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Log facies Prediction Using Self-Organizing Map for Carbonate Mishrif Reservoir in Buzurgan Oil Field, Southeastern Iraq

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ABSTRACT

In this paper, the author introduces a machine learning model to classify the facies of the Mishrif Formation in two wells in the Buzurgan oil field, southeastern Iraq, and then tests the results against the actual facies data. The model also utilizes data from this field, and a new model is introduced: the Self-Organizing Map (SOM), which is the best fit in cases where facies data is lacking or users are geologically inexperienced. The available data of well logs for the studied wells (BU-3 and BU-13) are imported to the Interactive Petrophysics software, which is used to create a SOM facies classification model. The wireline logs include Gamma Ray (GR), compensated neutron tool (CNL), Sonic log (borehole compensated BHC type), and formation density compensated (FDC). Petrographic and microfacies analysis of the subsurface section at well BU-3 enabled the recognition of five main environments: deep marine, shallow open marine, shoal, rudist biostrome, and lagoon. Geologic logs in the SOM technique are used to determine the different facies when dealing with intervals devoid of cores and cuttings, and the resultant log facies are used to interpret those intervals. The environments of well BU-13 are defined after examining available thin sections of cores and cutting samples from well BU-3, and then created using the SOM model. Comparison between the SOM technique using Interactive Petrophysics software and petrographic analysis of the subsurface section is made. The current study reaches 71.3%, providing a good calibration between log-derived facies and core-based descriptions of the Mishrif Formation.

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التنبؤ بالسحنات الجسية باستخدام خارطة التنظيم الذاتي لمكمن المشرف الكاربوناتي في حقل بزركان النفطي، جنوب شرقي العراق.

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الملخص

يقدم الباحث في هذا البحث نموذج التعلم الآلي لتصنيف السحنات الخاصة بتكوين المشرف في بئرين في حقل بزكان النفطي جنوب شرق العراق ومن ثم اختبار النتائج مع بيانات السحنات الفعلية. يستخدم النموذج أيضًا البيانات بناءً على هذا المجال وتم تقديم نموذج جديد وهو خريطة التنظيم الذاتي(SOM). سيكون نموذج (SOM) هو الأفضل في حالة عدم وجود بيانات السحنة أو عدم وجود الخبرة الجيولوجية للمستخدمين. تم استيراد البيانات المتوفرة لمجسات الآبار المدروسة (BU-3) و(BU-13) الى برنامج Interactive Petrophysics الذي استخدم لإنشاء نموذج تصنيف سحنة. SOM تشتمل المجسات البئرية المدروسة على أشعة كام(GR) ، والمجس النيتروني (CNL)، والمجس الصوتي (نوع BHC) ، ومجس كثافة التكوين (FDC). امكن تحليل الصخور والسحنات الدقيقة التحت السطحية في البئر BU-3 من التعرف على خمس بيئات رئيسية، وهي البيئات البحرية العميقة، والبيئات البحرية الضحلة المفتوحة، والمياه الضحلة، والرودست الحيوية، والبحيرات الشاطئية اللاكونية. تم استخدام المجسات الجيولوجية بتقنية SOM لتحديد السحنات المختلفة عند التعامل مع فترات خالية اللباب الصخرية او الفتات الصخري وتم استخدام السحنات الجيولوجية الناتجة لتفسير تلك الفواصل المفقودة. تم تعريف بيئات البئر BU-13 بعد دراسة الشرائح الصخرية الدقيقة المتوفرة والعينات المقطوعة من البئر BU-3 ثم تم مقارنتها باستخدام نموذج SOM. تم إجراء مقارنة بين تقنية SOM باستخدام برنامج IP والتحليل الصخري للمقطع تحت السطح. وصلت الدراسة الحالية إلى دقة تقريبا 71.3% مما يوفر معايرة جيدة بين السحنات المشتقة من المجسات والشرائح الصخرية المدروسة من نماذج اللباب الصخرية لتكوين المشرف.

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Introduction

Lithofacies are traditionally recognized from cores. Although core recovery is frequently less than 100%. Collecting cores is expensive and yields direct measurements of lithofacies. Additionally, core description might take a long time, and it is reliant on the knowledge of geologists. Thus, it would be ideal to have a less expensive technique that doesn't require cores but offers comparable or better accuracy and resolution. The study of rock distribution in the depth-interest domain is known as facies classification, and it is one of the most important procedures in the characterization of reservoirs. There are several ways to classify facies, but there are two main situations: complete information and incomplete data. The first step is to extract a sample of rock from the target well and identify the rock component using laboratory testing. (Kohonen, 2001). Although this technology is minimal risk and produces very precise results, it is not economically feasible. In the second, discriminant analyses are used to get rock samples from certain places, and to gather indirect test data from all target regions, including the locations of the rock samples, and attempt to deduce the mapping function between input (indirect measurements) and output (facies). (Kohonen, 2013). Additionally, it is challenging and time-consuming to manually examine a significant volume of this digitized data due to the poor accuracy rates and complexity of well log data. As a result, a different strategy has emerged that makes this interpretation task simpler and more precise. In terms of the Self-Organizing Map (SOM), it is a machine learning method. The Buzurgan oil field's facies are classified using a machine learning model, which is presented in this research along with test results using real facies data. This model makes use of data from this field as well, but we also provide a novel model—the Self-Organizing Map (SOM). Previous studies have provided extensive descriptions of the use and significance of electrofacies (EFs) in reservoir characterization (Serra and Abbott, 1982; Moline and Bahr, 1995). The foundation of this approach is the log answers for a certain bed and how it differs from the nearby lying beds.

Aim of the study

The goal of this study is to predict microfacies and paleoenvironment of well Bu-13 for Mishrif Formation in Buzurgan oil field after comparing with the microfacies description in key well (Bu-3), which was deduced from available thin sections and well logs. The log facies module is used to predict and propagate rock classification groups using Interactive Petrophysics (IP) software. The module is able to help you with your geological interpretation of log data and facies prediction by providing a 2D indexed and probabilized self-organizing map. The self-organizing map approach is developed for optimally deriving petrophysical parameters, such as hydraulic units, and for geological interpretation of well log data and facies prediction.

The study Area

The Buzurgan oil field lies in the Missan province, south of Iraq. Approximately 300 kilometers southeast of Baghdad and 40 km northeast of Amara City, Buzurgan oil field is located close to the border between Iraq and Iran (Fig.1). Tectonically, the Buzurgan field is located in the Mesopotamian Basin (Buday and Jassim, 1987) (Fig.1). Depositional setting, fracture intensity, and structural style are all directly impacted by this setting. Two boreholes in the Buzurgan oil field (Bu-3 and Bu-13) have been studied. It lies within the Universal Transverse Marketer (U.T.M) coordinates (Table 1). The structure of the field runs in a NW-SE direction and is made up of two domes.

Table 1: Wells coordinates and the top and bottom of the Mishrif Formation in the Buzurgan oilfield.

Wells	Northern	Eastern	Top (m)	Bottom (m)
BU-3	730686.9	3551009.1	3689	4053
Bu-13	729505.38	3551000.45	3670	4019

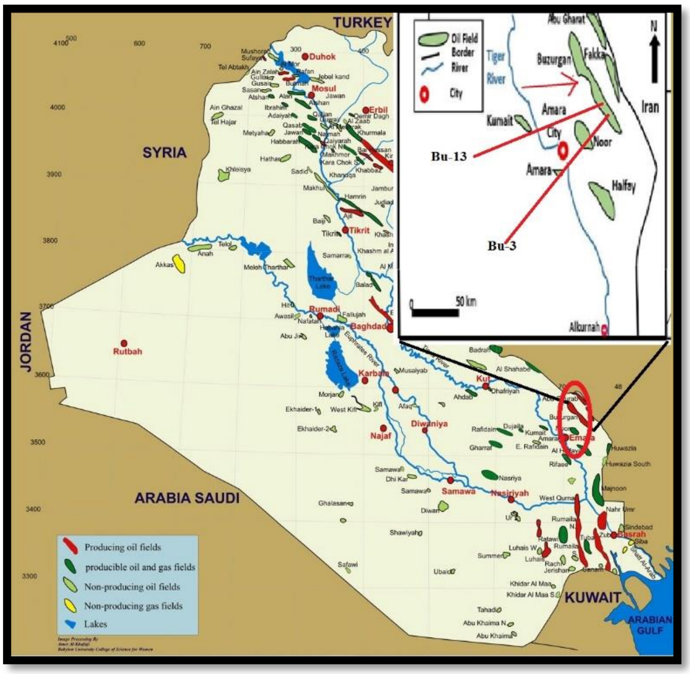


Fig. 1. Location map of the study area with studied wells (modified from Al-Khafaji *et al.*, 2013).

Stratigraphic Setting

The Mishrif Formation (Cenomanian-Early Turonian) expresses a heterogeneous carbonate succession originally characterized as organic detrital limestones, capped by limonitic freshwater limestone (Mohammed and Mahdi, 2019). The Mishrif Formation, which consists of limestone, marl, and shale layers, is one of Iraq's most important geological formations since it is one of the country's primary oil-producing reservoirs, accounting for a major amount of Iraq's oil reserves. The Iraqi Government and multinational oil firms have actively investigated and developed the formation, which now contains several oil fields (Al-Heeti *et al.* 2023).

As a component of the Wasia Group, the Mishrif Formation was formed over the Arabian Gulf during the Cretaceous in the secondary sedimentary cycle (Cenomanian-Early Turonian).

According to Sadooni and Aqrawi (2000), the formation is a carbonate series characterized by simple shallow open marine carbonates. According to Jassim and Goff (2006), the type area's formation is made up of thick, algal limestones with shell fragments above and detrital, porous, foraminiferal limestones with rudist debris below. According to Al-Ali *et al.* (2019), the formation was formed in a carbonate platform ramp environment. It is made of bioclastic-detrital limestone with rudist, algal, and coral facies. The transition from the shallow open marine facies to the basinal Rumaila Formation is represented by the lower limit of the Mishrif Formation. The surface is conformable (Aqrawi *et al.* 2010). An unconformity surface that divides the Middle from the Late Cretaceous truncates the upper border with the Khassib Formation (Aqrawi *et al.* 2010). The equivalent formations to the Mishrif Formation are the Gir-bir Formation in the north and the Balambo Formation in the deeper eastern and intrabasinal zone of the same basin as the Dokan Formation. The tectonostratigraphic megasequence AP8 of Sharland (2001) (Aqrawi *et al.*, 2010) corresponds to the Cenomanian - Early Turonian, which includes the Mishrif Formation (Fig. 2). Megasequence AP8's thickness rises over Iraq from west to east, reaching 2000 meters in the Balambo-Garaa Basin's axis. In the Buzurgan field, the thickness of the Mishrif formation varies from 221 to 380 meters.

	Age	Formation	Lithology	Note
Tertiary	Pliocene	Bakhtiary	Marly clay + Gypsum + Sandy clay	
	Upper Miocene	Upper Fars	Gravel Sand + Siltstone + Anhydrite + Shale	
	Middle Miocene	Lower Fars – MB5	Shale + Anhydrite + Limestone + Dolomite	
		Lower Fars – MB4	Shale + Anhydrite + Salt + Limestone	
		Lower Fars – MB3	Anhydrite + Salt + Shale	
		Lower Fars – MB2	Salt	
		Lower Fars – MB1	Anhydrite + Shale + Dolomite	
	Burdigalian	Jeribe/Euphrates	Limestone + Dolomite	Asmari Formation
	Aquitanian to Oligocene	Upper Kirkuk	Sand + Siltstone + Shale + Dolomite	
		M-L Kirkuk	Sand + Siltstone + Shale	
	Eocene to Paleocene	Jaddala	Limestone + Marl + Chert + Shale	
		Aaliji	Marl + Limestone	
Cretaceous	Lower Maastrichtian	Shiranish	Chalky Limestone	
		Hartha	Chalky Limestone	
	Campanian to Santomian	Sadi	Limestone + Marl	
	Coniacian to Turonian	Tanuma	Shale + Marl + Limestone	
		Khasib	Limestone + Shale	Unconfor mity
	Lower Turonian to Upper Cenomanian	Mishrif	Limestone	
		Rumaila	Limestone	
		Ahmedi	Marl + Limestone	
	Lower Cenomanian	Mauddud		
		Nahr Umr		

Fig. 2. The stratigraphic column of the Buzurgan oil field (Mohammed *et al.*, 2022).

Materials and Methods

In this study, a suite of well **logs,** which are less costly than utilizing core determination and offer indirect information on the subsurface, is employed. Log measurements from wells may be categorized into log facies. Log facies allow for the distinction of different beds or sedimentary units by reflecting the characteristics of both rock and fluid. When log facies are calibrated using core descriptions, they frequently match lithofacies. Log facies can therefore be built as lithofacies' stand-ins. Classifications of the detected log facies can then be applied to forecast non-cored intervals in cored wells or lithofacies in non-cored wells. At first, several clustering techniques were used to density log (RHOB), neutron log (NPHI), sonic log (DT), and gamma-ray (GR) log data to ascertain electrofacies for the Mishrif Formation in the Buzurgan field. Self-organizing maps (SOM) and multi-resolution graph-based clustering (MRGC) are two clustering techniques. In this study, the supervised clustering algorithms is applied to study well to predict lithology from well log data: Multi Resolution Graph-Based Clustering (MRGC) (Fig. 3) and Self-Organizing Maps (SOM) (Fig. 4). The clustering strategy that determines the ideal number of clusters and exhibits the best division between the various zones and levels is the most effective. Any alteration in the log trend can be taken into account to determine this ideal separation. Following an analysis of these four clustering techniques, the (SOM) approach has shown a better sensitivity in accurately differentiating several strata with varying petrophysical parameters at varying depths. The SOM method is the most effective technique to identify log facies and distinguish between various layers in this area when compared to the other four clustering methods examined in this study.

First, the author takes a set of input vectors (data from used logs: gamma ray, neutron log, density log, and sonic log) and presents it to a map grid of 'n' dimensions. In the case of the IP SOM, we are working with a 2-dimensional map. The map is initialized with a certain number of nodes, which, since we are using a square map, is equal to:

$$\textit{Total nodes} = \textit{map width}^2 \quad \ldots\ldots\ldots\ldots\ldots (1)$$

The nodes in the map each have a weighting value for the different input vectors. If you are using four input curves, then the node will store its weighting for each of those four curves. These weightings are visually presented on the map as bar graphs in each node, colored by the input vector. To start the training process, the weights in each node are initialized to a random value. Note that due to this random starting value, the trained map result will be different every time the SOM is trained. However, once trained, a map can be used for each different type of calibration or clustering without the need for retraining. Once the map is initialized, the input data is presented to the map. For each level of input data, the "Best Matching Unit" is calculated, that is, the node that most closely matches the input data given.

The Self-Organizing Maps (SOM) module arranges data according to a mathematical method so that a map may be created. Although standard neural networks are trained on a calibration curve, SOMs are a type of neural network that is self-taught. The SOM is calibrated to predict a continuously alternating curve, such as permeability, or to produce a facies type curve, related to the Cluster Analysis module. The size, shape, and training parameters of the SOM, as well as the number of training iterations to be carried out, are configured using the Train SOM. The data used are from two wells selected (Bu-3 and Bu-13), such as gamma ray log, neutron log, sonic log, and density log on the Input Tab. The classic SOM is a square map where each node is connected to its neighbors in a square grid. One of the drawbacks of this arrangement is known as the "border effect". This effect causes nodes along the border of the grid to be more poorly trained compared to nodes in the center. In order to mitigate and indeed remove this effect, there are two further SOM geometries available, which can be used to achieve a better-trained map.

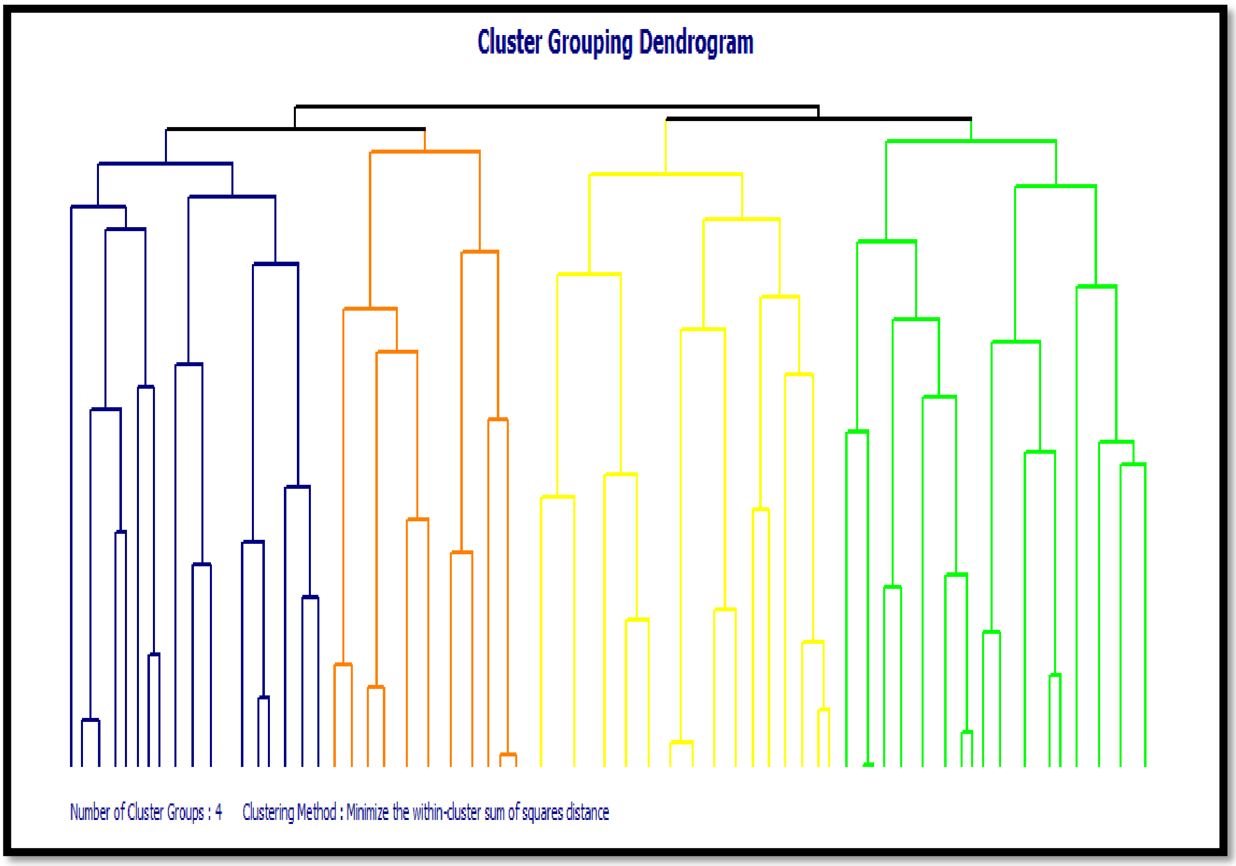


Fig. 3. Dendrogram Graph-based Clustering for Mishrif Formation.

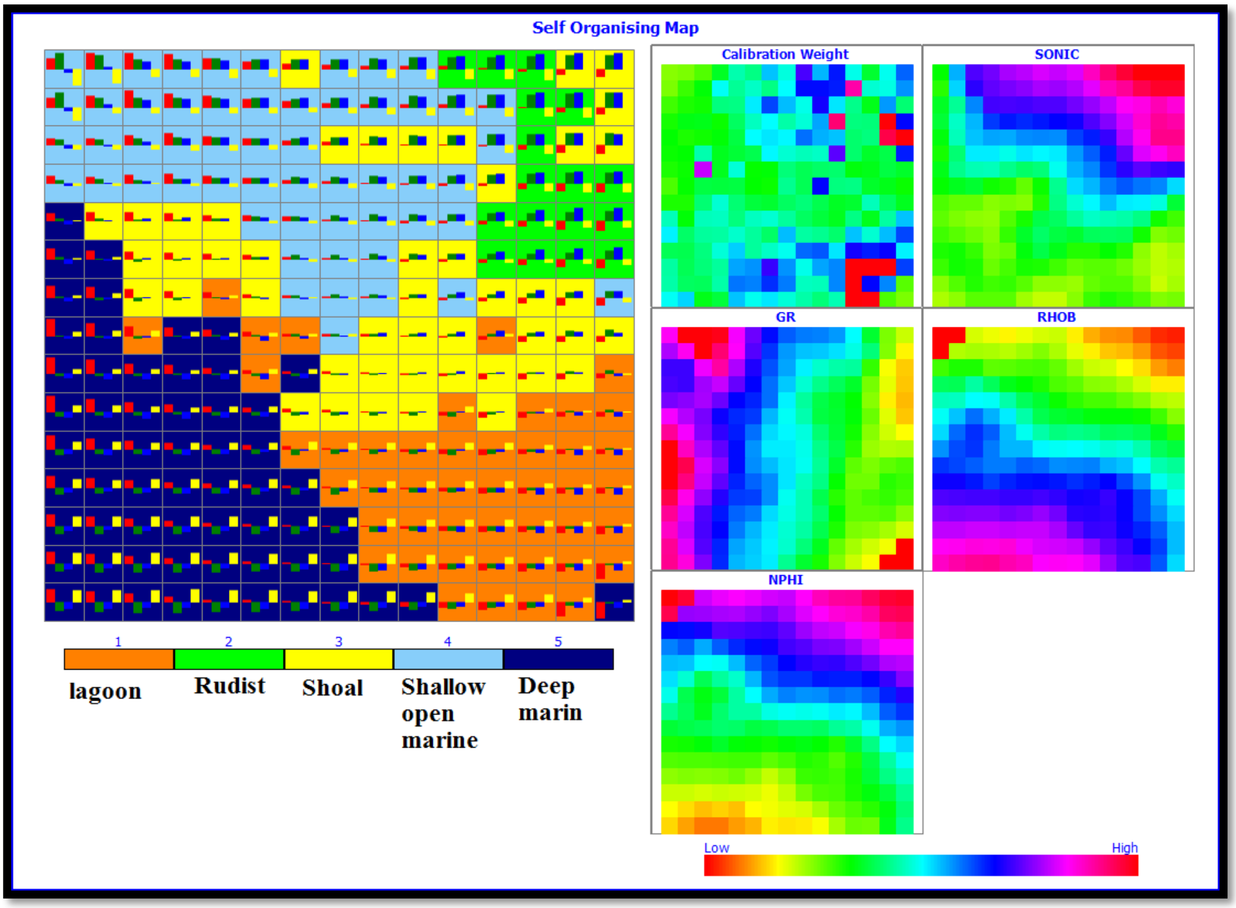


Fig. 4. Self-Organizing Maps (SOM) with calibration logs for the Mishrif Formation.

Results and Discussion

The interpretations of the sedimentary environment are compared with conventional microfacies of Wilson (1975) and facies zones for Flügel (1982 and 2004) based on the types of microfacies discovered in this study. Five main facies associations are identified in well BU-3 by microscopic analysis of thin sections, and they are listed in Figure 5. These include: 1- Lagoon facies that consists of benthonic foraminiferal wackstones (Fig. 6A) and Milliolidic mudstones to wackstones (Fig. B), 2- Rudist biostrom that consists of rudistones and rudist packstones (Fig. 6C), 3- Shoal facies that is represented by pelloidal packstones to grainstones (Fig. 6D), 4- Shallow open marine facies that consists of bioclastic wackstones to packstones (Fig. 6E), and 5- Deep marine facies, this facies consists mainly of fine-grained pelagic lime mudstones to wackstones (Fig. 6F).

The Mishrif Formation was divided into 6 units according to porosity and shale volume as well as lithology (MA, MB11, MB12, MB21, MC1, MC2) (Fig. 5). The primary lithology of the MB21 unit, which is thought to be the major oil-bearing reservoir in the Buzurgan oil field, is made up of bioclastic limestone (rudist and grainstone). Because of its interconnecting vugs in a grain-dominated framework, the rudist facies of the Mishrif Formation is thought to be the most valuable hydrocarbon reservoir in southern Mesopotamia (Mahdi *et al.*, 2013).

Geologic logs are used to determine the different facies when dealing with intervals devoid of cores and cuttings. The resultant log facies are used to interpret those intervals. Finally, the discussions are presented based on the final results of the SOM model in Interactive Petrophysics (IP) software, which are compared with the studied thin sections at Key well (BU-3).

In comparing these microfacies with the response of the geological log, a relationship between them was observed, and on this basis, the sequence can be divided into log facies reflected in the sedimentary environment. In this study, ladder diagrams and spider web have been used to define the log response for each log facies from the studied wells (Figs .7and 8)

These log facies were diagnosed in the wells of the study area to support the petrographic and microfacies analysis. Minor differences are the result of diagenetic effect; these log facies:

1. Log facies (1) - (Lagoon): These facies are represented mainly by the upper part of the Mishrif Formation in the studied wells and characterized by high faunal diversity. The well log response shows low sonic, neutron, and high gamma ray values (Fig.8)
2. Log facies (2) - (Ru0d0ist biostrem): This log facies is considered most important (high porosity) as indicated from the sonic and neutron logs (the highest recorded values) and the lowest gamma ray values (Fig.8).
3. Log facies (3) - (Shoal): This facies is noticed clearly in most of the studied wells throw the microfacies study of the available core and cutting samples, and was evident from geological log responses of other wells. It is characterized by a relatively high sonic and neutron values and low gamma ray values (Fig.8).
4. Log facies (4) - (Shallow open marine): This log facies is characterized by higher sonic and neutron values than the electrofacies one (Deep marine), whereas lower gamma ray and density values are recorded (Fig.8).
5. Log facies (5) - (Deep marine): This facies is represented by the lower part of the Mishrif Formation in all the studied wells. It is characterized by low sonic and neutron response and high gamma ray values (Fig.9).

The log facies from the study of sonic, neutron, density, and gamma ray are generally consistent with the microfacies study in interpreting the different environments; minor differences in well log values can be attributed to changes in porosity and composition due to diagenetic processes, especially dolomitization, and to a lesser extent, cementation. Boreholes with well logs as the only source of information are easily correlated with the others due to the clear well log response of the identified microfacies through cores and cutting.

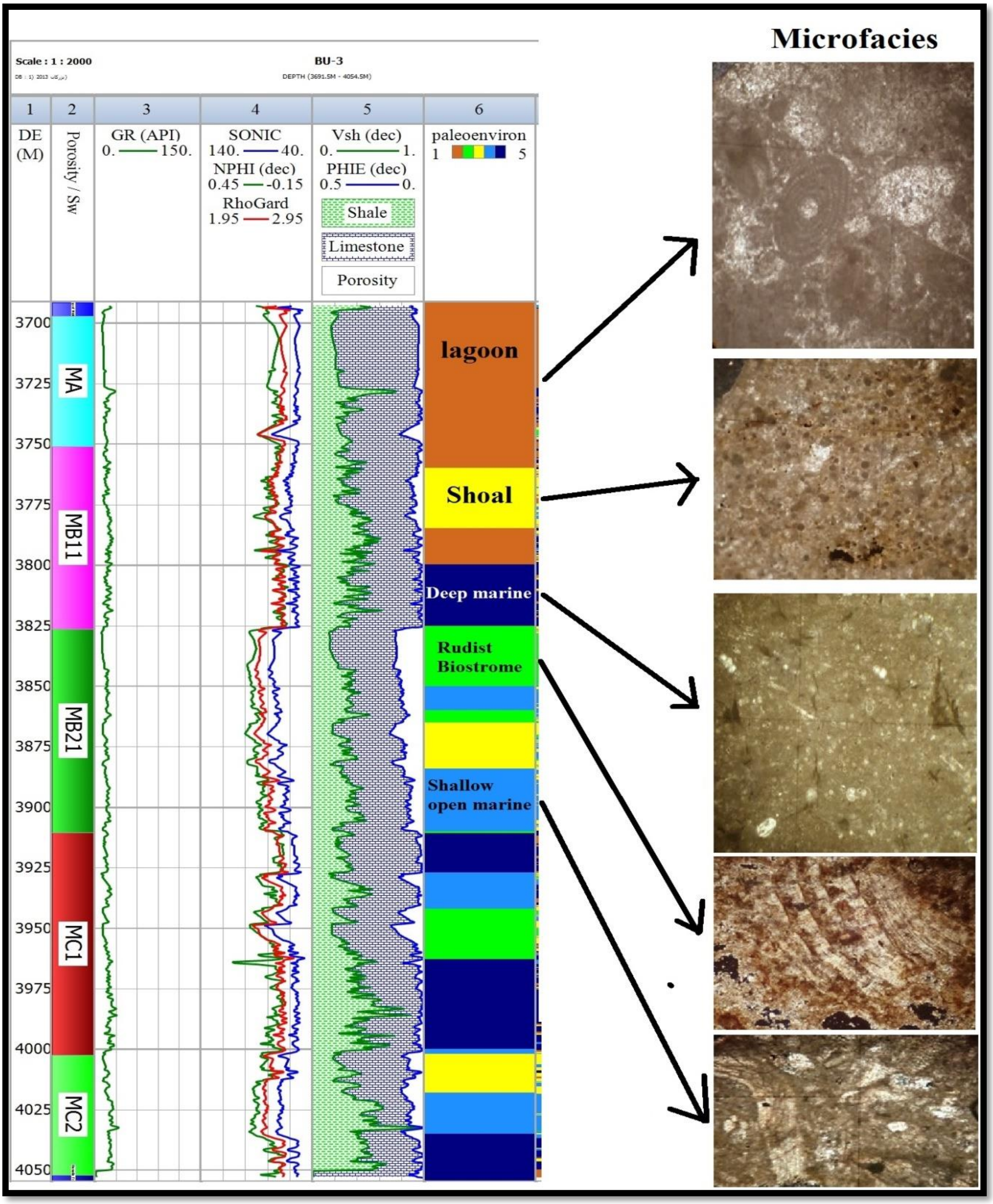


Fig. 5. Microfacies and paleoenvironments with slide photography of the Mishrif Formation in well BU-3.

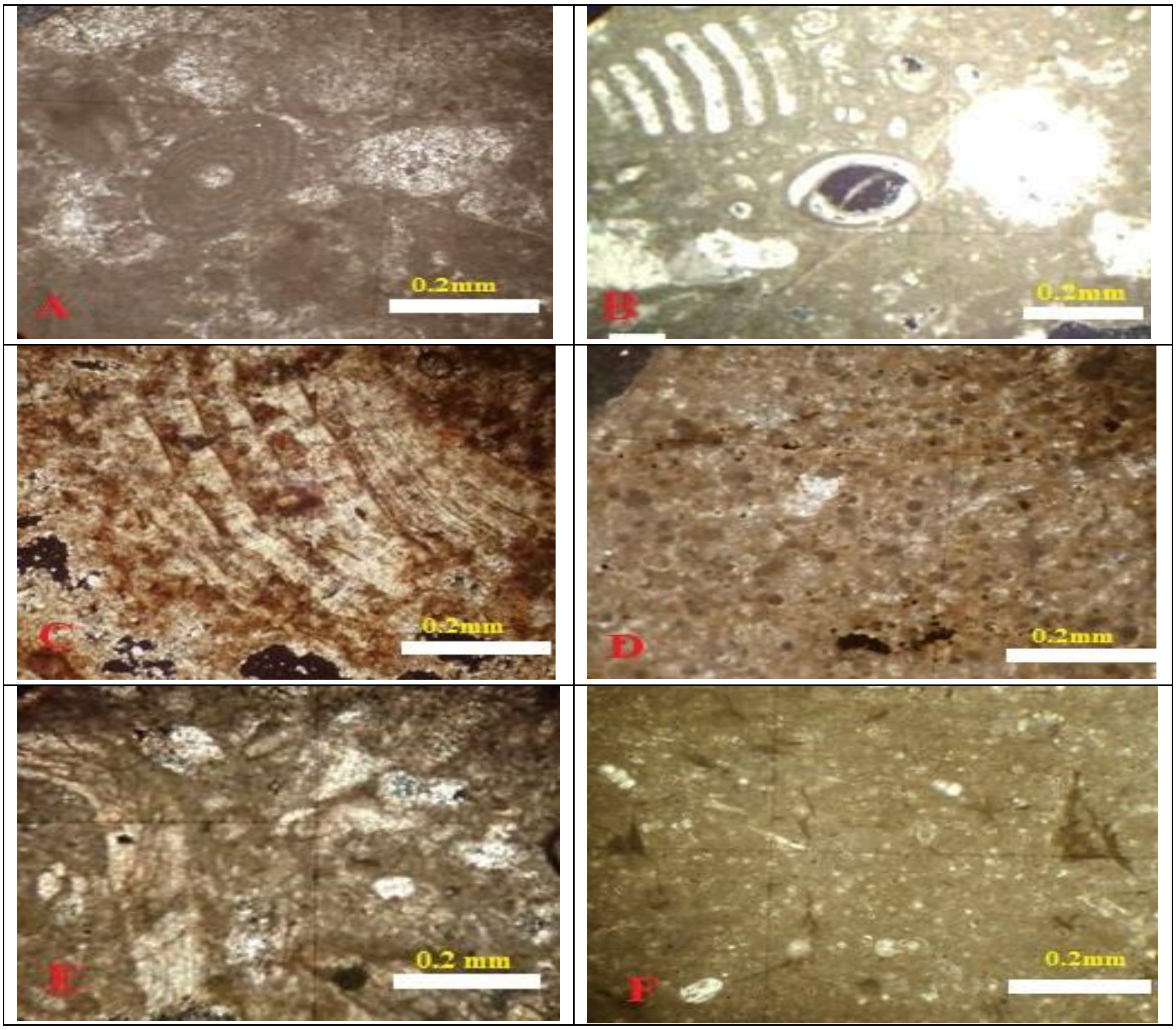


Fig. 6. Photomicrographs of thin sections showing: A- Benthonic foraminiferal wackstones, Lagoon facies, Bu-3, 3733m, 10X, XPL. B- Milliolidic mudstones to wackstones, Lagoon facies, Bu-3, 3742m, 10X, XPL. C- Rudist packstone, Rudist biostrom, Bu-3, 3828m, 10X, XPL. D- Peloidal packstone-grainstone, Peloidal grains with interpartical porosity, Shoal facies, Bu-3, 3872m, 10X, XPL. E- Bioclastic wackestone to packstone with Rudist fragments, shallow open marine, Bu-3, 3970m, 10X, XPL. F- Pelagic lime mudstones to wackstones, Deep marine, Bu-3, 4035m, 10X, XPL.

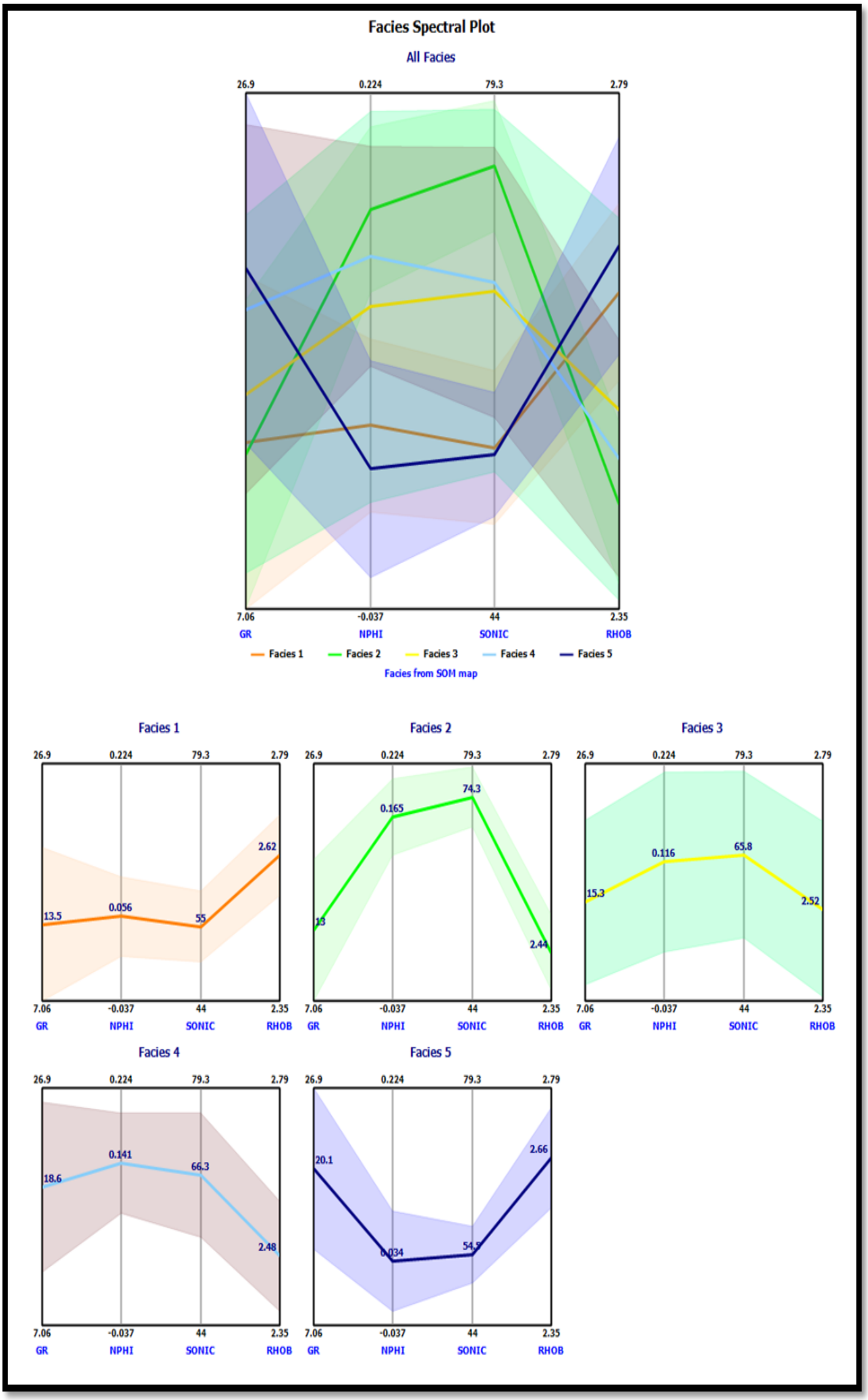


Fig. 7. Mishrif Facies spectral plot (ladder diagram) for studied wells in the Buzurgan oil field.

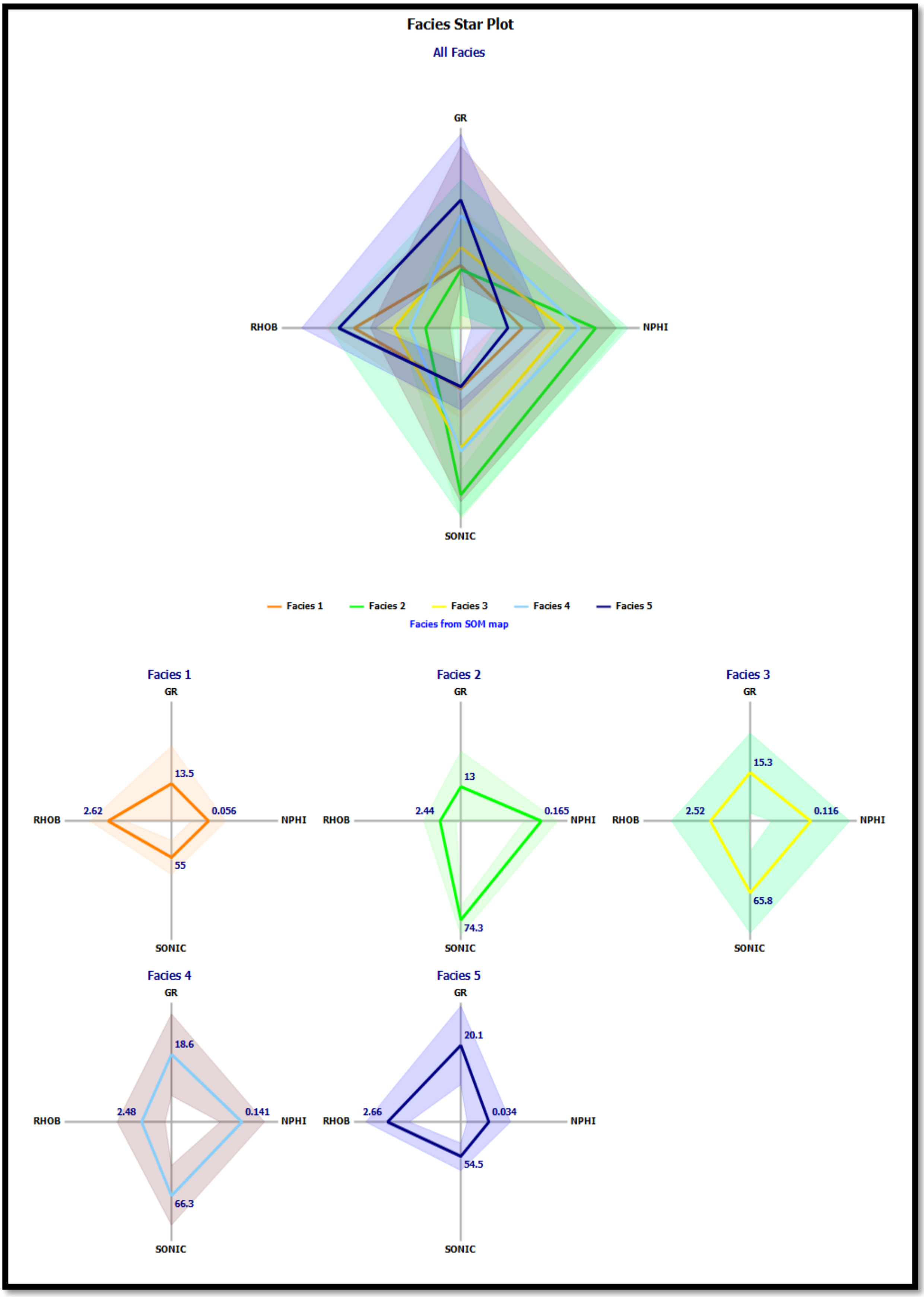


Fig. 8. Mishrif Facies star plot (spider web) for studied wells in the Buzurgan oil field.

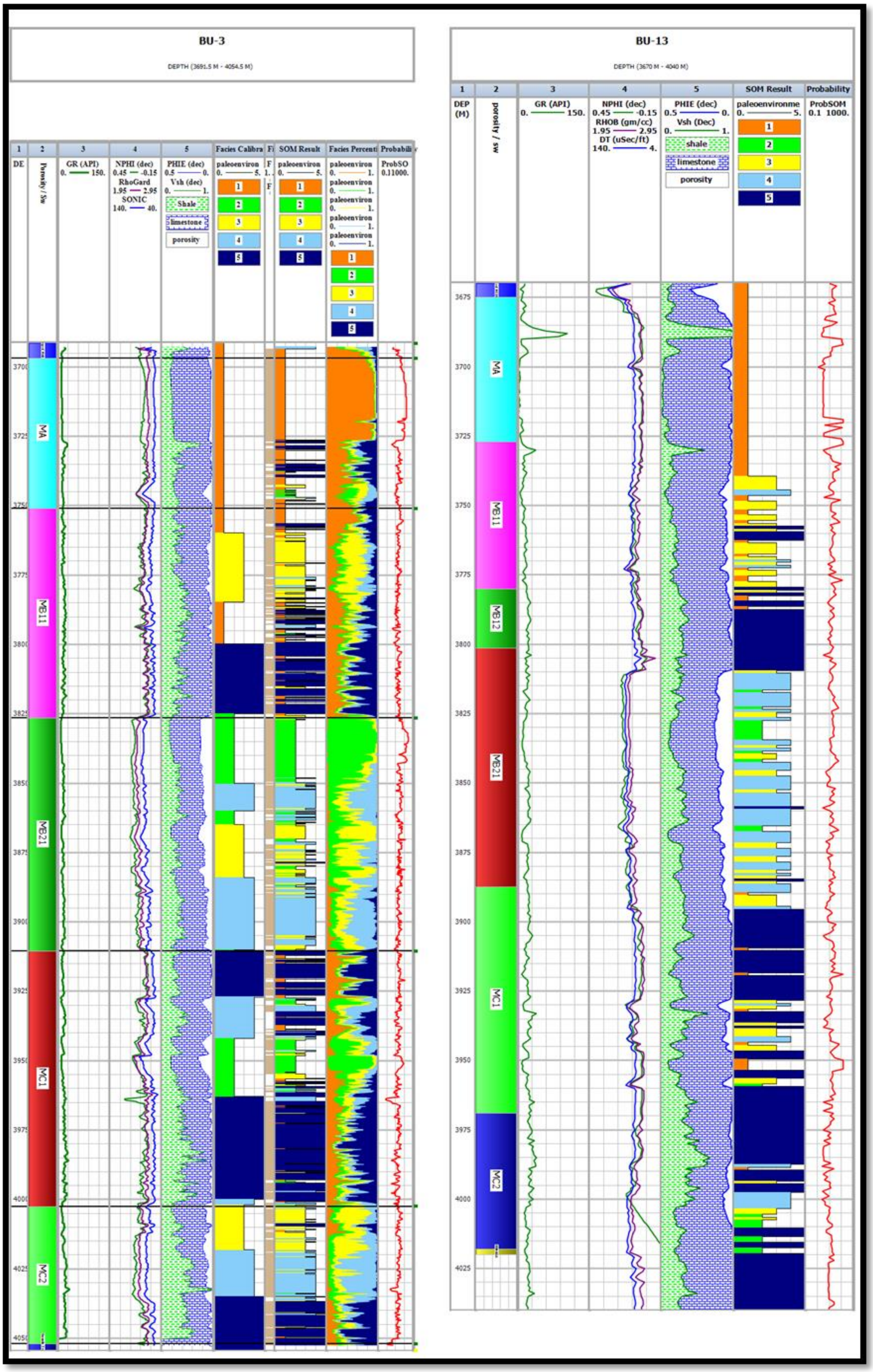
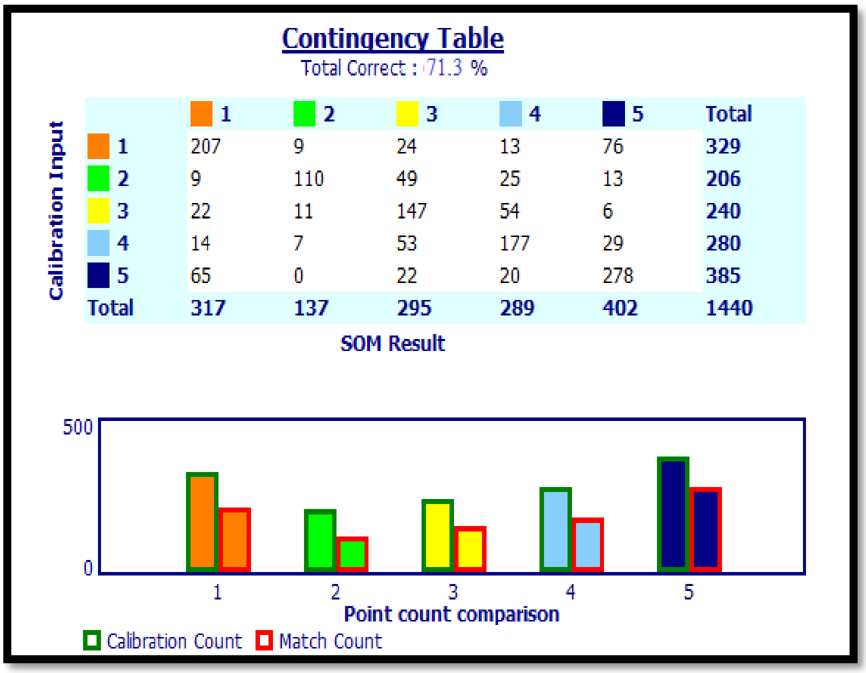


Fig. 9. Stratigraphic column of Mishrif Formation showing microfacies deduced from the SOM model using IP software, which is compared with thin sections in wells BU-3 and BU-13.

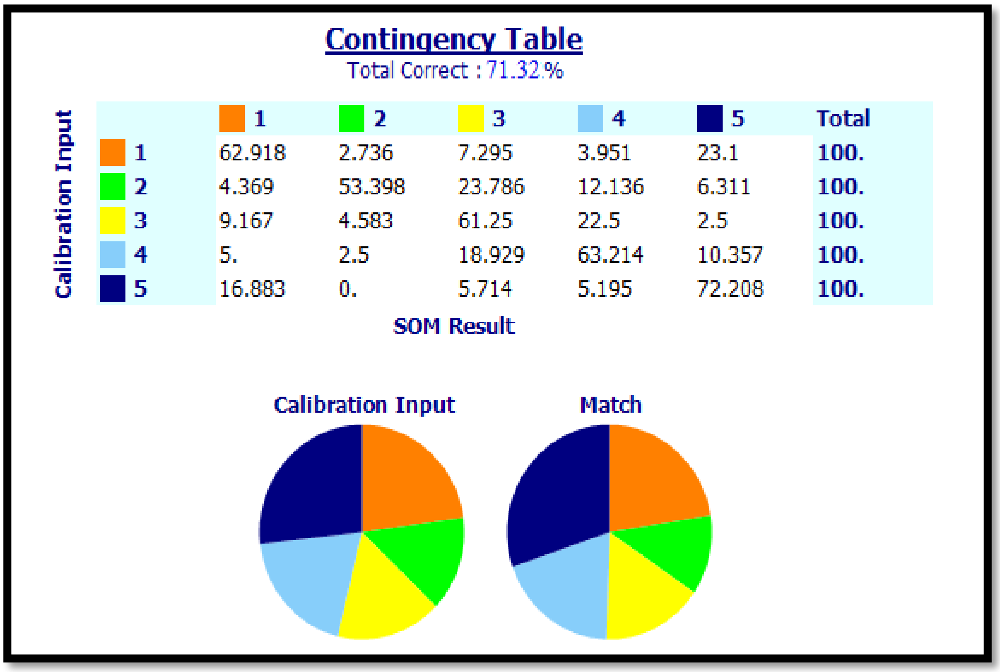


Contingency Table

Total Correct : 71.3 %

Calibration Input	1	2	3	4	5	Total
1	207	9	24	13	76	329
2	9	110	49	25	13	206
3	22	11	147	54	6	240
4	14	7	53	177	29	280
5	65	0	22	20	278	385
Total	317	137	295	289	402	1440

Fig. 10. Contingency table of histogram for Buzurgan SOM model



Contingency Table

Total Correct : 71.32 %

Calibration Input	1	2	3	4	5	Total
1	62.918	2.736	7.295	3.951	23.1	100.
2	4.369	53.398	23.786	12.136	6.311	100.
3	9.167	4.583	61.25	22.5	2.5	100.
4	5.	2.5	18.929	63.214	10.357	100.
5	16.883	0.	5.714	5.195	72.208	100.

Fig. 11. Contingency table of rose diagram for the Buzurgan SOM model.

Conclusions

The log facies from the study of sonic, neutron, density, and gamma ray are generally consistent with the microfacies study in interpreting the different paleoenvironments; minor differences in well log values can be attributed to changes in porosity and composition due to diagenetic processes, especially dolomitization, and to a lesser extent, cementation. Boreholes with well logs as the only source of information are easily correlated with the others due to the clear well log response of the identified microfacies through cores and cutting.

The procedure of self-organizing maps and the core well data calibration proved to be a helpful way to better data display, to eliminate data noise, and to correlate wells for a better understanding of the distribution of rock facies in the Buzurgan field, based on the contingency table of histogram (Table 2) and contingency table of rose diagram (Table 3), which are produced by IP software-SOM model. The contingency tables summarize the calibration facies input “deduced from microfacies analysis that was based on study of available thin sections of cores and cuttings from well BU-3” and facies output from results of the SOM model in the studied wells. As well as a clear link between core-based descriptions of the Mishrif Formation and log-derived facies is provided by the current research, reaching 71.3%. This should help to clarify how different environments are distributed around the formation in a dimensions model.

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Conflict of Interest

The author declares no conflict of interest.

References

Al-Ali, M.M., Mahdi, M.M., and Alali, R.A., 2019. Microfacies and Depositional Environment of Mishrif Formation, North Rumaila Oil Field, Southern Iraq. Iraqi Geological Journal, Vol. 52, No. 2, pp. 91-104. DOI: https://doi.org/10.46717/igj.52.2.7Ms-2019-12-30

Al-Heeti, A.M., Al-Fatlawi, O.F., and Hossain, Md. M., 2023. Evaluation of the Mishrif Formation Using an Advanced Method of Interpretation. Iraqi Journal of Chemical and Petroleum Engineering, Vol. 24, No. 2, 41-51.https://doi.org/10.31699/IJCPE.2023.2.5

Al-Khafaji, A., Al-Ameri, T., Abeed, Q., 2013. Oil and gas play and prospect assessments of Babel, Diwania, and Karbala Governorates, Middle Euphrates Region, Iraq. Arab J. Geosci. (Online first). DOI:10.1007/s12517-013-0980-8

Aqrawi, A.A.M., J.C. Goff, A.D. Horbury, and F.N. Sadooni, 2010. The Petroleum Geology of Iraq: Scientific Press, 424 P.

Aqrawi, A.A.M., T.A. Mahdi, G.H. Sherwani, and A.D. Horbury,2010. Characterization of the Mid-Cretaceous Mishrif Reservoir of the Southern Mesopotamian Basin, Middle East Conference and Exhibition, Manama, Bahrain. AAPG.

Buday, T., and Jassim, S.Z., 1987. The Regional Geology of Iraq. Vol. 2: GEOSURV, Baghdad.

Flugel, E., 1982. Microfacies Analysis of Limestones, Springer-Verlag, Berlin, 663 P.

Flugel, E., 2004. Microfacies Analysis of Limestone, Translated by Christensen, K., Springer-Verlag, Berlin, 633 P.

Jassim, S.Z. and Goff, J.C., 2006. Geology of Iraq. Dolin, Prague and Moravian Museum, Brno, Czech Republic, 341 pp .

Kohonen, T. 2001. Self-Organizing Maps, 3rd Edition, Vol. 30, Springer, Berlin, Heidelberg, New York.

Kohonen, T. 2013. Essentials of Self-Organizing Map Neural Networks, 37, pp. 52–65.

Mahdi, T. A., Aqrawi, A.A.M., Horbury, A.D. and Sherwani, G.H., 2013. Sedimentological Characterization of the Mid-Cretaceous Mishrif Reservoir in Southern Mesopotamian Basin, Iraq. Geo Arabia, Vol. 18, No. 1, 139-174.DOI: 10.2113/geoarabia1801139

Mohammed, M.J., Mahdi, T.A., 2019. Petrophysical Characterizations of Mishrif Formation in Selected Wells of Tuba Oil Field, Southern Iraq, Iraqi Journal of Science, pp. 516-527. DOI: 10.24996/ijs.2019.60.3.11

Mohammed, M.M., Hameed, M.S., and Kadhim, H.M., 2022. 3D Reservoir Modeling of Buzurgan Oil Field, Southern Iraq. Iraqi Journal of Science, Vol. 63, No. 2, 596-607. DOI:10.24996/ijs.2022.63.2.16

Moline, G.R. and Bahr, J.M.,1995. Estimating Spatial Distributions of Heterogeneous Subsurface Characteristics by Regionalized Classification of Electrofacies. Math Geol 27(1), pp. 3–22.

Serra, O. and Abbott, H.T., 1982. The Contribution of Logging Data to Sedimentology and Stratigraphy. Soc Petrol Eng J., 22(01), pp. 117-131.

Wilson, J.L., 1975. Carbonate Facies in the Geological History. Springer-Verlag, New York, 439 P.