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MAPPING DISTRIBUTION OF SANDSTONE AND SEISMIC MULTI-ATTRIBUTE ANALYSIS USING LINEAR REGRESSION METHOD IN THE "RMS" FIELD, SOUTH SUMATERA BASIN

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ABSTRACT

Multi-attributes seismic analysis is a statistical method that uses more than one attribute to predict some physical properties of the earth. In this analysis, we sought a relationship between the logs with seismic data on the location of the well and used that relationship to predict or estimate the volume of property log in all well sites at the seismic volume. This research was conducted to predict pseudogamma ray and pseudo-porosity (PHIE). The analysis in this multi-attribute process used linear regression method with stepwise regression technique. This method can help identify the reservoir which could be seen from the log data validation, cross plot value, and also results of gamma ray map slicing average, and the porosity average in the interest zone in "RMS" Field. Slicing the target area is taken based on the analysis of window slice by taking the range of value between the distribution of sandstone and shale (marker L1 and P2). Good results were obtained from analysis of multi-attributes to map the distribution of lithology and sandstones porosity. The range value of gamma ray is 0-90 API and range porosity (PHIE) values is 15-30% which can be interpreted as a porous sand. Areas of development potential are located on the North-West "RMS" field to a depth of 1560-1660 ms in time domain.

INTRODUCTION

Economic growth and increasing human population can result in increased energy demand. The higher level of energy consumption of society, especially fossil energy such as oil and gas, cause a decrease in energy availability over time. Therefore, to fulfill all human needs for oil and gas, it is necessary to carry out sustainable and efficient exploration and exploitation activities. Seismic interpretation is one of the important stages in hydrocarbon exploration where study, evaluation and discussion of processing seismic data is carried out in geological conditions that are close to the actual subsurface geological conditions to make it easier to understand. At this stage of seismic interpretation, a good basic knowledge of geophysics and geology is needed regarding the existence and characterization of hydrocarbon reservoirs.

Therefore, the reservoir is expected to be better characterized. As one of the researches and analysis methods of oil and gas exploration, multi-attribute seismic research was conducted to characterize sandstone reservoirs found in the "RMS" field of the Talangakar Basin in the South Sumatra Basin. According to previous research, the South Sumatra Basin also has good potential for hydrocarbon availability for new development wells (Ginger and Fielding, 2005)

REGIONAL GEOLOGY

The "RMS" tectonic field is located in the South Sumatra Basin which is a back-arc basin. According to Pulunggono, et al. (1992) the geological structure of the South Sumatra region is carried out by three tectonic phases, namely:

Rifting Phase (Paleogen)

This phase begins with the oblique subduction of the Indian Ocean Plate against the Asian Continent Plate (Sunda Land) during the Pre-Tertiary (Early Late-Cretaceous) period, with the direction of convergence N 30 W as the compression phase. This tilted motion forms the Final Jurassic fault and the Early Cretaceous shear fault which is thought to

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develop as the Musi shear fault and the Lematang shear fault.

Sagging Phase (Oligocene – Miocene)

This phase is thought to be formed due to the isostatic balancing process which results in superficial depression which in turn changes the South Sumatra Basin into a "back arc". From the Late Oligocene to the Miocene, throughout the basin there was a widespread subsidence. This decrease in joining the changes in "eustatic sea level" changes the sedimentation facies from land to shallow sea (Upper Talangakar / TRM Formation, Baturaja).

Compression Phase (Plio-Pleistosen)

At the end of the Miocene-Pliocene, the South Sumatra Basin experienced an increase in tectonics as a result of the convergence of the Indian Ocean Plate with the "Sunda Land" Plate. This compression tectonic lifts Bukit Barisan and becomes a new "source sediment" in the western part of the basin. This compression tectonic phase is very important in the petroleum industry, because the structures formed during this period produce many petroleum deposit structures. The deposits formed are not only limited to Middle and Late Miocene sediments, but also increase the previous deposits (Pre-Early Miocene).

BASIC THEORY

Checkshot

Checkshot data is an important component in seismic interpretation especially sonic logs as the translation of depth domains into the time domain. Sonic logs in the form of transit time measurements abbreviated DT can be converted into sonic speed logs. Sonic speed is what can translate the depth domain into the time domain. However, sonic velocity in well seismic bonds has several disadvantages so that other velocity data is needed as seismic data is obtained, ie checkshot data.

Well Seismic Tie

The changed domain is depth from the well domain into the time domain. With the ultimate goal of this binding process is to determine the position or geological markers on seismic data. The wavelet used should have the same frequency and band width as the seismic filter. This will make it easier to tie well data with seismic data. The final synthetic seismogram is a superposition of reflections of all reflectors. Synthetic seismograms are useful for diagnosing reflection characters from each horizon.

Seismic Attribute

According to (Chen and Sidney, 1997) seismic attributes can be divided into 2 categories, namely:

1. Horizon-based attributes, that is calculated as the average value between two horizons
2. Sample-based attributes are transformations of trace inputs to produce other trace output with the same amount as trace input (the value is calculated as samples per sample).

Multi-attribute analysis

Multi-attribute seismic analysis is one statistical method using more than one attribute to predict some physical property of the earth. In this analysis, the relationship between log and seismic data is sought at the well location and uses this relationship to predict or estimate the volume of log properties at all locations on seismic volume. Multi-attribute analysis in this study used the second category. The process itself involves making a pseudo log volume which will be used to map the spread of sandstones and shale. In the most common cases, we look for a function that will convert different multi-attributes into the desired property which can be written as:

$$P(x,y,z) = F[Ai(x,y,z),\ldots, Am(x,y,z)] \qquad (1)$$

Where :

P = log property, as a function of the x, y, z coordinates

F = function relationship between seismic attributes and log properties.

Ai = attribute m, where i = 1, ..., m.

For the simplest case, the relationship between log properties and seismic attributes can be indicated by the equation of the number of linear weights.

$$P = w_0+w_1A_1+\ldots+w_mA_m \qquad (2)$$

Where :

wi = weight value of m + 1, where 1 = 0, ..., m

Regression Linear Multi-attribute

In this method it aims to find an operator, which can predict well logs from nearby seismic data. The reason why using seismic attribute data is more beneficial than seismic data is that many of these attributes are non-linear, so they can improve predictive abilities. Extension of conventional linear analysis of multiple attributes (multivariate linear regression) was carried out directly. As a simplification, we have three attributes as shown in Figure 1.

In each time sample, the target log is modeled by a linear equation:

$$L(t) = w_0 + w_1A_1 (t) + w_2A_2 (t) + w_3A_3 (t) \qquad (3)$$

Weighting (weight) on this composition is made with minimize mean-squared prediction errors:

$$E^2 = \frac{1}{N}\sum_{i=1}^{N}(L_i - W_0 - W_1A_{1i} - W_2A_{2i} - W_3A_{3i}) \qquad (4)$$

The solution for weighting produces a normal standard equation:

$$\begin{bmatrix} W_0 \\ W_1 \\ W_2 \\ W_3 \end{bmatrix} = \begin{bmatrix} N & \sum A_{1i} & \sum A_{2i} & \sum A_{3i} \\ \sum A_{1i} & \sum A_{1i}^2 & \sum A_{1i}A_{2i} & \sum A_{1i}A_{3i} \\ \sum A_{2i} & \sum A_{1i}A_{2i} & \sum A_{2i}^2 & \sum A_{2i}A_{3i} \\ \sum A_{3i} & \sum A_{1i}A_{3i} & \sum A_{2i}A_{3i} & \sum A_{3i}^2 \end{bmatrix}^{-1} \text{x} \begin{bmatrix} \sum L_i \\ \sum A_{1i}L_i \\ \sum A_{2i}L_i \\ \sum A_{3i}L_i \end{bmatrix} \qquad (5)$$

As in the case of a single attribute, the mean-squared error calculated using weighting is a measurement of suitability for the transformation, such as a correlation coefficient, where now the x coordinate is a predicted log value and the y coordinate is the real value of the log data.

Step-wise Regression Method

The way to choose the best combination of attributes to predict the target log is to do a process called step-wise regression:

1. Search for the first best single attribute using trial and error. For each attribute contained in the prediction error is calculated. The best attributes are attributes that provide the lowest prediction error. This attribute will then be called the -a attribute.

2. Look for the best attribute pair by assuming the first pair member is a-attribute. The best pair is the couple that gives the smallest error. This attribute will then be called the b-attribute.

3. Look for the three best paired attributes, assuming the first two attributes a-attribute and b-attribute. The three best attributes are those that provide the least predictive error.

Validation

In general, if the error validation curve clearly shows the minimum, we assume the number of attributes at that point is optimum. If the error validation curve shows the regional minimum as in Figure 2, or shows a set of local minimums, we choose the point where the curve stops decreasing convincingly.

Log Sonic

Sonic log is a type of log used to measure porosity, in addition to log density and neutron log by measuring the transit time interval (Δt), which is the time needed by sound waves to propagate in a rock formation as far as 1 foot. Sonic log equipment uses a transmitter (sound wave transmitter) and two receivers (receivers). The distance between the two is 1 foot.

Log Gamma Ray

Specifically the Gamma Ray Log is useful for identifying permeable layers when the Log SP does not function because of a resistive formation or if the SP curve loses its character (Rmf = Rw), or when the SP cannot record because the mud used is not conductive (oil base mud). Besides that Gamma Ray Log can also be used to detect and evaluate radioactive minerals (potassium and uranium), detect non-radioactive minerals (coal), and can also be for correlation between wells.

Density Log

The main purpose of the density log is to determine porosity by measuring the bulk density of rocks, in addition it can also be used to detect the presence of hydrocarbons or water, used together with neutron logs, to also determine the density of hydrocarbons (ρh) and help in evaluating shaly layers (Harsono, 1997).

METHODOLOGY

Software and Data

3D PSTM seismic data

The seismic data used in this study is the 3D PSTM (Pre-Stack Time Migration) seismic data, in the form of preserve (data that has been carried out processing and filtering) data is considered correct. The seismic data used has a 2 ms sampling rate with zero phase in the SEG-Y format. Inline 2149-2443 and crossline 10400-10620 which are then used for multi-attribute seismic processes.

Well Data

The wells used in this study were four wells, namely SIM-81 wells, SIM-84, SIM-91 and SIM-92, but only in SIM-81 wells that had checkshot data. The availability of log data in each well can be seen in Table 1.

Base map

On this basic map you can also see the scale of the map and the position of the well on the seismic track. Figure 3 is a basic map of the “RMS” field which shows the research area with the well position.

Regional Geological data

Regional geological data is used to determine the general description of the geological conditions that exist in the target area of the "RMS" field, the South Sumatra basin. In the geological data, there are some data regarding the general condition of the regional areas of the South Sumatra basin in the form of stratigraphic, tectonic, and petroleum system conditions. This geological data is used to support and become an effective blend with geophysical data to provide an overview and characterization of target area reservoirs.

Checkshot Data

Basically, the well data is in the depth domain, while seismic data is still in the time domain. Therefore, checkshot data is very useful in the process of binding wells and seismic (well seismic tie).

Marker Data

The marker data is used as a reference for picking horizons. In addition, it is also used as a reference for binding wells and seismic data. The marker data used for this study came from previous studies. In this study the markers have the same names as the horizon used.

DATA PROCESSING

Wavelet Extraction and Well Seismic Tie

The ultimate goal of this binding process is to determine the position or geological marker on seismic data. The wavelet used should have the same frequency and band width as the seismic filter. This will make it easier to tie well data with seismic data. The final synthetic seismogram is a superposition of reflections of all reflectors. Synthetic seismograms are usually displayed in the same format (polarity and phase) as seismic recordings. Synthetic seismograms are useful for diagnosing reflection characters from each horizon. The process of wavelet extract can be done by several methods, namely statistical methods, ricker, bandpass and use well. In this study, trial and error was performed to obtain the best wavelets. From the wavelet extraction results, the ricker2 +180 wavelet is the most appropriate wavelet. The frequency used in the ricker method is 28 Hz, because it sees the dominant frequency of seismic. The window used in this extract is at the target zone boundary layer L1 to P2 which aims to get the results that are close to the actual. Then the extracted wavelet is convoluted with a reflection coefficient to get a synthetic seismogram, which is first converted from the domain into the time domain with the help of a checkshot.

Picking Horizon

Picking horizon with reference to marker data on wells. Picking is done at the L1 layer and P2 layer. This process is as important as the well seismic tie process because it is laterally influential when making inversion models and multi-attribute models. The selection of wiggle (peak / trough) on seismic is very influential if the picking zone is wrong, then the inversion carried out will not be in accordance with the initial model of the earth and the multi-attribute rock properties studied will not match the spread.

Time Structure Map

After picking the horizon, the next step is to make a time structure map, which aims to see how the structure at layer L1 and layer P2 in the time domain, besides that it is also used to overlay the results of multi-attribute slices.

Multi-attribute Process

The method used is the linear regression method with a step wise regression technique. After we bind the well data with seismic data and determine the log properties that will be used to separate sandstone and claystone using the gamma ray log and log porosity, then a multi-attribute analysis is performed. To determine which attributes will be used in this log prediction, training errors and validation errors are performed on the gamma ray log and log porosity as log targets with several seismic attributes. From this training process the best seismic attribute group will be used to predict reservoir distribution on gamma ray attributes and porosity.

Slice

After performing a multi-attribute process on gamma ray and porosity, the incision mapping or slicing process is carried out at a certain depth at layer L1 with the window width slicing 15 ms down from the marker then on P2-10 ms layer with slicing window width 15 ms up from the marker to see spread of the layer between sandstone and shale laterally. The results of slice maps of gamma ray and porosity are then overlayed with a time structure map to see areas that have high contours of the time scale and depth. The results of slicing can then be used for interpretation of the prospect zone and deposition direction of the distribution of sandstones on the "RMS" field.

RESULTS AND DISCUSSIONS

Target Zone Analysis

The area that was the target of the study focused between the L1 layer and the P2 layer to map sandstone and porosity spreading. The initial stage to analyze the target zone can be done by looking at the log response (quick look) on the well data that is owned. Gamma ray logs can be used to identify the lithology of the research area. The relatively low response value of the gamma ray log was identified as a sandstone and the relatively high gamma ray log value was identified as shale. In addition to using gamma ray logs, neutron porosity log and log density are used for determining the target zone. Sandstones have relatively low density values and high porosity. Cross-over between log density and neutron porosity can indicate that the zone is sandstone and there is a fluid. To map the distribution of sandstones and porosity, multi-attribute processes were carried out on SIM-81, SIM-84, SIM-91 and SIM-92 wells. In Figure 4, it can be seen the target zone found on the SIM-84 well.

Tuning Thickness Analysis

To find out the value of tuning thickness in this study we used equation 23. Based on the amplitude spectrum in Figure 5 can be seen the dominant frequency of 28 Hz (time 1450 - 1680) with different wave velocities in each well, so that the thickness zone of interest can be known at each well. Based on the results obtained, it can be seen in Table 2, the thickness of the target zone is greater than ¼ λ, so it can be read well on seismic.

Well Seismic Tie Analysis

Before well seismic tie is done, the calibration between P-wave log and checkshot data is done first. Next is wavelet extraction using wavelet ricker, use well and statistical. Wavelet extraction is done repeatedly (trial and error) to get a high correlation. After conducting a trial and error process, a ricker2 + 180 wavelet with a dominant frequency of 28 Hz is obtained, the wavelet length is 200 ms and the phase is used as a linear phase as the wavelet that is most suitable with the seismic trace. The wavelets extracted were then convoluted with AI values to obtain synthetic seismograms. The well seismic tie process is basically influenced by the process of shifting, squeezing and stretching. Shifting is done to move the synthetic seismogram as a whole to the desired place. Whereas stretching and squeezing is a stretching and compressing process between two amplitude adjacent to a synthetic seismogram. Using the right wavelet is one of the factors to increase the correlation value and the multi-attribute results obtained. In Table 3 we can see the results of repeated wavelet extraction (trial and error) and based on the table the ricker2 + 180 wavelet is the most suitable wavelet and has the highest correlation average value, which is 0.774. The following Figure 6 shows the correlation between synthetic seismograms and seismic trace in each well.

Picking Horizon

The search for horizons in seismic data is focused on L1 and P2 markers which are the target layer. The L1 picking marker was carried out at a seismic peak and in P2 marker picking was carried out at the trough. Before picking on inline and xline, first make an arbitrary line and do picking on the arbitrary line as a guide for picking on inline and xline. From the results of the withdrawal of the horizon in inline and xline, it will produce a time map on the L1 and P2 layers. The following (Figure 7) is the picking result that crosses the SIM-81 well inline 2336.

Then based on the results of the withdrawal and tracking of the horizon in the L1 and P2 markers, a time structure map can be made that will illustrate the shape of the contour pattern along the layers L1 and P2. From the map can be seen how the pattern of target structures in the time domain (ms) (Figure 7). Based on the map the time structure in Figure 8 is good at the L1 layer and P2 layer the area that has a low time is the height (anticline pattern) and which is indicated by high time in the form of damping or trough. The area which is the height (anticline) is located in the northwest of the city, this area is thought to be a reservoir.

Multi-attribute Seismic

This analysis uses linear regression methods with step wise regression techniques. This step wise regression technique looks for attributes with the smallest error validation value. The stages in the multi-attribute process are training log data, looking for desired attributes by considering the selection of length operators used, crossplot and validation to see the level of correlation between seismic data and log data. The parameters for determining the best seismic attribute group that will be used to predict the target log are error / training predictive values and error validation values. Training data is used to generate transformations while validation data is used to measure the final results of error predictions. The more attributes used, the smaller the prediction error, which means the validation value gets higher. But if the use of attributes is not well controlled, it will cause over training / over fitting. Assuming that over training on training data will result in poor compatibility with validation data.

Gamma ray prediction

In Figure 9 is the input data for the four wells to be trained, the red curve is the gamma ray log and the red one is seismic. The next process after inputting data is to find appropriate attributes by trying to find 10 best attributes and using operator length 5 parameters. In this process, the most similar sets of attributes and the smallest errors will be selected using step wise regression techniques of the 10 attributes that are training with operator length 5, then the next is to choose the best attribute based on the use of operator length. The results of the gamma ray attribute test are best at operator length 4 because they have the smallest error value (Figure 10a) and use the 3rd iteration attribute (Figure 10b). Three of the best attributes used in the gamma ray log prediction are: Second Derivative Instantaneous Amplitude, 35/40 - 45/50 Filters and 45/50 - 55/60 Filters, with a validation value of 23,425720. The use of more than three attributes will cause the data to be over training, this can be seen from the value of the validation error that increases after the use of more than three attributes (Table 4). After obtaining the best attributes needed, a crossplot between actual gamma ray is performed against predicted gamma ray (Figure 11).

The result of the multi-attribute parameter test in the 3rd attribute has a cross-correlation value of 0.737521 and error 21.1383 API. The cross-correlation value illustrates the validity of the multi-attribute results. Apart from the crossplot results between actual gamma ray and predicted gamma ray, the values of the multi-attribute linear regression with 3 attributes are predicted with a validation value of 0.669 and an average error value of 23.42 API. The results of this validation are used to see the multi-attribute outcome approach to the original seismic data. If the resulting correlation value approaches 1, the attributes used are increasingly similar to the original seismic data. After knowing the value of the validation correlation, note also the compatibility / similarity between the modeled log and the original log. In the form of a modeled log similar to the original log in the prediction window, the multi-attribute results obtained are valid for predictions of pseudo gamma ray. From the results of the training and validation of the multi-attribute process, the pseudo gamma ray volume is obtained as shown in Figure 12. The results of the multi-attribute application show a good match between the gamma ray prediction and the gamma ray value in the well.

Porosity prediction

After the data input is normalized, smooth and filter so that the log data is input according to the seismic data. Normalized is done to equalize the difference in the PHIE log scale in each well, smooth is done so that the log data resembles seismic data and finally the filter is done so that the log data has the same frequency as seismic data. Log data is filtered with a maximum frequency of 70 Hz and a high cut of maximum 80 Hz. The next process after inputting data is to find the appropriate attributes by trying to find the 10 best attributes and using operator length 5. In this process, the most similar sets of attributes and the smallest errors will be selected using the step wise regression technique.

Based on the results of the attribute test performed on prediction of porosity, the best attribute is obtained at operator length 4 because it has the smallest error value (Figure 13a) and uses the 3rd iteration attribute (Figure 13b), with a validation value of 0.030839. The 3 best attributes used in the prediction of log porosity are: Second Derivative Instantaneous Amplitude, Filters 35/40 - 45/50 and Filters 45/50 - 55/60. The use of more than three attributes will cause the data to become over training, this can be seen from the value of the validation error

that increases after the use of more than three attributes (Table 5).
After obtaining the best attributes needed, a crossplot was carried out between actual porosity and predicted porosity. The result of the multi-attribute parameter test in the 3rd attribute has a cross-correlation value of 0.783483 and error 0.0287122. This cross-correlation value illustrates that the results of the multi-attribute performed are valid.

Apart from the crossplot results between actual porosity and predicted porosity, the values of the multi-attribute linear regression with 3 attributes are predicted with a validation value of 0.744 and an average error value of 0.0308%. The results of this validation are used to see the multi-attribute outcome approach to the original seismic data. If the resulting correlation value approaches 1, the attributes used are increasingly similar to the original seismic data. After knowing the value of the validation correlation, note also the compatibility / similarity between the modeled log and the original log. In the form of a modeled log similar to the original log in the prediction window, the multi-attribute results obtained were valid for predictions of pseudo porosity.

The training results and validation in the multi-attribute process are the pseudo-porosity volume as shown in Figure 14. The results of the multi-attribute application show a good match between the predicted porosity and the porosity value in the well.

Slicing Window Analysis

The slicing window analysis is carried out to limit the area which is the prospect zone into the target window (Figure 15**)**. Based on the results of the analysis carried out the target zone is at the L1 horizon with a window width of 15ms below. Then the next target zone is at P2 -10ms horizon with a window width of 15ms above. From the results of the analysis and predetermined limits, it is expected that the sandstone reservoir distribution will pass through the results of the slice.

Interpretation

After performing a multi-attribute process and obtaining a prediction of pseudo porosity volume and prediction of pseudo gamma ray volume, slice is performed on both volumes according to the window slicing analysis. This process will produce a slice map that can describe the distribution of sandstone and porosity reservoirs in the "RMS" field. The size of the slice on both maps is the average value of the distribution of sandstones and shale based on the target in the slice window, so you must look back at the log data. The slice map made is a slice of gamma ray prediction (Figure 16) and prediction of porosity (Figure 17). Slice is done based on LI and P2 horizons, with a 15 ms window below the L1 horizon and P2 + 10 ms horizon with window 15 ms above. Based on the results of the slice horizon on the two layers the deposition pattern and the distribution of clear sandstones can be seen in the P2 layer. The horizontal slice of the pseudo gamma ray volume shows that the northwestern part of the study area has lower gamma ray values than the other parts. The slice of pseudo volume porosity also shows the north-west part has a higher average porosity value and on the map the time structure of the picking horizon results shows the high area (anticline) in the northwest, this is seen in the area low time. From the map it can be predicted the deposition of northwest-southeast direction sandstones and thick sandstones is in the P2 layer. The northwestern part of the study area has an average gamma ray value that is low from 0 to 90 API and porosity on average 15 - 30% and based on the map the time structure of this area is a height with a depth of approximately 1560 - 1660 ms time domain. The slice results of gamma ray and porosity in the RMS field, then overlayed with a time structure map so that the trend in which the fluid (hydrocarbon) accumulation can be detected and can determine the zone that has the potential for further development. Based on the analysis of the three maps, the northwest region has good potential for the development of further wells.

Determination of Development Areas

The three final results maps, that are time structure maps, gamma ray value maps and porosity value maps, show fairly uniform results. From these maps it can be concluded that the Southeast-Northwest part of the study area is a region of height with a time domain of 1560-1660 ms. In the northwestern part, sandstone reservoirs that have a gamma value range 0-90 API are interpreted and porosity values are 15-30%. Based on the analysis of the six maps, the North West in layer P2 has good potential for the development of further wells (Figure 18).

CONCLUSIONS

The conclusions obtained from the results of this study are as follows:

1. The results of the multi-attribute process depend on the number and type of attributes used and

this is influenced by several things, such as the character of the results of processing and data acquisition, and the process of well to seismic tie processing.

2. Validation of predictive results shows good results where the pseudo gamma ray prediction has a validation value of 0.669 with an error value of 23.42 API and the prediction of pseudo porosity has a validation value of 0.744 with an error value of 0.0308%.

3. Based on the results of the porous multi-attribute map as the target reservoir it is located in the North-West with the Northwest-Southeast deposition direction.

4. Sandstone reservoir distribution is known to have gamma ray log values with a range of 0-90 API and porosity in the range 12-30% with a depth of 1560-1660 ms time domain.

5. Based on the map of sandstone and porosity distribution, the potential for development in the "RMS" Field can be recommended in the northwestern part of the research area with a time domain of 1560-1660 ms.

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TABLE 1

COMPLETE LOG DATA

Well Name	SP	GR	NPHI	RHOB	PHIE	DT	Chk
SIM-81	Y	Y	Y	Y	Y	Y	Y
SIM-84	Y	Y	Y	Y	Y	Y	N
SIM-91	Y	Y	Y	Y	Y	Y	N
SIM-92	Y	Y	Y	Y	Y	Y	N

TABLE 2

TUNING THICKNESS ANALYSIS

No	*Well*	V (m/s)	F (Hz)	λ (m)	Tebal (m)	¼ λ (m)
1	SIM-81	3817.7	28	136.34	128.95	34.08
2	SIM-84	3801.76	28	135.77	126.85	33.94
3	SIM-91	3787.52	28	135.26	131.04	33.81
4	SIM-92	3793.38	28	135.47	116.02	33.86

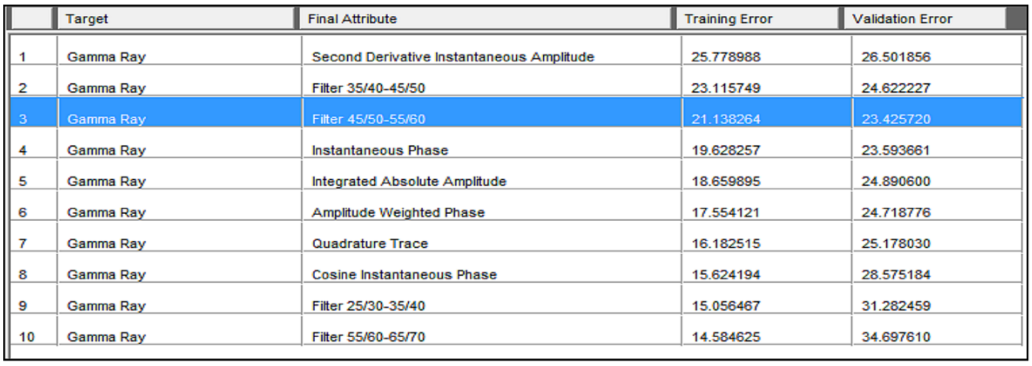
TABLE 3

WAVELET EXTRACTION RESULTS

wavelet/well	**SIM-81**	Shift (ms)	**SIM-84**	Shift (ms)	**SIM-91**	Shift (ms)	**SIM-92**	Shift (ms)	Rata-rata
wave1_stat	x		0.512	11	0.527	-7	x		0.519
ricker2 +180	0.804	0	0.851	-1	0.816	0	0.627	0	0.774
wave_allwell	0.875	-10	0.721	-1	x		0.566	-6	0.72
wave1_stat +180	x		0.675	-1	x		0.503	-7	0.589
ricker10	0.529	0	0.53	0	0.756	0	x		0.605
ricker11	0.568	0	0.615	-1	0.771	1	x		0.651

TABLE 4

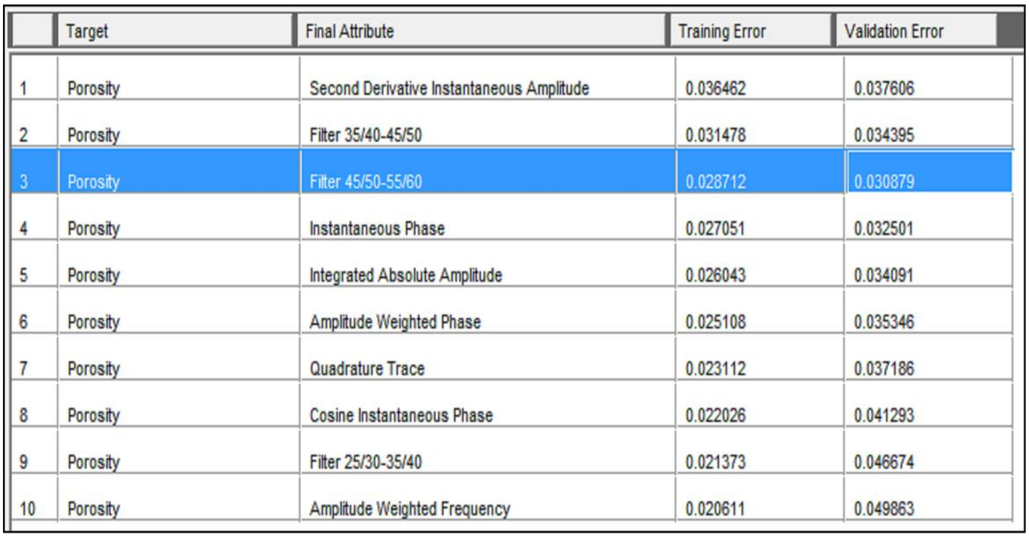
MULTI-ATTRIBUTE PREDICTION OF PSEUDO GAMMA RAY



	Target	Final Attribute	Training Error	Validation Error
1	Gamma Ray	Second Derivative Instantaneous Amplitude	25.778988	26.501856
2	Gamma Ray	Filter 35/40-45/50	23.115749	24.622227
3	Gamma Ray	Filter 45/50-55/60	21.138264	23.425720
4	Gamma Ray	Instantaneous Phase	19.628257	23.593661
5	Gamma Ray	Integrated Absolute Amplitude	18.659895	24.890600
6	Gamma Ray	Amplitude Weighted Phase	17.554121	24.718776
7	Gamma Ray	Quadrature Trace	16.182515	25.178030
8	Gamma Ray	Cosine Instantaneous Phase	15.624194	28.575184
9	Gamma Ray	Filter 25/30-35/40	15.056467	31.282459
10	Gamma Ray	Filter 55/60-65/70	14.584625	34.697610

TABLE 5

MULTI-ATTRIBUTE PREDICTION OF PSEUDO POROSITY



	Target	Final Attribute	Training Error	Validation Error
1	Porosity	Second Derivative Instantaneous Amplitude	0.036462	0.037606
2	Porosity	Filter 35/40-45/50	0.031478	0.034395
3	Porosity	Filter 45/50-55/60	0.028712	0.030879
4	Porosity	Instantaneous Phase	0.027051	0.032501
5	Porosity	Integrated Absolute Amplitude	0.026043	0.034091
6	Porosity	Amplitude Weighted Phase	0.025108	0.035346
7	Porosity	Quadrature Trace	0.023112	0.037186
8	Porosity	Cosine Instantaneous Phase	0.022026	0.041293
9	Porosity	Filter 25/30-35/40	0.021373	0.046674
10	Porosity	Amplitude Weighted Frequency	0.020611	0.049863

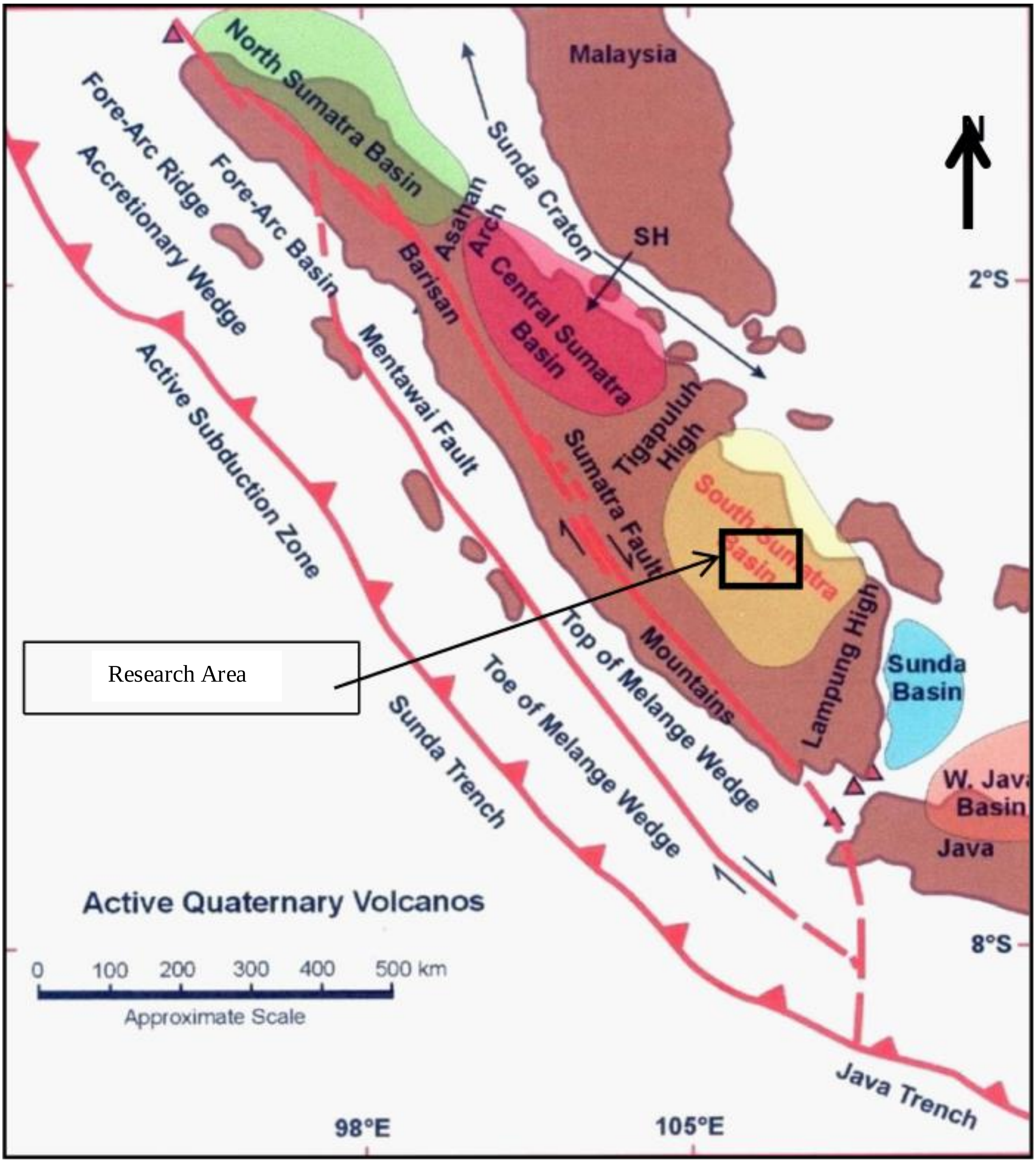


Figure 1 - Map of Sumatra Island Basin (Heidrick and Aulia, 1993).

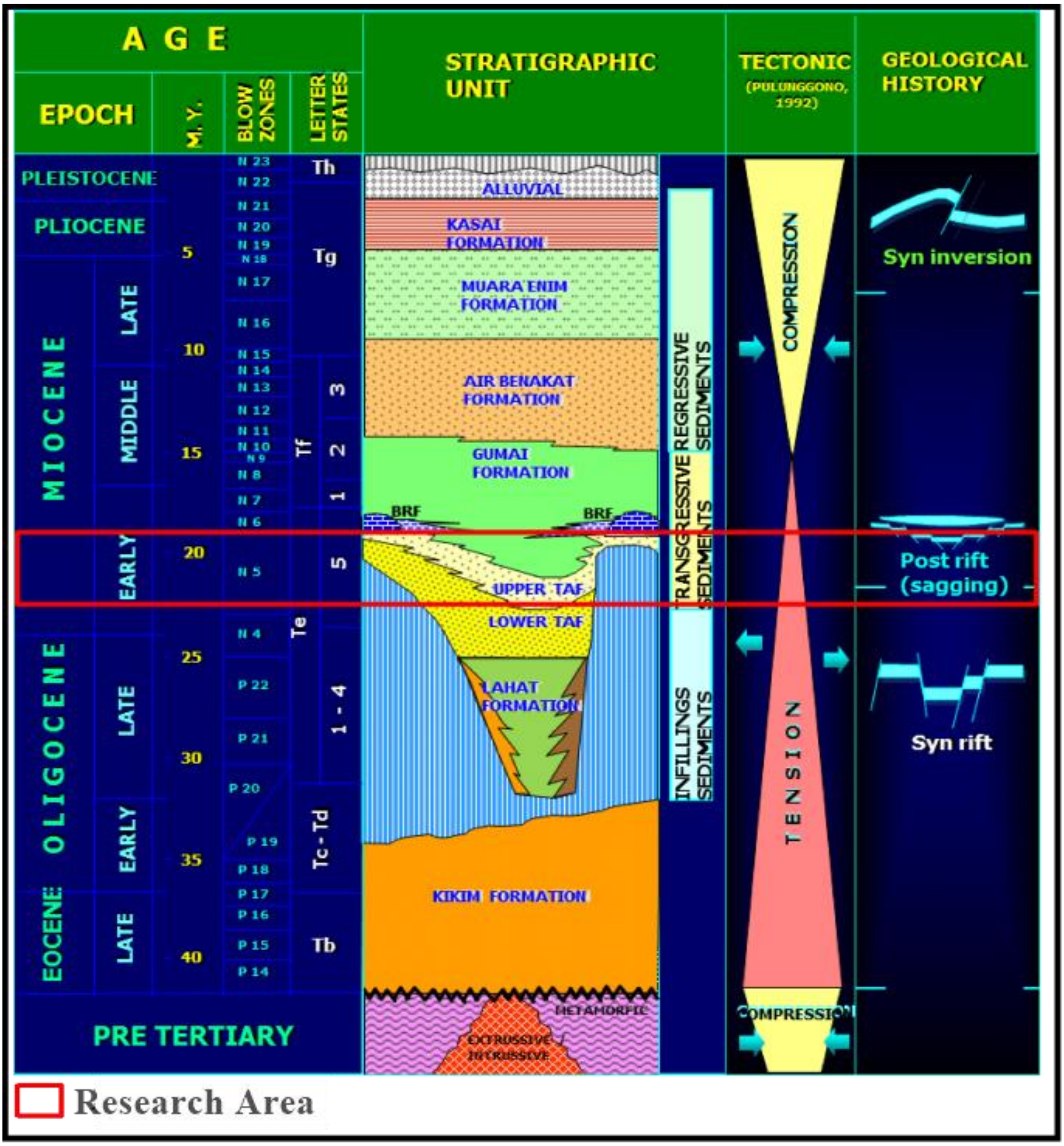


Figure 2 - Regional stratigraphy of the South Sumatra basin (Ryacudu, 2005).

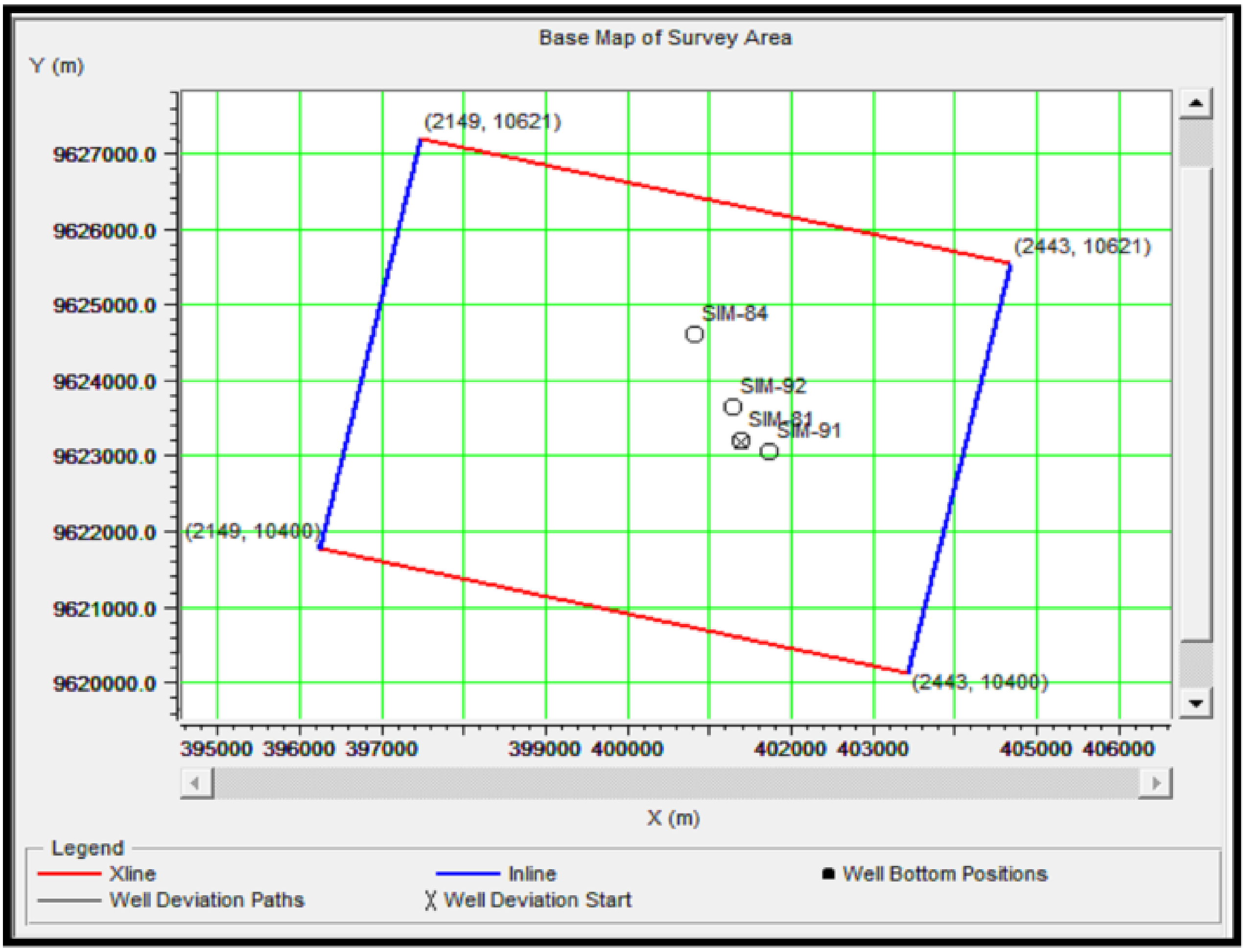


Figure 3 - Base Map RMS Field.

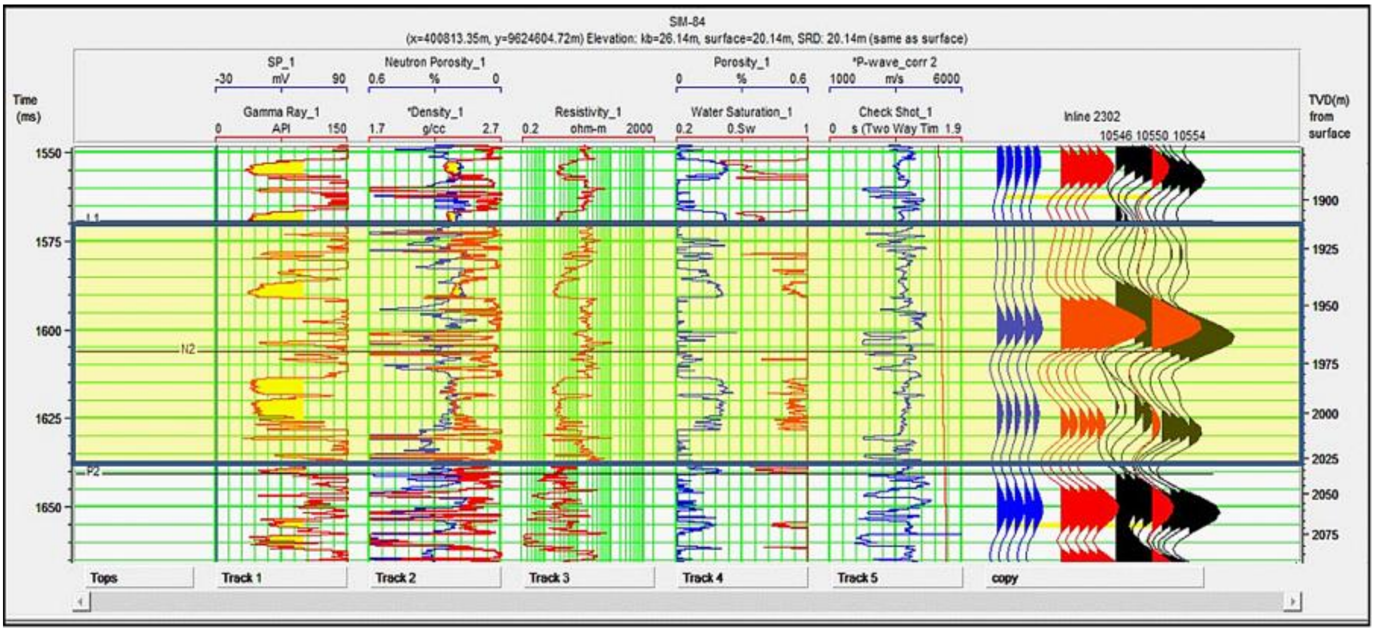


Figure 4 - The target zone on the SIM-84 well.

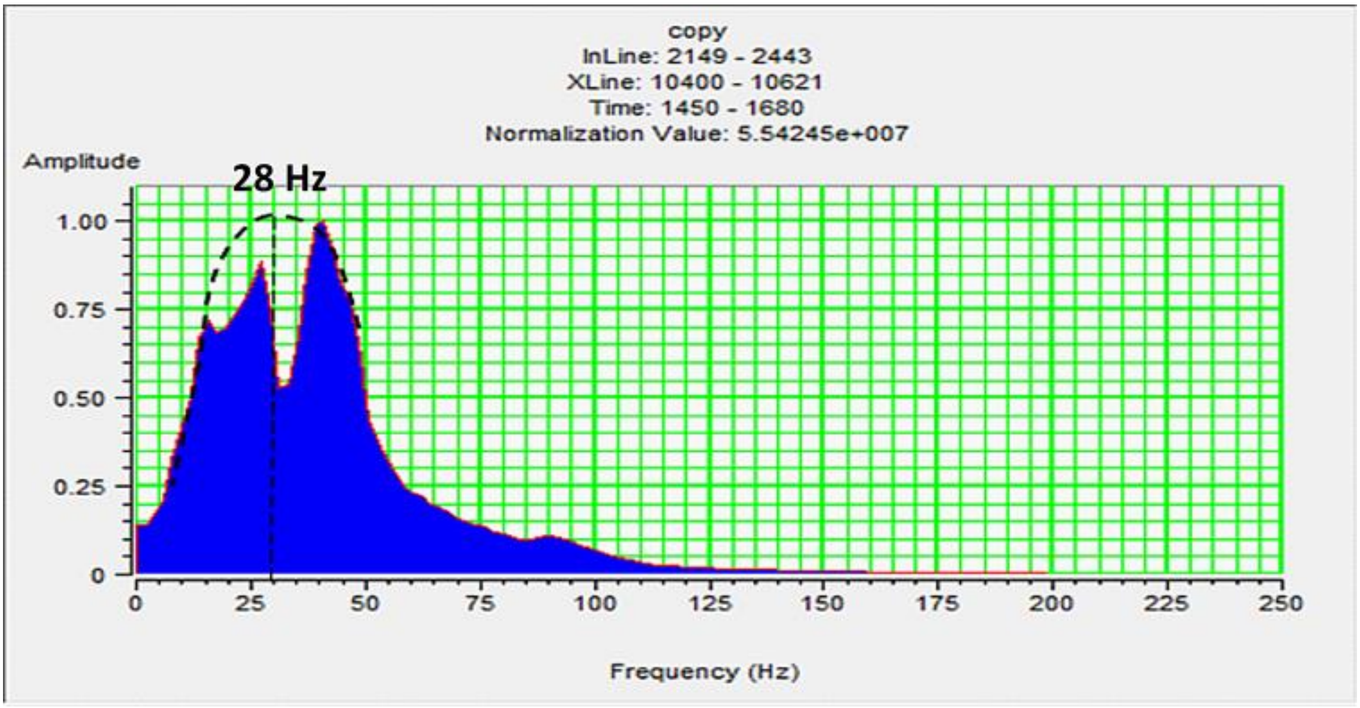
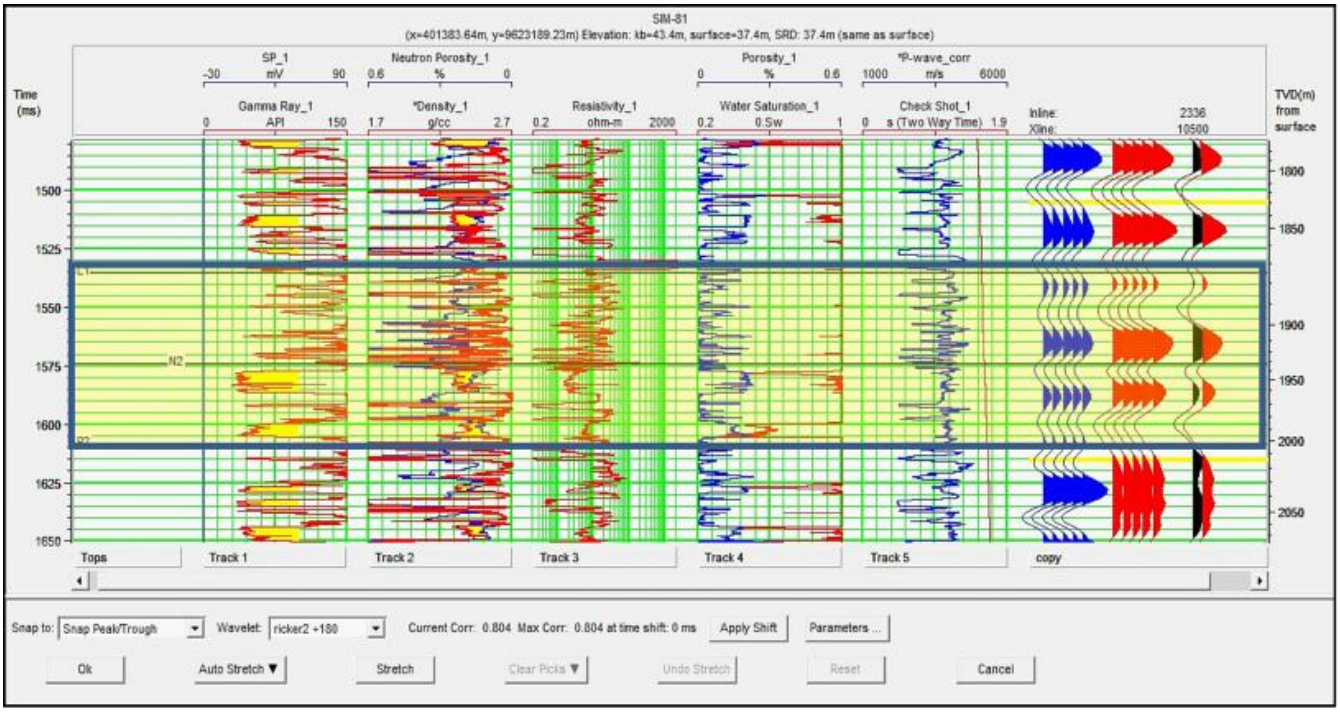
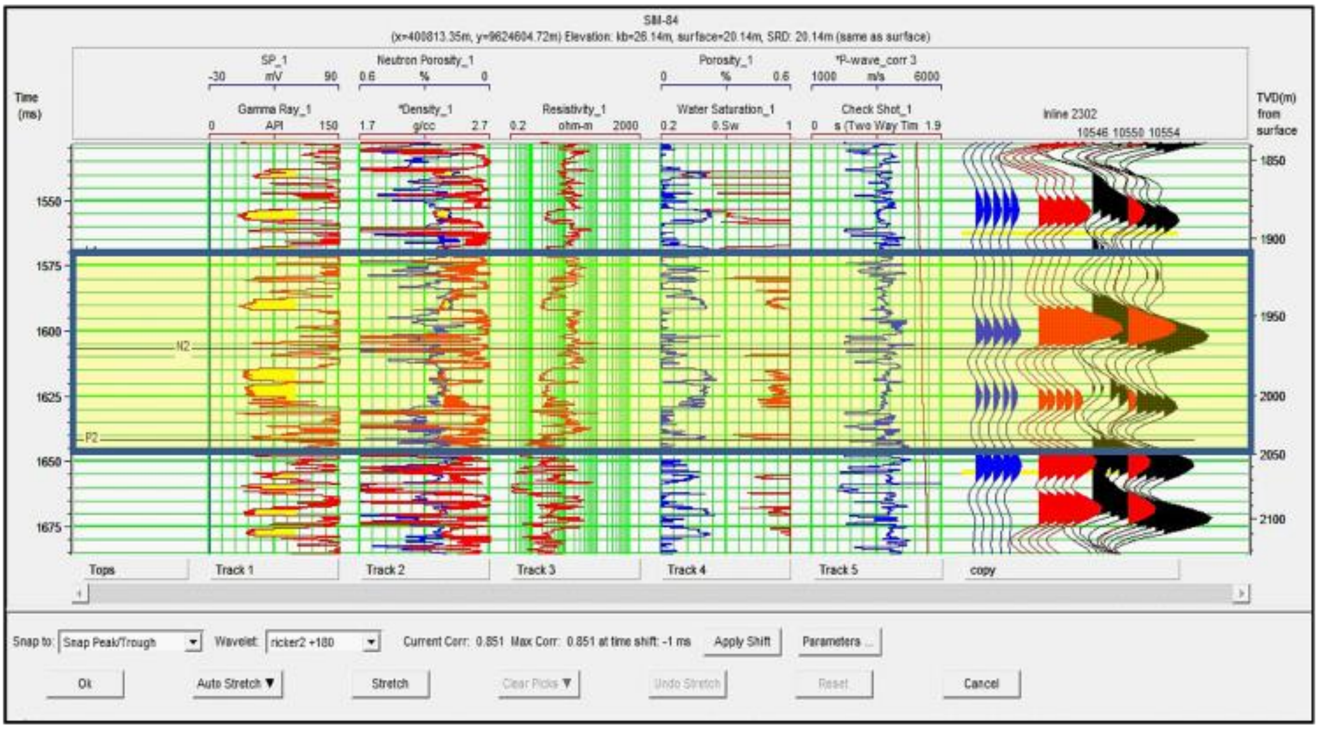


Figure 5 - Amplitude Spectrum.


SM-81
(x=401383.64m, y=9623189.23m) Elevation: kb=43.4m, surface=37.4m, SRD: 37.4m (same as surface)

Snap to: Snap Peak/Trough
Wavelet: ricker2 +180
Current Corr: 0.804 Max Corr: 0.804 at time shift: 0 ms

Figure 6a



SM-84

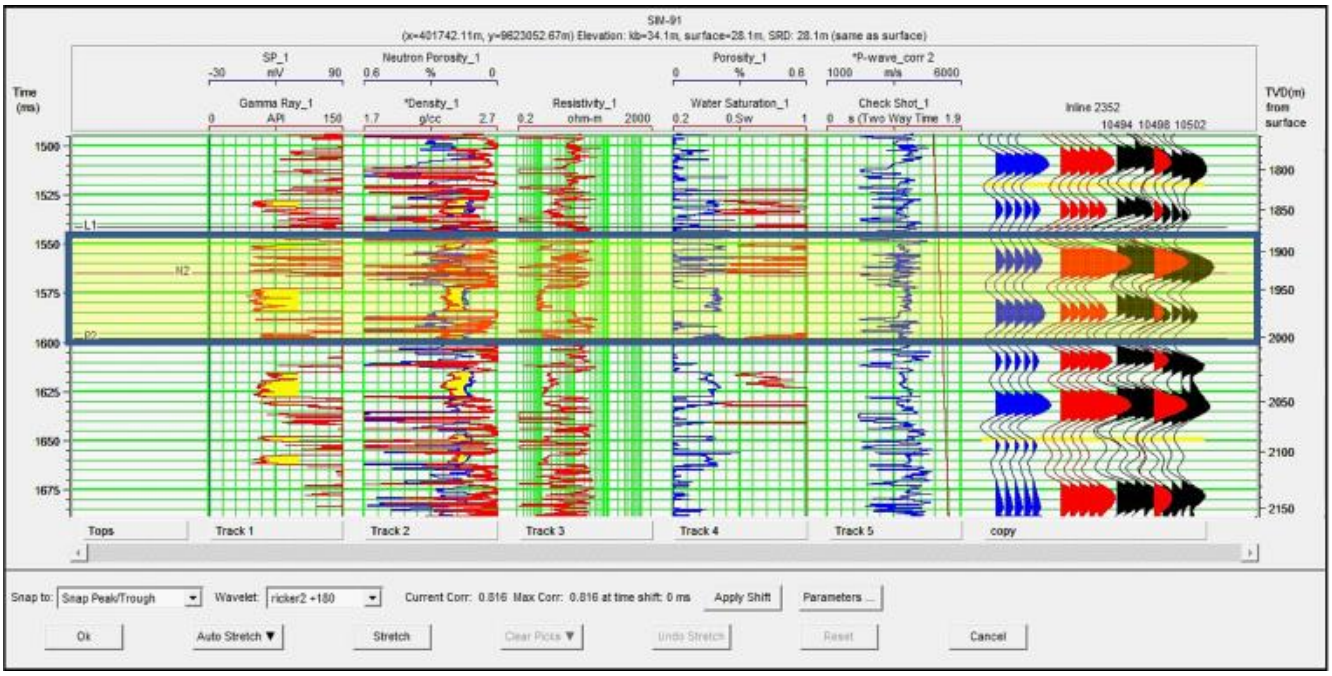
(x=400813.35m, y=9624604.72m) Elevation: kb=26.14m, surface=20.14m, SRD: 20.14m (same as surface)

Snap to: Snap Peak/Trough

Wavelet: ricker2 +180

Current Corr: 0.851 Max Corr: 0.851 at time shift: -1 ms

Figure 6b



SM-91

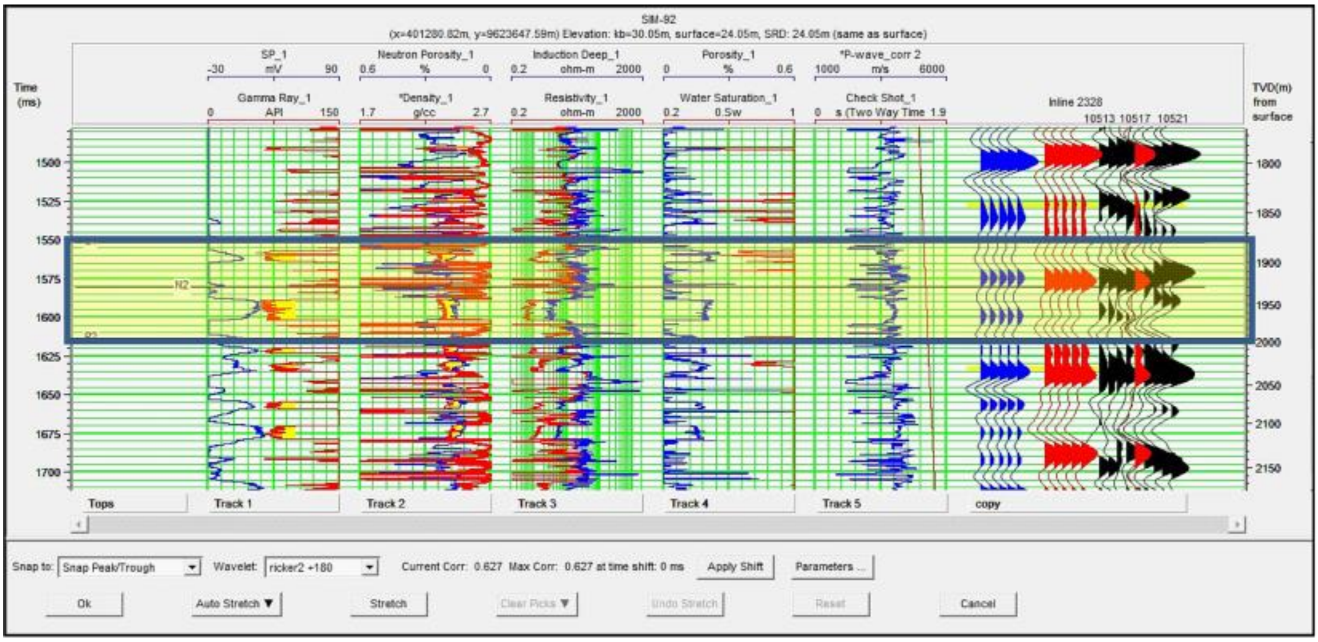
(x=401742.11m, y=9623052.67m) Elevation: kb=34.1m, surface=28.1m, SRD: 28.1m (same as surface)

Snap to: Snap Peak/Trough

Wavelet: ricker2 +180

Current Corr: 0.816 Max Corr: 0.816 at time shift: 0 ms

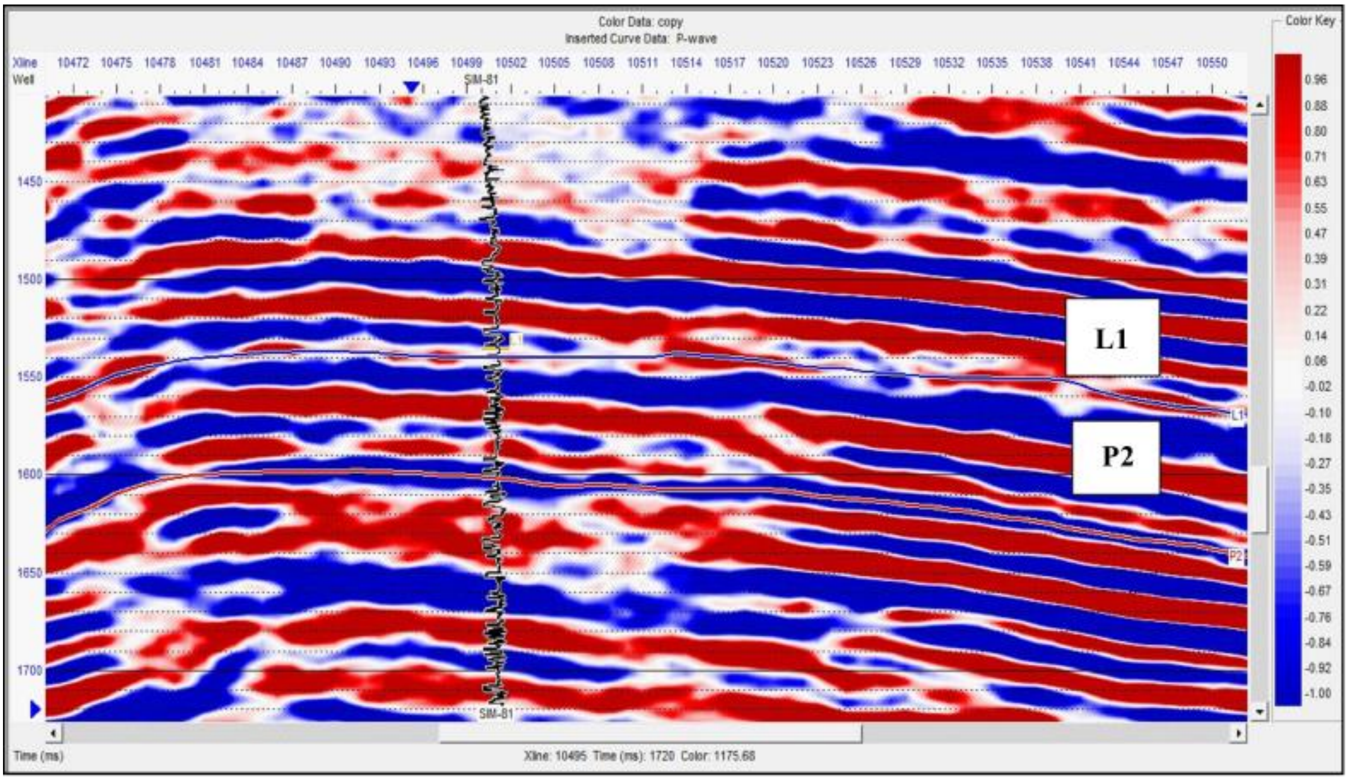
Figure 6c



Snap to: Snap Peak/Trough
Wavelet: ricker2 +180
Current Corr: 0.627 Max Corr: 0.627 at time shift: 0 ms

Figure 6d

Figure 6 - Results of well tie SIM-81 well, correlation 0.804 (a), Results of well tie well SIM-84, correlation 0.851(b), The results of well tie the SIM-91 well, correlation 0.816 (c) and Result of well tie SIM-92 well, correlation 0.627 (d).



Xline: 10495 Time (ms): 1720 Color: 1175.68

Figure 7 - The results of picking horizon through SIM-81 wells in inline 2336.

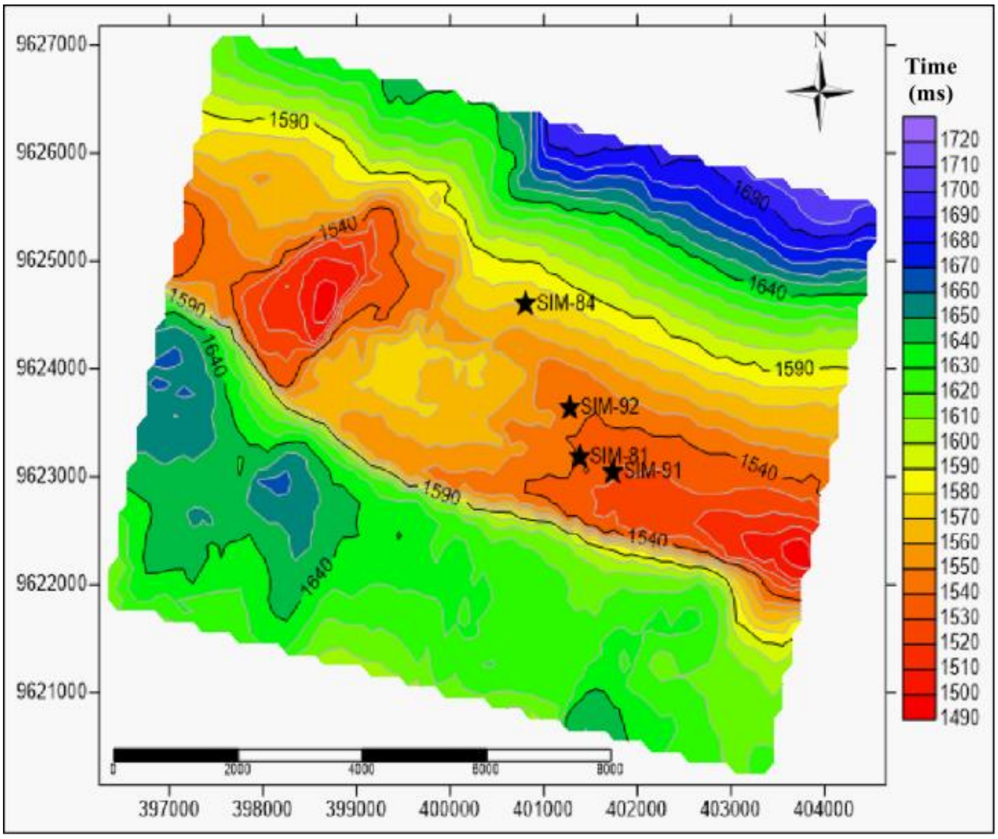


Figure 8a

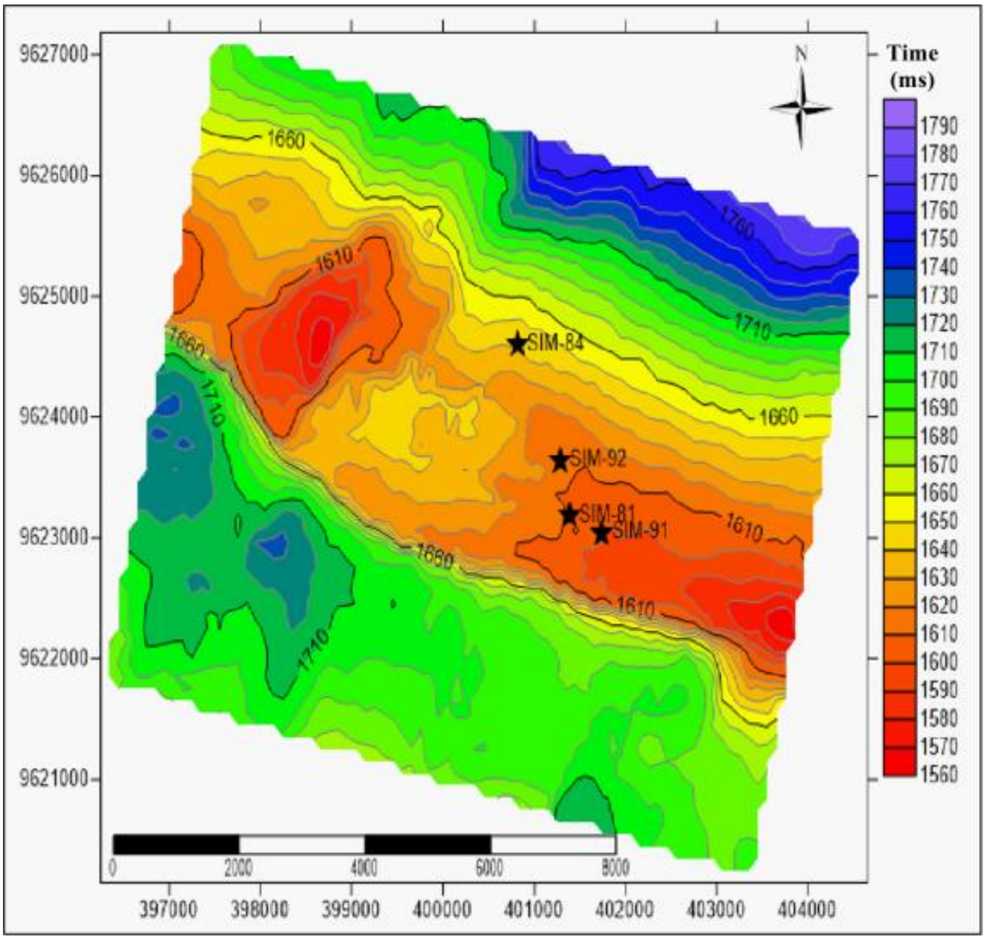


Figure 8b

Figure 8 - Time structure map (a) layer L1 (b) layer P2.

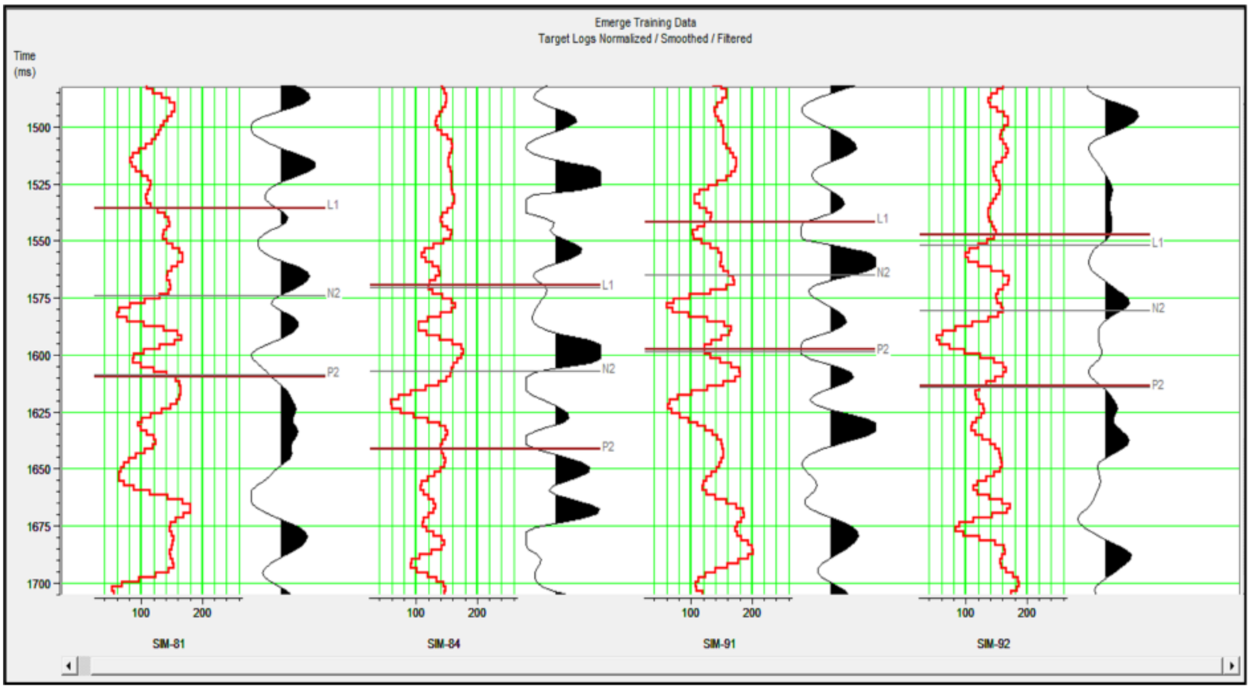


Figure 9 - Gamma ray log (red) and seismic data (black) input data.

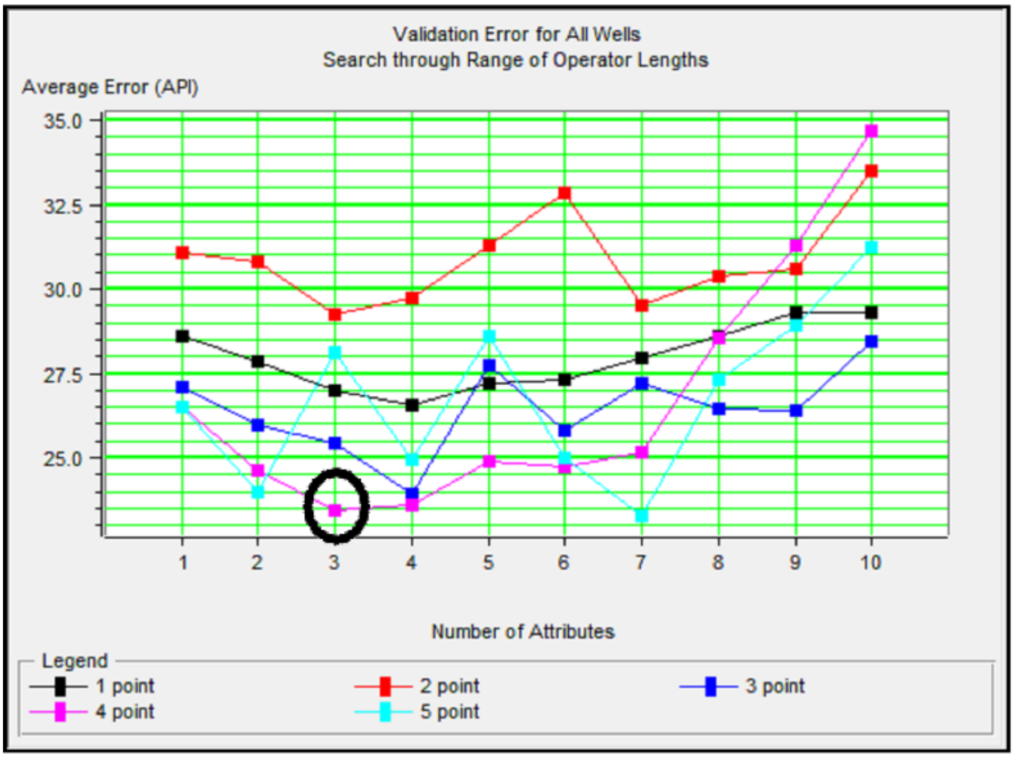


Figure 10a

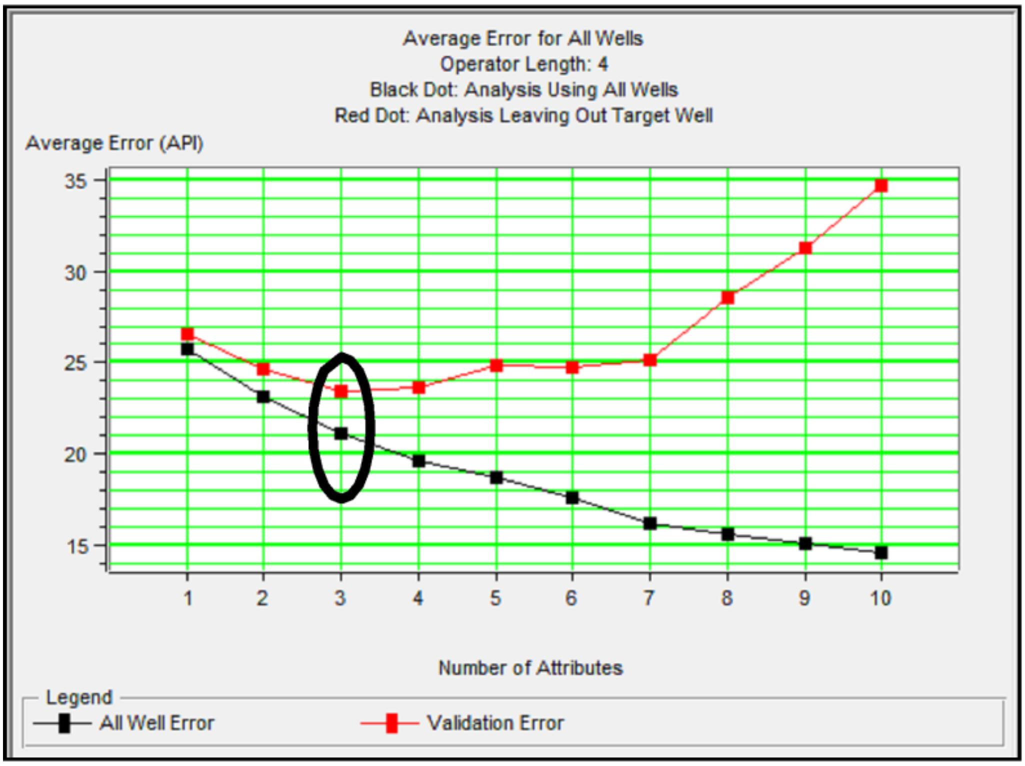


Figure 10b

Figure 10 - Gamma curve ray (a) length test operator, (b) attribute selection based on the selected operator length.

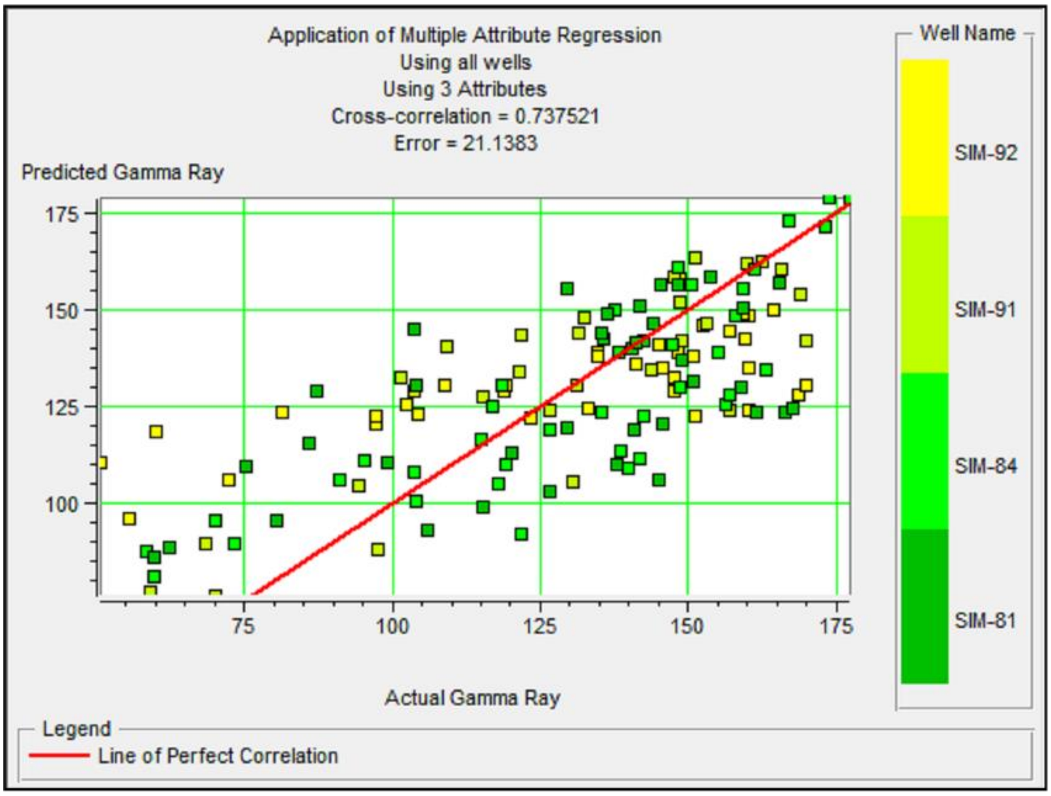


Figure 11 - Crossplot Actual Gamma Ray vs Predicted Gamma Ray.

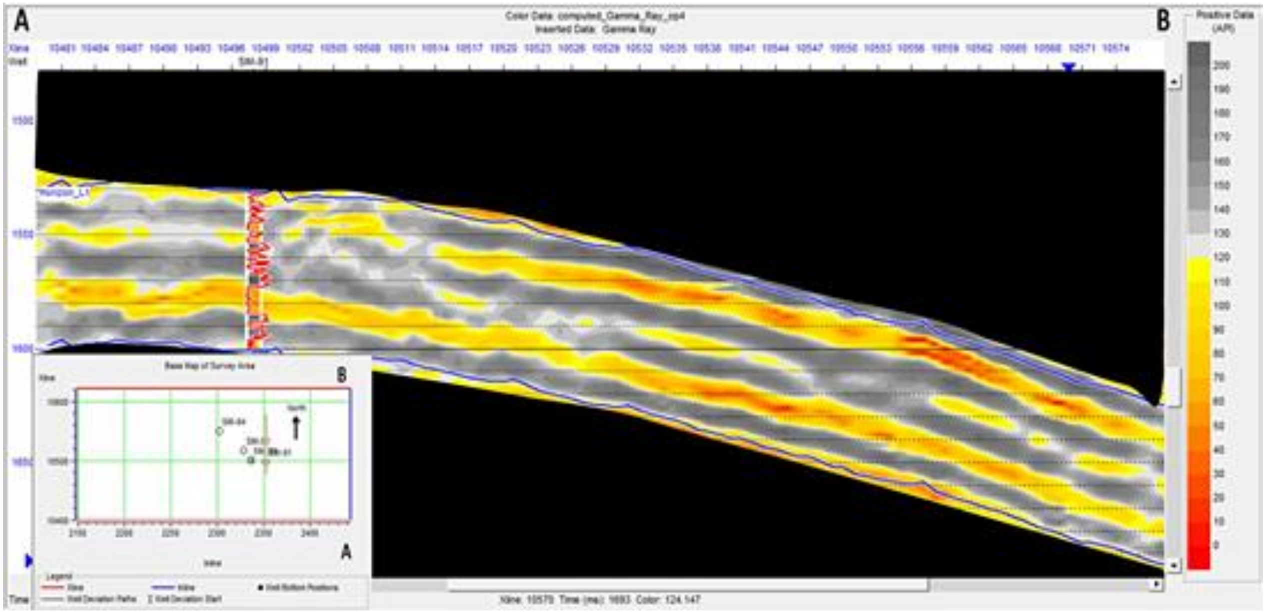


Figure 12 - Pseudo gamma ray volume through the SIM-91 well.

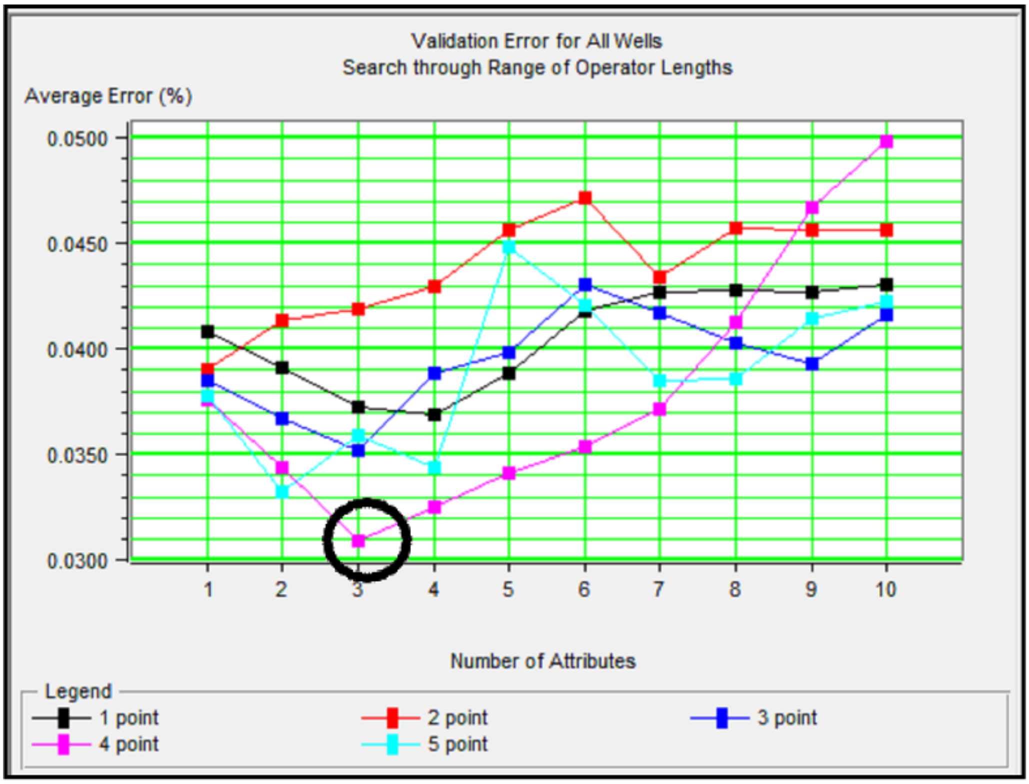


Figure 13a

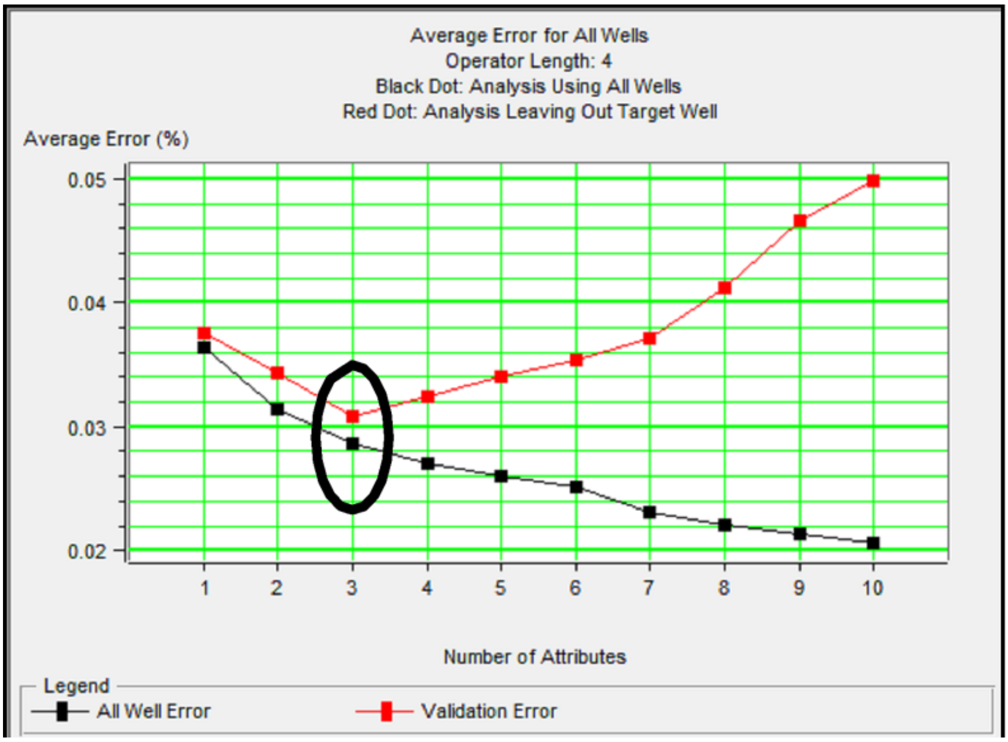


Figure 13b

Figure 13 - Porosity curve (a) length operator test, (b) attribute selection based on the selected operator length.

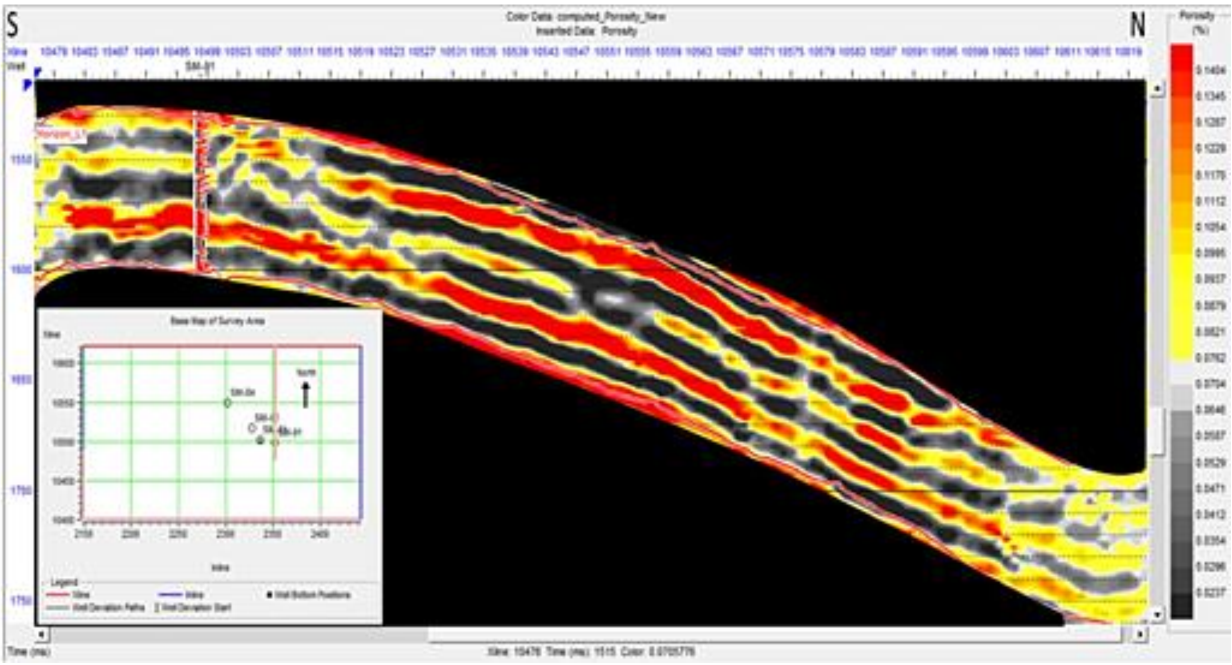


Figure 14 - Pseudo porosity volume through well-SIM 91.

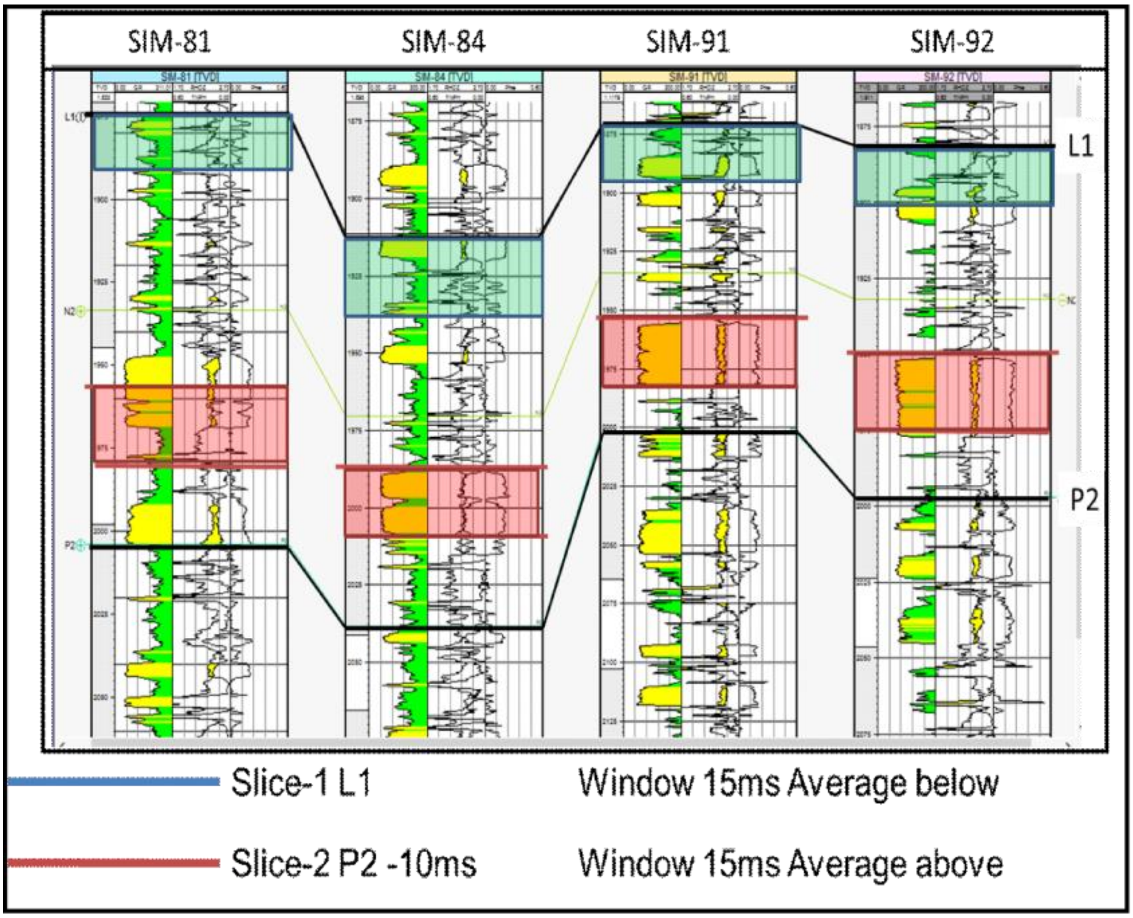


Figure 15 - Analysis of slicing window.

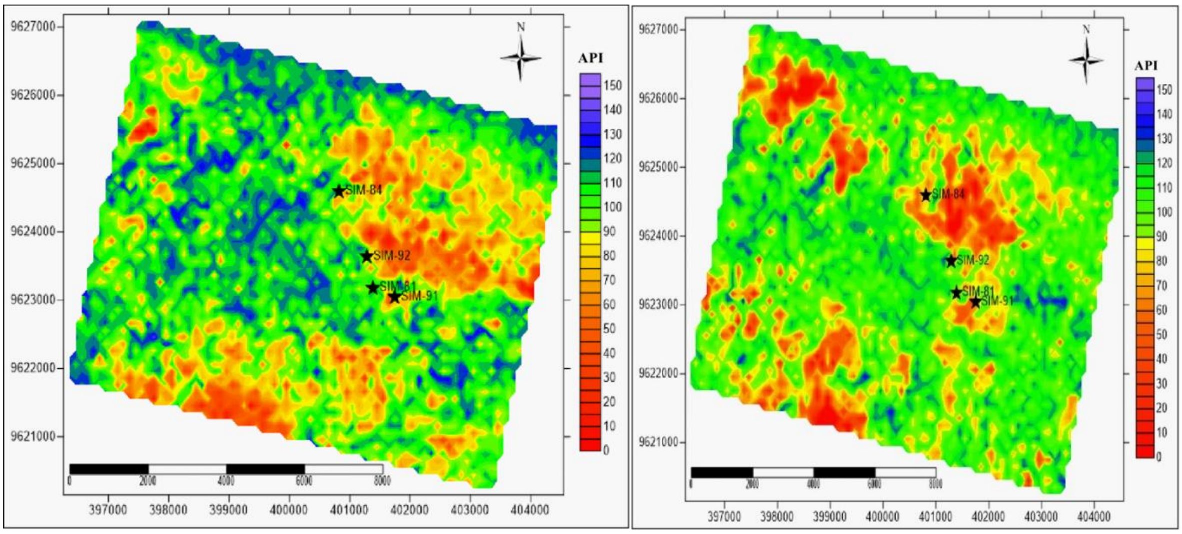


Figure 16a

Figure 16b

Figure 16 - Slice map gamma ray distribution average (a) L1 horizon (b) porosity P2 horizon.

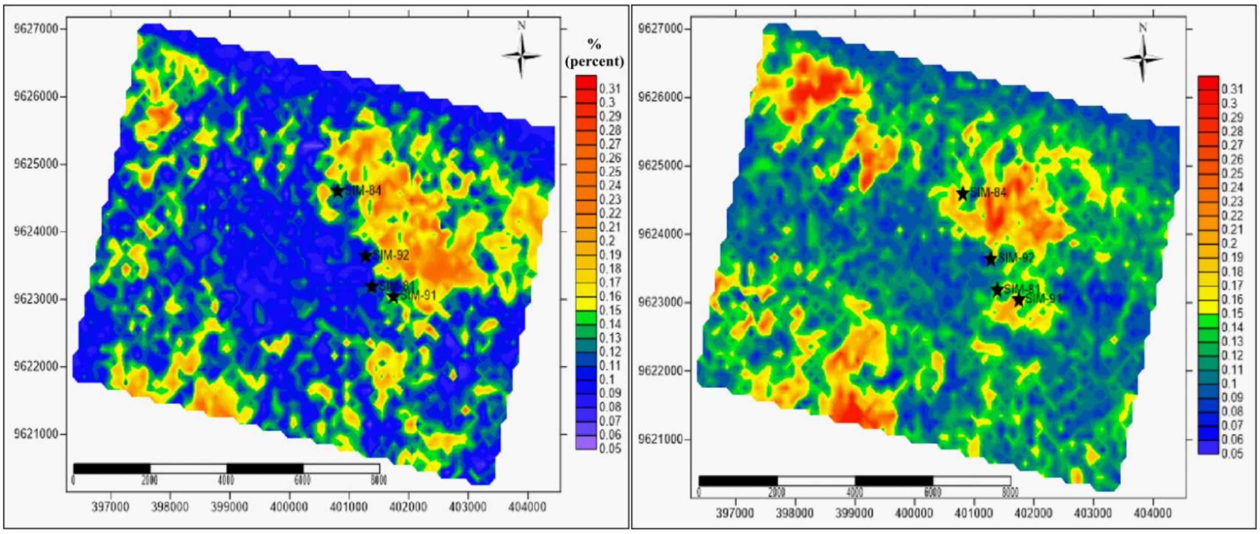


Figure 17a

Figure 17b

Figure 17 - Slice map average porosity distribution (a) L1 horizon (b) P2 horizon.

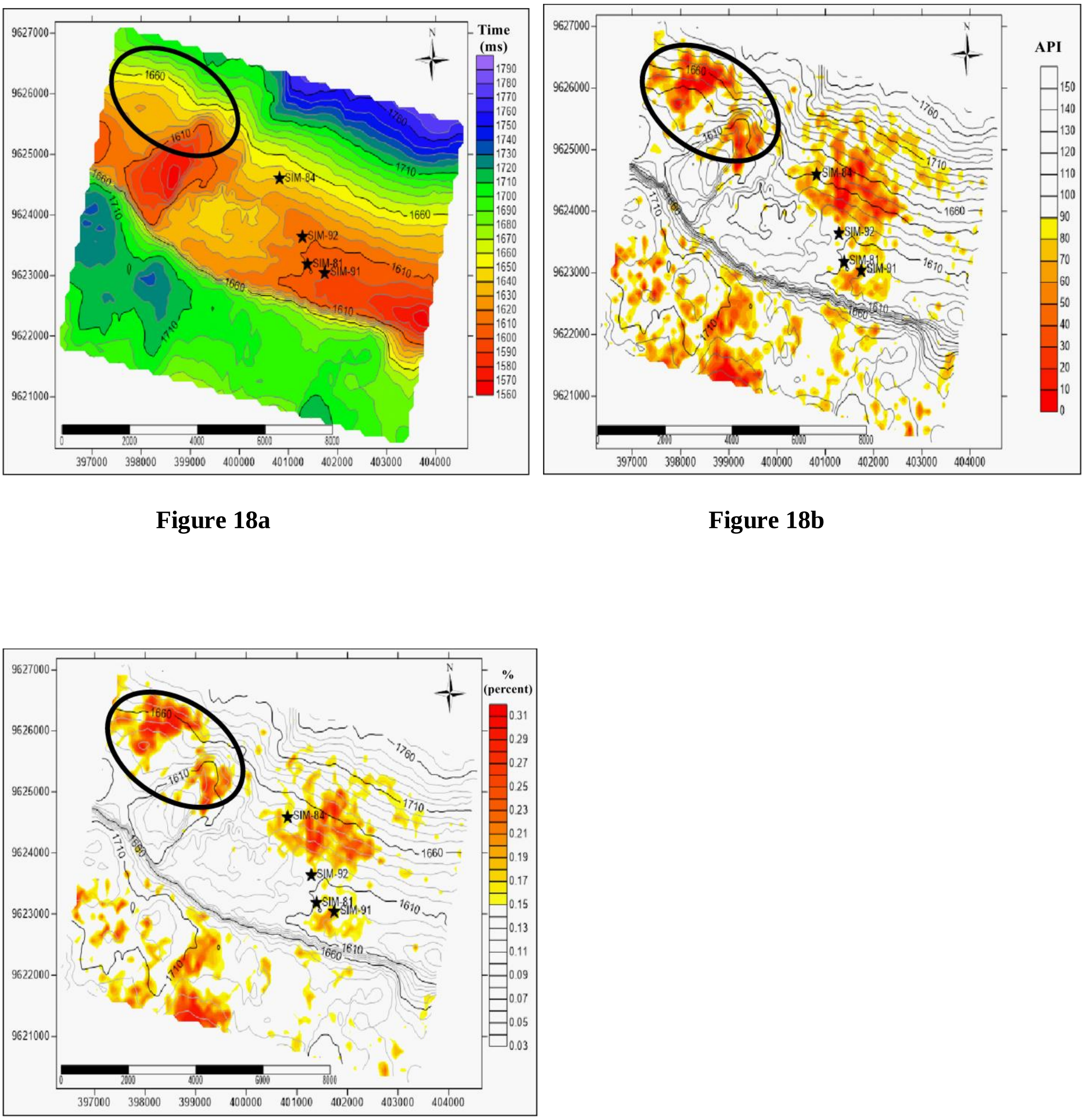


Figure 18a

Figure 18b

Figure 18c

Figure 18 - Areas of potential development in P2 layer based on (a) Time structure map (b) Pseudo Gamma ray map (c) Pseudo Porosity map.