Seismic Imaging in Complex Geological Area Using Pre-Stack Depth Migration (PSDM) and Tomography Method

A B Prabowo and Sudarmaji

1 Geophysics Universitas Gadjah Mada
Sekip Utara, Bulaksumur, Yogyakarta, Indonesia 55281
Agung.budi.p@mail.ugm.ac.id

Abstract. Pre-Stack Depth Migration (PSDM) method is required for seismic imaging in the area with complex geological structures such as fault, anticline, or syncline. Result of the PSDM depends on the interval velocity model as its input. A valid interval velocity model can yield appropriate seismic section and vice versa. One way to get an accurate interval velocity model is tomography method. This method can refine interval velocity model until it has minimum error. In this research, it’s used 2 kinds of tomography method, i.e. horizon based tomography and grid based tomography. Horizon based tomography considers the depth model in interval velocity refinement process, while grid based tomography doesn’t. Tomography is done till 6th iteration where the result of 6th iteration show the best quality of seismic section. The results show that the best quality section is PSDM using horizon based tomography. It has more geological sense than the PSDM section using grid based tomography and PSDM without tomography. Furthermore, PSDM using horizon based tomography is capable to correct pull-up effect with better continuity.

Keywords: PSDM, horizon based tomography, grid based tomography.

1. Introduction

Reflection seismic method is one of the geophysical methods to subsurface imaging. This method can yield section that have higher resolution and wide area coverage than other geophysical methods. One of the stages that determines the quality of section on seismic method is seismic data processing. In such case of simple geological structures and lateral velocity variations, the data processing is sufficient until PSTM. But, in complex geological area such as fault and presence of salt dome or reef carbonate with high lateral heterogeneity, it is necessary to apply pre-stack depth migration (PSDM) using interval velocity model as its input.

Previous PSDM research was conducted Atmaja and Sudarmaji by correcting the pull-up effect in seismic data using PSDM. The PSDM result indicates that the pull-up effect which is still visible on the PSTM section can be identified and corrected [1]. Then, Nugroho and Sudarmaji compared the horizon based tomography and grid based tomography methods in the PSDM on seismic data. The results show that horizon based tomography has better quality than grid based tomography [2].

2. Method

This research used 2D reflection seismic data located in Alberta foothills, Canada which was acquired by Husky Oil and Talisman Energy. Alberta Foothills has complex geological structure. On the southern part of the region is dominated by thrust faults, while in the north is dominated by folds [3]. The complexity of geological structure in Alberta Foothills can be seen in geological section that parallel to the seismic line as shown in figure 1. The seismic data has high velocity variation because it is located in complex geological area.
The International Conference on Theoretical and Applied Physics

IOP Conf. Series: Journal of Physics: Conf. Series 1011 (2018) 012033
doi:10.1088/1742-6596/1011/1/012033

**Figure 1.** Geological section in Alberta Foothills that parallel to the seismic line. It shows geological complexity such as folds and faults in Alberta Foothills (Modified from [4] and [5]).

The seismic data consists of 143 shot gather, 4 ms sampling rate, trace number 39764, and 3000 ms recording length [6]. This seismic data processing used software Paradigm Echos and Geodpeth. Steps in seismic data processing is divided into 2 parts, first is pre-stack time migration (PSTM). The second step is pre-stack depth migration (PSDM). On PSDM steps include of interval velocity model refinement process using horizon based tomography and grid based tomography methods. The tomography process is done iteratively to get the best section. Determination of section quality is seen from flat or not the gather, reflector continuity, and validated by geological section (figure 1).

3. Results and Discussion

3.1. Velocity model analysis

In this research, 6th iteration tomography shows the best result, so the tomography process stopped at 6th iteration. The result of the 6th iteration of horizon based tomography and grid based tomography are shown by figure 2 and 3. Based on these images, it is known that the result of horizon based tomography has a lower interval velocity at shallow depth. In addition, distribution of interval velocity on the horizon based tomography looks smoother than the grid based tomography results. It is caused horizon based tomography consider depth model in interval velocity model refinement process, whereas grid based tomography only refines velocity using statistical calculation considering the depth model [7].

**Figure 2.** Interval velocity model resulted from horizon based tomography 6th iteration. Blue colour indicates high velocity zone, while yellow colour indicates low velocity zone.
3.2. **PSDM section analysis**

Initial PSDM section (without tomography) is shown in figure 4, while PSDM using horizon based tomography section and PSDM using grid based tomography section shown by figures 5 and 6. Based on those sections, PSDM using tomography section shows a significant difference compared to the initial PSDM section. The first difference is shown by the anticline structure in figures 4 (a), 5 (a), and 6 (a). Geometry structure of anticline on PSDM horizon based tomography section looks more suitable with the geological section than the PSDM using grid based tomography section. It shows that horizon based tomography has more geological sense. The next difference lies in the reflector continuities shown by figure 4 (b), 5 (b) and 6 (b). It shows that the reflector on PSDM using horizon based tomography section have better continuities than reflector on the others section. Horizon based tomography is also capable in correcting the pull-up effect shown in figure 4 (c) on the initial PSDM section. The pull-up effect is characterized by the presence of an upward-looking reflector resembling an anticline. The pull-up effect is caused by a significant velocity difference between the Rundle Group and the Blairmore formation. The carbonate-dominated in Rundle group causes the seismic wave velocity in the area to be relatively higher than the seismic wave velocity in the sandstone-dominated in Blairmore Formation. On the PSDM using horizon based tomography section (figure 5 (c)), the pull-up effect is reduced. In contrast, on the PSDM using grid based tomography section, the pull up effect still appears as shown in figure 6 (c).

**Figure 3.** Interval velocity model resulted from grid based tomography 6th iteration. Blue colour indicates high velocity zone, while yellow colour indicates low velocity zone.

**Figure 4.** The result of PSDM initial. Input for PSDM initial uses velocity model without tomography (initial interval velocity model).
Figure 5. The result of PSDM horizon based tomography. This seismic section uses interval velocity model resulted from 6th iteration of horizon based tomography.

Figure 6. The result of PSDM grid based tomography. This seismic section uses interval velocity model resulted from 6th iteration section of grid based tomography.

3.3. Comparison of PSDM section and PSTM section
PSDM horizon based tomography section has several advantages compared with the PSTM section. PSDM horizon based tomography is capable to reduce the pull-up effect seen in the PSTM section as shown in figure 7 and 8 (a). It is characterized by the appearance of flat reflector. The next difference is shown in figure 7 (b) and 8 (b). The reflector on the horizon based tomography PSDM section has better continuity than the reflector on the PSTM section. It is caused by the accurate velocity model on the PSDM. The Velocity model that used in the PSDM section is generated from horizon based tomography method. This method uses ray tracing algorithm so that it can accurately calculate the velocity. Figure 7 (c) and 8 (c) show the structural imaging differences on the PSDM and PSTM sections. In the PSTM section, the reflector's appearance looks straight, while the horizon based tomography PSDM section shows the anticline structure. The appearance of the anticline structure is corresponding to a geological section shown in figure 1.

Figure 7. PSTM section. This seismic section uses RMS velocity model as input.

Figure 8. PSDM horizon based tomography. It was compared to PSTM section.

4. Conclusion
Based on the result, we know that PSDM section is better than PSTM section. It shows that the PSDM can handle lateral heterogeneity and high velocity variation in complex geological area. However, tomography method need to be applied on PSDM because this method needs accurate velocity to yield valid seismic section. On the resulted section shows PSDM horizon based tomography yields better seismic imaging than either PSTM or PSDM grid based tomography. In
addition, PSDM horizon based tomography yields seismic section close to geological appearance. Finally, the best appropriate method applied in complex geological area such as Alberta foothills is horizon based tomography.

5. Acknowledgement
We would like to say thanks to Paradigm Geophysical inc. for software donation and Chevron for hardware donation given to laboratory of geophysical Universitas Gadjah Mada, so we can finish this research.

References
[1] Atmaja I S and Sudarmaji 2013 Proc. Pertemuan Ilmiah XXVIII HFI Jateng dan DIY (Maret 23 Surakarta)
[2] Nugroho Y D and Sudarmaji 2014 J. of Applied Physics 4 63
[3] Wright G N, McMechan M E, and Potter D E G 1994 Structure and Architecture of Western Canada Sedimentary Basin (Alberta: Canadian Society of Petroleum Geologists and the Alberta Research Council) pp 25-40
[4] Anonim 1972 Geology Lake Minnewanka (East Half) West of Fifth Meridian Alberta (Alberta: Geological Survey of Canada Department of Energy, Mines and Resources)
[5] Anonim 1972 Geology Wildcat Hills (West Half) West of Fifth Meridian Alberta (Alberta: Geological Survey of Canada Department of Energy, Mines and Resources)
[6] Anggara R 2014 Pengolahan Data Seismik 2D Lintasan “Eda Calosa” Kaki Pegunungan Alberta, Kanada Berbasis Metode Prestack Time Migration (PSTM) dan Prestack Depth Migration (PSDM) Isotropy dengan Menggunakan Paradigm Epos 4.0 (Yogyakarta: Universitas Gadjah Mada)
[7] Anonim 2009 EPOS 4.0 Help (Houston: Paradigm Geophysical Co)