Quality Improvement of Seismic Image from 2D PSDM (Pre Stack Depth Migration) Using Tomography for Interval Velocity Model Refinement

Peningkatan Kualitas Citra Seismik 2D PSDM (Pre Stack Depth Migration) Menggunakan Tomografi untuk Perbaikan Model Kecepatan Interval

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ABSTRACT: The main goal of seismic exploration is to get an accurate image of subsurface section so it can be easily interpreted. Pre Stack Depth Migration (PSDM) is such a powerful imaging tool especially for complex area such an area where strong lateral velocity variations exist. The main challenge of PSDM is the need of accurate interval velocity model.

In this research, Dix Transformation, coherency inversion, and tomography are used for initial interval velocity model, and then tomography is used for interval velocity model refinement. We compare also between seismic image resulted from PSDM and PSTM to determine the best method. The seismic data that processed in this paper is derived from north western part of Australian Waters.

Keywords: Pre Stack Depth Migration, Dix Transformation, coherency inversion, tomography

ABSTRAK: *Tujuan utama dari eksplorasi seismik adalah menghasilkan citra yang akurat dari penampang bawah permukaan sehingga diinterpretasi lebih mudah. Pre Stack Depth Migration (PSDM) merupakan suatu metode yang memberikan hasil peningkatan kualitas citra seismik pada daerah kompleks dimana terjadi variasi kecepatan lateral yang signifikan. Salah satu syarat penting yang harus dipenuhi agar hasil PSDM lebih optimal adalah model kecepatan interval yang akurat.*

Dalam penelitian ini Transformasi Dix, inversi koheren, dan tomografi digunakan untuk memenuhi syarat tersebut. Perbandingan hasil penampang seimik PSDM dan PSTM dilakukan untuk menentukan metode terbaik. Data seismik yang diolah dalam tulisan ini berasal dari wilayah Perairan Baratlaut Australia.

Kata kunci: *Pre Stack Depth Migration, Transformasi Dix, inversi koheren, tomografi*

INTRODUCTION

Pre Stack Depth Migration (PSDM) is a high resolution imaging technique that can handle a complex area which cannot be done by time migration. In present times, PSDM is increasingly used by industries to fulfill the requirement of superior subsurface image.

The main key of PSDM is an accurate interval velocity model. In this experiment, 2D PSDM is studied using 3 interval velocity models to be compared, namely Dix transformation, coherency inversion, and tomography. Firstly, Dix Transformation and coherency inversion are combined to build the initial interval velocity model. Finally, tomography is used to enhance the quality of interval velocity model to get better seismic image.

Kirchhoff Migration

Mathematically, Kirchhoff migration derived by solving the wave equation based on Green's Theorem that written as:

$$\psi(\overrightarrow{x_0}, t) = \oint_{S_0} \left[\frac{4cos\theta}{vr} \left[\frac{\partial\psi}{\partial t}\right]_{(t+{}^{2r}/_{v})} \right] d_{surf} \qquad 1$$

$\psi(\overrightarrow{x_0}, t) = Kirchhoff\ diffraction\ integral$

$\frac{4cos\theta}{vr}\left[\frac{\partial\psi}{\partial t}\right]_{(t+{}^{2r}/_{v})}$ = *near-field term with θ vertical angle between receiver point and scatter point, v constant, r plane distance, t time arrival*

$\left[\frac{\partial\psi}{\partial t}\right] = hyperbolic\ travelpath$

$d_{surf} = surface\ divergence$

This expression is derived by many authors such as Schneider (1978). It express Kirchhoff migration as summation or integration of input data $\left[\frac{\partial\psi}{\partial t}\right]$ at time $(t + {}^{2r}/_{v})$

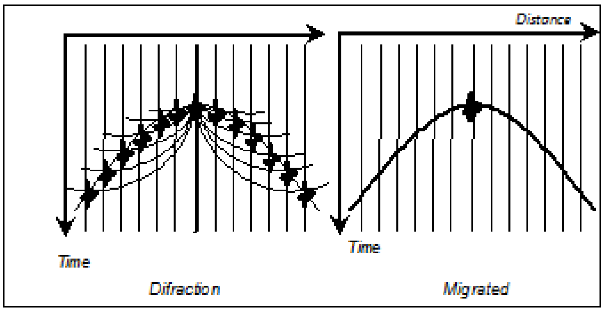


Figure 1. Kirchhoff migration principle (Yilmaz, 2001)

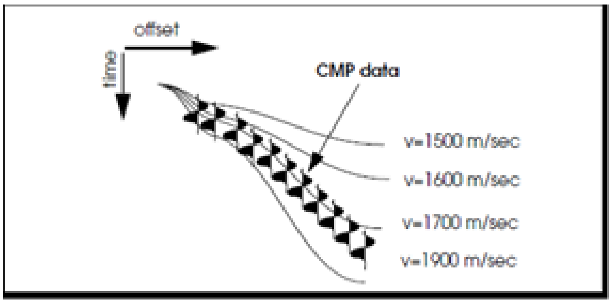


Figure 2. Coherency inversion principle (Furniss, 2000)

Dix Transformation

In order to get the best result from PSDM, it is required an accurate interval velocity model. Dix Transformation uses Dix Equation (Dix, 1955) to convert RMS velocity to interval velocity that written as:

$$V_{int_i}^2 = \frac{(V_{rms}^2 t_i - V_{rms-1}^2 t_{i-1})}{(t_i - t_{i-1})} \qquad (2)$$

$V_{int_i} = interval\ velocity\ at\ sample - i$

$V_{rms} = RMS\ velocity\ at\ step - i$

$t_i - t_{i-1} = time\ interval$

It is the most common approach of velocity transformation and has many assumptions, such as stacking velocity is equal to RMS velocity. Therefore, interpreter use stacking velocity as the input into equation (3). It is only valid for areas with no structural dip, no lateral velocity or vertical velocity gradient and common midpoint (CMP) gathers have small offset. Meanwhile, Dix Transformation frequently used where those assumptions are invalid.

Coherency Inversion

Coherency inversion (Figure 2) is a layer-stripping approach that uses ray-traced modeled travel times curve compared with actual travel time recorded from the earth. Therefore coherency inversion is better than Dix Transformation. In this method, velocity is estimated layer by layer from the first layer to the next deeper layers. Coherency inversion uses curved rays and account for vertical and lateral velocity gradient allowing modeled travel time curves to accurately match those recorded in CMP gathers.

Tomography

Tomography is one of velocity model refinement technique that corrects error in velocity model by analyzing residual moveout. Figure 3 shows a simple model with the subsurface being divided into nine rectangular cells each with its own constant velocity to illustrate the basic principle of tomography. The arrival time for the raypath ABC(t_{ABC}), which is a raypath from source A, that reflects off the dipping surface at B then arrived at receiver C, written as:

$$t_{ABC} = \frac{d_1}{V_1} + \frac{d_5}{V_5} + \frac{d_8}{V_8} + \frac{d_6}{V_6} + \frac{d_8}{V_8} \qquad (3)$$

To determine the velocity distribution along raypaths such as those shown in Figure 3, tomography tries to solve a set of simultaneous equations using many raypaths traversing the cells in the model. Ray tracing is used within the tomography algorithm to determine the various possible raypaths and path lengths within the model cells.

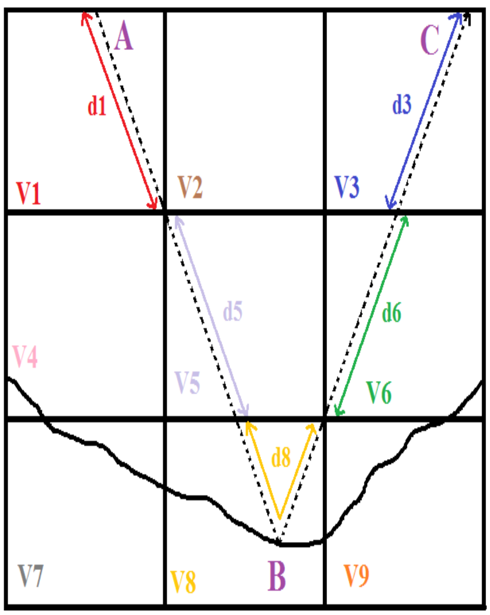


Figure 3. Simple tomography model (Fagin, 2002)

There are 2 types of global approach in tomography, grid-based tomography and horizon-based tomography. In grid-based tomography, residual delays in commom reflection point (CRP) gathers are picked automaticaly by the computer along small and coherent segments of the data. Meanwhile in horizon-based tomography, the residual delays are picked by interpreter at each CRP along the line (Figure 4).

Seismic Data

Seismic data is undertaken from 2D marine seismic data of North Western part of Australian Waters (Figure 5).

Seismic acquisition parameter obtained from observer report is used as input parameter in seismic processing software (Table 1).

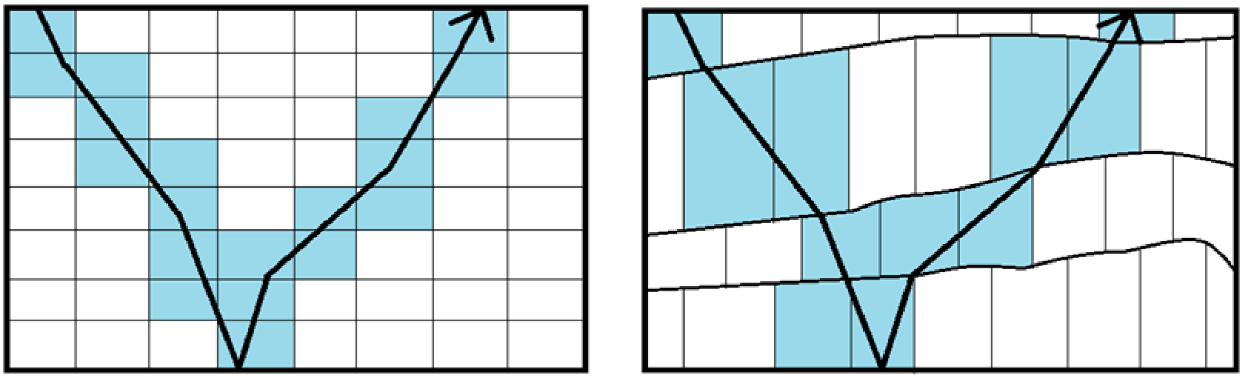


Figure 4. Grid-based tomography (left), model-based tomography (right) (Fagin, 2002)

Figure 5. Seismic acquisition location map (courtesy of Google Earth)

Table 1. Seismic acquisition parameter

Configuration	Off-end
Source	1024
Source interval	25 m
Receiver	400
Receiver interval	12.5 m
Near offset	130 m
Far offset	5117.5 m
CDP	4492

METHODS

Basic seismic processing is done to a real marine data used in this research, such as muting, NMO, velocity analysis, up to PSTM. From those steps we get RMS velocity model and PSTM section (Figure 6). The RMS velocity is converted into interval velocity using Dix Transformation, coherency inversion and tomography.

In addition, we separate the interval velocity building into 2 parts. Firstly, we combine Dix Transformation and coherency inversion, where Dix Transformation is used for 2 uppermost layers and coherency inversion for the other deeper layers, and then we run the PSDM. The second part is we still used Dix Transformation for 2 uppermost layers and coherency inversion for the other deeper layers. But we also use tomography for the interval velocity model refinement for this part in order to be compared with the result from previous part. And then we run the PSDM. We did 3 iterations for each part.

RESULTS

Figure 7 shows the comparison between seismic section resulted from Pre Stack Time Migration (PSTM) and Pre Stack Depth Migration (PSDM) with iterative tomography.

Figure 8 shows comparison between PSTM and time-converted PSDM section. It shown that PSDM gives significant improvement in amplitude as we expected.

Figure 9 shows the comparison between PSDM gathers using both Dix-Transformation and coherency inversion and PSDM tomography. Depth migrated gathers from PSDM uses tomography is flatter than depth migrated gather from PSDM that only uses Dix transformation and coherency inversion.

The effect of tomography to PSDM is shown in Figure 10, which compare between depth-migrated seismic section PSDM using both Dix-transformation and coherency inversion and PSDM tomography.

DISCUSSION

Tomography gives some improvements to the result that the continuity and fault definition in PSDM section which uses tomography is better than in PSTM. Compared with PSTM section, depth sections resulted from PSDM are converted to time domain then compared with PSTM section. We can see significant improvements, such as better continuity and fault definition given by tomography. From the comparison between their amplitudes, we can see that PSDM that uses tomography is more reliable, shown by stronger amplitudes.

CONCLUSION

PSDM is the ultimate seismic imaging tool proved by better image quality compared with one which resulted by PSTM. It shows better continuity and better fault definition.

Tomography plays an important rule in improving the quality of the seismic image both in PSTM and PSDM. The reliability of it shown by comparison of seismic gathers resulted from PSTM and PSDM. The seismic gathers from PSTM and PSDM that use tomography are more reliable proved by flatter gathers they have.

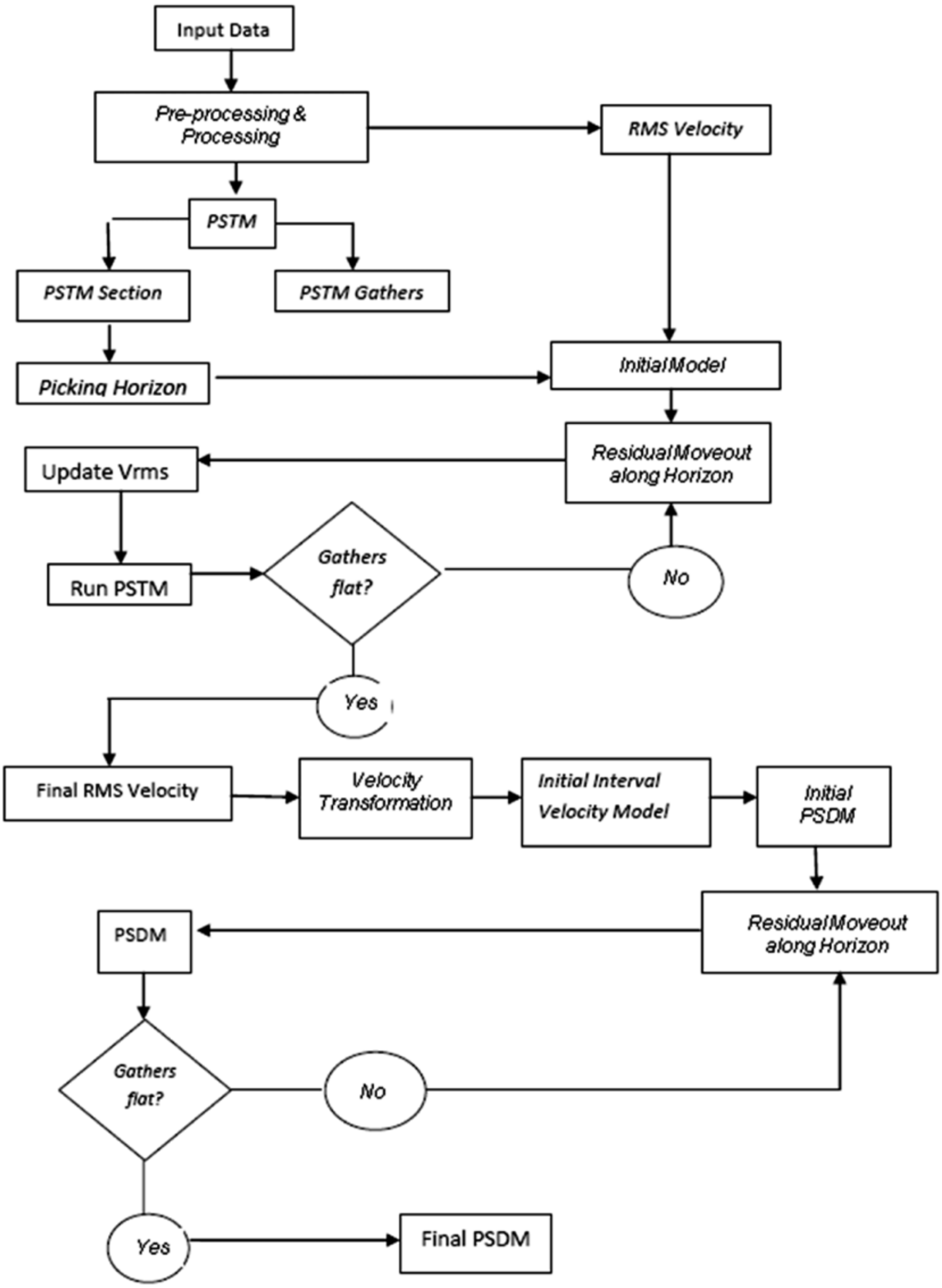
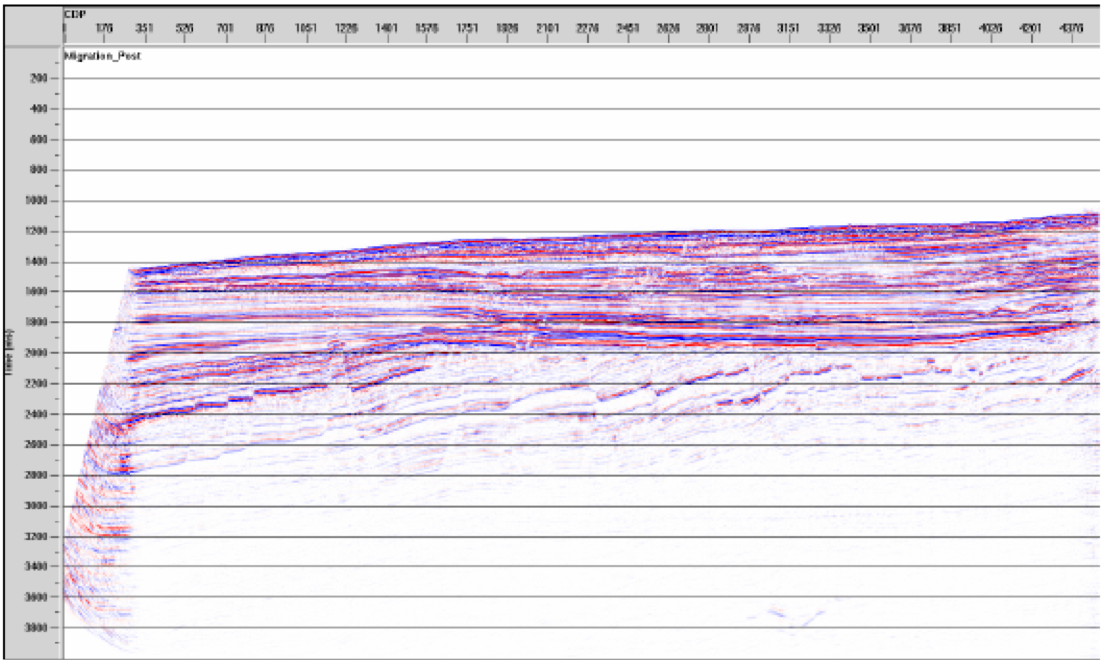


Figure 6. PSDM Flowchart



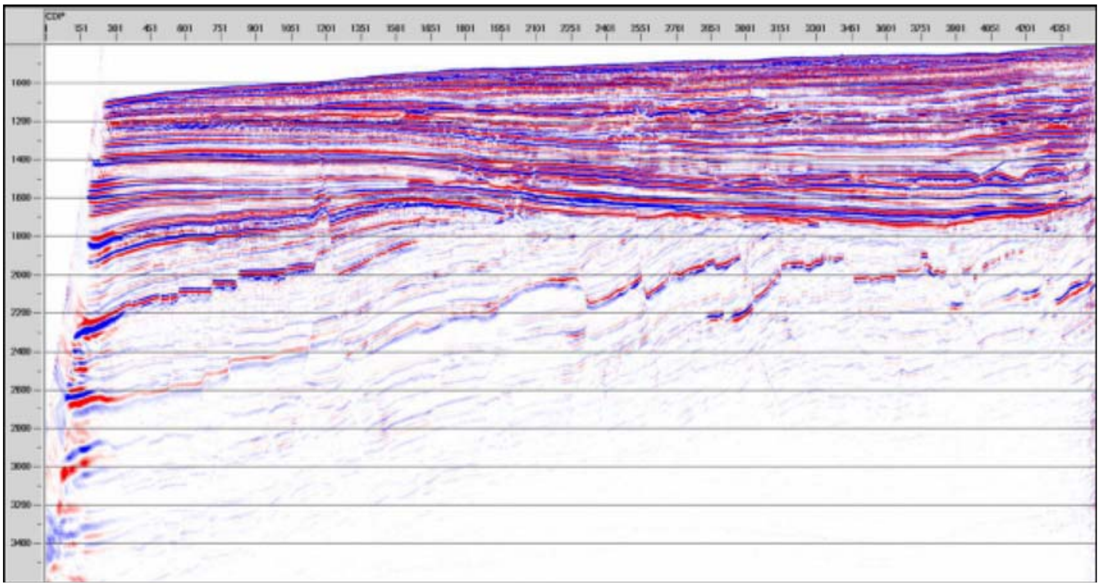


Figure 7. Comparison PSTM (top) and PSDM iterative tomography (below) seismic section

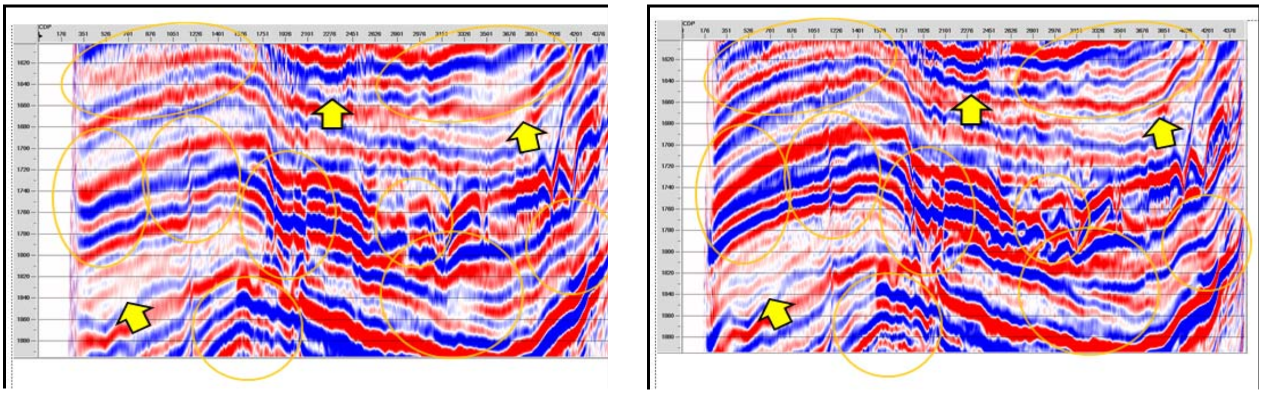


Figure 8. Comparison between PSTM (left) and time-converted PSDM (right) using tomography

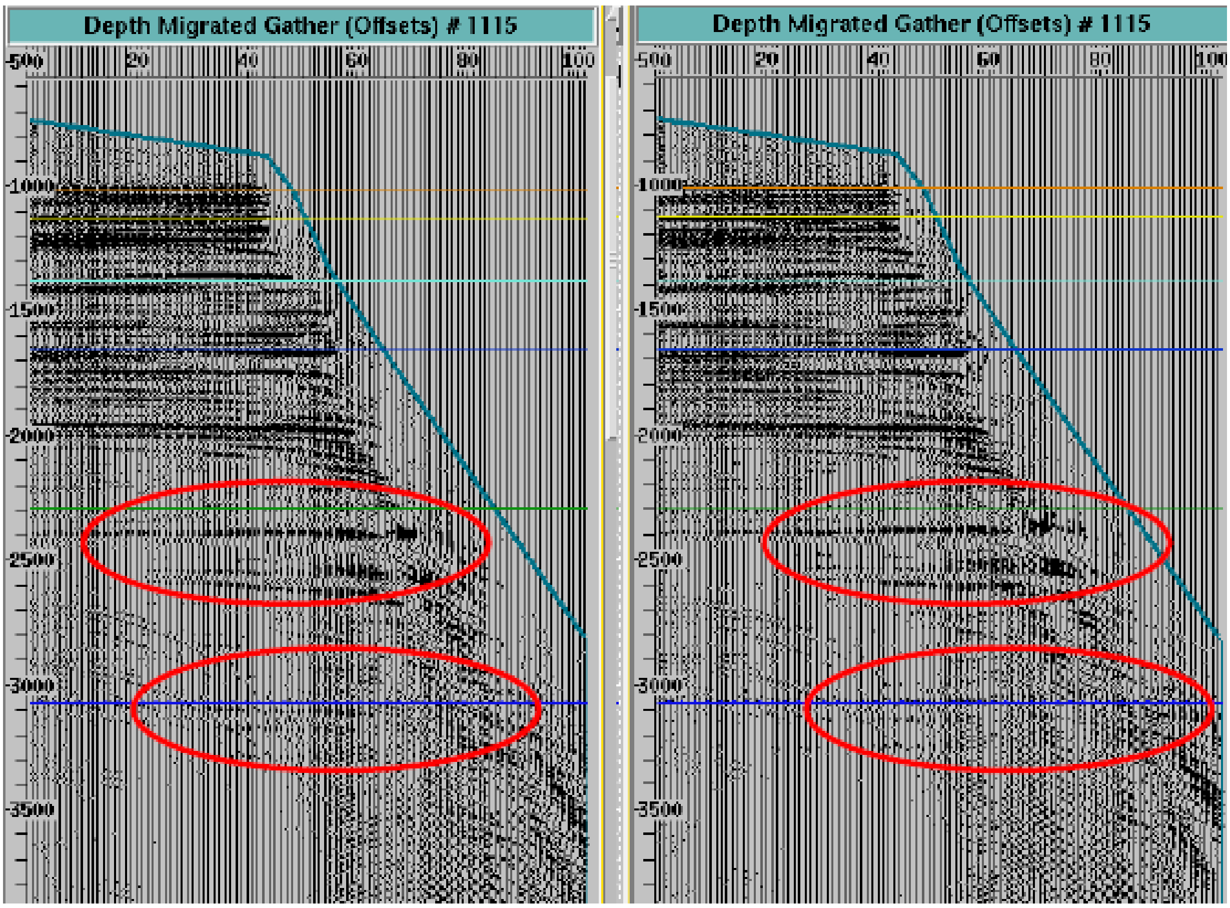


Figure 9. Comparison between depth-migrated gather PSDM using Dix-Transformation and coherency inversion (left) and tomography (right)

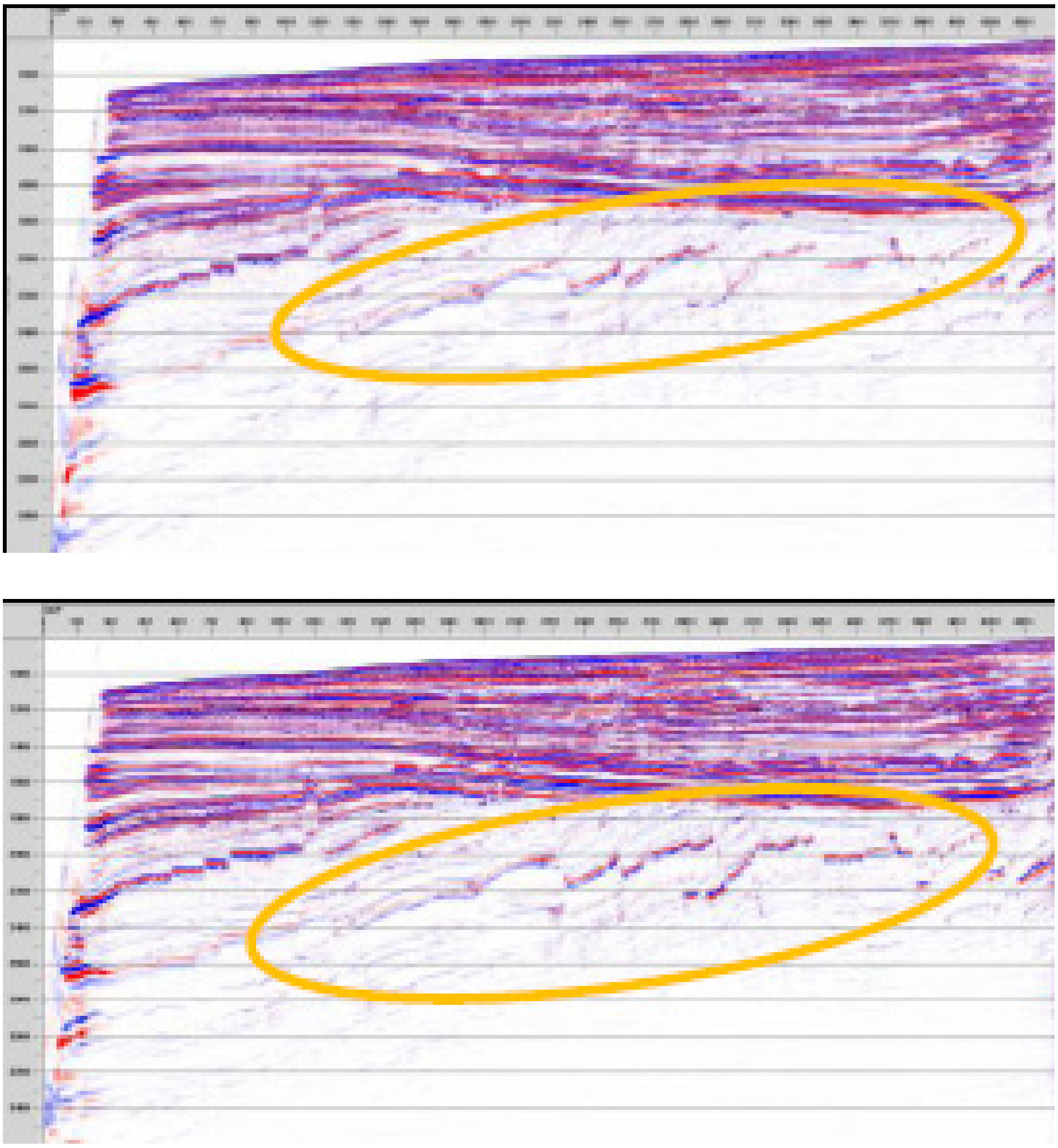


Figure 10. Comparison between depth-migrated seismic section PSDM using Dix-transformation and coherency inversion (top) and tomography (below)

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