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Geophysical approach to improve well correlation and stratigraphy package in the frontier area: example case of Upper Jurassic Fm. Semai Basin, Eastern Indonesia.

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Abstract. Well correlation needs to be done carefully in the exploration phase. In this study, due to a limited biostratigraphy data, the alternatives approaches to improve the well correlation were conducted. The approach is known as an Integrated Prediction Error Filter Analysis (INPEFA). The method generates a predicted Gamma Ray (GR) log based on the auto-regressive model. INPEFA generate and extract major sequence information curve and give the clue to the interpreter to get the general frame of correlation. INPEFA curve idea is related with sedimentation cycle where the package of sediment consists of para-sequence set and the para-sequence is formed by lamination, and so on. This phenomenon is known as an order of sequences. For the case study, the method is applied in to the frontier block located in Semai basin in the eastern of Indonesia. Six wells are included in to the analysis to be correlated by combining limited biostratigraphy data and INPEFA curve. The results conclude that the correlations from five wells have identical of eustasy cycle pattern, and validated by biostratigraphy marker. The correlation also show that the thickness of reservoir sandstone in the Upper Jurassic Formation increase to the north direction.

1. Introduction

The oil and gas exploration in the eastern of Indonesia are still challenging. There are several oil and gas contractors have explored in the region during the decades since the 80's century until today. However, within 30 years of exploration activity, only a few of exploration activity success to discovered oil and gas.

To success discover oil and gas, marker stratigraphy is very important to define since the beginning of subsurface works to eliminate miss interpretation, and give an accurate exploration target to find the potency of hydrocarbon accumulation. There is another challenge for subsurface works to conduct the correlation with limited well data and intensive tectonic activity which impact to deformation of original stratigraphy. This structural setting is typically happening in the tectonic margin along the trench border, especially in the eastern part of Indonesia. **Figure 1** is showing the situation map of oil and gas in Papua, eastern of Indonesia, where the study area has located.

To help improved the well correlation in the study case, author try to approach Integrated Prediction Error Analysis (INPEFA) curve as an alternative method to compute wireline log (GR) data to extract major

sequence information and give the general frame of sequence stratigraphy which developed. This approach will improve the quality and confidence of well correlation process.
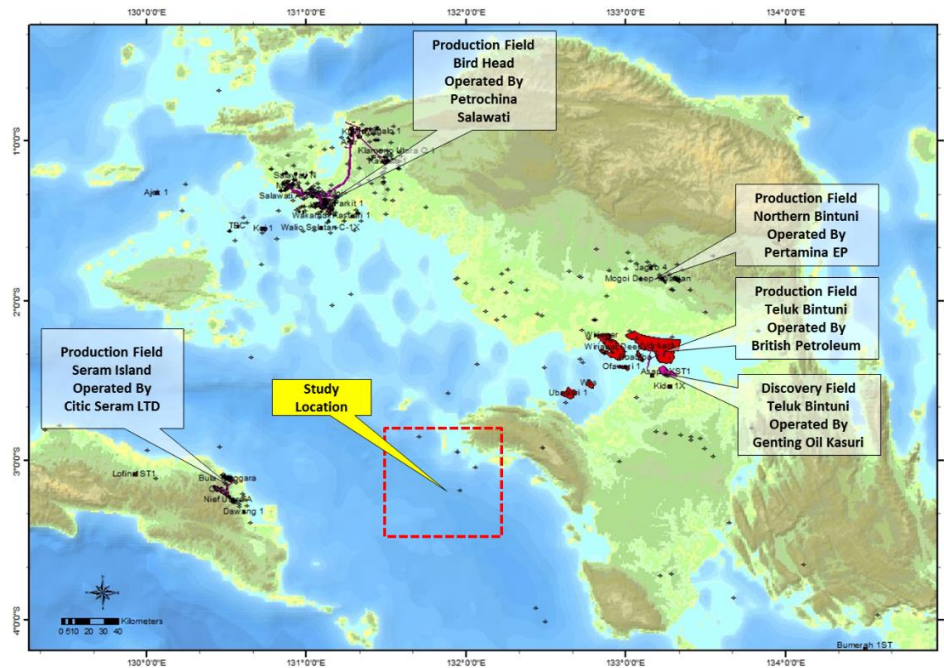

Figure 1. Study area location map surrounding oil and gas production field in Papua, Eastern Indonesia.

2. Methodology

Integrated Prediction Error Analysis (INPEFA) is a geophysical method that recommended to be used to performing well correlations in the regional scale data with far distance of each wells. It usually happen in the exploration phase. This method in principle has transformed the Gamma Ray (GR) curve into a spectral trend attribute curve or INPEFA curve [1]. This curve showed the succession of climatic phase at the sediment time was deposited. This succession curve is principally controlled by the relative transgression or the relative regression process that occurs in entire sedimentary basin during the sedimentation process as regionally. The INPEFA curve represents the order of sequences that develops in a stratigraphic packet. We can identify this sequence packet whether in the low order form (sequence or low resolution) through to the high order form (lamina or high resolution), in accordance to the research purposes. Moreover, the order of sequence detail information could be refer to the Holbrook, J. M. (2001) [4]. Holbrook diagram helps to explain the order of sequences from the low first order (mega sequence) through to the high - fifth order (lamination) of stratigraphy package.

Integrated Prediction Error Filter Analysis (INPEFA) is a geophysical method that utilizes the principle of auto regressive calculation from input data (GR curve) with transform the curve into the maximum entropy spectral analysis (MESA) and calculated prediction error filter analysis (PEFA) based on the difference of the prediction value compared with the original input from the log data. This approach was publicated by Enrest International, 2011 [3]. The auto regressive calculation as a mathematics computation is applied to the series of the data (window) to get the new prediction (of the series data) which inputted. The prediction data will be compared with the original input. The difference between a prediction data series comparing with original input data series from GR log, classified as the error calculation. In further steps, the summation of an error calculation will generate the new curve that we define as INPEFA.

To applied auto regressive calculation, we need to determine the value of coefficient error filter (Cn) which extracted from the input data itself. The process to obtain coefficient error filter (Cn) value are explained through the illustration below, following equation (1), where the order used in this example is (M) = 2. Hence, the value of C1 and C2 which needed are explained in the equation (2). For the example, the length of the window need to be predicted is Y1 to Y7. Hence, the process to obtaining the Cn value as the Burg algorithm is described in the following steps below.

$$Y^*_n = \Sigma^2_{J=1} C_n Y_{n-j} \tag{1}$$

Bottom   Y1 Y2 Y3 Y4 Y5 Y6 Y7   Top

2 orde ; C_1 , C_2

Foreward >
  a) $Y^*_3 = C_1 y_2 + C_2 y_1$
  b) $Y^*_4 = C_1 y_3 + C_2 y_2$
  c) $Y^*_5 = C_1 y_4 + C_2 y_3$
  d) $Y^*_6 = C_1 y_5 + C_2 y_4$
  e) $Y^*_7 = C_1 y_6 + C_2 y_5$

Backward >
  f) $Y^*_1 = C_1 y_2 + C_2 y_3$
  g) $Y^*_2 = C_1 y_3 + C_2 y_4$
  h) $Y^*_3 = C_1 y_4 + C_2 y_5$
  i) $Y^*_4 = C_1 y_5 + C_2 y_6$
  j) $Y^*_5 = C_1 y_6 + C_2 y_7$

$$
\begin{array}{ccc}
\begin{vmatrix}
y_2 & y_1 \\
y_3 & y_2 \\
y_4 & y_3 \\
y_5 & y_4 \\
y_6 & y_5 \\
y_2 & y_3 \\
y_3 & y_4 \\
y_4 & y_5 \\
y_5 & y_6 \\
y_6 & y_7
\end{vmatrix}
&
\begin{vmatrix} C_1 \\ C_2 \end{vmatrix} =
&
\begin{vmatrix}
Y^*_3 \\
Y^*_4 \\
Y^*_5 \\
Y^*_6 \\
Y^*_7 \\
Y^*_1 \\
Y^*_2 \\
Y^*_3 \\
Y^*_4 \\
Y^*_5
\end{vmatrix}
\\
A & X \quad = & b
\end{array}
$$

To find out X (C_1, C_2), following aperation were applied:

$$
\begin{aligned}
A^T A X &= A^T b \\
X &= [A^T A]^{-1} A^T b
\end{aligned} \tag{2}
$$

From the algorithm above we can explain that: *Yn* is represents the original value obtained from reading the GR log. *Yn**, represent the predicted value by using the input value *Yn-j*, is an error prediction in a new log prediction value (PEFA). *Cn* is a coefficient error filter determine from Burg algorithm which used to optimize the prediction results. And *M* is the length of selected order to predict the value.

After the error data calculation is resulted in the interest zone, the process is continued to sum of error values from bottom to the top (bottom-up) with aim to in line with sedimentation process. The results of the INPEFA curve will show the sediment deposition trends which controlled by regional eustasy. Eustasy is the global sea level fluctuation. With INPEFA curve, the subtle changes are clearer and easier to analyze than using the original log data (GR log). **Figure 2**.

3. Data Availability

There are 6 (six) exploration wells data which available has included in to these study. The first three wells were located in the study area i.e. LKS-1, S-1, and BP-1. The other additional wells (TJB-1X, EO-1, and ASP-1) were located in the northern part of the study area. The reasons of additional wells were included into the study is to observe the consistency of eustasy factors which working in the regional-basin scales. All of wells data are sourced and reproduced from Y. Setiawan, 2011 [5].

The distance of wells (except sidetrack) is in between range from 27 km through 89 km for the fares one. The stratigraphy between the wells is distorted with fault thrust series. With this situation, It was difficult to conduct the conventional correlation with lack of biostratigraphy report as a marker reference.

4. Case Study

Study area is located in Semai basin Papua, eastern of Indonesia, with limited well data and intensive tectonic activity which impact to deformation of original stratigraphy.

Based on explanation above, the first stage that we did to run the correlation is to define the key well from the available data, The LKS-1 well is selected as the key reference well due to the completeness of the set data, included the marker stratigraphy analysis.

The process continued with inputted the GR curve data from LKS-1 well in to the algorithmic to define the error prediction values through the INPEFA curve of LKS-1. The result of INPEFA curve of LKS-1 were continued to analyze and mark in the interest interval (formation) which obtaining from biostratigraphy analysis.

The result example INPEFA curve for LKS-1 in **Figure 2** below are presented in long, medium, short, and shorter of INPEFA curve. This variation of curve has influenced by the length of order (Cn) which determined by author. The long INPEFA curve usually used to correlate a regional sequences (1st order of sequences), while the more accurate curves can be used for more detailed correlation in the next step needed (2-5 order of sequence).
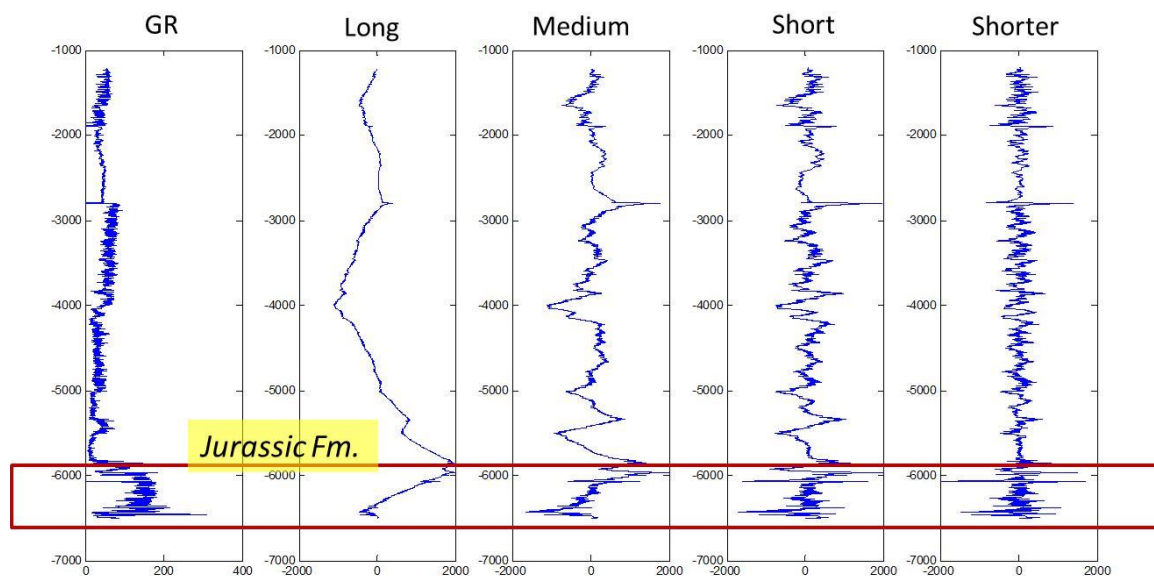

Figure 2. Results of INPEFA curve transformation from LKS-1 well.

The data from other wells (S-1, BP-1, TJB-1X, EO-1, and ASP-1X) also transformed into the INPEFA curve using same method. Then, the INPEFA curves of each wells is marked using marker fossil from biostratigraphy analysis while available.

After the INPEFA curve has obtained from each well, the work was continued with correlation stages. The first step in the correlation stages, we correlate the INPEFA curve from the three of wells which located in the study area, including the key wells, LKS-1. This correlation should be referred to the biostratigraphy marker which available as a main control to avoid an ambiguity during the process. Based on the first step correlation, there are three stratigraphic packets with fairly consistent INPEFA curves that can be determined. The top of the three stratigraphic packages were marked with the specific names of Marker-1, Marker-2, and Marker-3 from the bottom up as respectively. **Figure 3.**

The second steps of the correlation stages were made for the three of additional wells which located in the northern part of the study area as explained before. Based on the first steps experiences, the biostratigraphy markers need to be included before conducting the INPEFA curves correlation, even though the data has limited. Again, this biostratigraphy data will help to reduce an ambiguity during the correlation process. From this second steps, the two INPEFA curve from additional wells, TJB-1X and EO-1X, can be correlated with convincingly. Meanwhile the INPEFA curve of ASP-1 well cannot correlate with other two additional wells, due to crash with biostratigraphy marker. **Figure 4**.

In geology perspective, this situation can be explained as the facies changing to the ASP-1X well location as the impact of the transported mechanism. ASP-1X well is located far from the study location (± 150 km). The Jurassic sandstones has deposited in retro-gradation pattern (back stepping) to the shoreline with NW-SE depositional direction. Hence, the shale-break facies of Mid Jurassic age were found in the entire wells around the study area, but it changes to the sand facies at the ASP-1X well location.
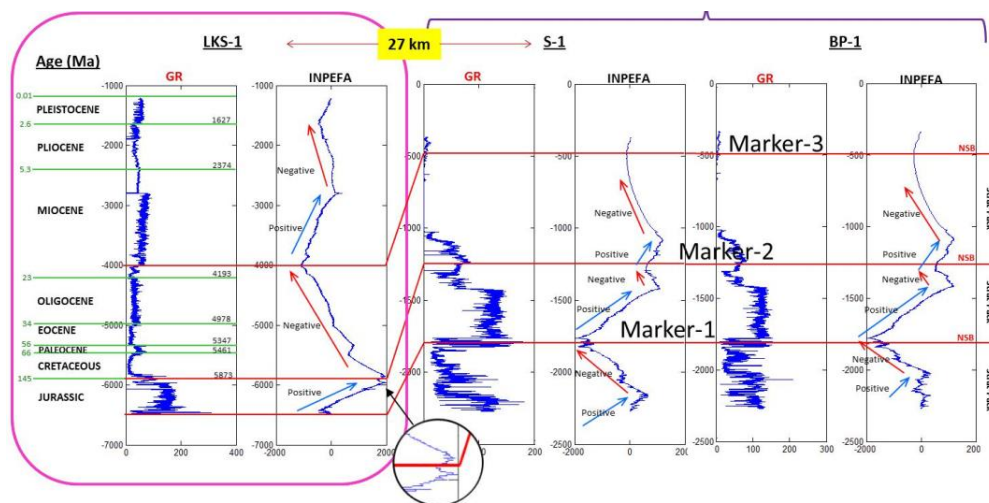

Figure 3. Correlation of 3 key wells of INPEFA curves with controlled biostratigraphy markers. Determined three obvious marker along the INPEFA curves. Marker-1, Marker-2, Marker-3.

For the step three, the work is continued with merging correlations of INPEFA curve from the first step and second step above. During the process, we found that there is have a variation thickness of *melanchovic cycles* which occur and control the sedimentation around the study area which showing in **Figure 5**. From the step three correlations, we found that the Jurassic Formations were controlled by two stratigraphic packages that begin with a negative trend of INPEFA curve until the Early Jurassic age. This process is identical with the regression event in the eustasy terminology. The event continued with a positive trend to the Mid. Jurassic age, which identical with the transgression event in the eustasy terminology. From the Mid. Jurassic age the curve continued with negative trend (regression) and closing with a positive trend which starting in the end of Late Jurassic age, near the Top of the Jurassic Formation. From the correlations we also conclude that the Jurassic Formation is contains the sand reservoir which the thickness were increase to the north (towards TJB-1X) and decrease to the south direction (towards LKS-1).
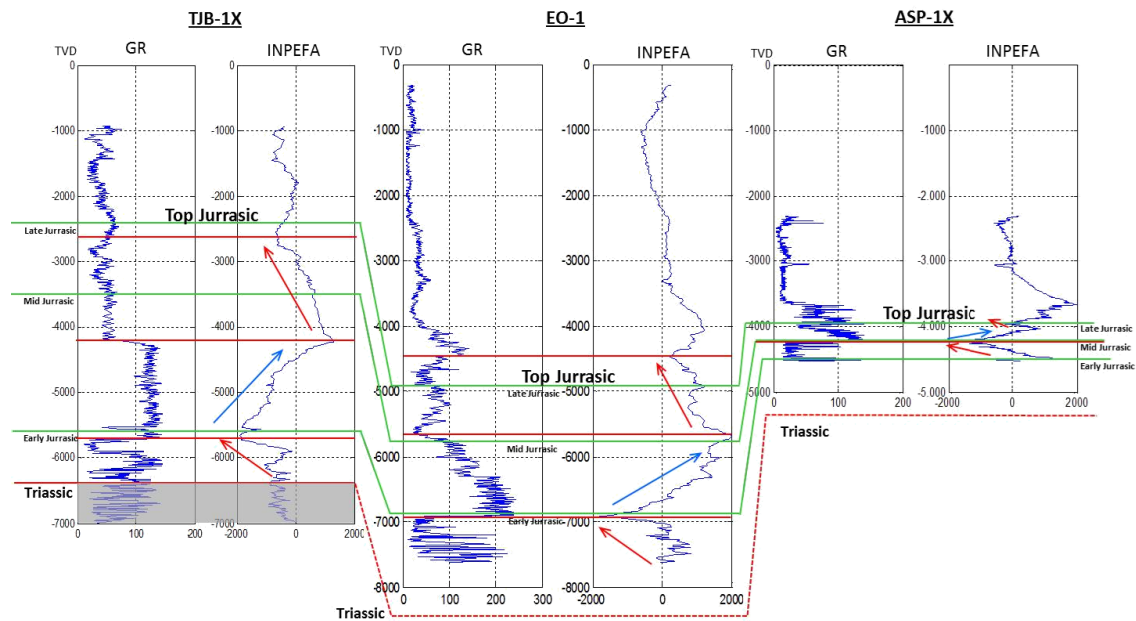
Figure 4. Correlation of additional wells of INPEFA curves with controlled biostratigraphy markers. TJB-1X, EO-1, and ASP-1X.
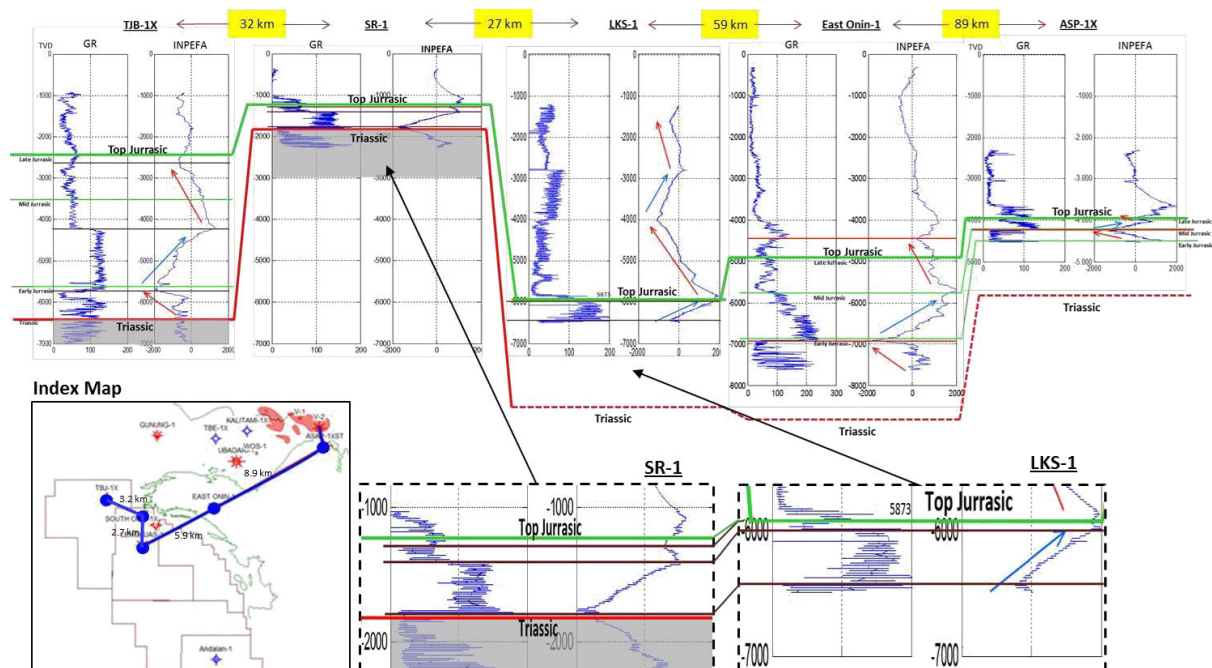

Figure 5. Correlation of the final INPEFA curve of TJB-1X, S-1, LKS-, EO-1, and ASP-1X well. The results identified that there is have variation of thickness of *melanchovic cycles* which occur and control the sedimentation around the study area.

5. Conclusion

From the case study, several conclusion notes as follows:

1. The results of the INPEFA curve shows the sediment deposition trends which controlled by regional eustasy.
2. In the study area, INPEFA curve can help to convincing the well correlation works with limited and far distance of well data.
3. Biostratigraphy information are still needed to be included to conduct the correlation, to avoid the ambiguity cycle from INPEFA curve, since the eustasy were repeated identically.
4. The INPEFA curve from each wells (except ASP-1) are shown an identical pattern, which controlled by the stratigraphy marker.
5. Based on the correlation, in the study area, the Jurassic Formation containing sand reservoir which the thickness has increase to the north (towards TJB-1X) and decrease to the south direction (towards LKS-1).

Acknowledgments

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