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QUANTITATIVE INTERPRETATION: A NOVEL APPROACH USING SPECTRAL TREND ATTRIBUTE ANALYSIS AND ITERATIVE WIENER FILTER IN CHARACTERIZING CARBONATE RESERVOIR ON WEST JAVA BASIN

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ABSTRACT

The conventional geological application of wireline logs is more likely to be qualitative. The increasing manner of challenges in oil and gas exploration has shifted the conventional process to unravel complex problems. Quantitative interpretation is now more commonly added to the perspective of seismic and wireline data application, as a way to enhance the qualitative approach. The pre-drill study suggested that the reservoir interval enclosed in thick sandstone formations, however the post-drill result showed the thin carbonate interval was the only formation that showed gas. This research is aimed at tackling this challenge by improving thin-bed carbonate reservoir characterization. We approach the quantitative interpretation to be able to enhance the stratigraphic interpretation of well logs and advance the conventional multi-attribute seismic analysis to improve seismic resolution. This thin-bed carbonate reservoir distribution is approached by combining these two steps. The spectral trend attribute analysis, commonly known as integrated prediction error filter analysis (INPEFA), is performed to quantitatively correlate wells using gamma ray log. In a way to enhance the seismic resolution, the iterative Wiener filter (IWF) is introduced to enhance the multi-attribute seismic analysis. The use of INPEFA conclusively revitalize the stratigraphic correlation process, this method is favorable especially when dealing with chaotic (high frequency) gamma ray log that would exacerbate qualitative interpretation. The resolution of seismic data is improved with the use of IWF as additional attribute in multi-attribute seismic analysis as the result shows an increased correlation value by 38 percent and a decreased in error value by 14 percent. An intensive analysis of INPEFA result must be carried out especially when the reservoir is non-clastic, as it helps to predict the possibility of facies distribution and the use of IWF on the other hand has successfully improved the seismic resolution.

INTRODUCTION

Conventional geological application of wireline logs is more likely to be qualitative. An increasing manner of challenges in oil and gas exploration has shifted the conventional process to unravel complex problems (e.g. thin-bed reservoir or non-clastic reservoir). Many giant fields in Indonesia that have been successfully drilled are mainly carbonate reservoirs, such as Baturaja Formation in South Sumatra, Kais Formation in West Papua, Parigi Formation in Northwest Java, and Kujung Formation in Northeast Java (e.g. Jambak et al., 2015; Widyanto, 2018). The diversity of its physical properties makes carbonate rock has relatively distinctive features compared to clastic reservoirs (Rider, 1986). Interpreting the distribution of carbonate reservoirs is another challenge. Quantitative interpretation is now more commonly added to the perspective of seismic and wireline data application, as a way to enhance the qualitative approach.

The real dataset from Northwest Java Basin on this research mainly consists of thin carbonate reservoir. We utilize some quantitative processes to resolve problems during the exploration process. Previous exploration stages failed to corroborate the preliminary study as drilling process showed no discovery along the thick carbonate reservoir. The development process aimed to investigate the relatively thinner beneath the previously proposed interval.

This research is aimed at tackling this challenge by improving thin-bed carbonate reservoir characterization. We approach the quantitative

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interpretation to be able to enhance the stratigraphic interpretation of well logs when dealing with high frequency wireline logs and advance the conventional multi-attribute seismic analysis to improve vertical seismic resolution. The spectral trend attribute analysis, commonly known as integrated prediction error filter analysis (INPEFA) (e.g. Nio et al., 2005; Huang, 2014; Teja et al., 2017; Yuan et al., 2018), is performed to quantitatively correlate wells using gamma ray log.

Picked horizons, from enhanced-well-correlation process through implementing INPEFA, are used as boundaries on multi-attribute analysis. Multi-attribute seismic analysis is a most common method in a way to enhance vertical seismic resolution when there is only post-stack seismic data available (Hampson, 2001). In a way to further enhance the seismic resolution, the iterative Wiener filter (IWF) is introduced to enhance the multi-attribute seismic analysis. The result of this research could be used to delineate the next possible drilling point and to further improve the distribution of other complex reservoirs property. The property distribution can also be used as preliminary judgement of the possibility of facies distribution.

GEOLOGICAL SETTING

The research area is implemented on 'FN' field on northwest Java Basin. Geographically, this Tertiary sedimentary basin is located in the northern part of West Java. This basin is bordered by Seribu Islands in the western part, Ardjawinangun (Kromong) High and Karimunjawa Platform in the eastern part, Sunda Shelf in the northern part, and Bogor Trough in the southern part (Widianto, 2018). The formation of the basin is an impact of a geological structure which is north-south trending normal block faults.

According to the study of Patmosukismo and Arpandi (1975), the lithologic units of the basin in ascending order are low grade metamorphic and igneous Basement (BSM), Jatibarang Formation consisting of synrift deposits (JTB), Talang Akar Formation (TAF) consisting of deposits deepening upwards, Baturaja Formation (BRF) comprising built up limestone and platform, and becomes fine-grained sedi- ments upwards, Upper Cibulakan Formation (UCB) consisting of three members, *i.e.* Massive Unit, Main Unit with the intercalation of limestone (Mid Main Carbonate), and pre-Parigi Unit, Parigi Formation (PRG) comprising porous and built up fossiliferous organic and platform limestone, and Cisubuh Formation (CSB) overlying conformably the rock beneath and is dominated by claystone.

Upper Cibulakan Formation is the main zone of interest of this research. Recent study shows that the limestone distribution on this formation is not continuous (Jambak et al., 2015). The same study also reveals that Upper Cibulakan Formation consists of four types of lithofacies; Mudstone-Wackestone Facies with 10-13% porosity, Wackestone-Packestone Facies with 10-17% porosity, Packstone-Grainstone Facies with 0-10% porosity, and Grainstone Facies with 0-10% porosity.

DATA

Data used in this analysis are wireline logs from three exploration wells, 3D post-stack seismic data, core analysis, and cutting analysis. The wireline logs consist of gamma ray log, density log, neutron log, shear sonic log, compressional sonic log, photoelectric log and resistivity log.

METHODS

Basically, general workflow of conventional property modelling consists of pre-conditioning wireline logs data, seismic-well tie, seismic attributes generation, picking well tops and horizons, sensitivity analysis, multi-attribute seismic analysis, and property distribution model. The additional steps proposed by this research (IWF and INPEFA) are respectively added to the multi-attribute analysis and picking well tops and horizons processes. The provided Figure 1 shows the overall workflow proposed during this research.

The INPEFA calculations on this study is primary performed using Burg's algorithm. Using the equation 1 of Burg's coefficient calculation (ρ_i), the coefficient directly measures the estimated error (e_i) between predicted data and the actual N input data with as an order of k. Figure 3 shows the result of Burg's coefficient with synthetic gamma ray log, Figure 2, as an input.

$$\rho_i = \frac{-2\sum_{k=i}^{N-1} e_{i-1}{}^{f}(k)e_{i-1}{}^{b}(k-1)}{\sum_{k=i}^{N-1}\{[e_{i-1}{}^{f}(k)^2]+[e_{i-1}{}^{b}(k)^2]\}} \quad (1)$$

The prediction error filter analysis (PEFA) is calculated through convolving this filter with the input, as shown in Figure 4. Although each point on PEFA logs corresponds to the prediction error value, further analysis needs to be done to make use of this log for well correlation process. The integration of

PEFA (INPEFA), Figure 5, is calculated to interpret the positive and negative trends that represent higher and lower gamma ray value respectively.

The commonly used multi-attribute seismic analysis is limited in the data length when predicting wireline logs by combining multiple seismic attributes. We approach this limitation by adding another external attributes that can predict any arbitrary data length by using iterative Wiener filter (IWF) process. The conventional process of calculating coefficient Wiener filter consists of auto-correlation calculation and Toeplitz matrix generation, cross-correlation calculation, and inverse matrix process. The iteration based on finding the best correlation value between input (acoustic impedance) and desired output (gamma ray log) is added during this research. The result is then convolved with seismic inversion result and imported as an external attributes in multi-attribute seismic analysis process. Figure 6 demonstrates transformation of seismic trace into becoming pseudo-gamma ray log through filtering.

The INPEFA calculation is used to further improve the stratigraphic well correlation process. The positive and negative trends of INPEFA logs are then analysed to deduce the vertical succession of gamma ray logs (coarsening upward or fining upward). Predicted log (GR or PHIE) from IWF calculation is used as an additional external attribute on the multi-attribute seismic analysis to improve vertical seismic resolution.

Both of these methods need a strong justification from the actual rock conditions as a way to perform QC process towards the results. The trends resulted from INPEFA is compared on each well within the same predicted stratigraphic marker. The result should clearly show similar trends (positive and or negatif) across different wells and this also should match with specific lithology when compared to the actual core data. In addition to this, the IWF result also needs further QC process involving the available core dataset on each well. Analyzing the overall predicted log (PHIE or VSH) on each well with the actual condition will help perform the QC process of this method.

RESULTS AND DISCUSSION

As shown in Figure 7 the INPEFA process conclusively revitalize the stratigraphic correlation process, this method is favorable especially when dealing with chaotic (high frequency) gamma ray log that would exacerbate qualitative interpretation. The use of INPEFA log improves the well correlation analysis and it is able to identify all of the formations distributed on the research field. All of the seven formations is identified on both well 1 and well 2. Despite the lack of data length in well 3, the INPEFA log is able to identify the Upper Cibulakan Formation which is the main focus of this research. The Upper Cibulakan formation is dominated by carbonate rocks, thus there's a further analysis in defining its formation top from INPEFA log. However, the formations analysis using INPEFA needs to be carefully carried out when distributing carbonate reservoirs. This research use both core analysis and cutting analysis to further interpret the distribution of carbonate rock form gamma ray logs. Each of the calculated INPEFA trends is closely compared with core data as a validation process, i.e. figure 7 clearly implies that the predicted MMC marker lies exactly between positive and negative INPEFA trends on all wells. When compared to the available core datasets, good INPEFA calculation will also show not only similar pattern of INPEFA trends, but also show exact same lithology.

The result of the IWF process is shown in Figure 8 The IWF process enhanced the resolution of seismic data in distributing the volume of shale (PHIE) property on the Upper Cibulakan horizon. It's clearly shown by comparing the pre-IWF process (Figure 8 left) with the post-IWF process (Figure 8 right). However, the generated porosity maps also needs to be compared with the provided core data. The pre-IWF PHIE map shows that on a relatively porous interval (dominated by sand and tight-limestone in schematic core) in well 3, the predicted porosity value gives lower value than it should be. The post-IWF map on well 3 shows relatively higher value and can be inferred it matches the actual condition. Although doesn't show any significant differences when analyzing well 1 and well 2, the post-IWF map, for both wells, implies that the tight-limestone affects the overall value on well 1. The post-IWF map on well 1 gives lower value as the IWF process could identify the presence of relatively tight-limestone lithology.

Similar to this, core dataset or any data related to actual lithological condition of well will play an important role on the QC process of the IWF result. Figure 8 shows after implementing IWF, well 3 and well 1 shows a better correlation with the core data (before IWF, well 3 shows relatively low effective porosity, while well 1 shows relatively high). This is on the contrary with the available core data (well 3 consists of relatively porous rock while well 1 is less porous). The integration of the two proposed methods is able to distribute property complex reservoir. Figure 9 implies that the correlation value in the multi-attribute analysis (between predicted PHIE and actual PHIE) of the post-IWF result (0.57) also significantly increases compared to the pre-IWF correlation value (0.79) by 38%. The post-IWF result also shows a decreased in error value (0.064) compared to the pre-IWF result (0.085) by 25%.

CONCLUSION

The use of INPEFA conclusively revitalize the stratigraphic correlation process, this method is favorable especially when dealing with chaotic (high frequency) gamma ray log that would exacerbate qualitative interpretation. Usability of INPEFA logs also has some pitfalls especially when dealing with non-clastic reservoirs. The use of other complementary datasets such as core analysis, cutting analysis, and elastic properties is needed to interpret the carbonate reservoir interval comprehensively. INPEFA logs have successfully improved the well correlation process on this study through analyzing its patterns.

The resolution of seismic data is improved with the use of IWF as additional attribute in multi-attribute seismic analysis as the result shows an increased correlation value by 38 percent and a decreased in error value by 25 percent.

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REFERENCES

Hampson, D. P., Schuelke, J. S., and Quireor, J. A. [2001] Use of multi attribute transforms to predict log properties from seismic data, Geophysics, 66, 1.

Huang, J. [2014] Study of autoregressive (ar) spectrum estimation algorithm for vibration signals of industrial stream turbines. International Journal of Control and Automation, 7, 349-362.

Jambak, M., Syafri, I., Isnaniawardhani, V., Benyamin, B., and Rodriguez, H. [2015] Facies and diagenetic level of the Upper Cibulakan and Parigi Formation, in Randegan and Palimanan Area. Indonesian Journal on Geoscience, 2, 157-166.

Nio S. D., Brouwer J. H., de Jong M. G. G., and Böhm, A. R. [2005] Spectral trend attribute analysis: applications in the stratigraphic analysis of wireline logs. First Break, 23, 71-75.

Rider, M. [1986] The geological interpretation of well logs. Blackie Halsted Press.

Teja, R. V., Rakesh, U., and Rao S. K. [2017] Spectral analysis of seismic signals using Burg algorithm. International Journal of Pure and Applied Mathematics, 114, 163-171.

Widianto, Eko. [2018] Petroleum system of Northwest Java Basin based on gravity data analysis. IOP Conference Series: Earth and Environmental Science. 106.

Yuan R., Zhu R., Qu J., Wu J., You X., Sun Y., and Zhou Y. [2018] Utilizing integrated prediction error filter analysis [INPEFA] to divide base-level cycle of fan-deltas: a case study of the triassic Baikouquan Formation in Mabei Slope Area, Mahu Depression, Junggar Basin, China. Open Geosci, 10, 79-86.

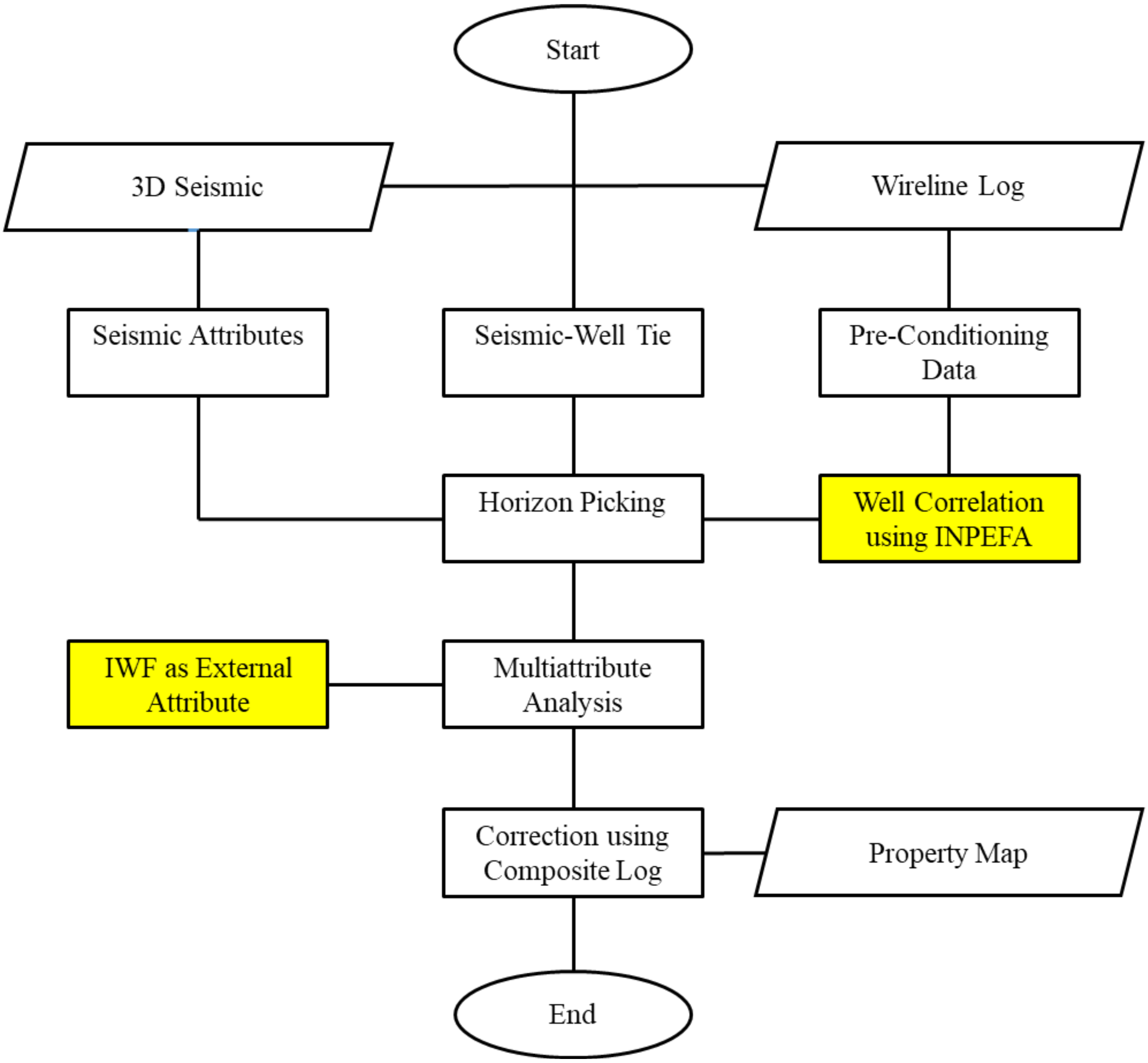

Figure 1 – Schematic workflow of the research. Highlighted boxes show the general topic of proposed methodologies (INPEFA and IWF).

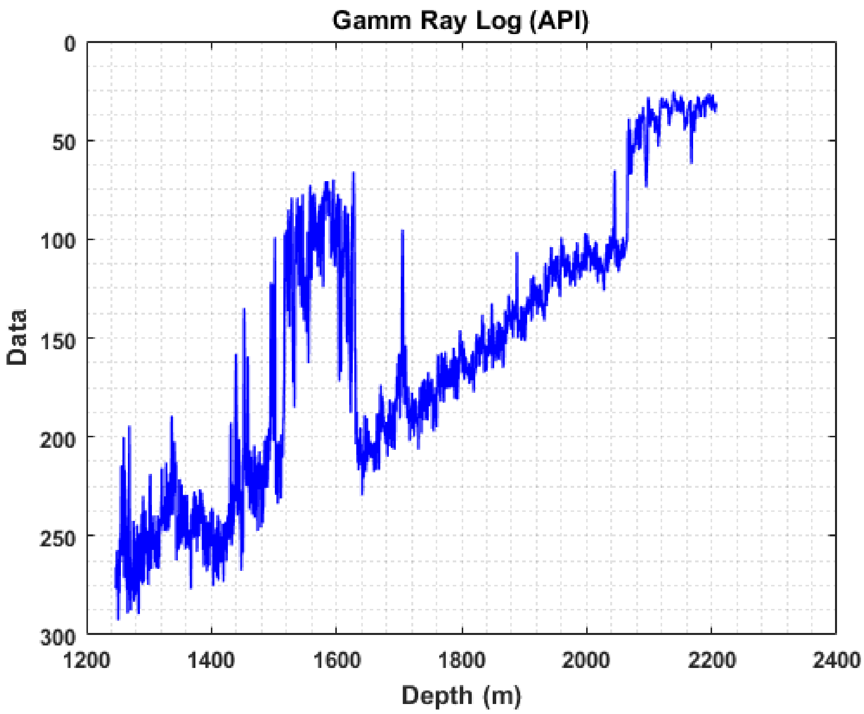

Figure 2 – Illustration of synthetic well data used in INPEFA calculation as the input data.

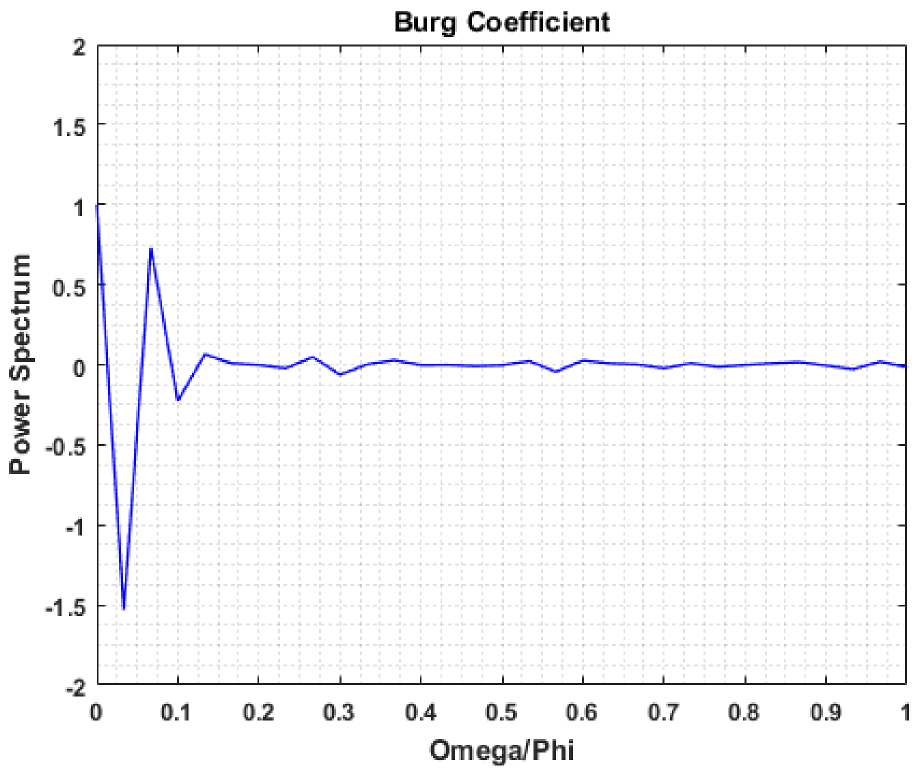

Figure 3 – Illustration of calculated Burg's coefficient used in INPEFA calculation.

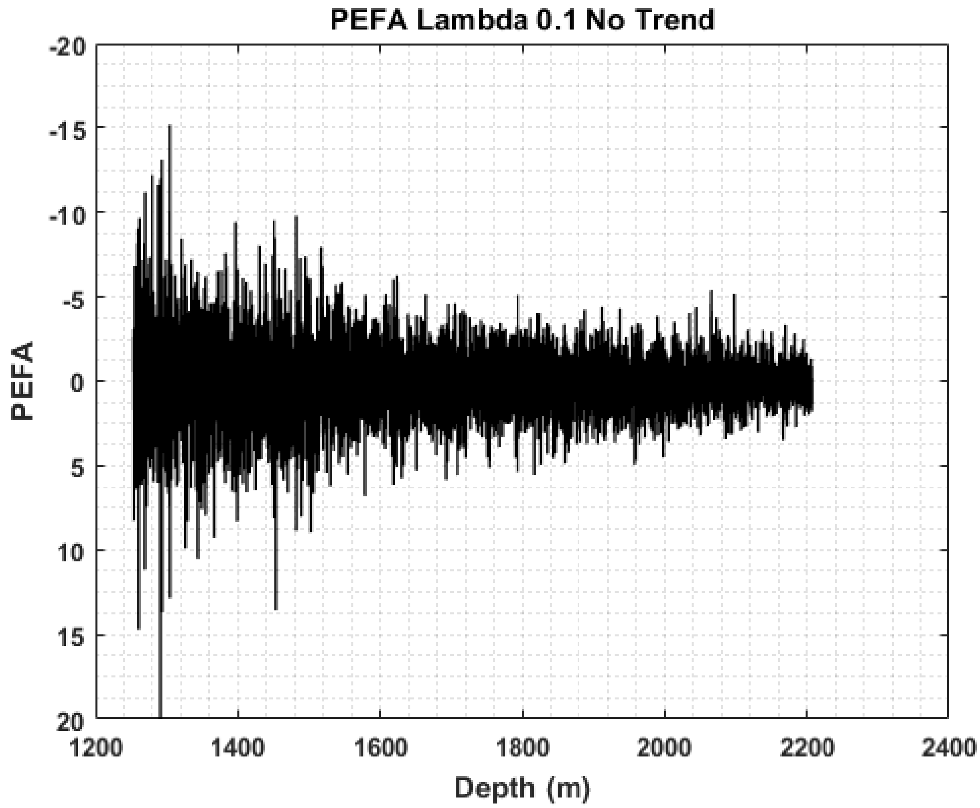

Figure 4 – Result from PEFA calculation. Each point can also be seen as a filter of predicting error between predicted data using Burg's algorithm and actual input data.

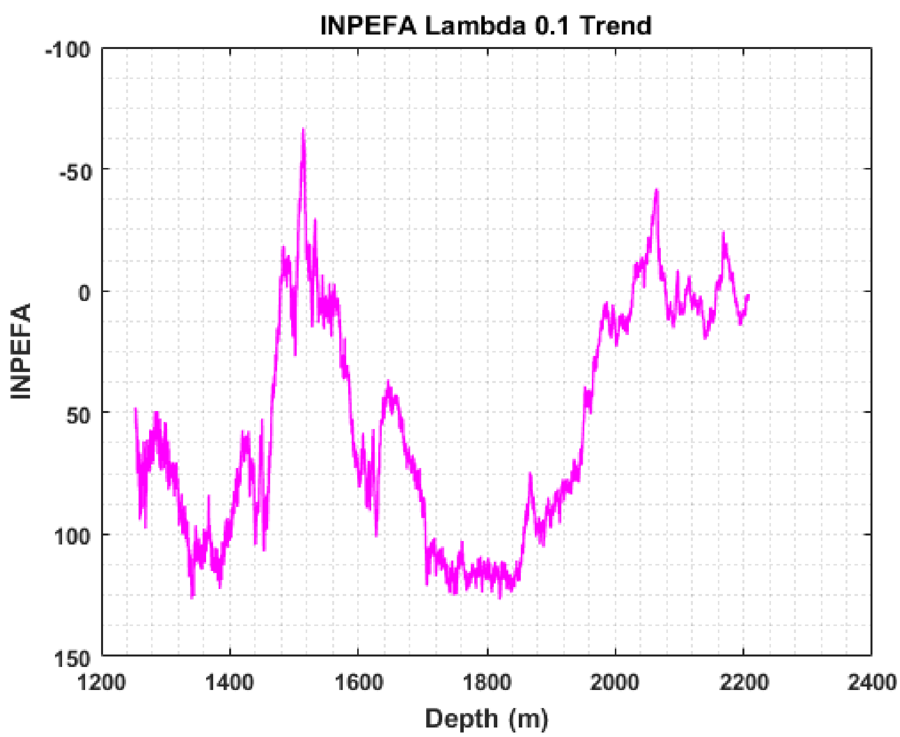

Figure 5 - Result from INPEFA calculation. Each gradient (positive and negative) represents high value of input data and low value of input data respectively.

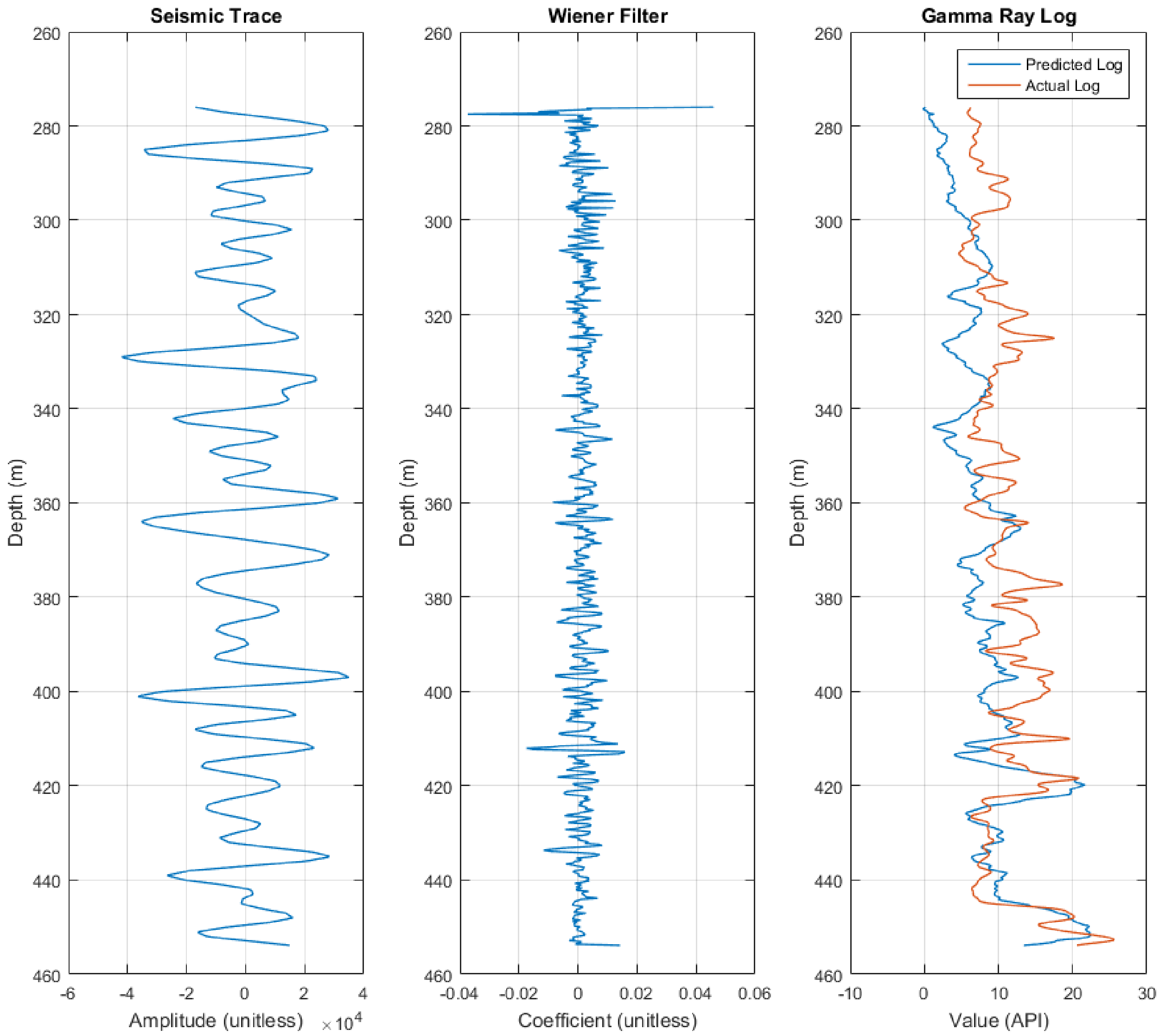

Figure 6 – Wiener filter coefficient demonstration. Seismic trace on the left is filtered using Wiener coefficient to produce predicted log on the right (blue line).

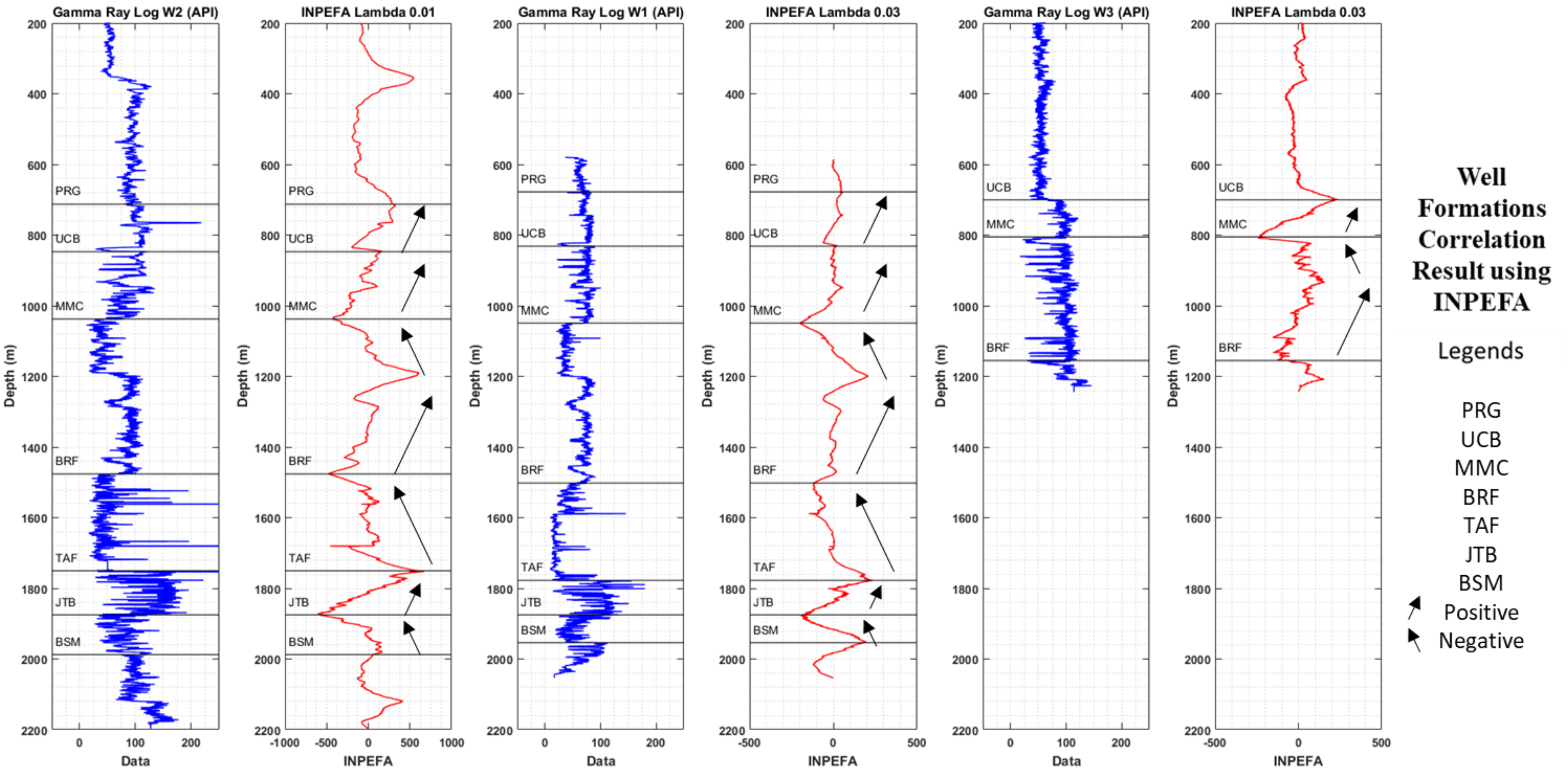

Figure 7 – Well correlations and top formation tops result using gamma ray logs (column 1, 3, and 5 from left to right) and INPEFA logs (column 2, 4, and 6 from left to right). The horizontal lines represent each stratigraphic unit presented on legends.

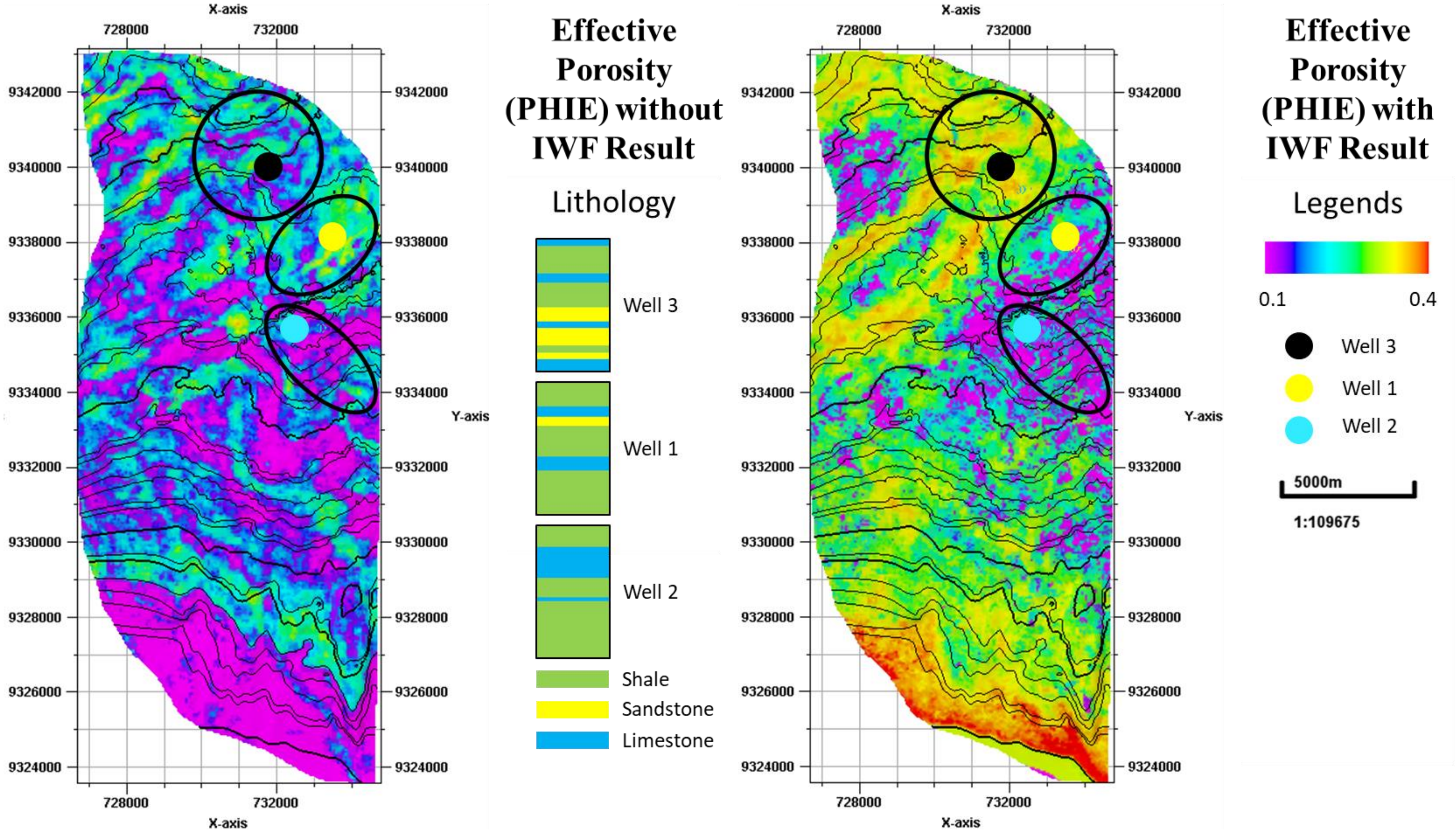

Figure 8 – The comparison between effective porosity distribution on horizon. Before using IWF method in multi-attribute (left) and after using IWF as an external attribute (right). The highlighted well locations are shown with black circles. Schematic core data also shown for each well.

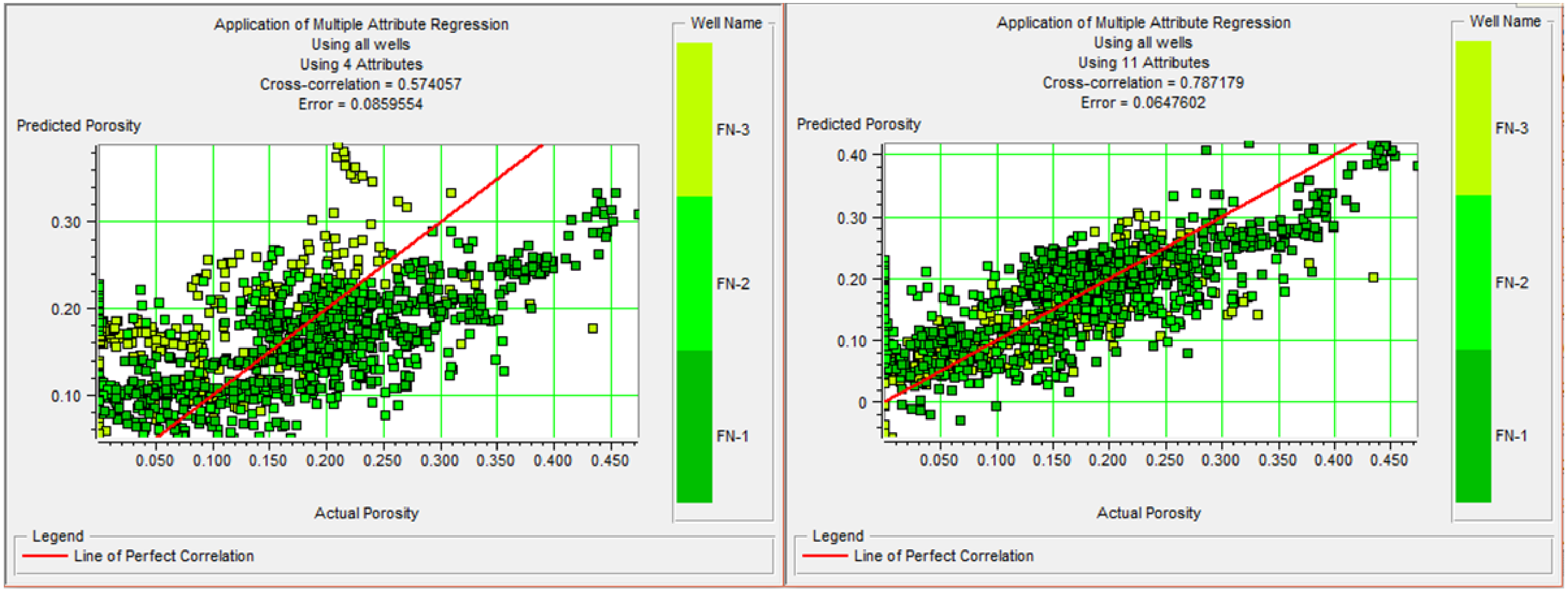

Figure 9 – Comparison between predicted porosity log and actual porosity log during multi-attribute process. The left cross-plot shows the result before applying IWF and the right cross-plot for after applying IWF.