Slope of Seismic Spectral as a New Initiative of Hydrocarbon Indicator to Unlock Remaining Gas Potential in Very Shallow Interval of Tunu Field at Mahakam Delta

Gadang Gentur Wihardy, Hilfan Khairy, Depi Restiadi, Effendy Siawira, Cepi M. Adam

Pertamina Hulu Mahakam
* Email: gadang-gentur.wihardy@pertamina.com

Abstract. Amplitude Versus Offset (AVO) methodology is massively used in the development of Tunu Shallow Zone (600-1500 m TVDSS), with high success ratio. However, when it comes to very shallow zone (<600 m TVDSS), the methodology is not working properly since the seismic gather data is limited and has poor quality. Therefore, application of new methodology is essential to unlock the remaining potential of gas accumulation in the particular interval.

Slope of Seismic Spectral approach is based on seismic signal behavior which tends to lose its high frequency component when passing through gas reservoir. Through decomposing the seismic signal into frequency spectrums, the Intercept and Gradient values of the spectrum on each seismic samples can be calculated. These parameters then transformed into Gas Probability data through the Probability Density Function, which indicates high probable gas occurrence. This result has been tested in the existing wells and will be applied for future wells planning.

Keyword: Shallow gas; Hydrocarbon indicator; Spectral decomposition; Mahakam

1 Introduction

Tunu is a mature giant gas field, located at the eastern side of the current Mahakam delta. Through its development lifetime, over 1400 wells have been drilled with more than 9 Tcf cumulative gas production has been delivered. The development strategy applied started from the deep interval or known as TMZ (Tunu Main Zone). As it became saturated, the development then slowly shifted to the shallow interval also known as TSZ (Tunu Shallow Zone), which initially considered as drilling hazards for TMZ development (Rengifo et al., 2012). The methodology applied in search for hydrocarbon is also different for each zones. Infill drilling, which utilizing gridding approach based on geological model is heavily used for TMZ development, while anomaly identification using seismic AVO is used for TSZ. The unique petro-elastic characteristic in TSZ; AVO Class III gas sands with abundant coal layers can be identified by analyzing the amplitude characteristic over the change of reflection's angle (Prabowo et al., 2015). In order to fight the production decline and economical value of the operation expenses, nowadays Tunu field still leaves a part of shallower interval to be explored. The hydrocarbon existence in this interval were already proven by existing wells, however still limited nearby the wells. The extension of the hydrocarbon rim throughout the field remains a challenge to be solved.

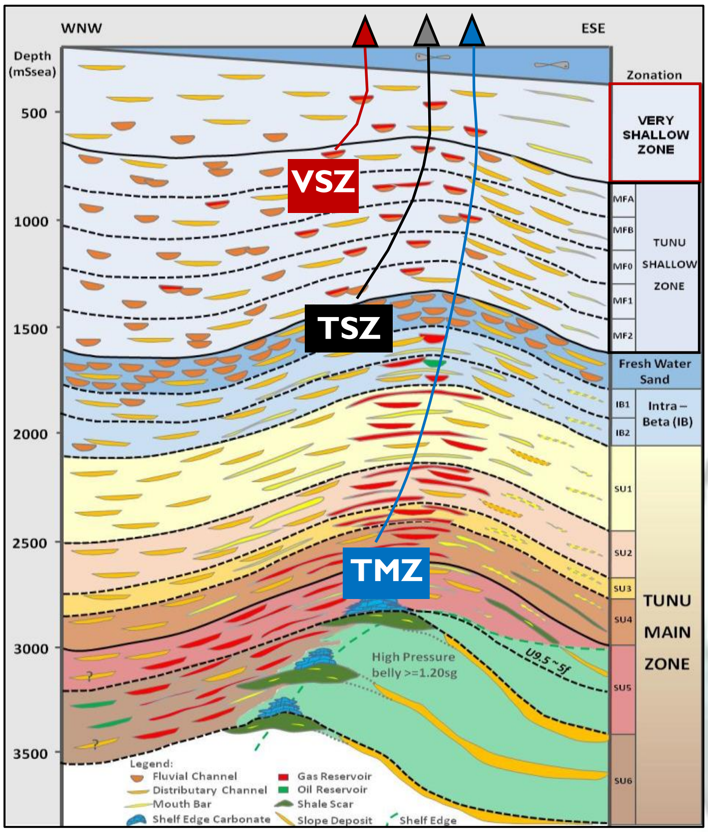

Figure 1. General section across Tunu Field with facies and hydrocarbon distribution

Tunu Very Shallow Zone (VSZ) is located above TSZ, defined as vertical section of 200m-600m TVDSS (Figure. 1). Within this very shallow interval, the AVO methodology cannot work properly due to the limited availability of seismic fold and angle, also the poor seismic data quality; unresolved noise, stretching effect from NMO correction, etc. The absence or limited sonic log data (compressional or shear) in this interval makes it impossible to create a representative petro-elastic model which can help understanding the elastic-to-fluid or lithology relationship.

Slope of Spectral Amplitude is a new geophysical initiative which intended to answer this challenge. It is developed from the spectral decomposition concept which theoretically does not affected by the limitation of seismic fold/angle like AVO. The objective in this study is to explore the ability of the methodology in indicating any potential hydrocarbon (especially gas) at very shallow interval, separates it from non-hydrocarbon seismic events.

2 Methodology

The Slope of Spectral Amplitude approach is based on the intrinsic seismic attenuation phenomenon, where seismic signal tends to lose its high frequency content when passing the hydrocarbon bearing formation such as gas bearing sand (Figure. 2). The variation of the seismic spectrum affected through this high frequency loss, can be characterized by the slope of the spectrum which represented by the Intercept and Gradient value. Highly attenuated zone theoretically is expected to give higher Intercept value and smaller (more negative) Gradient value, while the low attenuated zone is expected to show the contrary (Figure. 3).

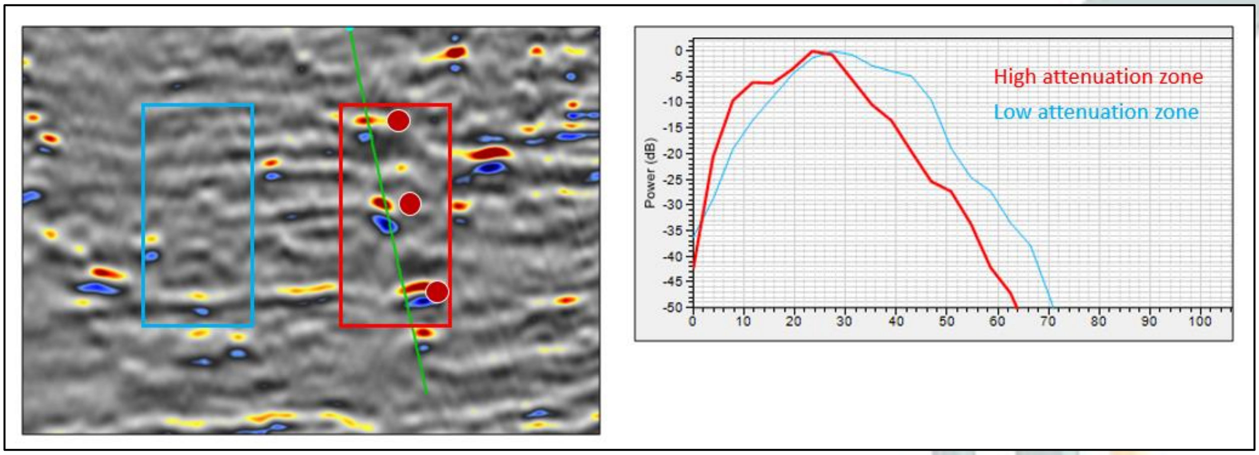

Figure 2. Seismic frequency spectrum (right) related to hydrocarbon presence (left)

Spectral Decomposition offers detail seismic spectrum information for every time samples of the seismic signal. Thus, it is a perfect methodology to estimate the Intercept and Gradient values for every time samples, on every seismic trace available in the 3D data (Figures. 4).

The Intercept and Gradient values are calculated using a simple quadratic sinusoidal function, inspired by Shuey approximation from Aki-Richard’s formula which typically used in AVO analysis (Figure. 5):

$$y = I + (G * sin^2 x)$$

where:

y = amplitude spectrum
x = frequency
I = Intercept
G = Gradient

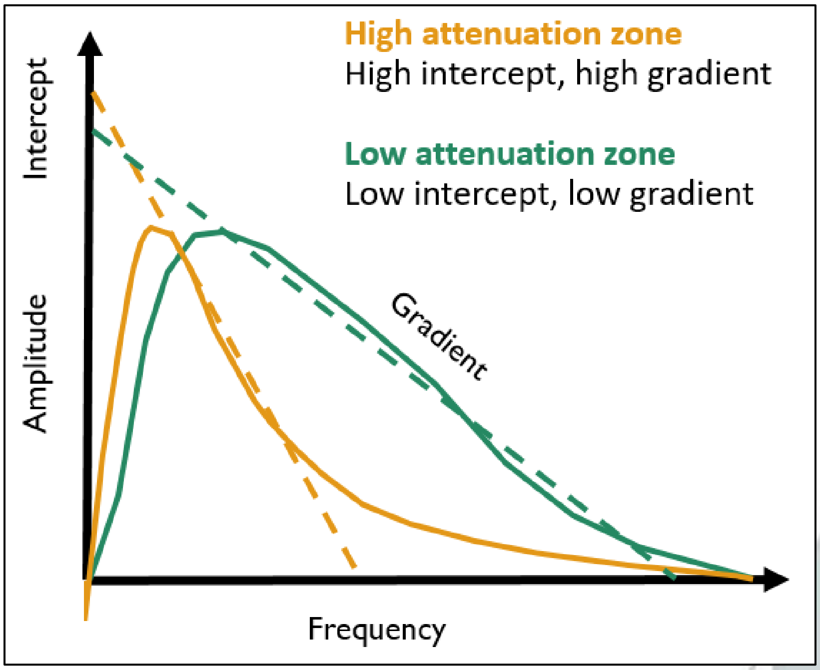

Figure 3. Attenuated seismic frequency spectrum characterized by Intercept and Gradient

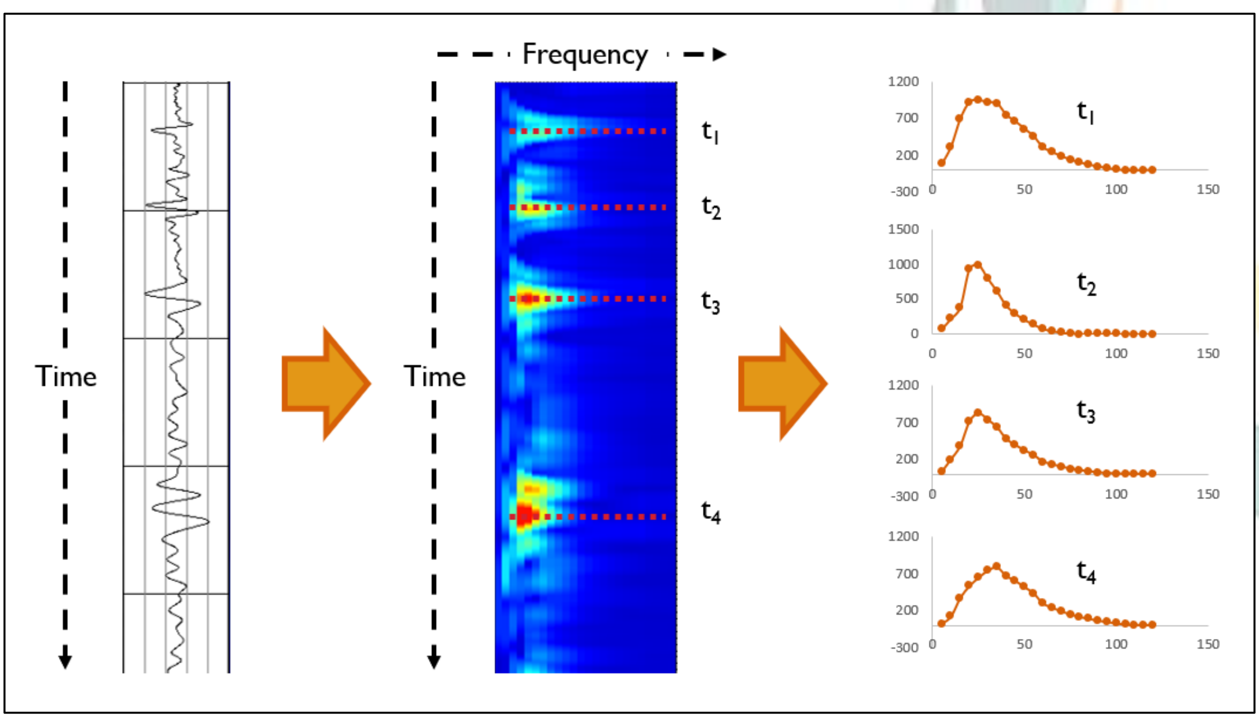

Figure 4. Spectral decomposition gives seismic spectrum details for every time samples

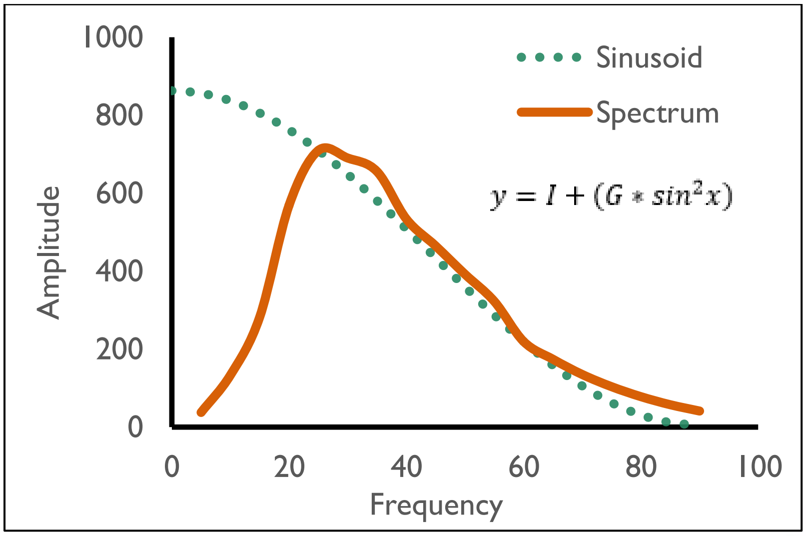

Figure 5. Intercept and Gradient estimation using quadratic sinusoidal function

There are four stages involved in the application of this study, as explained in Figure 6 below. The input is full stack 3D seismic data in Central Tunu area. The seismic is limited to an interval of 0-900 ms to cover the very shallow section. Then the iso-frequencies are created using spectral decomposition methodology. Three different spectral decomposition methodologies are applied and compared in this study: Generalized Spectral Decomposition (GSD), Continuous Wavelet Transform (CWT) and Short Time Fourier Transform (STFT). The outputs are the Intercept (I) and Gradient (G) datasets which calculated from the re-constructed spectrums based on the iso-frequency datasets.

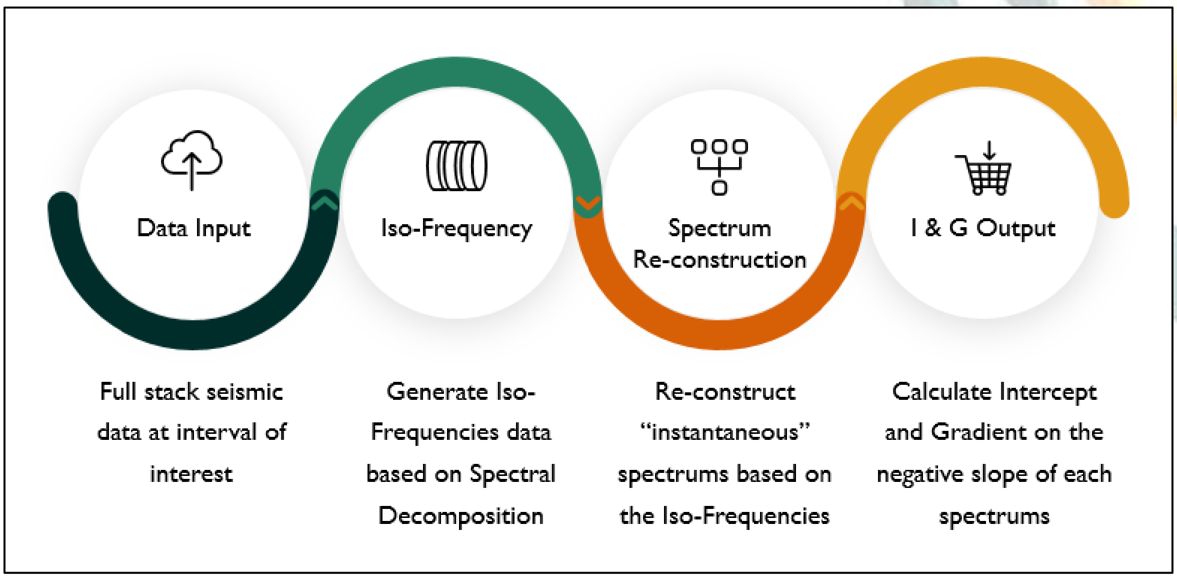

Figure 6. Workflow of study

3 Result and Discussion

From the product of Spectral Decomposition results, which are Intercept and Gradient, it is observed that there is a good correlation between high amplitude seismic anomalies with high Intercept (positive) values and low Gradient (negative) values estimated from GSD, CWT and STFT methodologies. These anomalies are also correlated with the presence of hydrocarbon gas sand which observed from the well result (Figures. 7 and 8).

In order to achieve better gas discrimination, the results can be elaborated further by examining the cross plot between Intercept and Gradient values and its correlation to the well result; gas or non-gas features (Figure. 9). The gas cluster is interpreted to be located in high Intercept and very low Gradient domain. The combination of high intercept and very low Gradient are translated then into a Gas Probability dataset by using Probability Density Function (Figures. 10 and 11).

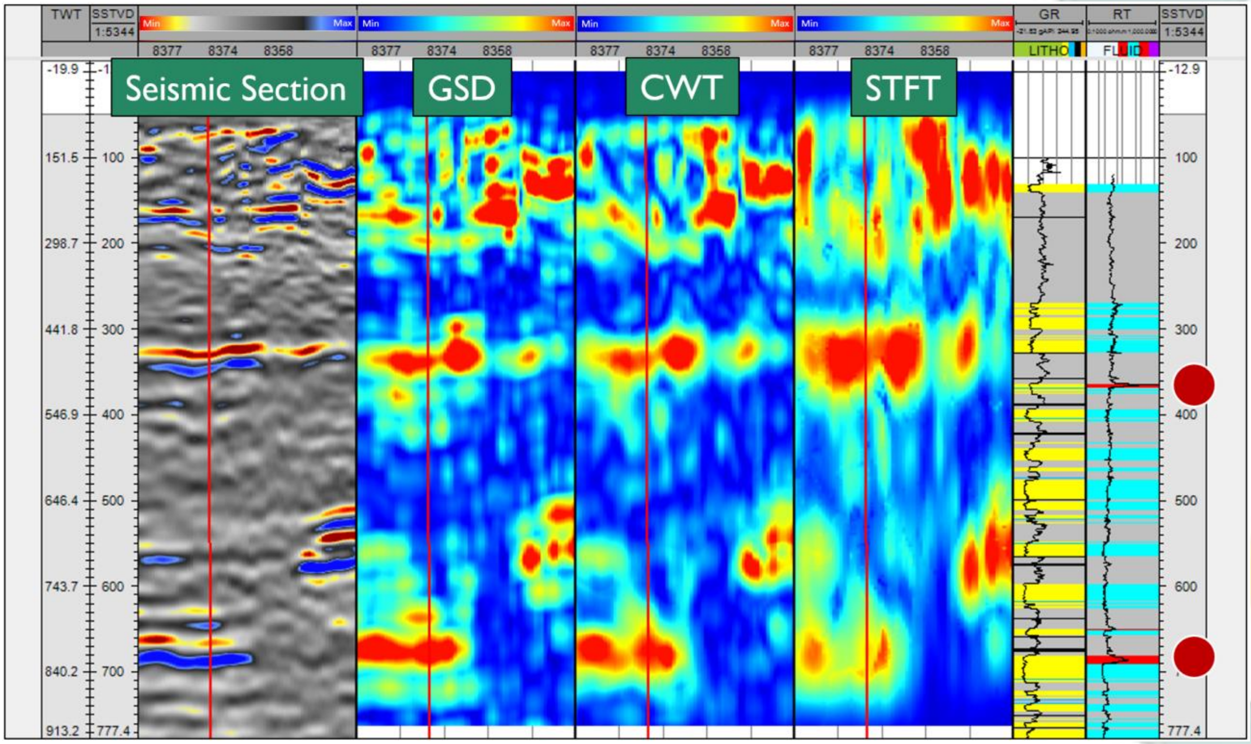

Figure 7. Comparison of seismic data and well result with the resulted Intercept datasets

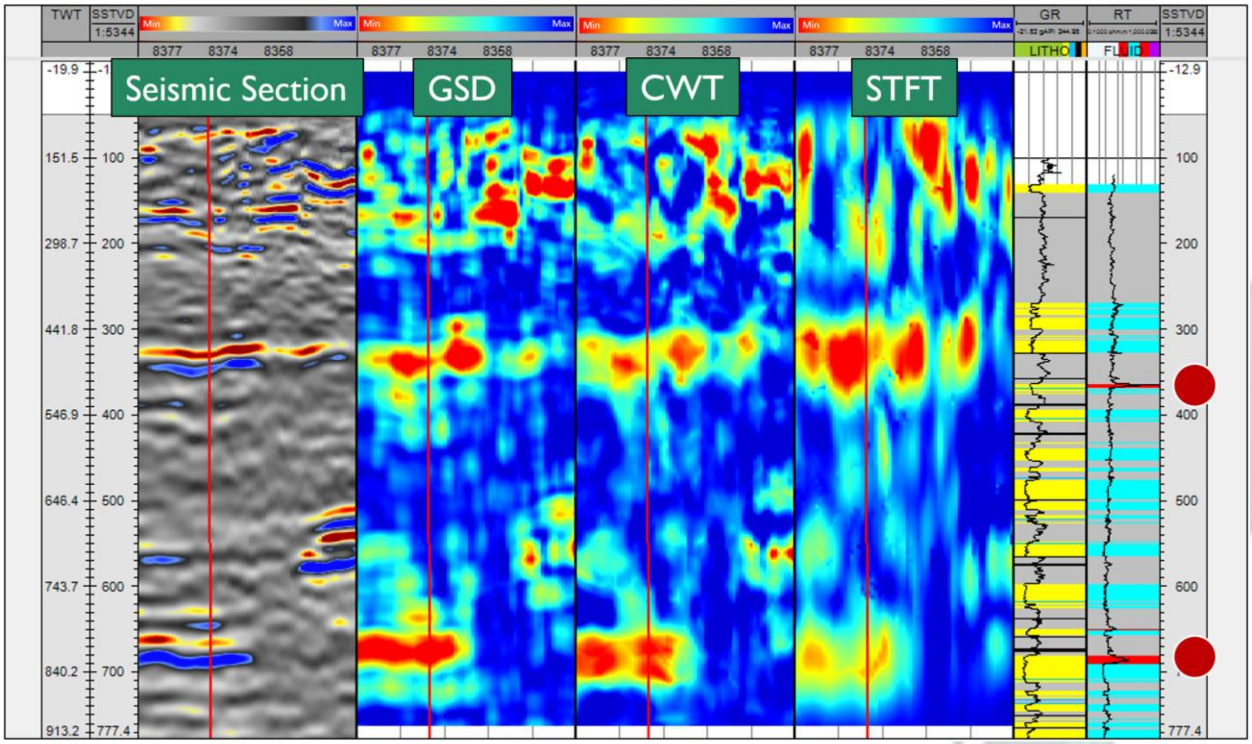

Figure 8. Comparison of seismic data and well result with the resulted Gradient datasets

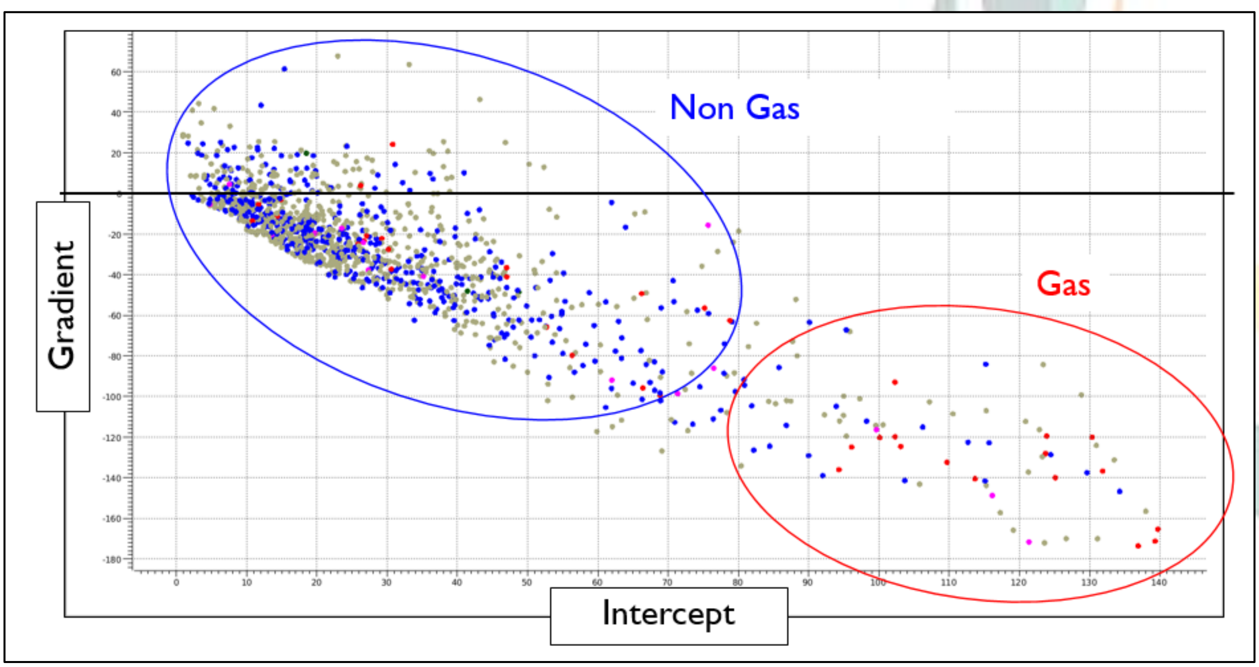

Figure 9. Cross plot between Intercept and Gradient (example result from CWT). Red, blue, gray color are gas bearing sand, water bearing sand, and shale, respectively.

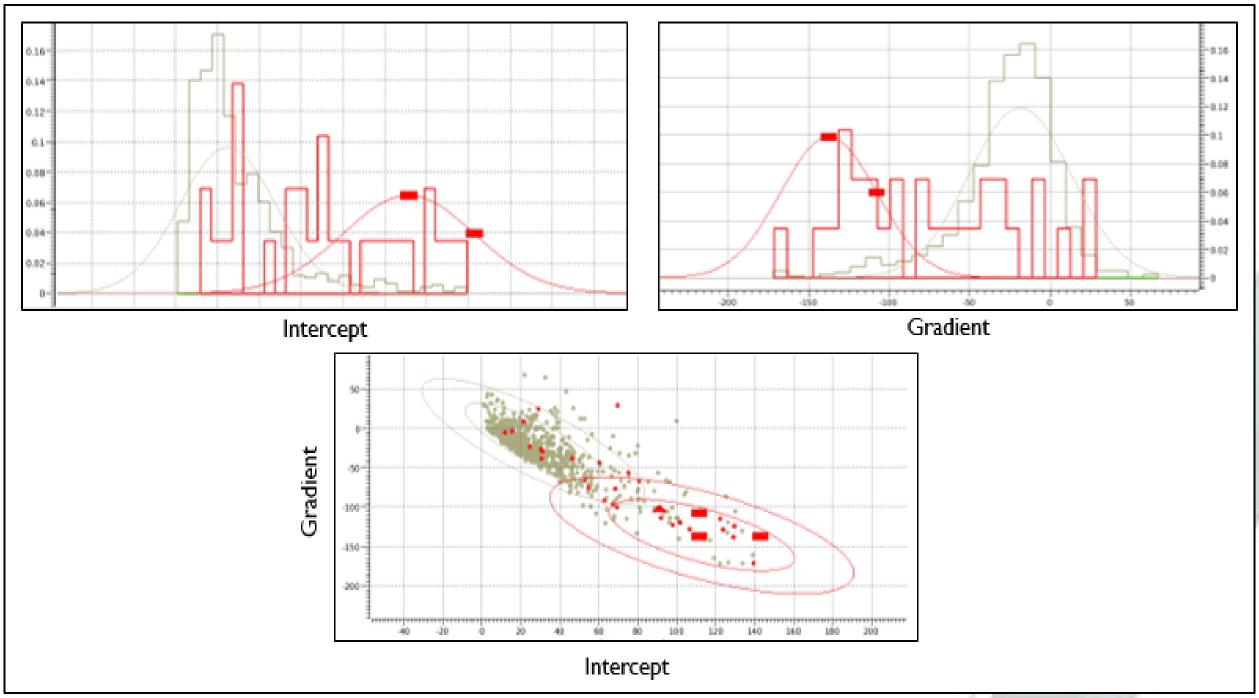

Figure 10. Two classes of Probability Density Function based on Intercept and Gradient cross plot, gas bearing sand (red) and background (grey).

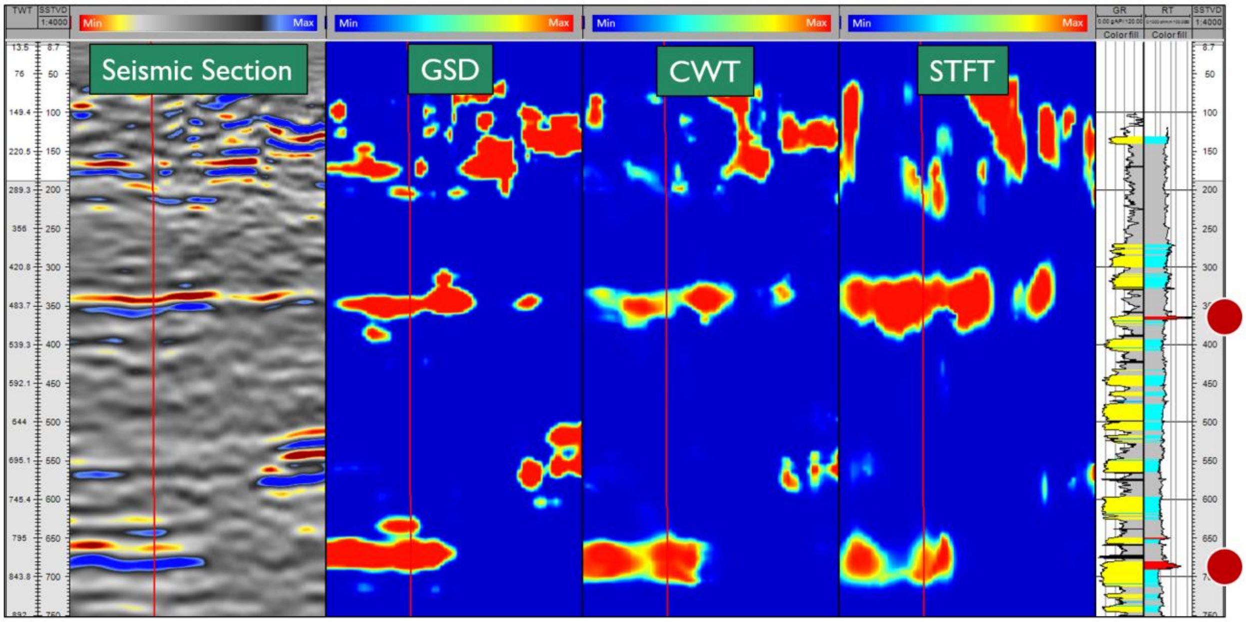

Figure 11. Comparison of seismic data and well result with the output Gas Probability datasets

Furthermore, the Gas Probability datasets can be transformed into high probability geobodies, which can be used for validation at the existing wells and finally used to identify new potential hydrocarbon accumulation in very shallow interval (Figure. 12)

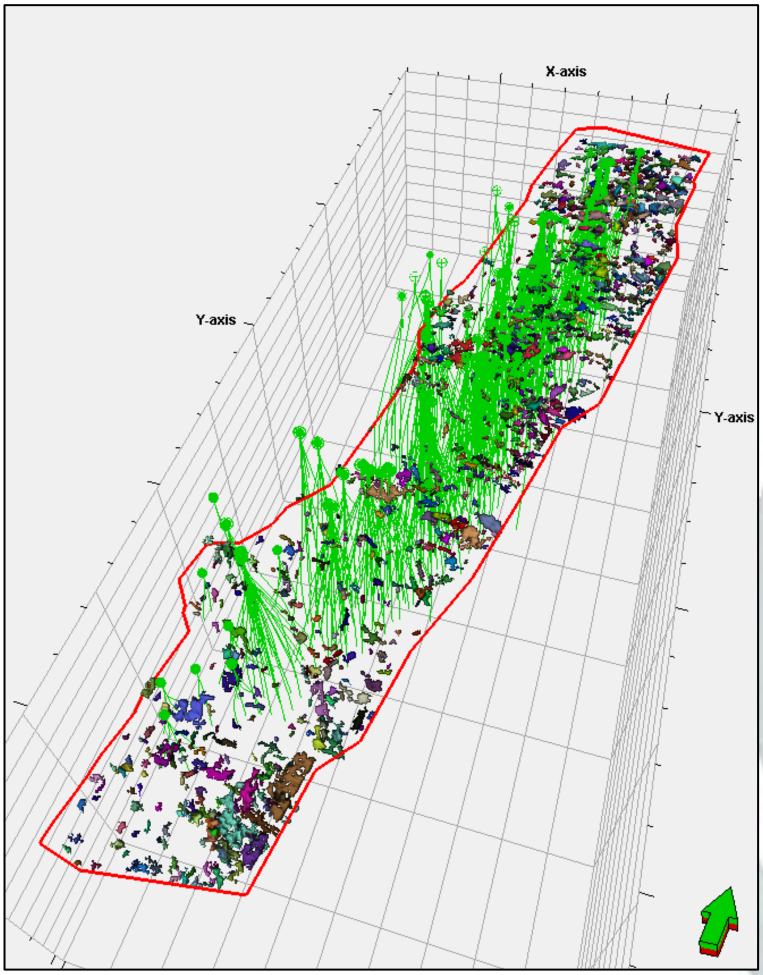

Figure 12. Geobodies extracted from high values of Gas Probability (example result from CWT),

4 Conclusion

The study shown that slope of seismic spectral methodology is applicable for very shallow interval in Tunu field. It is not limited by the available seismic fold and seismic angle; thus it offers alternative to analyze the behavior of seismic events in this particular interval. Since the methodology rely on the frequency quality embedded in the seismic data as in input, it is recommended to consider frequency factor since the early stage of seismic acquisition and processing, especially when dealing with very shallow objectives. Furthermore, a larger scale well result confirmation is required to accomplish better confidence in the application of this methodology. The preliminary result of the study gives promising prediction accuracy, with success ratio up to 70% depends on the applied spectral decomposition methodology.

References

[1] Rengifo, R., Yoga, T., Cibaj, I. 2012. Tunu Shallow Gas Combine Traps, From Drilling Hazard to Massive Successful Development: Proceedings of Indonesia Petroleum Association, 36th Annual Convention.

[2] Prabowo, D.B., Khairy, H., Yuh, S., Adam, C.A., Giriansyah, B., Vallon, G. 2015. De-risking Drilling Targets for Future Tunu Shallow Zone Development Phase: Application of Litho-Seismic Classification Based on Simultaneous Inversion: Proceedings of Indonesia Petroleum Association, 39th Annual Convention.