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Depth Migration Velocity: Differential Semblance Analysis for Sumatra Forearch Basin

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Abstract. The specific goal of this work is to present a complete velocity map obtained by picking the velocity in Common Image Gather (CIG) map. We simulated a shot gather in order to obtain a synthetic travel time data for depth analysis. We successfully determined the correct migration velocity and presented the velocity interval model. For further study, we also conducted a Semblance analysis in order to obtain a coherency panel between the energy and the depth migration velocity analysis. We successfully interpreted the conventional semblance profile that the correct velocity model maximizes that energy which is represent higher value. For the real case, The data set was acquired by CGGVeritas in 2009 of RMS velocities recorded in 48 CMP points. The results of the semblance analysis shows well coherence with the seismic reflectance data that reveals the Low Velocity Zone of Sumatra fault related to the present of fluid and gas.

1. Introduction

The aim of seismic imaging is to model the geological structures in the subsurface from reflection data recorded at the surface of the Earth [1]. One of Conventional seismic imaging consists of three steps: normal moveout (NMO), stacking, and migration. NMO is performed with the best *stacking* velocities, which must be converted to interval velocities in order to obtain a velocity model of the subsurface. Al-Yayha (1989). He conducted an imaging by performing the migration analysis in a subsequent step using these velocities. In his paper, velocity analysis and imaging are combined in one step, and migration itself is used as a velocity indicator [3]. To make velocity analysis valid for arbitrary reflector geometry and for areas where velocities vary laterally, NMO should be replaced by depth migration. The main reason for using depth migration is that it can be formulated for media with lateral velocity variations, which require migration velocity analysis methods to be capable of handling complicated structures.

In this study, The migration velocity using depth migration technic conducting by Al-Yayha (1989) wiil be conducted. We present the data in common image gather (CIG) for a velocity profile. For further study of NMO, we attempted to apply semblance analysis to the data set. The NMO velocity analysis using semblance spectra is an important first step toward building a velocity model. The accuracy of the preferred velocity model depends on the appropriate technique to pick the best matched velocity model, which means that it depends on the correct spectrum and resolution of semblance [2][4][7]. Semblance is the representation of a (normalized) coherency coefficient. The terms that emphasizing in a coherency coefficient calculation are sensitive to changes in velocity that increase the resolution of the corresponding velocity spectra [4]

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2. Methodology

according to work conducted by El Yahya (1989), the equation of the travel time is given by

$$t = \sqrt{(x)^2 + z^2}\overline{w} \qquad (1)$$

Where z is the depth to a horizontal reflector, $\overline{w}$ is the average slowness of the medium above the reflector, and t is a recorded travel time. If we migrate the average slowness $\overline{w_m} \neq \overline{w}$, therefore

$$t = \sqrt{(x)^2 + z_m^2}\overline{w_m} \qquad (2)$$

The travel time t in equation (1) and (2) must be equal[3]. And we get the final equation as it is shown below

$$z_m = \sqrt{\gamma^2 z^2 + (\gamma^2 - 1)x^2} \qquad (3)$$

Where, $\gamma = \frac{\overline{w}}{\overline{w_m}}$ (4)

For the quantitative data observation, we can derive the apparent depth as a function of Z_0 , than we have

$$z(h) = \sqrt{\gamma^2 z_0^2 + (\gamma^2 - 1)h^2} = \sqrt{z^2(h=0) + (\gamma^2 - 1)h^2} \quad (5)$$

Where x=h is the offset.

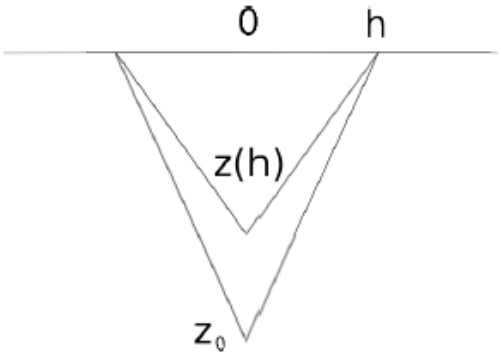


Figure 1. the apparent depth z(h) toward the depth of first reflector in z_0

The equation (5) that we used for demonstrated the depth migration analysis.

For further study, we also conducted both semblance and differential semblance analysis of the Common Image Gather (CIG) after migrating in order to obtain a velocity profile. The equation (6) and (7) were used for semblance analysis.

$$C_s(z;v) = \frac{[\int dh\, I(z,h)]^2}{\int dh \cdot \int dh\, I^2(z,h)} \qquad (6)$$

$$C_s(z;v) = \frac{\left[\int dh\, \frac{\partial I(z,h)}{\partial h}\right]^2}{\int dh \cdot \int dh\, I^2(z,h)} \qquad (7)$$

$I(z,h)$ is the CIG data.

In this report, we simulated the semblance analysis discretely. We transform the equation (6) and (7) in the sigma formula [6][8]

$$C_s(z;v) = \frac{\left[\frac{1}{N_z}\sum_{z_0}^{z_f}\frac{1}{N_h}\sum_{h=0}^{h_f} I(z;z_0,h)\right]^2}{\frac{1}{N_z}\sum_{z_0}^{z_f}\frac{1}{N_h}\sum_{h=0}^{h_f} I^2(z;z_0,h)} \qquad (8)$$

The normalized Semblance, $C_s(z;v)$, measures the degree of fitting of amplitudes of, I, of the traces of a CMP family for a certain stack velocity, from a first offset h =0 , to a last offset, h = h_f= h(n), with Nz points, in a temporal window dz, for a certain reflector n, marked by the depth $z0 = z(n)$.After we simulated both of the semblances analysis, then we got the semblance panel corresponding to depth and the migration velocity. We determined the velocity from up to bottom iteratively.

3. Result and Discussion

3.1. Result

First, we create a synthetic data of shot gather for 120 receivers within the interval of 5 meters. Therefore, the total offset we have is 600 m. we set the depth of the study for 1200 m depth. The travel time data before the depth migration Shows below

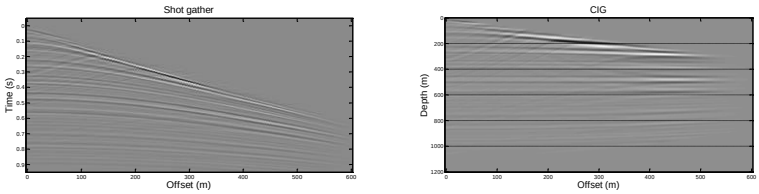


Figure 2. the shot gather map. (a) before the depth migration. (b) after depth migration

Here, we use the V_{rms} of 2000 m/s for the migration analysis.

The line corresponding to depth is not clearly straight. We only see the straight line at depth about 400 m. it means that at the depth of 400 m, our prediction of velocity (2000 m/s) is close to the real velocity. From the equation (4), if γ is less than 1, it means that the apparent velocity is bigger than the real velocity in that layer. In the reversal condition, we have γ bigger than 1, therefore, the real velocity is bigger than the apparent velocity. If the γ is equal to 1, this is the best condition of γ which gives us the information that the apparent velocity is equal to the real one.

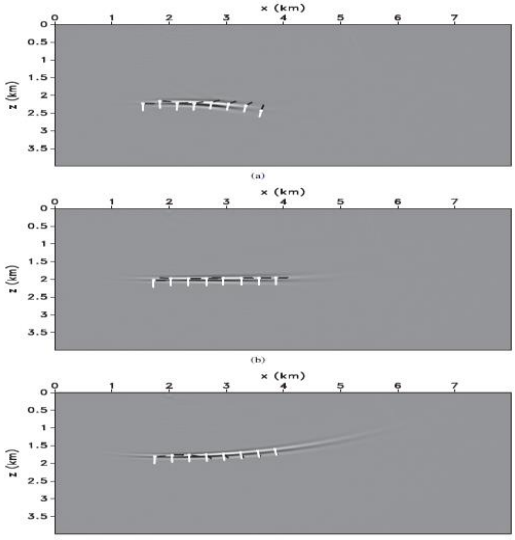


Figure 3. The density of Horizontal interface image using a single which indicates the error in velocities. The shot replace at x = 2 km with 800 receivers spaced 10 m at the surface: with the velocity is (a) lower, (b) matched, and (c) higher velocity. (extracted from *Linearized wave-equation migration velocity analysis by image warping* written by (F. Perrone *et al*. 2009)[1].

In order to find the velocity profile, we simulated another value of the velocity by trial and error so that we can see the CIG profile and define the velocity distribution in depth. We tried to predict the velocity at depth 200 m, 400 m, 600 m, 800 m, 1000 m, and 1200 m. here we present the image below

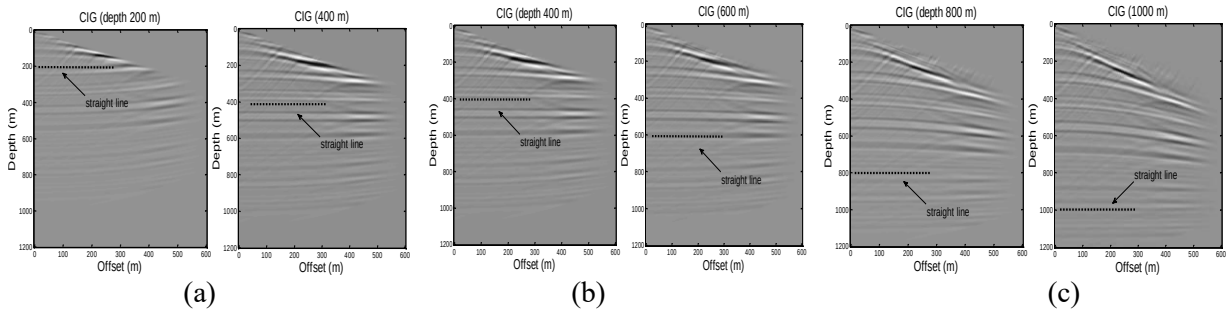


Figure 4. Straight line is correspond to the apparent velocity is equal to the real velocity model. The technic of measurement using trial and error. (a) at depth 200m and 400m. (b) at depth 400m and 600m. (c) at depth 800 and 1000m.

from this technique of measurement, we get a velocity profile at some point of depth. (table 1).

Table 1. Velocity Profile

Depth	**Velocity**
200 m	1850 m/s
400 m	2000 m/s
600 m	2050 m/s
800 m	2200 m/s
1000 m	2300 m/s
1175 m	2400 m/s

By picking manually, and according to the value in table 1., then we have the velocity interval profile as it is shown in

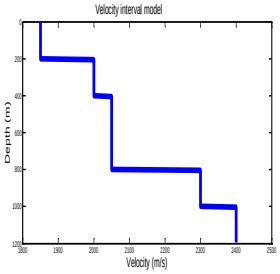


Figure 5. Velocity Interval model.

3.2. Discussion

The migration velocity analysis allow the velocity model to be known but as a predicted model. Nevertheless, It represents the main uncerrtainty and has to be calculated from the observed data. This technique is used to resemblance the dissimilarity of migrated images (by evaluating the redundant seimic data) using the semblance principle (Al-Yahya, 1989). This principle take into account to the unsteady subsurface of the seismic experiments. In this technique, the model generates unique and time-invariant data. Therfore, separated experiments should produce the same structures of seismic images [1][3].

Semblance analysis offers a somewhat more processed version of the same information available in the constant-velocity panels. The idea is that, when a reflection event is optimally flattened, its *semblance* will be maximized[1][4].

The semblance principle can be applicated in various ways: [1]

- First; In ordinary semblance analysis, the quality of the velocity image is represented by the energy of the stacked migrated images; the matched velocity model increase the amplitude;[7]
- Second; In differential semblance analysis, the first derivative of semblance represents the energy of the amplitude which is the correct velocity model; the correct model minimizes the energy.

Here, we simulated both conventional and differential semblance using the equation (8).

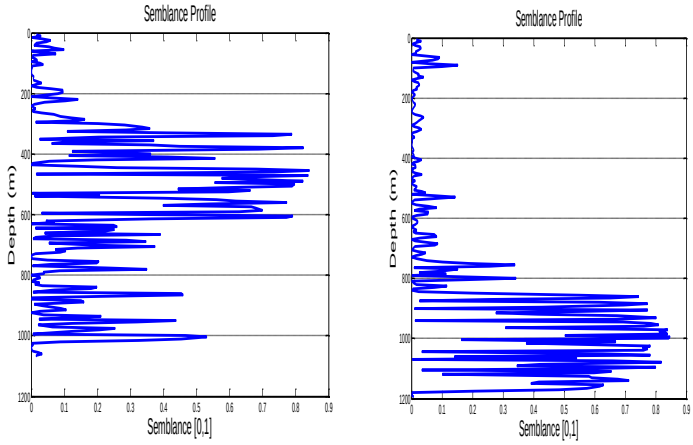


Figure 6. Semblance Profile for apparent velocity. (a) 2000 m/s at depth near 200m. (b) velocity 2300 m/s at depth near 1000m.

In figure 6., we have high value of semblance. It means that our apparent velocity of 2000 m/s is close to the real data. It fits with the concept of the conventional semblance that the correct velocity model maximizes that energy. Therefore, the value of the semblance will be high around the 200m depth. The semblance panel also tell us a detail explanation that if we compare the value of the semblance beneath the 200m depth toward the value above the 200m, the semblance value is higher. It makes sense since we built the velocity model that the deeper z we have, the higher velocity. Let us try again another data. Then we used the apparent velocity at deeper profile 1000 m which give us the interval velocity of 2300 m/s. here the semblance profile we have It is clearly give us a good data that in figure 7.

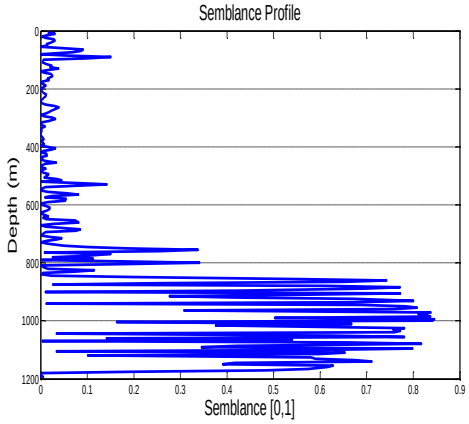


Figure 7. Semblance Profile for apparent velocity 2300 m/s at depth near 1000m.

we may see that the highest value is located around 1000m depth. Once again, the analysis of semblance profile shows us a good explanation about the relationship between the energy and the physical properties (velocity and depth profile).

4. Conclusion

The depth migration analysis of the velocity model have been done. we determined the interval velocity from CIG map by trial and error and give us a good velocity profile. In semblance analysis, we only simulated conventional semblance in z domain. The result gave us a good model which is fit with the semblance principle. The highest semblance value will give us the best fit model.

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