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Simultaneous AVA Inversion to Extract Physical Properties of Rock

Abd. Haris[1], Farid Hosni[2]
Geophysics Section, Physics Department Faculty of Mathematics and Natural Sciences
University of Indonesia
[1]aharis@fisika.ui.ac.id [2]farid_hosni@linuxmail.org

Abstrak

Inversi AVA simultan dengan menggunakan persamaan Fatti telah digunakan untuk menghasilkan nilai yang lebih akurat dibandingkan dengan inversi impedansi akustik maupun inversi impedansi elastik. Inversi simultan ini menggunakan data stack dari berbagai sudut datang dan kemudian secara bersamaan diinversi untuk mendapatkan parameter elastik batuan seperti impedansi gelombanhg P, impedansi gelombanhg S dan kerapatan batuan. Hasil inversi AVA simultan menunjukkan bahwa parameter elastik hasil inversi mempunyai nilai yang mirip dengan nilai yang diturunkan dari data log. Impedansi gelombanhg P dan densitas hasil inversi juga menunjukkan secara jelas bahwa zona reservoar gas mempunyai nilai yang lebih rendah dari pada lapisan di atasnya. Tetapi pada impedansi gelombanhg S, nilainya tidak berubah secara signifikan.

Abstract

Simultaneous AVA inversion using Fatti equation has been applied to provide more accurate value compared to acoustic and elastic impedance inversion method. This inversion use stacked-seismic data from many incident angle (near, mid and far), and then simultaneously invert the data to get elastic parameters such as P-wave impedance, S-wave impedance and density. The results of simultaneous AVA inversion show the elastic parameters of inversion results have similar value which are derived from well log data. The P-wave impedance and density sections of inversion results also show clearly that the zone of gas reservoir has lower value than the above. But at S-wave impedance section, the value unchanged significantly.

***Keyword:** AVA, impedance, inversion and partial stack.*

1. INTRODUCTION

Nowadays, seismic data do not record shear wave directly, since either the source or receivers that is used in the survey can not propagate or receive shear wave. So, instead of getting directly, Vs need to be derived from compressional wave. There are so many ways to extract shear wave that is derived from compressional wave. One of the ways is observing compressional wave that vary with offset or angle. This method is known by AVA analysis.

Curve of AVA is dependent from the compressional wave (Vp), shear wave (Vs) and density (ρ), so there are three parameters that is needed to define the properties of AVA curve which come from reflection of reservoir. Commonly, three equation are needed to calculate Vp, Vs, and ρ. The elements that define these equations are implicitly found in near offset, mid offset and far offset. Therefore, by observing curve of AVA in three offset above, the elastic parameters Vp, Vs and ρ can be calculated directly. This technique is usually called by simultaneous inversion. One of the advantages of simultaneous inversion is that the method does not need any simplification or approximation to solve the equations that have limitation in magnitude of Vp and Vs.

2. BASIC THEORY

There are two types of waves that are of great interest when analyzing seismic data, the compressional wave, or P-wave, and the transverse wave, or S-wave. The equation for both of these waves can be written:

$$\alpha = \sqrt{\frac{\lambda + 2\mu}{\rho}}, \quad \beta = \sqrt{\frac{\mu}{\rho}} \qquad (1)$$

where α P-wave velocity and β S-wave velocity.

When seismic wave impinged two boundary layers which have different elastic properties (Vp, Vs, and ρ), the energy of the wave are partitioned into reflected wave and transmitted wave. The Zoeppritz equations fully describe the relationship between incident and reflection/transmission amplitudes for plane waves at a welded elastic interface.

The Zoeppritz equation, while exact, does not give a feeling for how amplitudes depend on the various factors involved. So, many people tried to simplify the Zoeppritz equations. One of them is Fatti [1], the approximations for R_{PP} is

$$R_{PP}(\theta) = a(\theta)\frac{\Delta I_P}{I_P} + b(\theta)\frac{\Delta I_S}{I_S} + c(\theta)\frac{\Delta \rho}{\rho} \quad (2)$$

where I_P, I_S and ρ are the average P-wave impedance, S-wave impedance and density values across an interface, ΔI_P, ΔI_S, $\Delta\rho$ are the P-wave impedance, S-wave impedance and density contrasts across an interface, θ is the average of the angle of incidence and transmission across the interface, and

$$a(\theta) = \frac{1}{2\cos^2(\theta)}$$
$$b(\theta) = -4\frac{\beta^2}{\alpha^2}\sin^2(\theta) \quad (3)$$
$$c(\theta) = \frac{1}{2}\tan^2(\theta) - 2\frac{\beta^2}{\alpha^2}\sin^2(\theta)$$

If we have three partial stacks on seismic data (near, mid and far), we have three equations from the equation (2) to get contrast of elastic parameter. These equations is given by

$$\begin{pmatrix} a_{near} & b_{near} & c_{near} \\ a_{mid} & b_{mid} & c_{mid} \\ a_{far} & b_{far} & c_{far} \end{pmatrix} \begin{pmatrix} \Delta I_P / I_P \\ \Delta I_S / I_S \\ \Delta\rho / \rho \end{pmatrix} = \begin{pmatrix} R_{near} \\ R_{mid} \\ R_{far} \end{pmatrix} \quad (4)$$

by taking the inverse of equation (4) is relatively simple and gives the result of contrast impedance.

To get the elastic parameters absolutely from fractional quantity above, band limited inversion have been used. This inversion uses a well log data to provide low frequency which is required by inversion process.

A number of derived parameters may be used to highlight changes in lithology and pore fluid content. Many of them is Lame parameter as indicator of existence and discrimination of fluid [2]. Lame parameters that would be derived here are lambda-rho (λρ) dan mu (μρ) .

Relation between P-wave velocity and S-wave velocity can be used to calculate Lame parameters. For S-wave velocity

$$\beta^2.\rho^2 = \mu\rho \quad (5)$$
$$\mu\rho = I_S^{\,2}$$

from P-wave velocity we found

$$\alpha^2.\rho^2 = (\lambda + 2\mu)\rho \quad (6)$$
$$\lambda\rho = I_P^{\,2} - 2I_S^{\,2}$$

This concept was successfully tested by Goodway et al. [3] to show the potential of improved petrophysical discrimination.

3. RESULTS AND DISCUSSIONS

This procedure was successfully applied to invert a 2D line extracted from a set of reflection data which reveals presence of gas throughout the line at the time 630 ms. This data set has been processed previously up to preserved amplitude and prestack migration. The results of Simultaneous AVA inversion can be seen in figure 1, 2 and 3.

The P-wave impedance and density sections show clearly that the zone of gas reservoir has lower value than the above. But at S-wave impedance section, the magnitude unchanged significantly.

The results of this inversion are good enough and having similar trend compare to well log data and crossplot between P-wave and S-wave impedance in figure 4 shows linear trend and any point that is out of linear trend indicating a good reservoir.

Lambda-rho section (figure 5) gives an image that similar to P-wave impedance, any increasing image especially in gas reservoir (dark blue color). Likewise, Mu-rho section (figure 6) is similar to S-wave impedance that is an excellent lithology indicator.

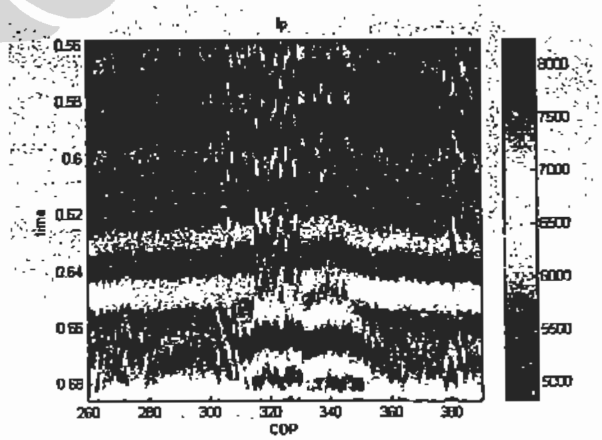

Figure 1. P-wave impedance.

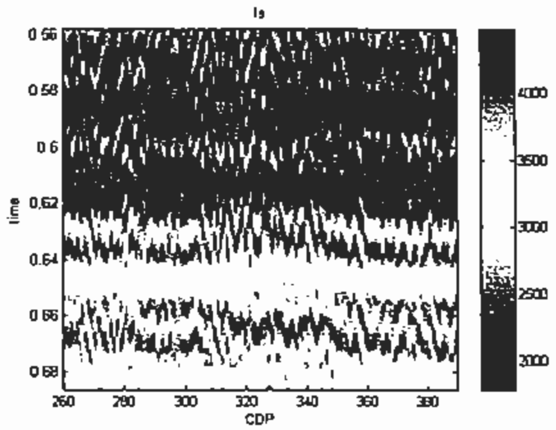

Figure 2. S-wave impedance.

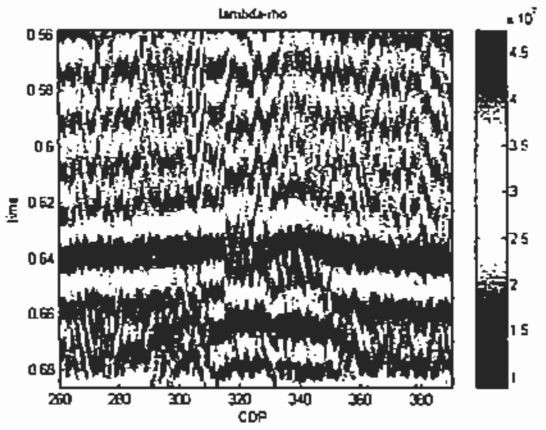

Figure 5. Lambda-rho.

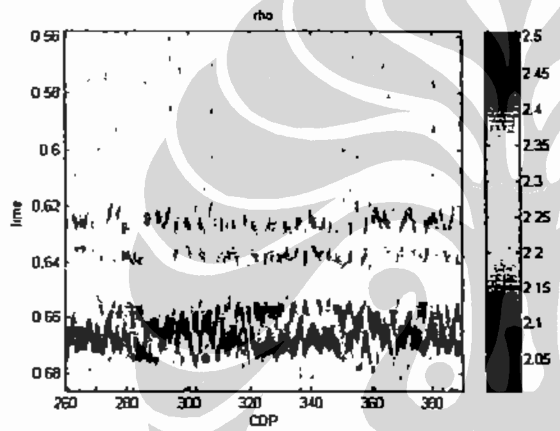

Figure 3. Density.

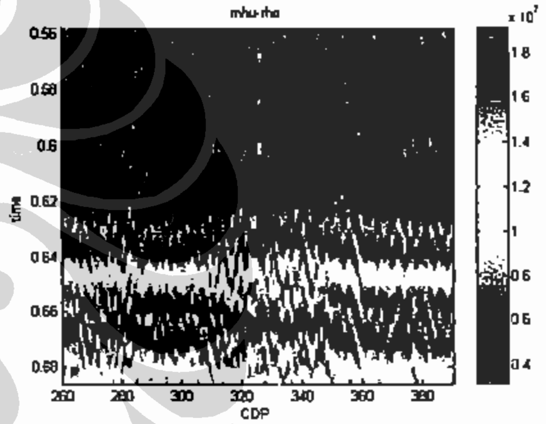

Figure 6. Mu-rho.

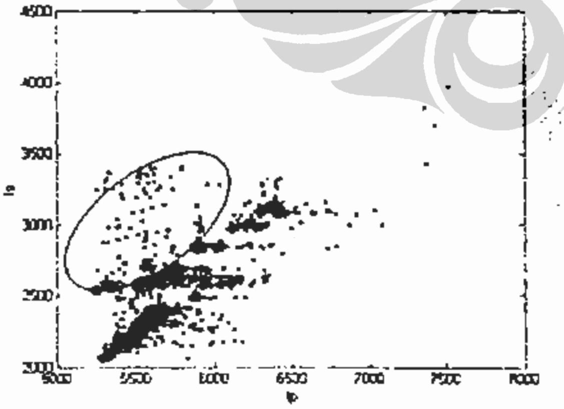

Figure 4. Crossplot between I and J.

4. CONCLUSIONS

Simultaneous inversion technique based on Fatti equation can be an alternative method to characterize gas reservoir. The output of this technique: P-wave impedance, S-wave impedance and density can be used to derive other physical properties of rock. In applying to real data set show that Lame parameter is more sensitive to detect gas reservoir than impedance parameter.

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