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Multi-variate attributes analysis to highlight vsh trend as soft guide into facies modelling

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Abstract

The following paper presents a simple method in generating volume of shale (VSH) from seismic attributes. Multi-variate statistic methods were used to analyze correlation of seismic attributes and well-log properties to define VSH. VSH is one of rock properties that is considered to have direct link with rock facies. Regression technique was utilized after the establishment function of high correlation between seismic attribute and VSH by using multi-variate analysis was achieved. Intermediate process was introduced by looking up the highest correlation of seismic attributes with other well-log properties (e.g porosity, density, or water saturation) in the case where correlation value of multi-variate matrices is low. This intermediate process should be performed where other rock properties have a high correlation with VSH. Once the intermediate correlation process is established, the seismic attribute – VSH correlation can be properly completed.

In this study case, example of 2 layers-horizon so called direct method (SS-1 & SS-2) and 2 layers- horizon of indirect method (SS-3 & SS-4) is discussed. Result of multivariate analysis from mean envelope relative impedance and RMS relative impedance of the SS-1 and SS-2 zone could correlate directly with VSH, respectively. Whereas, the SS-3 and SS-4 zone indicates direct correlation of RMS relative impedance to NPHI and attribute of mean sweetness corelate to PHIE. Fortunately, these well-log properties of NPHI and PHIE have high correlation with VSH.

In order to established mathematical relationship between rock properties and seismic attributes selected from multivariate analysis, we generate cross plot of each layer and define sensible envelop of the data distribution as an approximation of low – base – high case scenario related to polynomial function which generated later. The proposed method offers fast yet quite robust solution to generate VSH trend as soft-guide into 3D facies modeling whenever data is limited.

Keywords: seismic attributes, multi-variate, volume of shale, seismic facies

Introduction

Seismic attributes are widely used as input to geological model since they could expressing subsurface structure, stratigraphy, and/or rock properties. Analysis of seismic attributes is one of method to find relationship between seismic derived data and rock properties from well log. Since well log can only obtain the rock properties at well location or in vicinity of borehole, the seismic data has become the heart of reservoir characterization both vertically and laterally. However, the wealth of attribute avaibility raises the question what is the meaningful attributes to predict the rock properties? Moreover, in the event of the limited data, the process will be more complicated for the purpose of facies distribution or reservoir delineation.

One of general workflow to find the most related attribute to rock properties is multi-attribute analysis. In this study of the Mengoepeh Field in South Sumatra Basin, our study objectives is to generate volume of shale (VSH) which valuable information for reservoir modeling from seismic data. Since volume of shale has direct representative of the facies distribution or to predict reservoir characteristics, the VSH trend are expected to be helpful guidance in the geological modeling. Using the statistical analysis of multi-variate and cross-plot method, followed by generating polynomial function to predict VSH distribution, we believe that the establishment of seismic attributes to rock properties will be easily achievable.

Mengoepeh Field Overview

The Mengoepeh field is located in the onshore Northern margin of the South Sumatra Basin. The South Sumatra basin was influenced through three major phases, a rifting phase, a sagging phase and lastly a compressional phase. Along with tectonic activities, the South Sumatra basin was also influenced through sea level transgression-regression sequence occurring throughout the tertiary. As a result, the basin contained many different formations; going stratigraphically up, the basement, Lemat, Talang Akar, Batu Raja, Gumai, Muara Enim and Air Benakat Formations (Oldest-Youngest). The main reservoir target within the Mengoepeh field is the Talang Akar formation, which is a fluvial-deltaic deposits during the Late Oligocene-Early Miocene. The formation is composed of interbedded Sandstone, Shale and Coal. The Sandstone is the main reservoir rocks in the formation whereas the shale and coal acts as the source and sealing rocks, respectively (Bishop, 2000). General deposition fairway is coming from Northwest to Southeast of Mengoepeh field. All the stratigraphy and tectonic history in Mengoepeh Field is summarized in **Figure 1**.

In this study, we will discuss four layers or zones in the Talang Akar Formation of the Mengoepeh field. One of the layer is the main oil production reservoir. The other three layers or zones lays above and below this main producing reservoir.

Multi-variate Analysis Method

In the statistical analysis, bivariate analysis is measured by correlation coefficient. This correlation number measures the strength of association between two variables and the direction of the relationship ("Spearman's Rank Correlation Coefficient," 2005). In terms of the strength of relationship, the value of the correlation coefficient (rs) varies between +1 and -1. As the correlation coefficient value goes towards 0, the relationship between the two variables will be weaker. The direction of the relationship is indicated by the sign of the coefficient, namely a+ sign indicates a direct relationship and a- sign indicates an inverse relationship. In the case of more than two variables is measured, the multivariate analysis method is applied.

In this study we used Spearman's correlation to find relation between both seismic attributes and rock properties. Spearman rank correlation is used to measure the degree of association between two variables. The Spearman rank correlation test does not carry any assumptions about the distribution of the data. The following formula is used to calculate the Spearman rank:

$$r_s = 1 - \frac{6\sum D^2}{n(n^2-1)}$$

Correlation:
Rs = Spearman rank correlation
D = the diff. between the ranks of corresponding variables
N = number of observation

Seven set of seismic attributes derived from the 3D post stack seismic data and eight set of petrophysical parameter from well log were analyzed (**Table-1**) using Spearman's correlation to form multivariate matrices. The petrophysical parameters used are derived from 30 wells data with consistent logs. In this case, volume of Shale (VSH) is the main properties to be derived from this analysis. In order to determine which attributes were most related to rock properties. This statistical analysis was applied to 4-zones in the Mengoepeh field. These zones are SS-1, SS-2, SS-3,and SS-4 zone.

Higher correlation number (negative or positive) to VSH in the multivariate matrices means that properties can be pick directly as qualified candidate to cross plot as function of VSH. In this study we were using color bar scale from -1 (white) to +1 (dark blue) to visualize the multivariate correlation matrix.

In the event of the low correlation value to VSH is found or no dominant higher correlation to VSH, the direct establishment of attribute-shale volume relation could not be established. Hence, intermediate process was introduced by looking up the highest correlation coefficient from other rock properties rather than VSH. However, this so-called intermediate property should also have high correlation coefficient number with VSH. Then, the attribute-shale volume correlation can be properly established. We called this indirect approach.

Result and Discussion

In this section we will discuss the multi-variate method using Spearman equation result which reveals that mean envelope relative impedance, relative impedance, and mean sweetness observed to be the most reliable attributes to predict shale volume trend. Based on multivariate matrices result, those set attributes could correlate directly and indirectly to shale volume. Example of direct method is showing from good correlation which found in both the SS-1 and SS-2 zone (**Figure 2a and 3a**). In these zones, the seismic attribute can be directly related to VSH. However, notice from **Figure 3a** there are two candidate that have corelates directly to VSH. In the case having more properties that have relatively high correlation number, we can choose all the properties or we may choose one over the other. In this example we prefer to choose RMS relative impedance to be the nominator as an attribute estimator. In contrast, the low correlation in directly was found in the SS-3 and SS-4 zone that might affected by the tuning thickness (**Figure 4 and 6**). Hence, intermediate process was applied for both zones.

In SS-1 zone, multi-variate method show that mean envelope relative impedance is the most related seismic attributes to VSH (**Figure 2a**).We then cross-plot both properties to established the envelope of relative impedance - VSH distribution. Three set polynomial function is generated to define low-base-high case approximation to predict VSH distribution as shown in **Figure 2b**.

Multi-variate analysis for SS-2 zone observed that RMS relative impedance correlate directly with VSH (**Figure 3a**). We then cross plot both properties to established the envelope of RMS relative impedance to VSH distribution. Three set polynomial function is generated to define low-base-high case approximation to predict VSH distribution as shown in **Figure-3b**.

Another layer, SS-3 zone, shows low correlation between seismic attributes and VSH. In this case, the result suggested that RMS relative impedance is the most related attributes to the NPHI which have high correlation to VSH (**Figure 4**). Therefore, RMS relative impedance was intermediately bridge by NPHI. We then cross plot both properties to established the distribution envelope from RMS to NPHI and envelope of NPHI to VSH distribution. The distribution envelop from each cross plot is define by three set polynomial function respectively as low-base-high case approximation to predict VSH distribution as shown in **Figure-5**.

Intermediate process was also applied in the SS-4 zone. Multi-variate analysis observed that set of attributes have poor correlation with VSH. The mean sweetness attribute is the most attribute that have a good positive corelation to PHIE directly, which can be bridge to define VSH as intermediate properties (**Figure 6**). Again, we cross plot both properties to established the distribution envelope from mean sweetness attribute to PHIE and the envelope of PHIE to VSH distribution. The distribution envelop from each cross plot is define by three set polynomial function respectively as low-base-high case approximation to predict VSH distribution as shown in **Figure-7**.

The lateral distribution of shale volume are illustrate through the attributes map result which were generated using the established polynomial function from each zone. The shale volume trend map of each zones can be seen in **Figures 8-11**. In our case, the VSH trend is aligned with our depositional model where channel is generally deposited in the NW-SE direction through the area of study, as indicated by VSH trend map. Higher values in VSH map are showing more shaly facies compare to the lower value of VSH which indicates more sandy facies. However, the envelop from those figures indicate that we have wide range of uncertainties in predicting VSH quantitatively. Therefore, the establishment of VSH attributes in this case is to provide soft guidance for facies modeling from seismic data. Even though we can also generate the low and high case VSH distribution using outer band of the define envelope from the cross plot.

In modelling, conditioning facies to seismic can be done within facies modelling algorithms (e.g SIS (Sequential Indicator Simulation), Object-based Method, Multi Point Statistic). However, condition to seismic is very dependent on establishing a robust relationship between a property to be modelled and the seismic parameter. Moreover, the proportion of a facies type within a zone may vary laterally between wells, and/or vertically within a zone as an upward increase or decrease in proportions. Therefore, seismic attributes may represent important guidelines in evaluating such relations. The attribute map generated can be applied into facies modeling process to establish horizontal probability trend of facies proportion.

Conclusions

The applied multivariate method on the multi seismic attributes analysis appears as a simple yet reliable method in delineating shale volume trend. The proposed methods followed by crossplotting and defining distribution envelop zone has been proved in providing VSH trend as desired output. This technique offers a novel and robust solution to generate shale volume trend as soft-guide into 3D facies modeling whenever data is limited.

References

Bishop, M.G., 2000, South Sumatra Basin Province, Indonesia; The Lahat/Talang Akar Cenozoic total petroleum system. Open-File Report 99-50-S.

Spearman’s rank correlation coefficient. (2005, December 29). In Wikipedia. https://en.wikipedia.org/wiki/Spearman’s_rank_correlation_coefficient

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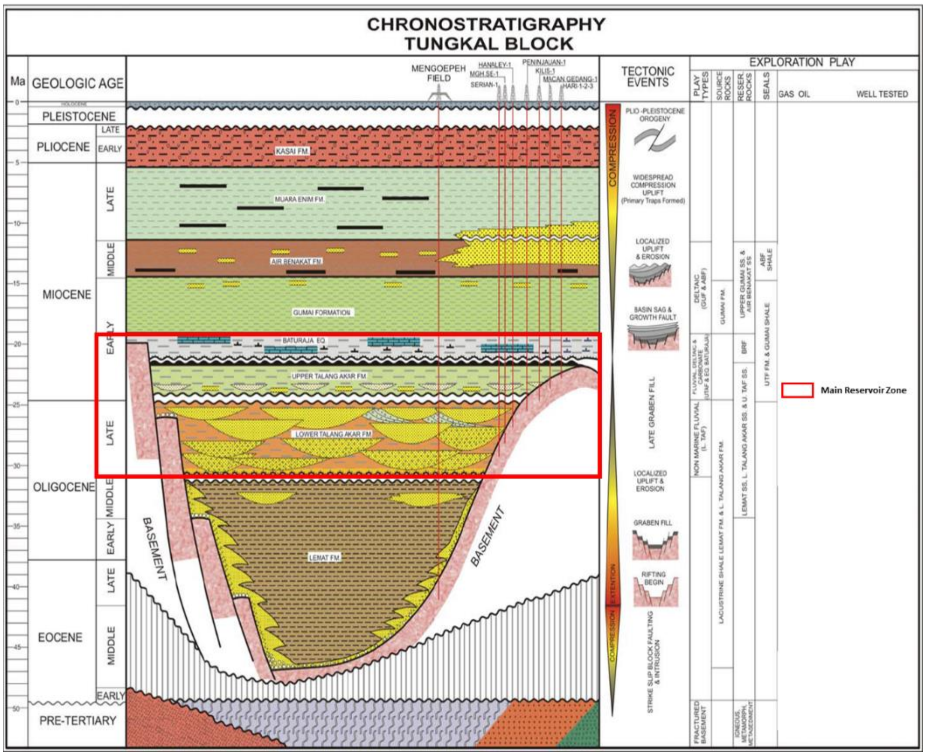

Figure 1 Chronostratigraphy of Mengoepeh Field

Simplify Workflow	Input Data	Expected Result
Quantitative Analysis	<u>**Set of Seismic Attributes**</u> - RMS Relative Impedance - Meane Impedance - RMSE Amplitude - Mean Envelope Average - Mean Sweetness Amplitude - Mean Bandwidth - Mean VpVs <u>**Set of Petrophysical Parameters**</u> - GR - LLS - RHOB - NPHI - VSH - PHIE - LLD - SW	• Understand relationship of set attributes to petrophysical parameters • Established relationship between seismic attribute to facies related petrophysics parameter i.e. VSH • Generate seismic facies maps distribution for each zone

Table 1 List of seismis attributes and petrophysical parameter

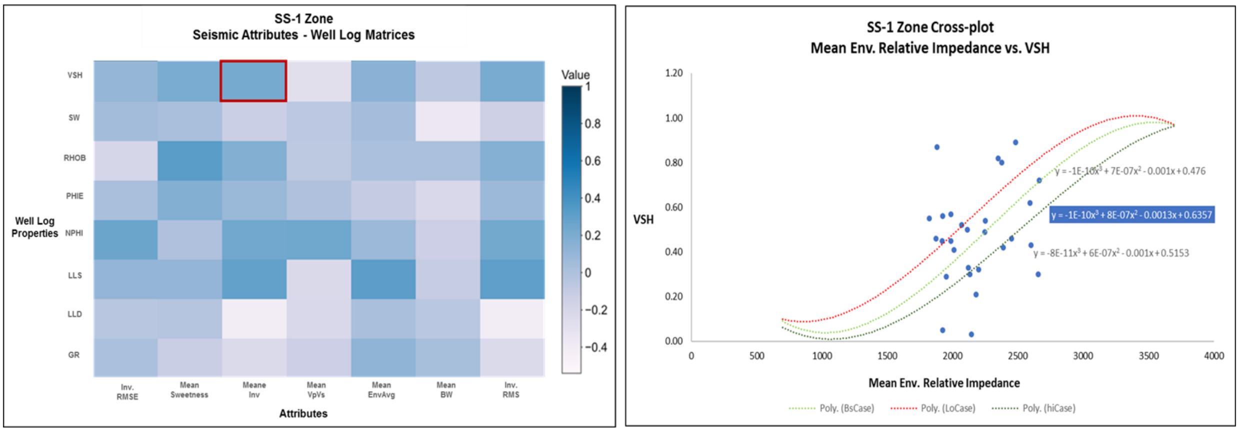

Figure 2 a) Multi-variate analysis result of SS-1 zone; b) Cross-plot of mean envelope relative impedance against VSH

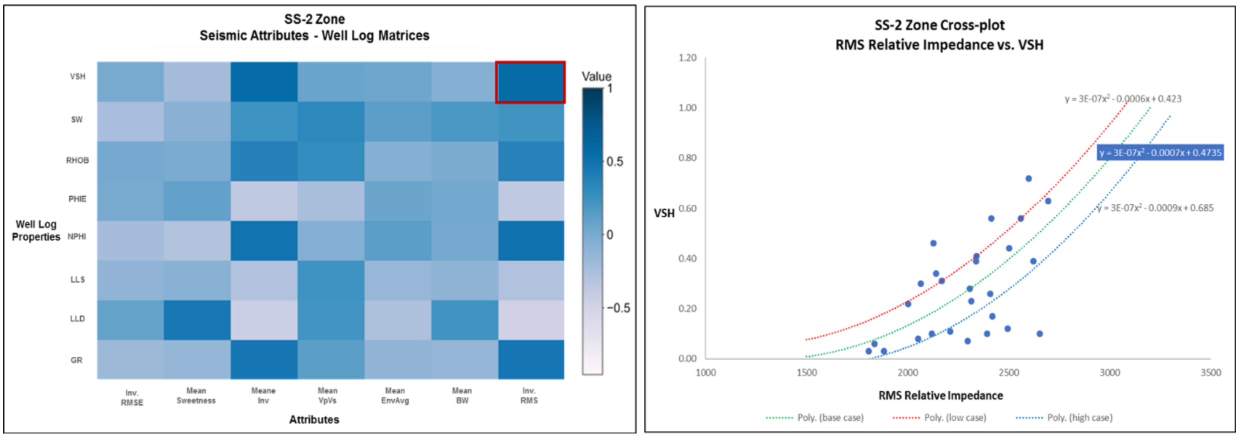

Figure 3 a) Multi-variate analysis result of SS-2 zone; b) Cross-plot of RMS relative impedance against VSH

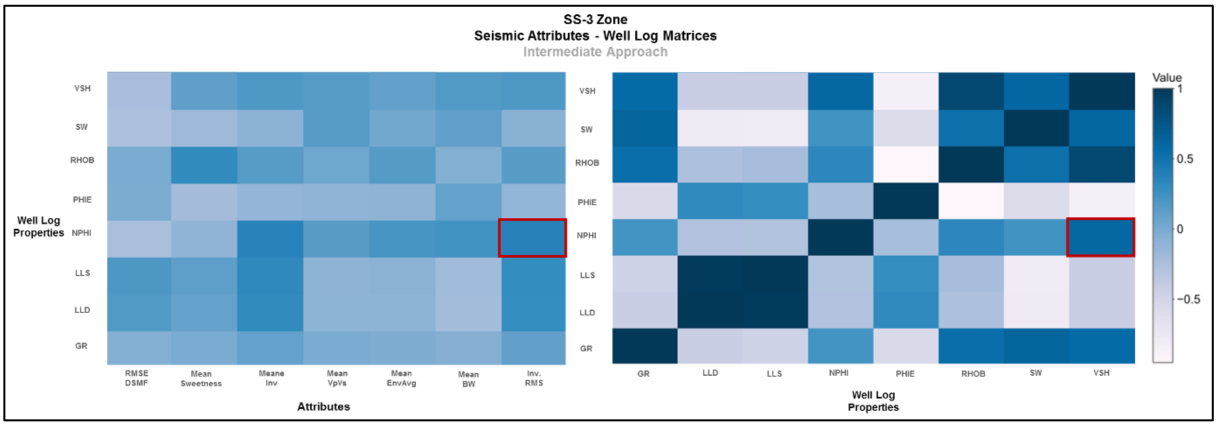

Figure 4 Multi-variate analysis result of SS-3 zone

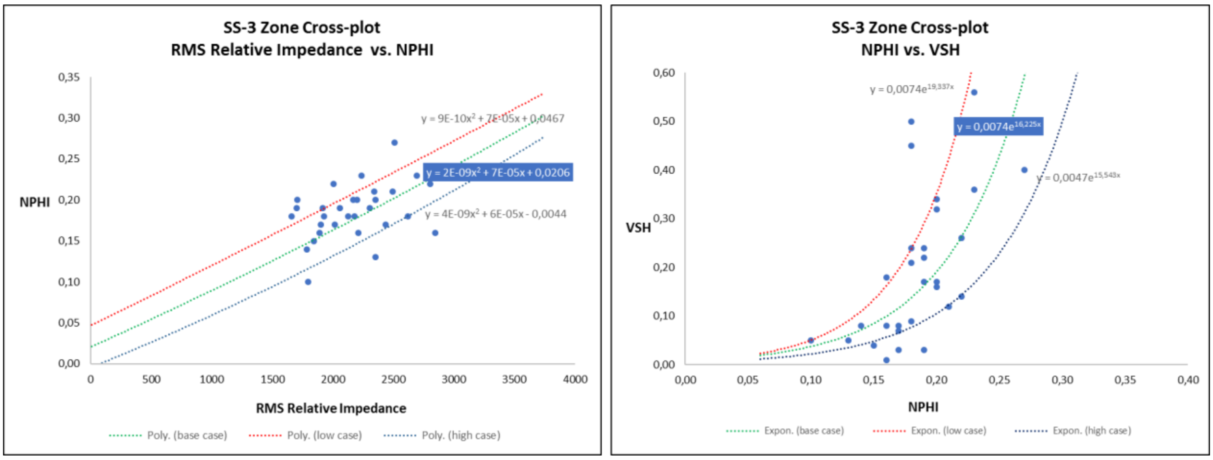

Figure 5 a) Cross-plot of RMS relative impedance to NPHI; b) Cross-plot of NPHI to VSH

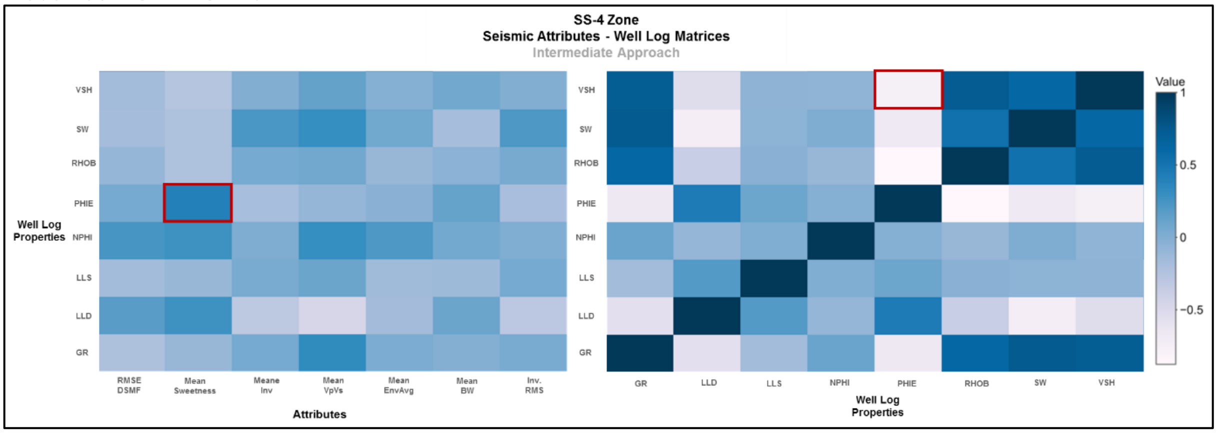

Figure 6 Multi-variate analysis result of SS-4 zone

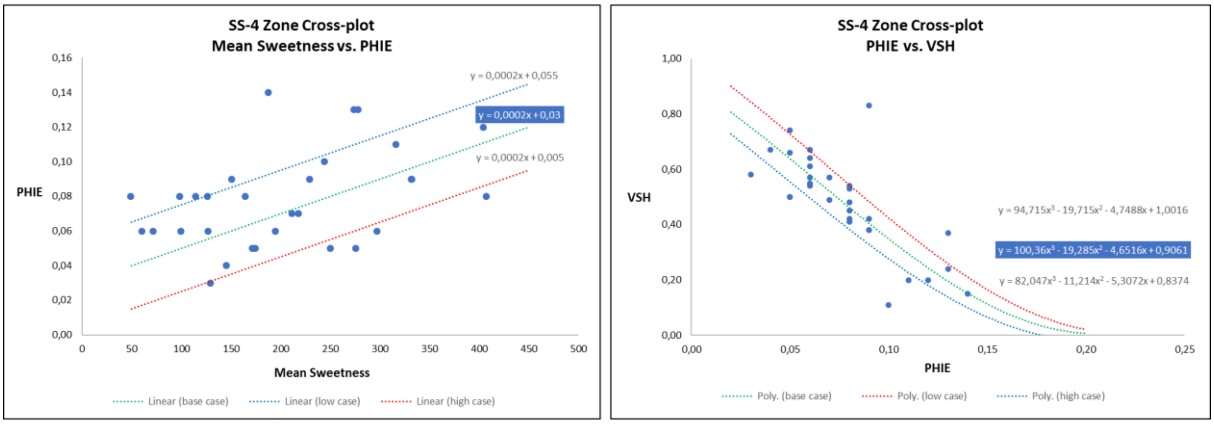

Figure 7 a) Cross-plot of mean sweetness to PHIE; b) Cross-plot of PHIE to VSH

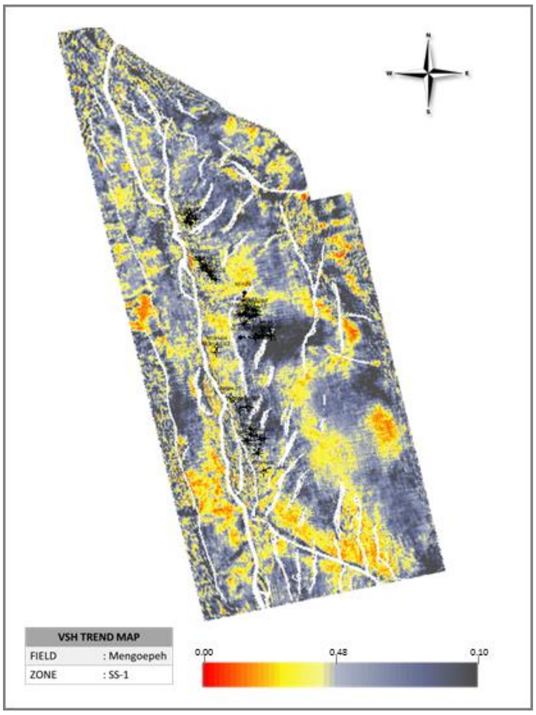

Figure 8 The VSH trend map of SS-1 zone

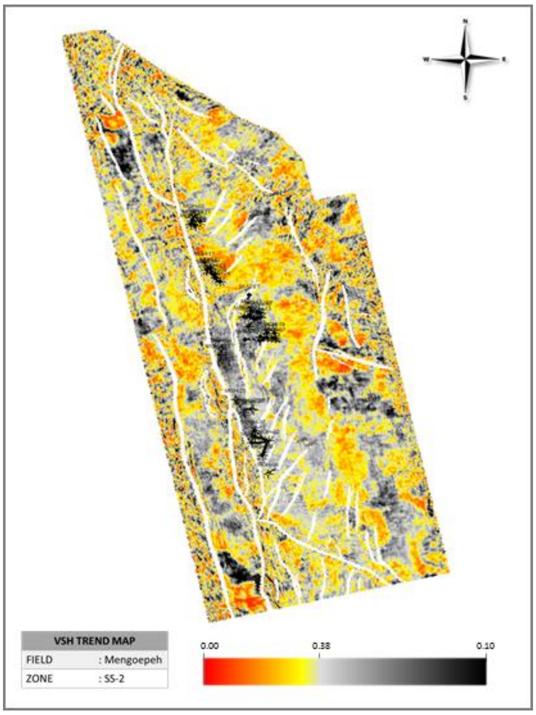

Figure 9 The VSH trend map of SS-2 zone

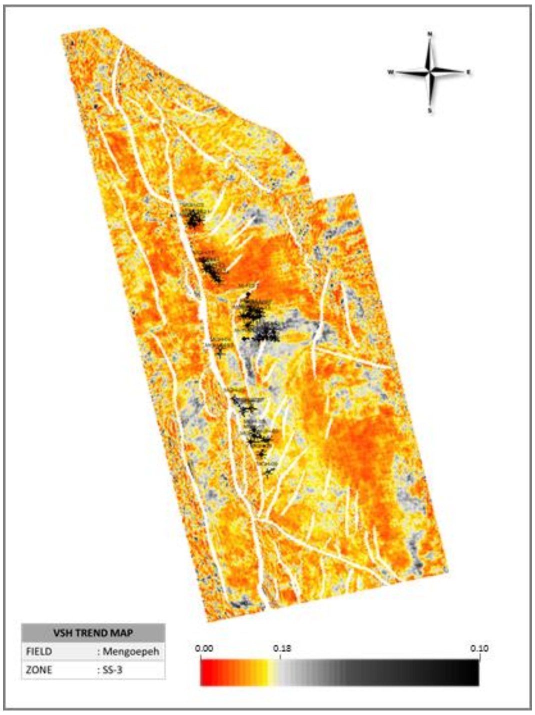

Figure 10 The VSH trend map of SS-3 zone

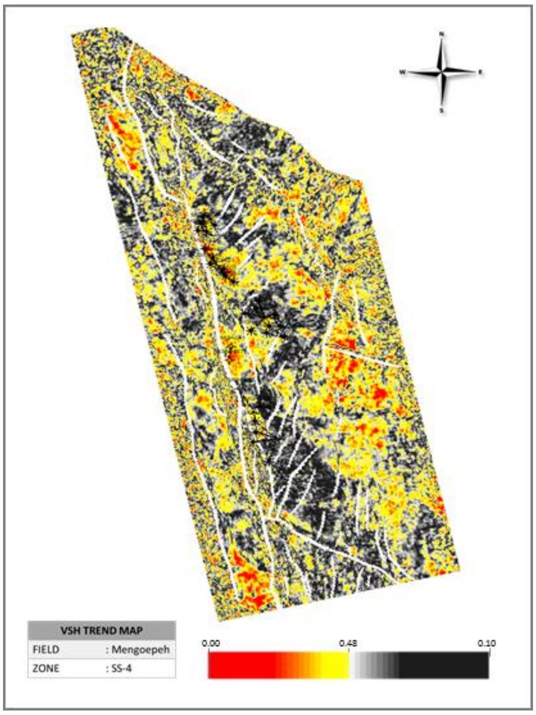

Figure 11 The VSH trend map of SS-4 zone