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IMPACT OF LITOFACIES OF MATULLA FORMATION ON ITS PHYSICAL PROPERTIES IN MUZHIL FIELD, GULF OF SUEZ, EGYPT

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تأثير السحنات الليثولوجية لتكوين مطلة على الخصائص البتروفيزيائية
لحقل مزهل، خليج السويس، مصر

الخلاصة: أمكن تقسيم تكوين المطلة فى منطقة الدراسة الى عدد ثلاث أعضاء صخرية كما أمكن تميز عدد من السحنات الصخرية للحجر الرملى ضمن العضوين السفلى والأوسط حيث تمت دراسة كلا من هذه السحنات عن طريق رسم علاقة بين المسامية والنفاذية لكل سحنة صخرية ودراسة توزيع المعادن الطينية ونوعياتها حيث تبين أن: (١) سحنة رمال وجه الشاطئ المميزة لخزان رمال العضو السفلى تقل فيها نسب المسامية والنفاذية فى الجزء الغربى من حقل مذهل وتزداد فى الجزء الجنوبى، (٢) سحنة قنوات المد والجزر التى تميز الجزء السفلى والعلوى من العضو الأوسط وتتميز باعتدال قيم المسامية مع انخفاض قيم النفاذية كما تتميز تلك السحنة الصخرية بتواجد معادن طينية متشتتة التوزيع يغلب عليها تواجد كلا من الجلوكونيت والميكا، (٣) سحنة الرمال الشاطئية التى تميز الجزء الأوسط من العضو الأوسط فى تكوين المطلة وتتميز باعتدال قيم المسامية والنفاذية كما تتميز بتواجد معادن طينية متشتتة التوزيع فى الجزء الجنوبى من منطقة الدراسة بينما تتواجد المعادن الطينية الصفائحية فى الجزء الشمالى والغربى كما يغلب عليها تواجد المواد الميكائية و(٤) سحنة رمال وجه الشاطئ " العضو الأوسط" التى تميز الجزء العلوى من العضو الأوسط وتتميز بقيم مسامية ونفاذية مرتفعة نسبياً فى الجزء الجنوبى من منطقة الدراسة بينما تقل قيم النفاذية فى الجزء الغربى من منطقة الدراسة. كما تتميز تلك السحنة الصخرية بتواجد معادن طينية متشتتة التوزيع يغلب عليها تواجد كلا من الإليت و الجلوكونيت.

ABSTRACT: *Matulla Formation in the studied area can be subdivided into lower, middle and upper members. Three main sandstone facies can be identified within the lower and middle members, shore face, tidal channel and beach to tidal flat sand. Each identified facies was studied on the base of shale type, clay minerals and porosity permeability relationship. The shore face of lower member is characterized by dispersed shale in the lower parts and laminated shale in the upper most parts and the illite clay mineral is the most dominant. The porosity ranged from 10 to 16% and the permeability ranged from 1 to 12 mD in the western parts of Muzhil field. In the southern parts, the porosity ranged from 13 to 21% and the permeability ranged from 30 to 130 mD. The tidal channel facies are characterized by dispersed distribution of shale. Glauconite, feldspar, mica and illite are the main clay minerals. This facies exhibit the porosity ranged from 10 to 20% and the permeability ranged from 70 to 100 mD. The beach to tidal flat sand facies are characterized by dispersed to laminated shale. The micaceous matters are abundant with the presence of illite and glauconite clay minerals and the porosity ranged from 14 to 22% and the permeability ranged from 40 to 110 mD in the western part of Muzhil field while in the southern parts, the porosity ranged from 10 to 16% and the permeability ranged from 30 to 130 mD. The shore sandstone facies of middle member are characterized by dispersed shale and illite, glauconite and mica represent the main clay minerals. The shore face of middle member exhibits porosity ranged from 10 to 20% and the permeability ranged from 40 to 120 mD in the southern part of Muzhil field while in the western parts of Muzhil filed, the porosity ranged from 10 to 15% and the permeability ranged from 1 to 12 mD.*

INTRODUCTION

The studied area is located in the offshore East Central part of the Gulf of Suez about 6 Km to the south of Abu Zenima and to the west of Abu Rudies city by about 4.5 Km (fig. 1).

The present study approaches the determination of lithofacies composing Upper Cretaceous (Coniasian Santonian) Matulla Formation and the study of its impact on reservoir rocks petrophysical properties by integration of well logs and geological data.

METHODOLOGY

Because Wireline log interpretation is no longer limited to an estimation of hydrocarbon reserves; it is even becoming more powerful for revealing stratigraphical paleoenvironments (Kessler 1995; Saner 1995; Bourquin 1998; Milana 2000; Murkute 2001). Serra, 1985. made extensive use of dipmeter analyses, closely integrated with other logs and profiles of bedding and textural properties. These provide a valuable atlas in the interpretation of sedimentary environments from logs. Well log data of ten wells have been processed through a sequence of graphical and analytical relations and integrated with the geological studies includes all sample description (Ditch/Core), missed section identification, dip analysis, image log analysis, clay models studies, clay studies and intensive geologic correlations (in conjunction with description of out-crops) for each significant geologic features. These are integrated together to estimate the environment of deposition. Gamma ray mirror image (GRMI) and Sonic travel time mirror image (DTMI) are used as log sign print for the certain criteria and were correlated within the studied area.

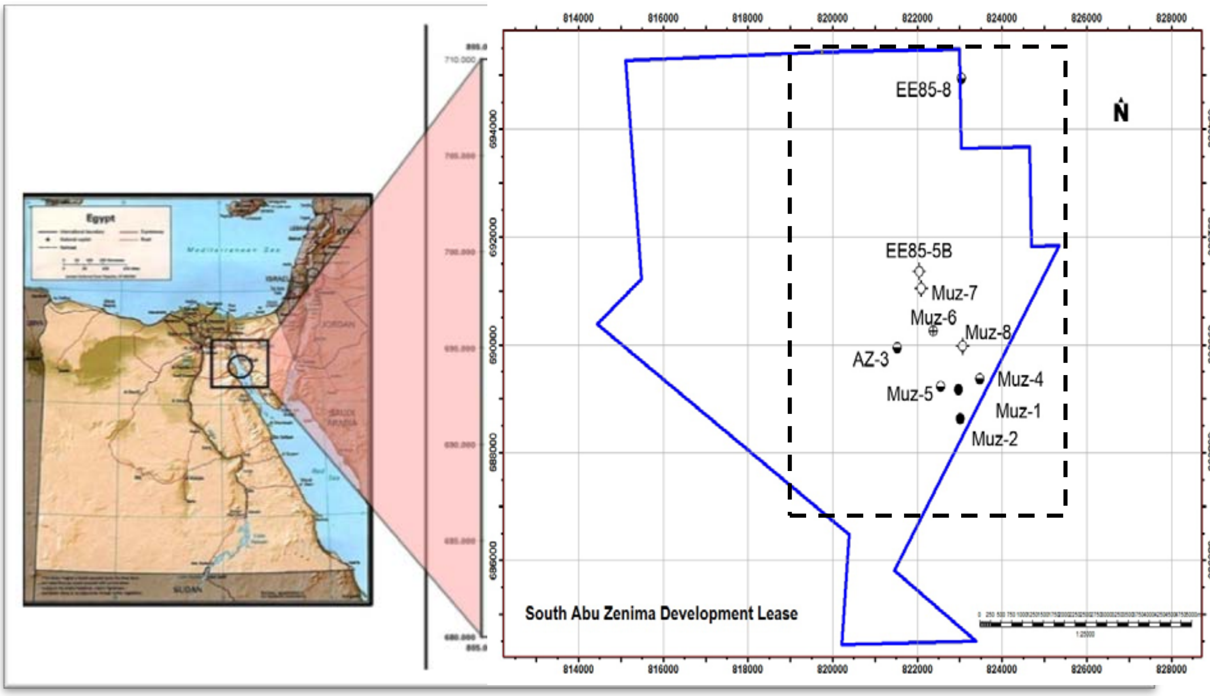

Fig. (1) Location map of the studied area.

The primary sedimentary structure and paleocurrent direction were obtained from imaging logs; Formation Micro Imager (FMI) which was run in wells Muzhil-2, 4, 5, 7and 8. The Paleocurrent analysis was carried over Matulla Formation in well Muzhil-4 only. The sedimentary structures are then compared to core and ditch cutting descriptions. For the intervals that not covered by FMI logging were correlated lithologically to those covered by imaging logs. Matulla Formation is built up of siliciclastic rocks (sandstone, shale, claystone and calcareous sandstone) with fossiliferous glauconitic, dolomitic limestone and brown to green dolostone intercalations. The lithofacies distribution of the Matulla Formation in the studied area shows clearly the predominance of clastic facies among the Matulla sediments, where clastic volume percentage exceeds 77% in all studied wells.

The results of the lithological correlations were compared to ditch cutting and core-cut (were obtained from Muzhil-4,7 and 8 wells) to differentiate laterally and vertically between lithofacies composing Matulla Formation. Consequantely, three main members could be identified throughout the Matulla Formation (Fig.-2).

1. **The Basal (Lower) Member:** it ranges in thickness from 52 ft to 72 ft and shows decrease in thickness towards southeast. The lower member overlies a chalky dolomitic limestone bed belonging to the Wata Formation and underlies glauconitic sandstone (middle member of the Matulla Formation). The lower member consists of alternating beds of shale, claystone and sandstone with thin interbeds of fossiliferous limestone, dolostone and reddish brown ironstone (sedrite).

The Lower Member is characterized by; serrated coursing upward with sharp top and base suggesting prograding sea toward the land (Fig. 3).

2. **The Middle Member:** it ranges in thickness between 153 ft and 184 ft, due to fault affected well EE85-8, the thickness of lower part of Matulla Fm. reduced to 84 ft. It shows thickening toward west central part of Muzhil block with gradual thinning toward north and south. The middle member of Matulla Formation overlies sandstone-1 bed of the lower member and underlies the upper member. Its composed mainly of sandstone of light grey to light greenish grey, Brownish grey, Medium greenish grey, very fine grained, laminated to slightly laminated to flaser laminated at base and laminated to deformed laminated toward the top, The sandstone are intercalated with: sandy bioclastic limestone, mudstone and argillaceous limestone (Fig. 3).

3. **The Upper Member:** its ranges in thickness from 142 to 179 ft, due to fault affected well EE85-8, the thickness of upper part of Matulla Fm. reduced to 86 ft. it show increase in thickness toward west central part of Muzhil block. The upper member conformably overlies the middle member of the Matulla Formation and underlies the Brown Limestone Formation. It consists predominantly of thick shale and claystone with thin interbeds of high calcareous sandstone and microcrystalline limestone. The shale is characterized by grey, light grey, brownish grey, sub block to sub flaky, silty, slightly calcareous to calcareous, glauconitic, highly fossiliferous.

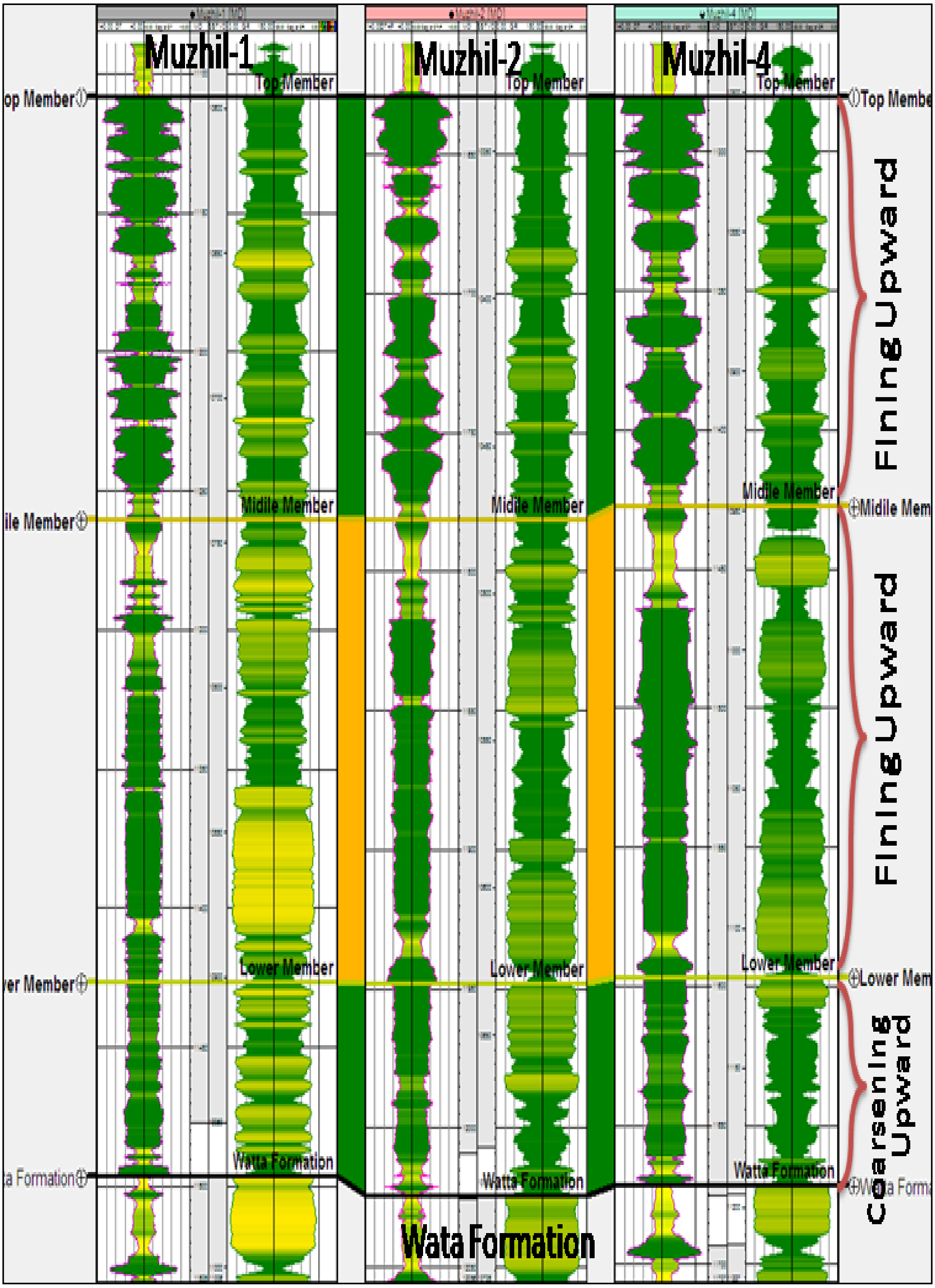

Fig. (2): Log correlation through wells Muzhi-1, 2 and 4 for identifying the three members of Matull Formation.

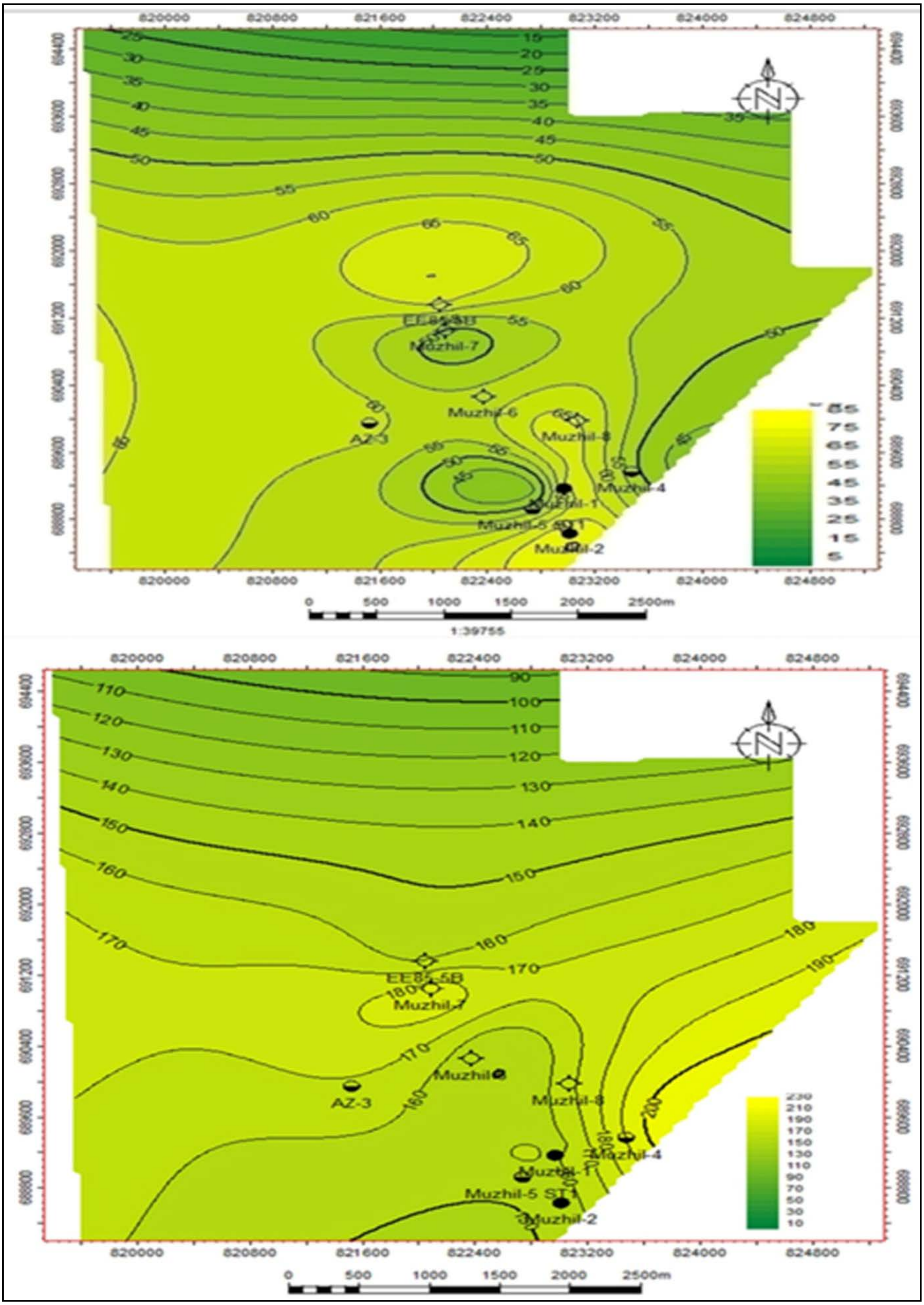

Fig. (3): Thickness variation maps of lower and middle members of Matull Formation.

RECOGNITION OF SEDIMENTARY FACIES AND ITS CORRESPONDING LOG SIGNATURE

The recognized facies represented in (fig. 4) can be descriped from bottom upward as follow, where (fig. 5) represent the ideal examples of some geological interpretation using wire-line log sins:

1- Lower Member:

a- Facies No. 1 Tidal Flat Mud (TFM):

This facies represent the basal most part of the lower member, its characterized by presence illite to mixed layers laminated shale/mudstone deposited in low energy environment assumed to be tidal flat mud.

b- Facies No. 2 Shore Face Sandstone (SF):

This facies represents the upper most part of the lower member. It is characterized by cross-bedded to massive, moderately sorted to well sorted, occasional siderite lamina and medium-pebble up to coarse pebble sized clasts near top and bottom, pyritic, occasionally bioturbated sandstone. Its glauconitic to mica at south, mica to illite in the northern parts, laminated occasionally dispersed, it shows serrated prograding flowerpot coarsing upward, uprupt top, gradual base. It was deposited in high energy depositional environment and interpreted as shore face to prograding marine barrier bar – shore face.

2- Middle Member:

a- Facies No.: 3 Tidal Flat Mud (TFM):

This facies represent the basal most part of the middle member, its characterized by presence of heterlithic, bioturbated shale/mudstone, its Glauconitic, mica and illite only illite is the clay mineral present northward. The laminated shale is present and is occasionally dispersed, its deposited in low energy tidal flat mud environment.

b- Facies No.: 4 Tidal Channel (TC):

This facies represent the lower part of middle member, its characterized by massive, laminated, cross laminated, burrows, heterolitic, glauconitic, rich in sedrite ironstone. It shows a serrated regarding flowerpot fining upward. It's also Glauconitic, micaceous to mixed layers and glauconitic to feldspathic at north, it is deposited in high energy tidal channel environment. A tidal channel can be observed at the bottom of Sandstone-2 in well Muzhil-7, where the lower member of Matulla Formation followed by transgression of sea indicated by the deposition thin lamina of shale/claystone (initialization of middle member) that was followed by deposition of about 32 feet of bioclastic sandy limestone (from 12461' to 12493') intercalated with shale/claystone. The bioclastic sandy limestone was followed by about 52 feet of massive sandstone (from 12408' to 12461'), that was followed by thin band of shale/claystone. These successions suggested to be the bioclastic carbonate channel fill materials. The channel succession then changed laterally into 7 feet of muddy limestone (from 11574' to 11581') which followed by 23 feet of massive sandstone intercalated with laminated sandstone (from 11551' to 11574') in well Muzhil-4 in the extreme east of Muzhil block. Also the equivalent lithology are clean sandstone in well Muzhil-1 and highly argillaceous sandstone in well Muzhil-2.

c- Facies No.: 5 Tidal Flat Mud (TFM):

These facies is present in the middle part of middle member, its characterized by presence of heterlithic, bioturbated shale/mudstone, it could represent shoreface flood tidal delta (lagoonal env.) to tidal flat mud deposites.

d- Facies No.: 6 Beach Sand:

Bioturbated sandstone: Light to medium grey, very fine (upper) grained, laminated to strongly bioturbated (sand filled horizontal burrows), argillaceous, strongly cemented by variable calcite cements. Locally massive sandstone beds, strongly calcite cemented, slightly gradational tops and bases.

e- Facies No: 7 Tidal Channel (TC):

Sandstone-3 characterized by massive, laminated, cross laminated, burrows, heterolitic, glauconitic in parts micaceous only in Muzhil-8 well, illite Laminated, deposited in Shallow moderate to high energy. Its fining upward and its interpreted as tidal channel.

f- Facies No: 8 Shore Face (SF):

This facies represent the top Sandstone unit of the Middle Member, its characterized by bioturbated sandstone fine grained in average, argillaceous, laminated to strongly bioturbated (small horizontal and subvertical burrows), strongly cemented by variable calcite cements, intercalated with Light grey, slightly sandy, massive, locally small amplitude stylolites, small thin fractures filled with calcite. Locally pyrite is observed. Occasional shell fragments, slightly glauconitic. In some parts its glauconitic, micaceous, feldspathic with mixed layers shale dispersed to laminated occasionally structural shale are present. It's also characterized by serrated prograding flowerpot coarsing upward with abrupt top and gradual base. Its transgressive shallow marine high energy deposits interpreted as shore face.

3- Upper Member:

Facies No: 8 Deep sub tidal or embayment; or restricted offshore transition (DST)

These facies is characterized the upper member of Matulla Formation, it's represented by gray shale illite, micaeous with mixed shale layers laminated-dispersed interlaminated with (glauconitic in the south and illite the northward, laminated to dispersed) limestone. These facies characterized by intercalated shale/mudstone and limestone, fining upward its deposited during Sediment fallout, low-energy periodic sedimentation. It's interpreted as deep subtidal or embayment to restricted offshore transition.

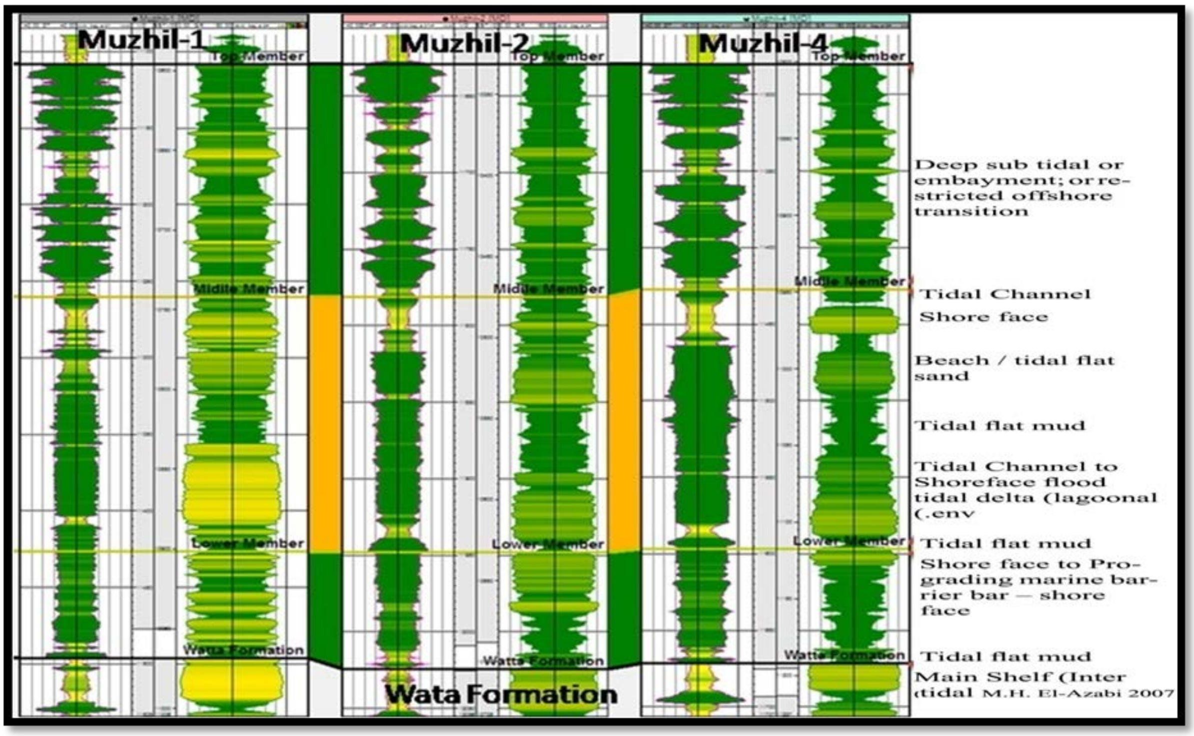

Fig. (4): Recognized Facies of Matulla Formation in the studied area.

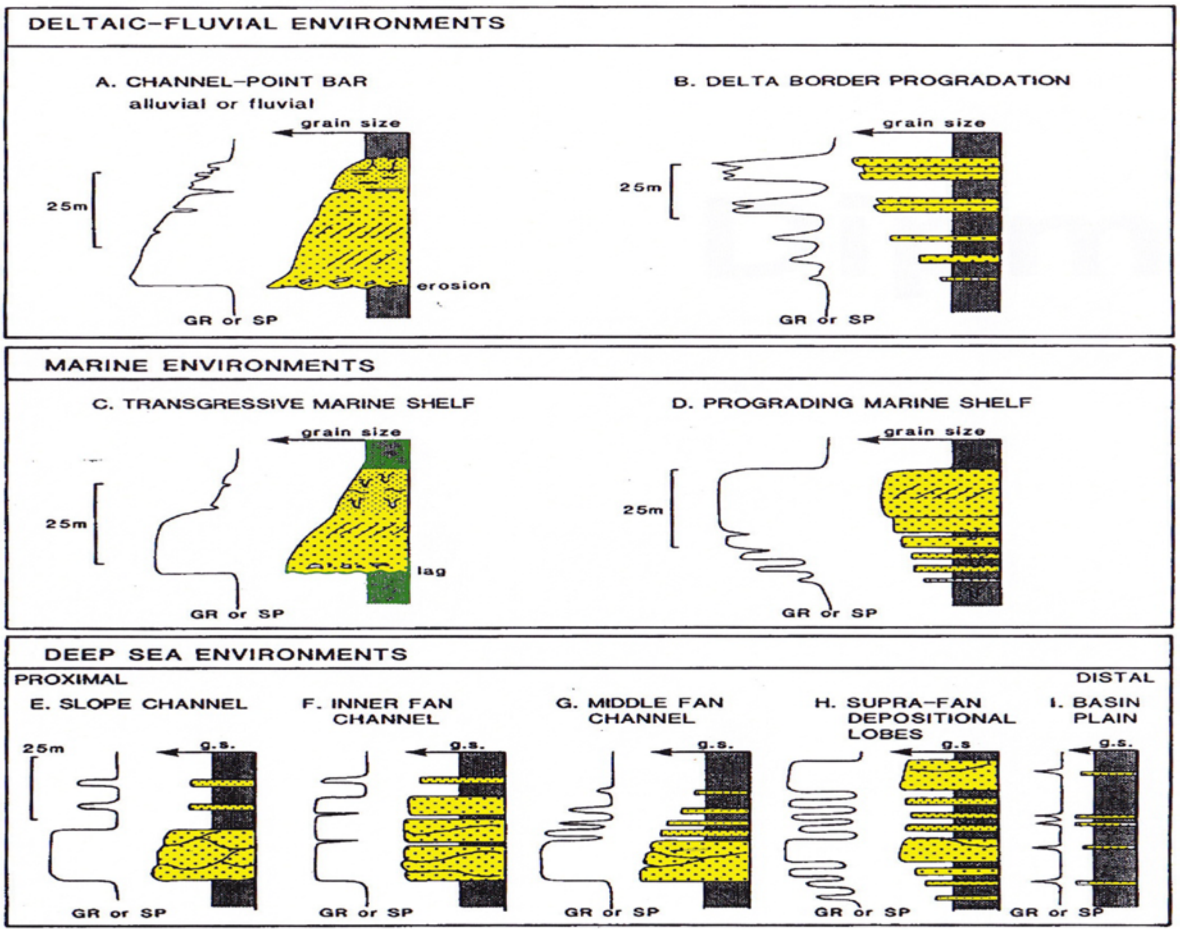

Fig. (5): Some geological interpretation of well logs (Raider, 1995).

Table no. (1) Identified Facies and Depositional Environment.

Code	Facies Name	Description	Depositional Environment	Log Sign
DST	Gray Shale Laminated with Limestone	Sediment fallout, low-energy periodic sedimentation	Deep sub tidal or embayment; or restricted offshore transition	Flowerpot fining upward, uprupt top and base
TC	Sandstone-3	Massive, laminated, cross laminated, burrows, heterolitic, glauconitic in parts micaceous only in Muzhil-8 well, illite Laminated, deposited in shallow moderate to high energy. Its fining upward and its interpreted as tidal channel.	Tidal Channel	Serrated regarding flowerpot fining upward
SF	Top Sand of Middle Member	Bioturbated SANDSTONE fine (lower) grained in average, argillaceous, laminated to strongly bioturbated (small horizontal and subvertical burrows), strongly cemented by variable calcite cements, intercalated with Light grey, slightly sandy, massive, locally small amplitude stylolites, small thin fractures filled with calcite. Locally pyrite is observed. Occasional shell fragments. Slightly glauconitic.	Shore face	Serrated prograding flowerpot coarsing upward, uprupt top, gradual base.
B/TFS	Upper Sand of Middle Member	Bioturbated SANDSTONE: Light to medium grey, very fine (upper) grained, laminated to strongly bioturbated (sand filled horizontal burrows), argillaceous, strongly cemented by variable calcite cements. Locally massive sandstone beds, strongly calcite cemented, slightly gradational tops and bases.	Beach / tidal flat sand	Serrated cylindrical shape gradual base and top
TFM	Middle part of middle member	Heterlithic, bioturbated mudstone.	Tidal flat mud	
TC	Lower Sand of Middle Member	Massive, laminated, cross laminated, burrows, heterolitic, glauconitic, rich in sedrite ironstone.	Tidal Channel to Shoreface flood tidal delta (lagoonal env.)	Serrated regarding flowerpot fining upward
TFM	Shale-3	Heterlithic, bioturbated shale/mudstone, its glauconitic, mica and illite	Tidal flat mud	
SF	Sandstone-1	cross-bedded to massive, moderately sorted to well sorted, occasional siderite lamina and medium-pebble up to coarse pebble sized clasts near top and bottom, pyritic, occasionally bioturbated and carbonaceous, glauconitic, non-calcareous in parts	Shore face to Prograding marine barrier bar – shore face	Serrated prograding flowerpot coarsing upward, uprupt top, gradual base.
	Limestone-1	Nudolar bioclastic L.St		
TFM	Basal Shale	Illite to mixed layers laminated shale/mudstone deposited in low energy environment	Tidal flat mud	
	Wata Limestone	Deep marine chalky limestone	Main Shelf (Inter tidal M.H. El-Azabi 2007)	

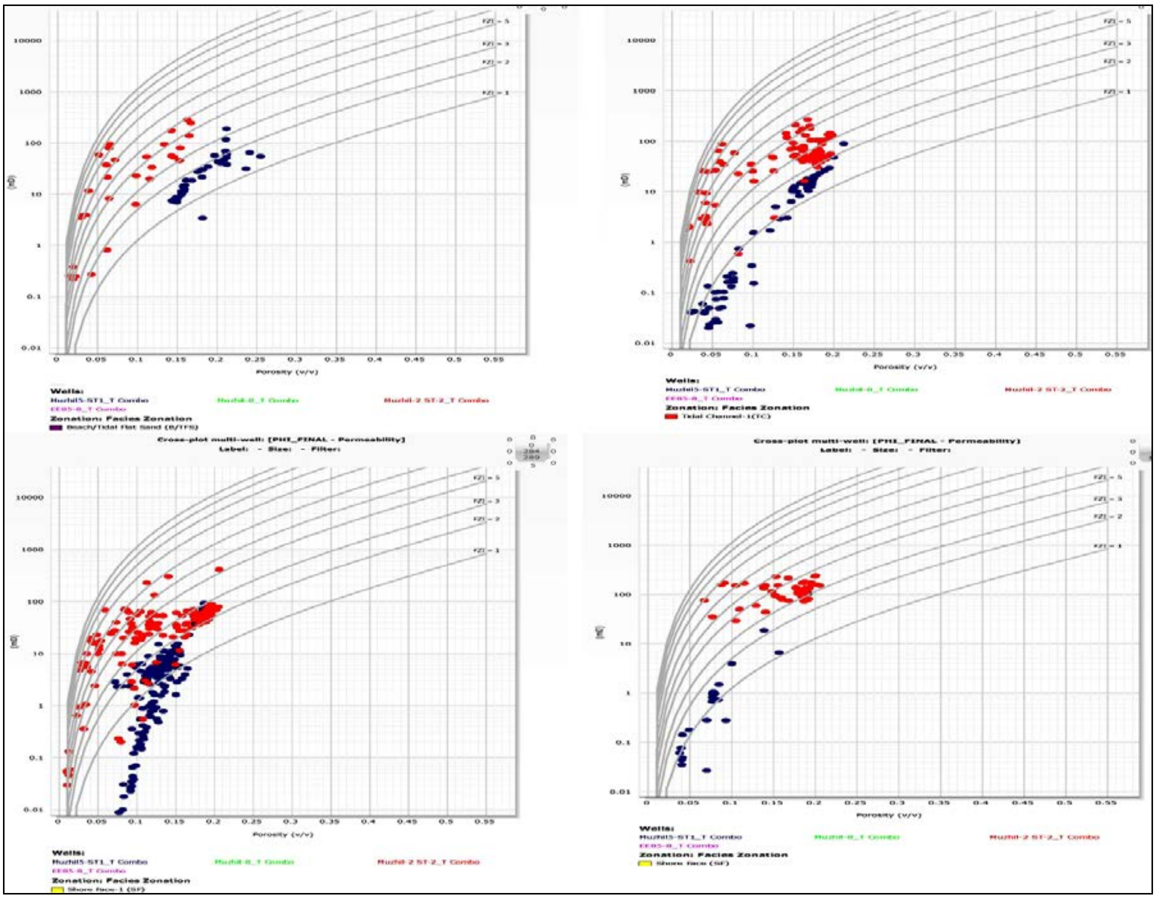

Fig. (6): Porosity permeability relationship over the identified facies.

RESERVOIR CHARCTRIZATION OF IDENTIFIED FACIES

1- Porosity-Permeability relationships:

The final effective porosity computed as arithmetic mean from the calculated density, neutron and sonic effective porosities were illustrated versus permeability which calculated using Wyllie-Rose equation $\left[k = \frac{C\,\phi_{eff}^{6}}{S_{wirr}^{2}} \right]$, the porosity permeability relationships created over the identified reservoir facies (fig. 6) indicated that:

a- Shore face facies which represent the Lower Sandstone Member exhibits varieties of porosity permeability relationship, where the porosity ranges from 10 to 16%, while the permeability values ranges from 1 to 12 mD in the western parts of Muzhil field. In the southern parts porosity ranges from 13 to 21% and permeability ranges from 30 to 130 mD. The relation indicate better reservoir facies quality toward the southern part of Muzhil field.

b- Tidal Channel facies which represent the basal part of Middle sandstone member exhibit porosity ranges from 10 to 20% and permeability ranges from 70 to 100 mD. The reservoir quality increases southward where Muzhil-2 well exhibit better porosity and permeability while well Muzhi-5 exhibit better porosity and less permeability.

c- Beach to Tidal Flat sandstone facies which represent the middle part of the Middle Sandstone Member exhibits the porosity ranges from 14 to 22% and permeability ranges from 40 to 110 mD in the western part of Muzhil field, while in the southern parts the porosity ranges from 10 to 16% and permeability values ranges from 30 to 130 mD.

d- Shore Face sandstone facies: This facies characterize the upper part of the Middle Member, this facies exhibits the porosity ranges from 10 and 20% with permeability ranges from 40 and 120 mD in the southern part of Muzhil field, while in the western parts of Muzhil filed the porosity ranges from 10 and 15% and permeability ranges from 1 to 12 mD.

2- Clay Type and Clay Minerals:

a- Shore face sandstone reservoir of the Lower Member is characterized by dispersed shale in the lower part while the laminated type is formed in the upper most part, in the other hand the illite clay mineral are most dominant in the northern and southwestern parts of Muzhil field while the Southern part a varieties of glauconite, mica and illite clay minerals are present (Figs.-7 &8).

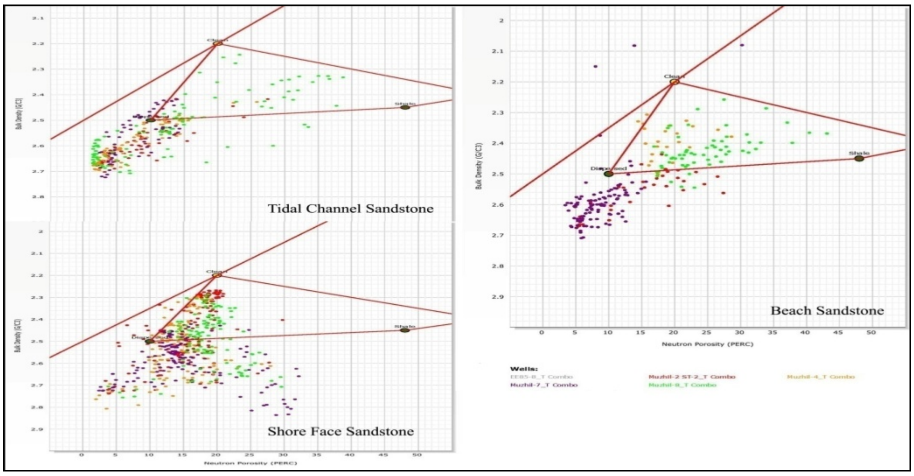

Fig. (7): Sandstone facies clay types.

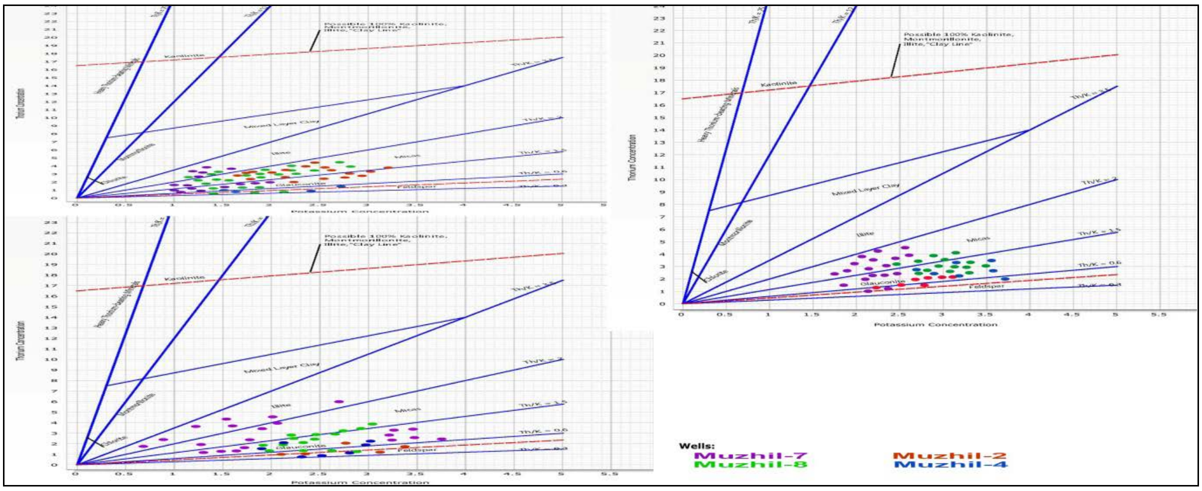

Fig. (8): Sandstone facies clay minerals.

The shore face sandstone reservoir of the Middle Member which represent the lower most part of Middle member exhibit 61-72ft thickness, dispersed shale is the main type, illite, glauconite and mica represent the main clay minerals.

b- The tidal channel facies exhibit 31 to 53ft thickness increasing eastward, dispersed shale is the main shale type while the glauconite, feldspar, mica and illite are the main clay minerals (Figs.-7 &8).

c- The beach sand facies exhibit 11 to 51ft thickness increasing westward, the main shale type is the dispersed shale in the south and western parts of Muzhil field, while in the North and Eastern parts the laminated shale are more abundant, the micaceous matters are abundant with the presence of illite and glauconite clay minerals.

SUMMARY

Four main sandstone reservoir facies can be identified within lower and middle members of Matulla Formation.

a- The shore face facies of the lower member is characterized by the presence of dispersed shale in the lower parts and laminated shale type in the upper most parts, in the other hand the illite clay mineral is the most dominant in the northern and southwestern parts of Muzhil field, also in the southern part the glauconite, mica and illite clay minerals are present. The types and distribution of caly affect the porosity-permeability relationship where the porosity ranges from 10 to 16% and the permeability ranges from 1 to 12 mD in the western parts of Muzhil field. In the southern parts the porosity ranges from 13 to 21% and the permeability ranges from 30 to 130 mD. The relation indicate that better reservoir facies quality is toward the southern part of Muzhil field.

b- The Tidal Channel facies is characterized by dispersed distribution of shale. Glauconite, feldspars, mica and illite are the main clay minerals. This facies exhibits the porosity ranges from 10 to 20% and the permeability ranges from 70 to 100 mD. The reservoir quality increases

southward where Muzhil-2 well exhibits that porosity and permeability in the while well Muzhi-5 exhibits that porosity and less permeability.

c- The Beach to Tidal Flat sand facies is characterized by dispersed shale in the south and western parts of Muzhil field, while in the north and eastern parts, the laminated shale are more abundant, the micaceous matters are abundant with the presence of illite and glauconite clay minerals. This facies exhibits that the porpsity ranges from 14 to 22% and the permeability ranges from 40 to 110 mD in the western part of Muzhil field, while in the southern parts the porosity ranges from 10 to 16% and the permeability ranges from 30 to 130 mD.

The Shore Face sandstone facies of the middle member is characterized by dispersed shale. The illite, glauconite and mica represent the main clay minerals. This facies exhibits that the porosity ranges from 10 to 20% with the permeability ranges from 40 to 120 mD in the southern part of Muzhil field, while in the western parts of Muzhil filed the porosity ranges from 10 to 15% and the permeability ranges from 1 to 12 mD.

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