Egypt. J. Geo. **Vol. 68,** pp: 97-113 (2024)

Egyptian Journal of Geology

https://egjg.journals.ekb.eg

Structural setting, facies characteristics, and geochemical aspects of the Middle-Upper Eocene outcrops along Beni Suef-El Zaafarana New Road, east of Beni Suef, Egypt

Alaa T. A. Amin [1,3*], **Ahmed M. El-Mezayen** [1], **Darweesh M. Elkholy** [2], **Ehab K. Abu-Zeid** [2], **Hossam A. Khamis** [2], **Wael Fahmy** [1] and **Hazem K. A. Sarhan**[2]

[1]*Department of Geology, Faculty of Science, Al-Azhar University, Cairo, Egypt*
[2]*Nuclear Material Authority, Cairo, Egypt*
[3]*Beni Suef Quarries Administration, Beni Suef, Egypt*

The Eocene Age is distinguished by the development of a carbonate platform covering a large area of Egypt. These Eocene carbonates are widespread in the eastern Beni Suef region of Egypt. In the present work, the lithostratigraphy, structural setting, petrography and, geochemistry of the Middle-Upper Eocene deposits east of Beni Suef, along both sides of the Beni Suef-El Zaafarana New Road, were studied. Stratigraphically, the present area exhibits two rock units arranged from base to top: the Beni Suef Formation and the Maadi Formation, ranging in age from the Middle to upper Eocene. The NNW-SSE, NNE-SSW, and NW-SE trending faults represent the main trend in the present area. These fault sets are extant on a large scale for numerous kilometers in the study area. Petrographically, three microfacies (F) were detected during the petrographic investigation of the studied samples, namely, nummulitic packstone (F1), foraminiferal bioclastic packstone (F2), and ferruginous bioclastic grainstone (F3), which indicate subtidal shallow reefal and warm platform conditions. XRF analysis shows that SiO_2 content is higher in the Qurn Member (the lower member of the Beni Suef Formation). In contrast, CaO content is predominant in the Tarbul Member (the upper member of the Beni Suef Formation) and the Maadi Formation, with some siliciclastic constituents. On the other hand, the Zr content is highest in the study area. Also, some trace elements, such as Ba, V, Sr, and Zn, are prevalent in all studied rocks. The Upper Eocene Maadi Formation has relatively higher U and Th contents than the Middle-Upper Eocene Beni Suef Formation.

Keywords: Beni Suef Formation, Maadi Formation, structural, El Zaafarana Road, Wadi Arhab, Geochemical.

1. Introduction

Since the Eocene age, the Egyptian margins have been predominated by vertical movements accompanied by the gradual flooding of the Mediterranean Basin and the rifting of the Red Sea (Sistini, 1984). The independence of the Red Sea from the Tethys had been started due to the Cenozoic tectonics with the latest Eocene–Oligocene uplift until the Early Miocene formed a major fault system (Said, 1990). However, The Eocene Age is distinguished by the development of a carbonate platform covering a large area of Egypt (Said, 1962; Saber and Salama, 2017; Salama et al., 2021). The study area is located between latitudes 28° 51` and 29° 00` North, and longitudes 31° 15` and 31° 28` East (Fig. 1).

The present work aims to study the geological-structural setting, petrographical, and geochemical aspects of the Eocene sequence around Beni Suef–El Zaafarana New Road, east of Beni Suef (north Eastern Desert), Egypt. The present area has not been

*Corresponding author e-mail: alaataha66@yahoo.com (ATAA)
Received: 25/04/2024; Accepted: 04/05/2024
DOI: 10.21608/EGJG.2024.284471.1073
©2024 National Information and Documentation Center (NIDOC)

easy to study in the past due to the difficulty of reaching it, through the new asphaltic road of Beni Suef–
El Zaafarana, we can easily reach the study area. The rock units of the area under study range in age from the Middle to Late Eocene.

The main wadi is W. Arhab which crosses the area from its western side to its eastern, then branches to the northern, and southern parts. On the other hand, W. Umm Jurdi is a tributary of W. Arhab (Fig. 2). Some studies were conducted, south of the study area in the W. Sannur region by Amin et al., 2022, 2024; El Mezayen et al., 2020; Philip et al., 1991; Gharieb,2003). Also, some studies have been carried out by Salama et al., (2021), and Ramadan et al., (2021) northward of the present area.

This area represents the downstream of the largest basin stretching from the western part of the Southern and Northern Galala plateaus to the Nile Valley, Minia, and Beni Suef regions. It was affected by three subsequent corrosion cycles after the uplift at the end of the Eocene, which continued until the Pliocene age (Philip et al., 1991). A lot of the Eocene sediments are exposed alone to great levels, such as the Nile Valley Plateau (Abd El-Aal, 2015). The Eocene rocks are exposed at Wadi (W.) Arhab, W. Bayad, W. Ghurab, and W. Um Jurdi in the present area. It was deposited in elongated tectonic basins that formed the arms of the Tethys (Saber and Salama, 2017). The Late Eocene sediments are largely tectonic and structurally controlled. Topographically, the study area is low relief and composed mainly of the Eocene deposits. The highest elevation point in the mapped area is 309 m above sea level, northeast of W. Arhab and the lowest point is 110 m above sea level, south of Gebel (G.) Ghurab (Fig. 1b).

2. Materials and Methods

Four stratigraphic sections of the Middle-Upper Eocene succession around the new asphaltic road of Beni Suef–El Zaafarana and W. Arhab (Figs. 2 and 3) have been measured, described, and sampled. A geological-structural map was constructed based on the field study using the geologic map of Conoco, (1987), NH 36 SW, Beni Suef. Seventeen thin sections were prepared for petrographical study under the polarized microscope to detect their textures and mineral composition. The studied samples were classified according to the schemes of Dunham, (1962). Five samples were selected for study by X-ray fluorescence analysis (XRF) to detect the major oxides and trace elements. The measurements were made using the PAN analytical Axios Advanced XRF in the Egyptian Mineral Resources Authority (EMRA), Dokki, Giza, Egypt. Radiometric analysis was carried out for some selected samples from the different rock units in the study area in Gamma Spectrometry Lap in Nuclear Material Authority, El-Ain El-Sokhna Road, El-Qatameya, Cairo, Egypt. All chemical elements not listed in Tables (3 and 4) were below the detection limit (less than 2 ppm) or were not present in the sample.

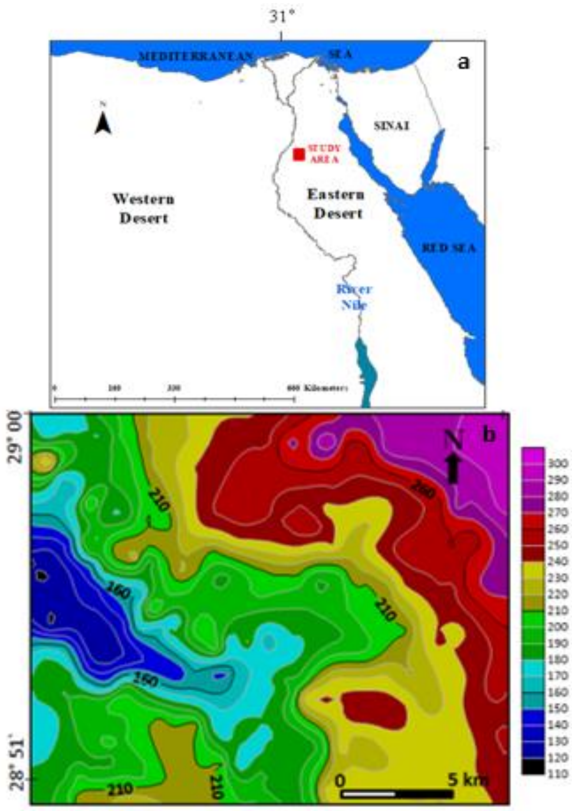

Fig. 1 (a). Location map of the study area, north Eastern Desert, Egypt, and (b) Topographic contour map shows the elevation points of the area.

3. Results and discussion

3.1 Field observation and lithostratigraphy

The Eocene deposits reflect the continuous uplift of the African craton that was produced by the tectonics between Africa and Eurasia (El Hawat, 1997).

The stratigraphic succession in the present area ranges in age from the Middle Eocene to the Late (Upper) Eocene, some covered by Oligocene gravels. The Middle Eocene rocks are the most widespread in the area under investigation and extend from Assiut to Beni Suef (Abdel Shafy, et al., 1983). The Quaternary deposits are covering the Wadis floors. Stratigraphically, in the study area, four lithostratigraphic sections (Fig. 2) were recorded, measured, and studied including two various rock units that represent the different stages of the Eocene age (Middle-Late Eocene) and are arranged from base to top; Beni Suef Formation (Temb) and Maadi Formation (Ted), (Fig. 3).

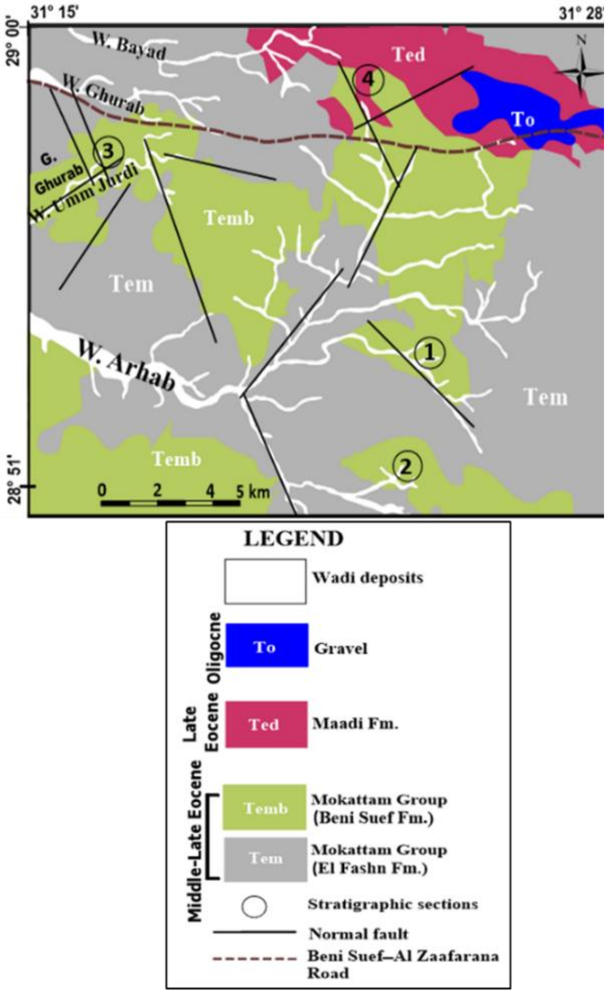

Fig. 2. Geological map of the study area, east of Beni Suef, north Eastern Desert, Egypt (modified after Conoco 1987; Saber and Salama 2017).

Beni Suef Formation (Middle-Late Eocene)

This rock unit was named by Bishay, (1966) to describe a 100 m thick Eocene sequence exposed at Gebel Homret Shaibun, east of Beni Suef City. Beni Suef Formation is conformably underlying the Maadi Formation and overlies the El Fashn Formation of Bishay, (1966). According to Said (1962), the Eocene successions underlying the Maadi Formation are considered the Mokattam Formation.

Beni Suef Formation belongs to the Middle-Late Eocene (Bishay, 1966; Saber and Salama, 2017; Salama et al., 2021).

The Beni Suef Formation exposed at the four studied lithostratigraphic sections in the study area and subdivided from base to top into the following:

A) Qurn Member

The term “Qurn Member” was named by Farag and Ismail, (1959) as a series to describe the exposed succession in east Helwan City. It is considered a member of the Beni Suef Formation by Mansour et al., (1982). This member unconformably overlies El Fashn Formation (Saber and Salama, 2017). In the present area, the Qurn Member attains 27.5 m thick composed mainly of intercalations of greenish-grey, fissile, gypsiferous, silty shale (Fig. 4a) and dark yellow marl with gypsum veinlets (Fig. 4b) at the base, followed by the intercalations of laminated shale; (brownish yellow band alternation with the whitish-grey band), and yellowish grey, marly limestone at the top (Fig. 4c). Generally, the Qurn Member consists of clastic sediments in the Gebel Ghurab section (Figs. 3C and 4g).

B) Tarbul Member

The term “Tarbul Member” was first introduced by Mansour et al., (1982) to describe a 60 m thick succession at Gebel Tarbul consisting mainly of marl and limestone capped by dolomitic or sandy limestone. In the present study, Tarbul Member is mainly carbonated. It is composed of yellowish-grey, jointed, limestone, sharp contact with Qurn Member (Fig. 4d), followed by greyish-white, strongly deformed, brecciated limestone (Fig. 4e), moderately hard limestone including patches of calcite. It is intercalated with a yellowish-grey color, soft, laminated marl (Fig. 4f), and capped by weathered, hard, fossiliferous, dolomitic limestone (Fig. 4f). However, the maximum thickness of Tarbul Member reaches 40 m as in the measured stratigraphic section south of W. Arhab (Figs. 3B, 4g, and h).

Maadi Formation (Late Eocene)

The Maadi Formation was named by Said, (1962 & 1971) to describe the clastic with minor carbonate sediments in the east of the Maadi region as a part of the Upper Mokattam succession. It overlies the Tarbul Member of the Beni Suef Formation and unconformably underlies the Oligocene sediment at thetype section.

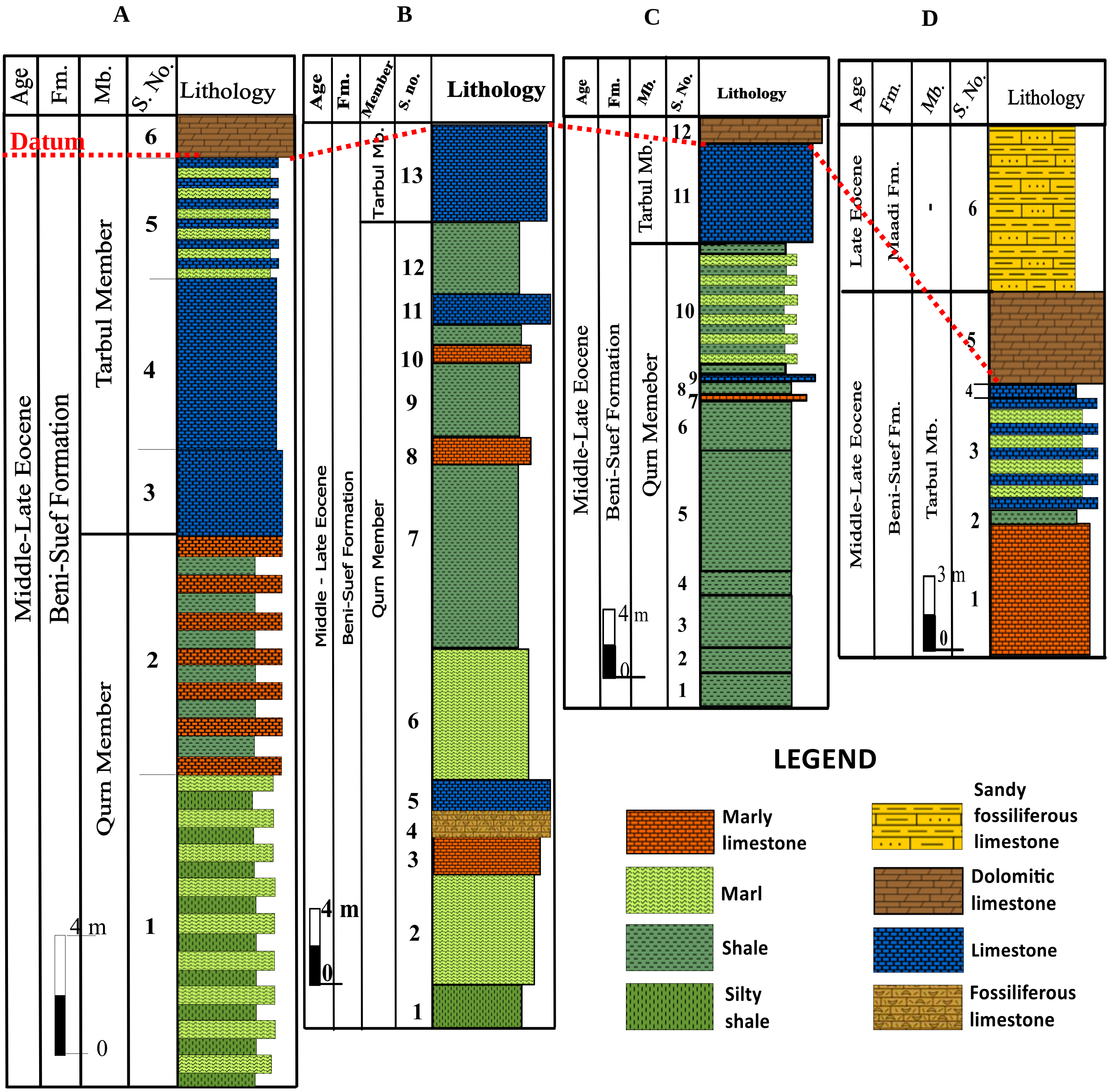

Fig. 3. Lithostratigraphic sections of the measured Middle-Late Eocene succession in the study area.

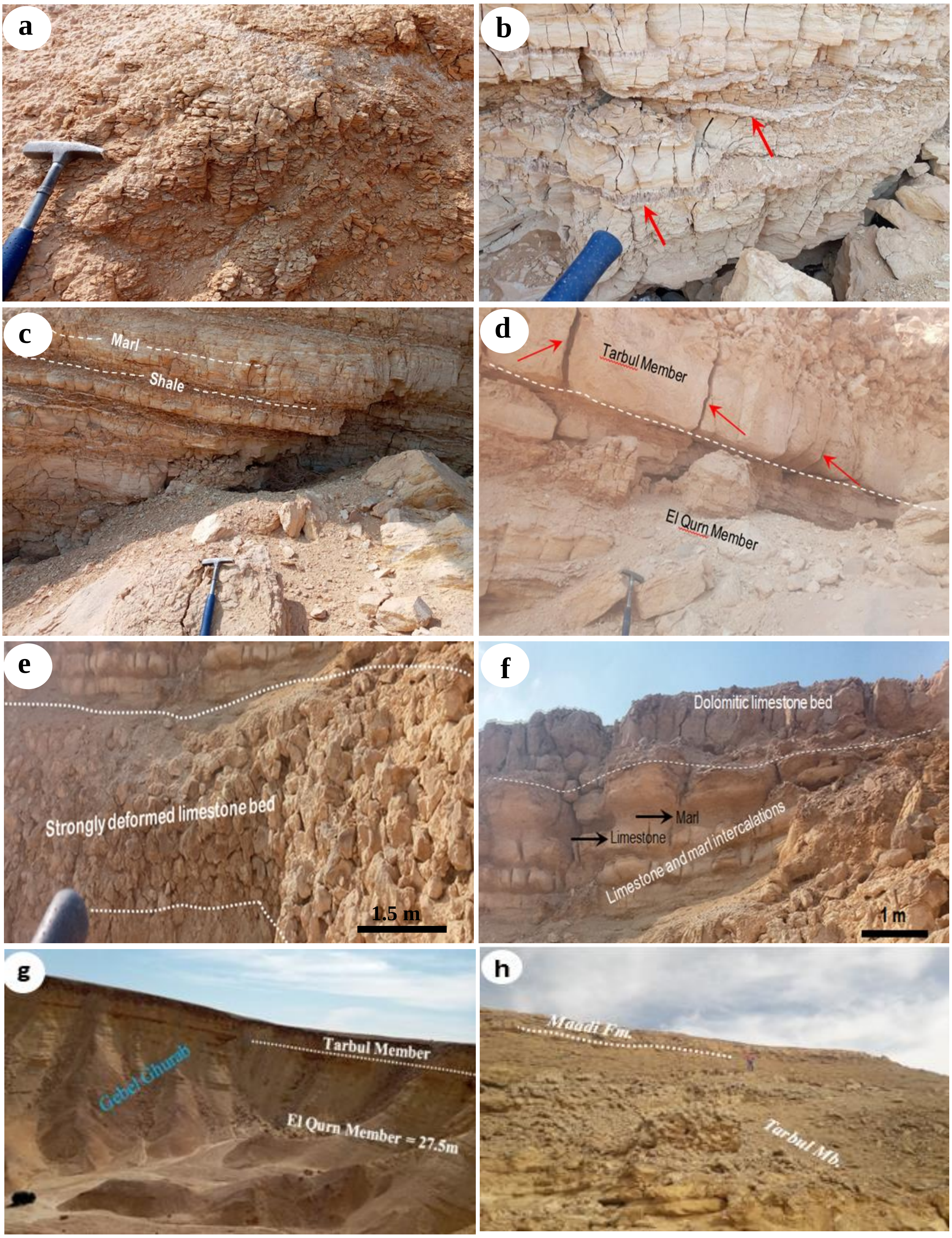

Fig. 4. Field photographs showing as follows:
(a) Fissile, gypsiferous, silty shale at the base of the Qurn Member, (b) Gypsum veinlets (arrows) within the shale bed, (c) Shale and marl intercalations in middle and upper parts of the Qurn Member, (d) Sharp contact between the Tarbul and Qurn members (dashed line), and jointed limestone bed (arrows) at the lower part of Tarbul Member, (e) Strongly deformed, brecciated limestone bed, (f) Intercalations of limestone and marl capped by weathered, dolomitic limestone bed, looking NW, (g) The maximum thickness of the Qurn of the Beni Suef Formation exposed at Gebel Ghurab section, looking E, (h) The maximum thickness of the exposed Tarbul Member in W. Arhab area, looking SE and N, respectively.

Mansour, (1982) studied 88 m thick Maadi Formation at Gebel Homret Shaibun near the study area), mainly represented from base to top by; shale, sandstone, sandy limestone, and capped by hard and sometimes fossiliferous limestone. Farag and Ismail, (1959) correlated the Maadi Formation with the Wadi Hof Formation in the Giza and Helwan regions, the Hamra Formation in Bahariya Oasis (Said and Issawi, 1964), and the Qasr El-Sagha Formation in the Fayoum area.
In the present study, the Maadi Formation measures 9 m thick and is exposed at the intersection of Latitude 28° 58.151`N and Longitude 31° 22.039`E, west of Beni Suef-El-Zaafarana Road (Fig. 2 and 3D). It conformably overlies the Beni Suef Formation with sharp contact (Fig. 5a). Lithologically, this rock unit is made up of a sequence of siliciclastic carbonate deposits. It is composed of yellow, fossiliferous, sandy limestone (Fig. 5b). It shows a weathered and cavernous surface (Fig. 5c).

3.2. Structural setting

The Middle Eocene outcrops are developed in central Egypt (Ghorab, 1960). The region of east Beni Suef is considered part of the downstream of a great basin extending from the western side of the Gulf of Suez to the Nile Valley and until the Minia area (Philip et al., 1991; Hussein, 2019). This basin is due to the break-up of Gondwana (Shehata et al., 2020) and is related to the tectonism of the Syrian Arc System (Salem and Sehim, 2017). It is formed within the unstable-shelf zone (Said, 1962) and is considered a type of major graben system (Salem and Sehim, 2017). During the late Bartonian of Eocene until the late Oligocene, the rising of the Red Sea Mountains in addition to the progressive retreat of the Mediterranean Sea shore northwards has resulted in the continued swallowing-upward (Sallam, 2015a).

The study area is dissected by brittle geological structures as a result of the stresses, represented by faults and joints. These structural elements have been measured in the area, recorded, and plotted on the geologic map (Fig. 2). It was formed after the formation of the rocks due to consecutive tectonic processes. A structural map was constructed based on a field study using a Landsat image (scale 1: 40000). It shows the structural lineaments that affected the study area (Fig. 5d).

Faults

The fault is defined as a planar fracture of rock across which there has been great displacement as a result of rock agglomerate movements. Many significant faults take place within the crust of the earth due to the movement of plate tectonics. Generally, faults can occur for one of the following reasons; tensional, compressional, and shear stresses. The present area is affected by several faults mainly of normal types cutting the Eocene successions. Most of the wadis represent major fault zones throughout the studied area. Fifty-seven faults were measured, recorded, and treated statistically according to their strike direction (Table 1).

Table 1. Frequency distribution and strike direction of the measured 57 fault trends in the W. Arhab area.

Trends	No.	%
NNW–SSE, NW–SE, and WNW–ESE	33	57.9
NNE–SSW, NE–SW, and ENE–WSW	21	36.8
N-S	3	5.3
Total	*57*	*100*

A rose diagram is created to show the main predominant fault trends in the study area (Fig. 5e). They will be studied as follows starting from their prevailing:

NNW–SSE, NW–SE, and WNW–ESE trending faults

Faults of these trends represent 33 % of the total measured faults in the study area. It is the main lineament in the study area (Table 1). The NNW–SSE faults represent the main trend in the present area. It is parallel to the Gulf of Suez trend. The outcrop shows two distinctive listric normal faults measured at G. Ghurab in the present area; the first is striking N25°W dipping toward NE and SW. (Fig. 5f). The zone of this fault is distinctive by shearing and breccia (angular fragments of limestone and dolomitic limestone), with width ranges from 15–20m (Fig. 5f). The second one is striking N30°W and dipping toward ENE (Fig. 5g).
These fault sets are extant on a large scale in the study area with striking between N17° to 30°W dipping ENE and WSW.

Faults of the NW–SE trend with striking between N42° and 50°W. They extend for numerous kilometers in the area under study and southward in W. Mawathil area and show sharp-cut straight faults and major fractures particularly, at W. Sannur Cave. These fault sets are parallel to the Red Sea trend. They are also, pre-existing as a result of span deformation from the northern rifts of the Gulf of Suez and Red Sea (Abou Elenean and Hussein, 2008). Also, Badawy and Abdel Fattah, (2002) mentioned that these fault trends are largely affecting the topography of the eastern part of the river Nile.

It is noticed that the faults of the NW–SE trend are parallel to the alabaster quarries trend which was measured by (Amin et al., 2022) in W. Mawathil area, thus, it is the main trend along which the alabaster quarries are located. The NW-SE trending graben-like basin was recorded by a seismic cube in the east Beni Suef basin, also the NW-SE-structural trend is related to the Syrian Arc System, which was followed by the subsequent subsidence forming the Beni Suef basin (Salem and Sehim, 2017). These fault trends play an important role in affecting the east of Beni Suef El Gedida City which is explained by five major principal fault blocks of the NW-SE trend; these are Umm Raqaba, Ghurab, north of G. Shaibun, south of G. Shaibun and G. Shaibun fault blocks (Abdel Wahed et al., 2007).

Generally, the NW–SE fault trends of normal type are dissected and accompanying Cretaceous–Early Tertiary tectonism which is related to the plate tectonic of Tethyan. Faults of the WNW-ESE trend are low frequency if compared with other trends. It is associated with tectonic deformation of Early Tertiary (Abd El Aal et al., 2015).

NNE–SSW, NE–SW, and ENE–WSW trending faults

Faults of these trends represent 21% of the total measured faults in the study area (Table 1). The NNE–SSW trending faults are considered one of the principal faults affecting the study area and striking between N18° and 25°E. They are the extent to affecting outside, northeast of the area under study at G. Homret Shaibun (Abdel Wahed et al., 2007). In general, these fault trends are parallel to the Gulf of Aqaba trend. Faults of the NE–SW trend are striking between N40° to 50°E in the study area. The faults of the NE–SE trend represent the main fault trends controlling W. Sannur Cave. They intersect with the NW–SE fault trends in most of the alabaster quarries caused by channel ways along with fractures within the Eocene limestone sequences which permit percolation of the hydrothermal solutions and meteoric water forming the karst processes and its products (Philip et al., 1991). At the basement rocks level, the Beni Suef basin is crossed by a major normal fault striking N75°E (Salem and Sehim, 2017).

The measured faults of the ENE–WSW trend are low frequency in the considered area. The normal fault striking N65°E cut another fault striking N26°W measured north of the study area, near the contact between the Maadi and Beni Suef formations (Fig. 5h). Both faults are normal and forming a horst structure. They show a shear zone enriched by breccia and iron concretions.

Joints

Several joints lie parallel to each other in the study area. These parallel joints are named “joint sets”. Commonly, Joints are of extensive functional significance. They are a widespread plane of expected slip and therefore should be considered for safety in quarrying and mining. Many joints are generally parallel, sub-vertical, or perpendicular to the earth's surface. Joints in bedded or otherwise stratified rocks are usually perpendicular to layering and exhibit variable spacing depending on the rock type and thickness of the bed. The joint spacing has increased when the thickness of the bed has increased. Also, it may be sometimes related to the nature of lithology.

Commonly, the exposed rock units in the investigated area have a well-distributed pattern of joints. It is concluded that the main trends are NNW, NNE, and NE. Most of the vertical joints exist with smaller displacement in limestones than in the marls and clays (Abdel-Wahed, et al., 2007). One hundred and twenty-two joints were measured and treated statistically according to their strike directions (Table 2).

Folds

In the investigated area, a few ductile deformation structures (Folds) were recorded. A syncline fold was recorded in the study area north of W. Arhab. It was measured in the fourth stratigraphic section in the Maadi Formation (Fig. 5h). The fold axis is striking N22°W. It indicates that the area under study was subjected to compression stress trending NE–SW to form this fold which affected the late Middle-Late Eocene (Beni Suef and Maadi formations).

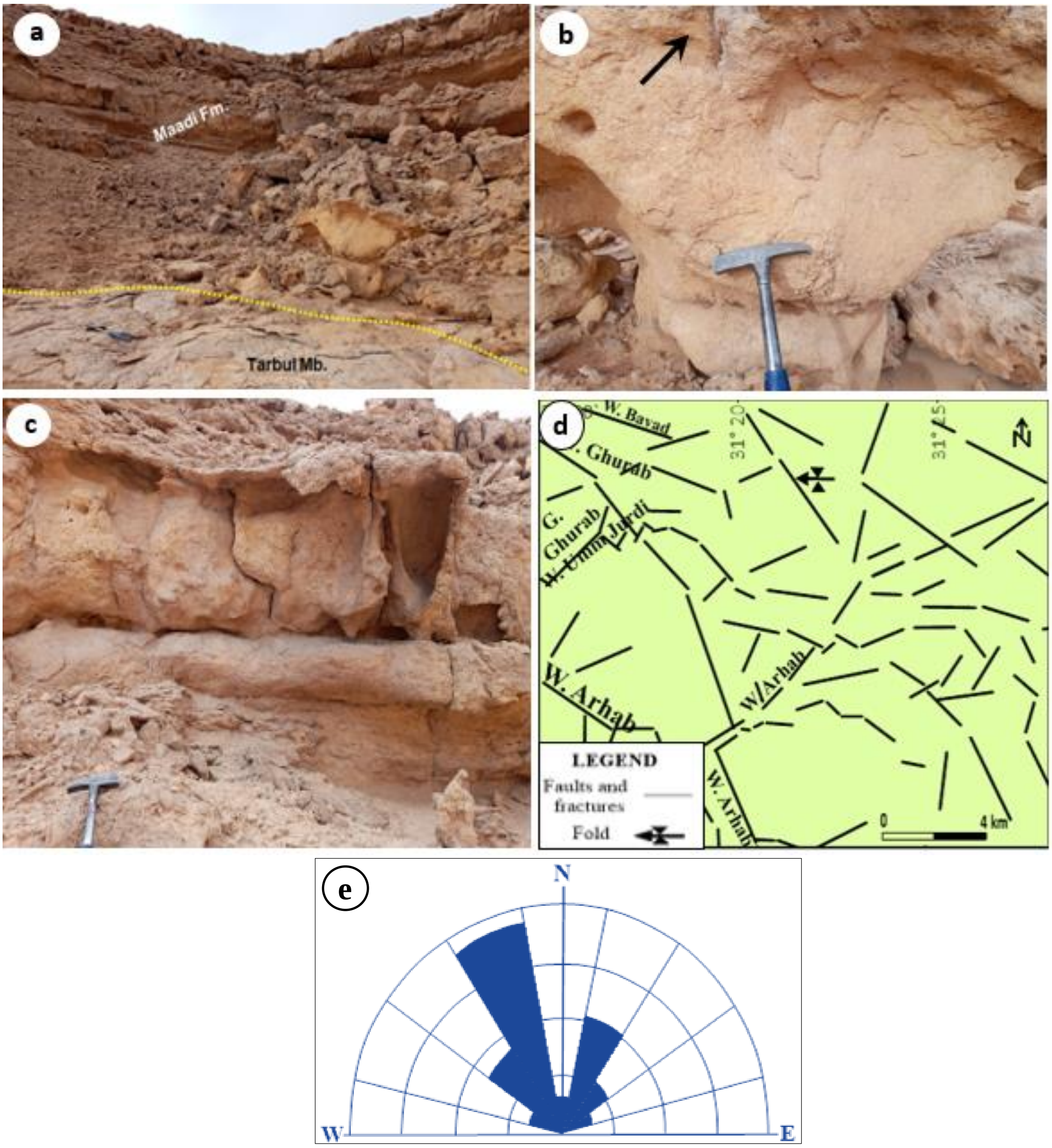

Fig. 5 Field photographs showing as follows:

(a) The exposed Maadi Formation overlies the Beni Suef Formation with sharp contact (dashed line), looking NW, (b) Fossiliferous (arrow), sandy limestone of the Maadi Formation, (c) The weathered, and cavernous surface at the top of the Maadi Formation, (d) Structural-lineament map of the W. Arhab area, (e) A rose diagram showing the predominant directional trends of 57 faults measured in the study area, (f) The shear zone of listric normal type (FZ) striking N25°W at G. Ghurab, northwestern part of the study area, looking NW, (g) The intersection of two faults; N65°E (F1) and N26°W (F2), north of the study area (both faults are normal and forming horst structure), looking NW, and (h) a syncline fold trending N22°W north of the W. Arhab area, looking, NW.

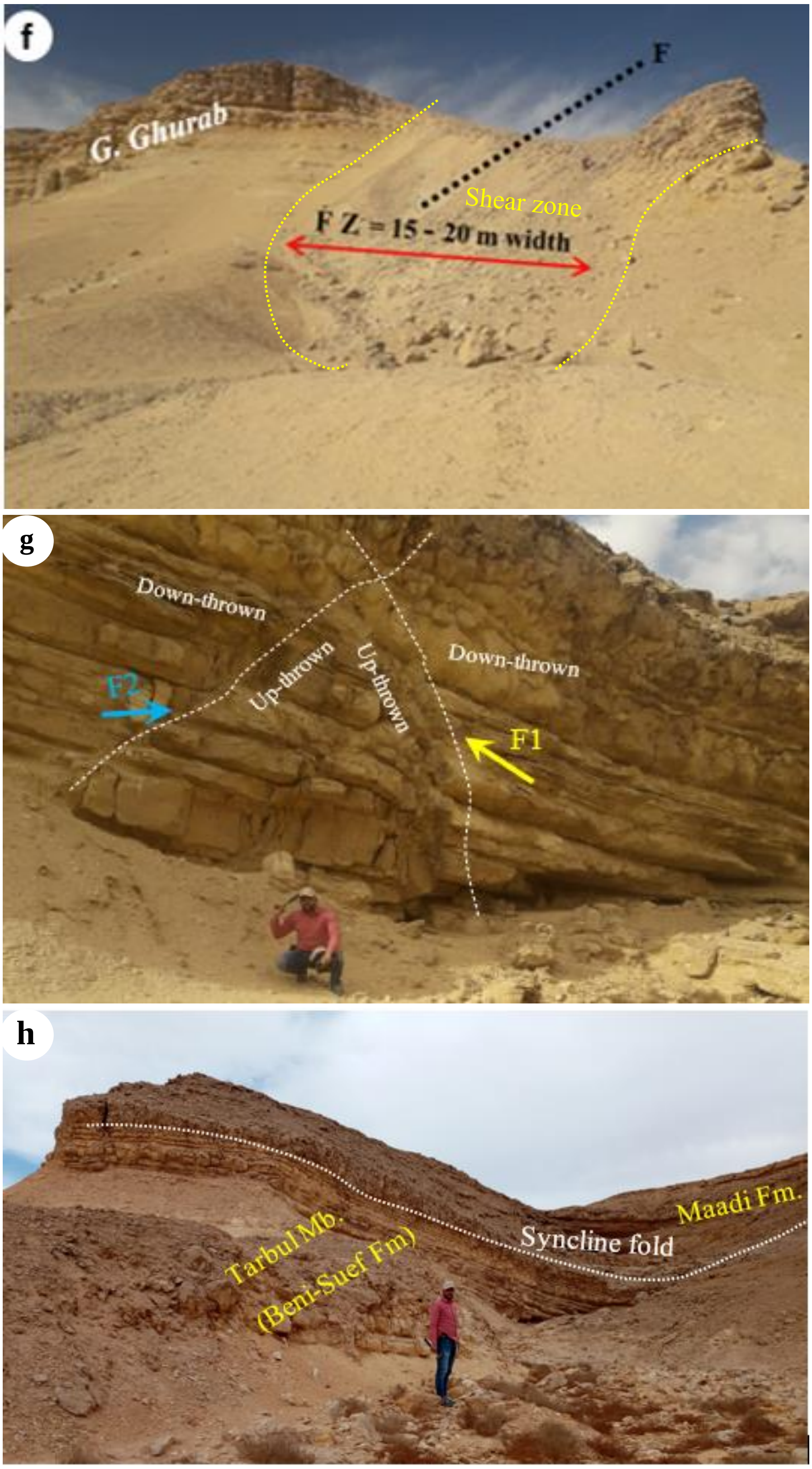

Fig. 5. Continued.

3.3. Microfacies Associations

Seventeen thin sections were prepared and microscopically examined for their textures, mineral composition, diagenetic processes, and the environmental conditions of the studied samples representing the Eocene rocks. The microfacies types of the studied carbonate rocks can be classified according to Dunham's, (1962) scheme based on the bioclastic and depositional textures. The microscopic examination of the studied Middle-Late Eocene carbonate samples revealed the existence of four microfacies types (F) in the studied section, as follows:

Three microfacies types (F1-F3) that are recognized in the rock units of the study area are discussed as follows:

Nummulitic packstone (F1)

This microfacies type is recorded in the middle part of the Beni Suef Formation. It is composed of various colors; whitish yellow, whitish grey, and moderately hard limestone. Microscopically, there is variation in the size of the allochems of this microfacies. The allochems of this microfacies are made of 50-60 % of this rock and are represented mainly by nummulite shell fragments (Fig. 6a). It shows chalcedony in the center of shell fragments. Nummulites had been widely distributed in the southern and northern of the Tethys margins (Abd-Elhameed, et al., 2023). Most of the allochem chambers are recrystallized into microcrystalline calcite, but their walls are micritized. Some spots of iron oxides are observed. These allochems are embedded in micrite (cryptocrystalline calcite matrix). The enrichment of the micritic matrix reflects the quiet marine or shallow subtidal depositional conditions (Wilson, 1975). The packstone texture is grain-supported carbonates that reflect high agitation water Flügel, (2004).

Foraminiferal bioclastic packstone (F2)

This microfacies type is recorded at the upper part of the Beni Suef Formation. It consists of varied colors; brownish-grey, snow-white, weathered, hard, fossiliferous, dolomitic limestone. The allochems of this microfacies compose up to 75% of the rock and are represented mainly by echinoids, gastropods, foraminifera (Miliolidae and Somalin), bivalve shell fragments, and peloids (Figs. 7b-d). The chambers of the foraminiferal tests are filled by recrystallized microsparit/ sparite calcite. The walls of these bioclastics are mainly micritized. It shows the bivalve shell fragments are neomorphosed into sparry calcite cement (Fig. 6b). Additionally, chalcedony (silica) is substituted about 30% for nummulite test fragments, as well as micritized peloids (Fig. 6c). Iron oxides are also recorded in this microfacies (Figs. 6c and d). The bioclastic grains are embedded in a micrite matrix which partially is recrystallized forming patches of sparry calcite.

Interpretation: The enrichment of packstone (calcite matrix) and the faunal content as bivalves, foraminiferal, and echinoids reflect quite shallow open marine environmental conditions (Wilson, 1975; Flügel, 2004).

Ferruginous bioclastic grainestone (F3)

This microfacies type is recorded at the upper part of the Beni Suef Formation. It consists mainly of brownish-yellow to yellowish-white, hard, fossiliferous limestone. This mirofacies is very rich in various fossils occupying up to 80 % of the rock and is represented mainly by gastropods, foraminifera, nummulite, miliolina, echinoid, ostracod, mollusca, and Pelecypod (Figs. 6e and f). The miliolina has multiple chambers which show random extinction. It shows iron oxides that occupy the allochem chambers and the wall of the shell fragments. Most of the allochems are recrystallized into microsparite and sparite, while its walls mainly are ferruginated envelopes by micrite. These allochems are embedded in microcrystalline to macrocrystalline calcite.

Interpretation: The diversity of macrofaunal content (gastropod, pelecypod, foraminifera, mollusca, and echinoids) and the high content of microcrystalline calcite matrix indicate the deposition under warm, shallow marine conditions (Tucker, 2001).

3.4. Geochemistry

The data of the chemical analyses of major oxides and trace elements are listed in Table 2. The SiO_2 content in the analyzed rock samples is higher in Qurn Member (the lower beds of Beni Suef Formation) ranging from 24.79 % to 27.84 % indicating the increasing terrestrial influx during deposition. The Qurn Member also has a relatively high percentage of CaO, Al_2O_3, Cl, Na_2O, and Fe_2O_3 ranging from 16.32 % to 29.38 %, 7.77 % to 11.72 %, 3.27 % to 8.29 %, 2.70 % to 6.89 %, and 2.97 % to 5.53 %, respectively which indicates high clay contents. CaO is prevalent in Tarbul Member (the upper part of Beni Suef Formation) ranging from 48.42 % to 55.84 % of the rock constituents. Na is a strong indication of water salinity during carbonate precipitation and can be significantly altered during diagenesis (Bricker, 1971).

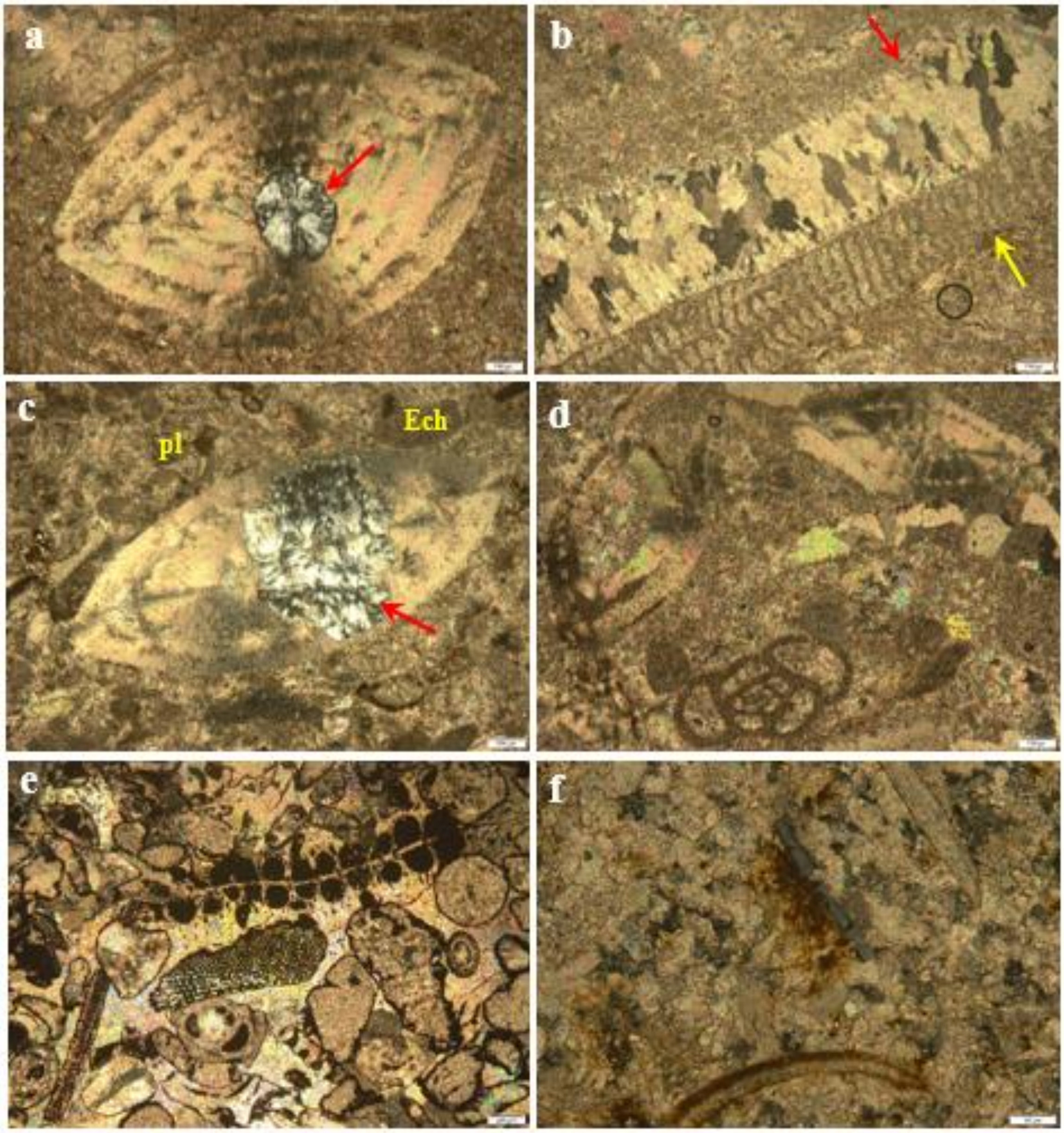

Fig. 6. Photomicrograph (C.N.) showing microfacies types in the Beni Suef Formation:

(a) Nummulitic packstone microfacies type "F1" including chalcedony (arrow) texture, (b) The bivalve shell fragments are recrystallized into sparite cement (red arrow), while the foraminifera (Somalina Sp.) is micritized (yellow arrow) in "F2", (c) Chalcedony textures substitutions (arrow) for a large part of nummulite test, in addition to pelloid grains "Pl", and echinoids (Ech), (d) Chambers of the bioclastics are filled with sparry calcite cement "F2", (e &f) Ferruginous bioclastic grainestone microfacies type "F3" in the upper of Tarbul Mb, at G. Ghurab, *(Scale of the figures = 200 µm).*

Table 2. Major oxides (%) and trace elements (in ppm) concentrations of the studied samples of the study area.

Major oxides (%) and trace elements (In ppm) concentrations	Beni Suef Fm.				Maadi Fm.
	Qurn Mb.		Tarbul Mb.		
	1	2	3	4	5
CaO	16.32	29.38	48.42	55.84	54.69
SiO_2	27.84	24.79	6.34	0.08	0.27
Fe_2O_3	5.53	2.97	1.26	0.05	0.83
SO_3	0.45	0.01	<0.01	0.13	0.24
MgO	1.81	1.09	0.46	0.17	0.17
TiO_2	0.62	0.29	0.08	<0.01	0.01
Al_2O_3	11.72	7.77	2.65	0.01	0.04
MnO	0.01	0.01	0.01	<0.01	0.01
Na_2O	6.89	2.70	0.73	<0.01	<0.01
K_2O	0.43	0.27	0.10	0.01	0.01
P_2O_5	0.04	0.05	0.03	0.02	0.02
Cl	8.29	3.27	1.04	<0.01	<0.01
L.O.I	19.76	26.93	38.58	43.39	43.41
Zr	3455	2559	64	1134	570
Ba	2322	1990	<2	26	74
V	1322	1146	16	32	53
Sr	243	191	564	108	46
Zn	227	170	21	33	58
Cu	74	63	4	44	40
Ni	69	63	12	17	23
Rb	48	29	U.D	12	12
Ga	u.d.	13	U.D	U.D	2
Y	16	14	U.D	2	6
Nb	49	34	4	14	8
Pb	8	7	4	2	8

U.D: Under the detection limit which is 2 ppm.

Table 3. Uranium (U) and thorium (Th) variation in the different Eocene rock units of the studied samples of the study area.

Age	Rock units	U (ppm)	Th (ppm)
Late Eocene	Maadi Fm.	30-68	35-76
Middle-Late Eocene	Beni Suef Fm.	9-15	11-34

Whatever the case, a Na concentration greater than 0.3% indicated a marine effect (as in the analyzed rocks), but a low value of less than 0.05% indicated a freshwater contribution (Ernest, 1970). The Na concentration of the examined rocks may be connected to the gypsum-based on lithology.

Commonly, Na concentrations within carbonate deposits correspond to biological fractionation, salinity, mineralogy, kinetics, and the level of the water (Rao and Adabi, 1992). The predominant oxide in the Maadi formation in the study area is CaO (54.69 %), followed by Fe_2O_3, and SiO_2, which are 0.83, and 0.27 respectively, which agrees with the lithology as well as the microscopic investigations.

On the other hand, the trace elements show variation in the studied sample content. Zircon (Zr) is the highest content in all studied samples, ranging from 64 to 3455 ppm, followed by Ba, V, Sr, and Zn ranging from $<$2 to 2322 ppm, 16 to 1322 ppm, 46 to 564 ppm, and 21 to 227 ppm respectively. The high concentration of zircon in rocks is owing to its strong resistance to physical and chemical weathering near the earth's surface (Pidgeon & Aftalion, 1978). According to Dragunov and Katchenkov, (1953, cited in Graf, 1960), the Ba-bearing mineral in the sedimentary rocks is barite, it is commonly observed as a replacement in limestone and as a coating in cavernous limestones. The Sr concentration changes according to carbonate mineralogy, increasing with aragonite content and decreasing with calcite content (Graf, 1960; Adabi and Rao, 1991). Morse and Mackenzie, (1990) found a clear correlation between rising water temperature and Sr concentrations. Also, Zr, Zn, V, and Sr contents are prevalent in the Maadi Formation. The uranium and thorium variations in the different Eocene rock units are listed in Table 3. It shows that the Upper Eocene Maadi Formation has relatively higher U and Th contents than the Middle-Upper Eocene Beni Suef Formation.

Fig. 7 shows the classification of the studied samples. This classification can be clarified based on their major oxides versus each other. The plotted samples in [(Al_2O_3), (CaO + Na_2O), and (K_2O)] ternary diagram (Hutcheon, 1998) reveal that all samples lie in the field of limestone except the samples of Qurn Member lie in the calcareous shale field (Fig. 7a). The SiO_2 - CaO - MgO ternary diagram exhibits all samples lie in the meta-carbonates fields, but the samples of Tarbul Member and Maadi Formation specifically limited in the limestone (calcite) field (Fig. 7b). Most of the plotted samples in the [(SiO_2) - (Al_2O_3 + Fe_2O_3) – (CaO + MgO)] ternary diagram (Mason et al., 1982) lie in the carbonate rocks field except only one sample lie between the carbonate rocks and shale field (Fig. 7c).

Finally, [SiO_2 - (CaO + Na_2O + K_2O) - (Fe_2O_3 + MgO + MnO)] ternary diagram (Raymond, 1995) shows the Qurn Member lies in the basic rocks field and on the borders of the carbonates and non-silicate rocks field, while the plotted samples which represent the Tarbul Member (Beni Suef Formation) and Maadi Formation lie in the carbonates and non-silicate rocks field (Fig. 7d).

4. Conclusion

The main results of this study can be concluded in the following:

- **i.** In the present area, the geology, structural setting, petrography, and geochemistry of the Middle-Upper Eocene deposits along both sides of Beni Suef-El Zaafarana New Road, east of Beni Suef, Egypt, was studied.
- **ii.** The stratigraphical study exhibits that the area includes two rock units arranged from base to top: the Beni Suef Formation and the Maadi Formation, ranging in age from the Middle to Upper Eocene, controlled by various faults mainly of normal types. NNW-SSE, NW-SE, and WNW-ESE trending faults represent the present area's main trend. These fault sets are extant on a large scale for numerous kilometers in the study area.
- **iii.** Three microfacies (F) were recognized during the petrographic investigation of the studied samples, namely, nummulitic packstone (F1), foraminiferal bioclastic packstone (F2), and ferruginous bioclastic grainstone (F3), which indicate subtidal shallow reefal and warm platform conditions.
- **iv.** Geochemical results show that the SiO2 content is higher in the Qurn Member (the lower unit of Beni Suef Formation), while the CaO content is predominant in the Tarbul Member (the upper unit of Beni Suef Formation) and the Maadi Formation, with some siliciclastic constituents. Zr, Ba, and V are the highest in all rock units. In contrast, the contents of Sr, Zn, and Cu are moderate. The Upper Eocene Maadi Formation has relatively higher U and Th contents than the Middle-Upper Eocene Beni Suef Formation.

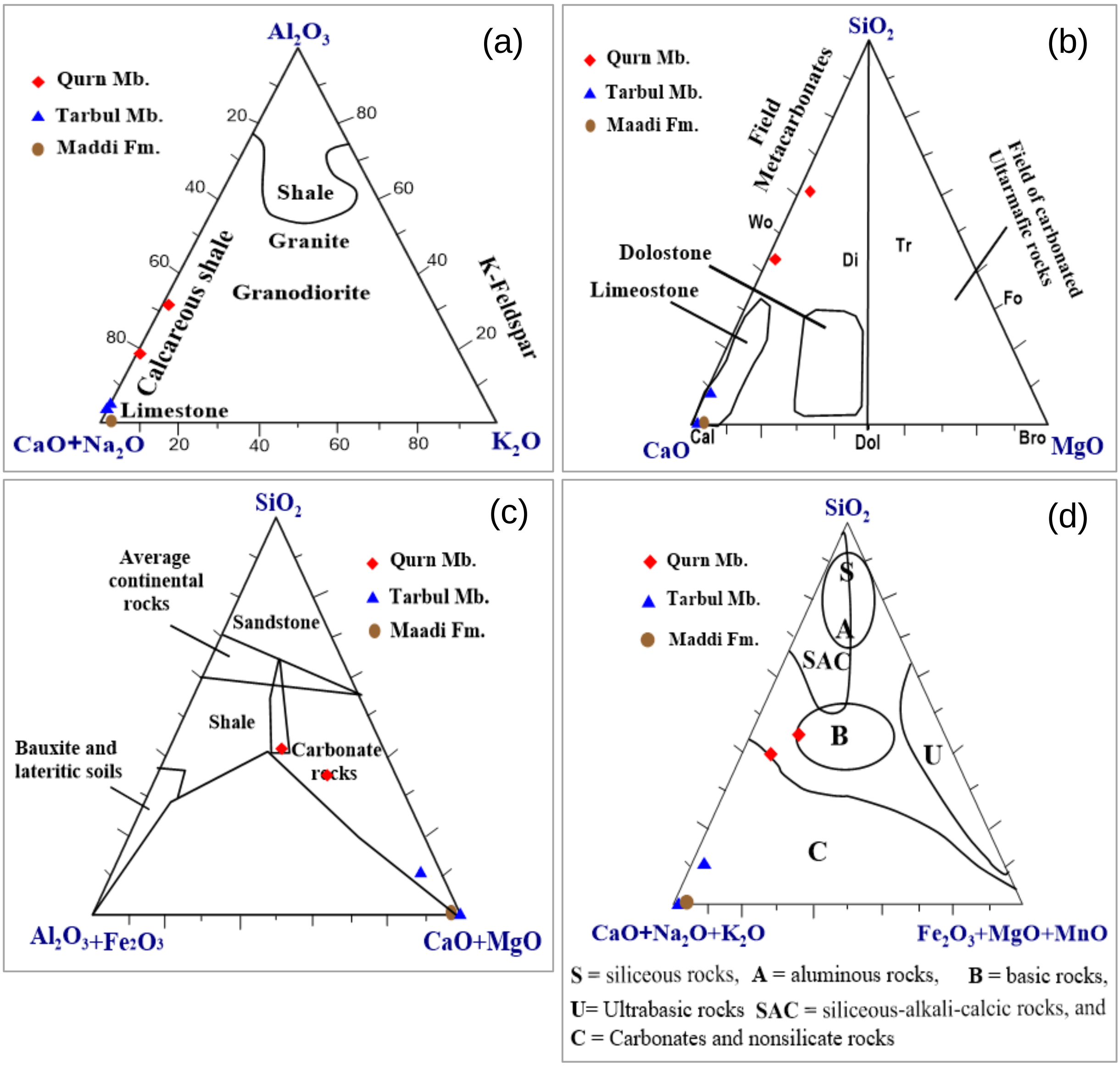

Fig. 7 (a). Ternary diagram (Hutcheon, 1998) between Al_2O_3 - ($CaO+Na_2O$) - (K_2O) for the *studied* samples, (b) Ternary diagram between SiO_2 - CaO - (MgO) (Winter, 2001) for the studied samples, (c) Ternary diagram between SiO_2 - (Al_2O_3+Fe2O_3) - (CaO+MgO) (Mason & Moor, 1982) for the studied samples, and (d) Ternary diagram between SiO_2 - ($CaO+Na_2O+K_2O$) - (Fe_2O_3+MgO+MnO) (Raymond, 1995) for the studied samples.

v. Based on this study, the Qurn Member is composed mainly of calcareous shale, while the Tarbul Member and Maadi Formation are composed mainly of carbonates (calcite).

Consent for publication: All authors declare their consent for publication.

Funding: Not applicable.

Conflicts of Interest: The author declares no conflict of interest.

Contributions of the Authors: A.T.A.A. carried out the fieldwork, and wrote the manuscript. E.K.A. performed the petrography analysis. H.A.K. conducted the structure study. H.K.A.S. performed the chemical analyses. W.F., D.M.E., and A.M.E. reviewed the manuscript.

5. References

Abd El-Aal, A. K. (2015) Engineering evaluation of some lower Eocene carbonate rocks as raw materials, Sohag Governorate, Egypt. *Eighth International Conference on the Geology of Africa.* **1**, 33–50.

Abdel Shafy, E., Abdalla, A.M., and Ismail, A.S. (1983) Contribution to the Eocene stratigraphy in Sohag–Beni Suef area, Nile Valley, Egypt. *Proc. 2nd Geol. Congress on the Middle East (GEOCOME II). Arab Geol. Ass. Baghdad*. 5–22.

Abdel Wahed, M., Fayed, L.A., and Refaie, A. (2007) Structural and GPR Studies on Beni Suef El Gedida City: Structural and Environmental Hazards. *The fifth Int. Conf. on the Geol. of Africa*, **1**, 1–23.

Abd-Elhameed, S., Mahmoud, A. Z., and Salama, Y. (2023) Late Paleocene–Early Eocene larger foraminifera from the Galala Plateaus, North Eastern Desert, Egypt: biostratigraphic, paleoenvironmental and paleoecological implications. *Carbonates and Evaporites*, **38**, 84.

Abou Elenean, K. M. and Hussein, H. M., (2008) The October 11, 1999 and November 08, 2006 Beni Suef Earthquakes, Egypt. *Pure Appl. Geophys*, **165**, 1391–1410.

Adabi, M. H., and Rao, C. P. (1991) Petrographic and geochemical evidence for original aragonite mineralogy of upper Jurassic carbonates (Mozduran formation), Sarakhs area, Iran, *Sedimentary Geology*, **72**, 3–4.

Amin, A.T.A., Elkholy DM, Khamis, H.A., Abd El-Moghny, M.W., El Zalaky, M.A., and Elmezayen, A.M. (2022) Structural and geochemical processes controlling the formation of Egyptian Alabaster at Wadi Mawathil area, Eastern Desert, Egypt. *Arab. J. Geosci*., **15**, 1–18.

Amin, A.T.A., El-Mezayen, A. M., Elkholy, D.M., Abu Zeid, E.K., Fahmy, W., and Khamis, H, A., (2024) Lithostratigraphy, petrography, and geochemistry of the Eocene–Oligocene rock succession, Wadi Arhab area, North Eastern Desert, Egypt. *Carbonates and Evaporites*, **39**, 27, *https://doi.org/10.1007/s13146-024-00928-7*

Badawy, A. and Abdel Fattah, A.K. (2002) Analysis of the southeast Beni Suef, northern Egypt earthquake sequence. *Journal of Geodynamics*, **33**, 219–234.

Bishay, Y. (1966) Studies on the large foraminifera of the Eocene (the Nile Valley between Assiut and Cairo and SW Sinai). *Dissertation, Alexandria Univ*.

Bricker, O.P., (1971): Carbonate cements. John Hopkins Press, Baltimore, 376 pp.

Conoco, (1987) Geological map of Egypt 1:500,000, NH 36 SW, Beni Suef, *Continental Oil Company, Cairo, Egypt*.

Dunham., R.J. (1962) Classification of carbonate rocks according to depositional texture. In: Classification of carbonate rocks (Ham, W.E., ed.), *Tulsa, Okla, Am. Assoc. Petrol. Geol. Mem.,* **1**, 108–121.

El Hawat, A. S. (1997) Sedimentary basins of Egypt: an overview of dynamic stratigraphy. In: Selley, R.C. (Ed.), African Basins, Sedimentary Basins of the World. *Elsevier Science, Amsterdam*.

El Mezayen, A. M., El-Kholy, D. M., Abd El-Moghny, M. W., Khamis, H. A., and Ahmed, A. T., (2020) Petrography and mineralogy of Egyptian Alabaster in Wadi Mawathil Area, Eastern Desert, Egypt. *Int. J. Min. Sci*., **6**, 4–14.

Ernest, W. (1970) Geochemical facies analysis. In: Methods in geochemistry and geophysics. *Elsevier Publ. Co., Amsterdam*.

Farag, I. A. M., and Ismail, M. M. (1959) Contribution to the stratigraphy of the Wadi Hof area (northeast of Helwan). *Bull Fac Sci Cairo Univ*., **34**, 147–168.

Flügel, E., (2004) Microfacies data: matrix and grains." Microfacies of Carbonate Rocks". Springer, Berlin, Heidelberg, **73,** 176.

Gharieb, S. E. (2003) Eocene rocks and associated karst features in the east Beni Suef area, north Eastern Desert, Egypt. *GÖttinger*. *Arb. Zur. Geol. Und Paläontologie Sb*., **5**, 7–22.

Ghorab, M. A. (1960) Geologic observations on the surface and subsurface petroleum indications in the United Arab Republic, *Second Arab Petrol. Congr., Beirut*., **2**, 25–38

Graf, D.L. (1960) Geochemistry of carbonate sediments and sedimentary carbonate rocks: Carbonate mineralogy carbonate sediments, *State of Illinois, Dept. of Registration and Education, Division of the State Geological Survey.*

Hussein, A. W. (2019) Cyclic hierarchy and depositional sequences of the Middle-Upper Eocene ramp facies: An example from Beni Suef area, east Nile Valley, Egypt. *Journal of African Earth Science*, **149**, 307–333.

Hutcheon, I., Bloch, J., De Caritat, P., Shevalier, M., Abercrombie, H., and Longstaffe, F. (1998) What is the cause of potassium enrichment in shales? In: Schieber, J., Zimmerle, W., Sethi, P.S., (Editors). Shales and mudstones (Petrography, petrophysics, geochemistry, and economic geology). *Schweizer Bart Sci. Publ*., **2,** 107–128.

Mansour, H. H., Philobbos, E. R., and Abdu, F. H. (1982) Contribution to the geology of the east and northeast of Beni Suef, Nile Valley, Egypt. *Qatar Univ. Sci. Bull*., **11**, 52–65.

Mason, B., and Moor, C.B. (1982) Principles of geochemistry. *John Wiley and Sons Ltd., (2nd edition) New York*, 352p.

Morse, J. W., and Mackenzie, F. T. (1990) Geochemistry of sedimentary carbonates. *Elsevier Publ. Co., Amsterdam*, 707 P.

Philip, G., El-Aref, M. M., Darwish, M., and Ewais, S. (1991) Paleoerosion surfaces and karst manifestations including "Egyptian Alabaster" in Gebel Homret Schaiboun-Gebel Sannur area, East of the Nile Valley, Egypt. *Egypt. J. Geol*., **34**, 41–79.

Pidgeon, R. T., and Aftalion, M. (1978) Cogenetic and inherited zircon U-Pb systems in granites: paleozoic granites of Scotland and England. *GEOL. J. SPEC.*, **10**, 183–220.

Ramadan, A. M., Abd El-Gaied, I. M., Saber, S. G., and Salama, Y. F. (2021) Foraminiferal biostratigraphy and paleoenvironment evolution recorded in the Upper Eocene succession in northeastern Desert, Egypt. *Journal of Sedimentary Environments*, **6**, 485–512.

Rao, C. P., and Adabi, M. H. (1992) Carbonate minerals, major and minor elements, and oxygen and carbon isotopes and their variation with water depth in cool, temperate carbonates, western Tasmania, *Australia. Marine Geology*, **103**, 249–272.

Raymond, L.A. (1995) The study of igneous, sedimentary and metamorphic rocks. *Wm. C. Brown Communications, Inc., USA*, P. 498.

Saber, S. G., and Salama, Y. F. (2017) Facies analysis and sequence stratigraphy of the Eocene successions, east Beni Suef area, eastern Desert, Egypt. *Journal of African Earth Sciences*, **135**, 173–185

Said, R. (1990) The geology of Egypt. *Rotterdam, Netherlands.*

Said, R. (1962) The Geology of Egypt. *Elsevier, Amsterdam, New York.*

Said, R. (1971) Explanatory notes to accompany the geological map of Egypt. 1:2.000.000. *Geological Survey of Egypt*, 56, P. 123.

Said, R., and Issawi, B. (1964) Geology of the northern plateau, Bahariya Oasis, Egypt. *Geol. Surv. Egypt,* **29**, P. 41.

Salama, Y. F., Sayed, M., Saber, S. G., and Abd El-Gaied, I. M. (2021) Eocene planktonic foraminifera from the north Eastern Desert, Egypt: Biostratigraphic, paleoenvironmental and sequence stratigraphy implications. *Palaeontologia Electronica, https://doi.org/10.26879/1088.*

Salem, E., and Sehim, A. (2017) Structural imaging of the East Beni Suef Basin, north Eastern Desert, Egypt. *Journal of African Earth Science*, **136**, 109–118.

Sallam, E., Issawi, B., and Osman, R. (2015a) Stratigraphy, facies, and depositional environments of the Paleogene sediments in Cairo–Suez district, Egypt. *Arab J Geosci*., **8**, 1939–1964.

Shehata, A. A., El Fawala, F. M., Ito, M., Aboulmagd, M. A., and Brooks, H. L. (2020) Senonian platform-to-slope evolution in the tectonically-influenced Syrian Arc sedimentary belt: Beni Suef Basin, Egypt. *Journal of African Earth Sciences*, **170**, 103934.

Sistini, G. (1984) Tectonic and sedimentary history of NE African margin (Egypt/ Libya). In: JE Dixon and AHF Robertson (eds), the geological evaluation of the Eastern Mediterranean, *Blackwell Scientific Publishers, Oxford*, **17**, 161–175.

Tucker, M.E., (2001) Sedimentary petrology: an introduction to the originof sedimentary rocks. Wiley, Blackwell, Oxford

Wilson, J. L., (1975) The Lower Carboniferous Waulsortian Facies. In: Carbonate Facies in Geologic History. Springer Study Edition. Springer, New York, NY. https:// doi. org/ 10. 1007/ 978-1-4612-6383-8_5

Winter, J.D. (2001) An introduction to igneous and metamorphic petrology. *Upper Saddle River, New Jersey: Prentice-Hall*, 697p.

الأوضاع التركيبية وخصائص السحنات والنواحي الچيوكيميائية لصخور الإيوسين الأوسط ـ العلوي على طول طريق بني سويف ـ الزعفرانة الجديد، شرق بني سويف، مصر

علاء طه أحمد أمين[١،٣]، وأحمد محمد المزين[١]، ودرويش محمد الخولي[٢]، وإيهاب قرني أبو زيد[٢]،ووائل فهمي[١]، وحسام أنور خميس[٢] وحازم كامل عبدالعزيز سرحان[٢]

[١] قسم الچيولوچيا، كلية العلوم، جامعة الأزهر، القاهرة، مصر
[٢] هيئة المواد النووية، القاهرة، مصر
[٣] إدارة محاجر بني سويف، بني سويف، مصر

تنتشر رواسب الكربونات على نطاق واسع في التتابعات الإيوسينية بمنطقة شرق بني سويف بمصر. يتضمن هذا العمل دراسات ليثوستراتجرافية وتركيبية وبتروجرافية وچيوكيميائية لصخور الإيوسين الأوسط –العلوي على طول طريق بني سويف– الزعفرانة الجديد. من خلال الدراسة تبين أن المنطقة من الناحية الاستراتجرافية تتكون من وحدتين صخريتين هما (من القاعدة إلى القمة)؛ متكوّن بني سويف ومتكوّن معادي، حيث تتراوح أعمارهما من العصر الإيوسيني الأوسط إلى الإيوسيني العلوي. أما من الناحية التركيبية فتعتبر الصدوع التي اتجاها شمال شمال غرب– جنوب جنوب شرق، شمال شمال شرق–جنوب جنوب غرب، شمال غرب–جنوب شرق هي الرئيسة في المنطقة. توجد هذه المجموعات من صدوع على نطاق واسع لعدة كيلومترات في منطقة الدراسة.

تم التعرف على ثلاثة أنواع من السحنات الدقيقة أثناء الفحص الميكروسكوبي لسبعة عشر قطاعاً لعينات مختارة دلت على ترسبها في بيئة بحرية ضحلة تحت المد والجزر وفي ظل ظروف دافئة في منطقة الرف القاري.

أظهر تحليل حيود الأشعة السينية (XRF) أن نسبة السيليكا هي الأعلى في عضو قُرن (الوحدة السفلي من متكوّن بني سويف)، في حين أن محتوى أكسيد الكالسيوم هو الغالب في عضو طَربول (الوحدة الأعلى من متكوّن بني سويف) ومتكوّن معادي، بالاضافة لبعض المكونات السليسيكلاستية. ومن ناحية أخرى، فإن محتوى الزركون هو الأعلى فى منطقة الدراسة، بعض العناصر الشحيحة مثل الباريوم والڤاناديوم والاسترانشيوم والزنك هي السائدة في جميع العينات الصخرية المدروسة. كما أظهرت أيضاً التحاليل أن محتوى اليورانيوم والثوريوم عالي نسبياً في متكوّن معادي الإيوسيني العلوي عن متكون بني سويف الإيوسيني المتوسط – العلوي.