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Results in depth focusing analysis for 3-D migration velocity estimation

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ABSTRACT

This paper is the continuation of a previous paper (Malcotti and Biondi, 1997) in which we discussed the theoretical and practical bases of depth focusing analysis for 2-D and 3-D. In this work, we present some results of the depth focusing analysis methodology based on a 3-D prestack common-azimuth migration (Biondi et. al., 1996). We apply this methodology to two differents data sets with complex velocities, a synthetic data set and a real 3-D data set. In both data sets, we show one iteration in the methodology loop for interval velocity estimation using depth focusing analysis. For the real seismic data set, our goal is to update the velocity model where the image has focusing problems. Therefore, we used the best velocity field available. For the interpretation of the depth error gathers, we use a three dimensional graphic tool that help to simplify the picking in complex error gathers.

INTRODUCTION

Velocity analysis based on the analysis of the focusing conditions of a downward continuation operator for a velocity field, has been redefined by different authors (Audebert, 1996; Berkhout, 1996; Clapp and Biondi, 1997). These papers explore new ideas in migration velocity estimation based on kinematic and dynamic focusing conditions, addressing complex lateral velocity gradients. In his last papers in 1997, Clapp combined the ideas presented by Berkhout (1996) and Audeberd (1996) and presented methodology for estimation of the focusing operator through homothetic perturbations of the traveltime field. In this paper we work with a more standard depth focusing methodology to estimate migration velocities for 3-D data sets, based on a fast and accurate 3-D prestack depth migration algorithm in common-azimuth domain Biondi and Palacharla (1996).

In our last paper (Malcotti and Biondi, 1997), we showed some preliminary results of the 2-D and 3-D depth focusing analysis methodology for the migrations velocity,

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using constant velocities and seismic diffractors. Those results were based on a 2-D phase shift migration in the CMP domain and constant velocity (Claerbout, 1985). In contrast, in this paper, we change the downward continuation operator to a 3-D prestack depth migration along common-azimuth sections(Biondi et al, 1996). We present some results using two different data sets, a 2-D synthetic data set and a real 3-D seismic data set. Both geologic models are characterized by complex shallow velocities that makes the imaging of deeper flat horizon difficult.

In addition, we show by applying this methodology 3-D real data set, one of the most important characteristics of depth focusing analysis is its independence from the dimensionality of the data. A depth-focus error-gather does not change for 2-D or 3-D prestack data. Moreover, a depth error gather is a 2-D gather of zero-offset traces extracted in every step of the downward continuation process. Therefore, it allows the evaluation of the migration velocity on a 2-D gather (i.e., depth error gather) which is built from 3-D downward continuation of the data.

DEPTH FOCUSING EQUATIONS

The focusing principles can be understood if we think of a point diffractor. The seismic response of a point diffractor is a hyperboloid in 3-D or a hyperbola in 2-D ($Z = 0$). If this CMP gather is downward continuated with a migration velocity different than the real propagation velocity, the image obtained at the imaging condition (t=0s) will not be well focused. A good focused image will be obtained at a depth (Z_f), called focal depth and the energy at zero-offset trace will be maximum. Therefore, the goal of depth focusing analysis is to estimate the real propagation velocity from the best focal depth.

In order to estimate the new migration velocity we use the following equations assuming small offsets and a small error in migration velocity (Doherty and Claerbout (1974); MacKay and Abma (1992)):

$$V_r Z_r = V_m Z_f, \tag{1}$$

$$2\frac{Z_r}{V_r} = 2\frac{Z_m}{V_m}, \tag{2}$$

where Z_f is the focusing point depth obtained with a migration velocity V_m and Z_r is the real depth. Expressing the estimated real velocity and depth as a function of the vertical depth error δ, we obtain the useful following equations:

$$V_r = \frac{V_m(2\delta + Z_m)}{Z_m + \delta}, \tag{3}$$

$$Z_r = \delta + Z_m. \tag{4}$$

The vertical depth error (δ)is defined by MacKay and Abma (1992) as

$$\delta = \frac{Z_f - Z_m}{2}, \tag{5}$$

where Z_f is estimated from the error depth gather defined by the zero-offset trace chosen at every downward continued operator step (a negative error implies a high downward-continuation velocity; a positive depth error implies a low downward continuation velocity).

The new estimated velocity V_r is a rms velocity that needs to be interpolated and converted to interval velocity. In general, it is necessary to use a different approach as a tomographic, in order to transform the depth error to interval velocity (Audebert, 1996).

RESULTS

In order to show the implementation of the basic tools for depth focusing analysis for a 3-D data set, we present some preliminary results with two differents data set: a 2-D synthetic data set of a salt diapire, and a 3-D data set from the North sea. The depth error gathers were obtained by using a prestack downward-continuation operator in common-azimuth, based on the stationary-phase approximation of the 3-D DSR. This approximation reduces the dimensionality of the downward-continuation operator from 5 to 4 dimensions, constraining the direction of propagation of source and receiver rays to the same plane and azimuth (Biondi and Palacharla, 1996).

The synthetic data set is the result of a finite-difference modeling of the synthetic model based on a geologic structure due to the rise of a salt diapire (Figure 1). This geologic model is characterized by a strong lateral velocity gradient in the cable length. Figure 2 shows the near-offset section result of the seismic modeling of this geologic structure. This synthetic data set have the following acquisition parameters: source spacing 50m; receiver spacing 25m; final CMP spacing 12.5m; near-offset 170m; far-offset 3350m; maximum recorded time 5s; and time sampling 4ms.

Figure 3 plots a prestack depth migration with 90% of the real velocity model (Figure 6). The final depth of this migrated depth section is 2500m in order to analyze the focusing condition of the shallow events through the depth error gathers show in Figures 4 and 5.

To migrate this data set with the 2-D prestack depth migration operator version of the 3-D common-azimuth operator, we defined 5 reference velocities (which kept constant) and an interval velocity model. Figures 4 and 5 show a cube of depth error gather where the lateral cube face represents a focal section resulting from choosing a specific depth error, in this case zero error. Changing the depth error plane (i.e. constant error surface) for a surface that follows the maximum focusing conditions in the depth error gathers, the resulting focal image would be the best. In this example the focal image is under-sampled in the CMP-domain because we saved the depth error gathers every ten CMP. In contrast, the top face of the cube in figure (4) is a depth slice that makes picking more easy in areas where the depth error gathers are difficult to interpret.

Figure 5 shows four different depth error gathers for the CMPs 15, 600, 700, and 1000. The lateral dispersion shown in a depth error anomaly is associated with the salt dome velocity complexity. Picking the depth error values at the maximum amplitude condition and using the equations 3 and 4, it is possible to update the velocity field. At this time we are working to develop the programs to update the interval velocity field.

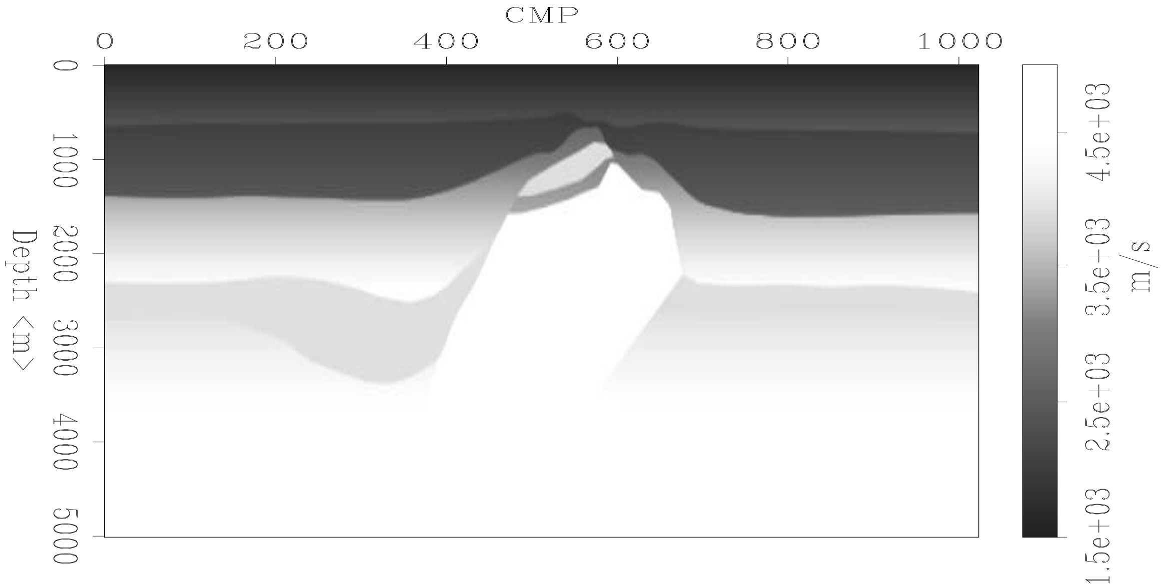

Figure 1: Depth velocity model. hermes-VelELF [CR]

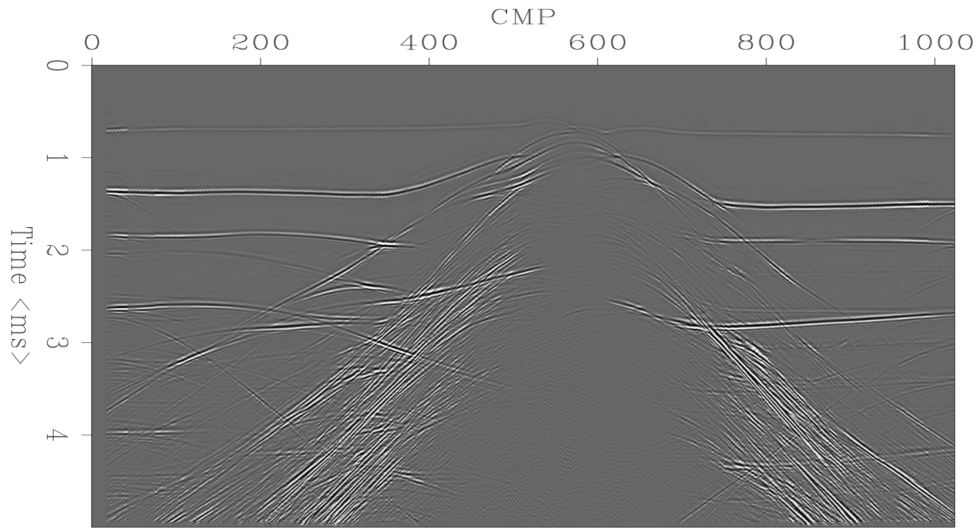

Figure 2: Near-offset section: 170m. hermes-ELFNEAROFF [CR]

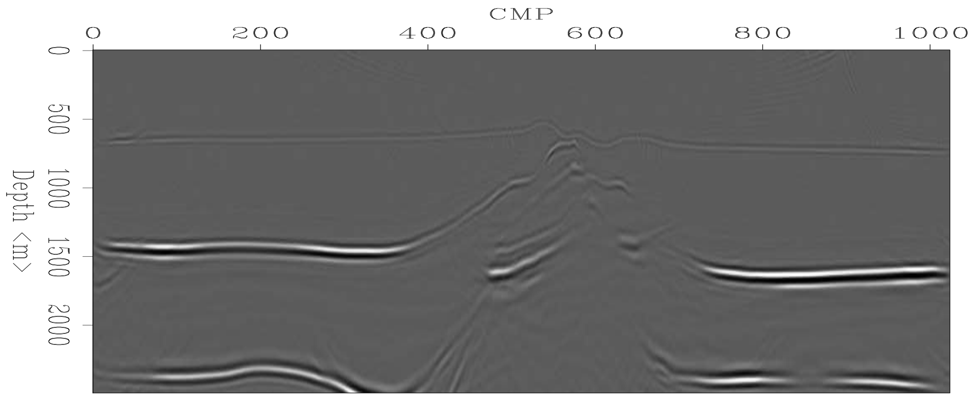

Figure 3: Prestack depth migration with a 90% of the velocity model in figure 1, and the final depth is $2500m$. hermes-WrongELFpreMIG [CR]

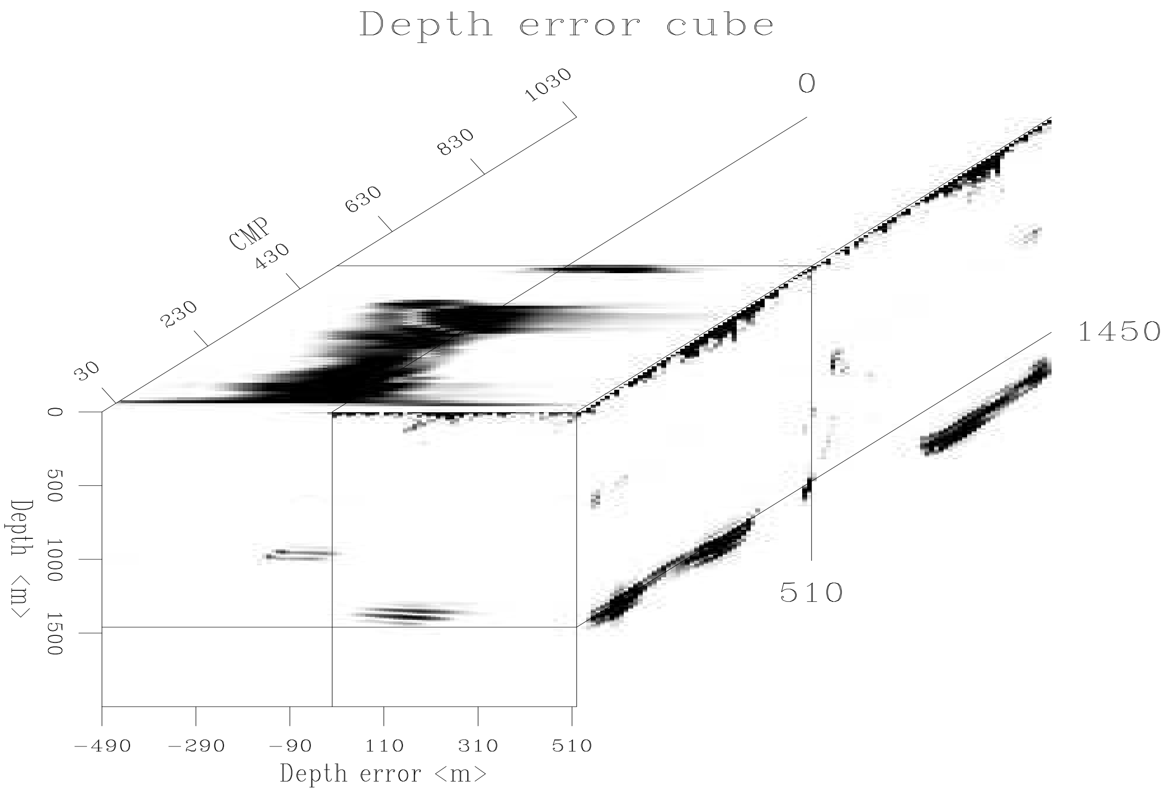

Figure 4: Depth error gathers from a 2-D prestack depth migration of a synthetic data set (maximum depth 2000m). hermes-DFA2DELF [CR]

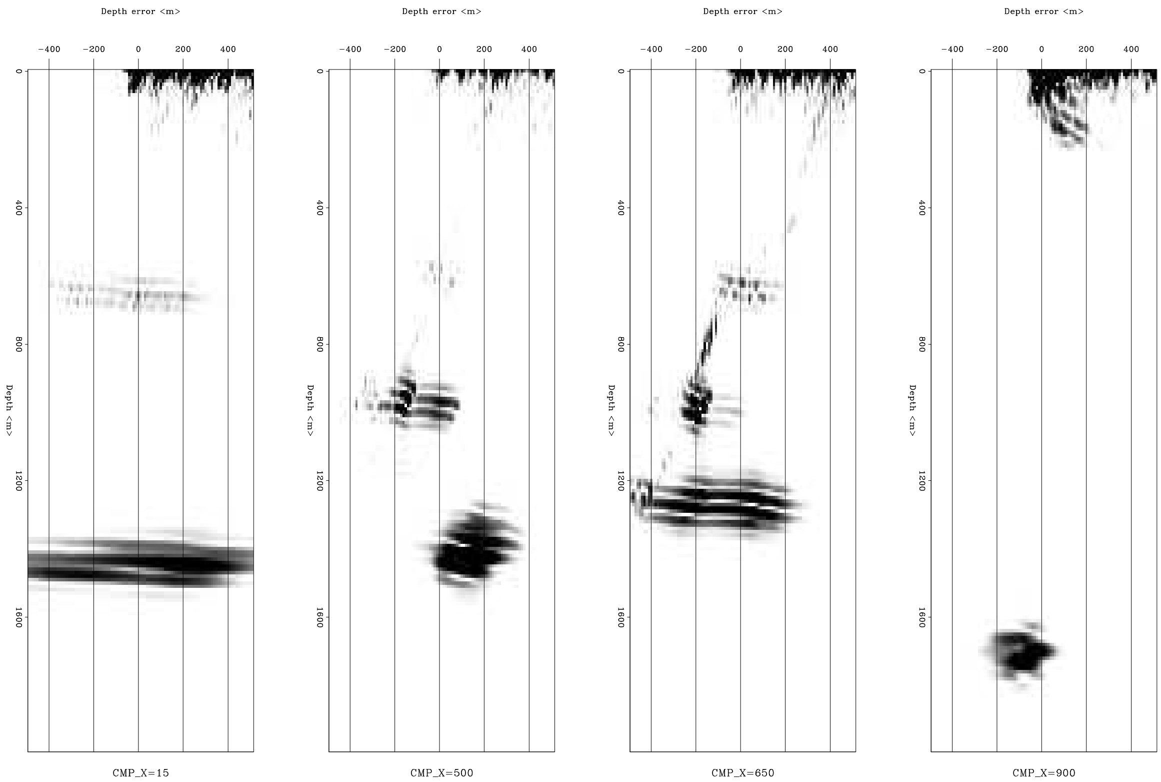

Figure 5: 2-D depth error gather for the CMP gathers: 15, 500, 650 and 900. hermes-dfaelf15500650900 [CR]

Figure 6 shows the velocity field in CMP domain for cross-line coordinate 19450m of a 3-D data set from the North Sea. This is characterized by a strong lateral and vertical velocity gradients due to geologic process. This 3-D marine data set has a CMP spacing of 9.375m in the in-line direction, 25m in the cross-line direction, and the far-offset is 2200m. Azimuth-moveout (AMO) transformation was applied to the data in order to apply an azimuth rotation over the data to obtain an effective common-azimuth data set for the 3D common-azimuth migration Biondi (1997).

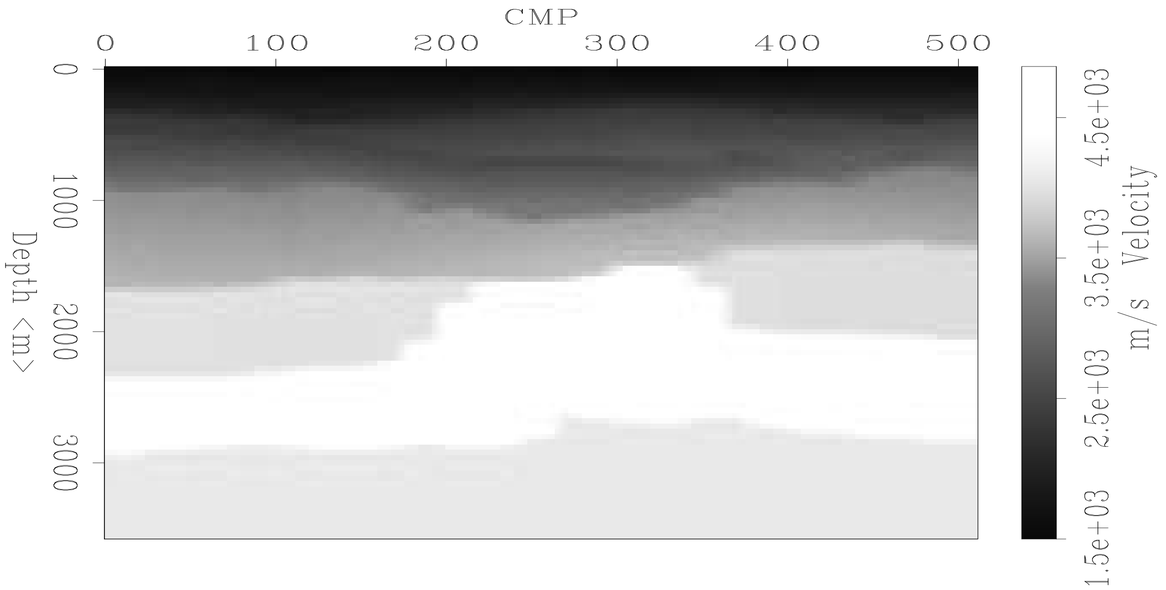

Figure 6: Depth velocity model for the real 3-D data set from the North Sea. hermes-velfield [CR]

This 3-D marine date set have been imaged successfully using common- azimuth migration Biondi (1997). Our goal is to update the velocity field in areas with focusing problems and show these problems using the depth error gathers. Future work will show more than one velocity analysis iteration because at present we are developing the codes for the interpolation of the velocities estimated on a CMP location.

Figure 7 shows a 3-D prestack depth migrated image using the best velocity field available. This migrated in-line section is located in the cross-line position 19450m. During the 3-D migration we saved the zero-offset trace for every depth step and every 10 CMP in order to obtain the depth error gather plotted in Figures 8 and 9. In those figures the depth error gathers are plotted for a final depth of 2000m, with the object to analyze the focusing condition of the shallow migration velocity. It is observed that the focusing condition is lateral shifted to positive error, implying a lower migration velocity velocity (CDP:500 and 650).

In order to help the interpretation of the depth error gathers in complex areas, we plotted the depth error gathers using 3-D graphic tools (Rickmovie, a SEPLib tool). In this way the picking of a maximum in amplitude can be easily checked through the focal image (lateral plane: CMP-depth plane for a constant depth error) or by a

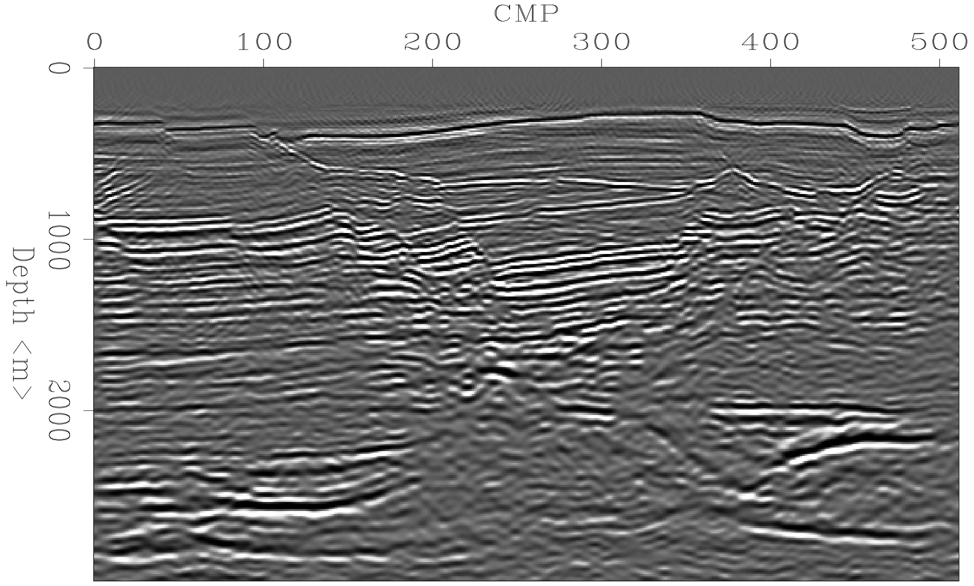

Figure 7: 3-D Prestack in common-azimuth for the cross-line 19450m using 6 reference velocities. hermes-twodremig [CR]

depth slice of the depth error cube (see Fig. 8). Analyzing the depth error gathers plotted in figures 8 and 9, it can be seen that the seismic event blow a 1000m has a depth error associated with a high migration velocity in the CDP 50. In contrast, the migration velocity at depth of 1000m needs to be decrease in the zone close to the CDP 200. This shallow velocity error affecting is the image of a deeper horizons, like one at 1350m depth.

CONCLUSIONS

Based on a 3-D prestack depth migration we built depth error gathers to analyze the focusing condition for a velocity field. In this paper we used two different data sets, a 2-D synthetic and a real 3-D marine data set. For both data sets we analyzed the depth error gathers. These depth error gathers probe to be useful tool in evaluating the focusing condition of the migration velocity to obtain a good 3-D image. In this paper we show one iteration of the depth focusing analysis methodology, future works will show more than one iteration in the migration velocity estimation for 3-D data sets.

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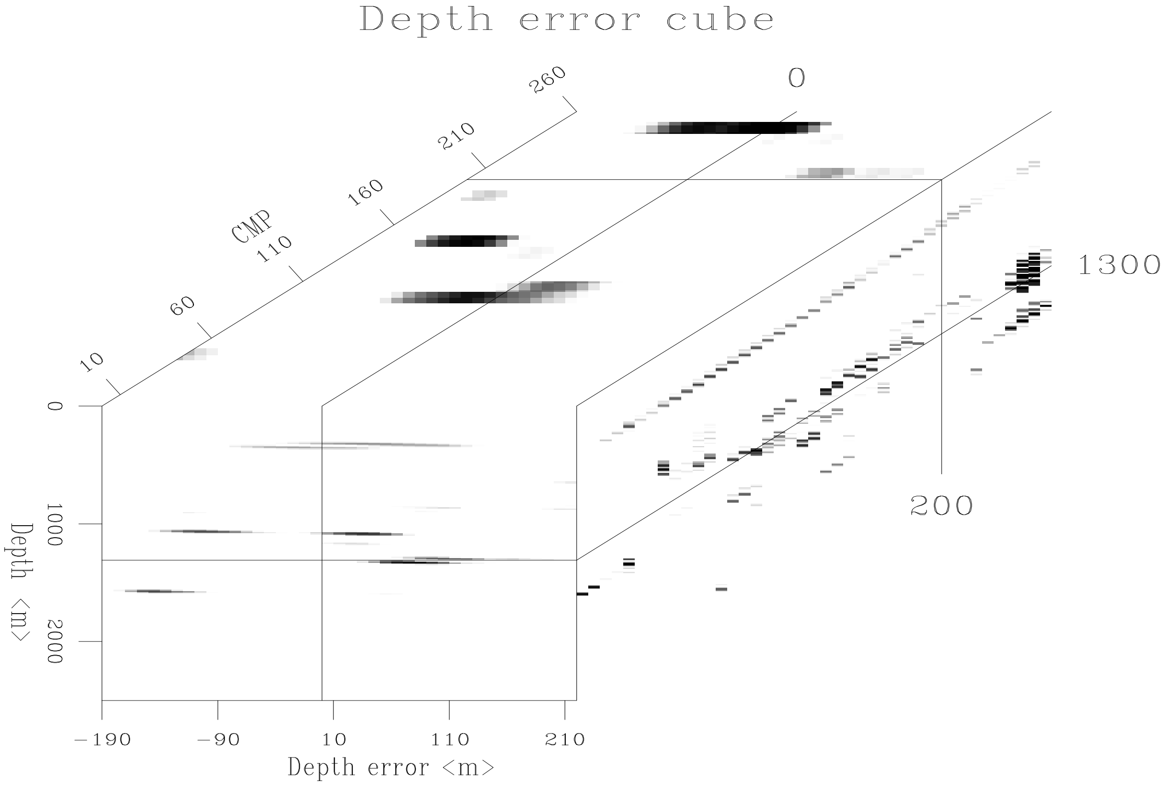

Figure 8: Depth error gathers from a 3-D prestack depth migration in common-azimuth of a real data set from the North Sea. hermes-DFA3D130 [CR]

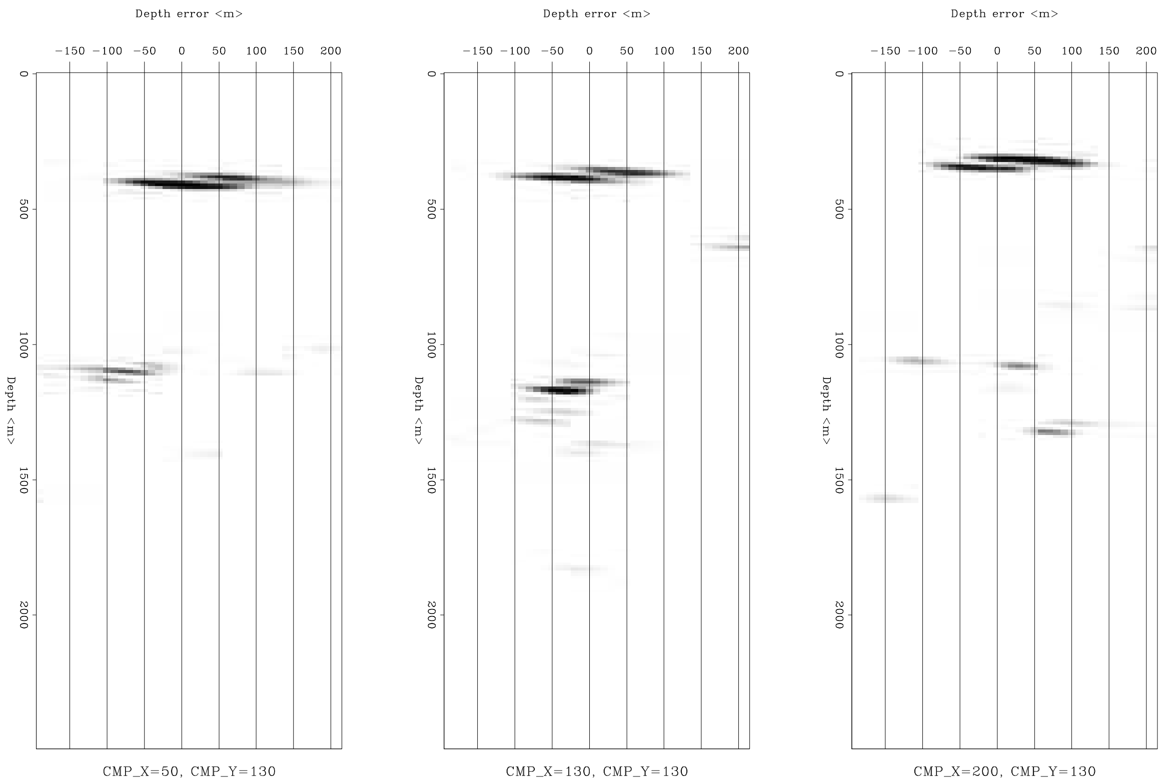

Figure 9: 3-D depth error gather for the cross-line 14950m and in-line CMP gathers: 50 130 and 200. This gathers were extracted from the depth error cube (Fig. 8). hermes-dfa3D50130200 [CR]

Conoco and its partners BP and Mobil, for the North Sea data set.

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