Achieving best practices in log pre-processing for facies and permeability modeling

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ACHIEVING BEST PRACTICES IN LOG PRE-PROCESSING FOR FACIES AND PERMEABILITY MODELING

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ABSTRACT

This paper relates the best practices in Log preprocessing in Petrophysics which are necessary to have a good model for Facies and Permeability. The well-logs which were used for the Electrofacies modeling and permeability modeling consist of Gamma-Ray(GR), Bulk Density Porosity(RHOB) Neutron porosity(NPHI). Meanwhile, the model distinct type of facies consists of sand, Shaly sand, and shale. Precise Electrofacies sorting was accomplished by the Multi-Resolution Graph-based Clustering (MRGC). The improvement in the Logs from the Well-X1 after undergoing pre-processing like Log Normalization, Compaction Effect Removal, Fluid Effect Removal returned the logs to their natural states and were used as input into Multi-Resolution Graph-based Clustering (MRGC) model to produce better output Facies and Permeability when compared to the Output which did not undergo pre-processing. These practices can be utilized to validate very good Facies and Permeability Models

Keywords: Log Processing, Log Normalization, Compaction Effect Removal, Fluid Effect Removal, Facies modeling, Permeability modeling

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1. INTRODUCTION

The aim of this paper is to show the best practices to resolve the issues around Logs from several wells that cut similar alternations of facies that are supposed to present comparable statistical parameters, but which are not. Classification of Electrofacies and permeability modeling using well logs and Core measurement is a vital point in uncertainty reduction in characterization of reservoir [7]. Classification of Facies brings improvement in the association amid porosity and permeability which eventually leads to efficient evaluation of petrophysical properties in non-core formation [3].

Classification process started by having the facies modeled with the well-log data for the chosen interval. Based on this model process, the distribution of facies is predicted for the whole depth intermissions for the well and further wells which have not measured facies [6].

There are several algorithms which exist, and which have been used severally for facies prediction and these include Multi-Resolution Graph-based Clustering (MRGC) which is used in this paper for the classification of the Electrofacies. Also, for the permeability modeling and prediction, the Multi-Resolution Graph-based Clustering (MRGC) method [1] [5] was adopted with using core permeability as the associate log for the Permeability prediction in this paper

1.1. Brief Geology of the Study Area

The data for this paper is from Well-X1 in an X-Field in Niger-Delta. The Field is located within NW-SE oriented Miocene depocenters in the wave dominated Western Niger- Delta system. The Basal Akata marine shales provide hydrocarbon source for overlaying Agbada parallic sandstone reservoirs The System overlain by continental to shallow marine sandstones of the Benin Formation.

2. MATERIALS AND METHODS

The data used for this process are shown in Table 1 and Table 2

The data are the composite well log data for an interval in Well-X1 which include the Measure Depth, the True Vertical Depth Subsea(TVDSS), Gamma ray(GR), for the lithology indicator, the Resistivity(RT) , the Neutron Porosity(NPHI) and Bulk density(RHOB) .The GR is used for normalization process, the Neutron Porosity and the Bulk Density logs will be used for the compaction removal process, and also for the fluid removal effect.

The data in table 2 comprise of the Core Permeability data which will be used as the associate log or reference log for the permeability log modeling

2.1. The Log Normalization

Log Normalization: Normalization enhances the removal of logging artifacts, to account for differences in environment, calibration etc, leaving only the preservation of subtle lithological variations and therefore get the same log response in the same facies. Normalization was done on GR. The interactive linear and piecewise linear transformation methods imbedded in Geolog software (Fig 1) were used to have the display in (fig 2) . The “Before GR Normalization” displayed the GR for the Well-X1 which is Red colour against the calibrated GR with Green Colour which was from the next Well in the same field. The GR for the Well-X1 needs calibration to be able to produce a good lithology result. Then the displayed “After GR Normalization” showed the calibrated GR for the Well-X1 with reference to the nearby Well-X2.

2.2. Compaction effect removal

This accounts for the porosity loss for a better comparison of similar facies seen at different depth The Fig. 3 showed the effect compaction has on the Well -X1 when Bulk density is used alone. Hence Neutron-Density Separation (NDS) was used rather than use the Density or Neutron log alone. NDS log cannot be measure but rather, it is a graphical representation of distance between Neutron and Density curves plotted by means of a well-matched limestone scale and recorded with a limestone matrix calibration [4]. The Fig.4 show the output of the Compaction effect removal in the Well which account for porosity loss for a better comparison of similar facies seen at different depth. Computation of Neutron-Density Separation (NDS) log and integration of this in facies and permeability modelling corrects the compaction effect problem as NDS log is not affected by compaction. The computation formula for neutron density separation is:

$$NDS = \frac{(RHOB - 1.95)}{0.05} - \frac{(0.45 - NPHI)}{0.03} \qquad \text{Equation 1[4]}$$

2.3. Fluid Effect removal

The paper showed how important the fluid effect removal could be in Facies and Permeability modeling because If Raw Density and Neutron logs are used, there is wrong recognition of facies especially in gas intervals where low density and neutron leads to a separation (balloon effect) causing wrong facies recognition. In Fig 5 the cross-plot of the Neutron and Density logs, displaying "Before Fluid Effect Removal" and in Fig.6 displaying same logs on layout indicated the effect of the hydrocarbon ,gas especially causing the Neutron and density to read low values and showing a balloon effect on the layout in Fig.6, while in the same Fig 5, the part indicating "After Fluid Effect Removal" and in Fig.6 displaying same logs on layout showed the result that the logs had been corrected for the fluid effect and restore the log responses to water "bearing state. Fluid Effect Removal restores the log responses to water "bearing state" and retain the facies nature. This was applied with the help of Geolog software to keep density and neutron logs unchanged inside the water bearing intervals or restore log responses to water "bearing state.

3. RESULTS AND DISCUSSIONS

The Facies and Permeability modeling starts with the Log normalization of the Gamma ray Log(GR) which improves the removal of logging artifacts, to take care of the variances in environment and calibration. This result into the preservation of subtle lithological variations and therefore get the same log response in the same facies. Then the Compaction Effect was taken care of by generating Neutron Density Separation (NDS) Log. This log is not affected by compaction. The Hydrocarbon Fluid effect was removed from the raw Density and Neutron logs as if the fluid was only composed of water and restores the log responses to water "bearing state" thereby retaining the facies nature. These clean logs form the input for the Facies and Permeability modeling.

3.1. MRGC and Dimensionality Problem in Facies and Permeability Modeling.

In this paper, the issue around dimensionality was resolved by using Multi-Resolution Graph-based Clustering (MRGC) [1] [5] from the FACIMAGE TOOL of Geolog software [2].

Dimensionality problem means log space is not equal to geological space, and two points closer to each other in log space does not mean they are similar geologically [1] [5]

MRGC gives clusters on the ground of distribution of natural points (local Density) at different scales [1] [5].

The Processed logs of GR normalization, NDS log, fluid corrected Density, Neutron logs were used as input logs as the training data , while the Core permeability was used as the associate log for the Permeability log prediction and MRGC KNN Facies prediction and KNN Log prediction in Geolog FACIMAGE TOOL were used to model the Facies and for the permeability. The figures 6 and 7 showed the facies and permeability before and after the Logs namely GR, NPHI and RHOB had been preprocessed through Normalization, Compaction effect removal and Hydrocarbon fluid effect removal. The Fig 7 showed that the facies predicted were affected by the effect of the Hydrocarbon on the input logs, The Porosity were over blown due to the gas effect while in Fig 8, the Fluid effect and Compaction effect were of no effect on the facies and the facies predicted were of better result

4. CONCLUSIONS

To obtain a very reliable Facies and permeability modeling, for any heterogeneity preserving formation, an excellent workflow which includes preprocessing of the well logs by normalization, compaction effect removal and fluid effect removal needed to be performed before proceeding to predict facies and model permeability. This workflow was applied in this paper before the used of Multiresolution-graph based clustering(MRGC) model for the Electrofacies prediction and classification and permeability prediction and modeling

5. TABLES AND FIGURES

Table 1 Well-X1 composite Raw Data

DEPTH FEET	TVDSS FEET	GR GAPI	RT OHMM	NPHI V/V	RHOB G/C3
5915	5346.759	106.6882	1.853	0.36875	2.353
5916	5347.629	101.7728	1.899	0.313	2.35675
5917	5348.498	103.0555	2.925	0.17925	2.24
5918	5349.368	103.984	8.401	0.08825	2.0055
5919	5350.237	103.9965	28.833	0.0615	1.9285
5920	5351.107	102.3668	52.463	0.0635	1.933
5921	5351.976	85.7375	125.439	0.07575	1.9075
5922	5352.845	75.5168	247.751	0.07775	1.90325
5923	5353.715	63.4125	316.672	0.075	1.90025
5924	5354.584	58.55	278.416	0.07225	1.89025
5925	5355.454	67.3757	266.457	0.075	1.89625
5926	5356.323	103.9063	283.197	0.08725	1.93125
5927	5357.192	102.3063	292.809	0.082	1.923
5928	5358.061	70.411	318.593	0.10825	1.8815
5929	5358.931	56.4948	349.718	0.15475	1.88675
5930	5359.8	53.9142	278.705	0.234	1.971
5931	5360.669	51.8055	195.118	0.2775	2.0365
5932	5361.538	48.1753	194.721	0.27675	2.02875
5933	5362.408	49.5677	255.188	0.2705	2.02
5934	5363.277	49.7033	208.092	0.266	2.02275
5935	5364.146	52.3295	134.855	0.27525	2.01025
5936	5365.015	50.667	153.122	0.27375	2.00475
5937	5365.884	52.9847	130.391	0.25575	2.00475
5938	5366.753	54.587	77.469	0.261	2.0065
5939	5367.622	52.652	67.19	0.2815	2.02
5940	5368.491	56.108	43.15	0.2985	2.04625
5941	5369.36	58.114	24.044	0.29225	2.063
5942	5370.229	60.8997	20.868	0.282	2.04475
5943	5371.098	62.3867	30.03	0.28025	2.038
5944	5371.967	63.2022	33.492	0.2845	2.0355
5945	5372.836	60.6815	37.213	0.25125	2.0475
5946	5373.705	66.3992	70.046	0.25575	2.07275
5947	5374.574	67.7985	117.35	0.2865	2.071
5948	5375.443	65.0533	133.692	0.269	2.05075
5949	5376.312	58.237	107.516	0.259	2.0495
5950	5377.181	53.3467	114.064	0.28275	2.05525
5951	5378.05	62.8848	162.364	0.2825	2.05425
5952	5378.919	63.7157	171.113	0.26075	2.03975
5953	5379.787	57.366	146.365	0.285	2.04025
5954	5380.656	52.875	228.057	0.27375	2.02925
5955	5381.525	49.0675	320.481	0.24875	2.05025
5956	5382.394	46.2965	279.093	0.235	2.0755

5957	5383.262	46.344	165.021	0.2685	2.05775
5958	5384.131	45.183	297.84	0.2735	2.0415
5959	5385	46.4907	348.688	0.2465	2.04275
5960	5385.868	43.0457	241.098	0.2405	2.05925
5961	5386.737	42.0168	180.515	0.27125	2.062
5962	5387.606	44.0847	270.484	0.2845	2.0625
5963	5388.474	44.439	305.634	0.25975	2.04775
5964	5389.343	42.679	232.315	0.25425	2.038
5965	5390.212	40.9232	178.509	0.2605	2.04375
5966	5391.08	41.6113	223.345	0.26975	2.03675
5967	5391.949	45.0825	238.668	0.2465	2.02325
5968	5392.817	47.099	178.588	0.259	2.0165
5969	5393.686	49.7803	138.033	0.2935	2.021
5970	5394.554	48.676	123.314	0.276	2.02825
5971	5395.423	47.9475	102.624	0.26975	2.04
5972	5396.291	48.8773	90.567	0.2685	2.0465
5973	5397.16	50.5215	63.105	0.2945	2.04975
5974	5398.028	52.8228	41.985	0.27975	2.05025
5975	5398.896	53.6588	31.228	0.2565	2.0405
5976	5399.765	53.0858	25.041	0.27225	2.053
5977	5400.633	57.4533	18.024	0.2785	2.0595
5978	5401.501	58.34	17.568	0.2665	2.044
5979	5402.37	57.6732	20.661	0.27275	2.02725
5980	5403.238	57.4615	26.876	0.27375	2.00475
5981	5404.106	55.348	52.142	0.262	2.00775
5982	5404.975	50.4645	91.709	0.256	2.031
5983	5405.843	48.4063	109.511	0.25875	2.041
5984	5406.711	50.544	87.167	0.274	2.03275
5985	5407.579	52.2702	43.943	0.27225	2.0465
5986	5408.448	61.5062	20.076	0.253	2.04825
5987	5409.316	62.2383	20.984	0.271	2.0615
5988	5410.184	64.4447	17.391	0.27975	2.0675
5989	5411.052	74.2695	18.946	0.27325	2.0895
5990	5411.92	66.9942	37.225	0.25725	2.07625
5991	5412.788	45.418	94.814	0.25675	2.0465
5992	5413.656	36.332	236.832	0.26775	2.0325
5993	5414.524	33.6395	443.287	0.26975	2.0125
5994	5415.392	33.8722	504.777	0.254	2.02225
5995	5416.26	32.911	639.558	0.2675	2.035
5996	5417.128	28.745	789.709	0.26225	2.0255
5997	5417.996	24.9002	846.453	0.24925	2.0155
5998	5418.864	26.484	868.891	0.25725	2.02125
5999	5419.732	29.7965	945.219	0.2525	2.01625
6000	5420.6	29.1105	1090.157	0.2555	2.0135
6001	5421.468	29.473	1128.004	0.25875	2.017
6002	5422.336	33.3162	706.129	0.283	2.03475
6003	5423.204	38.112	330.857	0.2885	2.05075
6004	5424.072	36.2142	301.402	0.28475	2.04575
6005	5424.94	39.3843	343.709	0.2775	2.053
6006	5425.807	41.7445	269.807	0.28425	2.04975
6007	5426.675	49.397	185.425	0.29775	2.04675

Table 2 Well-X1 Core Perm Data

DEPTH	CORE PERM
FEET	mD
5715	30.4
5716	72.5
5717	38.2
5718	130
5719	152
5720	61
5721	89.8
5722	49
5723	54.7
5724	14.3
5725	36.3
5726	131
5727	12.2
5728	167
5729	363
5730	148
5731	324
5732	279
5733	532
5734	504
5735	680
5736	361
5737	444
5738	517
5739	250
5740	187
5741	64.5
5742	9.68
5743	8.41
5744	10.5
5745	695
5746	1100
5747	1290
5748	1370
5749	1660
5750	2740
5751	2970
5752	2810
5753	2630
5754	815
5755	2600
5756	887
5757	1130
5758	1530
5759	4160
5760	5020
5761	5240
5762	4530
5763	4700
5764	7020
5765	6600
5766	5760
5767	5800
5768	6910
5769	4860
5770	2800
5771	4740
5772	4500
5773	3730
5774	3070
5775	3780
5776	2020

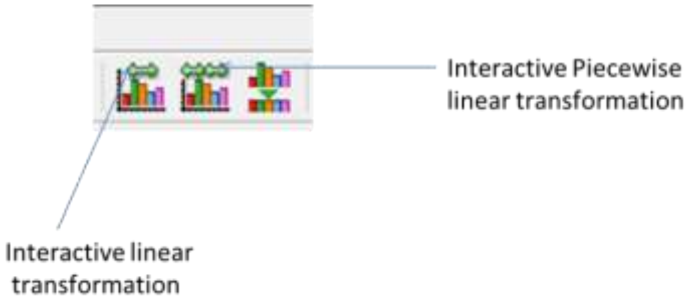

Figure 1 Log Normalization methods [1]

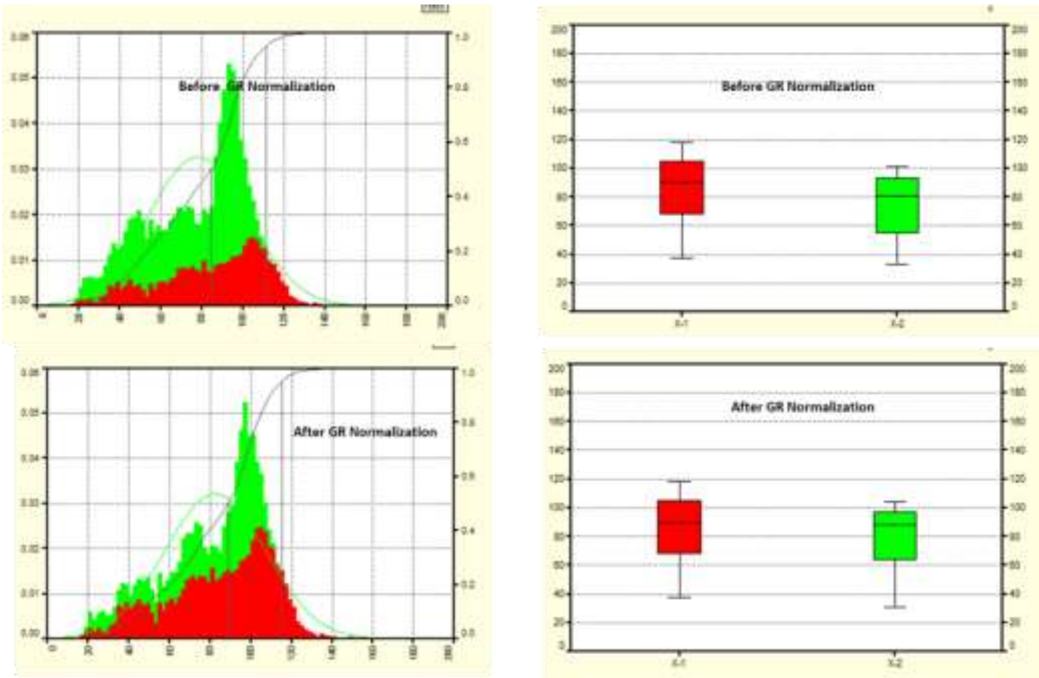

Figure 2 GR Normalization of the Well

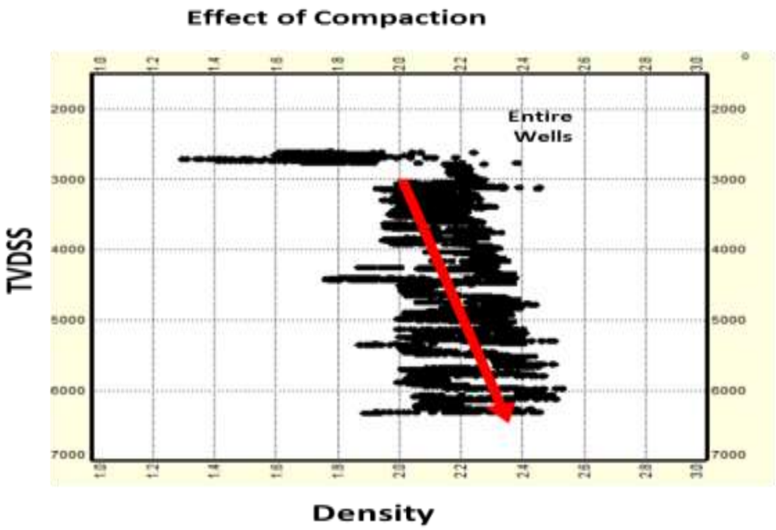

Figure 3 Effect of Compaction on Density

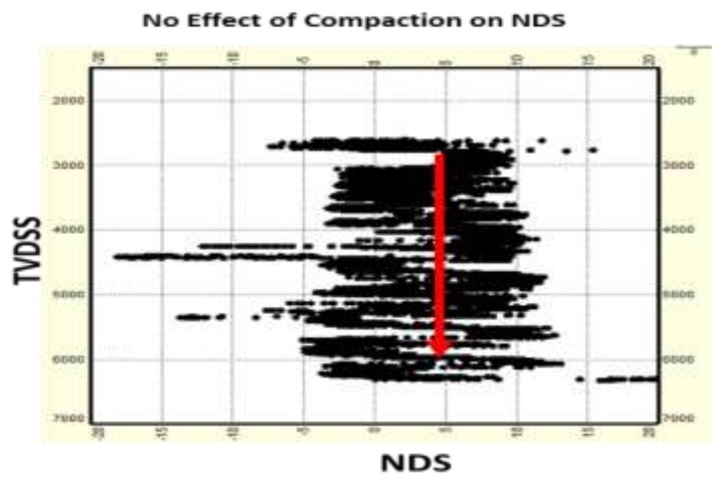

Figure 4 Compaction Effect Removal Via Neutron-Density Separation (NDS)

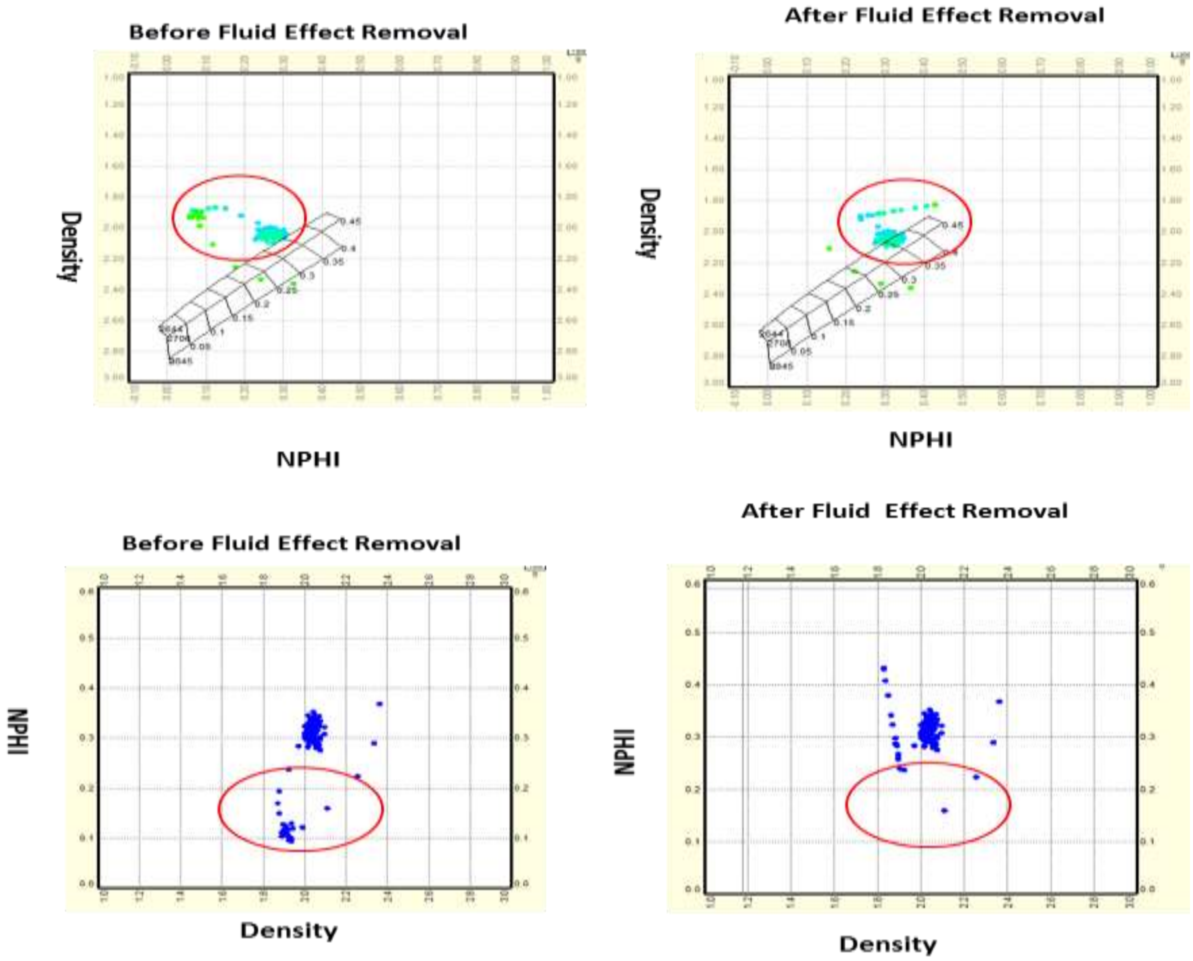

Figure 5 Fluid Effect Before and After Removal

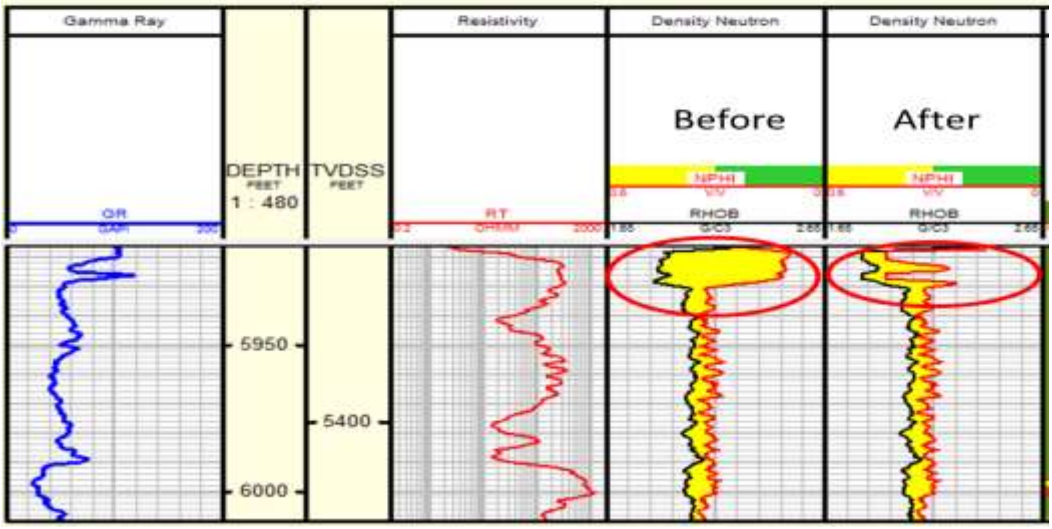

Figure 6 Fluid Effect Removal

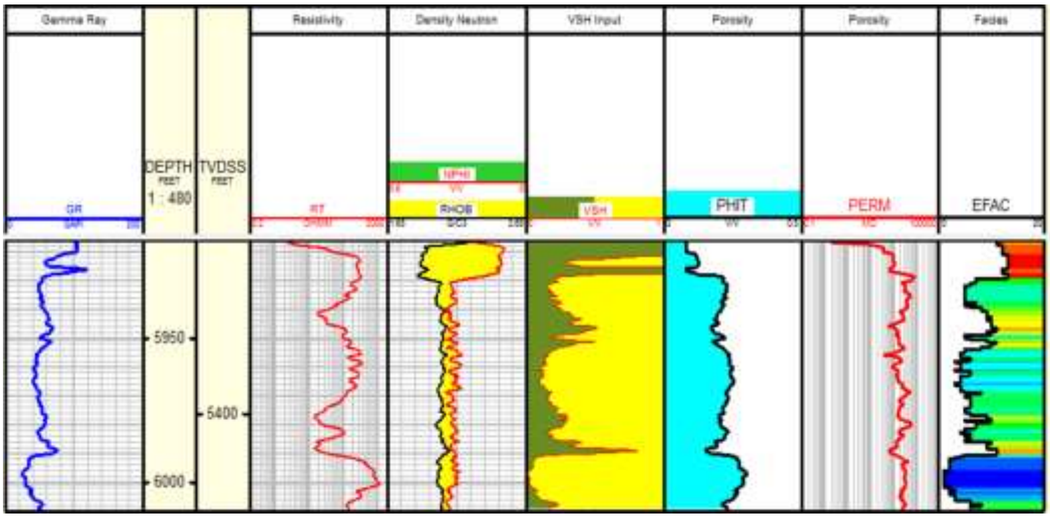

Figure 7 Outcome without the Preprocessing of Logs

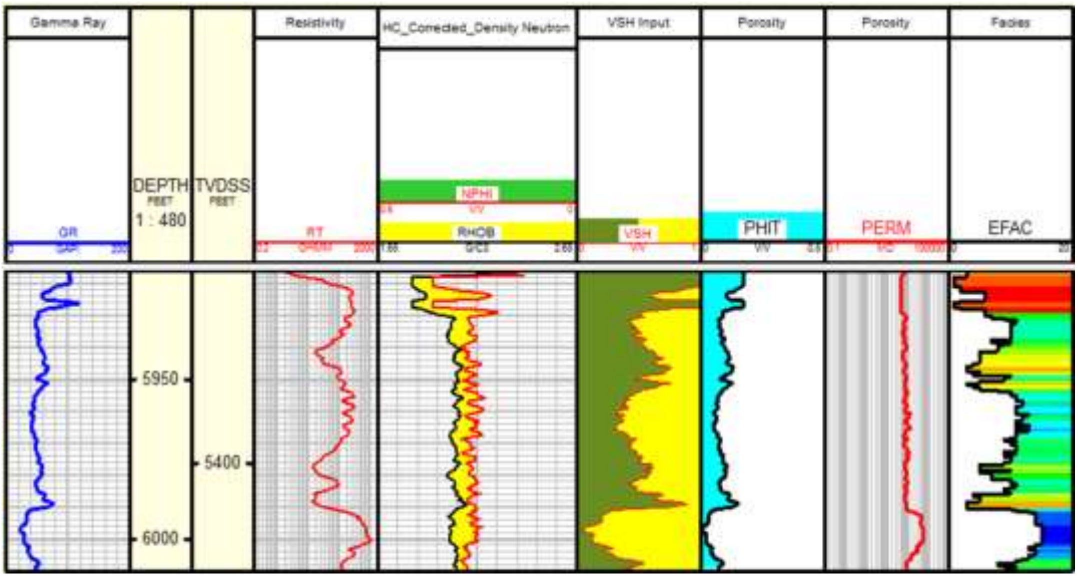

Figure 8 Outcome with Preprocessing of Logs

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NOMENCLATURE

Core Perm= Core Permeability

EFAC = Electrofacies

GR = Gamma Ray

KNN = Kennel Nearest Neighbour

MRGC = Multi-Resolution Graph-based Clustering

NPHI = Neutron porosity

NDS = Neutron Density Separation

PHIT= Total Porosity

RHOB= Bulk Density

RT= True Resistivity

TVDSS = True Vertical Depth Subsea

REFERENCES

[1] Asgari. A.A "A fully integrated approach for the development of rock type characterization, in a middle east giant carbonate reservoir", Journal of Geophysics and Engineering, 09/01/2006.

[2] Geolog® – Paradigm® 18 Emerson Paradigm Holding LLC., 2018. http://www.pdgm.com/products/geolog/

[3] Lee S.H. and Datta-Gupta A. (1999) Electro facies characterization and permeability predictions in carbonate reservoirs: role of multivariate analysis and nonparametric regression. In: SPE annual technical conference and exhibition (3–6 October), Houston, Texas. doi: 10.2118/56658-MS.

[4] Paradigm B.V., Electrofacies Analysis Using Facimage in Geolog 8 Paradigm® 17,2017, pp 6-2

[5] Ye S.J. & Rabiller P. A (2000) New Tool for Electro facies Analysis: MRGC Multiresolution graph based clustering, 41st Annual SPWLA Symposium,.

[6] Watheq J. Al-Mudhafar (2017) Integrating well log interpretations for lithofacies classification and permeability modeling through advanced machine learning algorithms. Journal of Petroleum Exploration and Production Technology, Volume 7, Number 4.

[7] Xu C., Heidari Z. and Torres-Verdin C. (2012) Rock classification in carbonate reservoirs based on static and dynamic petrophysical properties estimated from conventional well logs. In: SPE annual technical conference and exhibition (8–10 October), San Antonio, Texas, USA. doi: 10.2118/159991-MS.