Prediction of PEF and LITH logs using MRGC approach

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Abstract: The Fuzzy logic method offers superior log estimation properties for a large class of well log functions and has been employed as a standard tool in formation evaluation of Oil production zones. However it suffers from spurious behavior in the vicinity of edge trends in log signals. In this article, we used The MULTI-RESOLUTION GRAPH-BASED CLUSTERIN (MRGC) Supervised framework for obtaining lithology properties from PEF & LITH logs that estimated in one of the Well (D) in the field since there is no core data in most wells. Estimations are performed from basic information and model logs of another well (A), including RHOB, NPHI, DT, PHIE, and NDS. Taking advantage of this framework, we show that it is feasible to recover log data from a relatively accurate method especially in inhomogeneous formation than the Fuzzy logic method.

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Introduction

In recent years, fuzzy logic and artificial neural networks have been widely used for reservoir studies. For example, several researchers (Saggaf & Nebrijs, 2003; Cuddy, 1997; Nordlund, 1996; Bois, 1984) have applied neural networks and fuzzy logic in reservoir studies of several fields.

Fuzzy logic was introduced in 1956 by Lotfi zadeh in a paper entitled Fuzzy set. In the fuzzy logic, a membership function is described which allows the membership of more than one class with different membership degrees.

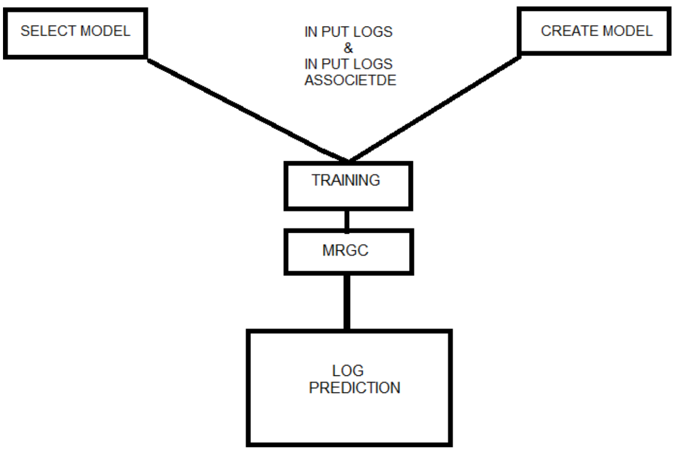
Most previous researchers (Olson and Brill, 1997; Bvbyk et al. 1999; Conte A. et al, 2006; Svtady Vieira, 2008) have attempted to determine PEF and LITH logs but none of them have used MULTI-RESOLUTION GRAPH-BASED CLUSTERIN (MRGC) method.

MRGC is one of the most important hierarchical methods. In this research, MRGC approach is presented to determine petrophysical parameters from well logs in order to create different resolution of the data. In this study, two logs from an oil field are used. In well A, the PEF log is available and the LITH log is derived from core data. These information are used to predict the same logs in well D where PEF and LITH logs are not available.

Methodology

MRGC method uses model logs and associated logs to find a relationship between them to predict PEF and LITH logs, so the estimated logs can be propagated to the rest of the wells.

The MRGS method is, in fact, a combination of artificial intelligence techniques and a hierarchical clustering method. This method uses KRI and NI index parameters which discern it from conventional methods.



WORKFLOW

Suppose there are 6 members, 3 clusters in a resolution and 2 clusters in a higher resolution. In this case, the MRGC method uses a parameter called KRI. In cross-plots, especially in Neutron- Sonic where two points are close to each other and there is no resemblance between them, this method successfully distinguishes them. In this approach, the following indices are added to make the MRGC method more robust than other hierarchical methods:

Neighborhood Index (Neighboring Index): This parameter substitutes the distance parameter. As mentioned before, when two points are close to each other, they can be easily separated if they have high NI. Unlike other hierarchical methods, depending on the facies' behavior, the user can specify the number of facies.

KRI Index: It is a combination of NI, distance and weighted distance function M(x, y) which specifies the Neighborhood or the degree of membership for M. If it is low, it is affected by M; otherwise it has a high membership degree and is not affected by M.

$$\mathrm{NI(X)} = \sum_{N=1}^{n-1} \exp(-m_{n.a}) \qquad (1)$$

Where m the neighbor ranking, a is the resolution parameter.

$$KRI=NI(x)M(x,y)D(x,y) \qquad (2)$$

In which M, is the weighting distance, D is the distance between x and y.
First kernel or the center point which influences all of its neighboring members" is specified", and then all the members will be compared. The members that are influenced by the kernel affect other members as well. The boundaries are, therefore, specified where a member is affected by its previous member but cannot affect other members. So, the boundaries determine the Split point and distinguish different groups based on the parameters. According to this method, the model logs (NDS, RHOB, NPHI, PHIE, and DT) are introduced into the facimage section of the software to get the clusters. The LITH log is then inputted as an associated log and the data are trained.

Figure 1, at first, each log is divided into 2 clusters. Next, clustering is done based on the MRGC method with minimum of 6 and maximum of 15 clusters.

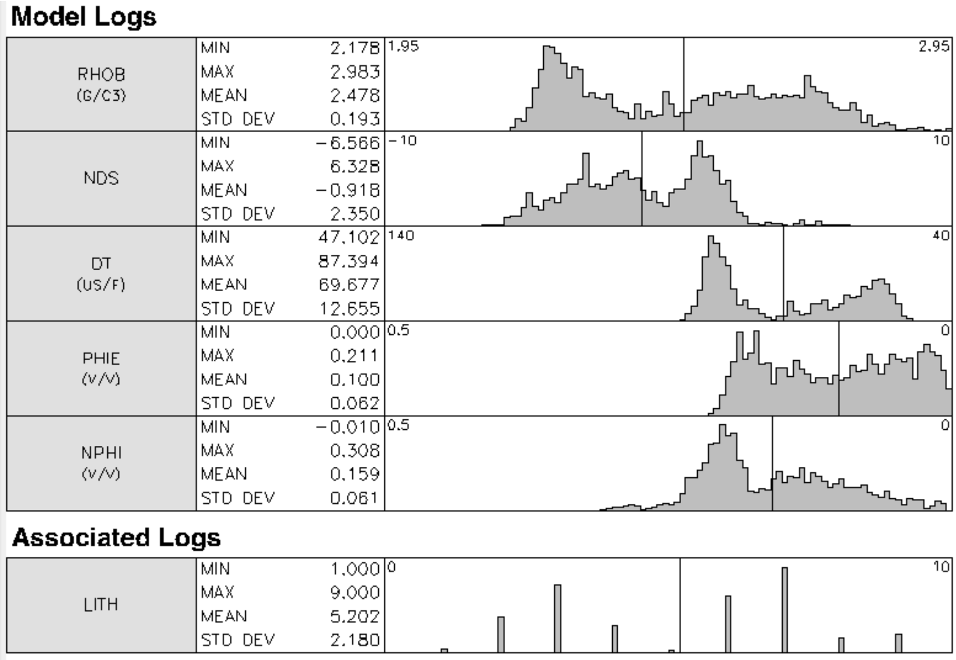


Figure 1: Training the data's model logs as follow:
Model log:"RHOB, NDS, DT, PHIE, NPHI
Associated log: LITH log

Figure 2, 15 clusters have been selected to estimate the PEF log in Well A as a model, where the PEF log is available. The estimated PEF log showed correlation with the actual PEF log in well A. figure 3, the PEF log is propagated to the well D and the derived lithology is drawn.

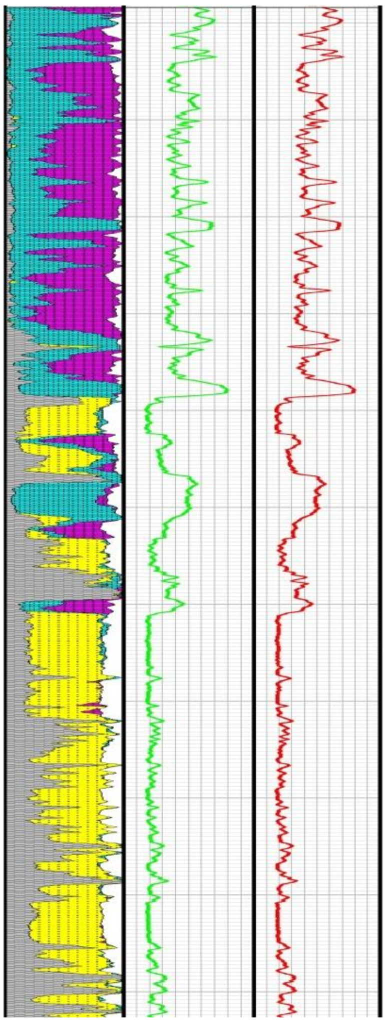


Figure2.Estimated PEF LOG in A well in red Color which has been drawn 0 to 10 and it is having correlation with PEF log in A well

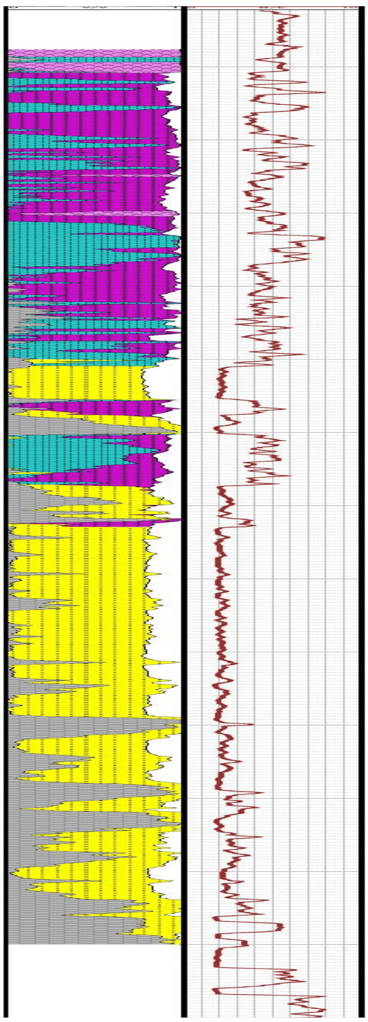


Figure 3.Estimated PEF log in D well IN brown color which has been drawn 0 to 10 and it is having correlation with formation of lithology.

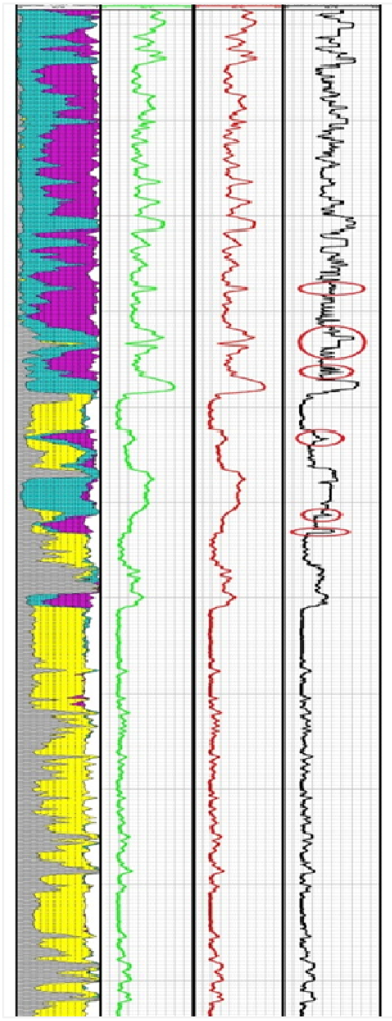


Figure 4.Estimated PEF log by Fuzzy method in black color which has been drawn from 0 t0 10 compared with estimated PEF log by MRGC method in red color and available PEF log in A well. In pointed circle, Fuzzy method has not been operated perfectly and MRGC method has been correlated completely with available PEF log in A well.

Figure 4, the results of FUZZY method is shown in which the RHOB, PHIE, NPHI, DT, and NDS logs are entered and the PEF log is estimated. Clearly, the where it shows a perfect correlation with the original log. predicted PEF log in well A with the Fuzzy method less accurate than the one predicted with the MRGC method

Results and Discussion:

The Lithology of formation is heterogeneous and is divided into dolomitic limestone, sandstone with Anhydrate and shale which is accurately estimated from LITH and PEF logs using MRGC method. The Formation is divided into seven zones A1, A2, A3, A4, A5, A6, and A7.

Shown in Figure 5 from left to right, the first track is the derived lithology, the second track indicates LITH log which is computed from core data and the last track is the estimated LITH log from MRGC method which shows a very good correlation.

Figure 3 shows well D where LITH and PEF logs are not available. The obtained lithology from predicted PEF log shows a good correlation with the obtained lithology from petrophysical logs in Well D. As it can be seen, the result of predicted PEF log is very reliable, i.e., PEF number is 2 in the sandstone, 3 in shale, nearly 3 in limestone and 5 in anhydrite.

The estimated LITH log at well D in Figure 6 shows a high correlation with PEF log and the derived lithology.

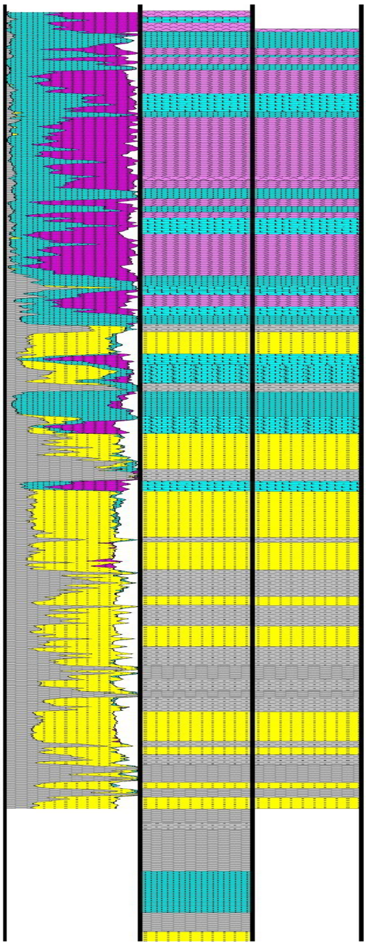


Figure 5. estimated LITH log by MRGC method in left track compared with LITH log obtained from Core in right track in A well.

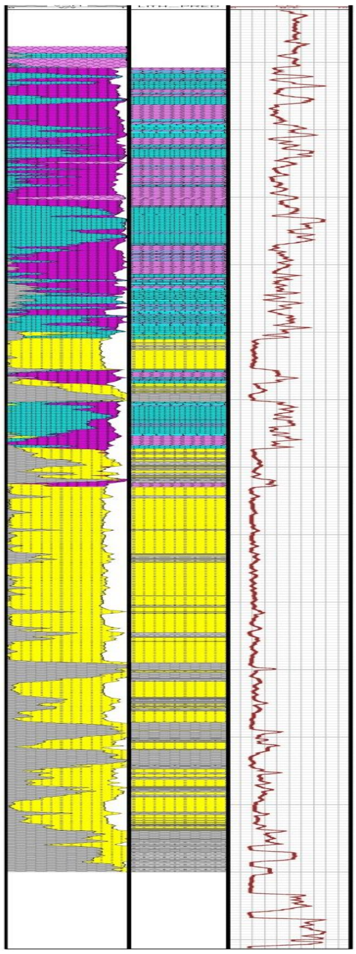


Figure 6.Estimated LITH and PEF log by MRGC method in D well

Figure 7, well A and D are shown in a section which demonstrates a good correlation between them and the zone A6 is the sandstone reservoir zone.

Figure 8, Cross plot of the PEF log and the sonic logs in well A is drawn, in which sonic log data are plotted in the horizontal axis from 40 to 140 microseconds. The colored data, green and yellow points, are the gamma ray log from 0 to 200 API, representing clean sands, shales and shaly sands respectively.

A linear relationship between DT and PEF logs is established as PEF= 9.70276-0.0906589DT and CC= 0.82 which is a high correlation between these logs. As the transit time in the formation is decreased, the corresponding PEF log value is increased.

In this case, the rocks are more condensate and porosity is decreased. The PEF log value approaches 5 to 5.5 which is an indicative of limestone or anhydrate. However, when the sonic log transit time is increased, the PEF log reads a lower value and the formation is more porous.

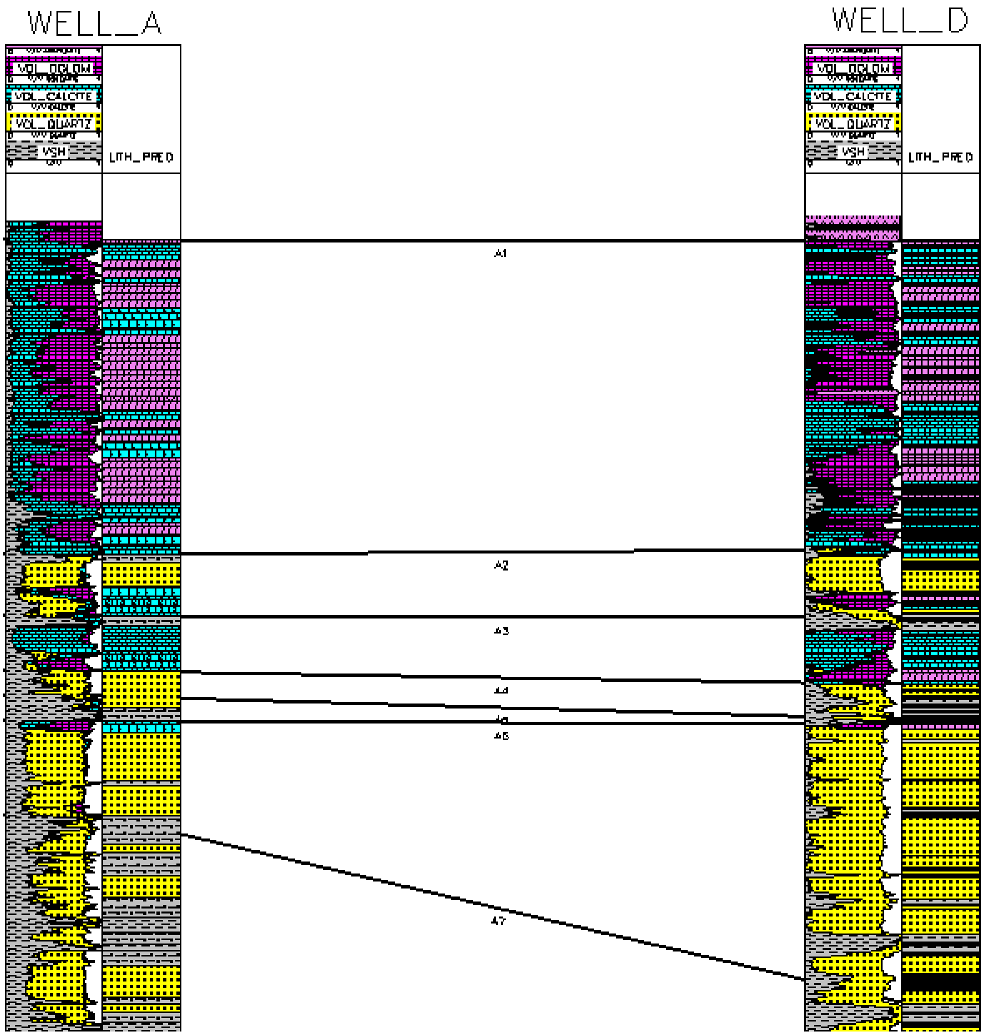


Figure 7. The section of A and B wells and the pointed correlation 7 Zones .

The range 2 to 3 of PEF log refers to sandstone to shale and dolomite (Figure 8). The negative slope of the regression line indicates an inverse relationship between Sonic and PEF log.

Figure 9, the Cross-plot of PEF and neutron logs in well A is shown. Neutron log data are plotted from -0.1 to 0.4 in the horizontal axis and the colored data refer to gamma ray from 0 to 200 API in which the green and yellow points are clean *sands, shaly sands and shales respectively. The linear relationship* between NPHI and

PEF logs is PEF= 5.76276-15.0999NPHI in which CC= 0.69 shows a high correlation.

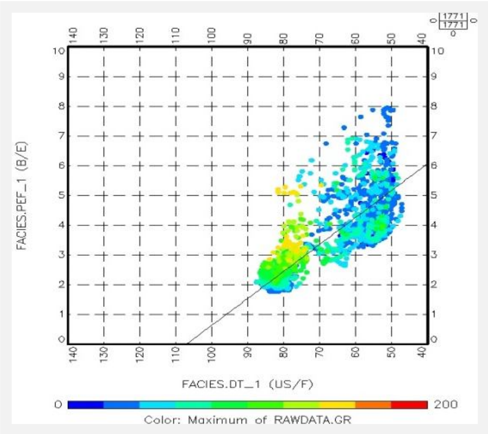


Figure 8. PEF and DT logs cross plot in well A

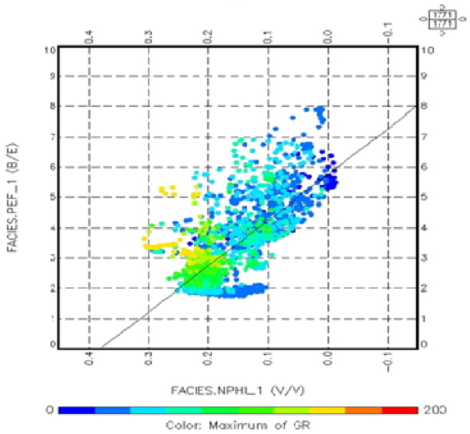


Figure 9. PEF and NPHI logs Cross plot in well

As neutron log reads a lower value, the PEF value increases and the rock tends to be more condensate, with PEF reading 5 belongs to anhydrate and limestone. On the other hand, as neutron log increases, the rocks is more porous and the PEF value decreases which is between 2 and 3 for porous sandstones and shale. The negative coefficient of the regression line indicates an inverse relationship between neutron and PEF logs.

In Figure 10, the Cross-plot of PEF and density logs in well A is shown. Density log data are plotted from 2 to 2.9 g/cm^2 in the horizontal axis and the colored data refer to gamma ray from 0 to 200 API in which the green and yellow points are clean sands, shaly sands and shales respectively.

The linear relationship between RHOB and PEF logs is PEF=-10.4896+5.59337RHOB in which CC= 0.78 shows a high correlation. AS the density log increases, the rocks become more condensate and the PEF value increases too, which refers to limestone and anhydrate. As the density log decreases, the porosity of formation increases.

The PEF value decreases to 2 and 3 for porous sandstones and shale. The positive coefficient of the regression line indicates a direct relationship between neutron and PEF logs.

Figure 11 is the Cross-plot of PEF and NDS logs in well A. The horizontal axis is the NDS log from -10 to 10 and the PEF log is plotted on the vertical axis from 0 to 10 and the colored data are gamma ray log. The NDS log value is negative in sandstones.

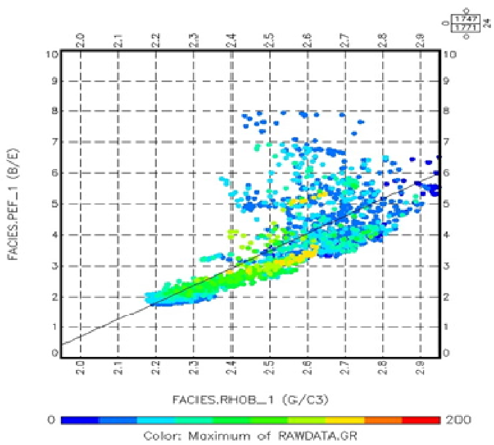


Figure 10. PEF and RHOB logs Cross plot in well A

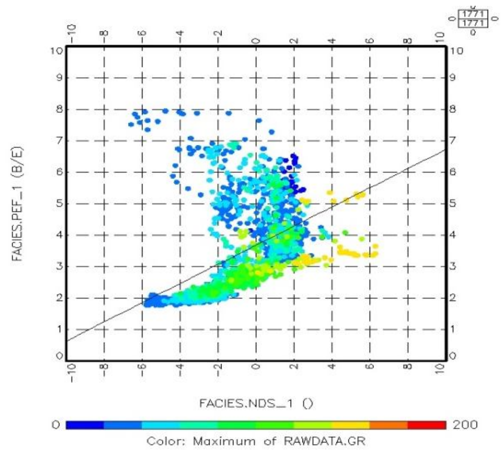


Figure 11. PEF and NDS logs Cross plot in well A

The NDS log value is positive in Anhydrite, dolomite and shale and near 0 where pure lime and the PEF log reads 2 in sandstones. The linear relationship is as PEF= 3.681140+3046690 * NDS and CC= 0.50, which shows a good correlation.
The NDS log is the separation of the neutron – density. In order to be separated, they should be normalized and shown with the same scale. The equation below is used for this purpose (Liu, 2012):

$$NDS=(RHOB-1.95)/0.06-(0.45-NPHI)/0.03 \quad (3)$$

Figure 12, the Cross-plot of the estimated PEF log and the sonic log in well D is drawn with sonic log data plotted in the horizontal axis from 40 to 140 microseconds. The PEF log data are drawn from 0 to 10 in the vertical axis. Points where the transit time decreases show a more condensate rock such as limestone and anhydrate.

At points where the transit time increases, the formation is more porous which tends to be sandstone and shale with green to yellow colors. The estimated PEF log in condensate formations reads 5 for porous rocks.

Additionally, where Sonic log transit time increases, the estimated PEF log reads between 2 and 3 which is related to sandstone and shale. This is an indicative of the correctness of the estimated PEF log by the MRGC method. The linear relationship between sonic log and the PEF log is as: PEF =9.70276-0.0906589 * DT and CC =0.82, which is a high correlation between DT and PEF logs.

Figure 13 is the Cross-plot of the estimated PEF and the neutron logs in well D in which the neutron log is plotted in horizontal axis from -0.1 to 0.4 mV and the estimated PEF log from 0 to 10. As the neutron log increases, the porosity increases as well and the estimated PEF log reads a low value between 2 and 3 which is related to sandstone and shale. As the neutron log decreases, the PEF value reads between 5 and 6.
The range between 5 and 6 shows a dense and less porous formation which is related to limestone and Anhydrite. This indicates that the estimated PEF log by the MRGC method is acceptable. The linear relationship between NPHI and PEF logs is as: PEF= 5.80432-14.7678 * NPHI in which CC= 0.69 .

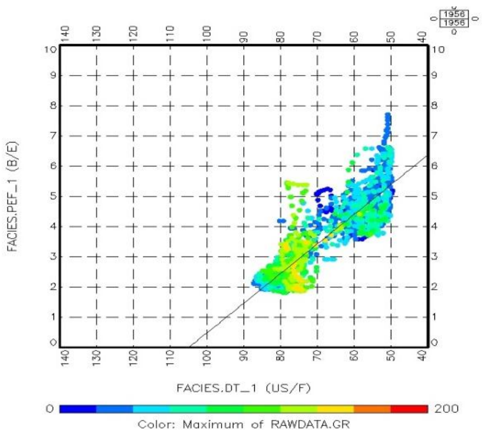


Figure 12: PEF and NPHI logs Cross plot in D well

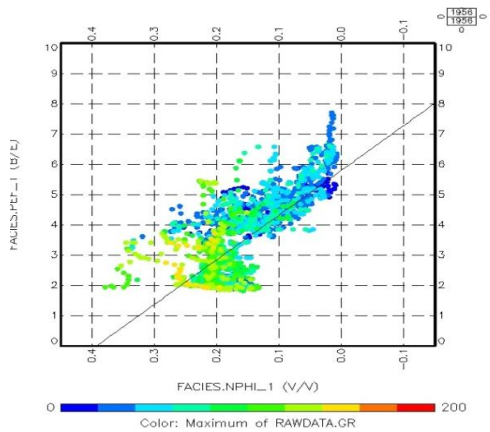


Figure 13. PEF and NPHI logs Cross plot in well D

Figure 14 the Cross-plot of the estimated PEF and the density logs in well D is drawn with the density log data plotted in the horizontal axis from 2 to 2.9 g/cm^2 and the PEF log data are drawn from 0 to 10 in the vertical axis. As the density is increased, the formation becomes less porous and more condense and the estimated PEF log reads between 5 and 5.5 which relates to limestone and anhydrate.
As the Density log reading decreases, the PEF reading is between 2 to 3 which shows porous formations like sandstone and shale rocks .This shows that the estimated PEF log by the MRGC method is excellent. The linear relationship between RHOB and PEF logs is

PEF= -11.53916.07501 with a high correlation of CC = 0.80.

Figure 15 is the Cross-plot of the estimated PEF and NDS in well D. The NDS log is plotted in horizontal axis from -10 to 10 and the estimated PEF log from 0 to

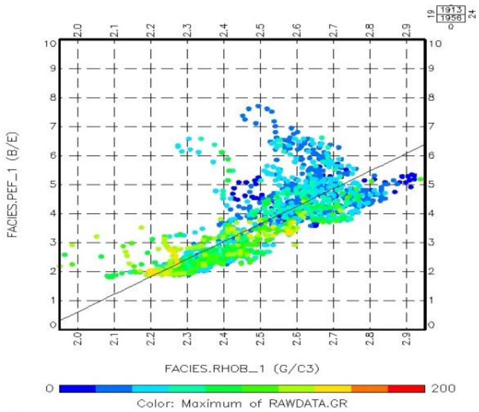


Figure 14. PEF and NPHI logs Cross plot in well D

10. In NDS log, the negative points show sandstones and the estimated PEF log reads 2. The linear relationship between NDS and PEF logs is PEF 3.669210.235632 with CC= 0.41.

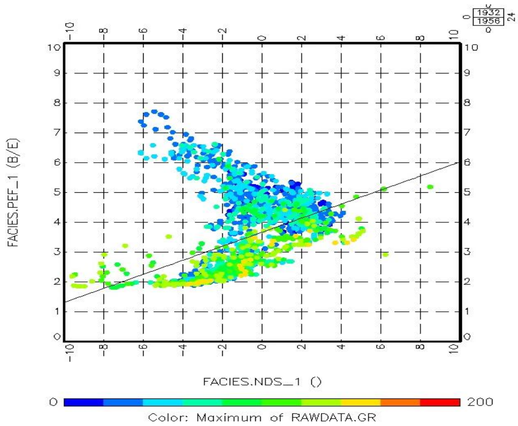


Figure 15. PEF and NDS logs Cross plot in well D

CONCLUSION

To identify formation lithology, it is required to have PEF and LITH logs. However, these logs are not available in old wells. Additionally, there is a limitation of core data and lack of coring in all the wells for lithology identification purposes.

In this study, the MRGC method is performed to estimate well logs. In this method, petrophysical data are grouped into a number of clusters based on NI and KRI indices. Compared to conventional methods, the introduced procedure is robust and shows superior results.

This type of clustering is the advantage of the MRGC method in respect to other clustering techniques. In each obtained cluster from the MRGC method, a relationship between PEF log and the model logs and also, between LITH log and the model logs is derived.

In this study, the formation is divided into 15 different clusters using MRGC method, in which, for each cluster the majority of PEF and LITH logs are derived and the average value of each cluster is related to PEF and LITH logs. For each average value, a number is defined which is the estimated PEF and LITH, so the MRGC method is more accurate. As the number of clusters are increased, the estimated PEF and LITH logs are smoother.

References

1. Bobick, A., Intille, S., Davis, J., Baird, F., Pinhanez, C., Campbell, L., Ivanov, Y., Schtte, A., and Wilson, A., 1999, The KidsRoom: a perceptually based interactive and immersive story environment, RESENCE: Teleoperators Virtual Environ. 8, 367–391.

2. Contea, D., Foggiab, P., Jolionc, J.-M., and Ventoa, M., 2006, AGRaph-based, multi-resolution algorithm for tracking objects in presence of oCClusions, Pattern Recognition 39, 562 – 572.

3. Liu Chengbing, 2012, SYSTEM AND METHOD FOR SWEET ZONE IDENTIFICATION IN SHALE GAS RESERVOIRS, Earth science well logging or borehole study by induction or resistivity logging tool, Patent application number: 20120065887.

4. Olson, T.J., and Brill, F.Z., 1997, Moving object detection and event recognition algorithm for smart cameras, Proceedings of DARPA Image Understanding Workshop, 159–175.

5. Sutadiwirya, Y., Abrar, B., Henardi, D., NuGRoho, B. H., and Wibowo, R. A., 2008, Using MRGC (Multi Resolution GRaph-Based Clustering) Method to InteGRate Log Data Analysis and Core Facies to Define Electrofacies, in the Benua Field, Central Sumatera Basin,

Indonesia, International Gas Union Research Conference, IGRC, Paris.

6. Ye, S.J., and Rabiller, Ph., 2000, A New Tool For ElectroFacies Analysis: Multi-Resolution GRaph-Based Clustering, paper, SPWLA 41st Annual Logging Symposium, June 4-7.

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