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# BLUEING REFLECTIVITY INTEGRATION (BRI) FOR SEISMIC SPECTRAL ENHANCEMENT AND ITS APPLICATION IN SEISMIC DATA INTERPRETATION

*Amir Abbas Babasafari[1*], Deva Prasad Ghosh[1], Ahmed Mohamed Ahmed Salim[1], Sayed Hesammoddin Kazemeini[2], and Teresa Ratnam[1]*

[1] *Center of Seismic Imaging and Hydrocarbon Prediction, Geoscience Department, Universiti Teknologi PETRONAS, 32610, Tronoh, Perak, Malaysia*
[2] *AlphaReservoir Plus, Houston, Texas, USA*

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**Abstract**

Enhancing seismic data resolution through broadening frequency bandwidth aids to reveal sub seismic, geological features. There are some approaches which try to overcome this limitation in different stages of seismic data analysis from acquisition to processing and interpretation. Some of these techniques boost high frequency noises. Hence, to mitigate generating pitfall reflectors in seismic data, the algorithm is preferred from which seismic vertical resolution is enhanced with less side effect of boosting noise. A new and practical technique is proposed by incorporating seismic and well data. Blueing Reflectivity Integration (BRI) technique helps to create a new seismic data set that can disclose thin beds below seismic tuning thickness. Using seismic and acoustic impedance log, an operator is designed and convolved with seismic data reflectivity series to produce enhanced seismic data. The more appropriate match between seismic and synthetic data in well to seismic tie process demonstrates the efficiency of this approach for seismic resolution enhancement. The BRI volume reduces uncertainties in seismic data interpretation. For this purpose, its applications in RGB blended display for structural-stratigraphical interpretation and also hydrocarbon prediction in reservoir characterization are analyzed and compared with original seismic data.

***Keywords****: Blueing Reflectivity Integration, broadening frequency bandwidth, seismic vertical resolution, sub seismic geological features.*

## 1. Introduction

In order to resolve thin beds in seismic data, the frequency bandwidth should be broadened [1]. Seismic data suffers from an intrinsic limitation of the bandwidth. In conventional seismic data, the frequency spectrum exists up to 80-90 Hz. To detect thin layers depends on the target depth and formation velocity, the frequency bandwidth more than this range is required. λ as a key parameter for seismic resolution is the predominant wavelength in the seismic data which depends on velocity and frequency. Since the seismic resolution limit (two way time) is assumed to be λ/4 with the presence of noise and velocity is not changeable, the attempts of geoscientists are focused on enhancing frequency bandwidth [2]. Acquiring high resolution seismic and 3D VSP is supposed to attack the seismic resolution limitation early on in the data acquisition stage, while wavelet transformation, spectral Whitening, spectral Blueing, matching pursuit, and Geostatistical stochastic inversion in the data processing and interpretation.

During wave propagation in the earth, the high frequency content of seismic data is attenuated due to absorption and scattering of elastic waves [3]. This phenomena make the seismic spectrum “Red” mean higher frequency data have lower amplitude than lower frequency one. Traditionally to compensate it, spectral Whitening is employed. However, earth spectrum according to the well reflectivity series is different. The well reflectivity spectrum shows a “Blue” trend meaning that the higher frequencies (refer to thinner geological events) have higher amplitude (more recurrent), and the lower frequencies (thicker geological events) have lower amplitude or less geologically recurrent.

Spectral Blueing [4-6] is a technique that shapes the mean seismic spectrum to follow the well-derived reflectivity trend and optimize the vertical resolution without boosting noise to an unacceptable level. The spectrum is reshaped to match the real trend of the reflectivity obtained from wells. Shaping the seismic spectrum to follow the Blue reflectivity is referred to as the spectral Blueing which enhances seismic resolution and outputs more geological details. Spectral Blueing technique recovers higher frequency data while it does not go beyond the seismic bandwidth and the spectrum still need to be broadened in order to get result that is much more consistent with well reflectivity spectrum.

Thin-bed reflectivity inversion was proposed to enhance seismic vertical resolution [7]. This approach works on the basis of removing wavelet interference from seismic data and generating thin-bed reflectivity series via spectral inversion. This method extracts more structural and stratigraphical information. However, for quantitative interpretation procedures, a band pass wavelet with a high end frequency needs to be convolved, which in turn doesn't follow the shape of frequency spectrum originated from seismic and well reflectivity [8].

We propose a new technique named "Blueing Reflectivity Integration (BRI)," which results in "Blue" and broadband frequency bandwidth. To this end, an operator is designed to be convolved with seismic data reflectivity series. This technique leads to achieving high resolution seismic data, which enables us to disclose subtle geological features below seismic vertical resolution limit and help in enhancement of fault detection and sub seismic channel delineation. Well, to seismic tie, RGB blended analysis and Bayesian probability classification of hydrocarbon distribution are used to demonstrate the validity of BRI results.

## 2. Methodology

The main objective of this research is broadening frequency bandwidth to resolve thin reservoir layers below seismic vertical resolution with less side effect of boosting high frequency noises. Hence, an advance and practical technique for seismic resolution enhancement are proposed that improves seismic data interpretation and hydrocarbon prediction.

The first smoothed mean amplitude spectrum of the seismic data reflectivity series is calculated. Next, an exponential curve is fitted on amplitude spectrum of well reflection coefficient series. Using this information, Blueing Reflectivity Integration (BRI) spectra is designed.

In detail, to attain a seismic data represents time reflectivity series with "Blue" amplitude spectrum, the following steps are carried out:

a) Extracting reflectivity series of seismic data (near, middle and far stacks) in two steps:
- Calculating the first derivative of the seismic traces
- Identifying the zero-crossings amplitude value

b) Calculating smoothed mean amplitude spectrum of seismic data reflectivity series (a) in the frequency domain
c) Obtaining well reflection coefficient derived from Acoustic Impedance log in the time domain
d) Fitting an exponential curve on amplitude spectrum of well reflection coefficient (a Blue spectra)
e) Multiplication of mean amplitude spectrum of reflectivity series (b) by fitted Blue spectra trend (d) to generate new Blueing Reflectivity Integration (BRI) spectra
f) Taking inverse Fourier Transformation of BRI spectra (e) to bring back the data to the time domain (BRI operator)
g) Convolving seismic data reflectivity series (a) by BRI operator (f) for near, middle and far stack data

All the procedures above are done three times for Near, Middle, and Far stack data separately and for a limited time window around the target. Figure 1a illustrates a well reflectivity spectrum. Figure 1b displays designed operator of BRI technique. The amplitude spectrums of different methods are compared in Figure 1c. Since the workflow is used to achieve the seismic data with amplitude spectrum closer to the real earth reflectivity series (Figure 1c), the technique is called Blueing Reflectivity Integration (BRI). The BRI results not only have the vertical resolution far superior to the original seismic data but also reflect more geological information.

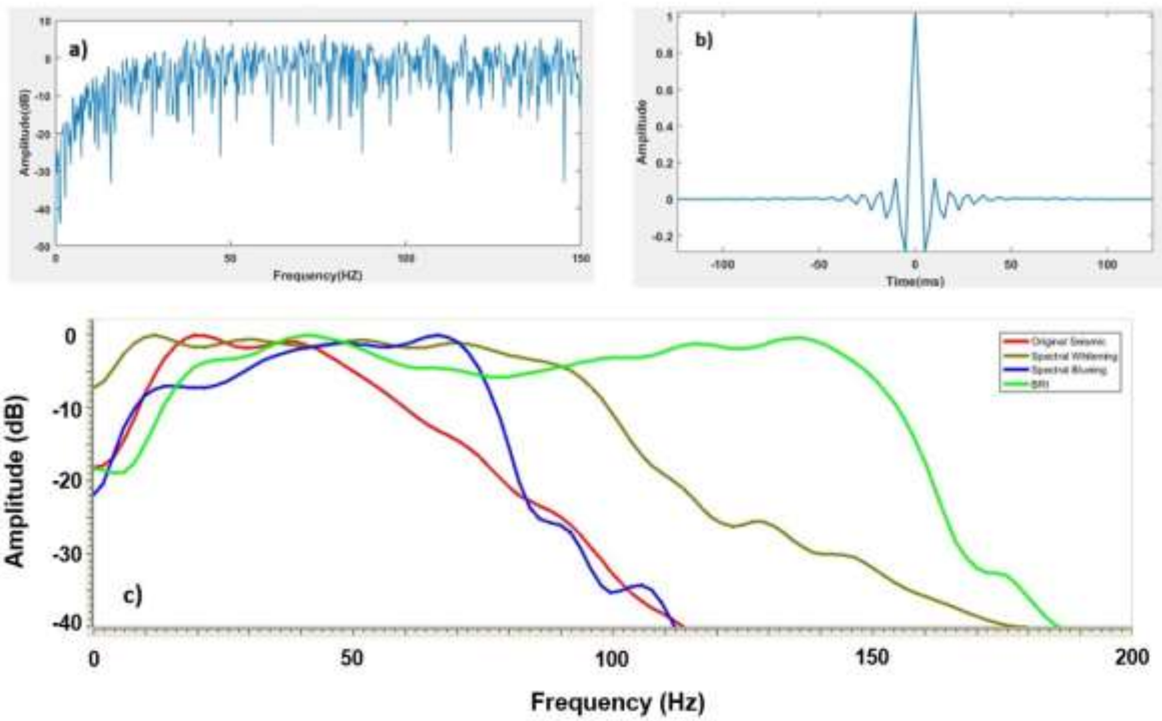



Figure 1. a) Blue amplitude spectrum of well reflectivity series. b) Designed operator of BRI technique. c) Amplitude spectrum comparison of Blueing Reflectivity Integration (BRI) technique with original seismic data, spectral Whitening and spectral Blueing approaches in a time window from 1400 ms to 1800 ms

## 3. Results and discussion

### 3.1. Well to seismic tie

In this research, well and seismic data from a field located in Malay Basin are utilized. The study focuses on clastic sediments of reservoir layer E in a fluvial channel depositional environment in Middle Miocene. The group E sand layers in this field are not only thin but also medium to poor quality and not continuous which is due to the stratigraphic nature of the sand distribution. The East Fault Block of this field is selected as the study area. 3D seismic pre-stack data and four wells including elastic and petrophysical logs are used. Four lithofacies classes are classified, including “Shale” “Wet sand”, “Gas sand,” and “Coal”.

Prior to the assessment of BRI technique application in reservoir characterization, seismic data is analyzed at well location. One of the efficient tools to evaluate quality of broadband seismic data e.g. BRI result is conducted through well to seismic tie. Figure 2 shows well to seismic tie for the original seismic data and BRI outcome at well location C in this study. As can be seen more consistent geological match between seismic data and synthetic seismogram in BRI result is obtained (better correlation between seismic events).

### 3.2. Application in seismic data interpretation

Figure 3 compares the 2D cross section of the original seismic data with BRI result. As it is illustrated BRI technique aids in delineating more subsurface details (both structure and stratigraphic features). The mentioned locations in Figure 3 (a, b, and c) indicate thin channel sediments, which are obscured in original seismic section. Location (d) in original seismic section demonstrates amplitude decrease of seismic reflectors, which potentially might be related to sub seismic fault. BRI section highlighted the fault trend.

Seismic attributes are known as helpful tools to derive structural, stratigraphical, and lithological information from subsurface features. Simultaneous RGB blended analysis is a seismic attribute that employs spectrally decomposed volumes leading to highlight subtle geological features such as faults, channel, sand bodies, and …

In this study, three iso-frequency volumes were produced after spectral decomposition analysis; 20, 30 and 50 HZ representing in Red, Green and Blue colors (RGB), respectively.

The basic distinction between two RGB blended volumes applied on original seismic data and enhanced spectral one (BRI) originates from different amplitude spectrums of iso-frequency volume 50 HZ.

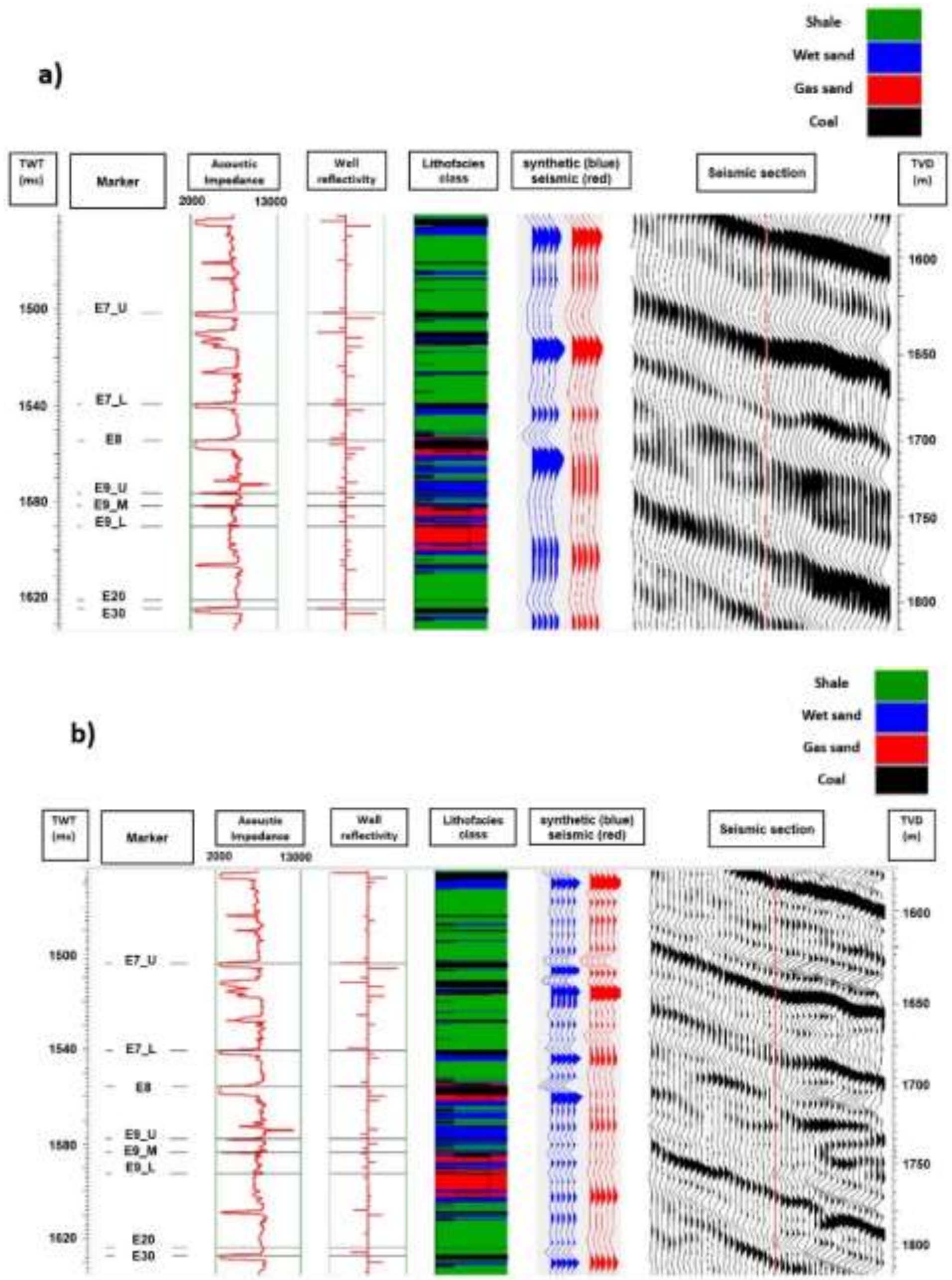
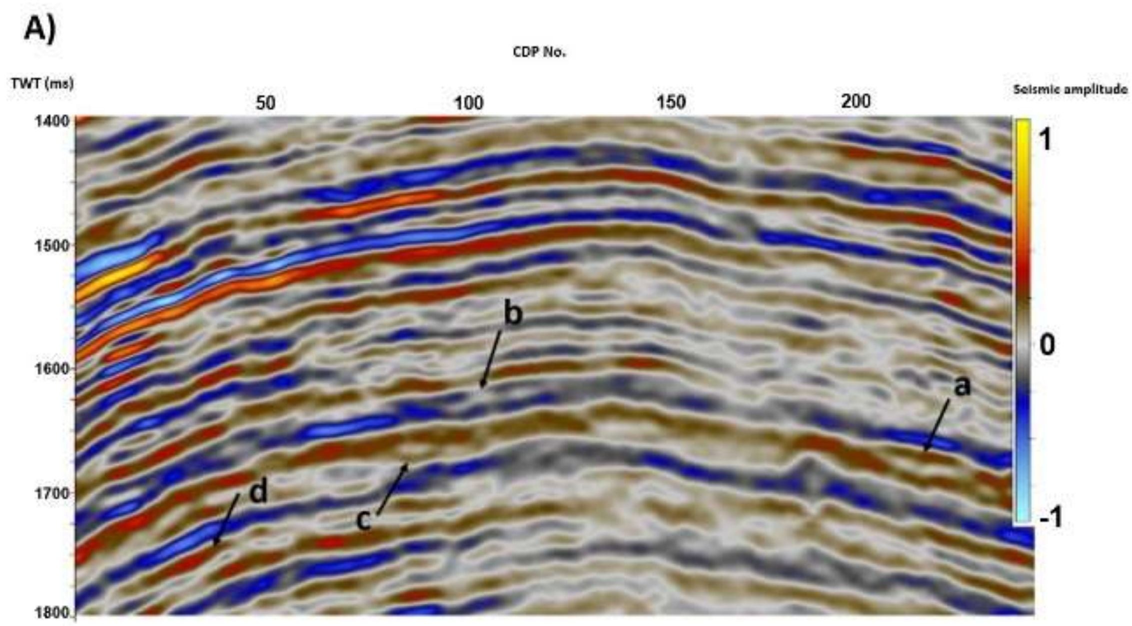



Figure 2. Well to seismic tie using a) original seismic data and b) BRI outcome; the tracks illustrate markers, Acoustic impedance log, well reflectivity series, lithofacies column, synthetic in blue color, seismic at well in red color and seismic section in black color, left to right respectively



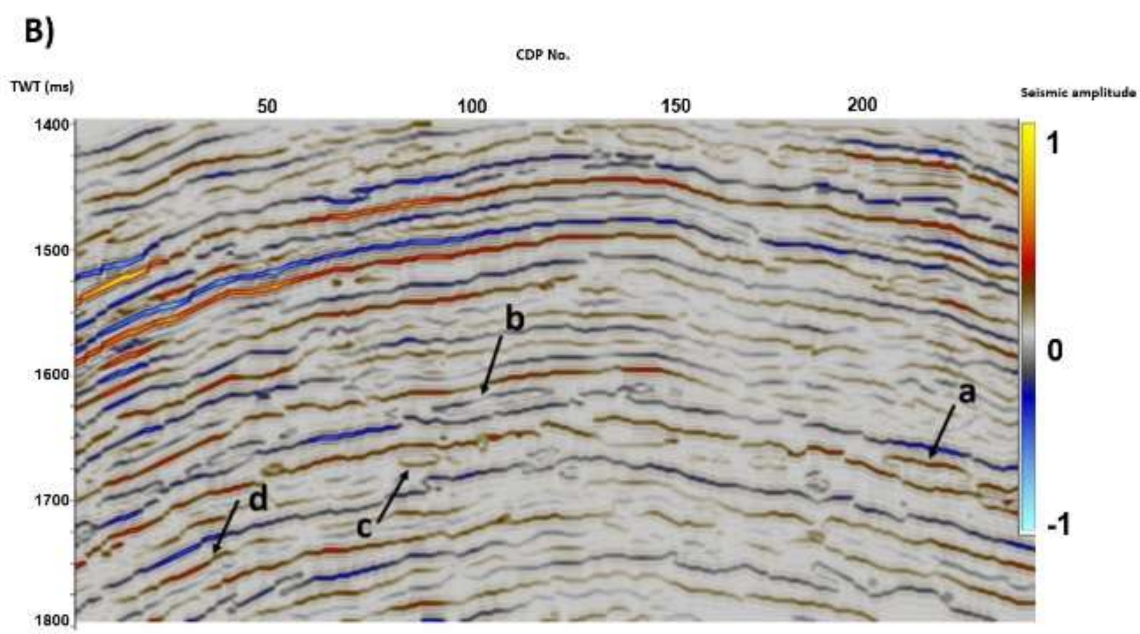




Figure 3. B) BRI seismic section reveals sub seismic geological features compare to A) original seismic data; (a), (b) and (c) locations are representing thin channel sediments and (d) demonstrates fault with minor displacement

Figure 4 shows the RGB blended display of spectrally decomposed volumes using original seismic data (a) and BRI output (b) on reservoir intervals. As can be seen more structural and stratigraphical features are disclosed. A new fault trend in the middle is observed in compliance with tectonic regime of this field which obscured in the original seismic data due to fault throw is less than seismic vertical resolution (white arrow). This clear boundary can be attributed to the edge of probable incised valley (representing by darker color) passing through the floodplain deposits in the field of study.

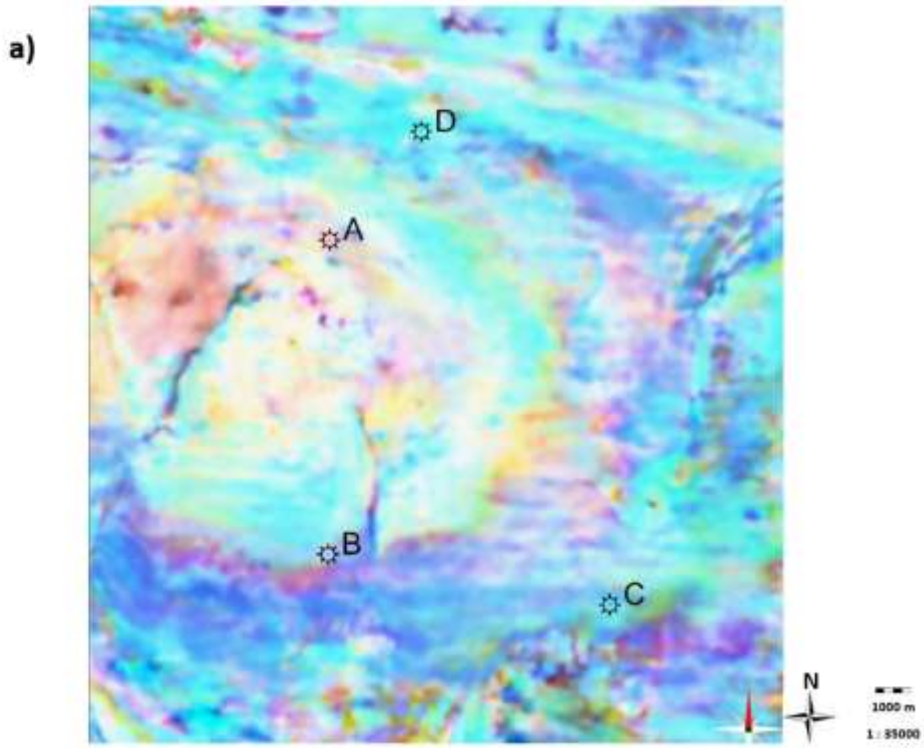



Figure 4a. RGB blended display of spectral decomposed volumes using original seismic data

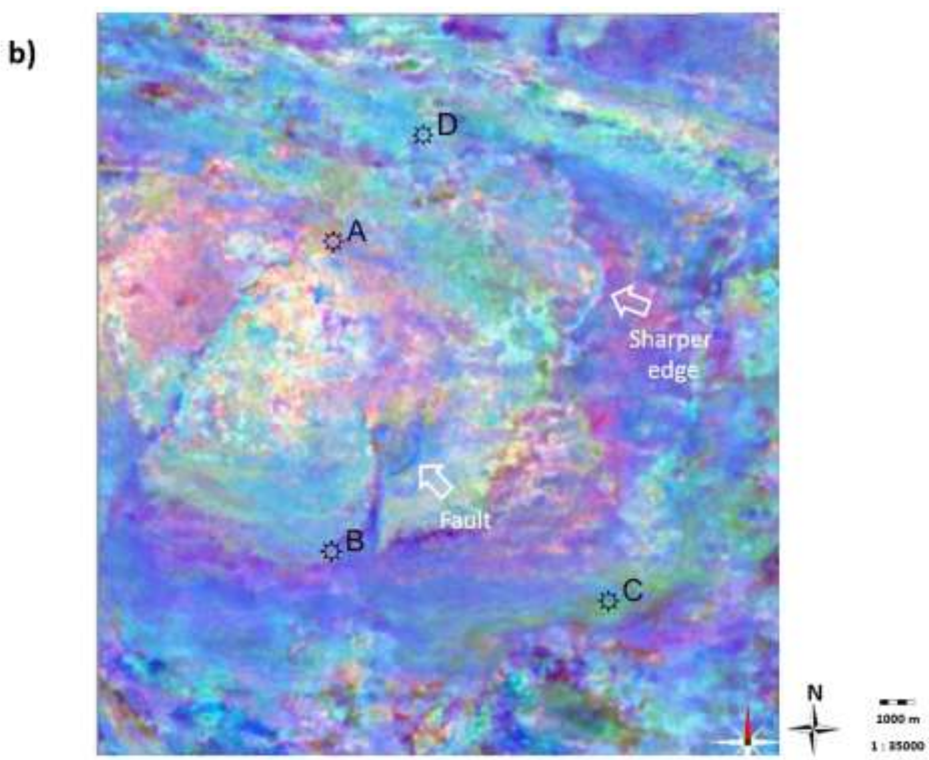



Figure 4b. RGB blended display of spectral decomposed volumes using BRI output on reservoir interval demonstrates that more geological features are revealed

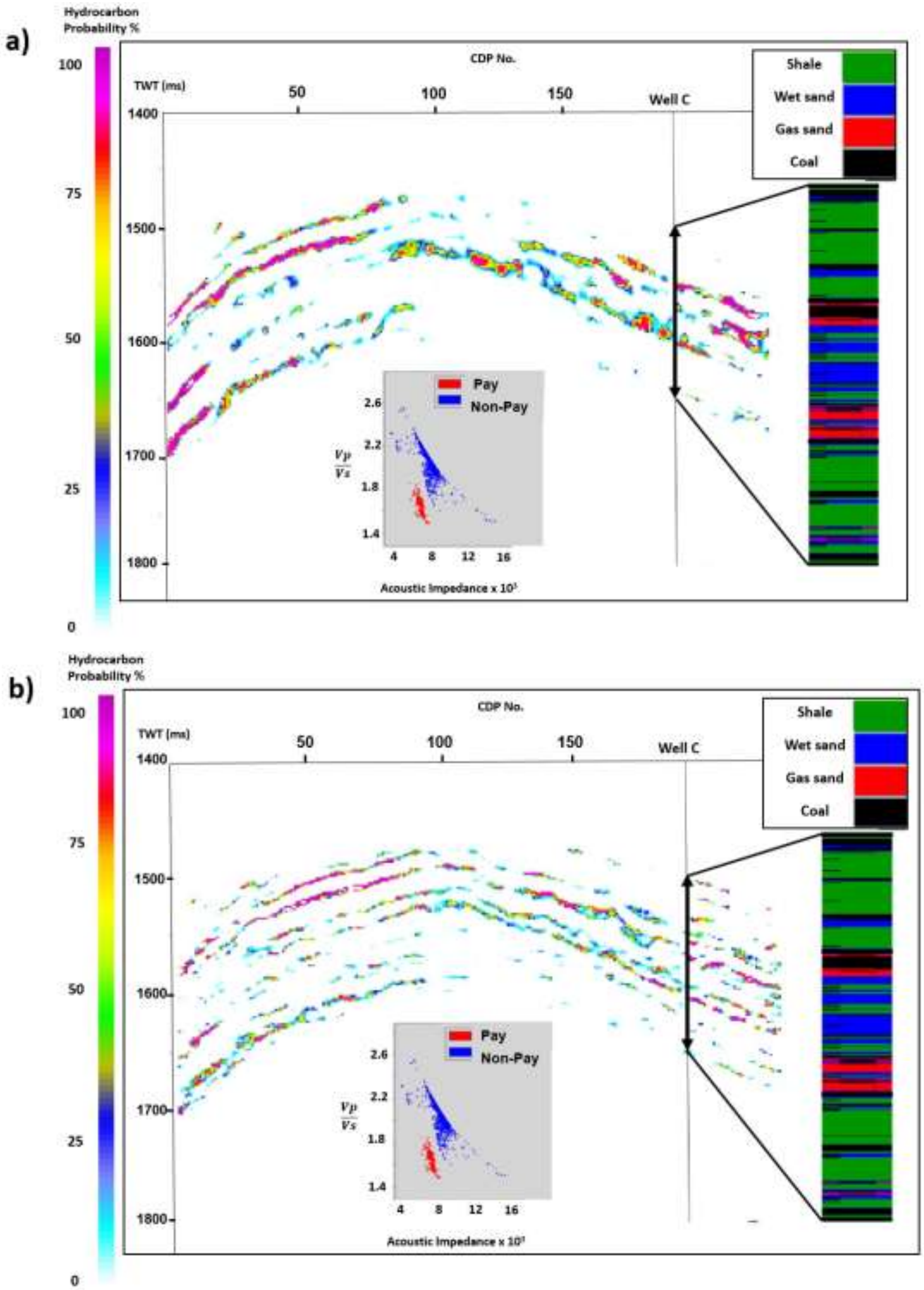



Figure 5. Hydrocarbon probability section passing through well (C) juxtaposed by lithofacies column, extracted from seismic pre-stack elastic inversion on a) original seismic data and b) BRI result; both produced by applying Bayesian probability classification on displayed Acoustic impedance vs. Vp/Vs cross plot

Thin reservoir layers below tuning thickness of seismic data are difficult to resolve. In this section for hydrocarbon prediction, an integration of Petro-Elastic modeling, seismic elastic inversion and Bayesian probability classification are applied. First, seismic pre-stack elastic inversion is conducted to estimate elastic properties away from the wells. Using elastic properties (Acoustic Impedance and Vp/Vs volumes) and Petro-Elastic modeling, litho-facies volume is obtained [9]. Next, Pay zone (Gas sand) from Non-pay zone (Shale, Wet sand and Coal) are differentiated by applying Bayesian probability classification on displayed Acoustic impedance vs. Vp/Vs cross plot in Figure 5.

Figure 5 shows the hydrocarbon probability section extracted from seismic elastic inversion passing through well C juxtaposed by lithofacies column.

More details of thin reservoir layers are revealed in BRI results. Also, the more appropriate match between hydrocarbon probability section and lithofacies column at well location C is concluded in hydrocarbon prediction results derived from enhanced seismic data (BRI output).

## 4. Conclusion

The proposed Blueing Reflectivity Integration (BRI) approach has been successfully examined. The results from this approach confirmed that it is capable of disclosing more details of the geological features, which may not be clearly observed on the seismic data. The Blueing Reflectivity Integration technique presented in this paper is a novel technique of broadening frequency bandwidth and enhancing vertical resolution below the tuning thickness. This technique compared to thin-bed reflectivity inversion produces seismic volume with frequency spectrum far closer to the well reflectivity spectrum. The output of this process can be used as co-volume for horizon interpretation in uncertain picking areas due to minimizing wavelet interference in thin layers compare to original seismic data. The outcome of this technique yields a reflectivity series with a Blue spectrum, which is geologically more sensible in terms of well to seismic tie. RGB blended products demonstrate seismic attribute analysis is enhanced using BRI technique. In fact this technique is useful for mapping sub seismic structural and stratigraphical features such as sand bodies, channels, pinch outs and faults. Hydrocarbon prediction using BRI results leads to more details of thin layers. This technique helps to reduce uncertainty of reserve estimation and build a more reliable reservoir model.

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*To whom correspondence should be addressed: Dr. Amir Abbas Babasafari, Center of Seismic Imaging and Hydrocarbon Prediction, Geoscience Department, Universiti Teknologi PETRONAS, 32610, Tronoh, Perak, Malaysia, E-mail a.babasafari@yahoo.com*