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Interval velocity estimation from beam-stacked data — field-data results

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ABSTRACT

My velocity estimation from beam-stacked data successfully reconstructs a velocity anomaly from a field data set. Using the estimated velocity model for depth migrating the data corrects the effects of the anomaly on the positioning and focusing of the reflectors. The estimated anomaly well explains the perturbations in the beam-stacked data caused by the actual velocity anomaly. An analysis of the transformed data also shows that the resolution of beam stacks is sufficient for measuring different effects of the velocity anomaly on the moveouts of the reflections at different offsets.

INTRODUCTION

Tomographic methods are needed for estimating a velocity model that varies rapidly along the lateral direction. In previous reports I presented the theory (Biondi, 1988) and the synthetic results (Biondi, 1989) of a velocity-estimation method capable of reconstructing velocity anomalies shorter than the cable's length. In this report I present the results of applying the method to the problem of estimating a velocity anomaly from a real data set.

The data set is particularly interesting for testing a velocity-estimation method because the velocity anomaly is shorter than the cable's length and it is not located near the surface but it is centered at a depth of about 1.5 kilometers. Therefore both the lateral and the vertical resolution of the estimation method are tested by the problem presented by the data. Furthermore the pull-down in the reflections caused by the anomaly can be corrected only if a good velocity model is used as an input for depth migration.

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DESCRIPTION OF THE DATA

The data that I present in this report are part of a marine survey donated to SEP by AGIP. The data were recorded with steam-gun sources and a 2.35-km cable. The shot spacing is 25 m and the group interval is 50 m; consequently the midpoint coverage is 48 fold and the midpoint spacing is 25 m. I sorted the data in common-midpoint gathers and kept the 341 gathers that were full fold. The data were sampled every 2 ms and were wide-band in frequency, reflected energy was as high as 100 Hz. SEP received the data already gained and deconvolved; I then muted the data to eliminate the first arrivals and dip-filtered the constant-offset sections to remove some steeply dipping noise. Figure **??** shows a typical common midpoint gather (CMP) of the data set, together with its beam-stacks.

Figure **??** shows the stack of the data. The velocity anomaly causes the large pull-down visible in the stacked section near the midpoint location of 5.5 km. The data set does not need to be migrated before stack, because the reflections underneath the anomaly stacked coherently, even if their moveouts were not hyperbolic. On the other hand, a poststack depth migration and a good velocity model are needed to position correctly the reflectors. Depth migration is particularly needed for correctly positioning the top of the anticline, which has been flattened by the velocity anomaly. The conventional methods for estimating interval velocity from stacking velocities cannot be used for this data set because the anomaly width, which is about 2 kilometers, is smaller than length of the cable. Therefore this data set is a good test case for a tomographic velocity estimation method such as the one using beam stacks.

DESCRIPTION OF THE VELOCITY ESTIMATION PROCEDURE

The velocity-estimation method that I described in previous reports (Biondi, 1989; Biondi, 1988) is based on the maximization of beam stacks' energy at the traveltimes and surface locations predicted by the velocity function and modeled with raytracing. Therefore in order to estimate the velocity, I computed beam stacks from the prestack data for 12 offset ray parameters p_h, from .05 s/km to .336 s/km, and for three midpoint ray parameters p_y, from -.04 s/km to .04 s/km. I transformed the beam-stacks according to the coordinate transformation introduced in the previous report (Biondi, 1989), assuming a constant velocity of 2.5 km/s. I then smoothed the transformed data along the midpoint axis and the time axis using Gaussian windows. The smoothed and transformed data from the 250 midpoint positions located around the anomaly were used by the velocity estimation.

The starting solution for the iterative estimation algorithm was a velocity profile function of depth, but constant in the lateral direction. This velocity function was derived from conventional stacking velocity analysis applied to a few of the CMP gathers. The estimation procedure started with few conjugate gradient iterations until the velocity model predicted the gross feature of the beam-stacked data, and then continued with some Gauss-Newton iterations for better estimating the finer components of the velocity function.

THE ESTIMATION RESULTS

The result of the estimation process is a velocity model with a velocity anomaly located around the midpoint location at 5.5 kilometers and centered at a depth of 1.6 kilometers. Figure **??** shows the resulting velocity model as the sum of two components: one background velocity profile, which is a function of depth but is constant in the lateral direction, and one anomalous model, which is a function of both depth and the lateral position. The anomalous model is shown with a contour plot superimposed to the result of migrating the stacked section using the background velocity. The contour interval is -40 m/s, and the maximum amplitude of the anomaly is 200 m/s. Migrating the stacked section using the background velocity as a velocity function did not correct the pull-down in the structure, although it approximately focused the data. Figure **??** shows that the estimated velocity anomaly is correctly positioned above the sag.

Figure **??** shows the result of migrating the stacked section using as a velocity function the estimated velocity model; that is, the background plus the anomalous velocity model. The inclusion of the anomaly has caused a considerable change in the positioning of the reflectors, as it can be noticed by comparing Figure **??** with Figure **??**.

The two migration results are better compared by a look at the windows of the data that have been directly affected by the anomaly, as shown in Figure **??**. The estimated velocity field corrects the mispositioning of the top of the anticline, both laterally and in depth. Furthermore, the migration with the background velocity did not perfectly focus the deeper reflectors; this misfocusing caused a decrease in the amplitudes of the migrated reflectors underneath the anomaly. This focusing effect is corrected in the migration that used the estimated velocity model as a velocity function.

Using beam-stacked data to check the estimation results

When a velocity model to be used for depth migration is built, it is important to use the prestack data to check the quality of the results. The beam-stacked data can be readily used for this purpose of quality check: the actual position of the semblance peaks in the beam-stacked data can be compared with the positions predicted by the estimated velocity model.

I sliced the beam stacks at the traveltimes corresponding to the reflector at about 4.5 km in the migrated section of Figure **??**. Figure **??** shows semblance, as a function of the transformed offset and midpoint location, and for a fixed p_h equal to 0.076 s/km and p_y equal to zero. The thinner line superimposed to the semblance plot corresponds to the transformed offsets predicted by the background velocity, and the thicker line corresponds to the transformed offsets predicted by the estimated velocity. The peaks of the beam stacks are well predicted by the final results of the estimation.

One of the main advantages of estimating velocity with local stacking operators, such as beam stacks, is the possibility of inverting data that depend locally on the moveouts of the reflections. This advantage would be only theoretical if the resolution of beam stacks were not sufficient to obtain independent measures for different offset ray parameters. Figure **??** shows that it is actually possible to measure the different effects of the velocity anomaly on the reflections having different offset ray parameters. The three panels show slices of the beam-stacked data taken at three midpoint locations, and for the same reflector as in Figure **??**, but as a function of p_h. In this figure the thinner line superimposed to the semblance plot corresponds to the transformed offsets predicted by the background velocity, and the thicker line corresponds to the transformed offsets predicted by the estimated velocity. The first and the third panel correspond to midpoints located on the side of the anomaly, and consequently the reflections with higher p_h were more strongly affected by the anomaly than were the ones with lower p_h. On the contrary the panel on the center corresponds to a midpoint located at the center of the anomaly, and consequently the reflections with lower p_h were more strongly affected by the anomaly than were the ones with higher p_h. It is useful to notice that the beam stacks are zero for p_h higher than 0.206 s/km because the corresponding reflections would have been recorded off the end of the cable.

CONCLUSIONS

The velocity-estimation method with beam-stacked data was successful in estimating a low-velocity anomaly from field data. Depth migrating the data using the estimated velocity model corrected the mispositioning of the reflectors caused by the anomaly and improved the focusing of the result.

The estimated velocity well explains the prestack data and, in particular, the beam-stacked data. An analysis of the beam-stacked data shows that the resolution of beam stacks is sufficient for the measurement of different effects of the velocity anomaly on reflections stacked at different values of the offset ray parameter.

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