Hydrocarbon Potentialities and Source Rock Recognition in the Area North of October Field-Gulf of Suez-Egypt

Aref Lashin, Harald Lindner (Freiberg), Nasser Abu Ashor, M. Sharf El Dien, H. Zahra (Egypt)

1 Introduction

Petroleum exploration around Gulf of Suez began just over 100 years ago at *Ras Gemsa*, with commercial scale oil production starting in 1909. The Gulf is now a well established oil province, presently ranked seventh in terms of production among the major grabens or rift basins of the world.

Allover the Gulf of Suez, the Miocene sediments seems to have a very important role in oil accumulation especially in the studied area (*October Field*), where the large oil discoveries are all located in the tilted fault blocks. In the present paper we are intended to assess the hydrocarbon potentiality of the Northern parts of October Field.

2 October field and available data

October field occurs nearly in the central part of Gulf of Suez. The area under study occupies the northern parts of October field (*Fig.1*).
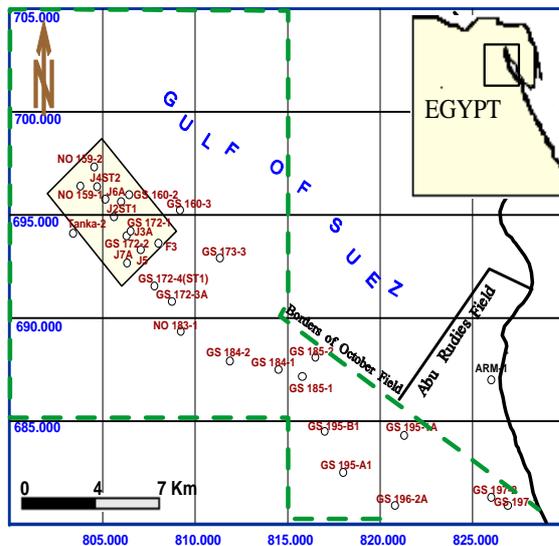

Figure 1 Location map of the study area.

The data used in this work are gathered from 9 wells (vertical and deviated). Our interpretation is fixed to all available logs (*Resistivity, Sonic, Gamma Ray, Density, Neutron, Caliper, Dipmeter, etc*). In addition some geochemical analyses of some wells are used.

3 Aim of study

The goal of this study is to evaluate two formations of prime interest (*Asl* and *Hawara*) of Lower Miocene age. For this purpose a complete well logging analysis, using the various logging data, is carried out to study these formations. For *Asl Formation* as the main oil reservoir in the area under study and for *Hawara Formation* as a possible source rock.

4 Well logging analysis

All logs are used for determining the hydrocarbon potentialities of *Asl Sand* reservoir and for detecting the possible source rock intervals within *Asl Marl* section and *Hawara Formation*.

4.1 Environmental corrections

Logging data have to be corrected for different unwanted environmental effects using the suitable mathematical relationships and charts *(Schlumberger Charts, 1991)*. In the present study preliminary corrections for borehole effects (hole diameter, temperature, presence of mud and mud cake, etc), correction of formation temperature with depth, correction of Gamma Ray for bore hole variations, correction of Neutron Log for matrix variations, etc, were made before running the interpretation techniques.

4.2 Resistivity of water R_W

A precise knowledge of R_W is essential in order to correctly determine the water saturation in a reservoir. Therefor it is important to take care of in its determination by matching and comparing the results obtained from various methods. In the present work a geochemical based value of $0.022\,\Omega\cdot$m was given for both *Asl* and *Hawara Formations*.

4.3 Shale content evaluation

Shales are one of the more important common constituents of rocks in log analysis. Aside from their effects on porosity and permeability, this importance stems from their electrical properties, which have a great influence on the measured resistivity. Thus, determination of shale content is necessary to accurately calculate the porosity from wireline data. The presence of shale in formation, if not accounted for, will normally effect the calculation of reservoir porosity, permeability, water and hydrocarbon saturations.

Volume of shale is determined quantitatively applying different methods and techniques

using both single and double curve indicators. The Gamma Ray method is considered the most accurate among the different used methods. For Tertiary rocks the equation of *Larionov (1969)* is used:

$$V_{sh} = 0.083 \cdot 2^{3.7I_{sh}-1.0} \qquad (1)$$

V_{sh} volume of shale, I_{sh} shale index.

4.4 Porosity determination

Total porosity can be easily determined using Sonic, Density and Neutron logs. Such porosities cannot be used for accurate determination of the fluid content, as they require further correction of the included shale volume in terms of its porosity and content. The following good known equations (*Dresser Atlas, 1979* and *Al-len et al., 1965*) were used:

$$\Phi_{Dcor} = \frac{r_{ma}-rb_{\log}}{r_{ma}-r_f} - V_{sh}\frac{r_{ma}-r_{sh}}{r_{ma}-r_f} \qquad (2)$$

$$\Phi_{Ncor} = \Phi_{N\log} - V_{sh}\Phi_{Nsh} \qquad (3)$$

$rb_{\log}$, $f_{N\log}$ log readings, f_{Dcor}, f_{Ncor} corrected density and neutron porosities, r_{ma} matrix density, r_f fluid density, r_{sh} shale density, f_{Nsh} neutron shale porosity, V_{sh} volume of shale.

Then the average porosity value f_{N-D} is used for interpretation:

$$\Phi_{N-D} = \left(\Phi_{Dcor}+\Phi_{Ncor}\right)/2 \qquad (4)$$

5.5 Water saturation determination

Water saturation S_W is the most important petrophysical parameter used for evaluation of certain reservoir. Just water saturation S_W is determined, accurate calculation and differentiation of the included hydrocarbon potentialities can be made. Water saturation is calculated using different equations of which *Archie's Indonesian* is the most important:

$$\frac{1}{R_t^{1/2}} = \frac{V_{sh}^{1-V_{sh}/2}}{R_{tsh}^{1/2}} + \frac{\Phi_{N-D}^{m/2}}{aR_w^{1/2}}S_w^{n/2} \qquad (5)$$

R_t formation resistivity, R_{tsh} resistivity of shale, V_{sh} volume of shale, R_W formation water resistivity, f_{N-D} effective porosity, a formation factor, m cementation factor, S_W water saturation.

4.6 Source rock determination

Source rocks are commonly shales and lime-mudstones that contain significant amounts of organic matter. Non-source rocks also contain organic matter, but the amount is generally not significant *(Passey et.al., 1990)*. The discrimination of hydrocarbon source rocks from non hydrocarbon source rocks using electric logs is a fairly new technique which is considered by many workers, with some limitations, to be very effective and helpful, especially when geochemical analytical data are not available.

4.6.1 Response of logs to organic matter

Presence of organic matter embeded in a certain rock produces significant changes in its physical properties (density, porosity, resistivity and radioactivity). Such changes make it possible to define the organic rich rocks using their electric logs. It makes Gamma Ray, Sonic, Neutron and Resistivity logs to read high values, while it reduces the reading of the Density log.

4.6.2 Used methods

In the present study the total organic carbon is estimated using two different methods. The first (**D**logR-Technique) is proposed by *Passey et.al (1989, 1990)*. This method depends mainly on the combination of resistivity with porosity logs and allows organic richness to be accurately assessed in a wide variety of lithologies and maturities using common well logs.

The second method of *Schmoker* and *Hester (1983)* relates the organic carbon content (TOC %) to the density log only. This method can be successfully applied, if the constants A and B are calibrated and matched with the available analytical geochemical data, if found.

5.6.2.1 **D**logR-Technique

It employs the overlaying of a properly scaled porosity log (Sonic, Density or Neutron) on a resistivity curve (preferably from deep reading tool). The transit-time curve and the resistivity curve are scaled such that their relative scaling is 100 μs/ft per two logarthmic resistivity cycles. The curves are overlain and baselined (in such manner that they directly overlie each other over a significant depth range) in front of non-source rock. The organic-rich intervals can be then recognized by the separation and non-parallesim of the rest of the two curves. The expression for the calculation of **D**logR

from Sonic/Resistivity overlay can be represented using *Passey et.al., 1990* equation:

$$\Delta \log R = \log \left(R_t / R_{tbl} \right) + 0.02 \left(\Delta T - \Delta T_{bl} \right) \quad (6)$$

D*logR* curve separation measured in logarithmic resistivity, R_t true resistivity, **D***T* sonic log reading, R_{tbl} and **D***T*$_{bl}$ resistivity and sonic log readings when the curves are base-lined in front of non-source, clay-rich rocks, 0.02 constant based on the ratio of 50 µs/ft per one resistivity cycle.

Then, total organic carbon *TOC* can be calculated:

$$TOC(\%) = (\Delta \log R) \cdot 10^{2.297 - 0.1688 \cdot LOM} \quad (7)$$

TOC total organic carbon content, *LOM* level of maturity (7 ... 12 for mature oil).

Density and neutron curves can be also used in combination with the resistivity curve in a similar way to that used in the sonic/resistivity combination.

4.6.2.2 Density Log Method
Density log method was applied to estimate the total organic carbon content *TOC* for the two studied formations. For *Hawara Formation* which consists mainly of shales interclated with thin limestone interbeds, and suggeted to be the possible source rock for the overlaying *Asl oil reservoir*, and for the upper marl section of *Asl Formation* which is also possible good source rock.

The following equation, after *Schmoker et.al, 1983* is used to estimate the total organic carbon content (*TOC%*):

$$TOC(\%) = A / \boldsymbol{r} b \log - B \quad (8)$$

r*b*$_{\log}$ density log reading (gm/cc).

A and *B* are constants varies from area to area and from formation to formation. In the present work *A* and *B* constants are estimated and matched with the available data obtained from the geochemical analysis of some wells in the study area. We used for *Asl Formation A* = 11.68 and *B* = 3.88, while for *Hawara Formation A* = 8.77 and *B* = 2.80.

5 Interpretation
Asl Sand Section exhibits very good petrophysical characteristics in the study area in terms of good effective porosity, low shale and good hydrocarbon contents. Effective porosity ranges in value between 8% and 14%. Shale content is lower than 10% in all studied wells. Very good hydrocarbon saturations of 82%, 84% and 88% were detected in wells *GS 172-2*, *J5* and *J7A* respectively among the studied wells. *Figs.* 2 and 3 represent the PDL log and source rock analysis of *GS 172-2* as an example. This well is located nearly at the southern part of the study area, more closely to *J3A* well. The interested *Asl Sand* reservoir encountered at depth of 10265ft and extends to depth 10599 ft. High $\boldsymbol{f}_{eff}$ of 9% is found especially at the lower most part as shown in Track 3 (*Fig.2*). Very low shale volume is detected as shown in Track 1. Low water (18%) and high hydrocarbon (82%) saturations are detected in this zone, associated with very high R_{wa} values (up to 20 Ω·m in some levels of the sand) as shown in Tracks 2 and 3.

Asl Marl section, on the other hand, shows no hydrocarbon saturations. Moderate $\boldsymbol{f}_{eff}$ of 5%, high water saturation of 96% and high shale content of 49% were recorded.

Moreover, *Hawara Formation* is composed mainly of shales with minor limestone interbeds. Avery low effective porosity of 3% and very high water content of 99% were detected for this formation.

Source rock analysis reveals good source rock characters of *Asl Marl* with good *TOC-* values in some wells and fair to good in the others. Good *TOC-* values of 1.85%, 1.26% and 1.79% were recorded in wells *J3A*, *J4ST2* and *J6A* respectively.

Fig. 3 shows the source rock analysis of *GS 172-2* well. Fair source rock values of 0.75% and 0.99% are detected for *Asl Marl* section using both methods of *Schmoker* and *Passey* as shown in Track 5. This is well indicated by the relative, not so wide right ward, deflection of the resistivity curve on the expanse of the other porosity logs in Tracks 2, 3 and 4. Good separation is observed in front of *Asl Sand* section. Such separation is due to the effect of the implied hydrocarbons which is not function of organic richness. In front of *Hawara Formation* all the resistivity and porosity curve overlays are matched and base-lined indicating the non source nature of this formation.
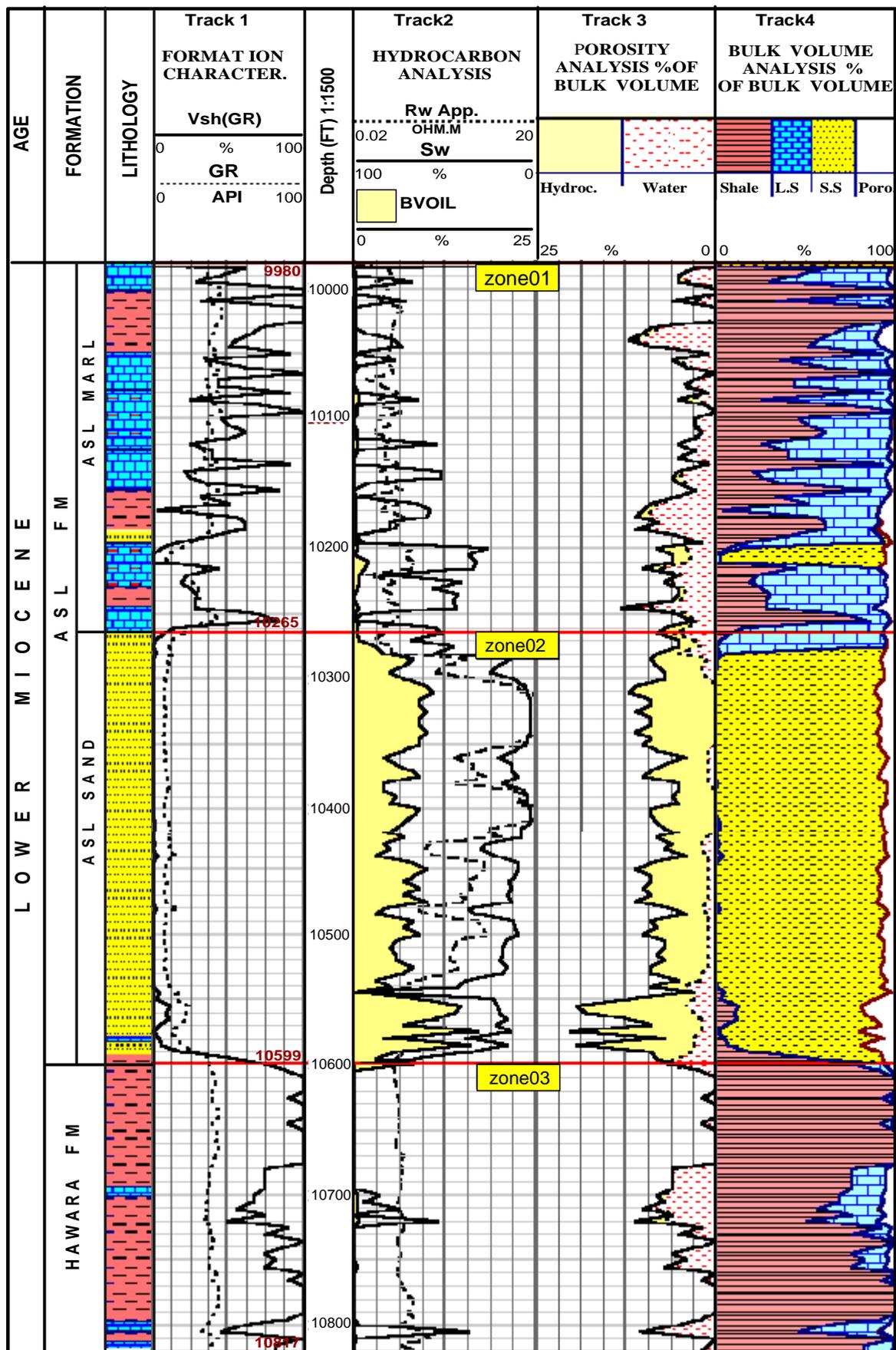
Figure 2 Petrophysical data log (PDL) of GS 172-2 well.
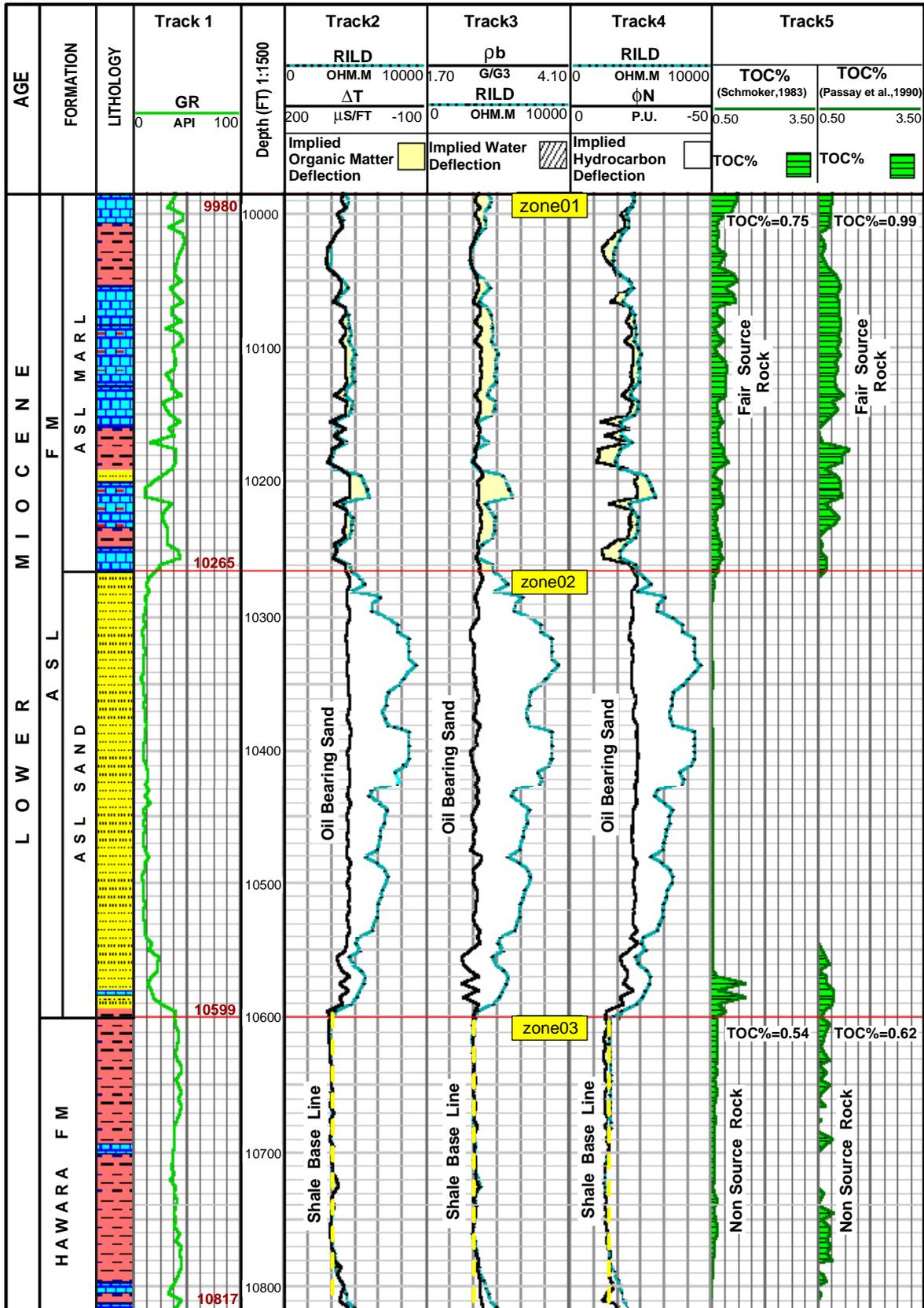
Figure 3 Source and non-source rock recognition of GS 172-2 well.

6 Summary

Comprehensive well logging analysis was carried out over the two studied formations. The suitable environmental corrections were applied before going on the analysis technique. R_w value is determined by many techniques. A geochemical based value of $0.022\,\Omega \cdot m$ was used in the interpretation.

Volume of shale is determined by Gamma Ray log method. *Larionov* equation for Tertiary rocks was applied. Very low shale content was recorded for *Asl Sand* (less than 10%), while much higher values were recorded for *Asl Marl* and *Hawara Formation*. It ranges from 14% (*J6A*) to 57% (*J5*) and from 63% (*NO159-2*) to 87% (*GS 172-2*) for both *Asl Marl* section and *Hawara Formation* respectively.

Effective porosity f_{N-D} was determined using the neutron and density porosities corrected for shaliness. The effective porosity of *Asl Sand* is ranging between 8% and 14%.

Water saturation is estimated using *Archie`s Indonesian* equation. *Asl Sand* section was found with very good hydrocarbon potentialities, as very good saturations of 82,% 84% and 88% were recorded in some wells like, *GS 172-2*, *J5* and *J7A*.

Source rock analyses were carried out for measuring *TOC* content using *Schmoker* and *Passey et.al* methods. Some geochemical measurements were used for matching. Non source rock characteristics were given for *Hawara Formation* which shows poor *TOC*-values.

Asl Marl on the hand is found having good *TOC*% in some wells and fair to good in the others. In general *Asl Marl* is considerd good source rock. Good *TOC*- values of 1.85, 1.26 and 1.79 were recorded in wells *J3A*, *J4ST2* and *J6A* respectively.

8 References

Allen, L.S., Mills, W. R. and Goldwell, R. L., The Effects of Fluid Invasion in Pulsed Neutron Logging, Geophysics Vol. 30, No. 3, 1965.

Dresser Atlas, *Log Interpretation charts, Houston*, Dresser Industries, Inc., 107 p., 1979.

Larionov, V. V., Borehole Radiometry, Nerda, Moskwa, 1969.

Passey, Q. R., Creany, S., Kulla, J. B, Moretti, F.J and Stroud, J. D, Well Log Evaluation of Organic Rich Rocks, 14th International Meeting on Organic Geochemistry, Paris, Abstract 75, 1989.

Passey, Q. R., Creany, S., Kulla, J. B, Moretti, F.J and Stroud, J. D, A practical Model for Organic Richness from Porosity and Resistivity Logs, AAPG, V.74, NO 12, pp. 1777-1794, 1990.

Schlumberger, Log Interpretation Charts, Houston, Texas, USA, 1991.

Schmoker, J. W. and Hester, T.C., Organic Carbon in Bakken Formation, United States Portion of Williston Basin. Vol. 67, No. 12, pp. 2165-2174, 1983.