wave travelt ime from the shot location to spatial location $x$. If the image condition above is satisfied, the vector wavefields at location $x$ are retained. An eikonal solver was used to calculate the one-way P-wave travelt ime.

SYNTHETIC EXAMPLES

Figure 6.1 shows the common shot records for an eight-layer model (Figure 6.2). The first layer of the model is the water layer where the S-velocity is equal to zero. Pressure sources were exploded on the free surface and geophones were located at the water bottom. A finite-difference staggered-grid solver was used to generate the shot records.

Figure 6.3 shows the results of applying Kirchhoff migration to each different component of data separately. For the horizontal component, the P-to-S converted-wave image condition was used. Because the P- and S- wavefields are not separated and multiples are not attenuated, the Kirchhoff migration produced many artificial layers. Figure 6.4 shows the reverse-time migration results using multi-component data simultaneously. Fewer artificial layers were generated. This is more clearly shown in the comparison with the true eight-layer model (Figure 6.5).
FIELD DATA EXAMPLES

Some preliminary tests were done on the Valhall field data (Thomsen et al., 1997). Figure 6.6 shows one common shot record of the Valhall data. Each geophone group has eight geophones where the geophone groups were not continuously shifted in the survey so that the reflections are not continuous in the common shot record. A total of 181 shot gathers were migrated here. Figures 6.7a and 6.7b show the Kirchhoff migration images using the horizontal and vertical component records, respectively. Figure 6.8 shows the reverse-time migration image. For the deep part, the reverse-time migration gave better images of the target area at a depth of about 3,500 m. However, there is still some question as to which method provided the best imaging because the actual reflectivity profile is not known. Further work is necessary.

HOW TO DECREASE THE COMPUTATIONAL COST?

Elastic prestack reverse-time migration is much more expensive than the conventional migration processing method. To practically apply the elastic reverse-time migration to field data, especially for 3D data, two possible schemes can be used to decrease the computational cost. For sea-bottom data associated with a low-shear-velocity contrast, representing an unconsolidated sea-bottom, an adaptive grid method can be used to extrapolate the wavefield using a fine grid for the shallow part and a coarse grid for the deep part. For this example, this method can decrease the computation cost by an order of magnitude (Wang, 1996). The phase encoding technique in the frequency-domain proposed by Morton and Ober (1998) can also be applied here. Recently we received a land-survey 3-component data set and an ocean-bottom 4-component data set. The adaptive grid method and the phase encoding technique will be implemented in our reverse-time code and applied to these two field data sets.

REFERENCE


Wang, Y. and Ji, X., 1996, 3-D viscoelastic adaptive grid finite-difference modeling:
University of Utah Tomography and Modeling/Migration Development Project, 1996 Midyear Report.
Figure 6.1: Common shot records for an eight-layer model: a) hydrophone pressure; b) horizontal particle velocity; c) vertical particle velocity.
Figure 6.2: P-velocity of an eight-layer model.
Figure 6.3: Migration images by Kirchhoff migration using a) hydrophone pressure; b) horizontal component; c) vertical component data, respectively.
Figure 6.4: Migration images by elastic reverse-time migration using multi-component data simultaneously: a) pressure; b) horizontal component; c) vertical component image, respectively.
Figure 6.5: Migration images compared with the true model: a) Kirchhoff migration image; b) true velocity model c) elastic reverse-time migration image.
Figure 6.6: Common shot record for Valhall field data set: a) horizontal component; b) vertical component.
Figure 6.7: Kirchhoff migration images for Valhall field data set: a) horizontal component; b) vertical component.
Figure 6.8: Reverse time migration images for Valhall field data set: a) horizontal component; b) vertical component.