Journal of Basic and Environmental Sciences, 5 (2018) 1-19

ISSN
Online: 2356-6388
Print: 2536-9202

Research Article Open Access

Contributions to the geology of Moghra-Qattara area, North Western Desert, Egypt

A. F.Yousf [1], M.A. El Fakharany[2], U.A. Abu Risha[1], M.M. Afifi[2], M.A.Al Sayyad[1]

[1]Desert Research Center, Mattaria, Cairo
[2] Faculty of Science, Benha University

Abstract

The Moghra-Qattara area represents an important part of the Egyptian land reclamation projects. Understanding the geology of the area is a must in order to properly plan and manage the different activities of the project. This study is based on the most up-to-date measurements and analyses conducted by the Desert Research Center as a part of this project. This study focuses on the Moghra Formation (MF) which represents the main aquifer in this area. Rock and sediment samples were collected from both surface sections and drilled wells. MF was distinguished into three members namely, El Raml, Bait Owian and Monquar El Dowi from base to top. The microscopic examination revealed that one microfacies association is defined in El Raml member which is Quartz-arenite, whereas Bait Owian member comprises two microfacies associations which are Sparite, and microsparite. Contrarily, four microfacies associations are investigated in Monquar El Dowi member which are Calcareous Quartz arenite, Glauconitic calcareous quartz arenite, Ferruginous calcareous quartz arenite and Sandy biomicrite. Mineralogically, twenty bulk samples were selected and examined by the X-ray Diffraction (XRD). The XRD shows that El Raml member is characterized by the presence of quartz, plagioclase and kaolinite as the predominant minerals followed by orthoclase and gypsum minerals. By comparison, Bait Owian member composes mainly of kaolinite and quartz followed by gypsum, calcite, aragonite and geothite. While, Monquar El Dowi member is characterized by the existence of quartz, plagioclase and kaolinite as dominant minerals followed by orthoclase, dolomite, calcite, gypsum, halite and hematite. The grain size analyses of sandy samples from these members show that the first was deposited in a fluvial environment whereas the second is shallow marine and the third is fluviomarine. These microfacies and mineral characteristics have direct impact on the hydraulic properties of Moghra aquifer.

Received; 16 Nov. 2017, Revised form; 30 Nov. 2017, Accepted; 30 Nov. 2017, Available online 1 Jan. 2018

1. Introduction

The Moghra-Qattara area represents an important part of the Egyptian 1.5 million feddan national reclamation project. It occurs at the base of a paleo megadelta to the south of the Qattara paleolake which forms the present Qattara Depression. The paleodelta is thought to be an ancestral Nile delta [1] should be the boundary of the Qattara Depression is adopted as the zero contour as proposed by [2], the moghra lake and the depression will be included in the Qattara Depression (Fig (**1**). However, a NE-SW ridge separates the Moghra Depression in the east from the main Qattara Depression to the west (Fig (**2**). An aquifer is developed in the Moghra Formation. Thus, this study focuses on the geology of Moghra Formation aiming to provide some recommendations on the exploration and management of the Moghra aquifer.

The area of study has been subjected to numerous geological studies (e.g. [3-11] and hydrogeological studies e.g. [9, 12-14]. However, the previous studies were predominantly based on surface data. Contrarily, this study is based not only on surface data, but also on subsurface data obtained from recent drillings conducted as a part of the 1.5 million feddan reclamation project. In addition, microfacies and mineralogy studies were not taken into consideration till now; therefore, they will be discussed in this paper.

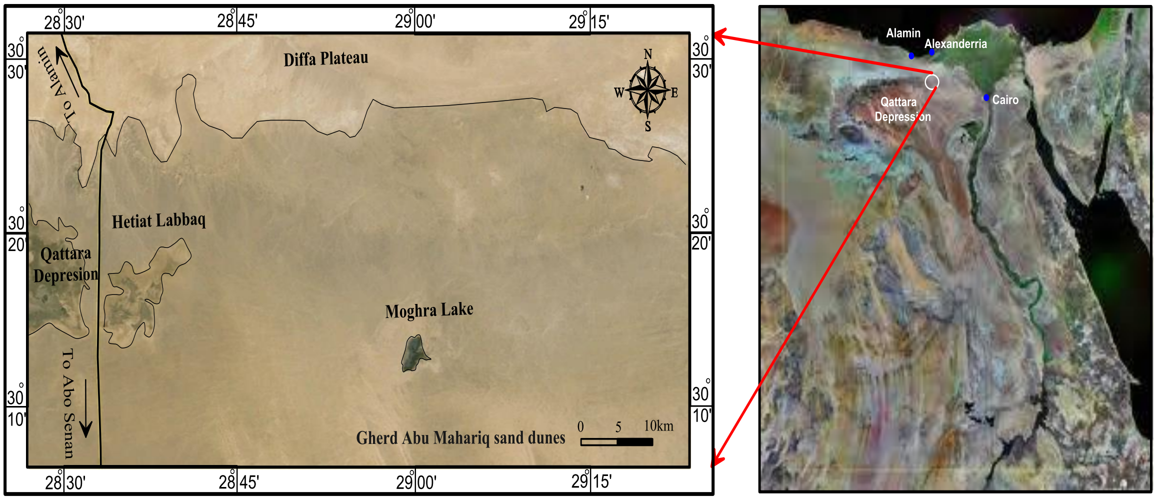

Fig (1): Location and the main landforms of the study area

2. Methodology

Sediment samples were collected from nine stratigraphic sections and from six drilled groundwater wells during field trip in Moghra Qattara area lasted for twenty days. Stratigraphic correlations were established to follow up the facies changes and to infer structure geology. Sieve analysis was performed on 86 sand and semi friable sandstone samples representing the sequence of the Moghra Formation in the area of study.

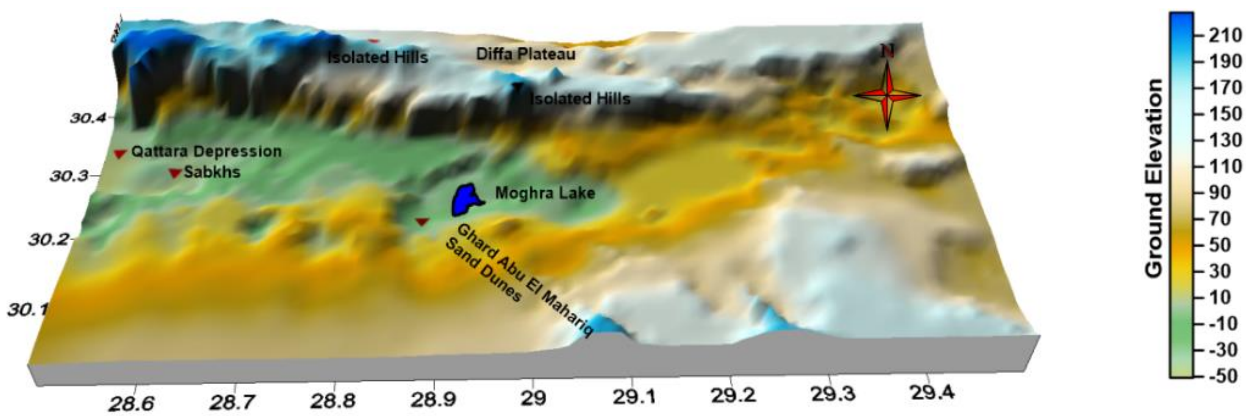

Fig (2): 3-D surface of the area of study showing the Qattara and Moghra Depression

The majority of samples were loose, but few were loosely cemented sandstone. These sandstones were gently crushed with rubber pestle. The analysis was carried out following the procedure described by [15]. A portion of each sample weighing 100 grams and subjected to dry sieving using a Ro-Tap shaker and a set of standard sieves at a quarter-phi interval as recommended by several workers [16], [17], [18], [19]and [20]. The weight percent of each sand grade was calculated, and the mud fraction was separated by using the 0.063 mm screen and its percentage was calculated. The data obtained were presented graphically in the form of histograms and plotted in cumulative percentages on probability paper and the values of Φ5, Φ16, Φ25, Φ50, Φ75, Φ84 and Φ95 were extrapolated from the cumulative curves. In order to determine the environmental characteristics and agent of transportation, it is necessary to measure the grain size statistical parameters i.e. mean size (MZ), standard deviation (σI), skewness (SkI) and kurtosis (KG). The four size parameters were calculated according to the equations given by [21].

Eleven samples of water bearing formation have been thin sectioned and carefully examined microscopically to determine petrographic constituents, microfacies associations and environment of deposition. The classifications of [22] and [23] were found to be the most appropriate for the sandstones under investigation. In this classification, the sandstones are described as arenite (with less than 15% matrix) or wackes (with more than 15% matrix). Dott classification is based on the relative proportions of the three basic components of sand; quartz, feldspars and lithic fragments. For the carbonate samples, the scheme of [24] was followed.

X-ray diffraction was carried out on twenty powdered bulk samples to determine the mineral composition of water bearing formation. X-ray investigations were carried out using a Philips X-ray diffractometer (type PW3710 Based) with Ni- filtered cobalt radiation at 40KV and 55MA. The samples were scanned at a speed of 2θ/minute. This analysis was carried out in the central labs of the Desert Research Center. The obtained X-ray data were interpreted based on ASTM data and the methods described by [25]. The studied samples were grinded to 200 meshes and analyzed without any chemical treatment. Finally, water samples were taken from the moghra aquifer and electrical conductivity (EC) was measured by using EC meter to determine the relationship between aquifer geology and EC.

3. Area of Study

The area of study is located in the northeast part of Qattara mega delta in north Western Desert of Egypt; about 40 kilometers south of El Alamein and 300 kilometers from Alexandria. It extends between latitudes 30°00' - 30°30' N and longitudes 28°30' - 29°30' E (Fig (**1**). It has altitude ranging from 41 m below sea level to 250 m above sea level. It is extended W-E 75 km with width varies from 16 to 26 km. It occupies an area of about 1600 km^2. It is bounded by a steep, and in places precipitous, escarpment in places along the northern side, which rises 250 m. By contrast the southern side of the oasis rises gradually to Ghard Abu El Mahareq sand dune belt.

Moghra Oasis lies in arid to semi-arid area, where the maximum temperature is 41.4 C˚ in August and the minimum temperature is 10.7 C˚ in December, humidity ranges from 39.5% in December to 19% in June. Wind speed reaches its maximum in September (3.7 m/Sec.) and its minimum in January and February (2.8 m/Sec.). The amount of rainfall is limited except sometimes sudden rain storms and the evaporation varied from 29.2 mm/day in May to 5.4 mm/day in December.

Geomorphologically, the area was divided based on topographic and geologic maps, satellite images, field observations and measurements, and previous literatures into three main units namely; structural plateau, sand dune belt and Moghra Depression (Fig (**2**). The structural plateau is classified into El Diffa plateau, isolated hills and drainage system. Sand dune belt constitutes the main southern portion of Moghra Oasis. It's differentiated into Sand sheets, gravely plain and longitudinal sand dunes. Moghra Depression is divided into low lands, sabkhas and Moghra Lake (ML).

The scarp of the Qattara Depression is dissected by numerous theater-head valleys (THV). Such valleys were formed by groundwater sapping [26]. The valleys emanate at the contact between the clastics of Moghra Formation and the carbonates of the overlying Marmarica formation and at the contacts between the sand and clay beds of Moghra Formation [26]. The THV indicate high groundwater levels which may be formed lakes in the Qattara Depression before the onset of the aridity which lasts until now. During the past wet periods the Moghra Lake, which was wider, was fed by braided distribution streams [11]). The formation of the THV, thus, represents a mechanism of the northward retreat of the Qattara Depression.

Stratigraphically, Moghra Qattara area is covered by rocks ranging in age from Lower Miocene to recent (Fig (**3**). The Lower Miocene unit is called Moghra Formation [3] and is composed of fluviomarine sediments which grades northwards to more marine facies called Mamura Formation. The fauna of Moghra Formation reveal that these deposits accumulated in swamps and lakes in which forests were present [27]. The Middle Miocene unit is called Marmarica Formation and is composed mainly of marine fossiliferous carbonates. The Pliocene rock unit is called El Hagif Formation and is composed mainly of smoky white unfossiliferous limestone with marl interbeds. Moghra Formation is the only aquifer in the area of study; that is why it is intensively studied. Moghra Formation can be distinguished into El Raml, Bait Owian and Monquar El Dowi members. El Raml sediments are almost deposited in fluvial environment while Monquar El Dowi beds are formed in fluvio-marine environment.

Sedimentologically, the paleodepositional environment of this area is fluviomarine. From grain size analysis, It is obvious that the deposits in the south of Moghra Lake are fluvial changed to fluviomarine in the north. The paleomega delta is about six times the size of the modern Nile Delta Size. It must be formed by a very large river that was capable of carrying heavy sedimentary loads into the paleo shore of the Mediterranean. The Moghra Formation succession shows a repetition of transgressive-regressive units with the regressive component thickening seawards and the transgressive component thickening landward [10]. The occurrence of petrified wood reflects past humid tropical forest conditions in the study area as the petrification process took place in situ [28].

Structurally, the Western Desert of Egypt is divided into two geologic provinces from south to north; they are the stable and the unstable shelves [7]. Qattara Depression lies in the unstable province and is situated between two isolated intracratonic closed basins, Abu Gharadig in the south and Al Alamin in the north [6]. According to [3], this region was submitted to a long period of predominantly compressive forces. A short but efficient episode of tensional release followed it. **Structurally**, the area suffered from different forces creating NW anticline and NE and NW faults [11].

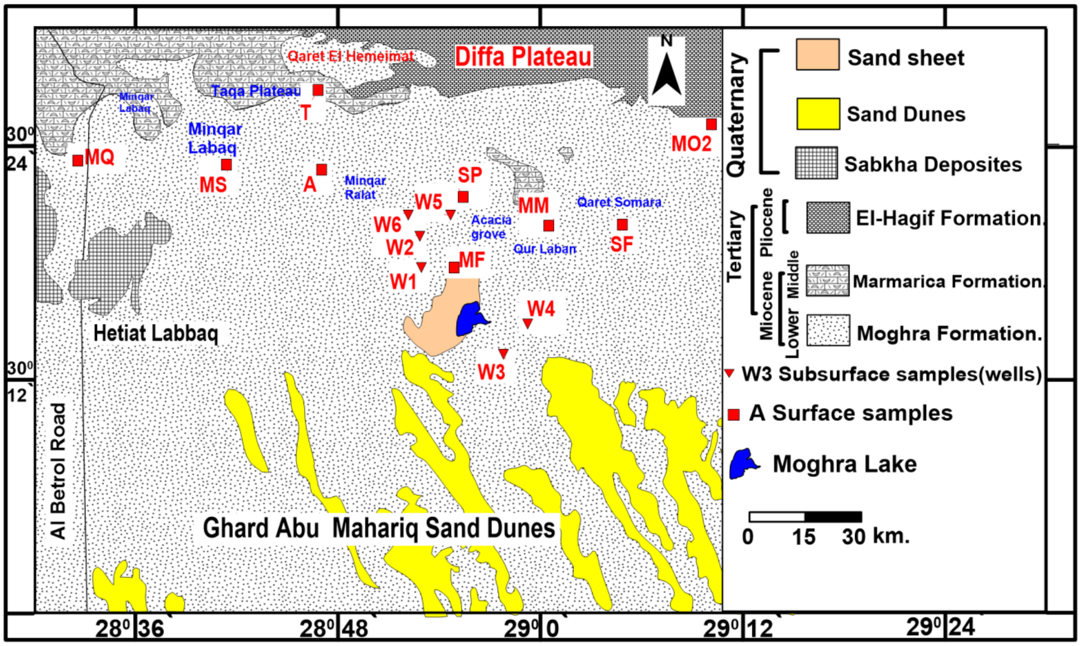

Fig (3): Geological map of Moghra Oasis and its vicinities, modified after CONOCO 1986

The structural and depositional history of the area of study during the Miocene-Pliocene period is rather complicated as reflected by the rapid lateral and vertical facies change of the aforementioned rock units. This is can be understood in the light of the transitional nature of the fluvio-marine environment. During the early Miocene, clastic sedimentation prevailed. Moghra Formation was deposited under such fluvial environment (Fig (**22**). During the Middle Miocene a change of the climate and reactivation of the coastal high left of the north-Western Desert; a distinctive basin in which clastics were deflected and organogenic carbonate deposits accumulated. In this environment the Marmarica Formation was deposited.

The Moghra seems to have been deposited in a high-energy wave-dominated delta similar to the present Nile Delta depositional environment. In Qattara area, the thickness of Moghra Formation is about 200 m. This thickness increases northward to reach up to 738 m at Dabaa on the Mediterranean coast. Moghra Formation occasionally contains silicified tree trunks which are thought to be rafted [3]. The size of the paleodelta, which is more than six times that of the present-day Nile Delta, and the type of sediments are a result of a strong river ending in the shelf area. This river ran under tropical to subtropical climate [2].

4. Results and discussion

Based on the sedimentary studies of the rock samples collected nine surface sections and six drilled wells were collected from the area of study (Fig (**3**). These samples show lateral facies and mineral changes of Moghra Formation. Moghra Formation can be distinguished from base to top into the following three members [4].

4.1 El Raml Member: Base

To understand the sedimentary basin of El Raml member; the structure contour map on the top of Oligocene shale (Dabaa Formation (DF)) before the deposition of Moghra Formation (MF) shows that the main basin of deposition is to the northwestern part of MO with depth more than -550 m (Fig (**5**). Moreover, there are two small sub-basins in northeast and southwest parts with depths of -530 and -540 respectively. El Raml member is the lower portion of MF and composes of alternating vary colored sand and sandstone interbedded and partially intercalating with claystone and it contains streaks and spots of gypsum, heavy mineral detrital grains and patches and spots of iron oxides (Fig (**4**). The abundance of sandstone with cross lamination is noted within most of this member, together with petrified wood and plant roots indicate fluvial environment of sedimentation. The shale percentage of El Raml member varies from 0 % in areas dominated by fluvial environment in the southwest of the studied area increase to 45.9 %in the northeast of Moghra Lake where marine conditions prevailed. El Raml member is partially penetrated by water wells. The basin of deposition after DF was continuous after the deposition of RM. This is noticeably appearing from the existence of high areas to the east, west and south of MO with the continuous main basin of deposition in the northwest part with maximum depth reach to -127 m (Fig (**6**). Thickness map of RM reflect the impact of DF basin of deposition on the occurrence and thickness of their sediments (Fig (**7**). Where, it is relatively thin in southern and western part and main basin of deposition was shifted eastward with thickness more than 410 m. Two small sub-basins were recorded to the southwest and southeast of MO with maximum thickness ~ 400 and 390 m owing to the rejuvenation of faults during deposition.

Petrographically, only one sample (samples No.12) has been selected from MM surface section in the northern exposures at Qur Laban represent RM (Fig (**8**.A) for petrological investigations. It is mostly quartz-arenite (85-90% quartz), partial compaction on the grains and cementation, moderately sorted and iron oxides rim some quartz grains. Pore spaces are filled with silica (10-15) and sometimes fe-oxides cement. James and Oaks, 1977, stated that the quartz arenite may be deposited in shallow marine shelf setting.

Five sediment samples were selected for X-ray diffraction analysis to represent RM laterally and vertically. The main mineral compositions are quartz and feldspars (orthoclase and plagioclase) with minor amount of kaolinite (Fig (**10**). The mineralogy of bulk clayey sample (sample No. MM 5) are kaolinite, gypsum, and hematite.

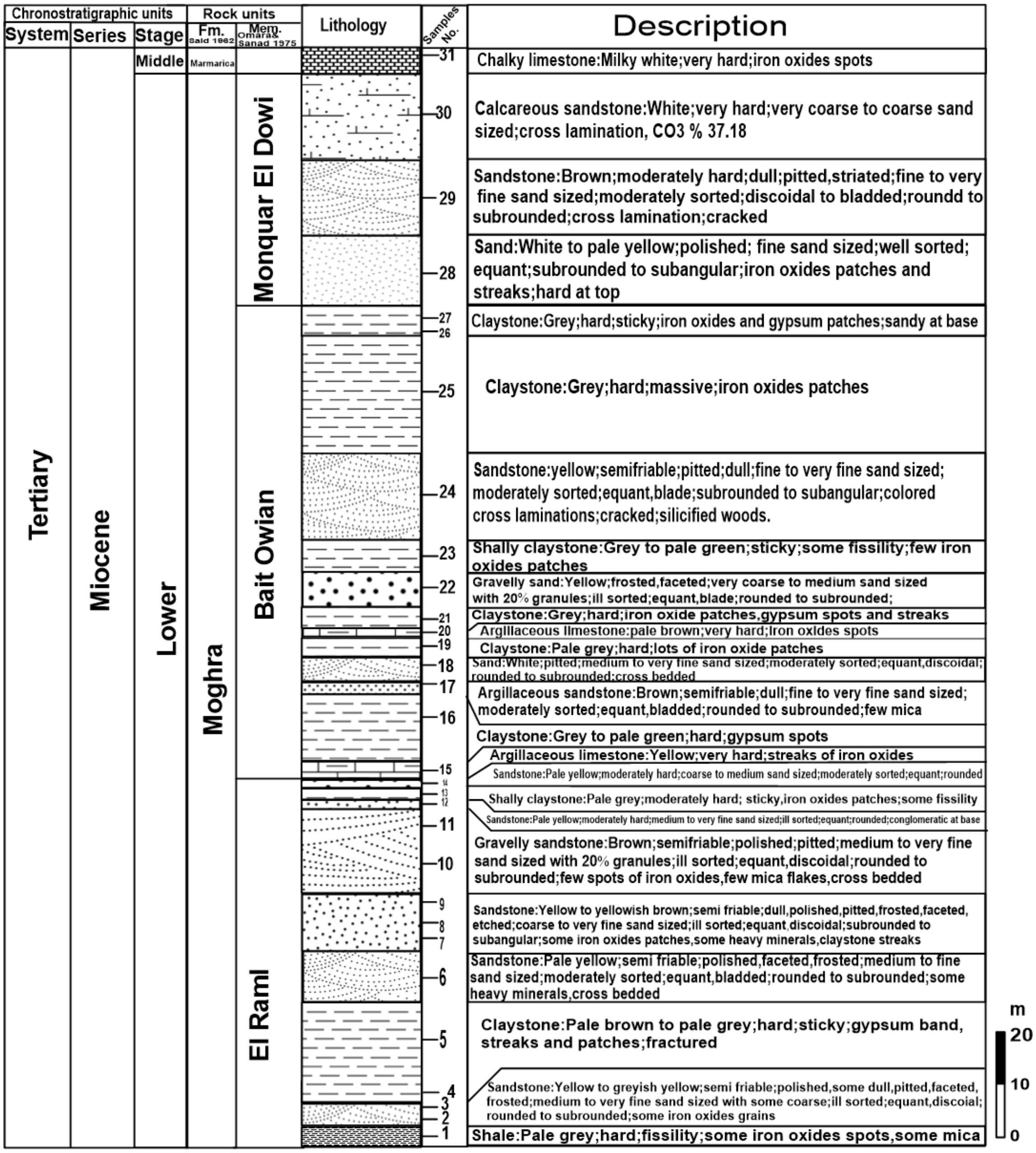

Fig (4): Columnar section at Qur Laban area (MM surface section) showing the composition of Moghra Formation which is capped by Marmarica Formation.

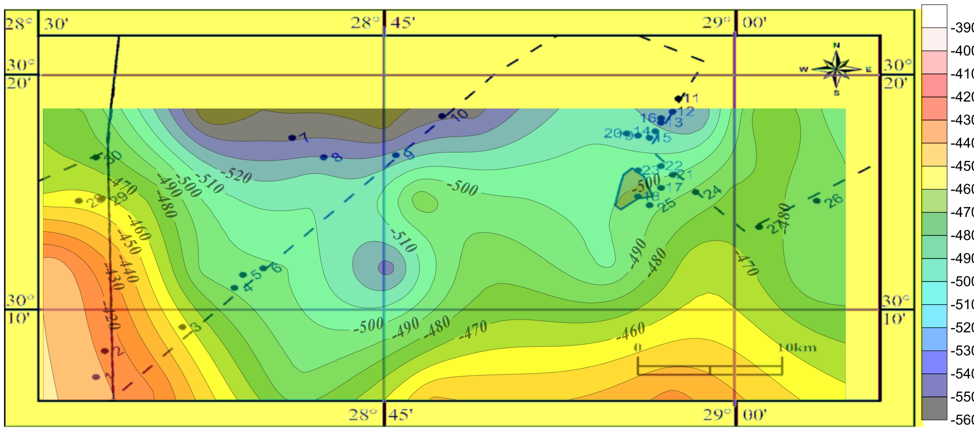

Fig (5): Structure contour map on the top of Dabaa Formation.

4.2 Bait Owian member (Deir El Tarfaya)

Bait Owian is characterized by the dominance of clayey sediments interbedded with sands and sandstone in some parts. This member composes of varicolored claystone with bands of argillaceous limestone containing spots and patches of iron oxides (Fig (**4**). As well as, it contains streaks, spots and bands of gypsum and halite. Isopach contour map (

Fig (9) exhibits that Bait Owian thickness increases toward east and west of Moghra Lake while it is small at the center. This reflects that Bait owian was deposited on horst fault. Petrographically, there are two microfacies associations: Sparite, and microsparite (Fig (**8**.B and C) in the limestone layers. Mineralogically, X-ray diffractograms of BOM displays the dominance of kaolinite and quartz with gypsum, calcite, aragonite and goethite (Fig (**11**). It is changed laterally westward from arenaceous at Acacia grove (MF surface section and well no. 3), to calcareous and gypsous facies at Naqb Abu Dowis (MQ surface section) and ferruginous facies at Qur Laban (MM surface section and well no.2).

4.3 Monquar El Dowi member (Qaret El Rikab): Top

Monquar El Dowi composes of vary colored sand and sandstone interbedded and intercalated with claystone and the significant color is white and grey sands (Fig (**4**). The distinctive property of Monquar El Dowi sediments is the common spreading of carbonate cement and sometimes calcareous sand and sandstone and grading to sandy limestone at Minqar Labaq. Additionally, it contains patches, spots and streaks of iron oxides at some parts and cross laminations. From isopach map (Fig (**15**) The measured thickness of Monquar El Dowi varies from 0 m at Acacia grove (MF surface section) and well no. 4 to 96 m at Qaret Somara (SF surface section).

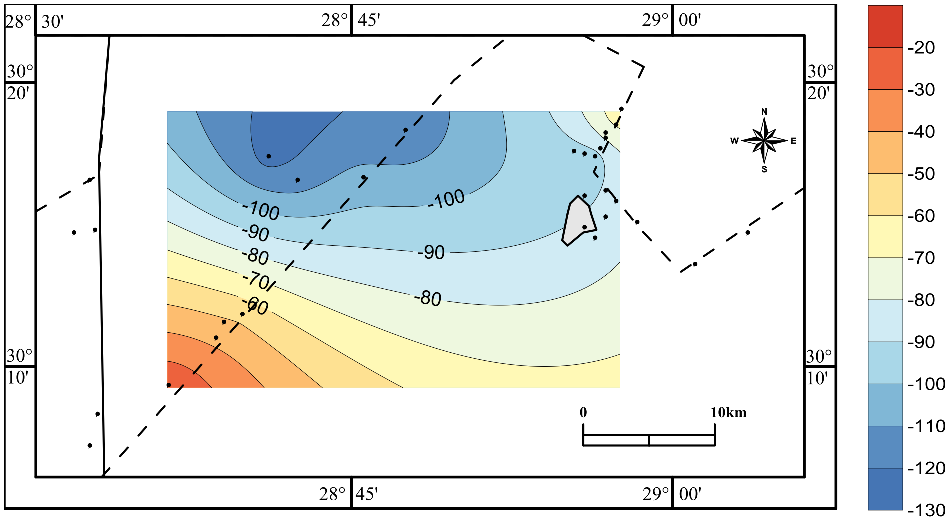

Fig (6): Structure contour map on the top of Raml member.

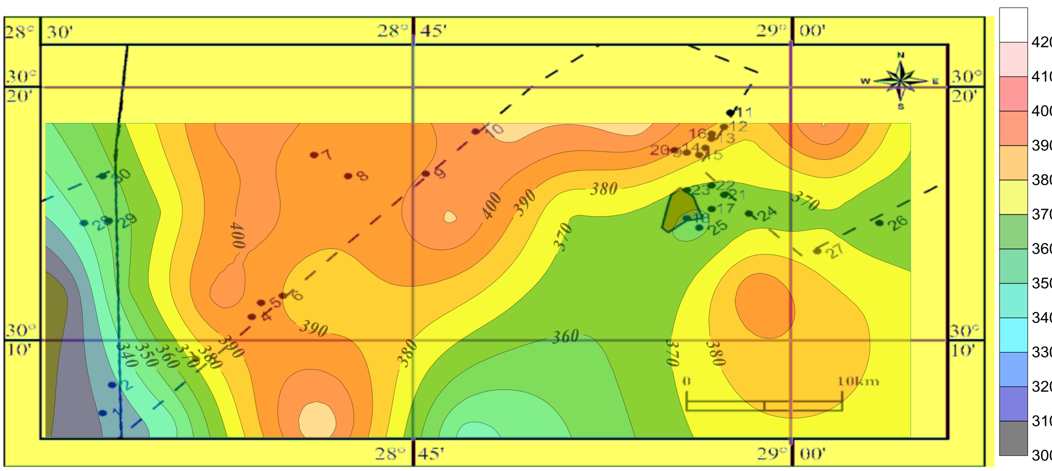

Fig (7): Isopach contour map of Raml member.

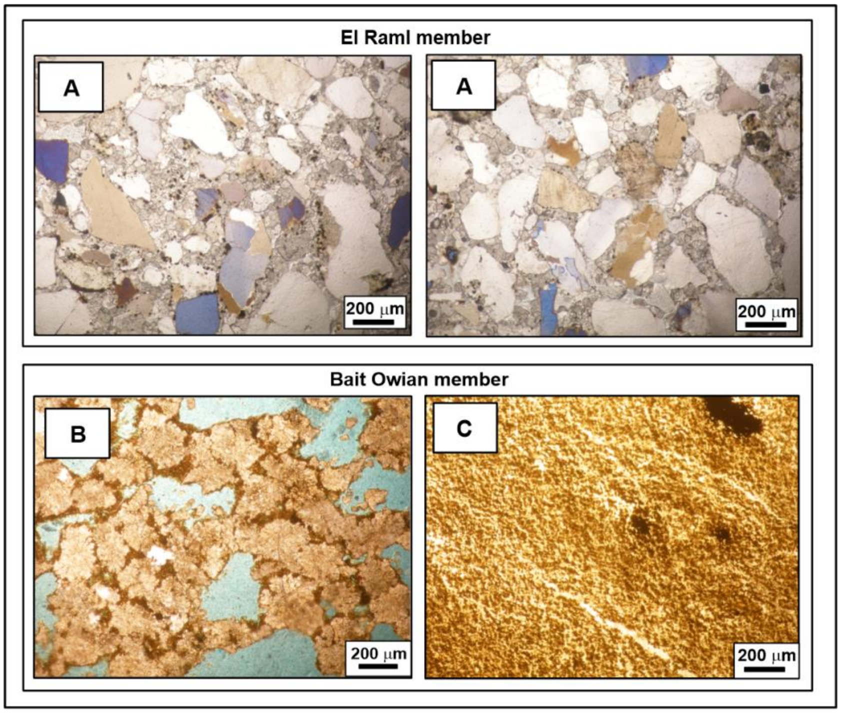

Fig (8): Photo No. 1: Microfacies of Raml member sample in MM, surface section s. no. 12 (A) Quartz-arenite showing partial compaction and cementation, moderately sorted, iron oxides rim some quartz grains; microfacies of Bait Owian member (B) Sparite showing vuggy porosity ,pores are stained by blue dye, streaks of iron oxides, section MM, s. no. 15 , (B) Micrite showing disseminated and patches of iron oxides, XPL, section MM, s. no. 20 , Bait Owian member, Moghra Formation, XPL, 4X

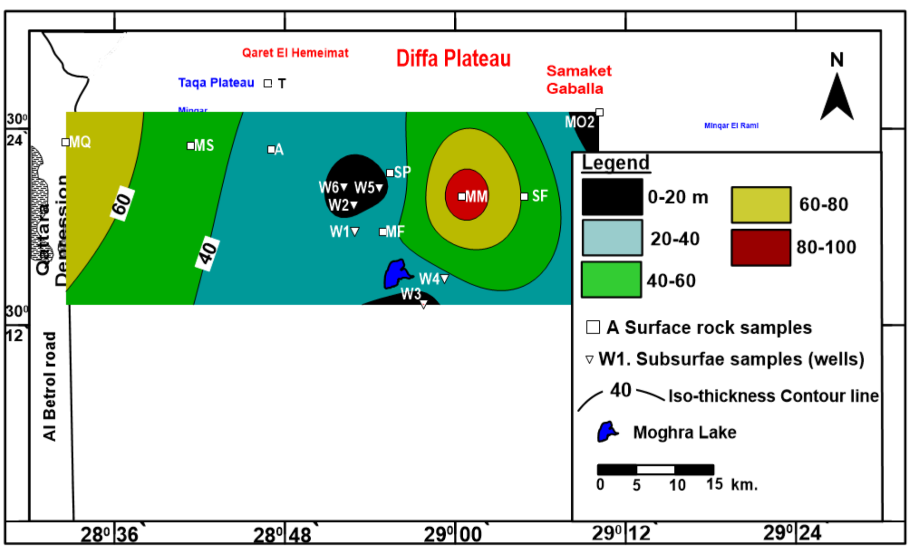

Fig (9): Isopach contour map of Bait Owian member in Moghra -Qattara area; large thickness recorded in MM and MQ sections indicating topographic high and structure low (sedimentary basins)

Monquar El Dowi member is intensively Petrographically examined through eight (8) samples (Figure 15). There are four (4) microfacies associations namely, calcareous quartz arenite, glauconitic calcareous quartz arenite, ferruginous calcareous quartz arenite, and sandy biomicrite from west to east.

1. Calcareous Quartz arenite is represented by four samples from Samaket Gaballa, Qaret Somara, Quar Laban and west Qur Laban (Fig (**12**: A, B, C and D). It consists of coarse to medium quartz grains (about 95% of the rock), moderately sorted, rounded to sub-rounded, with some mica (1%) in MO2 surface section that are cemented by calcite about (4-3%) with intra-granular porosity. Matrix, calcite and iron oxides as well as porosity increase westward to 10%, 12% and 5% (SF surface sedtion). The quartz grains more decrease in the same direction (SP surface section) to 75-80%, calcite increase to 25% and the pore spaces are filled with iron oxides (8-9%). The variation attributed to the difference of environment of deposition from continental to near shore shallow marine.
2. Ferruginous calcareous quartz arenite is represented by two samples from MS section (Fig (**12**: E and F). It is composed of quartz grains (70%) and Calcite (30%) with little matrix. The pore spaces are filled with iron oxides (8-9%) and vuggy porosity is noted very low (3). That mean it is deposited in a near shore shallow marine environment
3. Glauconitic calcareous quartz arenite is represented by one sample from MS section (Fig (**12**: G). It consists of quartz grains (75-80%) with matrix about 5% iron oxides, 20% calcite and 5% glauconite grains that deposited under shallow marine environment. The glauconitic crystals have brownish green color.
4. Sandy bio-micrite is noted in the upper bed in MS surface section (Fig (**12**: H). It consists of echinoid spines and pelloids with some detrital quartz grains are noted within the micrite groundmasses. Both primary and secondary porosity types are noted (intraparticles, vugs, mauldic and short fractures). They reflect channel deposition in nearshore, tidal flat environment.

Mineralogically, by XRD analysis Monquar El Dowi member consists mainly of quartz and plagioclase with minor amount of orthoclase, calcite, kaolinite, hematite, gypsum, and dolomite (Fig (**13**and Fig (**15**). Orthoclase is recorded in Naqb Abu Dowis (MQ surface section), Qaret El Himmimat (T surface section) and well no 3. Calcite is in Minqar El Raml (MO2 surface section) and at Qaret Somara (SF surface section), while dolomite is recorded in T and wells Nos. 2 and 3. On the other hand, hematite, gypsum and halite are only identified in Quar Laban (MM surface section). The variation of mineralogy is related to the difference of environmental conditions and their sources.

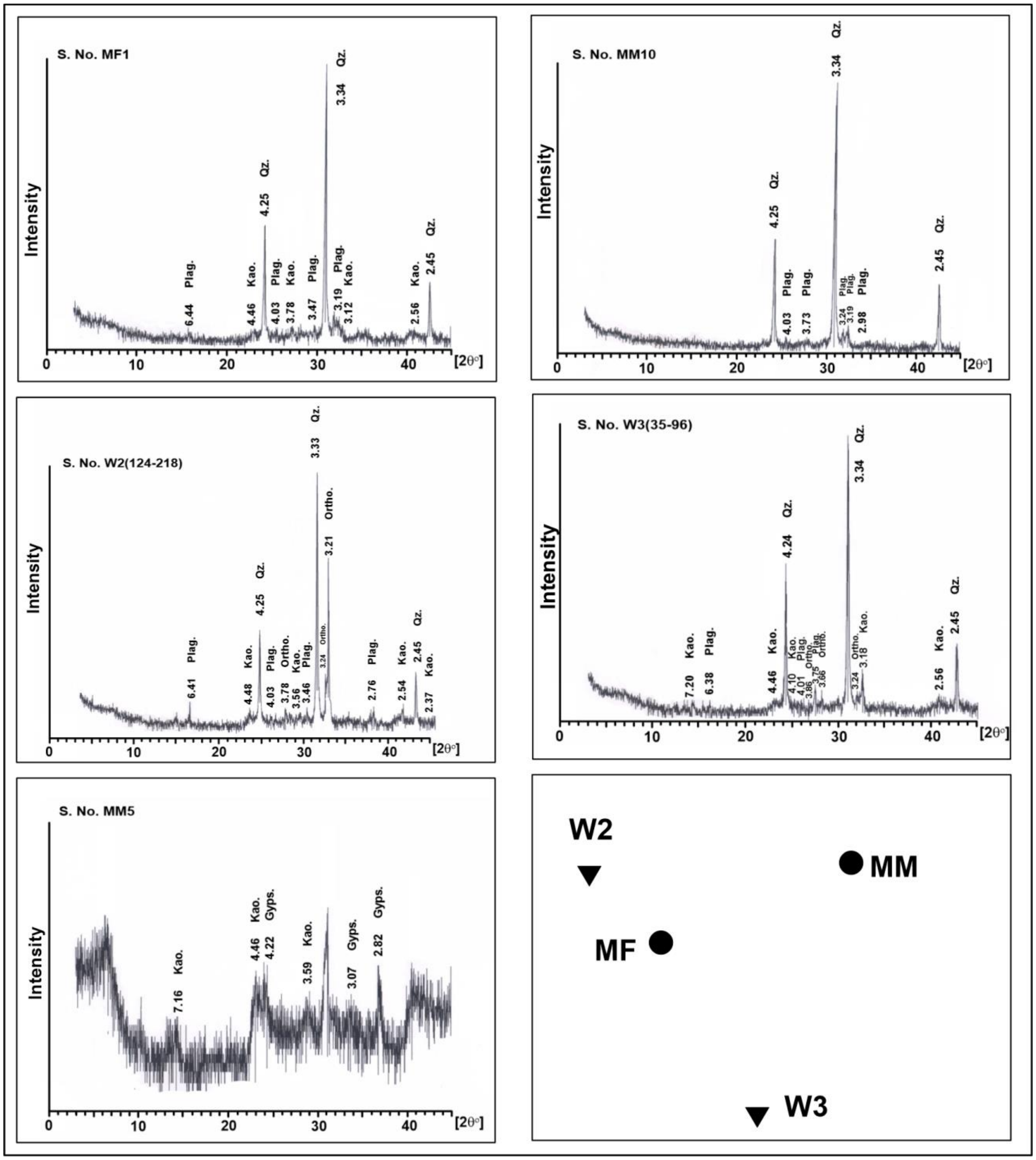

Fig (10): X-ray diffraction of Raml member

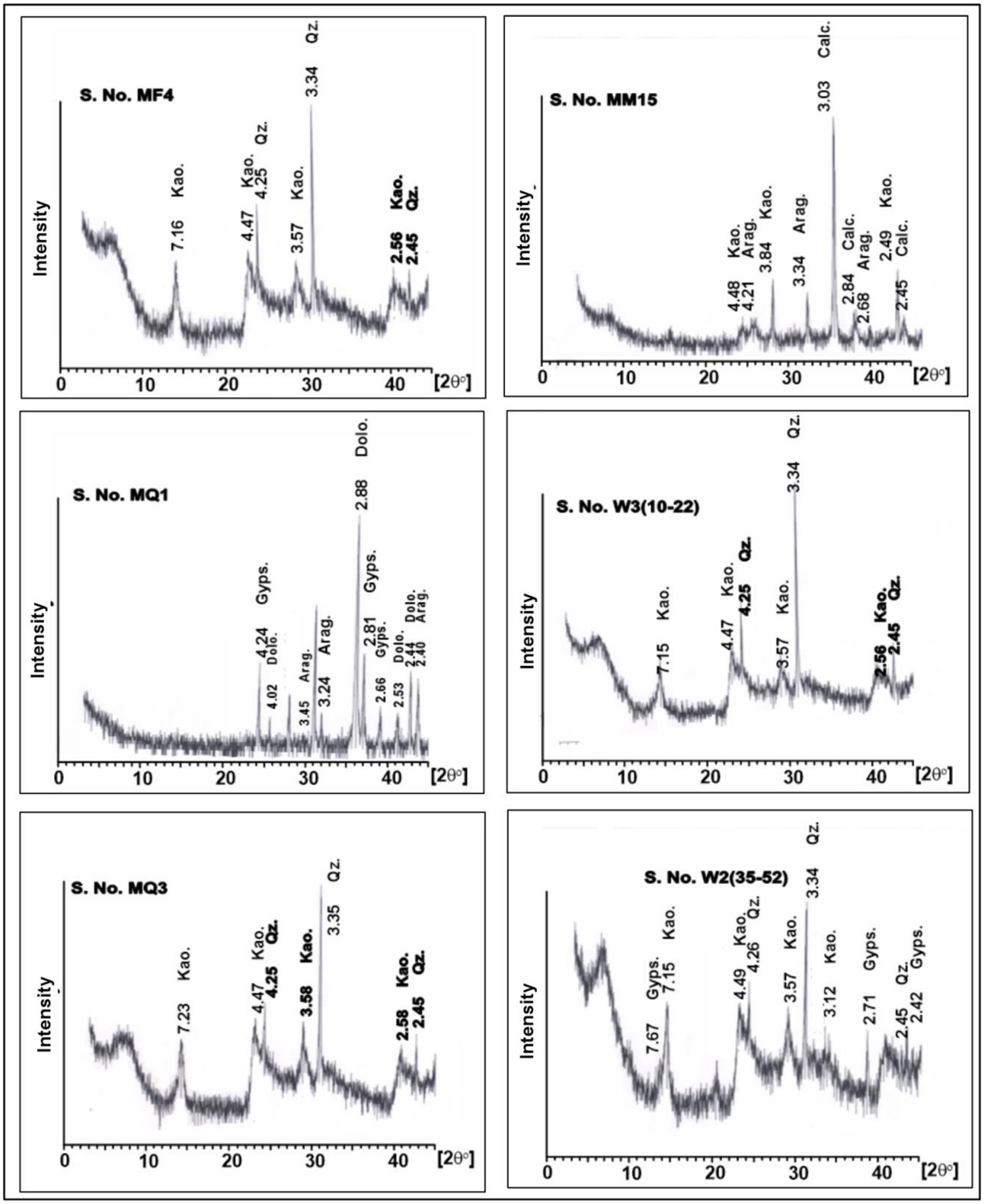

Fig (11): X-ray diffraction of Bait Owian member.

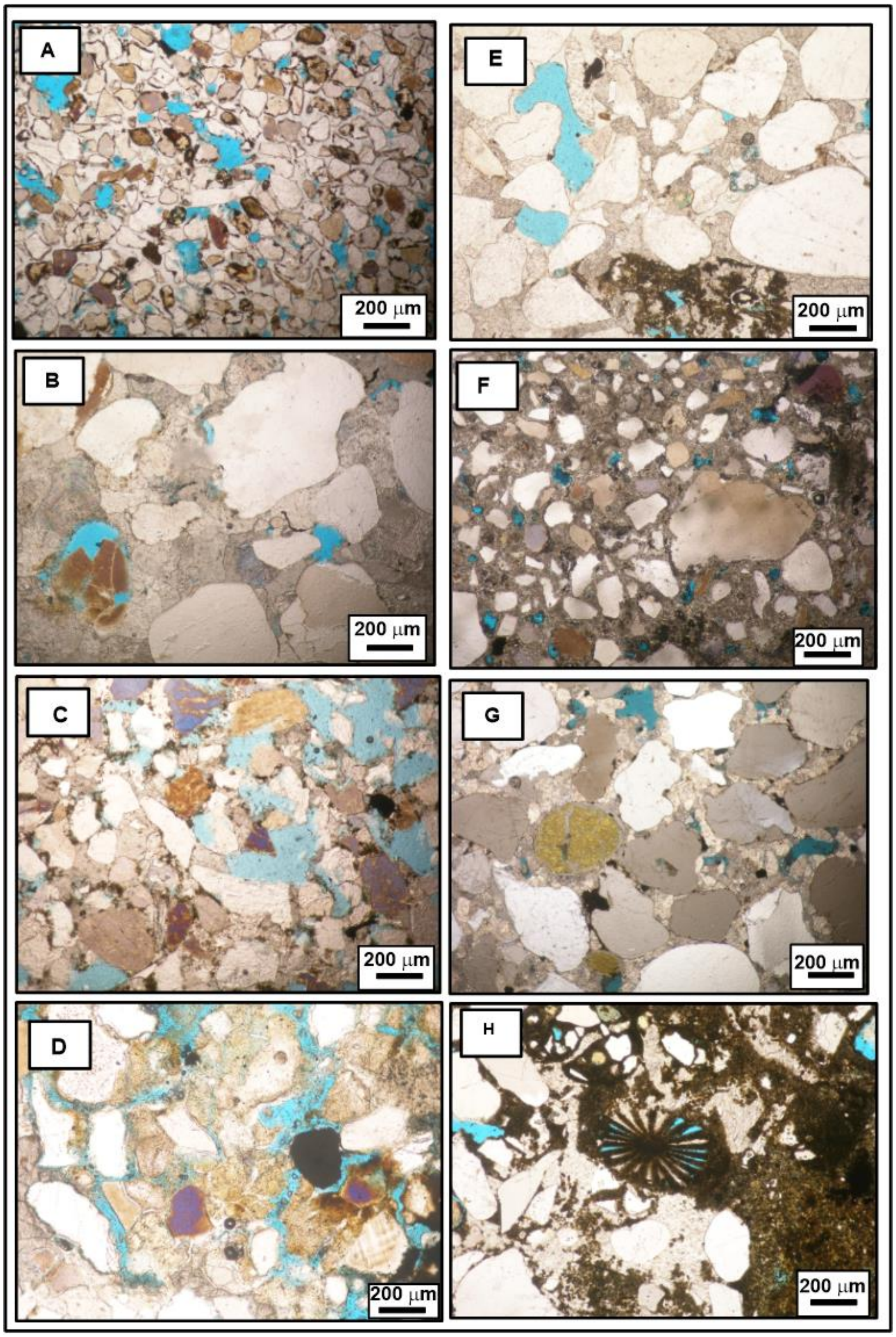

Fig (12): photomicrograph showing different recorded sandstone microfacies (A), (B), (C) and (D) calcareous quartz arenite; (E) and (F) ferruginous calcareous quartz arenite; (G) glauconitic calcareous quartz arenite; (H) sandy biomicrite.

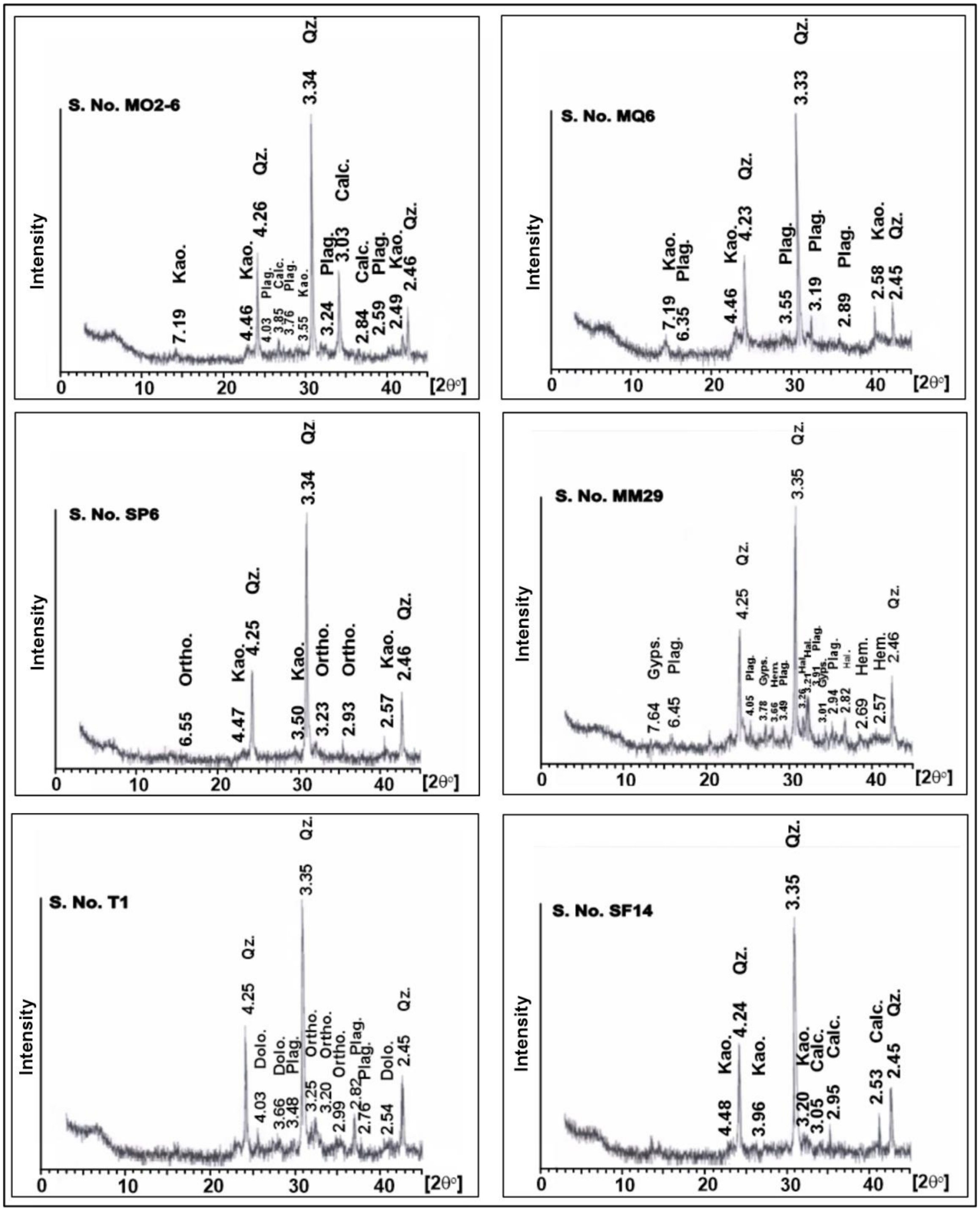

Fig (13): X-ray diffraction of bulk samples from Monquar El Dowi member, Moghra Formation, MO2, MM, SP, SF, T and MQ surface sections

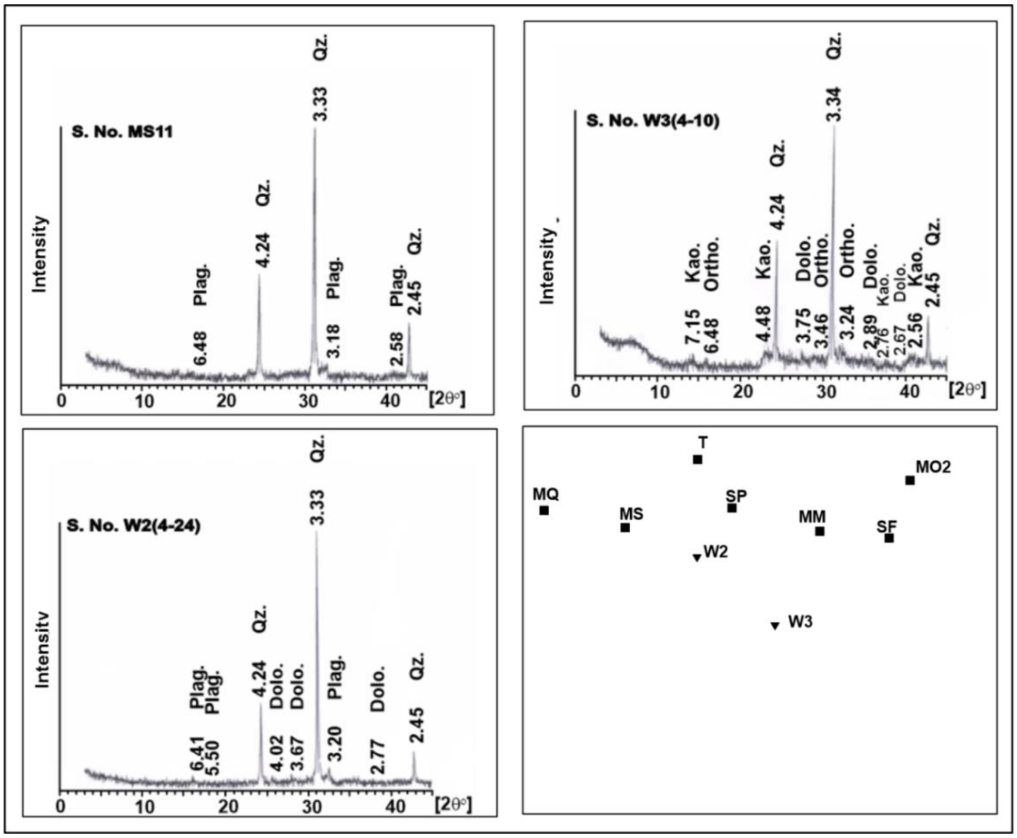

Fig (14): X-ray diffraction of bulk samples from Monquar El Dowi member, Moghra Formation, MS surface section and wells nos. 2, 3.

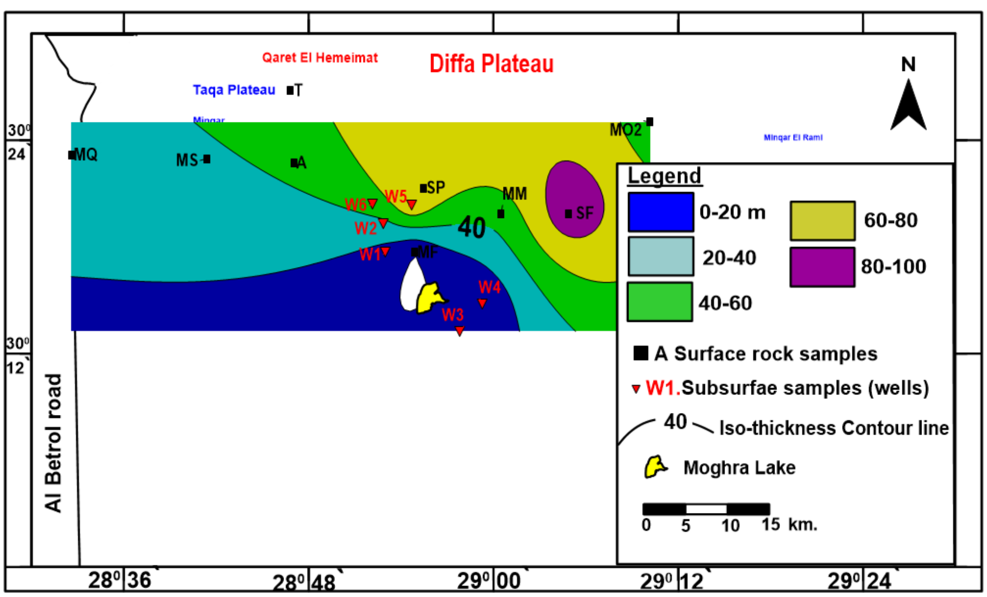

Fig (15): Isopach contour map of Monquar El Dowi member in Moghra Qattara area

5. Inferred Geologic Structures

Map of inferred faults from stratigraphic correlation (Fig (**20**) between the surface and the subsurface sections, structural contour maps, Isopach maps and the field investigation reveal that the area is affected by a number of local folds and faults (Fig (**16**). NW-SE fold has strikes in NW direction where Raml Member; older; is exposed in the core at Moghra Lake and the limbs display Bait Owain and Monqar El Dowi Members (younger). The Moghra Qattara depression is affected by two sets of faults. NW-SE faults are associated with NW-SE folds. Normal fault directed from NE to SW is identified at the mouth of Moghra Lake and it is the dominant direction in the studies area (Fig (**17**); this agreed with the contour map of depth to Dabaa Formation and Bait Owian beds (Fig (**18** and Fig (**19**).

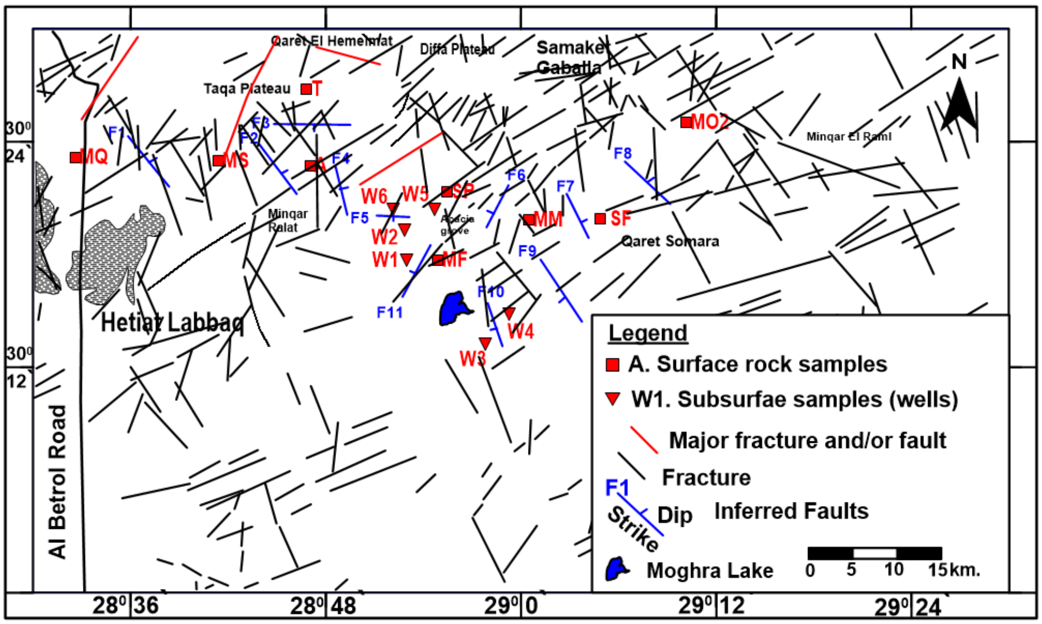

Fig (16): Faults and fractures of the area of study modified after Conoco, 1986

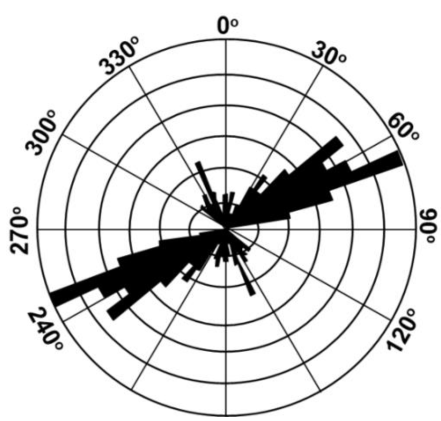

Fig (17): Rose diagram shows the directions of the Fractures/faults mapped by Conoco (1986) (Khan et al. 2013)

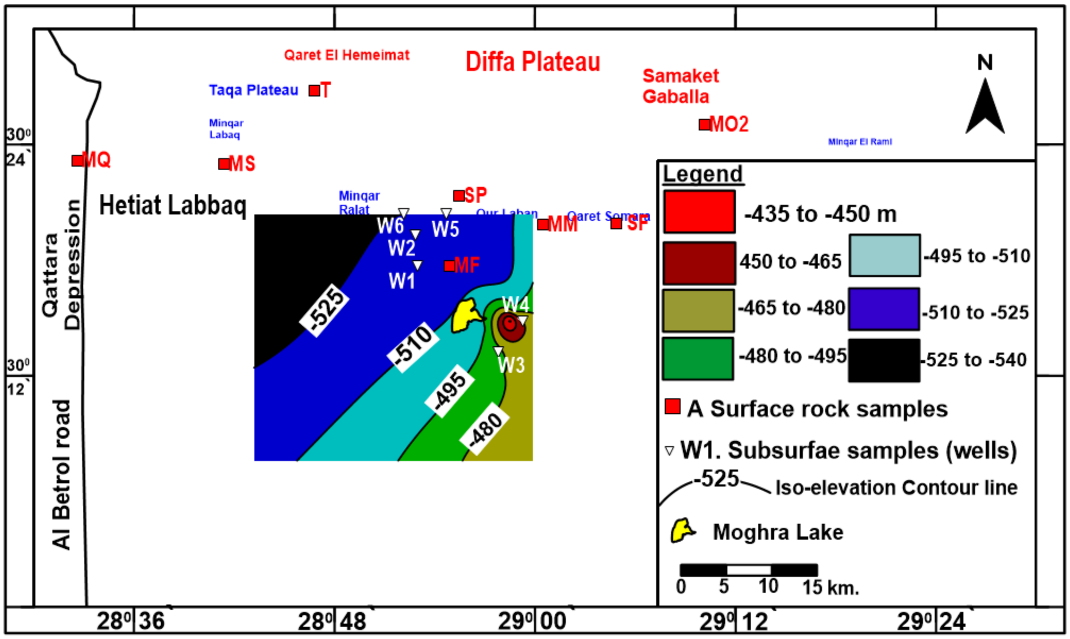

Fig (18): Structure contour map on top of Daba`a Formation in Moghra Qattara area showing normal fault at the mouth of Moghra Lake

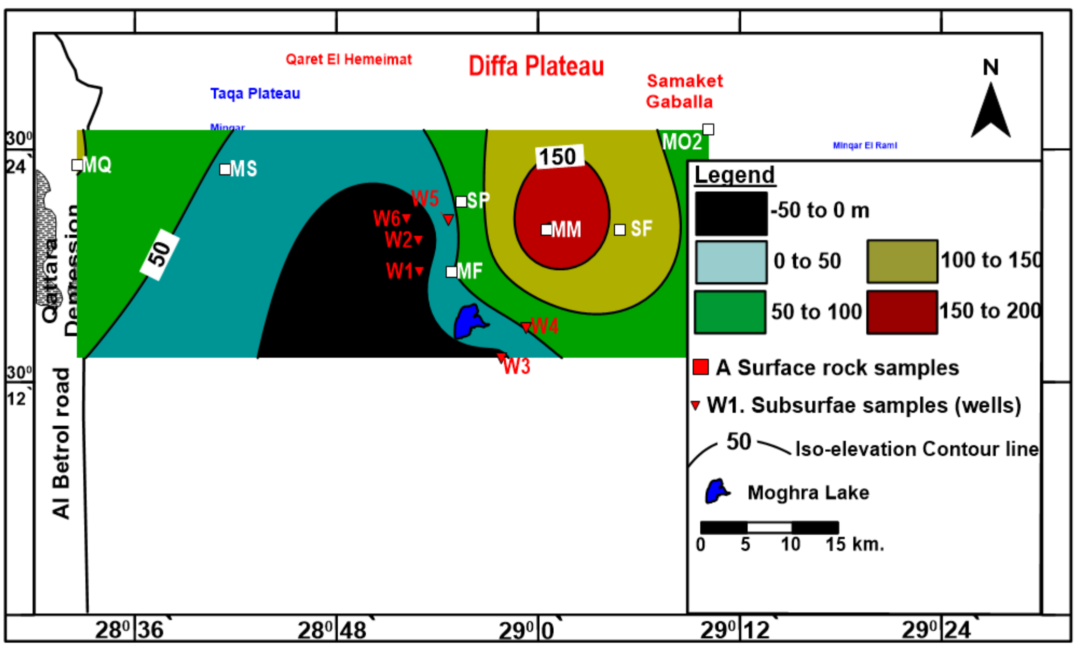

Fig (19): Structure contour map on top of Bait Owian member in Moghra Qattara area. It shows a dome to the east and a syncline to the west. The synclinal structure is favorable to groundwater accumulation.

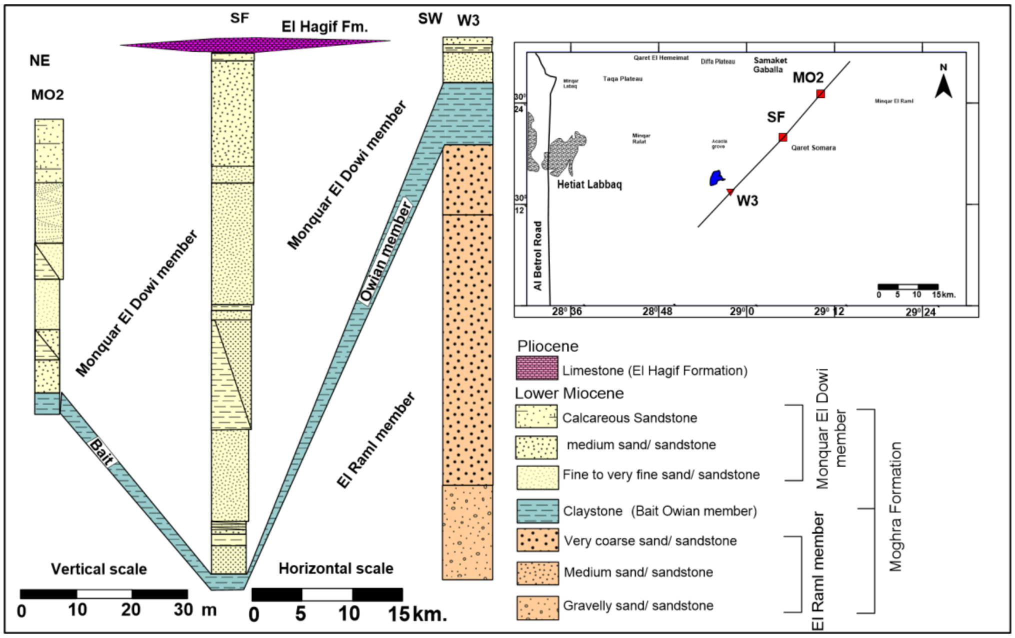

Fig (20): Correlation between Moghra Formation from northeast to southwest depending on the Bait owian as marker bed

6. Depositional Environments of the Miocene sand beds:

From grain size analysis, Bivariant relations of skewness (SKI) versus inclusive graphic standard deviation (σ1) are applied to discriminate between beach and river sand [22]. As a result, El Raml sediments reflect the dominance of river environment with some exceptions of beach one, while Monquar El Dowi deposits demonstrate river and beach environments (Fig (**21**). Moreover, both petrographic investigation and X-ray diffraction interpret that the upper part of El Raml beds is deposited in shallow marine environment, contrarily microscopic investigation shows that Monquar El Dowi is mainly deposited in shallow marine conditions. From aforementioned properties it can be concluded that the lower part of El Raml member was deposited in fluvial conditions but the upper one was deposited in shallow marine environment. On the other hand, Monquar El Dowi beds had been deposited under fluvio-marine conditions due to the existence of carbonate cement and glauconite grains except the upper portion had been deposited in marine environment owing to the presence of echinoids spines. These characteristics indicate repetition of regression and transgression and rapid facies change.

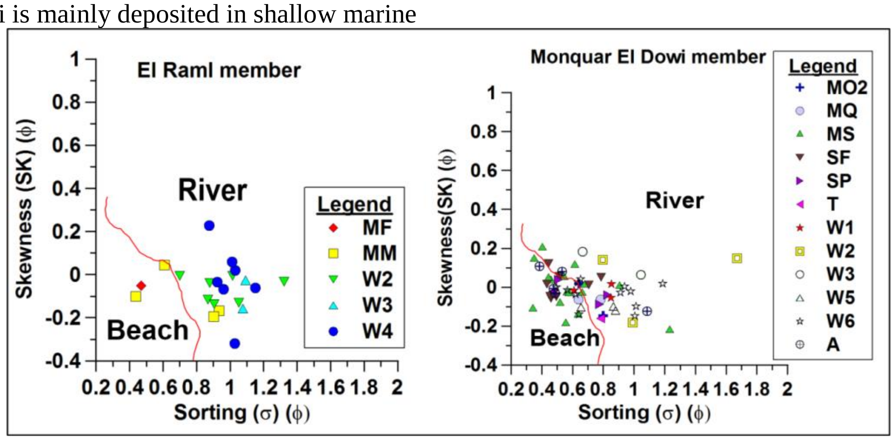

Fig (21): Bivariant plot of sorting vs. skewness of Lower Miocene sediments to determine the depositional environment, (after Friedman 1961, 1967)

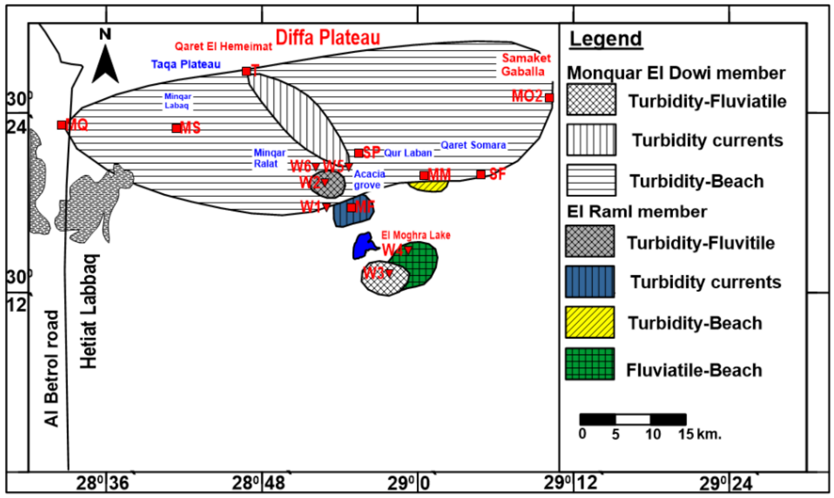

Fig (22): map showing detailed depositional environmental condition of sand members of Moghra Formation (Early Miocene sediments) which agreed to the defined depositional environment (shelf sediments influenced by fluviatile action).

7. Implications for groundwater exploration and management

The geological data provided in these paper shows that the southern and eastern parts of the area are better than the northern and western parts for the reclamation project (Fig (**23**). This is because Moghra aquifer in the south and east is composed mainly of the sand of El Raml member which forms in this area an aquifer of good potentialities. However, the increase of the clay content accompanied by the decrease of grain size of the sands of El Raml member in the north and west strongly affects both the aquifer potentiality and the groundwater quality. Care must be taken in well designs to avoid mixing the low salinity water from the sand beds with saline water from the clay interbeds. The wide range of groundwater salinity of the drilled wells is more likely due to improper well designs.

The historical space images (Fig (**24**) of the Moghra Lake show an increase of the vegetation cover between 2003 and 2005. No significant change is noticed between 2005 and 2007. Deterioration of the vegetation cover is noticed in 2012 image accompanied by the development of salt crust due to the increase of the water level in the lake. This problem is increasing since 2012 as evidenced by the increase of the areas submerged by water as is easily noticed in photos(c) and (d) which are parts of 2017 image. The source of this increase in the lake water level is the discharge of the irrigation-excess water from the newly cultivated lands in the higher areas surrounding the lakes as there is no agricultural irrigation measures have been constructed in the area, but this is checked in field in between March 2015 and May 2017.

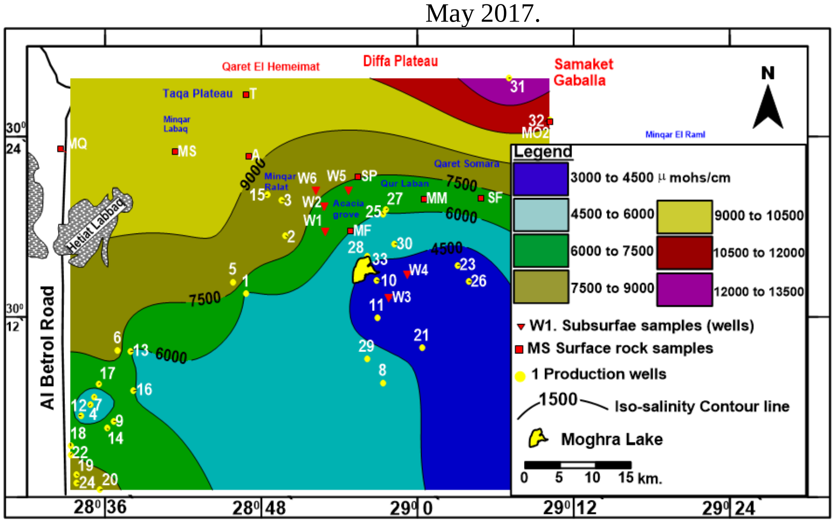

Fig (23): Iso-salinity contour map of Lower Miocene Groundwater in Moghra Qattara area

8. Conclusion

Moghra Oasis and its vicinities represents a terminal part of the probable delta like pattern therefore, the sediments should be fluvio-marine and the grain size grading from coars to fine (SE to NW) which is the direction of paleo-delta.

Geomorphologically, El Diffa Plateau in the north and sand dunes in the south act as watershed areas while the Moghra-Qattar Depression act as water collector. Structurally, the Moghra Oasis and its vicinities affected by compressional stress producing anticline fold oriented from SE to NW. Moreover, this area suffered from tensional stresses creating two types of normal faults one directed from SE to NW and the other directed from NE to SW. Lithostratigraphically, the rock units in Moghra –Qattara area arranged as following, Marmarica Formation overlays conformably Moghra Formation in the northwest, whereas El Hagif Formation overlays unconformably Moghra Formation in the northeast of the studied area. Moghra Formation can be distinguished into El Raml, Bait Owian and Monquar El Dowi members connected by faults. Grain size analysis and microfacies examination stated that El Raml sediments are almost deposited in fluvial environment while Monquar El Dowi beds are formed in fluvio-marine environment. The microscopic examination only investigated one microfacies association type which is Quartz-arenite, whereas Bait Owian member comprises Sparite, and microsparite.

Contrarily, Monquar El Dowi member contains four microfacies associations which are Calcareous Quartz arenite, Glauconitic calcareous quartz arenite, Ferruginous calcareous quartz arenite and Sandy biomicrite. The obtained mineral composition data demonstrated that Monquar El Dowi sediments are more calcareous and salty than El Raml deposits. El Raml member is characterized by the presence of quartz, plagioclase and kaolinite as the predominant minerals followed by orthoclase, montmorolinite and gypsum minerals. Bait Owian member composes mainly of kaolinite and quartz followed by glauconite, montmorolinite, gypsum, calcite, aragonite and geothite. While Monquar El Dowi member is characterized by the existence of quartz, plagioclase and kaolinite as dominant minerals followed by orthoclase, dolomite, calcite, gypsum, halite and hematite.

9. Recommendations

It is highly recommended to start an agricultural irrigation-excess draining project in the reclaimed areas as soon as possible to prevent the deterioration of the areas in the low land and also to prevent the destruction of the Moghra Lake ecosystem. It is also recommended to confine the reclamation project to the eastern and southern areas which have greater aquifer potentialities and better groundwater quality. The area with petrified wood should be declared a national park area with touristic significance.

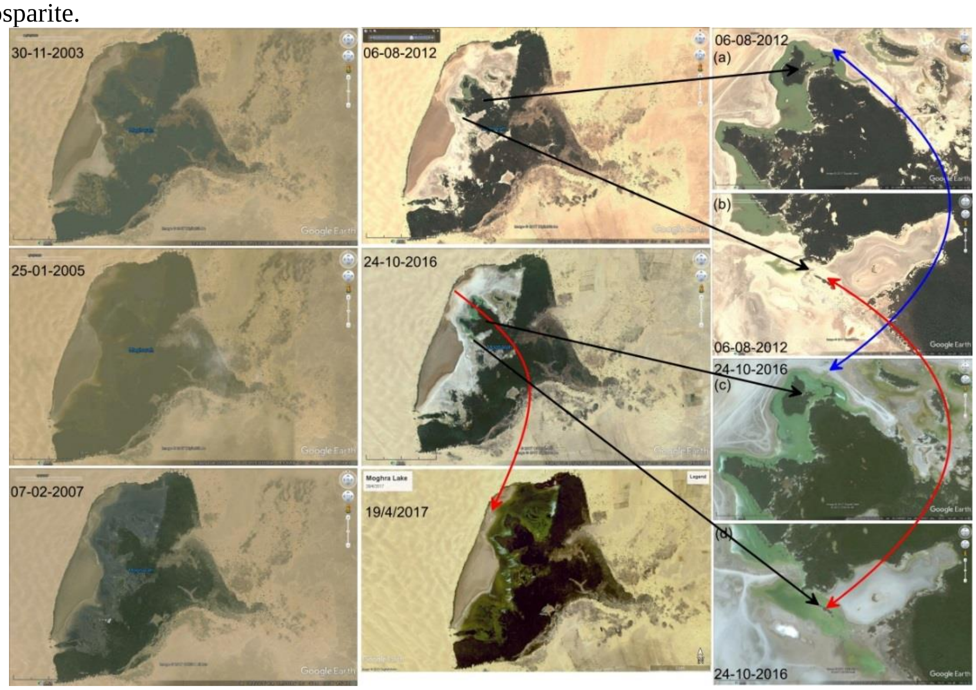

Fig (24): Space images show the evolution of Moghra Lake between 2003 and 2017.

10. Acknowledgment

The authors thank both Prof. Dr. Tarek Yousef, Head of The Sedimentology Laboratory, and Prof. Dr. Ahmed Salama of the Egyptian Petroleum Research Institute for their help in the examination of Microfacies.

References

[1] M. A. Abdel-Rahman, F. El-Baz, 1979, Detection of a probable ancestral delta of the Nile River. ASTP Summary Science Report.

[2] R. Said, 1990, The Geology of Egypt. AA Balkema, Rotterdam, 734 p.

[3] R.Said, 1962, The Geology of Egypt. Elsevier Publishing Company, Amsterdam, New York, 370 p.

[4] S. Omara, S. Sanad, 1975, Rock stratigraphy and structural feature of the area between Wadi El Natrun and the Moghra Depression (Western Desert), Egypt. GeologischesJahrbuch16, 45–73.

[5] R. Misak, (1979), Geology of the area between the Moghra Oasis and the Mediterranean Sea, Western Desert, Egypt. Ph D. Thesis, Faculty of Science, Ain Shams Univ, Cairo.

[6] A. Abdel Aal, A. Moustafa, 1988, Structural framework of the Abu Gharadig basin, Western Desert, Egypt. Proceedings of the 9th Exploration Conference, Egyptian General Petroleum Corporation, Cairo.

[7] N. Sultan, M. Halim, 1988, Tectonic framework of northern Western Desert, Egypt and its effect on hydrocarbon accumulations. Proceedings of the 9th Exploration Conference, Egyptian General Petroleum Corporation, Cairo, Vol. 2, pp. 1-22.

[8] E. El Gammal, O. Cherif, 2006, Use of remote sensing for the study of the hazards of Ghard Abu Muharik sand dune field, Western Desert, Egypt. The 2nd International Conf. on Water Resources & Arid Environment, 1-21.

[9] A. F. Yousef, 2013, Lights on the Hydrogeology of Moghra Oasis, North Western Desert, Egypt. Accepted in 29/8/2013 Annals Geol. Surv. Egypt, V. XXXII

[10] S. Hassan et.al, (2012), Stacked, Lower Miocene tide-dominated estuary deposits in a transgressive succession, Western Desert, Egypt. Sediment. Geol. 282, 241–255.

[11] S.D. Khan, et al., 2013, Remote sensing and geophysical investigations of Moghra Lake in the Qattara Depression, Western Desert, Egypt, Geomorphology http://dx.doi.org/10.1016/j.geomorph.2013.10.023

[12] M.A. Ezzat, 1982, Impact of a future Qattara salt-water lake on the Nubian Sandstone aquifer system in the Western Desert, Egypt. Improvements of Methods of Long Term Prediction of Variations in Groundwater Resources and Regimes Due to Human Activity (Proceedings of the Exeter Symposium, July 1982). IAHS Publ. no. 136, p. 297-314

[13] Z.S. Rizk and A.D. Davis, 1991, Impact of the proposed Qattara Reservoir on the Moghra aquifer of northwestern Egypt. Groundwater, 29(2), p. 232-238.

[14] M. A. Sh. El Sabri, 2016, Groundwater origin and management in Moghra Oasis and its vicinities, Qattar Depression, Western Desert, Egypt

[15] R. L. Ingram, 1971, “Sieve Analysis”: In “Procedures in Sedimentary Petrology”, by R. E. Carver, Wiley Intercedences, New York, 653 p.

[16] R. L. Folk, 1966, A review of grain size parameters. Sedimentology, 6, p. 73-93.

[17] G.M. Friedman, 1967, Dynamic processes and statistical parameters composed for grain size frequency distribution of beach and rivers sands: Jour. Sed., Petrology, V. 37, p. 327 – 354.

[18] R. J. Moiola, and D. Weiser, 1968, Textural parameters and evaluation. Jour. Sed. Petrology, 38, p.45-53.

[19] F. J. Pettijohn, 1975, Sedimentary rocks. 3rd ed. Harber and Row, New York, 628 p.

[20] E. j Amaral and W. A. Pryor, 1977, Depositional environment of the Peter Sandstone deduced by textural analysis. Jour. Sed. Petrology, 47, p.32-52.

[21]). R. L. Folk and W. C. Ward, 1957, Brazos River bar, a study in the significance of grain size parameters. Jour. Sed. Petrology, 27, p.3-27.

[22] F. j. Pettijohn, P. E. Potter and R. Siever, 1972, Sand and Sandstones. Springer-Verlag, New York, 618 p.

[23] R. H. Dott, 1964, Wacke, graywacke and matrix-what approach to immature sandstone classification? Jour. Sed. Pet., 34, p. 625-632.

[24] R. J. Dunham, 1962, Classification of carbonate rocks according to depositional texture: In classification of carbonate rocks (Ed. Ham. W.E) Tulsa. Okla. Amer. Assoc. Petrol. Geol. Mem. 1, p. 108-121.

[25] R.E. Carver, 1971, Procedures in sedimentary petrology: New York, Wiley, 633 p.

[26] A.Z. Abotalib, M. Sultan, R. Elkadiri, 2016, Groundwater processes in Saharan Africa: Implications for landscape evolution in arid environments, Earth-Science Reviews (156), p. 108–136

[27] M. Pickford, E.R. Miller and El‒Barkooky, A.N. 2010, Suidae and Sanitheriidae from Wadi Moghra, early Miocene, Egypt. Acta Palaeontologica Polonica 55 (1): 1–11.

[28] E. M. Khoriby, 2004, MECHANISM AND FACTORS AFFECTING THE PETRIFICATION OF THE WOOD FOREST, NORTH MOGHRA OASIS, WESTERN DESERT, EGYPT. 6th Intern. Conf. On Geochemistry, Alx. Univ. Egypt, 15-16 Sept., P. 243-257

[29] CONOCO, 1987: Geological map of Egypt, scale 1:500,000.