Near-Surface Modeling Using First Arrival Tomography: A Case Study on High Variation Topography and High Surface Energy Attenuation Area

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Abstract. This paper describes a method to build a near-surface velocity model. The purpose of this work is to have a better understanding of the near-surface condition below area with high variation topography and high surface energy attenuation. The velocity model built then was used as input for statics calculation. The method applied to this work is first arrival tomography. This method was tested using two datasets with different acquisition geometries. And to verify the result, we compare the calculated statics correction with a conventional method. The results of this work is two similar near-surface models with detail model and the statics applied on the seismic data showed better correction compare to the conventional one. We conclude that the method is applicable accurately on the area with high variation of topography and high surface energy attenuation.

1. Introduction
Some near surface problems can affect seismic data quality. Near surface problem such as extreme topography and high attenuation at near surface can make reflector looks discontinuity. The model velocity that build from travel time tomography method can be used to near surface Subsurface condition can be determined from velocity model that build from traveltime tomography. Furthermore, that model velocity can be used for static correction calculation of the seismic data (Zhang, 2015). Static correction with this velocity model expected better than static correction with elevation static method.

The case study of this work use two kinds of acquisition method to model velocity building control. The first type of acquisition method use the conventional method with buried source beneath the surface and receiver at the surface. The second acquisition method is almost the same as first parameter except for receiver depth. The receiver for second acquisition method is buried beneath the surface. Location of the source and receivers for second acquisition method the same as first acquisition method.

2. Methodology
2.1. Fermat’s Principle
Important property of seismic raypath is given by fermat’s principle. Raypath is spatial curve along the medium which traveltime with minimum slowness is stationary. After all curve are connecting,
minimum traveltime between source and receiver can be found (Moser, 1991). Traveltime between source and receiver can be calculated by summing traveltime of each curve.

2.2. Refraction Traveltime Tomography Method
A number of refraction traveltime tomography methods have been developed. White (1989) described a refraction traveltime tomography method that applies a two point raytracing algorithm and solves a damped least-squares problem for both velocities and refractor depths. Zhu and McMechan (1989) performed refraction tomography using an analytic traveltime solution and requires the initial model to have positive velocity gradients. Ammon and Vidale developed a refraction traveltime tomography method that regularizes the inverse problem with second-order model derivatives in a jumping fashion. The use of the traditional two-point ray-tracing algorithms limits the accuracy of tomography inversion. The ray methods suffer from the problem of converging to a local minimum traveltime path and occasionally missing the global minimum (Moser, 1991). An ill-posed inverse problem must be properly regularized in order to obtain a stable solution, which is independent of the model discretization (Delprat-Jannaud and Lailly, 1993). Rodi (1989) and Zhang et al. (1996) showed that regularizing the model stepsize (creeping) rather than the model itself (jumping) cannot ultimately avoid solving an illposed inverse problem. Further, not all the regularization approaches perform well, and an appropriate criterion for refraction traveltime tomography must be defined.

2.3. Shortest Path Ray Tracing Method
To perform a tomography study, we need ray tracing technique to travel time and raypath calculation. There are some solutions to the wavefront ray tracing calculation. One of the solution is shortest path ray tracing (SPR). On the SPR method use graph theory expand a wavefront by finding the shortest path. Seismic raypath can be found by the shortest traveltime paths through a network that represents the earth. The network consists of nodes, and the nodes connection is based on a graph template. These node functioning as new source on the wavefront calculation (Zhang dan Toksöz, 1998).

The SPR method include three steps. First, timing nodes along an expanding wavefront from its original source or secondary source. Second, finding the minimum traveltime point along the wavefront and taking this point as a new secondary source. Third, expanding the wavefront from this minimum time point. These steps are repeated until the whole model is traced. (Zhang dan Toksöz, 1998). With a small number of ray legs in a graph template, SPR usually yields zig-zag raypaths in homogeneous or smooth velocity zones in the model, and produces longer raypaths (Fischer and Lees, 1993).

3. Acquisition Parameter
There are two parameter acquisition at this work. Both of acquisition parameter, source and receiver at the same location. First parameter, receiver is buried at surface (conventional method). Second parameter, receiver is buried 6 meters beneath the surface. The source in buried about 40 meters beneath the surface.

4. Case Study
The survey area of this case study contain an extremely topography (fig. 1). The extremely topography make discontinuity reflector at near surface. The receiver elevation is about 79.3 to -6.4 meter.
Aside from topography problem, in this case there is strong surface attenuation, so energy from source can’t be well propagated. Shot gather from surface source contained low frequency velocity and make reflector aliasing with low frequency noise. Fig. 2 shows shot gather obtained from conventional acquisition with strong surface attenuation. This attenuation is caused by weathering layer with velocity range from 880-1100 m/s. Fig. 3 shows velocity model with surface receiver.

In this study, we use 2 different acquisition parameter as comparison. First acquisition parameter is conventional acquisition method with source and receiver buried 40 m beneath surface. Second acquisition parameter is also conventional acquisition method with source buried 40 m and receiver 6 m beneath surface. Velocity model from both acquisition relatively identical. Fig 3 shows velocity model with surface receiver. Fig 4 shows velocity model with buried receiver 6 m beneath surface. Fig 5 shows velocity model different between 2 velocity model.
Fig. 4. Velocity model with buried receiver.

Fig. 5. Difference between two velocity model.

Velocity model obtained from both data seismic are used for static correction. Static correction from these velocity model shows better result than using elevation static method. Fig 6 shows gather data before static correction. Fig 7 shows gather after static correction using elevation static method. Fig 8 shows gather after static correction using travel time tomography. Rough topography in elevation static correction method can be corrected using velocity model from travel time tomography method.

Fig. 6. Shot gather before static correction. Fig. 7. Shot gather after static correction using elevation static method.
Fig. 8. Shot Gather after static correction using travel time tomography method.

Stacked data seismic with static correction using travel time tomography shows better result than using elevation static method.

Fig. 9. Stacked seismic after correction static with conventional acquisition method

Fig. 10. Stacked seismic after elevation static correction with conventional acquisition method.

Fig. 11. Stacked seismic after static correction using travel time tomography and conventional acquisition method.

Fig. 12. Stacked seismic before static correction with buried receiver method.
Fig. 13. Stacked seismic after static correction using travel time tomography and buried receiver method

5. Conclusion
Velocity modeling can be used for determine near surface problem. Velocity model that build form travel time tomography can represent near surface condition. The proper of velocity model can be used to static correction. Static correction method with velocity model that build from traveltime tomography batter than elevation static method.

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