Applied Seismic Reservoir Characterization to Distinguish Coals and Sandstone Reservoir of Southwest Betara Field, South Sumatra Basin, Indonesia*

M. N. Alamsyah[1], Bambang W. Handono[1], and Teguh Fitrianto[1]

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[1]PetroChina International Jabung Ltd., Jakarta, Indonesia (m.alamsyah@petrochina.co.id)

Abstract

Seismic reservoir characterization of a 3D seismic and well data has been applied to 60 km^2 of seismic over Lower Talang Akar Formation sand reservoirs intervals in Southwest Betara Field of Jabung Block, South Sumatra Basin, Indonesia. The field has produced oil since first production in late 2005 from the sandstone-A reservoirs. The main problem on this field is internal coal distribution on sandstone-A reservoirs that affect seismic reflectivity and shows the ambiguity between the coals and sandstone-A reservoir. The objectives of this study are to delineate sandstone-A reservoir distribution laterally by using seismic reservoir characterization methods and to compare the result with a previous study.

The sensitivity analysis from log data, seismic multi-attribute and amplitude attribute study has been carried out to solve this problem. Results from crossplot analyses of well data indicate that the coals can be identified and distinguished over and between the sandstone reservoirs by using pseudo log Gamma Ray Index (GRI) within certain cut-off values. By using this pseudo log GRI and generating multi-attribute analysis with linear regression, the GRI volume has been created. Based on this GRI volume, the lateral distribution of sandstone-A reservoir and coals can be created separately by using amplitude attributes of RMS Amplitude, Threshold Value and Sum of Negative Amplitude. These attributes can be used to delineate the paleo-depositional environment of sandstone-A reservoir and coals in the Southwest Betara Field.

The distribution maps show the delineation of sandstone-A reservoirs and coals with a NW-SE direction, which is consistent with well data. By comparing these data to the previous study, the result of latest study has been successfully differentiates the sand reservoir and coals, also defines both in laterally distribution within Southwest Betara Field.

Introduction

Jambi Sub-Basin is part of the South Sumatra Basin (SSB). SSB is a series of back arc basins, which are relatively located elongated in the northern part of Sumatra Island, Indonesia. Geologically, SSB is located between the stable micro-continent block of Sundaland and an active subduction zone between the Indian Ocean plate and southeast Asia plate. The Southwest Betara (SWB) Field is located in the Jambi Sub-Basin. This field has a three-way dip closure faulted-anticline and formed by a process of extension and compression that occurred in the formation of regional sub-basin Jambi and South Sumatra Basin as a whole (Figure 1).

The main reservoirs of SWB field are from the Lower Talang Akar Formation (LTAF). This formation is generally composed of sediment with grain size of fine to coarse, sometimes consisting of conglomerate, well sorted, relatively clean, and thick-coated porous sandstones. Figure 2 shows the SWB Field log type of LTAF which has a similar character and environment of deposition of log types described by Ginger and Fielding (2005). LTAF facies gradually change from fluvial deposition on the bottom towards a delta and shallow marine environments (shallow marine) at the top.

The SWB Field has produced oil since first of its production in late 2005 from the sand-A reservoir of LTAF. The main problem on this field is many coal intercalations within sand-A reservoirs interval which affecting into seismic reflectivity and it will create ambiguity between coals and sand-A reservoir (Figure 3). The objectives of this study are to delineate sand-A reservoir distribution laterally by using seismic reservoir characterization methods and to compare the result from the previous study.

Methodology

Four steps were carried out in this study to solve this problem: 1) the sensitivity analysis from log data; 2) seismic multi-attribute analysis; 3) surface seismic attribute calculation; and 4) cross-plot analysis of reservoir properties from log data with the attribute distribution value.

Sensitivity analysis was done by using a mathematical approach from gamma ray and density log data. The equation used is GRI or Gamma Ray Index, otherwise known as Pseudo Gamma Ray corrected. The assumption of GRI equation is the log curve of gamma ray and density has same character except coal character. Coal in density log curve has a very sharp shape when compared to the gamma ray log (Figure 3). In addition, the values are extremely small on the density log. With this assumption, if the value of gamma ray log is divided by the density log, then the value for coal in GRI will be greater than or equal to the value of shale than sandstone. The expected result from the GRI's analysis will be to distinguish sandstone, shale and coal.

Multi-attribute analysis was performed for log properties prediction to seismic data based on previous sensitivity analysis. It will produce a seismic data volume or seismic cube with its value in accordance with the log data. In this case, GRI log is used as input data to change the 3D seismic volume into GRI volume.

The reservoir distributions are determined from surface seismic attributes by statistical calculations using GRI volume as an input data. The calculation is done using a certain window from single horizon of LTAF, which represents the interval of sand-A reservoirs.

Validation on the lateral distribution of seismic attributes representing sand-A reservoir can be performed by cross-plot analysis from the relationship of seismic attributes value with the physical property value from well log data such as thickness and porosity of sand-A reservoir. The good correlation value from the crossplot analysis showing the distribution of seismic attributes is valid.

Result and Discussion

The sensitivity analysis of well data by using pseudo log Gamma Ray Index (GRI) within certain cut-off value shows significant separation between the sandstone reservoir, coal, and shale. The example from well #2 log data in Figure 4a shows a sandstone reservoir located on the lower zone of the Gamma Ray Index with a cut-off value of 60. Another unique characteristic of the existence of coal is the neutron-porosity log, which has a significantly high value than sandstone. To prove the existence of coal on the sensitivity analysis cross-plot, the gamma ray color index is replaced by neutron-porosity color index. Refer to color index on neutron-porosity, coal lithology is characterized by large values (purple), while the reservoir sandstone is characterized by a small value (yellow-green). Again, the sandstone reservoir located on the lower zone of the Gamma Ray Index with a cut-off value 60 (Figure 4b).

Based on log data, rocks with good porosity (sandstone and coal) have small gamma ray and density values and coal has a density value, which is much less significant than the sandstone. That GRI calculation creates a pseudo log where the coal value is almost equal to the shale value and greater than the sandstone value (Figure 4c).

This sensitivity analysis method was applied to 13 wells of SWB field. The results are shown in Figure 5. The analysis summary showed the consistency of data distribution. Linearly, sandstone reservoir is in the zone boundary values below 60 for GRI while the value of coal is in the zone above the value of 60 relatively same with shale value.

By using this pseudo log GRI and seismic 3D data, multi-attribute analysis with linear regression approach was generated and it will create the GRI volume. Based on this GRI volume, the lateral distribution of sand-A reservoir and coals can be created separately by using surface seismic attribute calculation of Threshold Value and Sum Negative Amplitude. In the threshold values attributes calculation, the distribution of sand-A using threshold values is less than 60. The value to be distributed is the percentage of the value of GRI which is less than or equal to 60. Figure 6a shows the percentage of the Gamma Ray Index (GRI) value with the threshold value parameter less than 60. High percentage values (40-100%) described the distribution of sand-A reservoir. Figure 6b shows the calculation result of Sum Negative Amplitude attribute. Before performing the calculation the attribute, the GRI volume was subtracted by the value of 60 and the GRI volume value changed into positive and negative values. The cut-off GRI at 60 value is important, since at 60 GRI, values will be assigned as zero values, less than 60 GRI value would be negative values and above 60 GRI value will be assigned positive values. The zero and negative values are a picture of the intensity of the sand-A indirectly. The distribution maps show the delineation of sand-A reservoirs within NW-SE direction, which is consistent with the well data. By comparing these data to the previous study (Figure 6c), the result of the latest study has successfully differentiated the sand reservoir and coals. Qualitatively, sand-A reservoir distribution patterns shows distributary channel more clearly than previous study with coal influence.

To see the validity results of the Threshold Value and Sum Negative Amplitude attributes results representing sand-A reservoir, the crossplot analysis has been carried out between each attribute value on a target point with the thickness and porosity values of the sand-A reservoir which derived from well data on the target. Figure 7a shows the result from crossplot analysis of Threshold Value Attribute to the thickness and porosity of the sand-A reservoir. The average correlation value is 0.83. Correlation value of Threshold Value Attributes to the Sand-A reservoir thickness is 0.86 and 0.81 to the porosity. The same result is shown in Figure 7b, the average correlation value is 0.86. The Sum Negative Amplitude Attributes to the Sand-A reservoir thickness correlation value is 0.88 and 0.85 to the porosity. This good correlation indicates that the sand-A reservoir thickness and porosity data to the Threshold Value and Sum Negative Amplitude attributes values from GRI volume has a fairly linear relationship (correlation coefficient close to 1), where a thick reservoir with good porosity indicated by the high value of the attribute, and vice versa. In general, both Threshold Value and Sum Negative Amplitude attributes can be used to delineate the paleo-depositional environment of sand-A reservoir with minimum coal influence in SWB field.

Conclusions

The influence of coal distribution in the LTAF intervals especially within sand-A reservoir interval can be minimized by using the Gamma Ray Index (GRI), as seen from the results of sensitivity analysis of reservoir on well data and seismic data.

Based on the linear regression analysis from the multi-attribute and reservoir distribution using surface seismic attribute calculation, sand-A reservoir distribution on the SWB Field consistently shows a trend northwest (NW) to southeast (SE). This is supported by each cross correlation plot of the reservoir property and attribute distribution. Qualitatively, sand-A reservoir distribution patterns show distributary channels with coal influence more clearly than the previous study.

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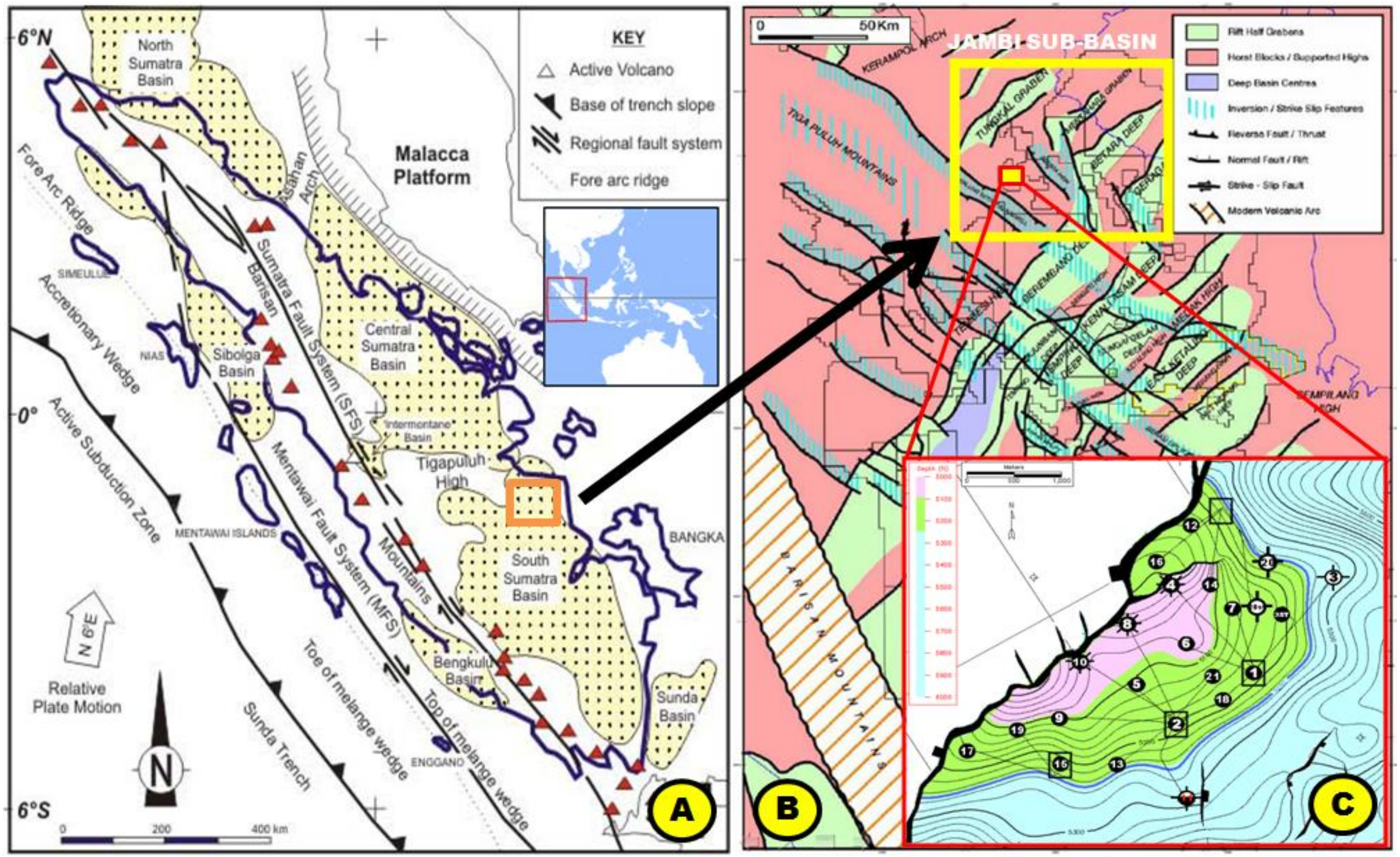

Figure 1. (A) South Sumatra Basin is a series of back arc basins, which located relative to the northern part of Sumatra Island, Indonesia. (B) Jambi Sub-Basin is part of the South Sumatra Basin (modified from Ginger and Fielding, 2005). (C) The SWB Field is located on Jambi Sub-Basin of South Sumatra Basin. This field has a three ways dip closure faulted-anticline.

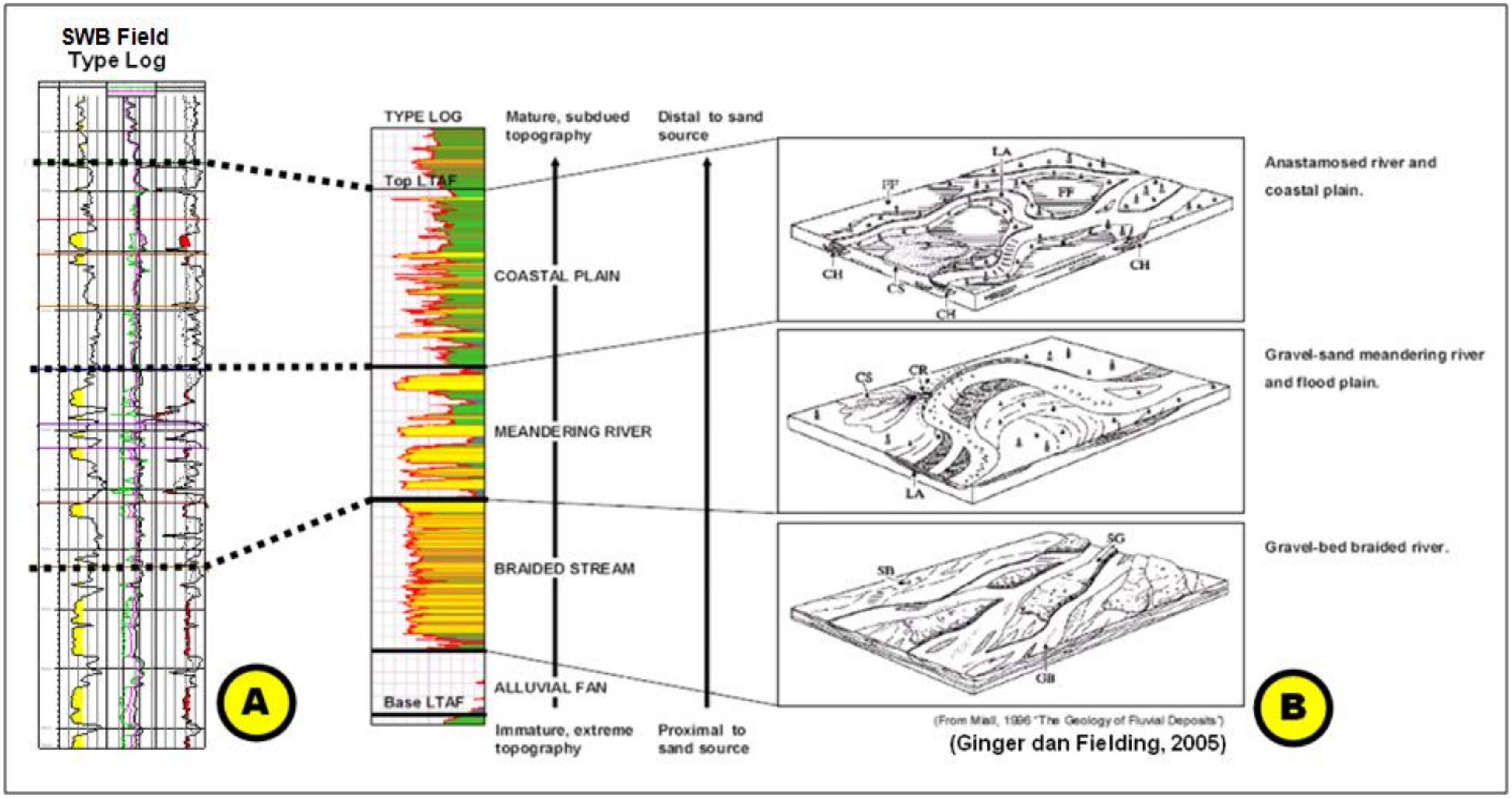

Figure 2. (A) The SWB Field log type of LTAF Formation. (B) Depositional character and environment of log types described by Ginger and Fielding (2005). LTAF facies gradually change from environmental regime fluvial deposition on the bottom, and towards the top of a delta and shallow marine environments (shallow marine).

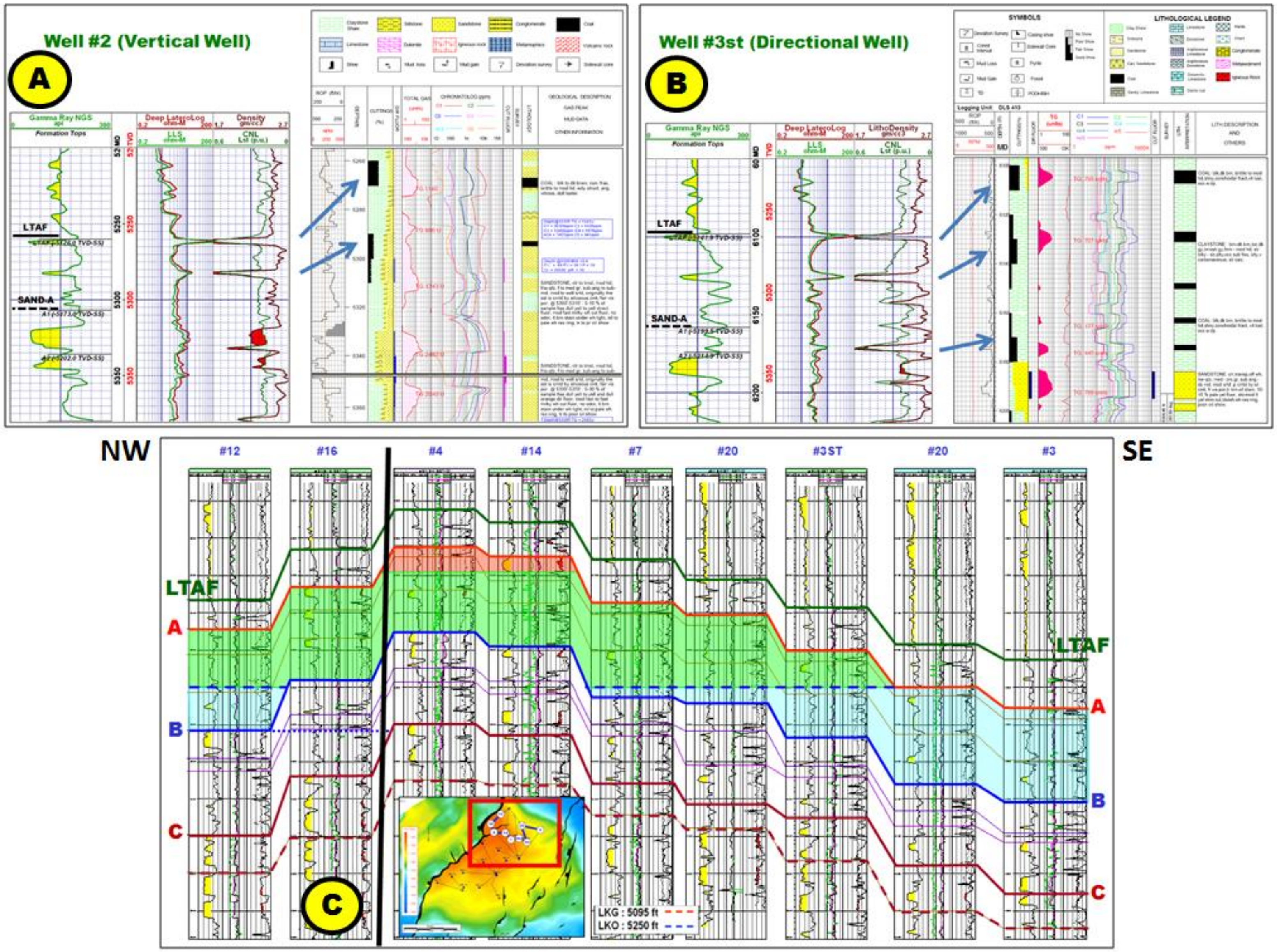

Figure 3. (A) Log data example from vertical well #2. Black color in cutting and lithology column representing coal. (B) Log data example from directional well #3. Black color in cutting and lithology column representing coal. (C) The NW-SE direction structural well correlation of SWB Field. Color zone represent hydrocarbon zone in Sand-A reservoir interval with along the interval many coal content. Red is gas zone and Green color is oil zone.

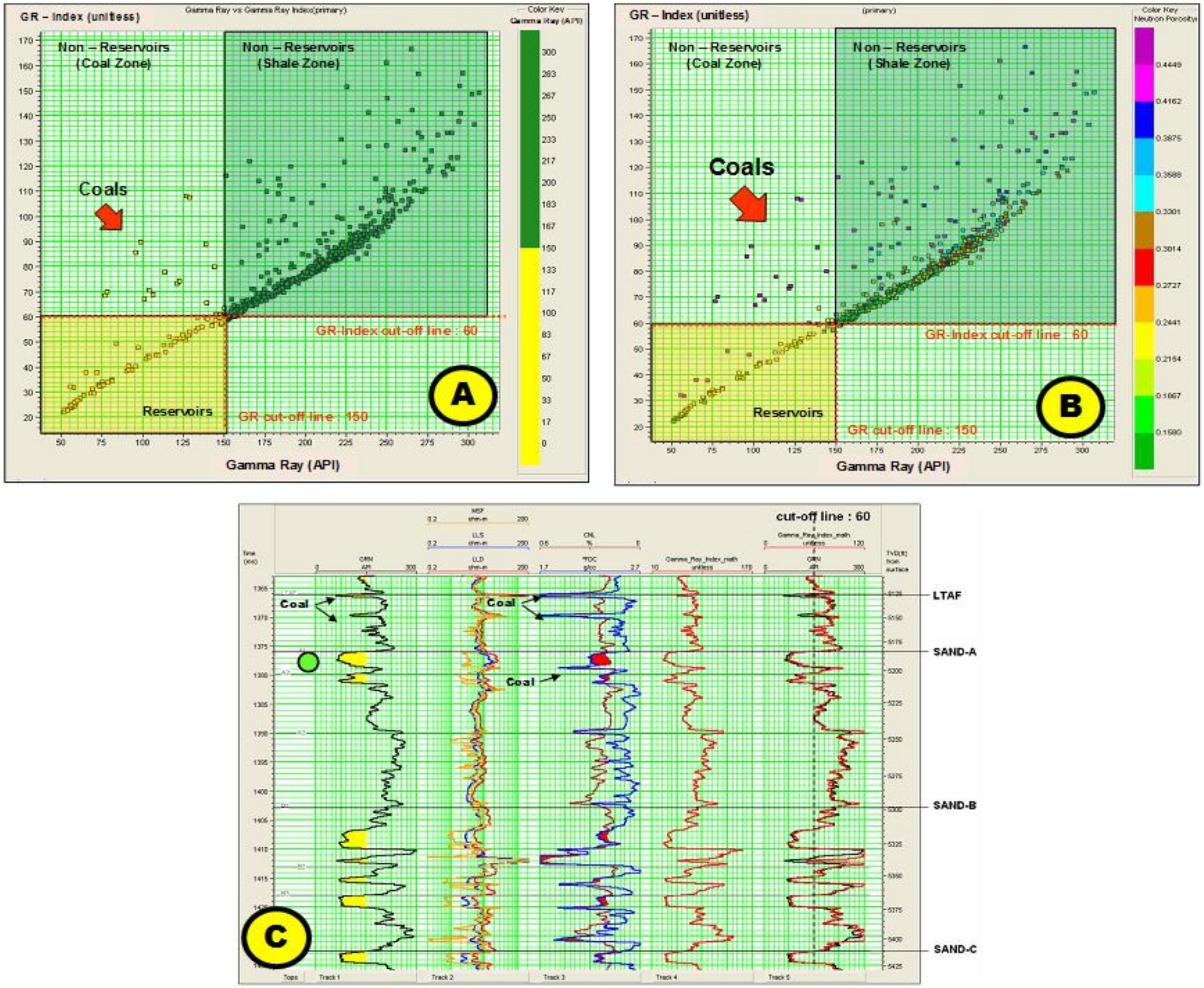

Figure 4. The sensitivity analysis of well #2 log data by using log gamma ray and pseudo log Gamma Ray Index (GRI) within cut-off value 60 shows significant separation between the reservoir sandstone, coal, and shale. (A) The sensitivity analysis of GRI vs gamma ray with color index gamma ray. (B) The sensitivity analysis of GRI vs gamma ray with color index neutron-porosity. (C) GRI calculation (right column) creates pseudo log in red line overlay with gamma ray log in black line which shows the coal value is almost equal to the shale value (above cut-off value 60) and greater than the sandstone value. Green circle is tested oil.

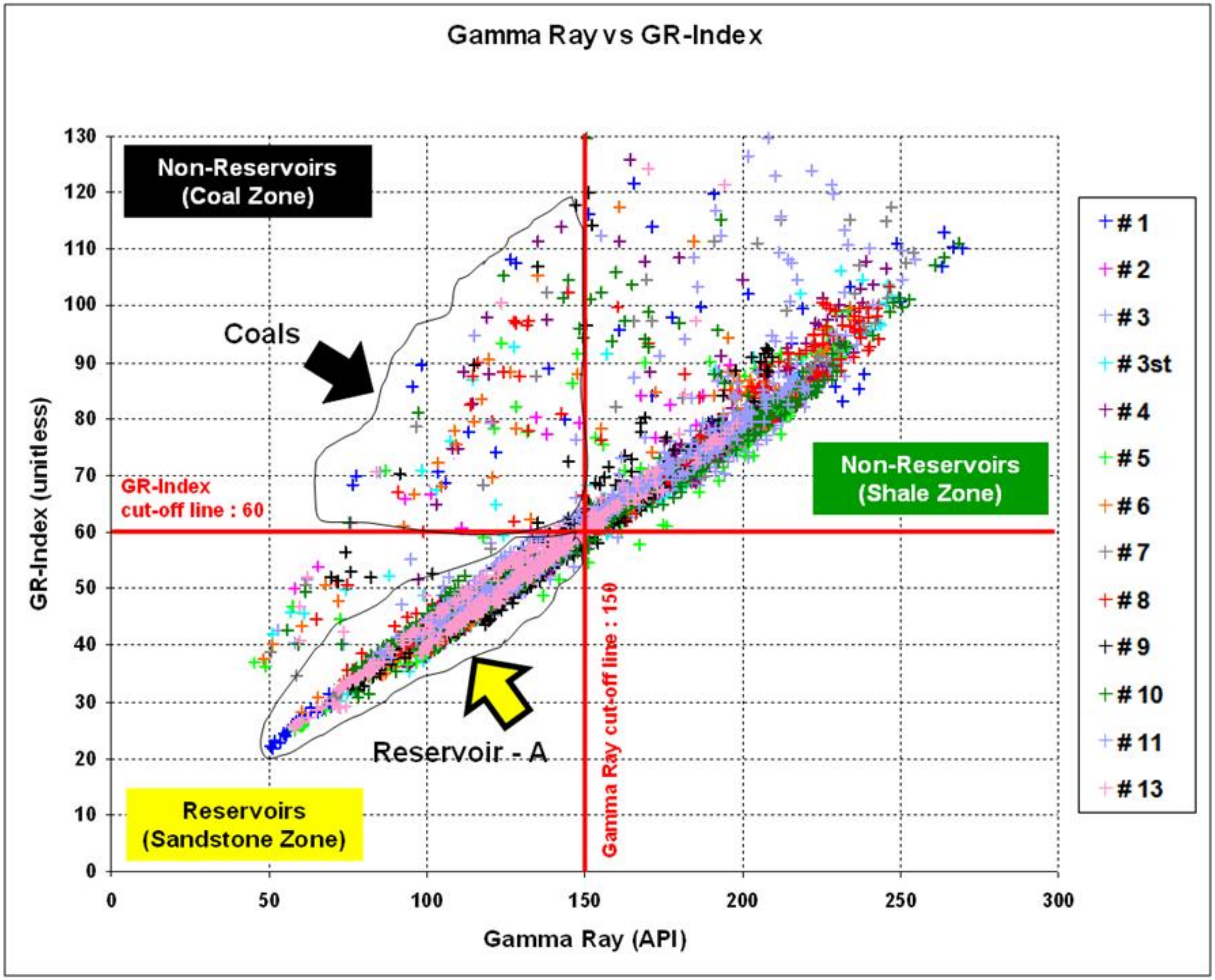

Figure 5. The consistency of sensitivity analysis method result which applied to 13 wells data of SWB field. Linearly, sandstone reservoir is in the zone boundary values below 60 for GRI while the value of coal is in the zone above the value of 60 relatively same with shale value.

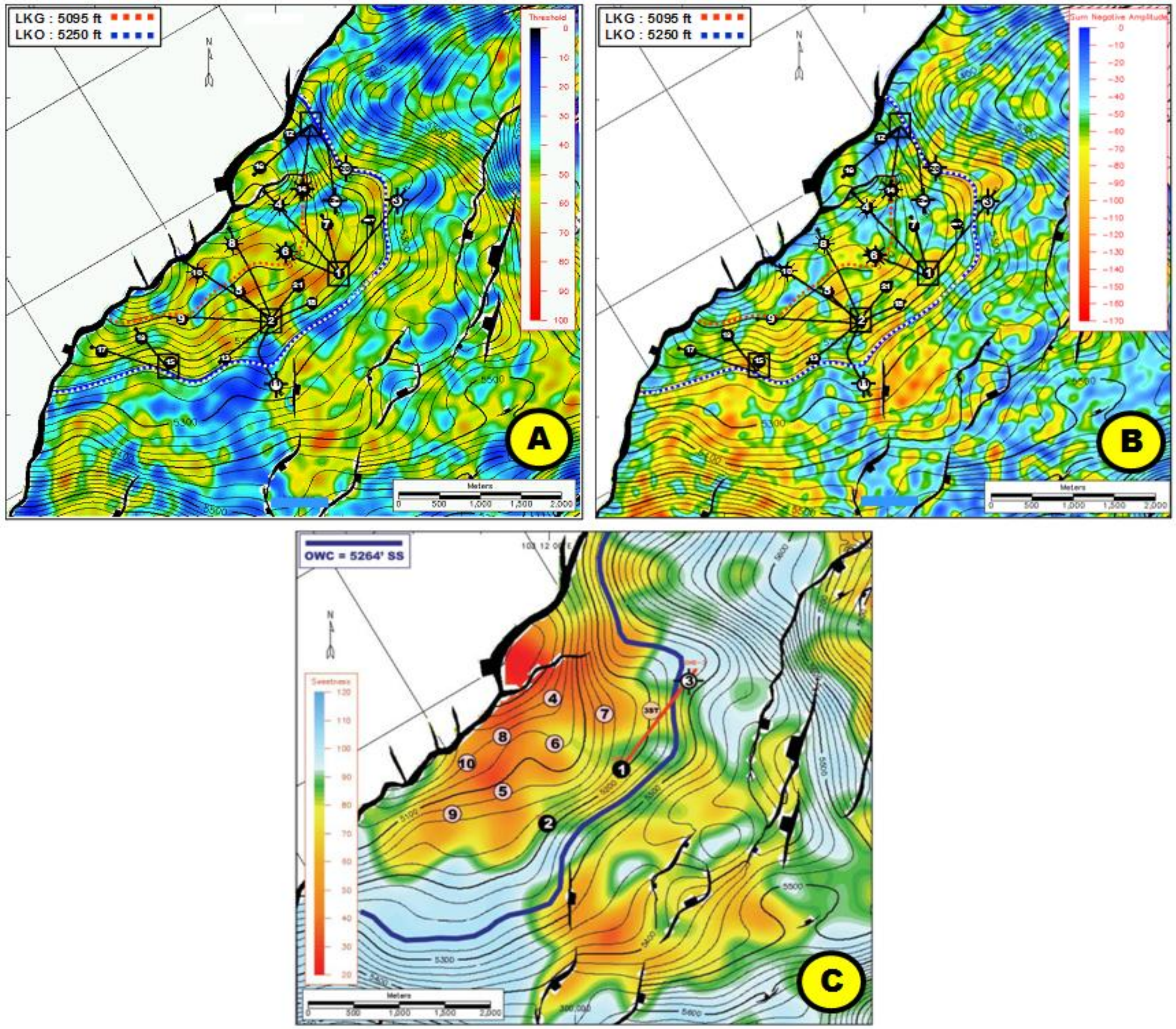

Figure 6. The lateral distribution of sand-A reservoir. (A) Seismic attribute of Threshold Value. High percentage values (40-100%) described the distribution of sand-A reservoir. (B) Seismic attribute of Sum Negative Amplitude. High negative values is a picture of the intensity of the sand-A. (C) Hybrid Seismic Attribute of Sweetness with coal influence from previous study (Alamsyah et al, 2008).

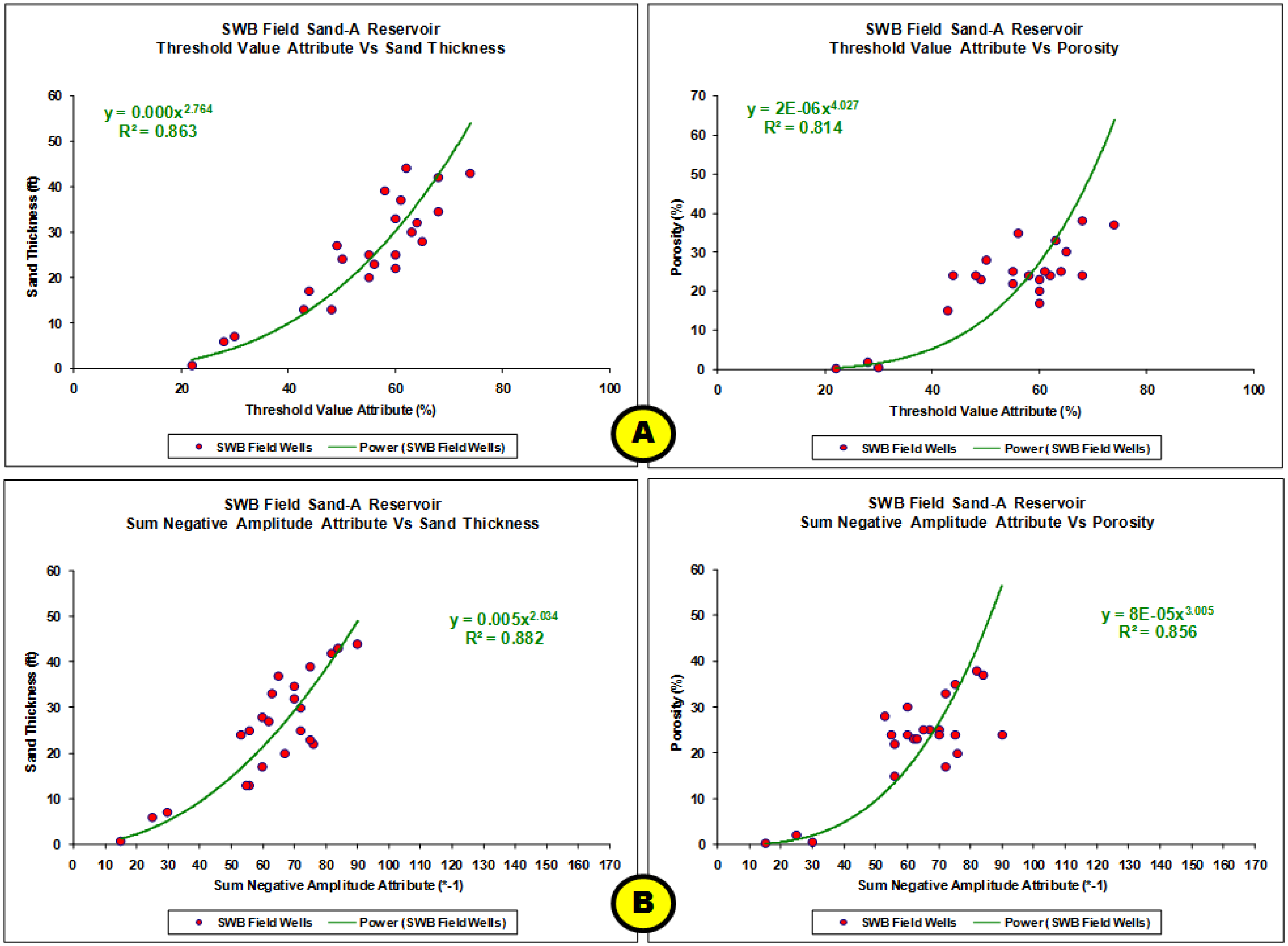

Figure 7. The Cross-plot analysis to validate surface seismic attribute calculation result which representing Sand-A reservoir distribution. (A) The result from cross-plot analysis of Threshold Value Attribute to the thickness and porosity of the sand-A reservoir. (B) The result from cross-plot analysis of Sum Negative Amplitude Attribute to the thickness and porosity of the sand-A reservoir.