Complex Model Building using Objective Construction of Curve Ray Time Migration Moveout with Geologic Constraints*

Kerry Stinson[1], Shlomo Levy[1], Edward Crase[1], and Wai-Kin Chan[1]

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[1]Data Modeling Inc., Calgary, AB, Canada (dmi@data-modeling.com)

Abstract

A time domain system for high density, high resolution migration velocity estimation, and imaging is introduced. The methodology for objective, data driven determination of the velocity and effective anisotropy is based on direct optimization of the image gathers and image cube. With the inclusion of additional structural constraints on the resultant interval velocity, meaningful geologic interval velocity models are constructed. The automatic process is detailed using real and synthetic data sets. The veracity of the determined geologic interval velocity model is tested using prestack depth migration, and also as the initial model for subsequent prestack depth updating.

Automatic Time Imaging and Velocity Determination: Methodology

An objective process for the automatic estimation of time migration velocities and effective anisotropy was previously introduced (Stinson et al. (2004), Stinson et al. (2005), Stinson et al. (2006)). A number of objective functions are utilized to measure different aspects of the fidelity of the migration as a function of the migration velocity and effective anisotropy. For example:

1. Flatness of events in migrated image gathers (see Figure 1a).
2. Local continuity of events on migrated image cubes/sections (see Figure 1b).

The total objective function (as in Equation 1) is then optimized in the automatic inversion to produce densely sampled cubes of optimal velocity and effective anisotropy:

$$\boldsymbol{\Phi = w_1 * \Phi_1 + w_2 * \Phi_2} \qquad (1)$$

Where: $\boldsymbol{\Phi_1}$ measures flatness in the migrated image gathers

$\boldsymbol{\Phi_2}$ measures local continuity on the migrated image

An additional objective function may be added to invoke structural or geologic consistency of the interval velocity during the automatic determination. Utilizing localized estimates of the 3D structure (determined from the normal AutoImager migration cube), the use of this objective function will ensure consistency of the interval velocity along local 3D structures (see Figure 2).

Example: "WaveModel" Synthetic

To demonstrate the approach and to highlight some possible pitfalls, we constructed the 2D model shown in Figure 3a (in depth) and Figure 3b (vertically compressed to time). The "wavy-ness" of the model interfaces ensures that the downgoing and upgoing wavefields will be complex.

Using the AutoImager curve ray velocity and effective anisotropy determination, (with the optimized determination only utilizing the gather flatness and image continuity objective functions), results in the image shown in Figure 4. It is noted that due to the complex model and the resultant focusing and defocusing of the wavefield, the best imaging velocity (shown overlain on Figure 4) for time migration is not necessarily smooth, or interface consistent (as pointed out by Cameron et al. (2006)). The efficacy of the derived imaging velocity is seen also from the common offset migration gathers (Figure 5) which are quite flat.

A second run of automatic velocity determination was then made, but now imposing the constraint on the Vrms determination that the resultant interval velocity adheres to the Structural Constraints. The resulting image is shown in Figure 6, with the resultant interval velocity overlain. To test the veracity of this interval velocity, we have run prestack depth migration. The resultant depth section (shown in Figure 7) is a good match to the true depth section (see Figure 3a).

Example: Marmousi 2 Synthetic

The optimized determination of the velocity with structural constraints was applied to the Marmousi 2 synthetic data set. (No knowledge of the velocity model was used in the determination.) The AutoImager prestack time migration result is shown in Figure 8a, with the RMS migration velocity field overlain. The same image is shown in Figure 8b, but now with the interval velocity overlain (calculated with the Structural Constraint applied). To confirm the veracity of the interval velocity model, prestack depth migration was used in conjunction with the interval velocity to produce the depth image shown in Figure 9. Finally, as a final check on the fidelity of this interval velocity, it was used as the starting model for iterative prestack updating. The final result (in Figure 10) has improved the image in both image quality and depth and positioning of events (as compared to the actual model of Figure 11).

Conclusions

Automatic dense estimation of time migration velocities and effective anisotropy is possible and practical based on optimization of measures of gather flatness and image continuity. The approach has proven to be robust over a wide range of geological settings and complexities. The addition of Structural Constraints for interval velocity into the objective function optimization allows the methodology to determine geologically reasonable interval velocity models, as will be shown on real and synthetic data sets.

References Cited

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Stinson,K.J., W.K. Chan, E. Crase, S. Levy, M. Reshef, and M. Roth, 2004, Automatic imaging: velocity veracity (abstract): 66th EAGE Conference, Paris, Extended Abstracts, Paper C018.

Stinson,K.J., E. Crase, W.K. Chan, and S. Levy, 2005, Optimized curved ray migration velocity determination including anisotropy: CSEG Recorder, October 2005.

Stinson,K.J., E. Crase, W.K. Chan, and S. Levy, 2006, Optimized estimating intrinsic layer anisotropy from surface seismic: CSEG Recorder, June 2006.

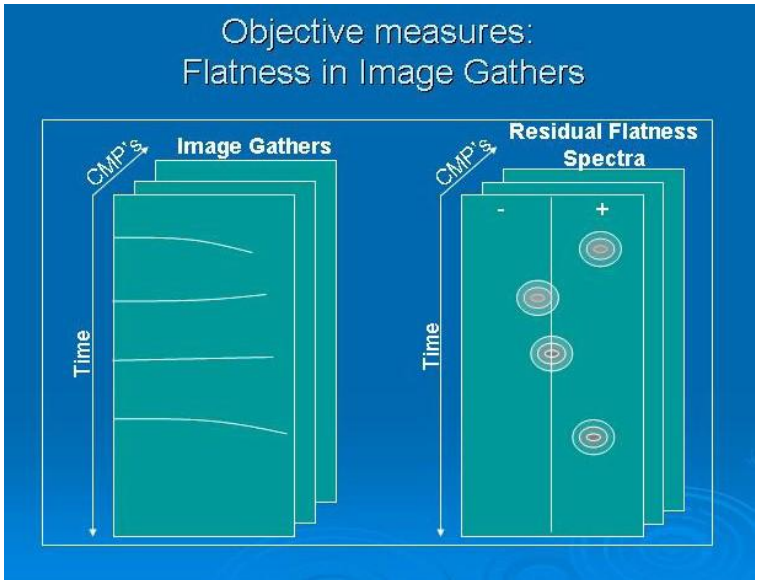

Figure 1a. Getting a measure of flatness in image gathers.

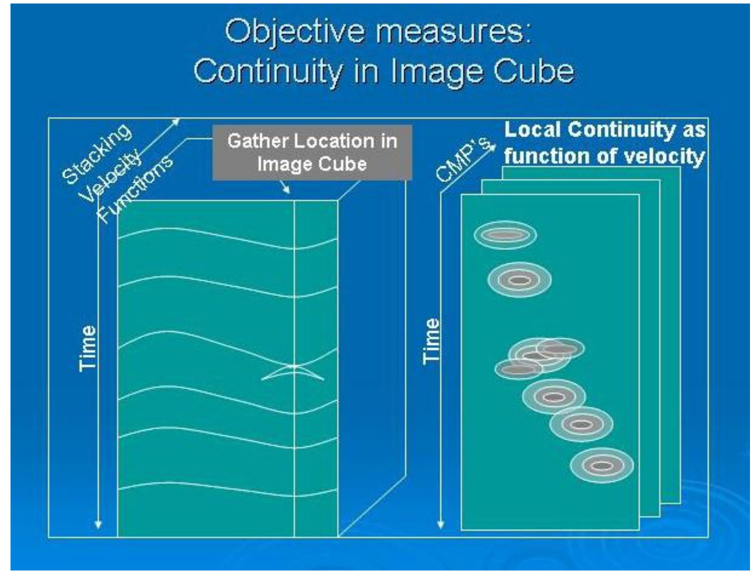

Figure 1b. Getting a measure of image continuity in the image cube.

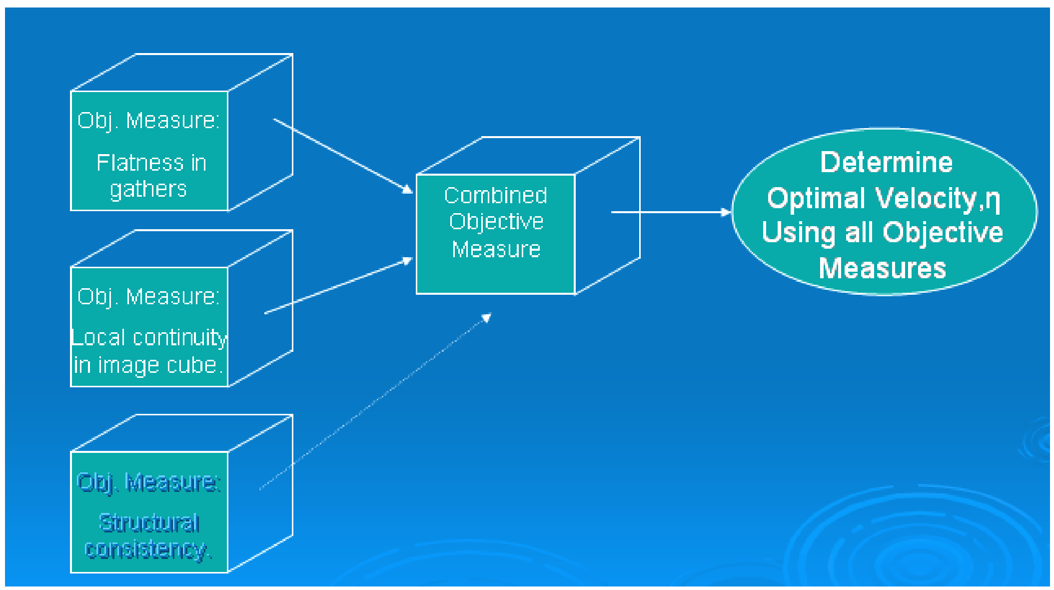

Figure 2. Adding in interval velocity Structural Consistency constraint into optimal velocity determination.

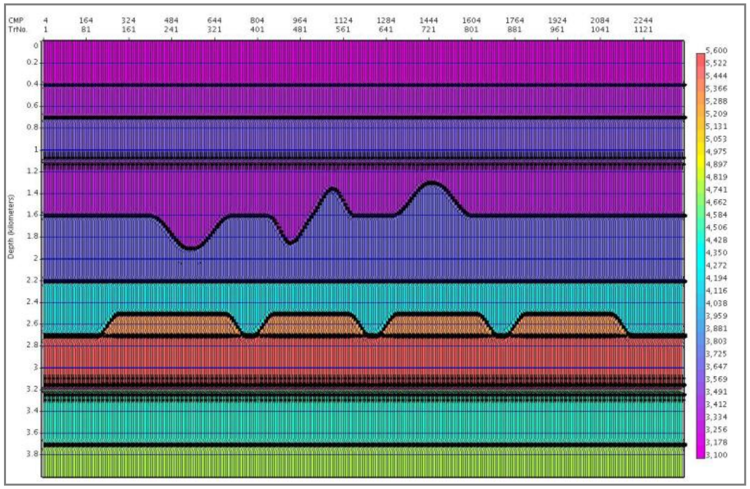

Figure 3a. P reflectivity of model with P velocity overlain (in depth).

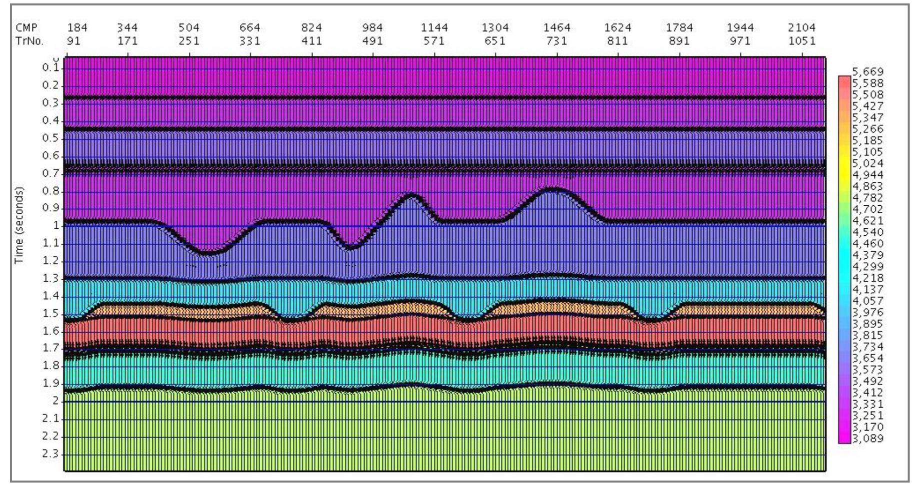

Figure 3b. P reflectivity with P velocity overlain (compressed to time).

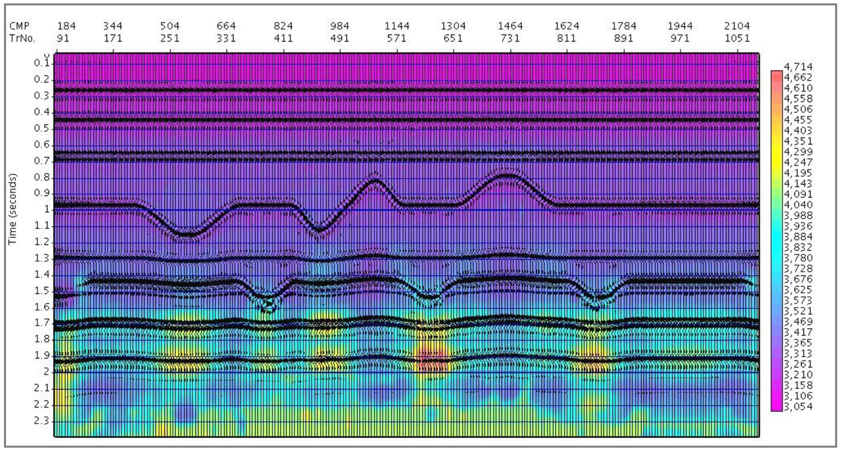

Figure 4. Standard automatic imaging result (image with Vrms overlain) using only gather flatness and image continuity objective functions.

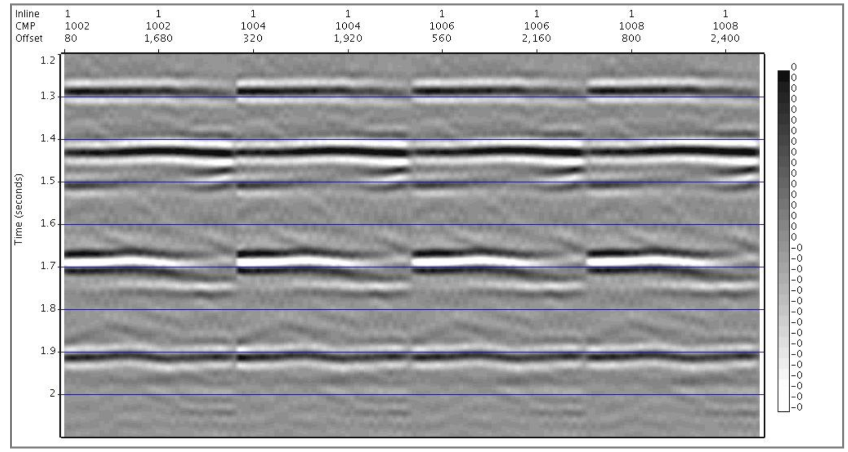

Figure 5. Common offset migration gathers after imaging.

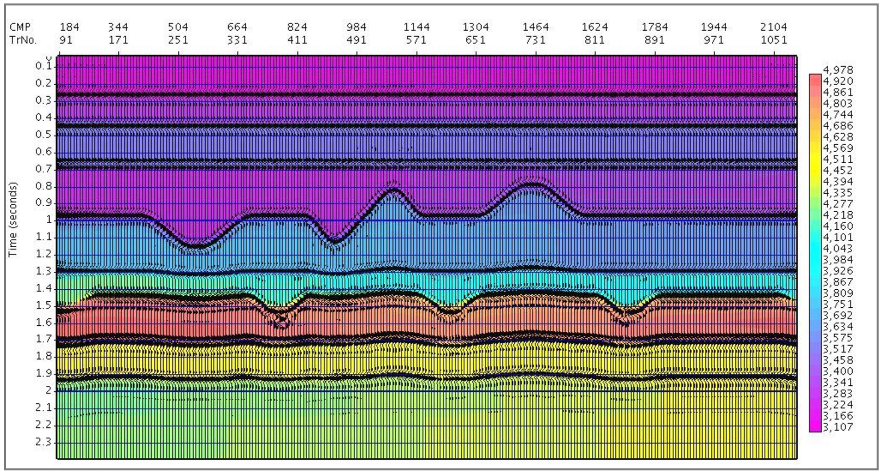

Figure 6. Automatic imaging result (image with interval velocity overlain) derived from the velocities with Structural Constraint.

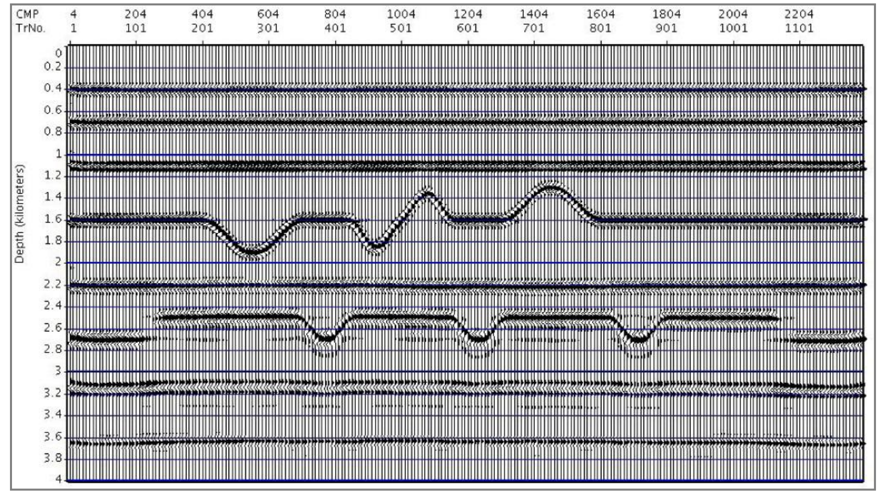

Figure 7. Prestack Depth Migration using interval velocity determined using Structural Constraint (as in Figure 6).

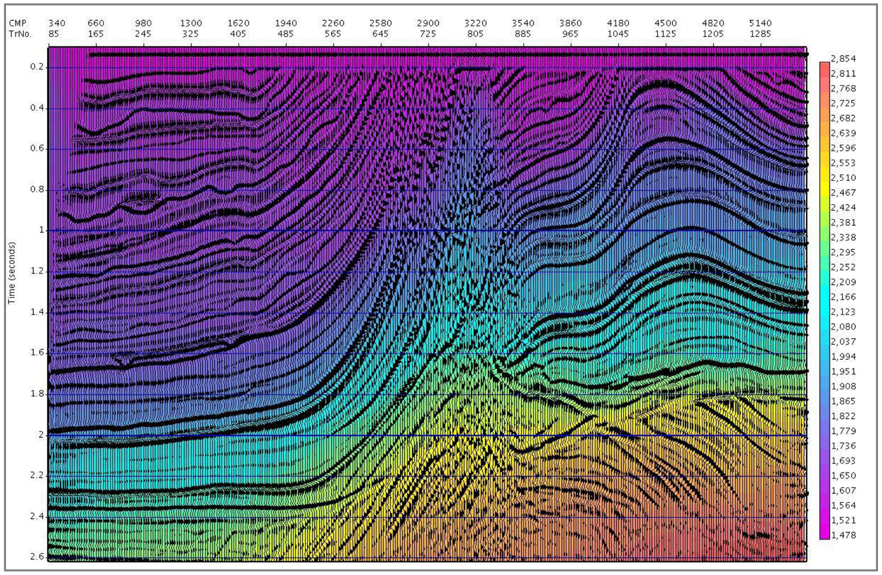

Figure 8a. Automatic prestack time migration (calculated RMS velocity overlain).

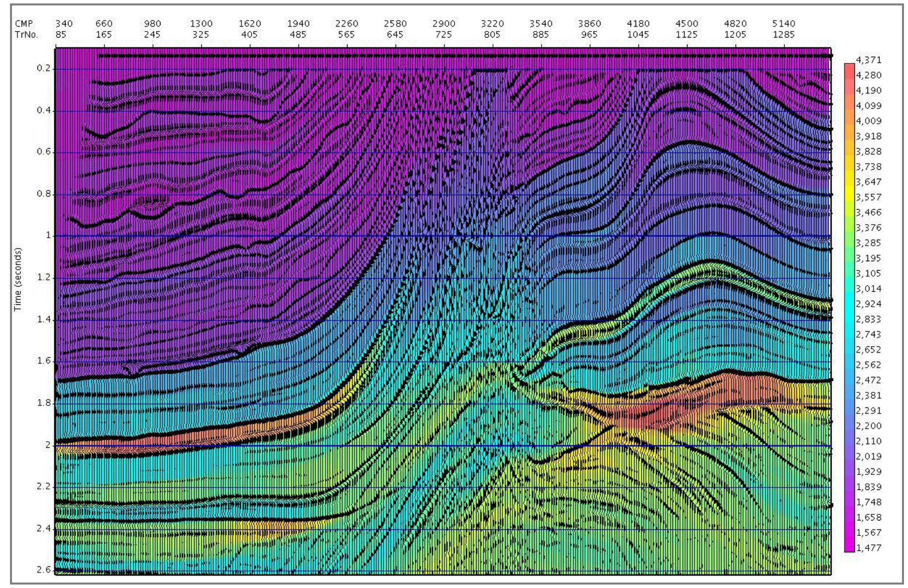

Figure 8b. Automatic prestack time migration with Structural Constraint (calculated interval velocity overlain).

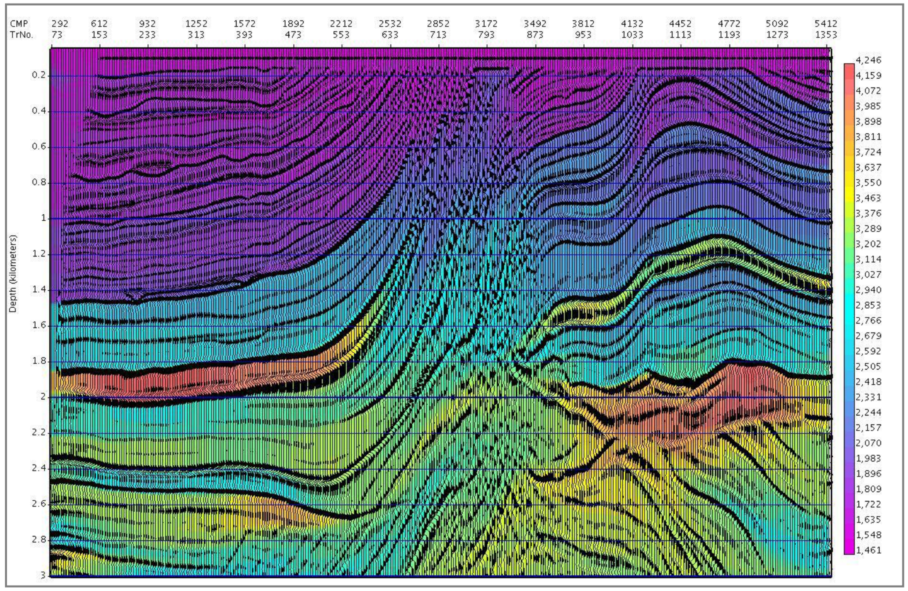

Figure 9. Prestack depth migration using automatic RMS and interval velocity determination with Structural Constraint.

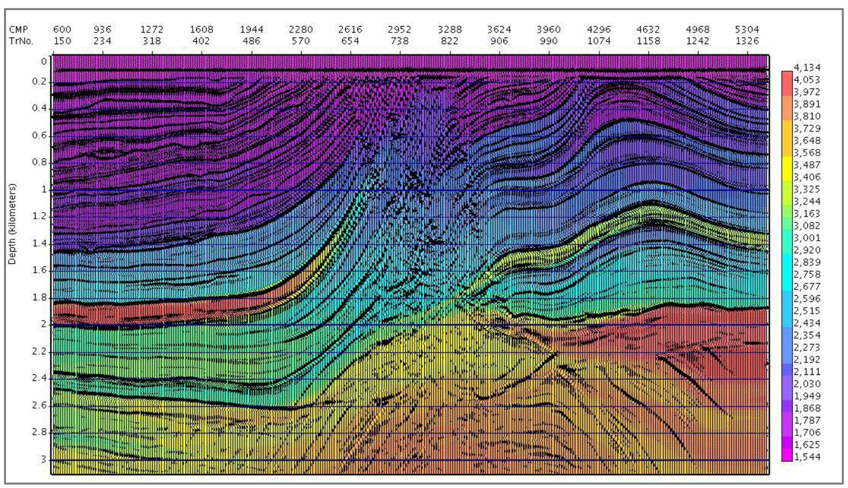

Figure 10. Prestack depth migration and interval velocity after iterative updating.

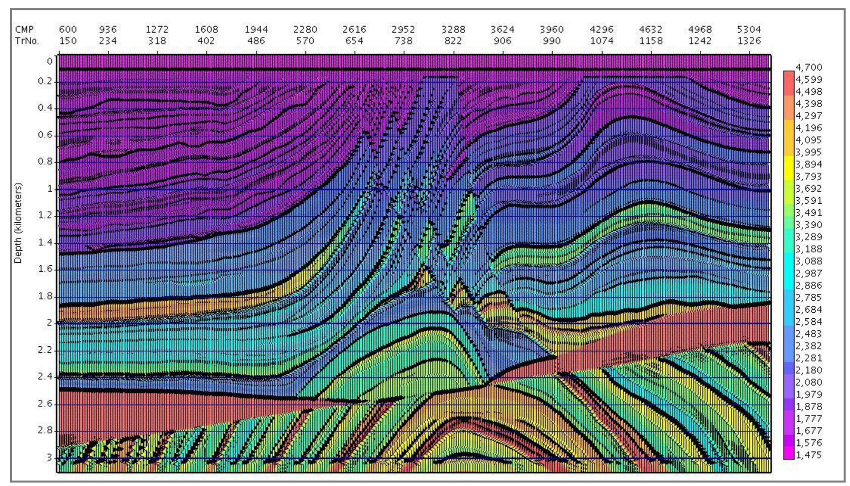

Figure 11. Model Reflectivities and Interval Velocities.