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TOTAL ORGANIC CARBON (TOC) PREDICTION FROM RESISTIVITY AND POROSITY LOGS: A CASE STUDY FROM IRAQ

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ABSTRACT

The open hole well log data (Resistivity, Sonic, and Gamma Ray) of well X in Euphrates subzone within the Mesopotamian basin are applied to detect the total organic carbon (TOC) of Zubair Formation in the south part of Iraq. The mathematical interpretation of the logs parameters helped in detecting the TOC and source rock productivity. As well, the quantitative interpretation of the logs data leads to assigning to the organic content and source rock intervals identification. The reactions of logs in relation to the increasing of TOC can be detected through logs parameters. By this way, the TOC can be predicted with an increase in gamma-ray, sonic, neutron, and resistivity, as well as a decrease in the density log. In calculating TOC content, sonic/resistivity overlay technique was used. The results detected that the upper and lower parts (3300-3460 and 3570-3700 respectively) of the formation were the principal source rock in this location. The TOC results from logs are ranged respectively from 1-6 and 1-4 wt % for the upper and lower parts from the formation. These results are compared with TOC from (58) samples of Rock -Eval Pyrolysis, which showed a close pattern of increasing and decreasing in TOC values. This comparison was made so as to enhance the results of this technique. In addition, this tool revealed the possible lithology of the studied intervals, where the logs originally would give an indication to the lithology, as such high TOC is significant to relatively low energy environments. TOC calculation showed that the upper and lower packages represent source-seal rocks, while the middle had good reservoir properties. This relation may indicate a locally stratigraphic trap, and a need for further detailed studies.

Key words: Resistivity logs, Southern Iraq, TOC prediction, Zubair Formation, Δt log R.

INTRODUCTION

The assessment of source rocks for any basin studies in various geological settings needs to grow the uses of logs techniques to enhance the database, especially when geochemical information is restricted. These uses provide an integrated assessment of source rock ability for volumetric determinations. Source rocks are mainly formed of fine-grained sediments like mudstones and shale (Tissot and Welte, 1984).

The important component of source rocks is the organic matter (OM), which expresses the Total Organic Carbon (TOC). The later have to be more than 1% to be worthy in the source rock studies (Hunt, 1996). In organic geochemical studies and petroleum exploration, the TOC is the main indicator of the quantitative parameters of any source rock, in addition to S2 and the qualitative once (Peters *et al.*, 2005). Forasmuch, due to the value of TOC is the main parameter to expect the quantity and quality, this paper focuses on the method of how to get the real values or to be closer (Leckie *et al.*, 1988 and Dymann *et al.*, 1996). A number of logs data have been prepared and predestined to use in determining variations and absolute quantities of TOC. In this work, two main logs have applications in quantifying organic content from wire line logs. The resistivity and porosity, in addition to the gamma ray and calibre logs, are established for determining the TOC in the evaluated units as shown by (Passey *et al.*, 1990). In south east in the Mesopotamian zone of Iraq in Euphrates subzone precisely, is the area of interest and is considered as one of the promising regions (Map 1). The case study was from southern oilfield, well X was chosen due to the integration of data.

The total depth of this well is (4700 m) from sea level. The interval of interest is located from (3300-3700 m) which represents the Zubair Formation. The formation is comprised from alternation of sandstone, siltstone, and shale, representing the delta and pro delta facies, while limestone is restricted to the upper part, of the formation, which represents transgressive phase deposits (Buday and Jassim, 1980). It is divided into three units; Upper, Middle, and Lower Zubair Formation. The shale packages become thinner toward the western area of the study while the coarse clastic packages become thinner within and toward the eastern parts (Jassim and Goff 2006). Such differences in the thickness of the packages must be due to progradation of the delta sand bodies. On the other hand, Euphrates Subzone lies in the west of Mesopotamian zone. It is the shallowest unit but has thicker Quaternary deposits compared with the Tigris Subzone (Aqrawi *et al.*, 2010).

MATERIALS AND METHODS

Logs of resistivity, porosity, gamma ray, and calibre were converted from hard formula into digital data to be possibly used in calibration by Excel software. This operation was made by the didger program. Primarily, the logs of resistivity (ILD) and the sonic (Δt) are superimposed to be in one harmonic track, where each 50 µsec/ft from Δt equal one logarithmic ILD cycle (Passey *et al.*, 1990). The gamma ray (GR) log is synchronous to delineate the shale base line. As shown in detail in Diagram (1) (Shayesteh, 2011), the ILD and Δt baselines (which represent the overlapping between them in non-source, clay rich rocks based on relatively high values of GR) specified and appointed to equal 30.71 ohm.m and 81.43 µsec/ft respectively at the interval 3500-3550 m. Then the equation (1) was run in Excel software as below:

$\Delta \log R = (R/R\ baseline) + 0.02(\Delta t - \Delta t\ baseline)$ .... (1)

Where:

R is the resistivity measured from log, Δt is the transit time from log, R baseline (30.71 ohm.m) is the resistivity corresponding to the Δt baseline value (81.43 µsec/ft) when the curves overlap in non-source, clay rich rocks, and 0.02 is based on the ratio of (50) µsec/ft for each resistivity cycle.

The resulted Δ log R, as well, entered to the Excel software to calculate the total organic carbon (TOC) as shown in equation (2).

$TOC = (\Delta \log R) * 10\ exp\ (2.297 - 0.1688 * LOM)$............ (2)

Where:

TOC is the total organic carbon measured in wt%, LOM is the level of organic maturity. Depending on the calculated Ro and comparing with (Hood *et al.*, 1975); the LOM value

is eight (8) for this research as shown in Table (1) and Diagram (2), which means of Ro had ranged from 0.5-0.6 depending on (Jarvie, 1991), the other numbers are constant.
In each practical study, the resulted values have to be realized and ensured for their certainty, wherefore; fifty eight (58) samples of cutting were analyzed to determine the geochemical parameters of Rock-Eval pyrolysis techniques. The samples were selected as far as possible from the shale intervals of different depths as shown in Table (1). These data were inverted from the South oil company (SOC) in Basra governorate.

Finally, all the collected logs data were used to describe the organic richness in the interval of interest. Furthermore, the TOC results from Rock - Eval pyrolysis were represented in a log curve and superimposed with TOC resulted from equations, as in Diagram (3).

Table (1): The organic geochemical parameters obtained from Rock-Eval Pyrolysis with calculated Ro according to the equation of Jarvie (1991).

No.	Depth	TOC	S2	Tmax	Cal. Ro	No.	depth	TOC	S2	Tmax	Cal. Ro
1.	3306	1.3	1.11	429	0.562	30.	3528	0.74	1.03	433	0.634
2.	3312	0.96	0.55	429	0.562	31.	3532	0.83	0.87	434	0.652
3.	3316	0.92	1.03	429	0.562	32.	3537	0.51	0.37	441	0.778
4.	3324	1.07	1.05	432	0.616	33.	3542	0.58	0.38	429	0.562
5.	3332	1.65	2.88	425	0.49	34.	3550	0.66	0.66	440	0.76
6.	3338	0.6	0.79	424	0.472	35.	3554	0.76	0.58	431	0.598
7.	3346	1.24	1.4	430	0.58	36.	3562	1.28	1.25	425	0.49
8.	3358	0.97	1.66	422	0.436	37.	3567	0.45	0.38	435	0.67
9.	3366	0.74	0.5	430	0.58	38.	3570	0.54	0.59	438	0.724
10.	3388	0.4	0.2	435	0.67	39.	3578	0.58	0.24	429	0.562
11.	3392	0.86	0.39	431	0.598	40.	3582	0.67	0.48	435	0.67
12.	3399	0.49	0.25	439	0.742	41.	3588	1.19	0.9	433	0.634
13.	3408	0.92	0.57	429	0.562	42.	3592	1.52	0.27	427	0.526
14.	3414	0.46	0.14	423	0.454	43.	3598	0.5	0.17	429	0.562
15.	3422	1.01	1.31	432	0.616	44.	3604	0.54	0.41	440	0.76
16.	3430	0.87	1.07	433	0.634	45.	3610	0.5	0.23	440	0.76
17.	3435	0.82	0.59	428	0.544	46.	3618	0.76	0.59	434	0.652
18.	3442	0.74	0.43	427	0.526	47.	3624	0.72	0.53	430	0.58
19.	3456	1.02	0.83	433	0.634	48.	3628	0.53	0.31	432	0.616
20.	3470	0.85	0.96	435	0.67	49.	3636	0.75	0.41	432	0.616
21.	3476	1.13	1.71	431	0.598	50.	3640	0.74	0.45	437	0.706
22.	3482	0.82	0.93	433	0.634	51.	3644	0.95	0.54	438	0.724
23.	3488	1.9	3.56	431	0.598	52.	3650	1.8	0.48	441	0.778
24.	3493	3.17	10.61	431	0.598	53.	3656	0.64	0.16	439	0.742
25.	3500	1.17	0.98	430	0.58	54.	3666	1.1	0.36	428	0.544
26.	3506	1.16	1.13	434	0.652	55.	3676	1.03	0.38	430	0.58
27.	3512	0.85	1.16	432	0.616	56.	3682	1.52	0.45	440	0.76
28.	3516	0.64	0.37	434	0.652	57.	3688	1.55	0.66	435	0.67
29.	3524	1.54	1.01	431	0.598	58.	3695	2.6	1.75	435	0.67

RESULTS

The main results of this paper are:

1. The TOC can be calculated from the right integration of porosity and resistivity logs. These results are supported by comparison with TOC from the Rock-Eval pyrolysis.
2. TOC is a good indicator for the lithology of different intervals. As well as, the studied section is divided into three rock packages in respect to the TOC, and as a result, to the lithology. These three rock packages started in 3300- 3460m (160m), 3460-3570m (110m), and 3570-3700m (130m) from top to bottom respectively.
3. Similar to these studies can be used and applied in the promising areas that lack geochemical data.
4. The correlation between the TOC results from log and core analyses is important to determine and prove the success of the logs techniques in organic geochemistry evaluation. In well X, the correlation between the calculated and the measured TOC reflects a good obvious similarity between them (Diag. 3). Thus, the overlay proved real tools for quantitative determination of TOC in this well.

DISCUSSION

Wire line logs of sonic and resistivity overlays are applied for the certain interval of interest (Zubair Formation) in the well X. One overlay is drawn for the well, combining both of the calculated TOC values and the GR log (Diag. 3). This type of presentation may help in identifying the organic rich rocks and evaluating the organic richness in a whole formation or intervals that have no enough data to study the geochemical properties.

The sonic - resistivity overlays of the formation can be presented as in (Diag. 3).This overlay reflects the dominant of a good Δ log R separation with high percentage of the TOC (wt %) in the upper (3300-3460m) and lower (3570-3700m) parts of Zubair Formation. The calculated TOC range between 1-6 wt % in the upper formation, while 1-4 wt % in the lower, indicating the prevalence of organic matter in these two intervals. This result refers to good source rock quantity parameters, which may indicate a possible source rock, and can provide oil and/or gas to the nearby reservoir rocks.

The middle Zubair Formation (3460-3570m) showed a decrease in the TOC values. This may indicate good reservoir characteristics in the studied area as shown in (Diag. 4). Rock characteristics are dominantly solid and have good total porosity as expected by the company of porosity, resistivity, and Gamma ray, in addition to calibre log; this may mean the consistence of pure sandstone as assigned by (Idan *et al.*, 2015). The resulting ideas may suggest three different rock packages, the middle of them diagnosed to be the cleaner sandstone reservoir trapped between two shale-rich intervals acting as source-seal stratigraphic trap or complete petroleum system as explained in (Idan, 2012). This conclusion may be enhanced by several later studies for the promising area, concerning with reservoir characterization (porosity, permeability, and water saturation) and oil habitat.

CONCLUSIONS

Logs method is considered as the up-to-date to the identification and quantification source rock. The evaluation method primarily starts by exposing the responses of the logs GR, Δt, and ILD, in addition off course to the neutron and density, to increasing TOC.

Increase of GR, Δt, neutron, resistivity and decrease of density may indicate increasing in TOC but this is not necessarily always true in all cases (Diag. 4).

Porosity/resistivity tool shows that logs can be used to identify organic-rich formations. As in this case, the calculated TOC ranged from 1-6 wt %. This result is close to the Rock-Eval analysis which means that the studied interval is considered as source-seal rock in the study area. To detect that log, analysis may really evaluate and be applied for quantitative determination of TOC, it is essential to correlate with Rock-Eval pyrolysis data. Results from the overlay showed a generally accepted compatible with core data in estimating TOC in this area (Diag. 3). As a result, these calculations can be used in intervals that lack of geochemical data to obtain an overview in exploration.

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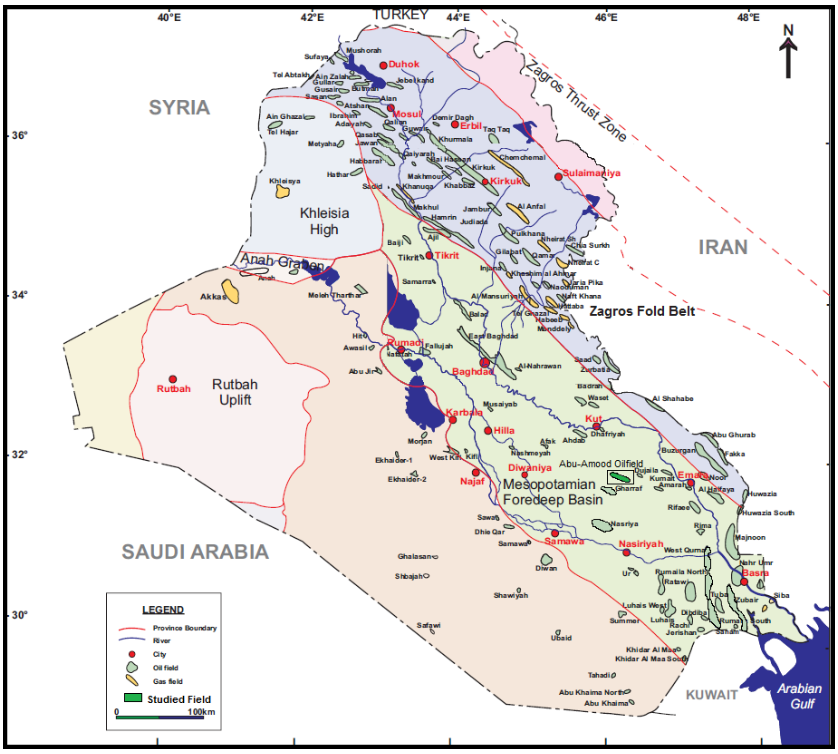

Map (1): The tectonical zonation and the area of study representing the target oil fields (Al-Ameri *et al.*, 2011).

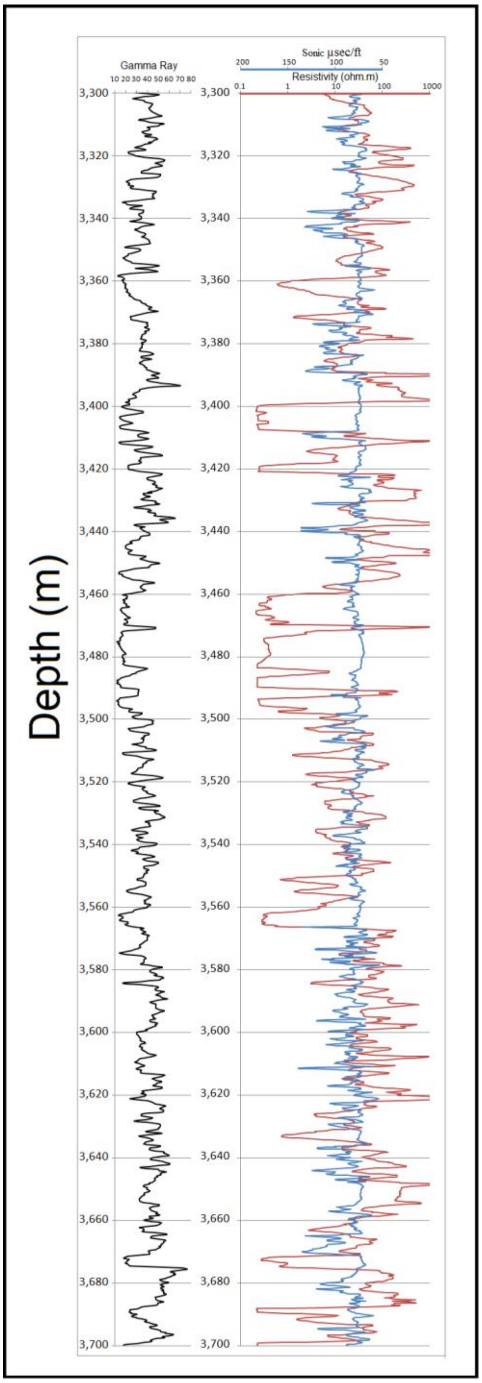

Diagram (1): Sonic/Resistivity overlay, showing Δ log R separation in the organic rich intervals. Gamma Ray (in API units) is contemporaneous to find out the shale base line in the studied case.

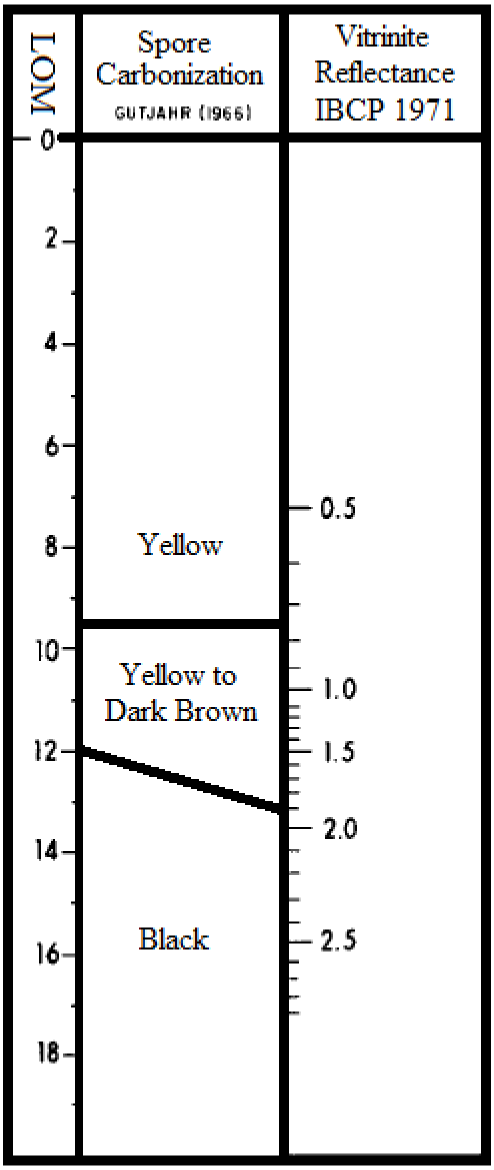

Diagram (2): Level of Organic Maturity or Metamorphism (LOM) explains how the LOM value has been chosen depending on the Vitrinite reflectance (Ro), which calculated as Jarvie (1991), modified from Hood *et al.* (1975).

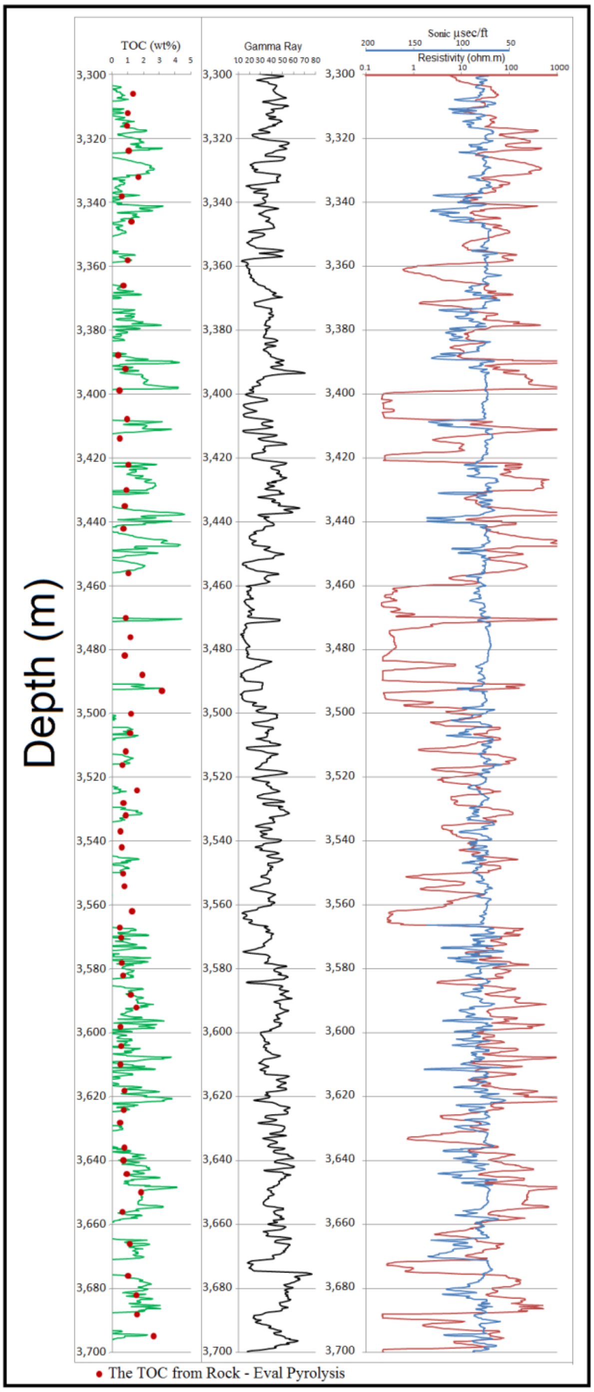

Diagram (3): representing the resulted TOC from log overlapped by the TOC from Rock - Eval pyrolysis to compare the results.

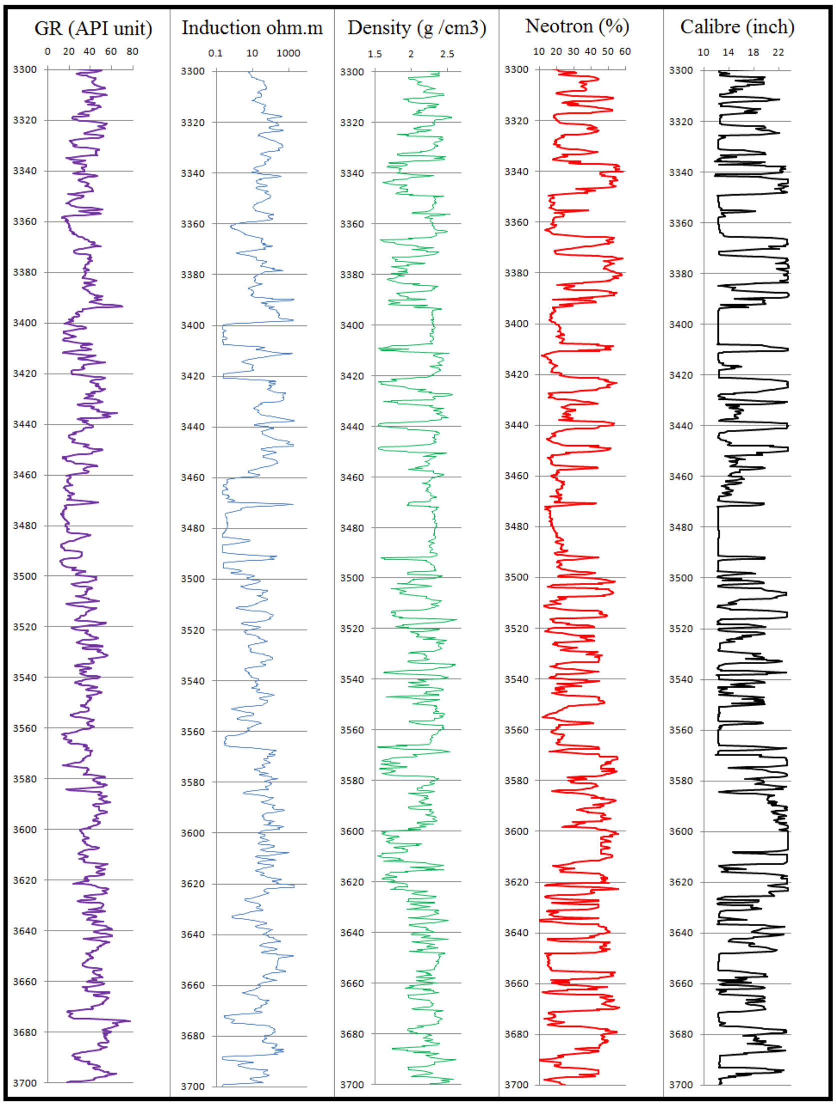

Diagram (4): Full set of resistivity, porosity, GR, and calibre of the interested interval, showing the petrophysical properties of the formation. Note that middle section (3460-3570m) behaves relatively different than upper and lower parts.

LITERATURE CITED

Al-Ameri, T.K., Zumberge, J. and Markarian, Z.M. 2011. Hydrocarbons in The Middle Miocene Jeribe Formation, Diyala Region, NE Iraq. *Journal of Petroleum Geology*, 34(2): 199 – 216.

Aqrawi, A., Goff, J., Horbury, A. and Sadooni, F. 2010. The Petroleum Geology of Iraq, Scientific press ltd, 1st edition, 424pp.

Buday T. and Jassim S.Z. 1980. The Regional Geology of Iraq Stratigraphy and Palaeogeography. State Organization for Minerals, Baghdad, Iraq, 445pp.

Dymann, T.S., Palacos, J.G., Tysdal, R.G., Perry, W.J. and Pawlewicz, M.J. 1996. Source Rock Potential of Middle Cretaceous Rock in South Western Montana. *AAPG Bulletin*, 80: 1177-1184.

Hood, A., Gutjahr, C. C. M. and Heacock, R. L. 1975. Organic Metamorphism and the Generation of Petroleum. *AAPG Bulletin*, 59(6): 986-996.

Hunt, J.M. 1996. Petroleum Geochemistry and Geology. W. H. Freeman: New York, 1996, 743pp.

Idan, R.M. 2012. The petroleum system of Zubair Formation in selected oil fields-Southern Iraq, unpublished Ph.D. thesis, University of Baghdad, 200pp.

Idan, R. M., Al-Rawi, D., Nasser, M. E. and AlMashaekhy, D.A. 2015. Reservoir properties and seal efficiency in the Zubair Formation in Euphrates Subzone, Southern Iraq. *Arabian Journal of Geosciences*, 8(2): 773-780.

Jarvie, D.M. 1991. Factors Affecting Rock-Eval Derived Kinetic Parameters. *Chemical Geology*, 93: 79-99.

Jassim, S.Z., and Goff, J.C. 2006. Geology of Iraq. Published by Dolin, Prauge and Moravian Museum, Brno, 1st edition, 341pp.

Leckie, D.A., Kalkreuth, W.E. and Snowdon, L.R. 1988, Source Rock Potential and Thermal Maturity of Lower Cretaceousa Strata. *AAPG Bulletin*, 72: 820-838.

Passey, Q.R., Creaney, S., Kulla, J.B., Moretti, F.J. and Stroud, J.D. 1990. A Practical Model for Organic Richness from Porosity and Resistivity Logs. *AAPG Bulletin*, 74(12): 1777-1794.

Peters, K.E., Walters, C.C. and Moldowan, J.M. 2005. The Biomarker Guide, 2nd Edition, Volume I, Biomarkers and Isotopes in Petroleum Systems and Human History, United Kingdom at the Cambridge University Press, 471pp.

Shayesteh, M. 2011. Source Rock Analysis from Well Logs in the Southern Dezful Embayment. The 2nd South Asain Geoscience Conference and Exhibition, Geo-India, 12-14th Jan, 2011,Gearter Noida, New Delhi, India.

Tissot, B.P. and Welte, D.H. 1984. Petroleum Formation and Occurrence. Springer, Berlin, 2nd Ed.

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التنبؤ بكمية المادة العضوية الكلية من خلال مجسات المقاومية والمسامية: دراسة حالة من العراق

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الخلاصة

تم تطبيق معلمات مجسات المقاومية والمجس الصوتي ومجس اشعة كاما للبئر X في شبه نطاق الفرات العائد لنطاق سهل مابين الرافدين، لغرض تحديد كمية المادة العضوية الكلية في تكوين الزبير جنوبي العراق. لقد ساعد التفسير الرياضي للمجسات في كشف عن كمية المادة العضوية وانتاجية الصخرة المصدرية. اضافة لذلك، فأن التفسير الكمي لمعلومات المجسات قاد الى المحتوى العضوي وتحديد اعماقه في الصخرة المصدرية. يمكن الكشف عن العلاقة بين استجابة المجسات لزيادة كمية المادة العضوية من خلال المعطيات الرقمية. بهذه الطريقة ممكن استنتاج المادة العضوية عند زيادة المجسات كاما والصوتي والنيتروني والمقاومية، وبالتاكيد انخفاض قرائة مجس الكثافة. لقد استخدمت تقنية تراكب مجسي المقاومة / الصوتي في حساب كمية المادة العضوية وقد اظهرت النتائج ان الجزء العلوي والسفلي من التكوين (٣٣٠٠-٣٤٦٠ و ٣٥٧٠-٣٧٠٠ على التوالي) هما الصخرة المصدرية الرئيسية في هذا الموقع. لقد تراوحت كمية المادة العضوية من المجسات ما بين ١-٦ و ١-٤ وزن % للجزئين العلوي والسفلي على التوالي. ومن ثم قورنت هذه النتائج مع نتائج تحاليل ٥٨ عينة صخرية لنفس التكوين تم تحليلها بجهاز تقييم الصخور المصدرية والتي اظهرت نمطا مقاربا للزيادة والنقصان على حد السواء في كمية المادة العضوية. جائت هذه المقارنة لتعزيز نتائج تقنية المجسات. بالاضافة لذلك فقد كشفت هذه الطريقة عن الصخارية المحتملة للفترة العمقية موضوع الدراسة، حيث اعطت المجسات بصورة متأصلة توقع حول الطبيعة الصخرية للتكوين حيث يعتبر المحتوى العالي من المادة العضوية دلالة على بيئات الترسيب الهادئة نسبيا. اظهرت حسابات كمية المادة العضوية ان الحزمة الصخرية العليا والسفلى تمثل صخور مصدر - غطاء بينما مثلت الحزمة الوسطية صخرة مصدرية ذات خواص مكمنية جيدة. هذه العلاقة قد تدل على وجود مصائد طباقية محلية تحتاج الى دراسات تفصيلية كثيرة لاحقا.