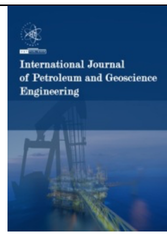
Volume 2022, 5 pages | Article ID : IJPGE-2206302112795

**International Journal of Petroleum and Geoscience Engineering**

Journal homepage: www.htpub.org/ijpge/

H & T PUBLISHER

ISSN: 2289-4713




# Evaluation of AVO method for delineation of hydrocarbon: An example from Malay Basin

Saiful Azam Mohd Nor, Muhammad Faris Abdurrachman, Zaky Ahmad Riyadi, Maman Hermana Husen*

*Universiti Teknologi Petronas, Persiaran UTP, 36100 Seri Iskandar, Perak Malaysia*

**Article**

Article history
Received: 15 September 2021
Received in revised form: 30 June 2022
Accepted: 01 July 2022

Keywords:
J Attribute,
Avo,
Fluid Changes,
Malay Basin

**Abstract**

A quick look at the well in Malay Basin data on the suitability of the AVO attributes and how the modeling result and derivatives of the product can lead to the false estimation of hydrocarbon. In most cases the amplitude change in the Malay basin is very small with regards to the rock quality, however, with the calibration to the well information, some products are feasible for application in the region. AVO method is the most common method practiced in the industry to delineate hydrocarbon prospecting based on pre-stack/partial seismic data, with no exception in the Malay basin field. There are a lot of AVO attributes developed by various researchers around the world, however, the sensitivity of each attribute in identifying the fluid types at the targeted reservoir is different. This paper discusses the study of the sensitivity of several AVO attributes in differentiating the fluid types through AVO modeling and fluid replacement on the data set from a well located in the Malay Basin field.

## 1. Introduction

The prominence of Amplitude versus Offset (AVO) analysis principally from its ability to characterize the fluid content of target reservoir for hydrocarbon exploration activity. At present, the AVO attribute analysis play significant role in hydrocarbon prediction in many basins where subsurface rocks are unconsolidated, soft, and sensitive to fluid replacement as per Gassman model [1].

In this evaluation, the method for AVO attributes will be discuss and discussion prior to limitation with regards to each attribute.

On the general overview, PETRONAS (2019) based on the systematic study with ARCO has concluded that over two third of the AVO responses observed in Malaysia Basins were of Class 2. highlighted that the application of reservoir characterization from seismic attribute output in the development field in Malay Basin are limited to general observation that [2]

1) Data quality in some part of the field especially in the crestal due to amplitude wipe-out with presence of shallow gas

*Corresponding author at: Universiti Teknologi Petronas, Persiaran UTP, 36100 Seri Iskandar, Perak Malaysia
Email address: maman.hermana@utp.edu.my

2) P-wave contrast between sand and shale are for most reservoirs

3) Coal layers in many fields poses challenge in application of seismic inversion for effective reservoir characterization tools

4) Thinly bedded and lower than seismic resolution for most reservoirs and bring significant uncertainties.

## 2. Theoretical Background

The published Aki-Richards (1980) and Shuey (1985) linear approximation of Zoeppritz (1919) reflectivity terms being referred and used to establish the workflow for the evaluation[3, 4]. The AVO terms can be referring to:

$$R(\theta) = A + B\, sin^2\theta \tag{1}$$

$$R(\theta) = A + B\, sin^2\theta + \, C\, tan^2\theta\, sin^2\theta \tag{2}$$

where, A is the intercept, B is the gradient and C is the curvature term, given by

$$A = \frac{1}{2}\left(\frac{\Delta Vp}{Vp} + \frac{\Delta\rho}{\rho}\right) \tag{3}$$

$$B = \frac{1}{2}\frac{\Delta Vp}{Vp} - 2\,\frac{Vs^2}{Vp^2}\left(2\frac{\Delta Vs}{Vs} + \frac{\Delta\rho}{\rho}\right) \tag{4}$$

$$C = \frac{1}{2}\frac{\Delta Vp}{Vp} \tag{5}$$

The calculation for the reflectivity and elastic properties based on the formula was compared by fluid sensitivity of 100% Brine case, 100% oil case and 100% gas case of a well in Malay Basin. Several AVO attributes were tested for the evaluation, from the list:

1. Envelope (Far minus Near*Far),
2. Product stack of Intercept x Gradient (A*B),
3. Pseudo Poisson's ratio, (A+B)/2,
4. Fluid Factor,
5. J attribute (Liu & Ghosh, 2015)

For the AVO Envelope, the simple calculation made for synthetic at Far and Near to boost the magnitude of the AVO response. However, this method is equally beneficial for the Class II and III AVO as the expand of far offset reflectivity in the calculation.

For Intercept x Gradient (A*B) and Pseudo Poisson's ratio (A+B)/2, is the simple algebraic expression to obtain attributes that have relation to certain elastic properties. For fluid factor, widely used published by Smith & Gidlow (1987) based on Castagna et al. (1985) mudrock line [5, 6]. The fluid factor written as:

$$\Delta F = \frac{\Delta V_p}{V_p} - 1.16\frac{\Delta V_p}{V_p}\; / \,\gamma \tag{6}$$

where γ is the background Vp/Vs ratio and the constant 1.16 can be local value of mudrock line.

For J attribute, it was published by Liu & Ghosh (2015) to predict the existence of hydrocarbon and claimed to be more stable and less ambiguous by incorporates rock physics constraint [7]. The formula given as:

$$J = J_p \sin\alpha - J_s \cos\alpha \tag{7}$$

where,

$$J_p = 2\left(\frac{\Delta\rho}{\rho} + 2\frac{\Delta V_p}{V_p}\right) / \gamma^2 \tag{8}$$

$$J_s = 2\left(\frac{\Delta\rho}{\rho} + 2\frac{\Delta V_s}{V_s}\right) / \frac{\Delta V_p^2}{V_s^2} \tag{9}$$

$\gamma$ is the Vp/Vs ratio for the interface of brine sand and shale, and $\alpha$ is the rotation angle defined as the angle between Y-axis parallel line and brine response in the Jp-Js curve which is based on rock parameters extracted from the reservoir and surrounding layer.

## 3. Numerical Cases

A numerical simulation is built up for AVO modeling and comparison. The model has two layers of shale and sand. The petrophysical log can be referring to Figure 1. The model was flooded by pure brine, oil and gas by Gassman fluid substitution to compute the P-velocity (Vp), S-velocity (Vs) and Density. Then, the reflectivity was calculated using Aki-Richards 2 terms formula for 0 to 40 degrees angle before it was convolved with theoretical Ricker 25 Hz wavelet to generate the synthetic AVO. Figure 2 shows the fluid substitution model for difference cases while Figure 3 shows the synthetic AVO for the study.

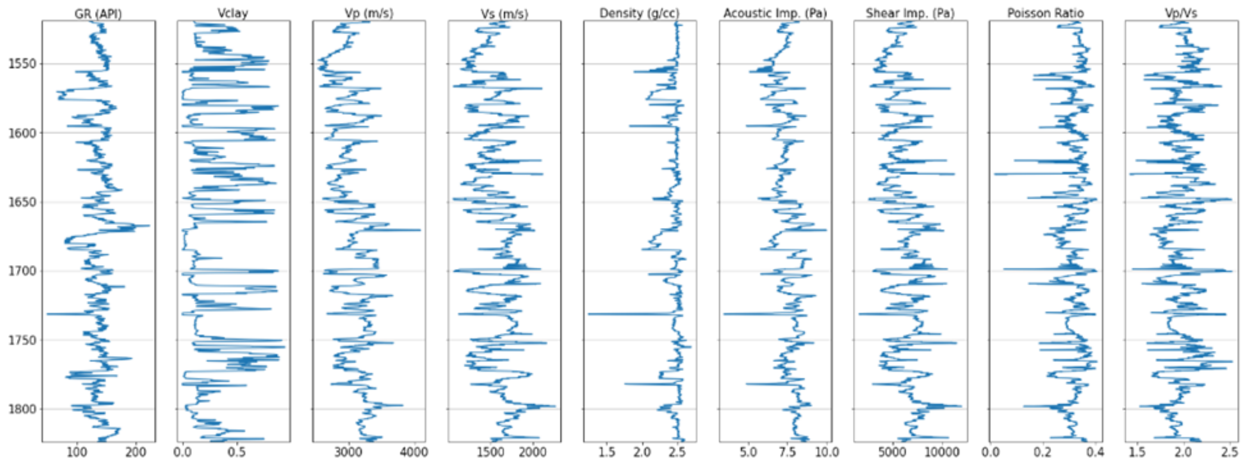



**Figure 1.** Raw well log

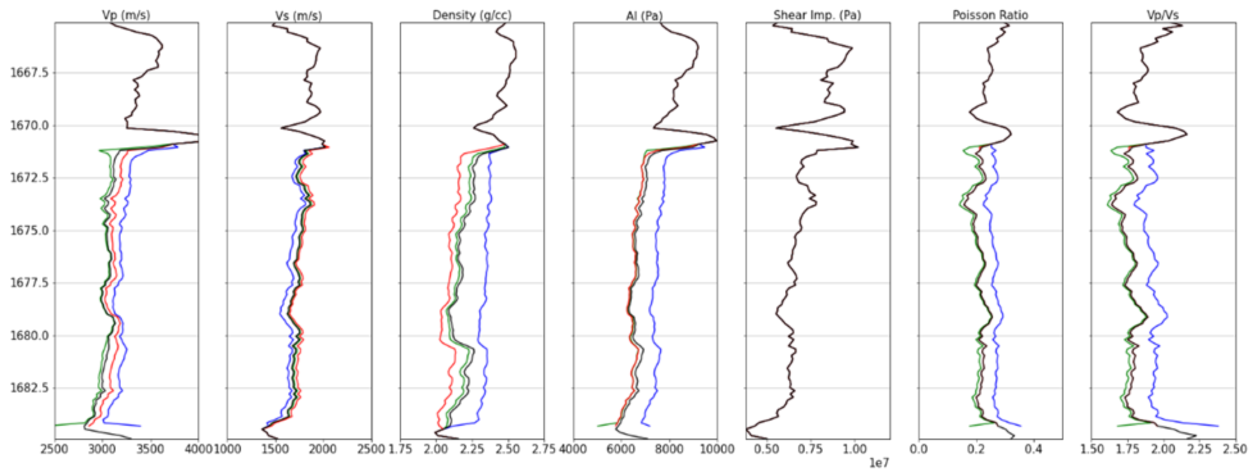



**Figure 2.** Fluid substitution for different fluid case

The calculated elastic properties were used to calculate the AVO attributes explained earlier.

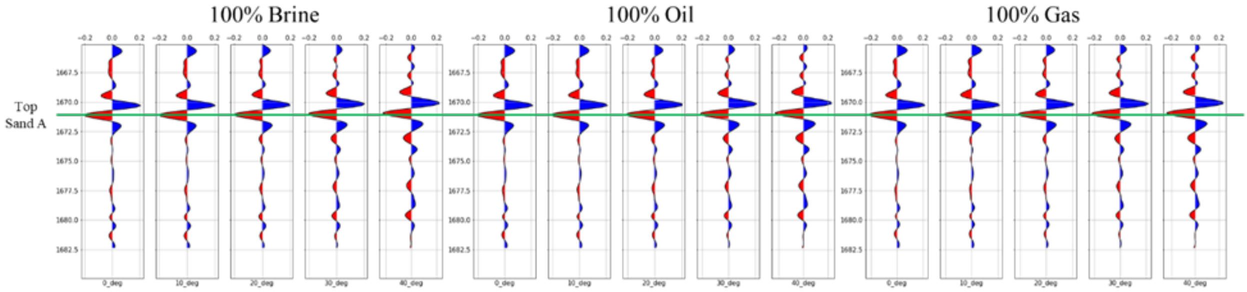



**Figure 3.** Synthetic AVO for different fluid case

## 4. Result

A numerical simulation is built up for AVO modeling and comparison. The model has two layers of shale and sand. Figure 4 show the plot for the Envelope, A*B and A+B/2 attribute with details of each attribute values in Table 1.

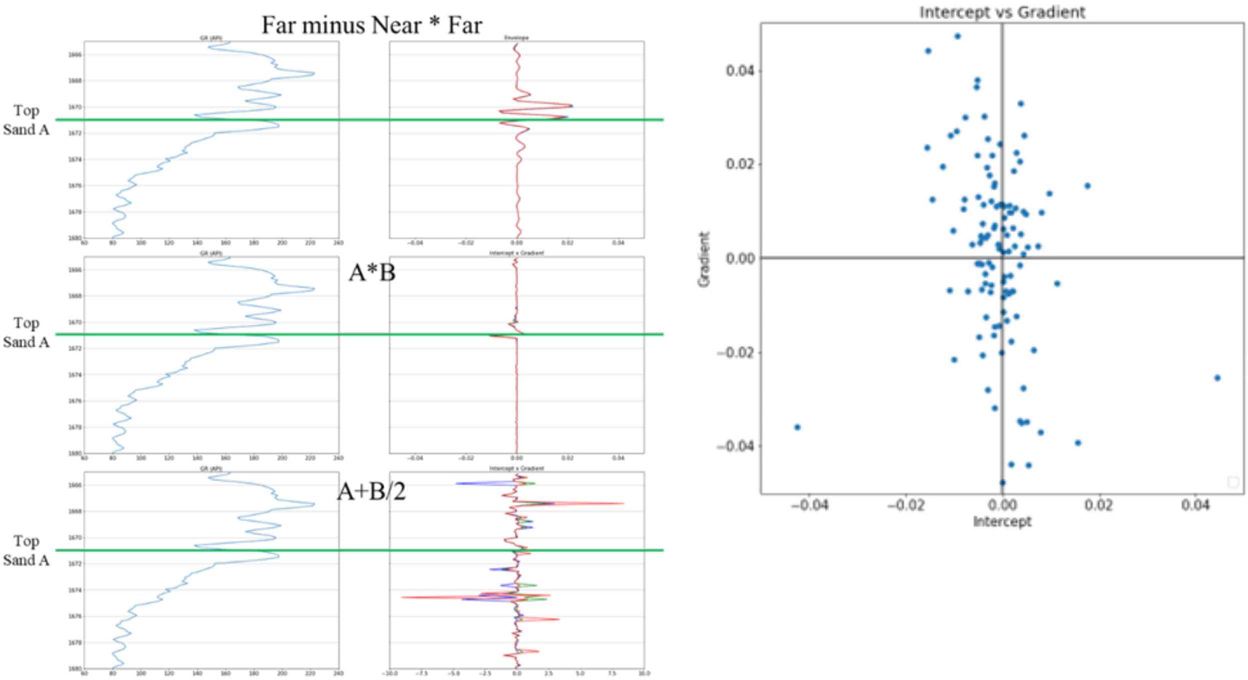



**Figure 4.** AVO plot for different attributes (Left: Far-Near*Far, A*B, A+B/2; Right: Intercept vs Gradient crossplot)

The result is based on quick computation and plot of the attribute show the difference in each method with regards to the well data. In general, there are several discrepancies in the oil and gas attributes values, for example the A+B/2 that in general giving similar value range for the simple 2-layer model. Some attributes are well corresponded to the fluid such as Far-Near*Far and A*B, however, the observation made that the properties are not able to differentiate the oil and gas except for the fluid factor and J attribute.

**Table 1.** AVO attributes dual layer of sand shale with different fluid cases

| AVO Attributes | Brine case | Oil Case | Gas Case |
|---|---|---|---|
| **Far minus Near * Far** | 0.001013 | 0.000069 | -0.000394 |
| **Intercept * Gradient** | -1.0533 | -0.0107 | -0.0100 |
| **Pseudo Poisson's ratio** | -0.3614 | -0.3612 | -0.3618 |
| **Fluid Factor** | 0.0471 | 0.1209 | 0.1011 |
| **J attribute** | -11.30 | -47.59 | -8.39 |

## 5. Conclusion

The analysis provide a quicklook on the methodology of AVO and evaluation made for a well in Malay Basin. The attributes generated are straight forward with understanding of the AVO from synthetic model and sensitivity to the fluid change. In general, Intercept*Gradient (A*B) are the quick approach with reasonable quality while the J attribute giving clear separation with some understanding to the rock physics relationship.

## References

[1] Ghosh D., Halim M. F. A., Brewer M., Viratno B., Darman N.: Geophysical issues and challenges in Malay and adjacent basins from an E & P perspective. The Leading Edge, **29**, 436-449 (2010). DOI: 10.1190/1.3378307

[2] Geophysical Application in Malaysian Basin, PETRONAS EAGE, Petroliam Nasional Berhad (2019).

[3] Aki K., Richards P. G.: Quantitative seismology (2002).

[4] Shuey R. T.: A simplification of the Zoeppritz equations. GEOPHYSICS, **50**, 609-614 (1985). DOI: 10.1190/1.1441936

[5] Castagna J. P., Batzle M. L., Eastwood R. L.: Relationships between compressional-wave and shear-wave velocities in clastic silicate rocks. GEOPHYSICS, **50**, 571-581 (1985). DOI: 10.1190/1.1441933

[6] Gassmann F.: Uber die elastizitat poroser medien. Vierteljahrsschrift der Naturforschenden Gesellschaft in Zurich, **96**, 1-23 (1951).

[7] Changcheng L., Ghosh D. P.:A New AVO Attribute for Hydrocarbon Prediction and Application to the Marmousi II Dataset, in International Conference and Exhibition, Melbourne, Australia 13-16 September 2015Society of Exploration Geophysicists and American Association of Petroleum Geologists32-32 (2015)