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SUBSURFACE AND WELL LOG STUDY ON THE WESTERN AREA OF NILE DELTA WITH SPECIAL EMPHASIS ON ITS HYDROCARBON POTENTIALITIES

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ABSTRACT

The subsurface geology of west Delta area has been integrated by the well-log analysis to evaluate the hydrocarbon potentialities of this area.

The subsurface geology comprises the study of lithostratigraphy and lithofacies analysis of Kafr El Sheikh, Abu Madi and Sidi Salem Formations as well as the outlining of the regional structural deformation and the tectonic implications operated in the study area. These elements are illustrated by isochore maps, correlation charts, the shale and net sand percentage maps, structural contour maps and geologic cross sections.

The well-log analysis is concerned with logging interpretation of the given logs to perform quantitative estimation of reservoirs in subsurface sequence by using the well-log techniques. Environmental corrections were applied on the log readings for evaluation of Abu Madi Formation in the study area.

The lithologic composition, effective porosity, hydrocarbon and water saturations were clarified through the litho-saturation crossplots. The horizontal distributions of the above mentioned petrophysical parameters and their relation to the geologic setting of the study area were presented through the iso-parametric maps.

Based on the obtained results, Abu Madi sandstones have a promising reservoir characteristics which should be taken into consideration.

INTRODUCTION

Since the 1920's interest in Deltas has been stimulated by the fact that the sediments of many ancient Deltas contain large accumulations of hydrocarbons.

Twenty years ago, hydrocarbons have been discovered in Abu Madi gas field, and later in Qantara field within the Nile Delta onshore. Recently, hydrocarbons have been discovered in west Abu Qir gas field.

In the last years, Abu Madi Formation in west Nile Delta area received particular attention from petroleum geologists as it represented the main gas producing formation in the Nile Delta. Its age is attributed to Lower Pliocene or Middle Miocene (Barakat, 1982).

The area of study is located to the west of Rossetta Branch (Fig.1). It occupies an area delineated by longitudes 30° 00 to 30° 45' E, and latitudes 30° 50` to 31° 15` N. It embraces an area of about 3105 Km^2.

For the present research the geologic and well-log data of six wells covering the study area were selected. These six wells (Mahmodiya-1, Kaf El Dawar-1, South Damanhour-1, Itay El Baroud-1, Hosh Isa-1 and North Dillingat-1) were drilled by Philips Petroleum Company in 1970. The geologic setting of the Nile Delta has been studied by many authors such as Rizzini et al. (1976), Zein El-Din and Marzouk (1973), Zaghlul et al. (1977), Marzouk (1981), Halim (1992) and others. However, this study was suggested to integrate the subsurface geologic developments for understanding Abu Madi reservoir in west Nile Delta area.

1. SUBSURFACE GEOLOGIC SETTING

The subsurface evaluation, dealt with in this study, is based principally on the lithologic and depth data obtained from the composite logs of the studied wells in the west Delta area.

The sedimentary sequence of the Nile Delta (Fig.2) ranges in age from Pre-Miocene (Oligocene or older) to Holocene.

Regarding the hydrocarbon potentiality in the study area, more emphasis was made on Sidi Salim, Abu Madi and Kafr El Sheikh Formations.

Thickness Variation : The isochore map of Sidi Salim Formation (Fig.3) indicates that the maximum thickness of the formation is recorded in the center of the study area around South Damanhour-1 well, with a gradual thinning outwards. The isochore map of Abu Madi Formation (Fig.4) illustrates a considerable reduction in thickness of this formation with complete change in the basinal and ridge-like areas as they were during deposition of Sidi Salim Formation. This thickness pattern indicates that the deepest part of the Abu Madi sedimentation basin was at the northern sector of the study area, with a gradual rise of the basin floor southward. This may point to the presence of the shore-line in the South. Similar to Abu Madi Formation the isochore map of Kafr El Sheikh Formtion (Fig.5) illustrates that the thickness increases gradually towards the northern and western parts around Mahmodiya and Kafr El Dawar wells.

However, the study of isochore maps of Sidi Salim, Abu Madi and Kafr El Sheikh Formations indicates that the basinal distribution of Sidi Salim Formation of Miocene age is completely different from that of Abu Madi and Kafr El Sheikh Formations of Early and Middle Pliocene age.

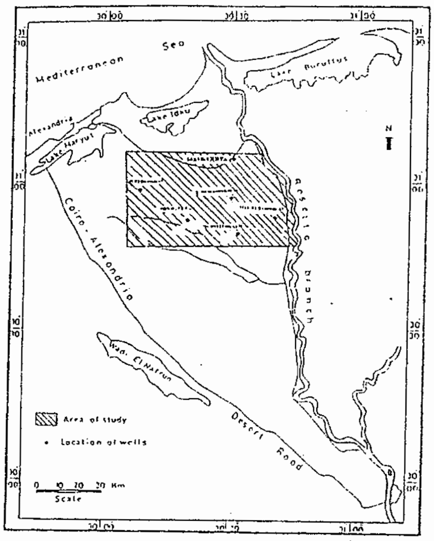


FIG. (I) LOCATION MAP OF THE STUDY AREA.

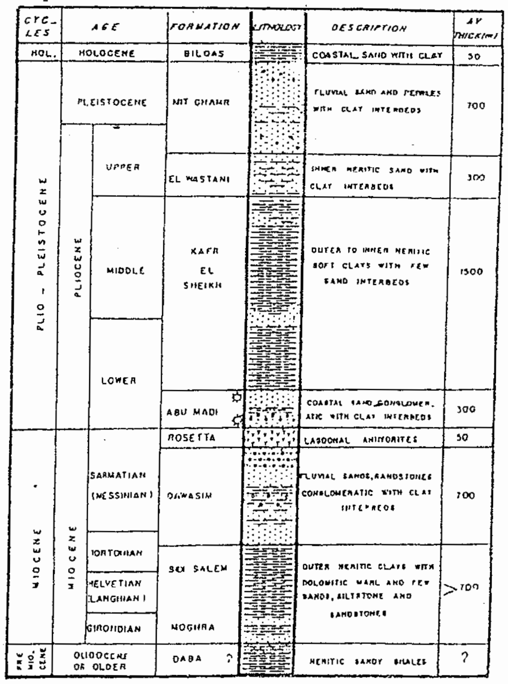


FIG. (2) SUBSURFACE STRATIGRAPHIC COLUMN FOR THE NILE DELTA AREA, EGYPT

(AFTER ZAGHLOUL, ET . AL. 1980, BARAKAT, 1982 AND OTHERS)

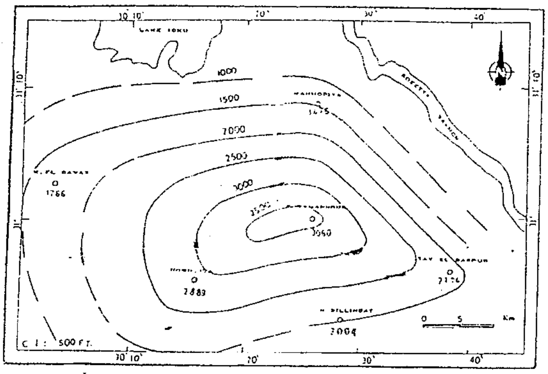


FIG. (3) ISOCHORE MAP OF SIDI SALEM FORMATION,
WEST DELTA AREA, EGYPT.

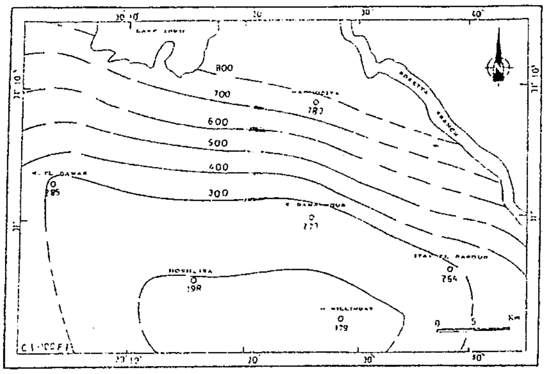


FIG. (4) ISOCHORE MAP OF ABU MADI FORMATION,
WEST DELTA AREA, EGYPT.

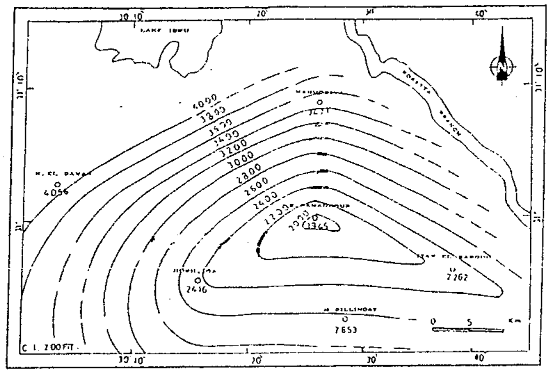


FIG. (5) ISOCHORE MAP OF KAFR EL SHEIKH FORMATION,
WEST DELTA AREA, EGYPT.

Configuration of the Structures : The constructed structural contour maps (Figs. 6 to 8) show that Abu Madi and Sidi Salim Formations appear to be deformed in the form of anticline structure with a general SW-trend, while Kafr El Sheikh Formation is a monocline or very gentle anticline dipping towards East. Faulting is observed allover the study area. The faulting system is discriminated essentially into three main trends; ENE - WSW, NW - SE and E - W. These faults produce horst and step structures. The constructed cross-sections (Figs. 9 to 13) revealed the same conclusion that previously obtained from the structural contour maps.

Lithofacies Analysis : The lithofacies analysis of Sidi Salim and Kafr El Sheikh Formations (Figs. 14 to 19) show that these formations are composed mainly of argillaceous sediments as evidenced from their shale percentage maps. On the other hand, Abu Madi Formation can be classified into two more sandy and two more shaly units; namely 1, 2, 3 and 4 from base to top of the formation (Figs. 20 and 21). However, the geologic history of the west Nile Delta area reveals that the area was influenced by different phases of transgression and regression of the Mediterranean Sea.

2. WELL LOGGING ANALYSIS

The sandstone of Abu Madi Formation was subjected to comprehensive well-log analysis for evaluation of its hydrocarbon potentiality. The formation evaluation process was based on equation and charts recommended by Schlumberger: Principles (1972) Essentials (1972), Applications (1974) and Charts (1985) as well as Clavier et al. (1971) and Helander (1978). The determination of the formation temperature (FT) and the correction of fluid resistivities at this temperature were made through Helander equation (1978). Corrections of bore-hole effect on resistivity logs were also done. The

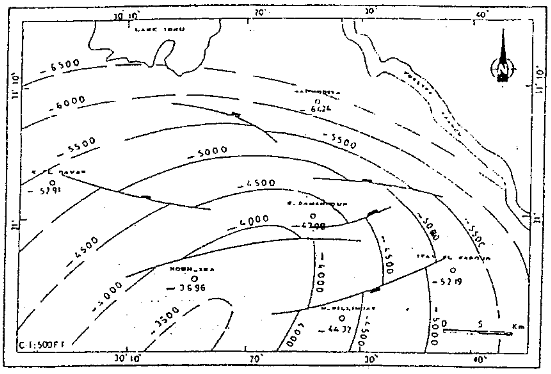


FIG. (6) STRUCTURAL CONTOUR MAP ON TOP SIDI SALEM FORMATION, WEST DELTA AREA, EGYPT. (FAULT TRENDS MODIFIED AFTER PRESUTI, 1971)

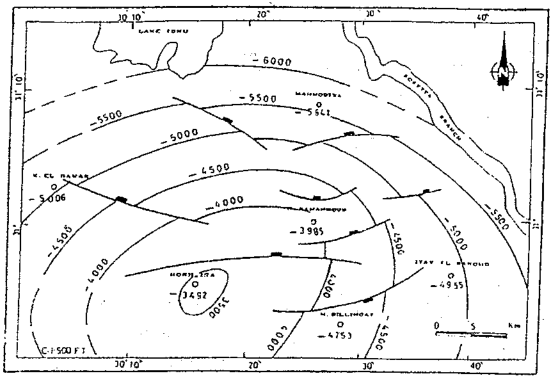


FIG. (7) STRUCTURAL CONTOUR MAP ON TOP ABU MADI FORMATION. WEST DELTA AREA, EGYPT. (FAULT TRENDS MODIFIED AFTER PRESUTI, 1971)

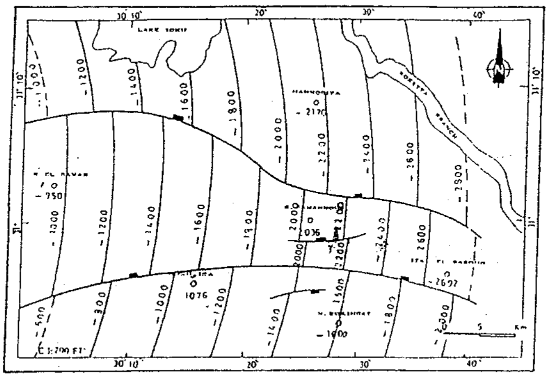


FIG. (8) STRUCTURAL CONTOUR MAP ON TOP KAFR EL SHEIKH FORMATION, WEST DELTA AREA, EGYPT. (FAULT TRENDS MODIFIED AFTER PRESUTI, 1971)

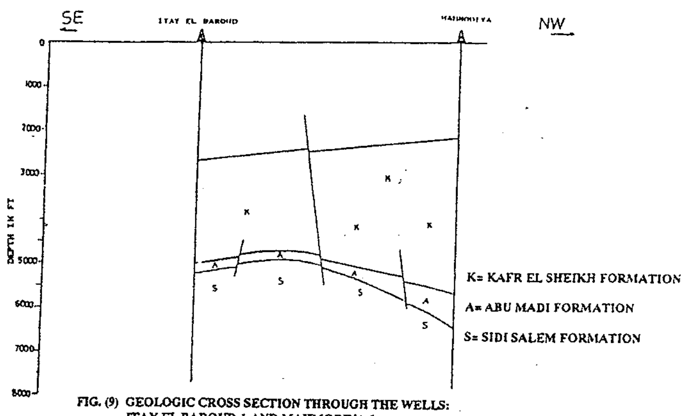


FIG. (9) GEOLOGIC CROSS SECTION THROUGH THE WELLS: ITAY EL BAROUD-1 AND MAHMODIYA-1.

0 5 Km
H-SCALE

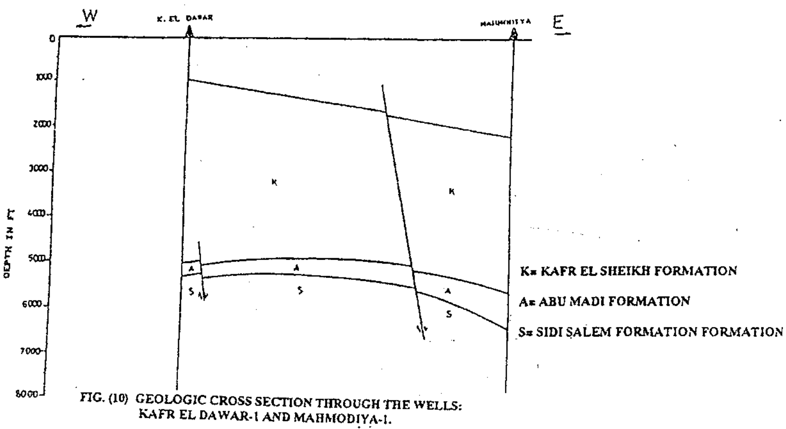


FIG. (10) GEOLOGIC CROSS SECTION THROUGH THE WELLS: KAFR EL DAWAR-1 AND MAHMODIYA-1.

0 5 Km
H-SCALE

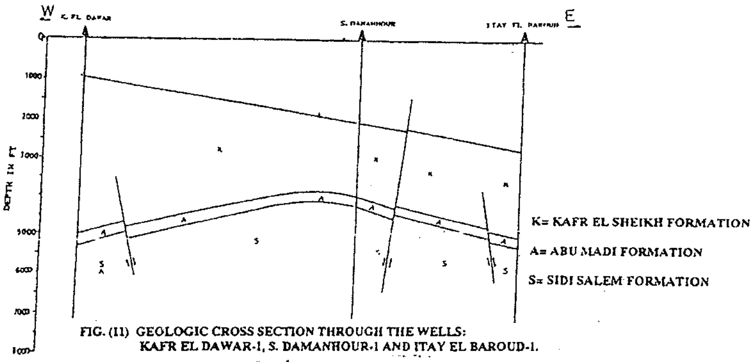


FIG. (11) GEOLOGIC CROSS SECTION THROUGH THE WELLS: KAFR EL DAWAR-1, S. DAMANHOUR-1 AND ITAY EL BAROUD-1.

0 5 Km
H-SCALE

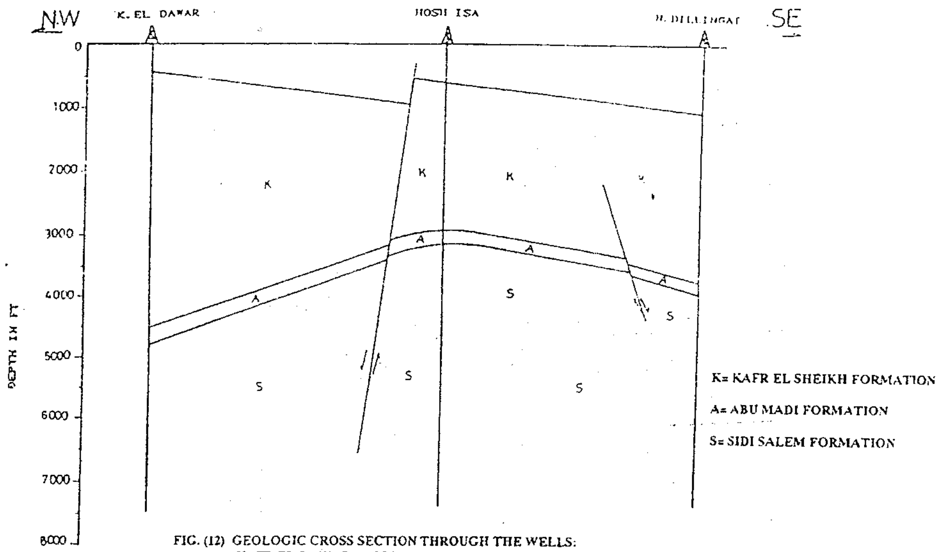


FIG. (12) GEOLOGIC CROSS SECTION THROUGH THE WELLS:
KAFR EL DAWAR-1, HOSH ISA-1 AND N. DILLINGAT-1.

0 5 Km.
H. SCALE

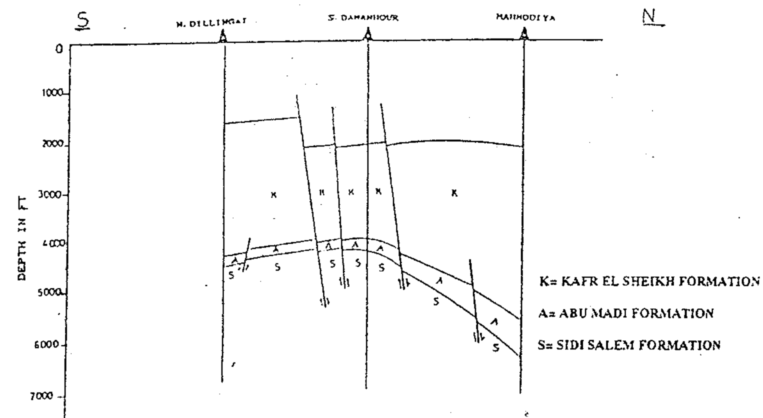


FIG. (13) GEOLOGIC CROSS SECTION THROUGH THE WELLS:
N. DILLINGAT-1, S. DAMANHOUR-1 AND MAHMODIYA-1.

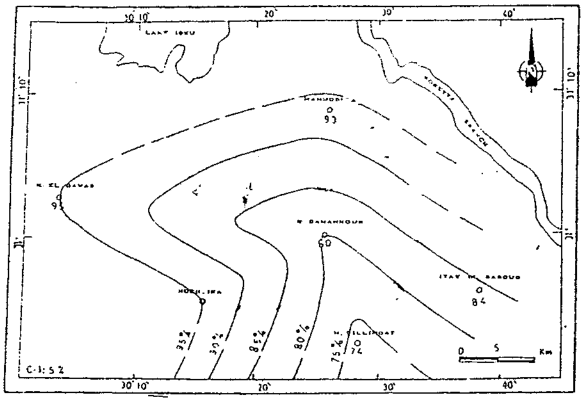


FIG. (14) SHALE PERCENTAGE MAP OF SIDI SALEM FORMATION, WEST DELTA AREA, EGYPT.

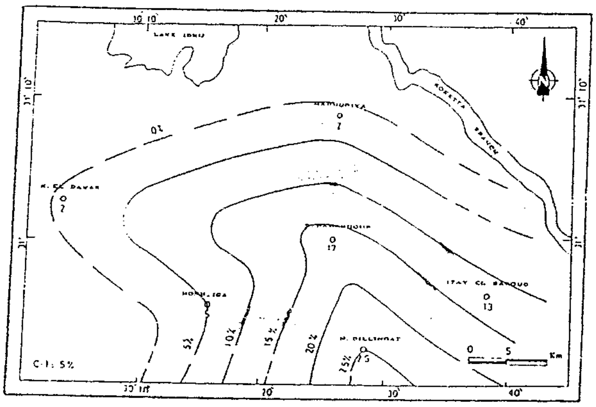


FIG. (15) SANDSTONE PERCENTAGE MAP OF SIDI SALEM FORMATION, WEST DELTA AREA, EGYPT.

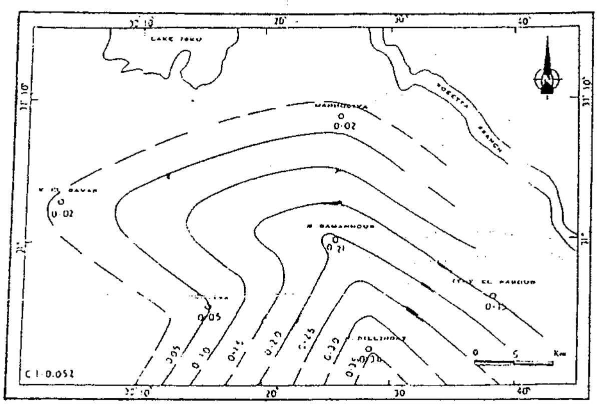


FIG. (16) SAND / SHALE RATIO MAP OF SIDI SALEM FORMATION, WEST DELTA AREA, EGYPT.

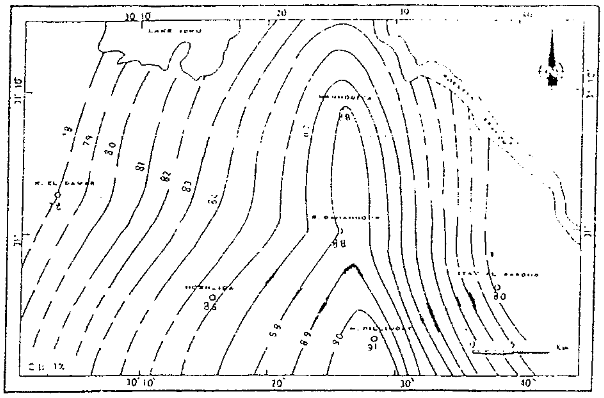


FIG. (17) SHALE PERCENTAGE MAP OF KAFR EL SHEIKH FORMATION, WEST DELTA AREA, EGYPT.

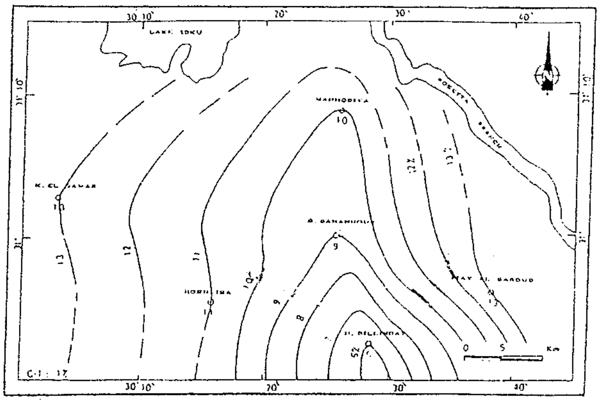


FIG. (18) SANDSTONE PERCENTAGE MAP OF KAFR EL SHEIKH FORMATION. WEST DELTA AREA, EGYPT.

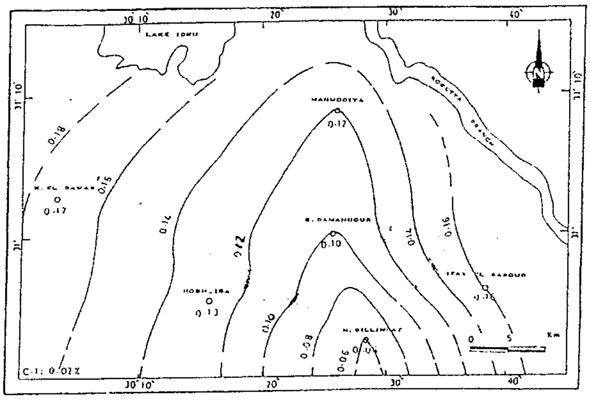


FIG. (19) SAND / SHALE RATIO MAP OF KAFR EL SHEIKH FORMATION, WEST DELTA AREA, EGYPT.

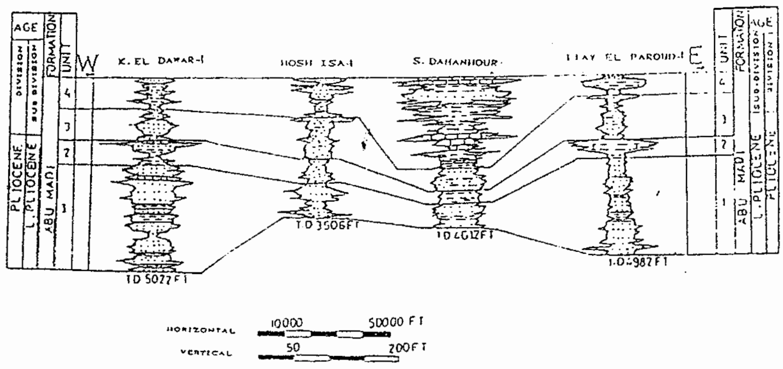


FIG. (20) STRATIGRAPHIC PANEL OF ABU MADI FORMATION THROUGH : KAFR EL DAWAR-1, HOSH ISA-1, SOUTH DAMANHOUR-1 AND ITAY EL BAROUD-1 WELLS.

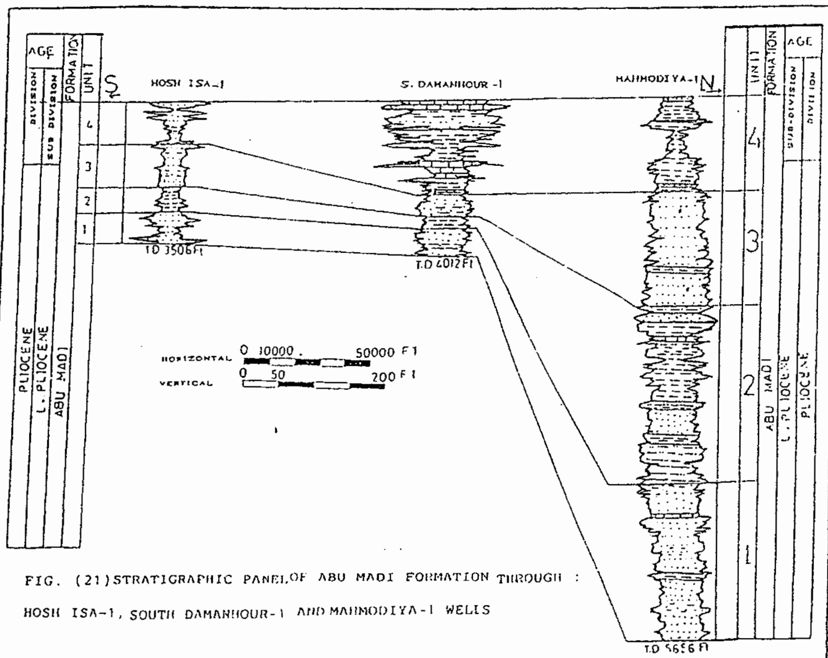


FIG. (21) STRATIGRAPHIC PANEL OF ABU MADI FORMATION THROUGH : HOSH ISA-1, SOUTH DAMANHOUR-1 AND MAHMODIYA-1 WELLS water resistivity (R_W) was determined by the graphical technique, using the static spontaneous potential (SSP) and the mud filtrate resistivity (R_{mf}) at the formation temperature through Schlumberger Conversion Charts (1972). The determination of the shale content (V_{sh}) is achieved through both gamma-ray and spontaneous potential after executing the needed corrections. The minimum value of these indicators is subjected to correction formula (Clavier et al. 1971) to be very closed to actual value of V_{sh} through core analysis. The determination of the corrected effective porosity $\varnothing_E$ is executed using the combination of the density and sonic logs (Figs. 22 to 25), after applying the various corrections needed to those logs. The deviation of the plotted points in Figures 24 and 25 is due to the high values of $\varnothing_s$ which may attributed to the effect of hydrocarbons or the secondary porosity. Evaluation and discrimination of the fluid contents as water, movable and immovable hydrocarbons are also carried out for each zone using Simandoux (1963) and the normal analytical equations :

$$S_h = 1 - S_W, \quad S_{hr} = 1 - S_{xo}, \quad S_{hm} = S_h - S_{hr}$$

(Schlumberger Applications, 1974)

Averaged values of each parameter for Abu Madi Formation in each well was calculated. Average of these parameters is achieved by using the weighed average equations (Table 1).

3. RESERVOIR-ROCK STUDY

Several attempts have been made to deduce the reservoir characteristics of Abu Madi Formation within the study area by integrating the various results obtained from the subsurface geologic studies and the formation evaluation process. This can be achieved through the study of the vertical and lateral changes in the Abu Madi Formation in the investigated wells through the litho-saturation crossplots and isoparametric maps.

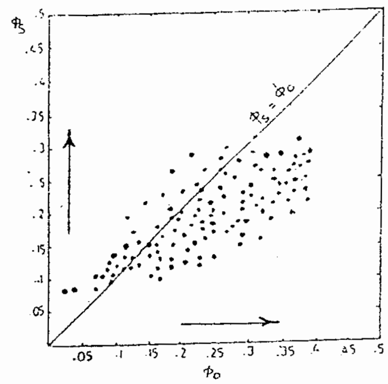


FIG. (22) DENESITY-DERIVED VERSUS SONIC DERIVED POROSITIES IN WELL MAHMODIYA, ABU MADI FORMATION.

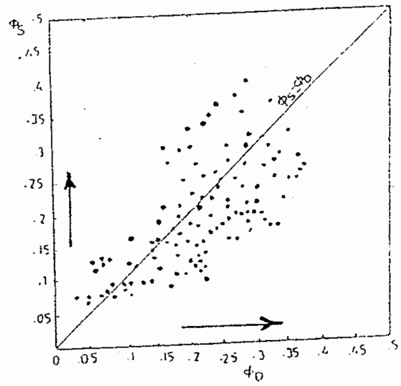


FIG. (23) DENESITY-DERIVED VERSUS SONIC DERIVED POROSITIES IN WELL KAFR EL DAWAR, ABU MADI FORMATION.

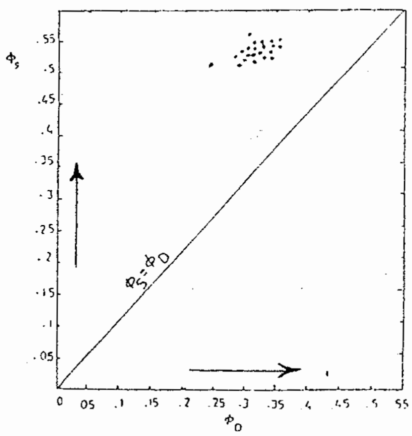


FIG. (24) DENESITY-DERIVED VERSUS SONIC DERIVED POROSITIES IN WELL S. DAMANHOUR, ABU MADI FORMATION.

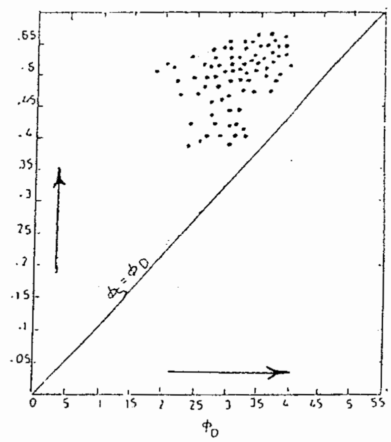


FIG. (25) DENESITY-DERIVED VERSUS SONIC DERIVED POROSITIES IN WELL HOSH ISA, ABU MADI FORMATION.

ϕ_s: porosity dervied from Sonic Log

ϕ_D : porosity dervied from Density Log

Table (1) : Average Reservoir Parameters of Abu Madi Sandstone (Lower Pliocene), West Delta Area.

Table (1) : Average Reservoir Parameters of Abu Madi Sandstone (Lower Pliocene), West Delta Area.

Well	Formation		Gross thick FT	Net sand				
	Top FT	Bottom FT		Net FT	VSH %	Phie %	SW %	SH %
Kafr El-Ddawar-1	5006	5291	285	207	31 %	33 %	73 %	27 %
Mahmodiya-1	5641	6424	783	462	20 %	23 %	71 %	29 %
Hosh Isa-1	3492	3696	198	135	21 %	37 %	79 %	21 %
S. Damanhour-1	3985	4208	223	39	26 %	38 %	69 %	31 %
Itay El Baroud-1	4955	5219	264	190	9 %	39 %	99 %	1 %

N.B. : Net San Calculation :

Litho-Saturation Crossplots

1- Mahmodiya-1 well

Fig. (26) shows almost identical relationship between rock and fluid fraction in Abu Madi Formation of Mahmodiya-1 well. The shale matrix content is relatively lower than sand matrix, while the limestone matrix increases towards the top of Abu Madi Formation.

The porosities of Mahmodiya-1 well are generally considerable (average $\varnothing_E$ =23%). Such pores are filled with more than (70%) of water. Movable hydrocarbons are predominant in this well.

2. Hosh Isa-1 well :

In the Abu Madi Formation of Hosh Isa-1 well (Fig. 27), the

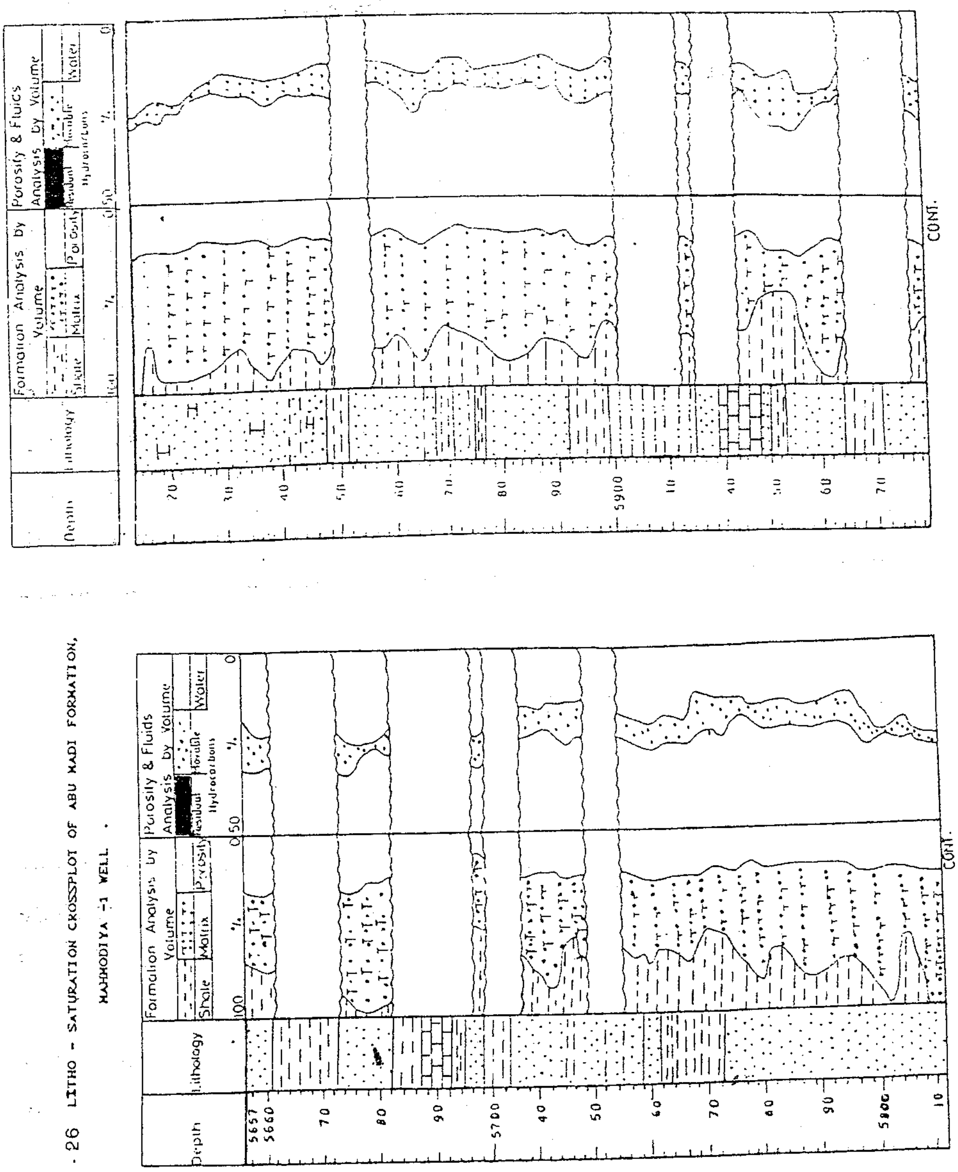
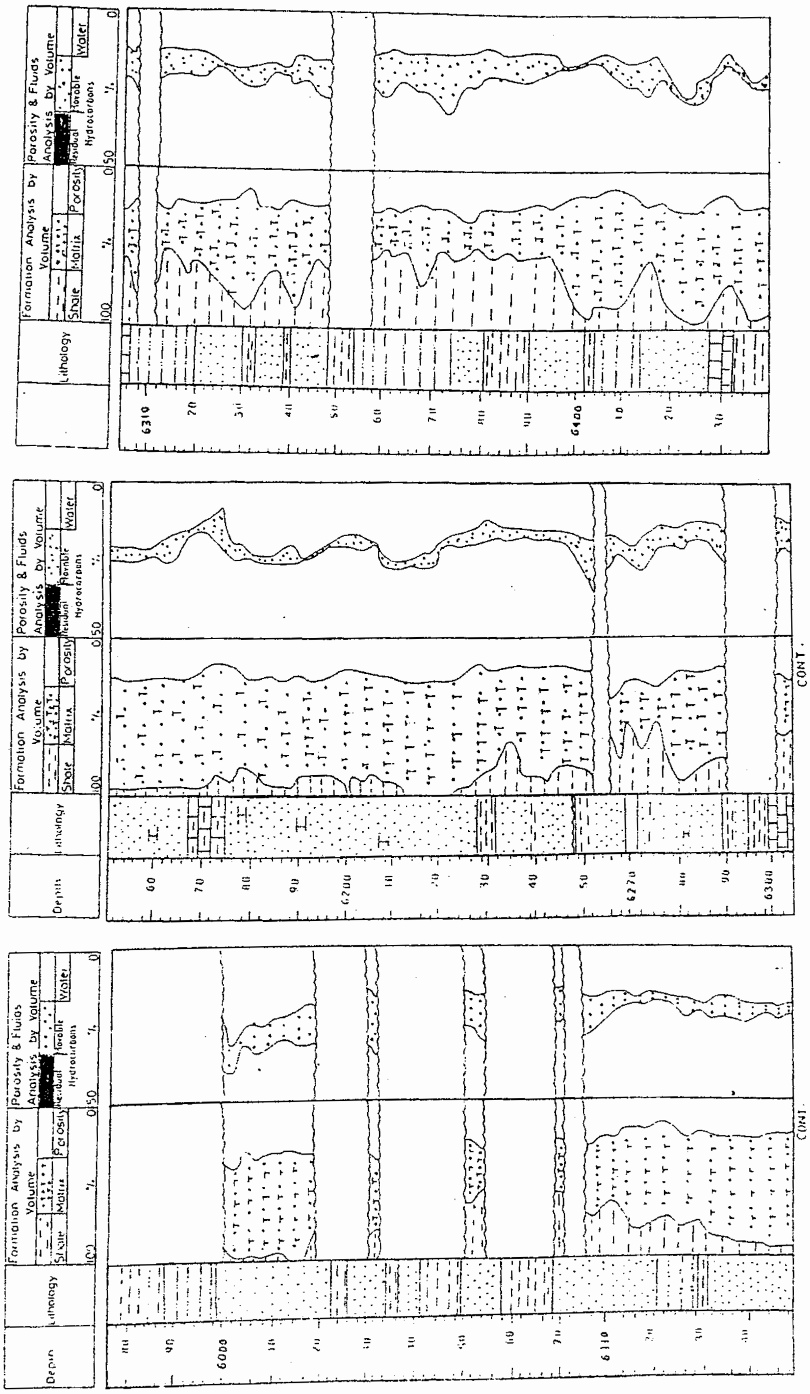


FIG . 26 LITHO - SATURATION CROSSPLOT OF ABU MADI FORMATION, MAHMODIYA -1 WELL .


Formation Analysis by Volume
Shale
Matrix
Porosity
Porosity & Fluids Analysis by Volume
Residual
Movable Hydrocarbons
Water
Lithology
Depth
6310
6400
6200
6270
6300
6000
CONT.

sand matrix constitutes the major part of this formation, while the shale and the limestone matrices are the minor constituents. The porosities of Abu Madi Formation in Hosh Isa-1 well are generally higher than that of Mahmodiya-1 well (average $\varnothing_E$ = 37%). These pores contain high percent of connate water (average S_W = 79%) and a relatively low hydrocarbon content which is represented only by movable hydrocarbons (average S_h = 21%). The composite log of this well suggested that the top of Abu Madi Formation is a shaly sand, while the well-log analysis reveals that this top is nearly clean sand. This may be due to the accurate calculation of the corrected V_{sh} through the well-log analysis.

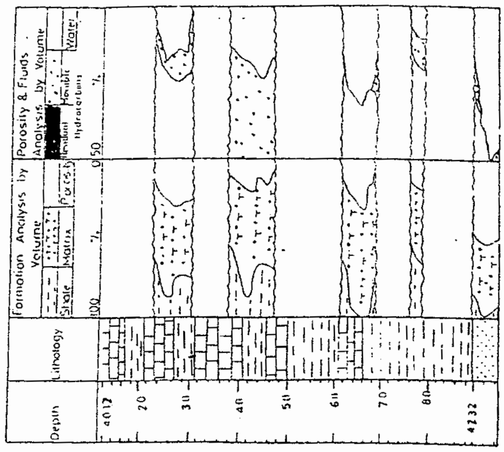
3. South Damanhour-1 well :

The litho-saturation Crossplot of South Damanhour-1 well (Fig. 28) exhibits that the shale matrix is the minor constituent in Abu Madi Formation, while the sandstone matrix represents the major part. There is limestone intercalations in the upper and central parts of the Abu Madi Formation. The porosity of Abu Madi Formation in this well is rather high compared with the other studied wells (average $\varnothing_E$ = 38%). Such pores are filled with more than 31% of movable hydrocarbons, which represent the highest value comparing with the other wells.

Lateral Variation of Hydrocarbon Plays :

The lateral variation of hydrocarbon plays can be illustrated through a number of porosity and saturation maps. These maps utilize the important effect of some of the petrophysical parameters (available pore spaces and the fluid content) in the Abu Madi Formation through the studied wells.

FIG. 28 LITHO - SATURATION CROSSPLOT OF ABU MADI FORMATION, SOUTH DAMANHOUR -1 WELL.



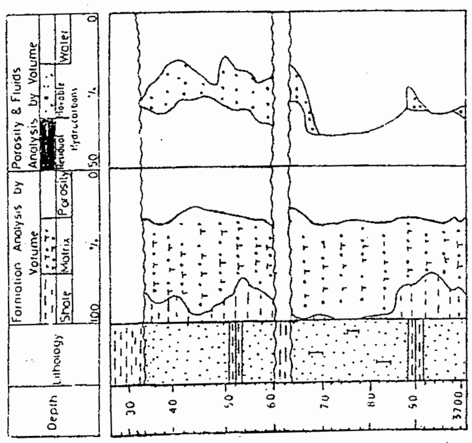
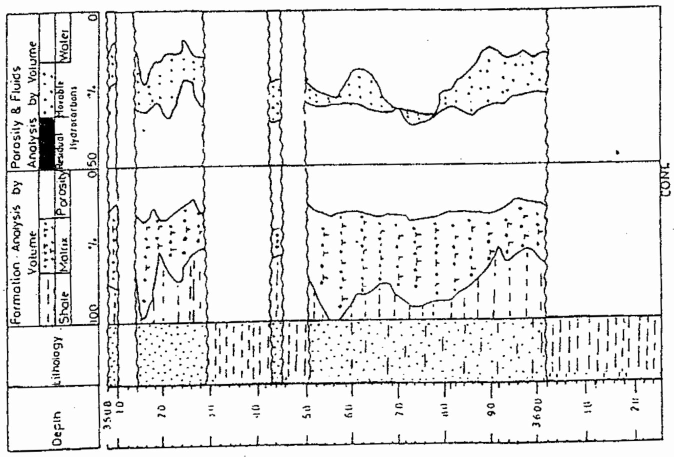


FIG. 27 LITHO - SATURATION CROSSPLOT OF ABU MADI FORMATION, HOSH ISA -1 WELL.



1. Effective Formation Porosity :

The iso-effective porosity map (Fig.29) for the Abu Madi Formation in west of Delta area, shows a porosity gradient ranging from (23%) in Mahmodiya-1 well to (39%) in Itay El Baroud-1 well with a general increase from the northwest to the southeast direction. However, the porosity highs are occupying the eastern part of the study area (between wells South Damanhour and Itay El Baroud and the area which extending between wells South Damanhour-1 and Hosh Isa-1) while the porosity lows occupying the northern and northwestern parts of the study area (between wells Mahmodiya and Kafr El Dawar). The coincidence between the porosity highs and the ridge belt (at the flanks of the study area) may attribute such increase in porosity to either the erosion which occurred after the deposition of Abu Madi Formation or to the sedimentation on a longitudinal positive feature.

The presence of the porosity lows in the northern and northwestern parts of the study area may be attributed to the sedimentation of Abu Madi Formation on a negative feature in northern area, which can be confirmed by the obvious increase in shale content of this area. Consequently, it can be concluded that the effective porosity of Abu Madi Formation generally increases from northwest to southeast, and was affected by the sedimentational processes and structural factors.

2. Water Saturation :

The distribution of the water saturation in the Abu Madi Formation of west Nile Delta area (Fig.30) is strongly affected by the structural setting and the effective porosity underneath the considered area. The step and graben blocks (between Mahmodiya-1 and Kafr El Dawar-1 wells) which represent the two porosity lows are replaced by the two water saturation minima reflecting the effect of these step-blocks in which the two wells (Mahmodiya-1 and Kafr El Dawar-1) located in the downthrow side of this fault block, while the horst blocks around Itay El-Baroud-1 well, which represents the porosity highs, are replaced by areas of high water saturation. The water saturation in the horst block of well south Damanhour-1 is relatively low and consequently the hydrocarbon saturation seems to be high, may be attributed to the migration of oil-up to this horst block. The water saturation within Abu Madi Formation of the study area generally increases from the northwestern parts (70%) to the southeastern parts around Itay El Baroud-1 well (99%).

3. Hydrocarbon Saturation :

The hydrocarbon saturation map (Fig.31) confirms the effect of the structural setting and the effective porosity of Abu Madi Formation on the distribution of fluids, and shows a regional matching with the water saturation map with a conversion of regional increasing trend to become northwestwards, indicating a deficiency in the hydrocarbon content of the southeastern parts of the study area.

Moreover, there is a probable migration of hydrocarbons from both North and South, where the source rocks may lie (Kafr El Sheikh and Sidi Salim Formations), towards the horst blocks (around and between Hosh Isa-1 and South Damanhour -1 wells in the central part of the study area), where there are two structural closures suitable for hydrocarbon trapping mechanism.

CONCLUSION

Based on subsurface geologic studies and well-log analysis of Abu Madi Formation in west Delta area the following results can be concluded :

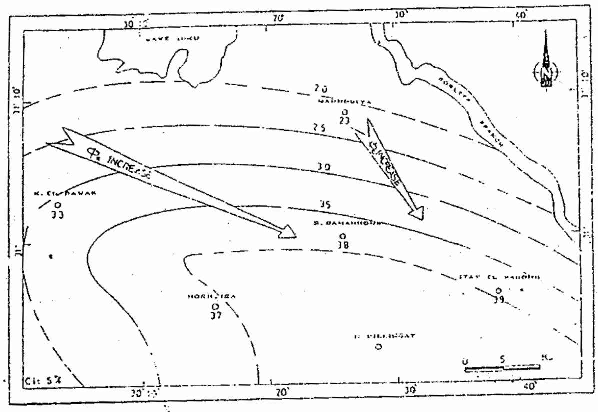


FIG. (29) ISO-EFFECTIVE POROSITY MAP OF ABU MADI FORMATION, WEST DELTA AREA, EGYPT.

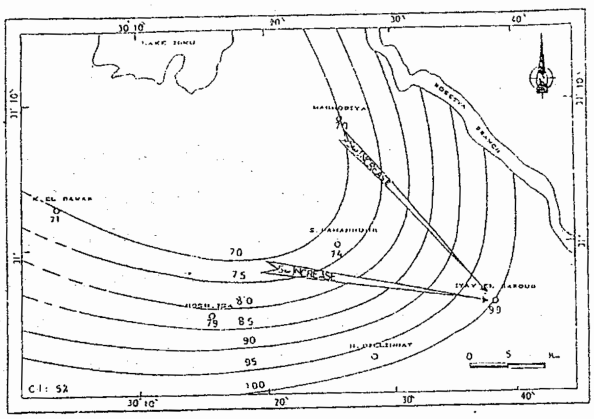


FIG. (30) WATER SATURATION MAP OF ABU MADI FORMATION, WEST DELTA AREA, EGYPT.

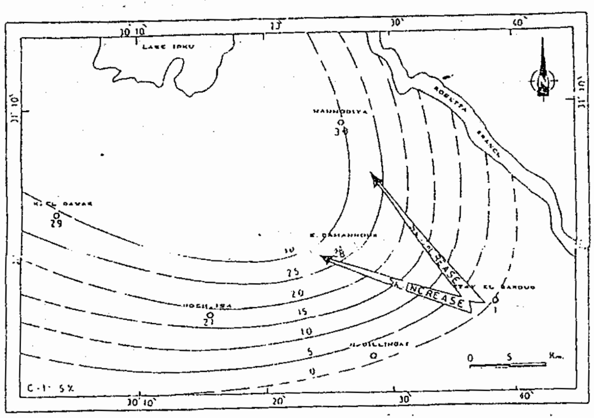


FIG. (31) HYDROCARBON SATURATION MAP OF ABU MADI FORMATION, WEST DELTA AREA, EGYPT.

1. The west Delta area has all the essential elements for hydrocarbon generation, migration and accumulation, but the extreme change in hydrocarbon saturation, as shown on the hydrocarbon saturation map of Abu Madi Formation, indicates that the hydrocarbons in the study area are present in a scattered pattern. Several explanations can be given for the scatter of the hydrocarbon in the area under investigation; among those:

- The regional tilting may have caused the hydrocarbons to spill out of the traps. (the tilting is to north direction in the study area).

- The large anticline (occupying the whole area with a double plunging around Hosh Isa-1 well), which is lying along the migration pathway, would prevent hydrocarbons from reaching a smaller up-dip anticlines.

2. There is a frequent distribution of shales in Abu Madi Formation especially, in the northern wells, while a considerable amount of sandstone matrix is found in the northern and southwestern wells of the study area.

3. The effective porosity of Abu Madi Formation increases from Northwest to Southeast in the study area.

4. Within the study area, the structural closures suitable for trapping mechanism are represented by two horst blocks: the first block comprises South Damanhour-1 well in the central parts of the study area, while the other horst block comprises Hosh Isa well, which is located to the southwestern parts of the study area.

5. The structural setting and the effective porosity, in the study area, play an important role in the distribution of water and hydrocarbons.

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دراسة جيولوجية تحتسطحية وتسجيلات الآبار لمنطقة غرب الدلتا مع التركز على إحتمالاتها الهيدروكربونية

الملخص العربى

يعتبر البحث دراسة تكاملية بين الجيولوجيا تحت السطحية وتحليل تسجيلات الآبار بهدف تقييم الإحتمالات الهيدروكربونية لمنطقةغرب الدلتا .

وتشمل دراسة الجيولوجيا تحت السطحية ليثوستراتيجرافية المنطقة وتحليل السحنات لتكونات كفر الشيخ وأبو ماضى وسيدى سالم بالإضافة إلى تحديد التشوهات التركيبية والعوامل التكتونية السائدة فى منطقة الدراسة . وقد أمكن تمثيل تلك العناصر فى مجموعة من خرائط السمك والخرائط الكنتورية التركيبية وكذلك مجموعة من القطاعات الجيولوجية التى تظهر الوضع التركيبى لمنطقة الدراسة .

وتهتم الدراسة أيضا بالتحليل الشامل للتسجيلات الكهربائية فى الآبار وذلك لوضع التقديرات الكمية للخزانات وقد أخذ فى الإعتبار التصحيحات البيئية لقراءات التسجيلات الخاصة بتقييم متكون أبو ماضى فى المنطقة قيد البحث .

ولقد أمكن معالجة التوزيع الرأسى للهيدروكربونات عن طريق انشاء مجموعة من التسجيلات البيانية (التشبع - الليثولوجى) بينما أمكن دراسة التوزيع الأفقى لهذه الهيدروكربونات عن طرق رسم عدد من خرائط التوزيع والتركيز (خريطة المسامية وخريطة التشبع بالماء وخريطة التشبع بالهيدروكربونات) .

وقد خلص البحث الى أن الحجر الرملى لمتكون أبو ماضى له خصائص خزانية مشجعة يجب أن تؤخذ بعين الإعتبار .