Indonesian Journal of Physics
Vol 20 No. 2, April 2009

Characterization of Subsurface Coal Using Seismic Tomography : a Case Study in Muara Enim South Sumatera

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Abstract

In recent years, coal as well as coal bed methane becomes important energy resources. Therefore, the characterization of coal seam is also important in predicting the quality, porosity and pore's fluid of CBM's reservoir. Seismic wave is very important parameter to characterize reservoir's properties of coal bed methane as well as quality of coal. In this paper, we show methodology to image the subsurface velocity using seismic tomography. It is very useful for characterizing the coal's seam as well as to detect the position of intrusion body.
A case study was carried out in Suban Block, Muara Enim Sumatera. This coal mining block contains igneous rock intrusion which becoming main control of coal's quality. Coal which is close with intrusion body usually has better quality than far zone.
To acquire the data, we used 48 channels of seismic recorder controlled by telemetry for controlling the shot and first break. Then, data are processed by Fresnel interpolated wave-path (FIW) wide-band inversion tomography.
The results show that the intrusion body can be imaged clearly and the seam coal can be delineated from well information. The information in well controls are quite match with tomography results.

Keyword: *Coal seam characterization, Fresnel interpolated wavepath tomography, Wide band inversion, Intrusion body imaging*

1. Introduction

In recent years, tomography has become an important tool for mapping unknown objects. Tomography is often used in medical engineering for finding tumors in the brain as well as in applied seismology for mapping the earth's interior, and in exploration geophysics for unraveling complex geological structure. Geotomography appears to be very serviceable since it can provide accurate estimates of seismic velocities regardless of their complexities.

Suban coal mining block is located in Muara Enim, South Sumatera. This coal mining block contains igneous rock intrusion. Aims of this study is to image the position of interface between sedimentary rock and intrusion igneous rock. This result, then, is important for designing the mining plan.

Imaging subsurface igneous intrusion rock is quite difficult. It is due to the complexity of subsurface body of intrusion. The body of intrusion bodyhas usually steep dip, even overhang dip. Therefore, to handle the limitation of geophysics method in order to image the subsurface intrusion body, we propose seismic tomography with wide-angle configuration. This wide-angle tomography is a cheaper configuration compared with cross well tomography. So, we can produce a high quality subsurface velocity tomography image with relatively low cost.

Output of this measurement procedure is not only position and dimension of intrusion body, but also velocity information of the subsurface. This velocity information is proportional with rock's stiffness. Therefore, this information is very useful for mining plan, i.e: estimating the ripability of rock, estimating the remaining reserve in subsurface, and estimating.

2. Methodology

In this survey, we use wide angle tomography configuration. Configuration of the wide-angle will produce deeper image than narrow configuration. The data is computed and imaged using Fresnel interpolated wave-path (FIW) wide-band inversion tomography. The FIW is an interpolation between imaginary part of Rhytov scattering wave-path and ray-path[1-4)]. FIW is then combined with wide band inversion for producing a stable inversion procedure.

Wide-band inversion of FIW tomography has been tested into various difficult and challenge seismic field data in order to image intrusion, void, fault and even fracture. The results showed that tomography based on FIW could handle the limitation of configuration angle, sparseness configuration and resulting good image. We have used this method in many difficult cases of field data such as: subsurface tunnel imaging and also void-fracture imaging in volcanic rock[2,4,5)].

3. Fresnel Interpolated Wavepath Tomography

Fresnel interpolated wavepath (FIW) is a interpolation approach of raypath and the imaginary part of Rhytov approximation wavepath. Eventhough this wavepath contains scattering wavepath, by following formulation we can simplify of calculation procedure of FIW by means travel times from source to any points, receiver to any points and source to receiver see Nurhandoko[5,6].

Let phase perturbation can be expressed by Rhytov approximation.

$$\Delta\phi(g\,|\,s)=\sum_r\left(2.\omega_0{}^2\,p_0G(r\,|\,s,g)\right)\Delta p.d \qquad (1)$$

Where $\Delta\Phi$ indicates wave field phase perturbation. d is a raypath length in a cell and G is Green function. We would like to minimize the slowness difference Δp by minimizing phase misfit $\Delta\phi$ of equation (4). By Lagrange multiplier, let the error function (*E*) of Δp prediction is expressed as follows:

$$E=\sum_r\left((\Delta p)^2-L_\lambda A(k)\left(2\omega_0{}^2\,p_0G(r\,|\,g,s)\Delta p.d-\Delta\phi\right)\right) \qquad (4)$$

By minimizing the error, we can find Δp prediction as following:

$$\Delta p=L_\lambda A(k)\omega_0{}^2\,p_0G(r\,|\,g,s)d \qquad (5)$$

Where,

$$L_\lambda=\frac{\Delta\phi(g\,|\,s)}{\sum_r\left(2\omega_0 4\,p_0{}^2\Delta pG(r\,|\,g,s)^2d^2A(k)^2\right)} \qquad (6)$$

To normalized the equation, the weight factor A(k) is assumed to be $A(k)=\left(2\omega_0{}^2\,p_0{}^2\right)^{-1}$

The phase can be expressed by product of frequency and time, then the Rhytov scattering wavepath can be extracted using following equation:

$$\Delta p=\frac{d.L_{wavepath}.\Delta T}{\sum_r d^2.L^2_{wavepath}}. \qquad (7)$$

Then, we interpolate $L_{wavepath}$ of equation (7) with raypath and normalized it to produce Fresnel zone interpolated wavepath[1,6].

While the frequency is higher, the Fresnel zone wavepath oscillates spatially more frequent than when the frequency is lower (see Figure 1). In the high frequency, Fresnel Interpolated wavepath becomes similar to the ray path. If we consider on first Fresnel zone only, the character of FIW is quite similar with Fresnel wavepath which has been proposed by other authors[7-10]. In the application of Fresnel zone wavepath to the inversion tomography, we sweep gradually the frequency from low to high to produce Wide-Band Fresnel Interpolated wavepath.

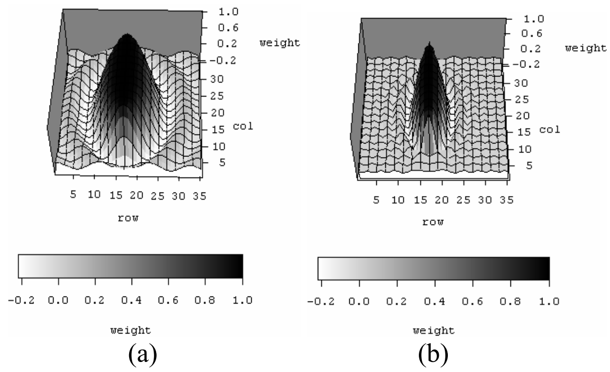


Figure1. Fresnel interpolated wavepath in homogeneous medium, (a) 10 Hz wavepath, (b) 30 Hz wavepath.

4. Field Data Acquisition

To acquire data of seismic tomography, we used a set of seismic recorder 48 channels or 2 set of 24 channels including set of acoustic wave sensors (geophones). After the recorder and geophones were set up on the field as shown Figure 2, then a series set of shots are done as shown in Figure 2 and Figure 3 a.

Strategy of shooting in this survey uses quite dense shot configuration, every 3 space of geophone are shot, see Figure 3. This strategy is done to reach the high resolution imaging. It can be seen in Figure 3 that the line of seismic tomography across the road, therefore we should use telemetry system when acquire seismic data. The geophone lay-out is designed in order to create the seismic wave propagation can reach and image the detail of intrusion body. Figure 4 shows the position of geophone's lay-out and position estimated of intrusion body.

Figure 5 shows the data which resulted from two seismographs: RAS-24 and Mc Seis 120. The data is quite clear but sometimes contains noise which may be caused by traffic from the mining road.

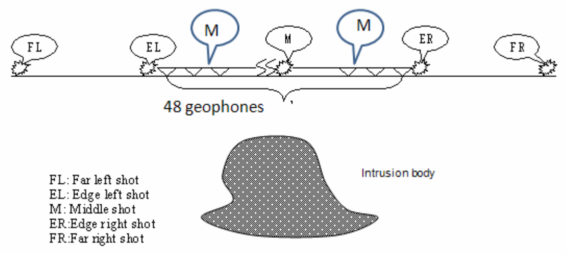


Figure 2. Configuration of tomography measurement

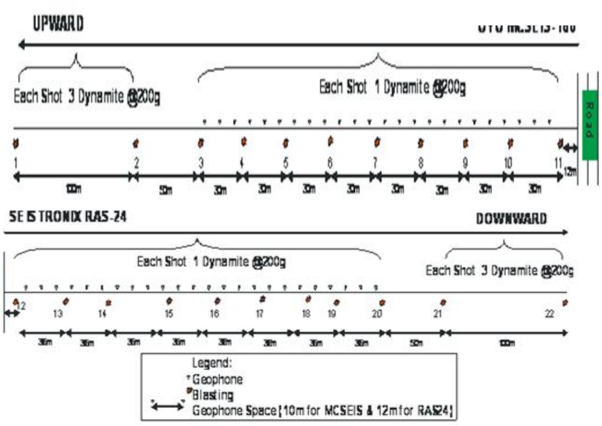


Figure 3. Real shot plan in field in plan view.

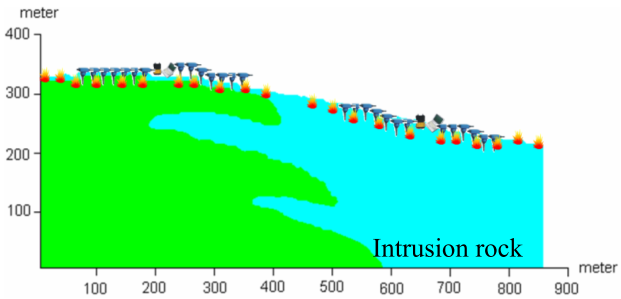
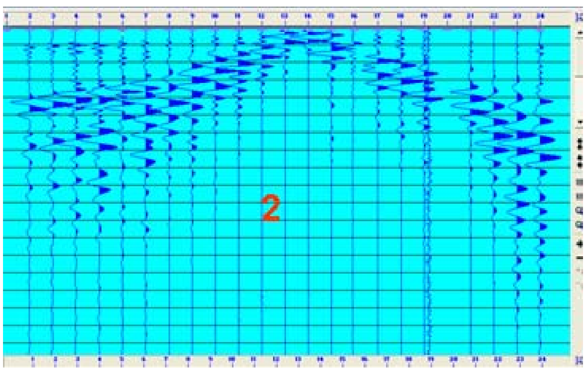


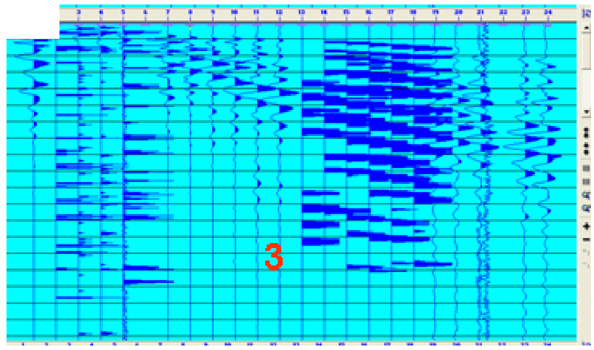
Figure 4. Cross section view of seismic tomography

5. Tomography Result

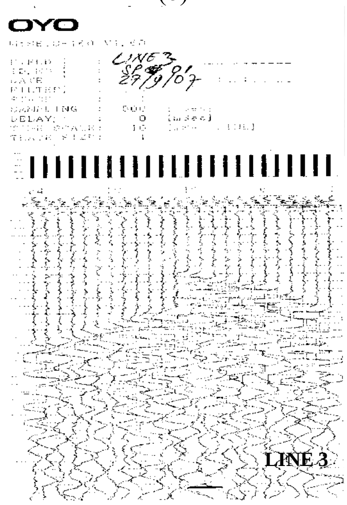
The imaging result of tomography by calculating equation (7) are shown in following figures. Figure 6 shows the tomography result of subsurface, it is clearly seen the boundary of high velocity zone which can be interpreted as intrusion body and the low velocity zone which can be interpreted as coal seam position. If we tie the tomography result with the well correlation as shown Figure 7, we can be reinterpreted to delineate the position of coal seams (see Figure 8). It is clearly seen from these Figure 6,7 and 8 that tomography image is match with borehole data, therefore we can delineate directly the distribution of coal near and surround the intrusion body.



(a)

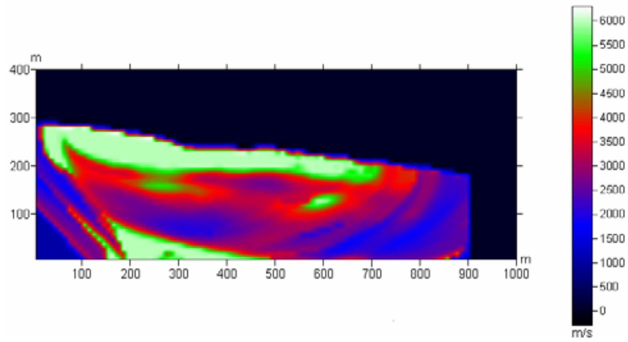


(b)

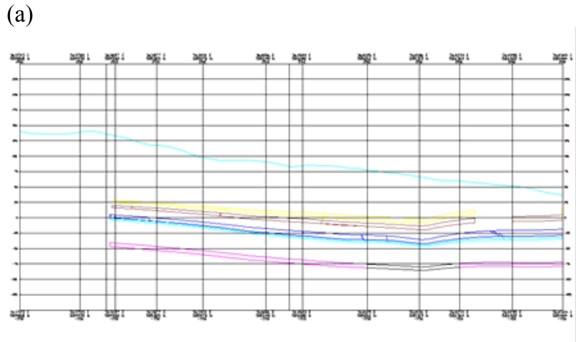


(c)

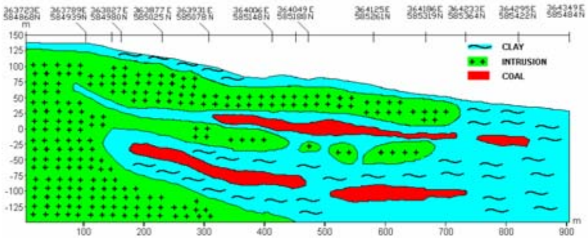
Figure 5. Raw seismic data, (a) data resulted by RAS-24 which quite noise free, (b) data resulted by RAS-24 which contained noise in some positions of geophone, (c) data resulted from Mc-Seis 120 which quite noise free.



(a)



(b)



(c)

Figure 6. Tomography result. (a) velocity image from tomography imaging, (b) Well correlation, (c) interpretation result from tying of tomography velocity image and borehole information.

6. Conclusions

Tomography is useful tool for imaging the remaining reserve of coal especially near intrusion zone which often very difficult because of their irregularity.

Tomography can produce good image even though using normal land seismic data acquisition data, we do not need cross-hole acquisition which is very expensive.

Acknowledgements

Authors would like to thanks to PT. Tambang Batubara Bukit Asam for giving us a permission to publish this data set.

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