

# Application of Geophysical Logs to Estimate the Source Rock Quantity of Ratawi Formation, Southern Iraq: A Comparison Study

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**Abstract.** Quantitative detection of the parameters of source rock that targeted Ratawi Formation in the south of Iraq is achieved via the Geophysical log data, precisely the resistivity, porosity, and gamma-ray log of the well X in the northern part of Mesopotamian basin, which is so called Euphrates subzone. Total organic carbon and source rock productivity is detected by mathematically interpreting of the log parameters and that lead to assigning and identification of the content of organic matter and source rock intervals. The responses of log curvatures are relevant to the rise of total organic carbon, which can be identified via logs indicators. Thereby, the organic carbon can be expected with a surge in values of sonic log, gamma-ray values, neutron or total porosity log, and resistivity as well as a decrease in the density log. The adoption of sonic/resistivity overlay technique for the determination of total organic carbon content has indicated the likely lithology of the intervals of interest where the logs initially could indicate the lithology. As such, high organic carbon content is significant to environments that have relatively low energy.

## 1. Introduction

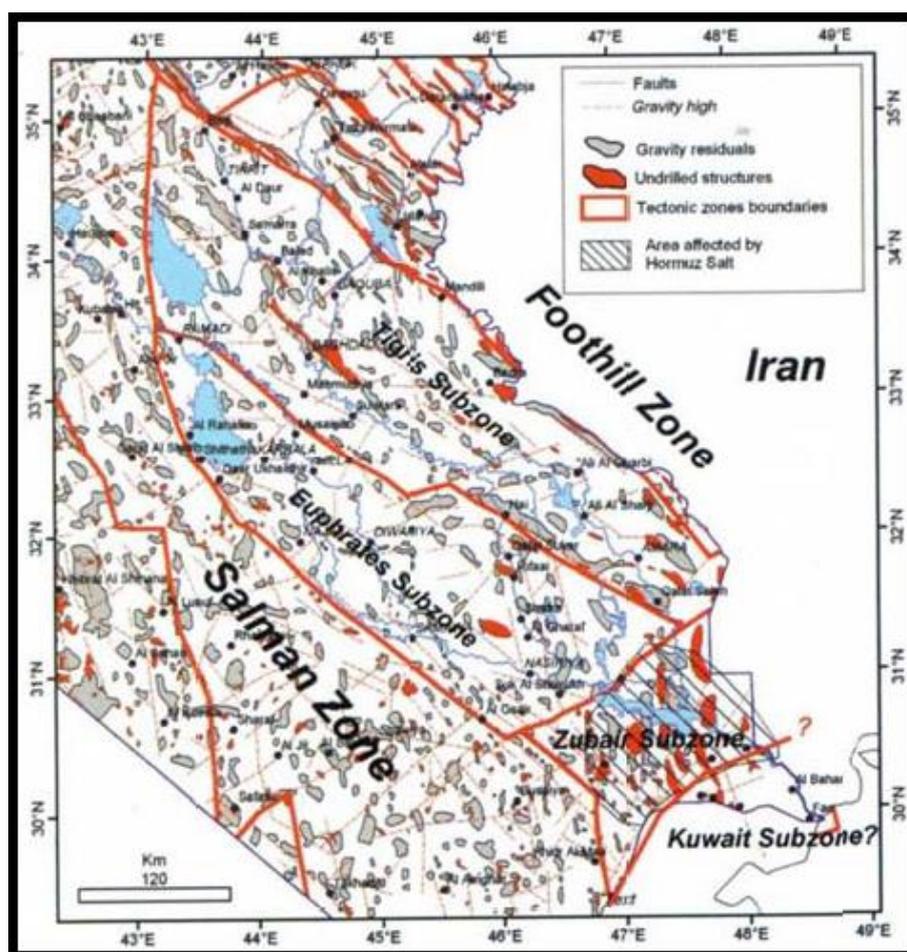
Typically, source rock is described as very fine particles, which is mainly Shale rocks. The source rock comprises a considerable quantity of organic matter (OM) that is frequently called Total Organic Carbon “TOC” which possibly will yield hydrocarbon within maturity or Catagenesis phase [1]. The evaluation of source rocks requires to develop the applications of logs to augment the information, especially when geochemical data is limited. This research is a complementary and comparison study with [2], which focused on the calculation of the source rock quantity parameter from geophysical logs to Zubair Formation with the underlying Ratawi Formation. This formation is underlain Zubair Formation and of the same depositional cycle. The former represents deeper environments. The research aims to compare the equations of the (TOC) prediction that has been used to determine the TOC of Zubair Formation on the Ratawi Formation. These equations are derived from [3] with modification to lithology and temperature in respect to the new parameters. In addition, due to the importance of TOC parameter to expect the source rock efficiency in the interesting interval, this complementary research focuses on how to calculate these values and provide a prior indication about the TOC in the same succession representing by Zubair and Ratawi formations [4] and [5].

Consequently, accumulation of hydrocarbon depends on many factors, like kerogen type, burial rate,



and geothermal gradient in the studied locations. Numerous techniques have been used to evaluate the source rock. The favorable technique to be used is organic matter identification, Rock-Eval pyrolysis, and Infrared analysis [6]. Besides logs are used to evaluate source rock, containing sonic, gamma-ray (GR), and resistivity logs, in addition to neutron and density. This study represents a feasibility effort to evaluate OM from log data depending on TOC properties. Organic rich intervals have low density values, while high sonic transit time, and high resistivity values [7].

The L. Cretaceous Ratawi Formation represents the deposits of inner shelf environments [8]. Ratawi Formation consists of two members, the lower composes of detrital limestone from the inner shelf environments during a high stand system tract (HST). Whereas the upper shale member deposited in deep inner shelf environments within the low stand system tract (LST) facies [9], and this division is not fixed in the Iraqi studies concerning Ratawi Formation. The lower and upper contacts in the studied well are conformable with Yammama and Zubair respectively [10]. The formation is approximately 140 m thickness and increases toward the south and the southwest area, as well as in central Iraq near Baghdad. From the geological point of view, the field of study is located in the Mesopotamian zone of Iraq in Euphrates subzone, Figure 1.



**Figure 1.** The Tectonic map of Iraq, illustrating the tectonic divisions, and illustrate the study area in Euphrates subzone [11].

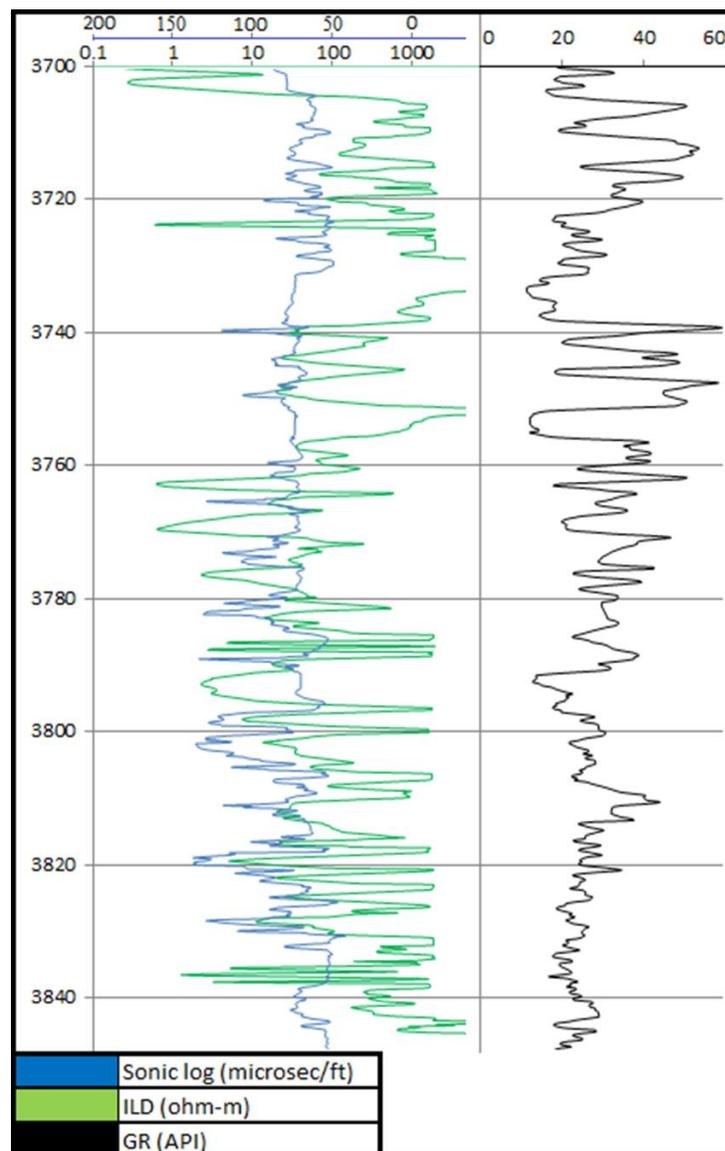
## 2. Materials and methods

$\Delta$  Log R is an applied technique, for detecting TOC in organic-rich intervals that established by well logs analysis. The method uses the overlay of sonic log (Delta t) curve with the induction latero-log

(ILD) in water-saturated, organic-lean intervals. These two curves are corresponding to each other and can be correlated in the same depths, which each 50  $\mu\text{sec}/\text{ft}$  from Delta t equal to one logarithmic resistivity cycle.

The separation of the Delta t and ILD curves in organic-rich intervals takes place as shown and detailed in Figure 2. Furthermore, the same separation also takes place in reservoir rock but in different pattern. The differentiation between these two cases is depending on the low or high values of GR in a reservoir or organic-rich intervals respectively [3].

The organic-rich intervals separation occurs due to the decrease in velocity and density values, [3]. In immature organic-rich intervals, the separation is mainly due to voids occurrence. While in hydrocarbon-bearing intervals, the resistivity increases due to the presence of liquids, in addition to pore space activity. The curve separation in non-reservoirs depends on the TOC and thermal maturity, and this method is worthy in the geochemical exploration especially when data samples are not available. This technique results in providing a TOC assessment close to reality in all lithology types and maturity. Finally, the baseline values characterize overlapping interval between the ILD and Delta t logs in immature source rocks based on relatively high values of GR.



**Figure 2:** Delta t/ILD overlap, illustrates  $\Delta \log R$  separation in the organic-rich intervals. Gamma Ray

is contemporaneous to find out the shale baseline in the studied case.

Initially, logs of resistivity, porosity, gamma-ray, and caliber are prepared in digital data file to use [12]. The logs of ILD and Delta t are overlain to be in one harmonic track.

GR curve is concurrent to detect the shale baseline. As shown in [13] in Figure 2, the ILD and Delta t baselines have been determined and fixed to equal 324 ohm-m and 88  $\mu$ sec/ft respectively at the interval 3800-3820 m. Then the equation 1 ran, as below:

$$\Delta \log R = (\text{Res} / \text{Res baseline}) + p (\text{Delta t} - \text{Delta t baseline}) \dots (1)$$

Where:

- Res is the resistivity from the log.
- Delta t is the sonic log data.
- Res baseline value is calculated and equalize to 324 ohm-m, at 3800-3820 m.
- Delta t baseline value is calculated and equalize to 88  $\mu$ sec/ft, at 3800-3820 m.

p is the relationship of 50  $\mu$ sec/ft to each logarithmic cycle of resistivity log.

The results of  $\Delta \log R$  are equivalent to each 0.25 m or less from the formation. These results from the above equation 1 are submitted to calculate the TOC as shown in equation 2, as follow.

$$\text{TOC} = (\Delta \log R) * 10 \exp (2.297 - 0.1688 * \text{LOM}) \dots (2)$$

Where:

- TOC is the total organic carbon measured in wt % for each 0.25 m or less from the targeted interval.
- $\Delta \log R$  values are calculated in equation 1.

LOM is the level of organic metamorphism. Vitrinite reflectance  $R_o$  values compared with [14], to predict the LOM value that was nine to this work as shown in Figure 3, which the mean of  $R_o$  had ranged from 0.6-0.7 as calculated by [15].

- Other numbers are constants.

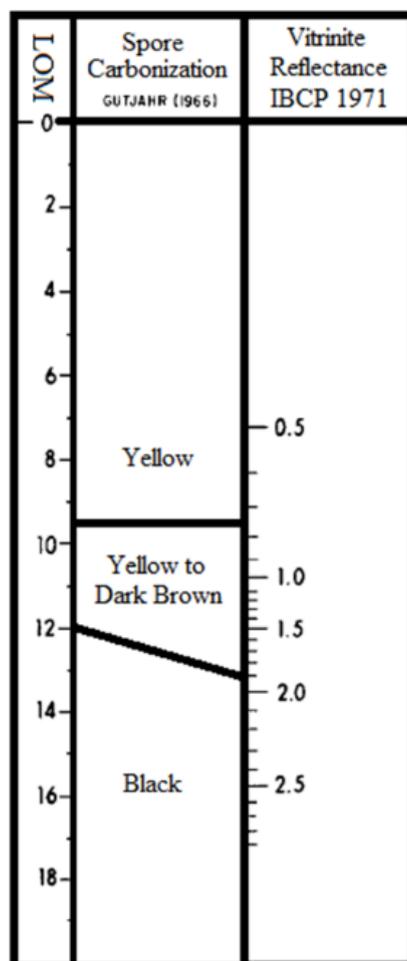
As well as, equations 3 and 4 to calculate TOC from the density and neutron logs respectively were ran in the same method of calculation.

$$\Delta \log R = (\text{Res} / \text{Res baseline}) + p (\text{pb} - \text{pb baseline}) \dots (3)$$

$$\Delta \log R = (\text{Res} / \text{Res baseline}) + p (\Phi N - \Phi N \text{ baseline}) \dots (4)$$

Where:

- Res is the resistivity from the log.
- pb is the density from the log.
- R baseline value in the  $\Delta \log R$ .
- pb baseline value in the  $\Delta \log R$ .
- $\Phi N$  is the porosity from the log.
- $\Phi N$  baseline value in the  $\Delta \log R$ .

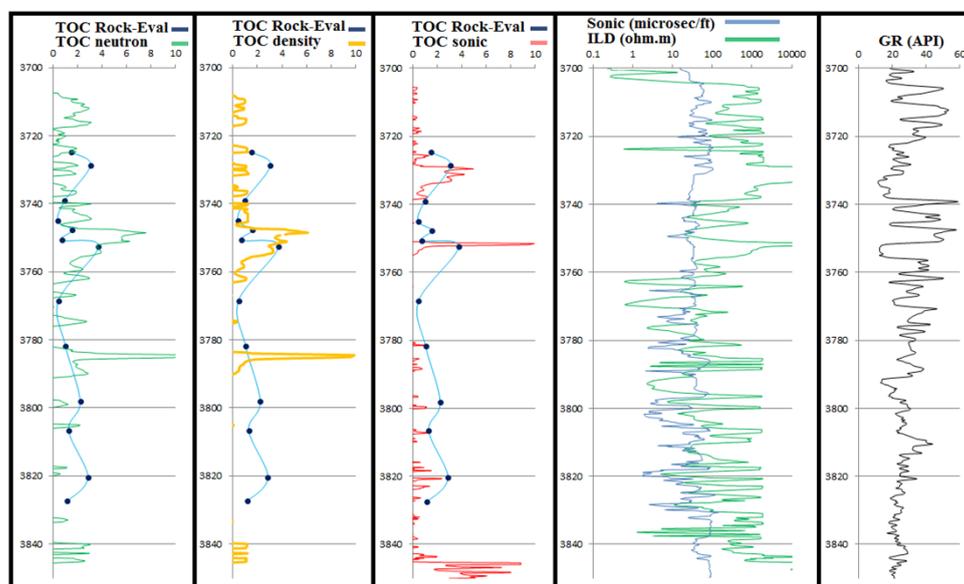


**Figure 3:** Level of Organic Maturity or Metamorphism (LOM) chart, from [3].

### 3. Results and Discussion

Typically, this technique operates as a function to the different porosity logs interaction with resistivity logs. The calculated TOC from the log is compared with Rock-Eval TOC from thirteen (13) of cutting samples, Fig. 4. Calculation of  $\Delta \text{Log R}$  depends on the basis of porosity - resistivity technique was exercised.

The results of this complimentary work summarize as the TOC can be calculated by the effective integration between porosity and resistivity logs. These results are supported by comparison with TOC from the Rock-Eval results. Logs response, as well as TOC, are good indicators to the litho-facies of the studied interval. As a result, the studied section is divided into two main lithologies in respect to the TOC and porosity logs response. These two rock packages start at 3700 to 3760 m (60 m), and 3760 to 3840 m (80 m) from top of Ratawi Fn. To the end of the interval. The recognized two intervals of Ratawi Formation represent a succession of layers of limestone intercalated with shale at the bottom, turn into overlapping sand layers with shale at the top of the formation [16]. The relationship of the TOC results from log and Rock-Eval analyses is important to fix and demonstrate the accomplishment of the log techniques in organic geochemistry evaluation. In well X, the correlation between the calculated and the measured TOC reflects a noticeable similarity between them, Figure 4. Thus, the overlay proved real tools for quantitative determination of TOC in this well. On the other hand, resistivity / RHOB and NPHI logs method were used (equations. 3 and 4) and the results are also illustrated in Figure 4. The comparison between these results detects that Sonic/resistivity integration is the more accurate results, as revealed in Figure 4, in comparing to Rock-Eval TOC from cutting samples.



**Figure 4:** Demonstrates the resulted TOC from porosity logs overlapped by the TOC from Rock-Eval pyrolysis, to compare the results.

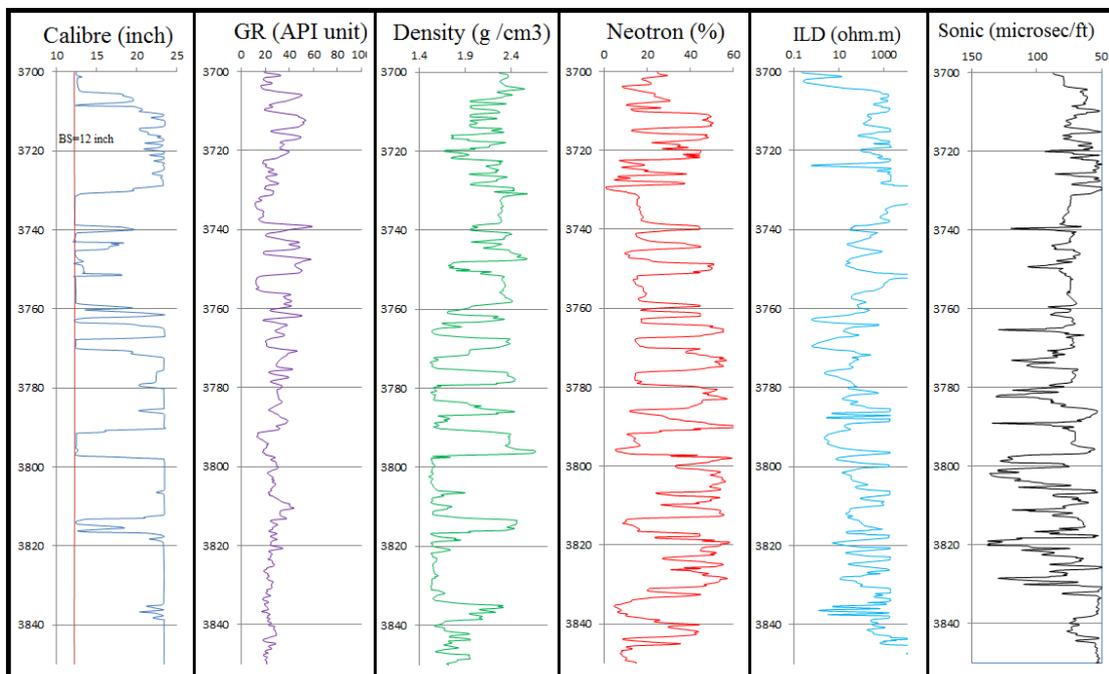
Moreover, the petroleum system analysis took place to indicate the maturity of the Ratawi Formation. Ratawi Formation has a transformation ratio ranged between 69 – 83.5 % in the study area, Fig. 6. While the temperature within the formation ranged between 107.36 – 110.28 C°. These results can indicate that Ratawi Formation is within the peak of oil generation [17]. This indication gives an idea about the source rock type and its ability to produce hydrocarbons. The additional section of petroleum system analysis is a complementary section to illustrate the elements of petroleum system, that they are quantity, quality, and thermal maturity. In this research, the quantity and thermal maturity are detected from wireline log data and simple information from final geological report of the well of interest.

#### 4. Conclusions

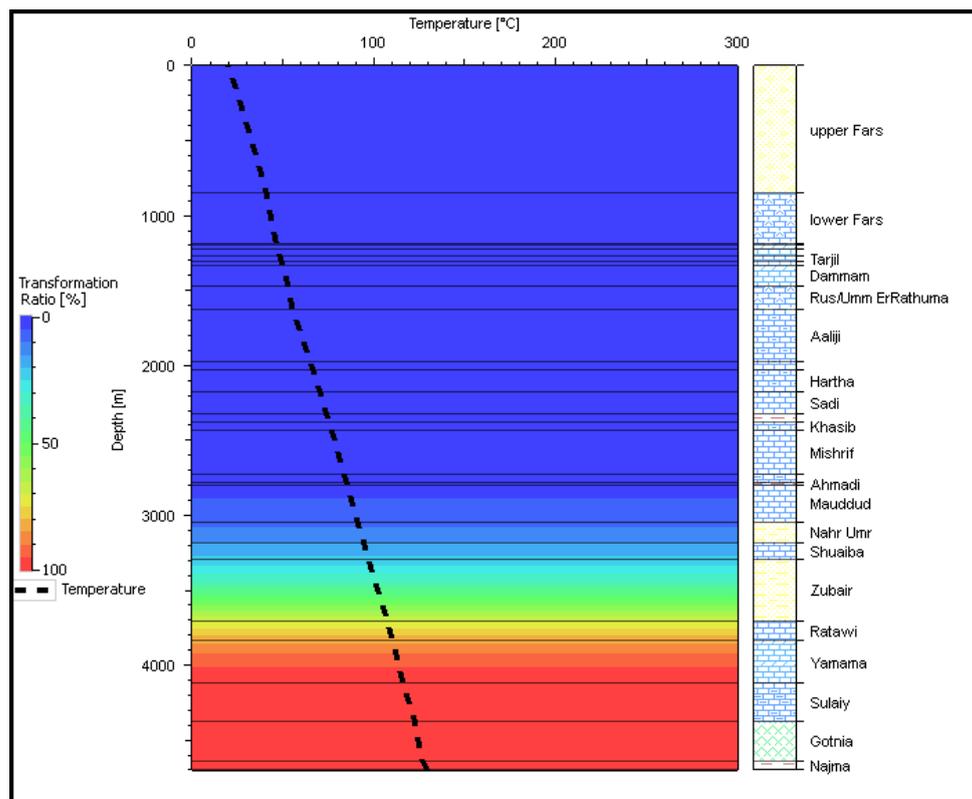
Geophysical logs evaluation to geochemical properties is considered as the up-to-date tool to identify and quantify source rock. The assessment method predominantly starts by detecting the reactions of the GR curvature, Delta t,  $\Phi_N$ , pb and ILLD, to TOC increment. Raising of GR, Delta t, neutron, resistivity and decreasing of density may indicate the increase of TOC but this is not definitely true at all times in each case, see Figure 5.

Porosity/resistivity tool shows that log curves can be used to indicate organic-rich intervals within the formations. As in this case, the calculated TOC ranged from 1-10 wt %; and result is close to the Rock-Eval analysis which means that the studied interval is considered as source-seal rock in the studied section, particularly in the part that ranged 3700-3760 m from the top of the formation. Detecting TOC from log analysis may consider as a useful tool of TOC determination. It is indispensable to calibrate with Rock-Eval pyrolysis data. Results from the overlay show a general accepted compatible with core data in estimating TOC in this area Figure 4. Evaluation of results indicates sonic/resistivity combination provides the most correct or acceptable results as explained in Figure 4, compared with neutron/resistivity and density/resistivity logs methods. As a result, these calculations can be used in intervals that lack geochemical data to obtain an overview of exploration.

Petroleum system analysis showed that Ratawi Formation is within the peak of oil generation. This means the source intervals within the Ratawi Formation is generating petroleum regardless of the type of generated petroleum.



**Figure 5:** Full set of resistivity, porosity, GR, and caliber of the interesting interval, showing the petrophysical properties of the formation. Note that the interval below 3760 m behaves relatively different from upper part.



**Figure 6:** A cross-section between temperature and depth with the transformation ratio overlaid versus the formations succession.

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