GEOLOGICAL AND GEOMORPHOLOGICAL STUDY OF WADI ABOU AL GOMEL, WEST, TOBRUK CITY, NORTHEAST LIBYA

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Abstract

This study has been carried out in Wadi Abou Al Gomel area in the eastern region of the Libyan seacoast, which lies between latitudes N32°03’00 N32°08'30 and Longitudes E23°45' 00 E23°52'00. This area has specific geological features, where the different rock formations exhibit good exposures that give a clear view of the stratigraphic column.

The exposed formations belong to Al Faidiyah and Al Khowymat Formations. The main objective of the study is to evaluate some features namely lithology, stratigraphic analysis, fossil distribution, and structural features.

The results of field surveys, supported by photo interpretation, have led to the classification of coastal geomorphological features, which outlines the processes and related deposits and landforms.

Field observations and the obtained data revealed that the area has been affected by variable geological factors and changes in depositional environments, in addition to tectonic movements that led to the formation of various structures such as normal faults, fissures, joints, and unconformities.

Keywords: Geological; Geomorphological; Al Faidiyah; Al Khowymat; Libyan Northeast.

Introduction

Because this area has not been thoroughly studied, this study will highlight the geological characterizations and geomorphological features that have characterized this area namely lithology, stratigraphy, structures and fauna distribution as well as some structural patterns.

Since the 18th century, geomorphologists have tried to explain landforms using various theoretical frameworks. This means that the explanation for landforms development rests on geomorphic processes occurring at present. In other words, that old landforms can be studied in the light of present processes. This consistent idea led to the relatively early development of climatic geomorphology, a concept that was first introduced by (De Martonne, 1913) in the publication Le climate, facteur du relief.

Surprisingly, the geographical cycle (or erosion cycle) Davis (1899) gave secondary roles to the spatial and temporal variability of climate, such as relief evolved through stages of youth, maturity and age, and hence providing a simplistic and deterministic view of landscape evolution and the product, which would be a peneplain (Leopold et al, 1964).

For Davis, the identification of certain landscape characteristics was sufficient to provide information on past and future landscape development. Perhaps this was the reason for the popularity of Davis' geographical cycle and ideas, which dominated geographical investigations until the mid-20th.

Some authors stressed, perhaps overly, that Davis' ideas were responsible for decades of backwardness in the science of geomorphology relative to the environmental sciences (Tricart,1965; Tricart,1978) because of the marginalization of climate-driven geomorphic processes (Passarge,1931).

A change in paradigm was pioneered by the studies of Â Horton (1945) on the morphometry of rivers and basins and it was established with Strahler (1952) and Leopold et al (1964) who gave a marked impetus to geomorphology by emphasizing the role of field and laboratory research, physics and mathematics in quantitative geomorphology. From theoretical, extremely complex, and valuable approaches, some authors established simplistic solutions, classifying countries, schools and scientists as geomorphologically positives, historicist, or non-positivist (Capel, 1983).

It is obviously from this study that these rock types are belonging to two different formations namely Al Faidiyah Formation and Al Khowymat Formation.The Al Faidiyah and Benghazi Formations are part of the Al Jabal Al Akhdar region. Al Faidiyah and Benghazi Formations belong to Oligo-Miocene and Middle Miocene ages respectively. These formations were sediments in shallow marine environments (Berggren, 1974 ; Klen, 1974).

The age of the Al Faidiyah Formation is Early Miocene as dated by ElHawat & Shelmani, 1993; Mazhar & Issawi, 1977; and Swedan & Issawi, 1977. However, it has been dated as Late Oligocene – Early Miocene by (Megerisi and Mamgain, 1980; El D Rohlich, 1974). Moreover, Banerjee (1980) considered the AlKhowaymat Formation as Upper Campanian-Lower Oligocene, which contradicts others such as El Deftar & Issawi (1977) at Burdi; Mazhar & Issawi (1977) at Zawiyat Msus; Swedan & Issawi (1977) at Bir Hacheim who dated this formation as Late Eocene to Early Oligocene. (El Deftar & Issawi, 1977; Rohlich, 1974; Imam, 1999).

The Al Khowaymat Formation of El Deftar & Issawi (1977) is considered one of the problematic exposed rock units in Libyan northeast due to the differing views or stratigraphic conclusions provided for example by El Deftar & Issawi, 1977; Megerisi & Mamgain, 1980; Imam, 1999; Abdulsamad & Tmalla, 2008/2009.

Al Faydiah Formation is mainly of limestone and has greenish clay flakes at the bottom of the formation that grades upwards into yellowish limestone. The basal clay layer is rich in glauconite and common fossils including abundant Bryozoans (ELSAFORI, 2007).

On the other hand, Al Faidiyah Clay unit is mainly glauconitic in composition with few foraminifers. The thickest exposed part is at Umm el Rezzam area that excavated by the GOWFE Company for Oil Technology for local row materials, which are used to produce Bentonite (El Ebaidi, 2000). Al Faidiyah Formation is also chalky due to the high purity of calcite (El Ebaidi, 2000; El Ebaidi, et al., 2015).

Al Faidiyah Formation contains mainly carbonate rocks and clay rocks. Carbonate of Al Faidiyah Formation occurs in a high thickness ranges from 3 to 4 meters and involves various types of lithology e.g. limestone, fossiliferous limestone dolomite and marl Figure (1).

Figure (1): Photographic Image Showing Fossiliferous Limestone.

Figures (2) and (3) depict the various types of calcareous rocks and impression and molds for fossils species in studied area.

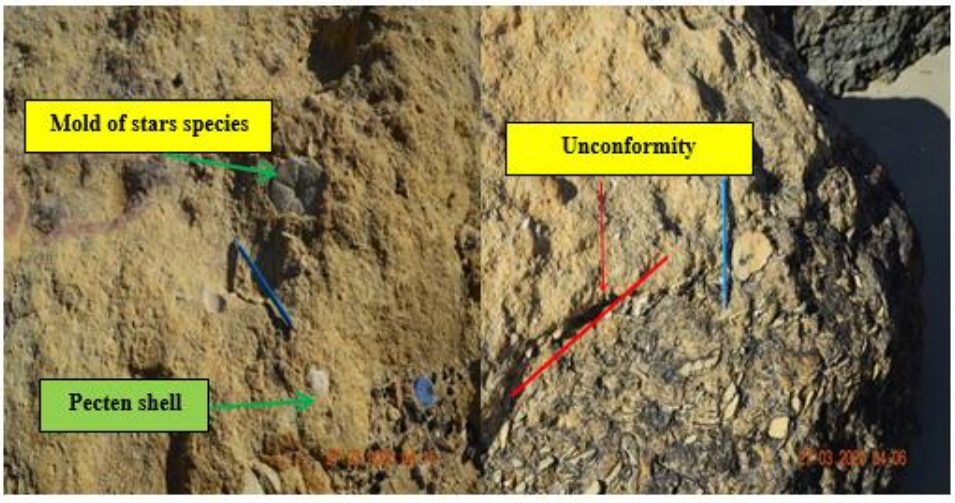

Figure (2): Fossiliferous Limestone of Tertiary Age.

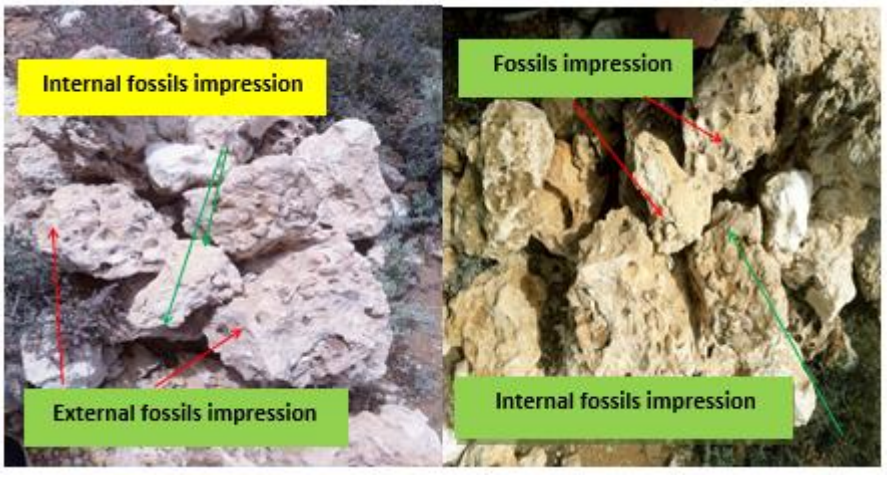

Fig. 3 Various of Impression and Molds for Fossils Species in Studied Area.

Location of Study

The studied area lies in the Libyan eastern the coast on the Mediterranean Sea at about 6 Km to the west of Tobruk city and about 2.5 Km from the coastal road, between N32°0’30 N32°11'30 and E23°46' 30 E23°57'30 Figure (4). The area is characterized by its elevation location, where the elevation above sea level is ranging from 80-120 m. The area comprises different valleys that were formed by the tectonic movement. The major one is Wadi Abou Al Gomel (Syamadas, 1980) Figure (5).

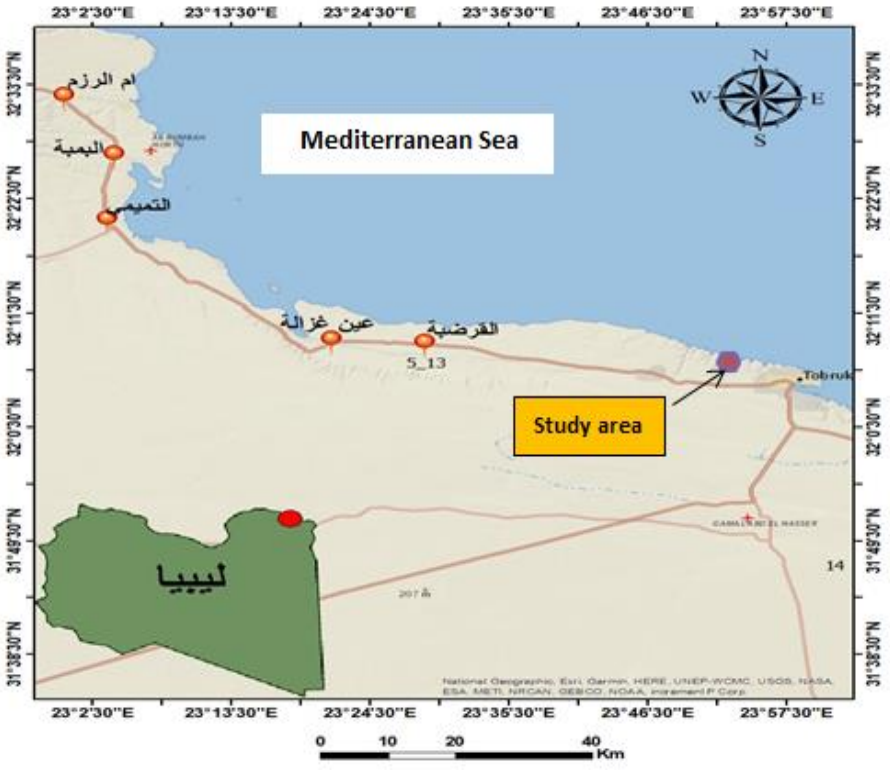

Figure (4): A Map Showing Location of Studied Area.

The study concentrated on this wadi due to its location importance and the good exposures of rock formations.

Figure (5): General View of Wadi Abou Al Gomel Area.

Study Objectives

This study aimed to evaluate some characterization parameters e.g. lithology, stratigraphic analysis, fossil distribution, geomorphological, and structural patterns.

Literature Review

Some geological studies have been performed about the Libyan north-east cost. Imam (1999) studied three stratigraphic sections in Al Burdi area using planktic and larger benthic foraminifers. These sections from west to east are Wadi al Zeitun, Wadi al Hash and Wadi Al Rahib.

El-Ekhfifi et al (2017) determined the mineralogical and foraminiferal components of the sand beach of Tobruk, NE Libya. They found that these sediments consist of fine to coarse grained sediments rich with benthic foraminifera. Carbonate content ranges from 60 to 95% while detrital quartz and feldspar varied from 5 to 40% depending on erosional factors. The researchers attributed these components to marine waves blown by winds to form exposures of calcarenites around the study area.

Muftah et al (2017) studied three surface sections, namely Wadi al Hash and Wadi al Shaigh at Tobruk area, and Wadi al Rahib at Al Bardia area. The first location is described as a transgressive event, which was recognized at the basal part of the Oligocene – Miocene. Al Faidiyah Formation remarks the disconformity surface separating the Oligocene -Miocene Al Faidiyah Formation from the underlying Middle Eocene Darnah Formation. A disconformity surface of a short interval time is traced between the Al Faidiyah Formation and the overlying Al Jaghbub Formation.

Abdulsamad et al (2018) reported that Tobruk coastal area of the northeastern Cyrenaica (NE Libya) is marked by steep cliffs rising more than 100 m above the sea and are dissected by wadis coming down from these scarps. These escarpments are of Middle Eocene to Middle Miocene rocks.

Adam et al (2021) reported that Al Faidiyah Formation reveals three microfacies associations varied between packstone, floatstone and grainstone rich with algae, bivalves, bryozoans and foraminifera indicating deposition in continuous sea level that rises from shallow energetic marine conditions to mid - outer shelf marine settings.

Materials and Methods

The study has been carried out through repeated field trips to collect different rock samples that represent the different formations beds, and a paleontological study to trace the distribution of the various fossil types in the different formation beds. In addition, the various structural types were investigated by using measuring tools and these structural types' main directions and magnitudes were determined. Moreover, the main forces that lead to form these structural patterns were studied.

Results and Discussion

1. Lithology and Stratigraphy

In general, the characterization lithology of the studied area encountered in few rock types are represented by calcareous fossiliferous rocks, shale, sandy shale and conglomerate (Horton, 1945; Capel., 1983).

The stratigraphic succession shows some variation among wadies in thickness and the extent of the variation of depositional factors such as deposition environment and the tectonic movements.

The thick sedimentary section exposed the Wadi Abou Al Gomel area, especially noticed along the cliffs overlooking the Mediterranean Sea, is classified into three main stratigraphic formations belonging to Early Tertiary. Besides, several, five in number, quaternary deposits were recognized near the foot slopes of the cliffs and inward covering older units. The following units were recognized in the field as given in Table (1).

Table (1): Stratigraphic Sequence of the Studied Area.

<table>
<tr><th>Tertiary</th><th>Quaternary</th></tr>
<tr><td rowspan="2">Lower-Middle Miocene: Al Jaghbub Formation</td><td>Alluvium deposits</td></tr>
<tr><td>Beach and coastal sand dune</td></tr>
<tr><td rowspan="2">Upper Oligocene-Lower Miocene: Al Faidiyah Formation</td><td>Sabkha sediments</td></tr>
<tr><td rowspan="2">Eolian deposits</td></tr>
<tr><td>Upper Eocene-Lower Oligocene: Al Khowymat Formation</td></tr>
</table>

1. **Al Khowymat Formation**: dolomitic limestone, yellowish white, hard compact, fossiliferous including; *Globgerina* spp., *Globorotalia* spp. and *Nummulites* Figure (6).

2. **Al Faidiyah Formation**: limestone, faint brown to dark yellow, sandy and marly. Lithologically, the formation is made of alternating limestone, marly limestone and clay beds with a thickness varies from 3 to 4 meters. The beds are nearly horizontal, thin to thin-bedded and highly fossiliferous Figure (7). It includes the following assemblage of macrofauna: *Cardiumgallicum, Strombus* sp. Worm tubes, *Brissoposisfrassi* and *Tllina lacunose*.

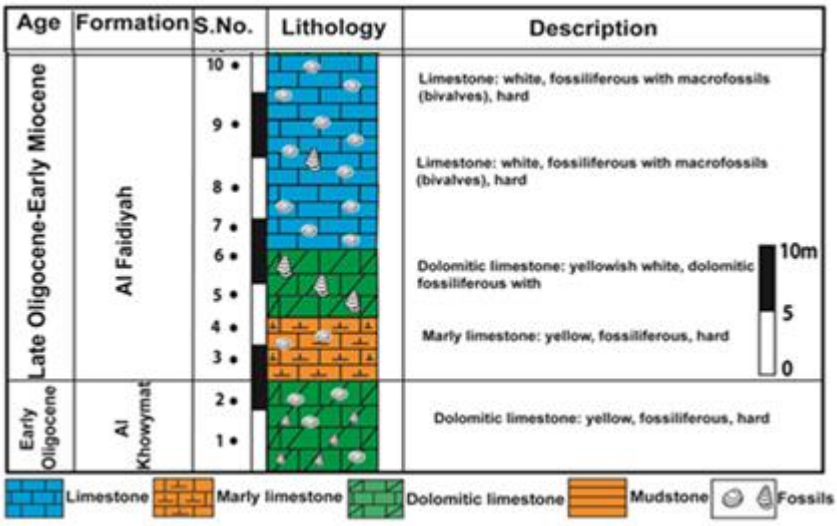

Figure (6): The stratigraphic sequence at Wadi Abou Al Gomel (after Adam, 2021).

Figure (7): Fossiliferous Limestone.

On the other hand, the main dominant distribution fossils in the studied area are distinguished throughout the stratigraphic sequence that is represented by different species as shown in Figure (8).

Figure (8): The Main Fossil Species in the Studied Area.

1: (Bivalve –*Pectin)*; 2, 3, 4: (Echinoderms –*Clypeaster*).

The Al Faidiyah Formation is the youngest unit in the studied area and stratigraphically ranges from the Upper Oligocene to the Lower Miocene (El Ebaidi, 2015). The

formation consists of limestone that is whitish to yellowish and thick bedded to massive. It contains fossiliferous layers.

Pietersz (1968) introduced the name Faidiyah Formation, which is derived from the Qaryat (Qaryat in Arabic this means village) Al Faidiyah. It comprises the lower Faidiyah Clay Member and an upper Faidiyah Limestone Member. Its thickness is about ten meters, as seen in Figure (9). Figures (10) and (11) represent Al Khowymat Formation in Wadi Abou Gomel.

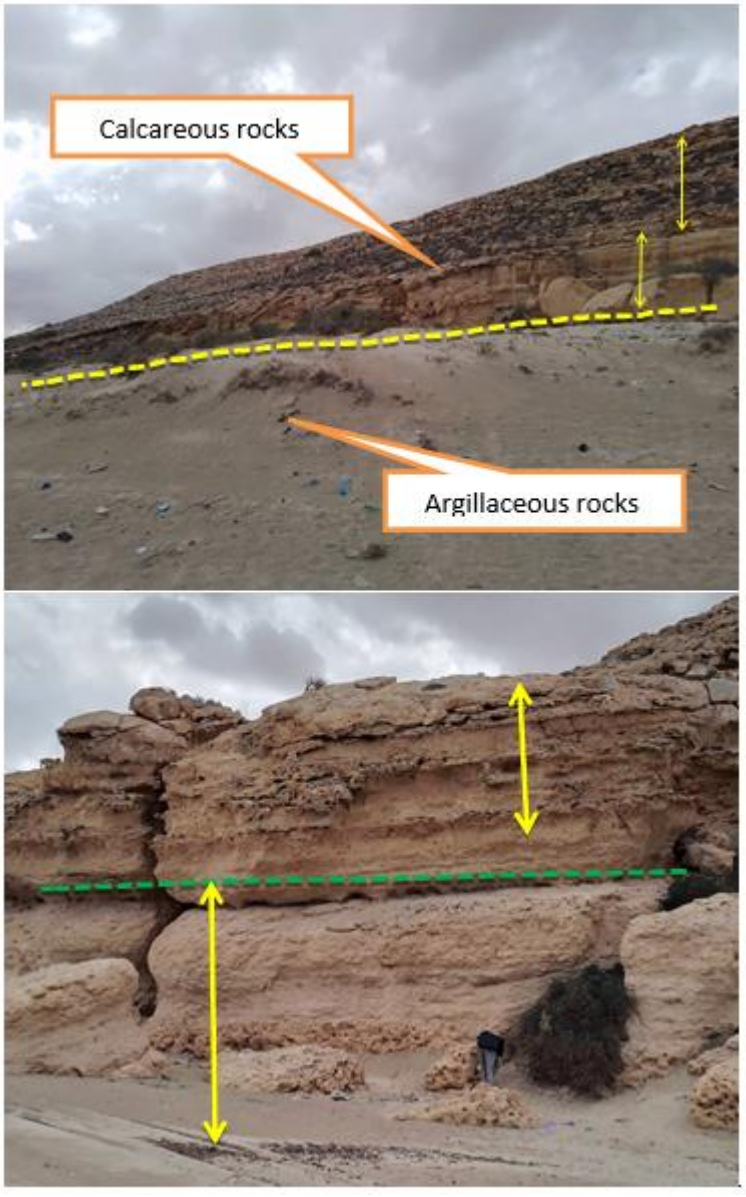

Figure (9): The Sharp Contact between the Faidyah Shale and Faidyah Limestone Members of Al Faidyah Formation in Wadi Abou Gomel in E -W Direction.

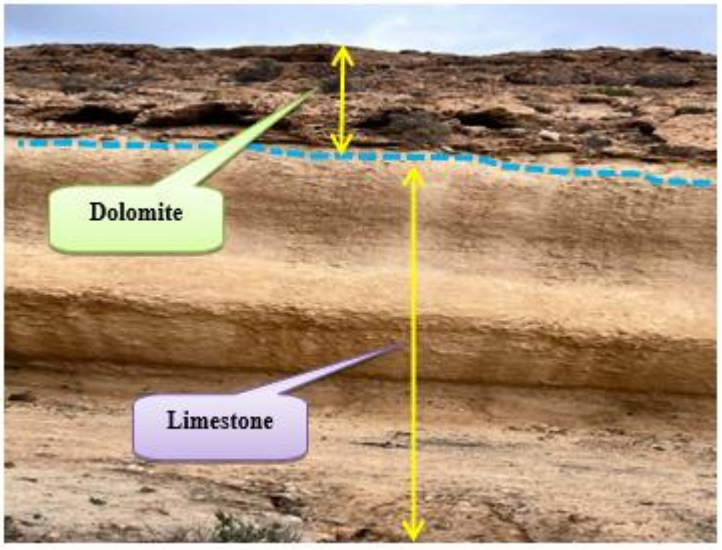

Figure (10): The Sharp Contact between the Al kowymat Dolomite and Al khowymat Limestone Members of Al khowymat Formation in Wadi Abou Gomel.

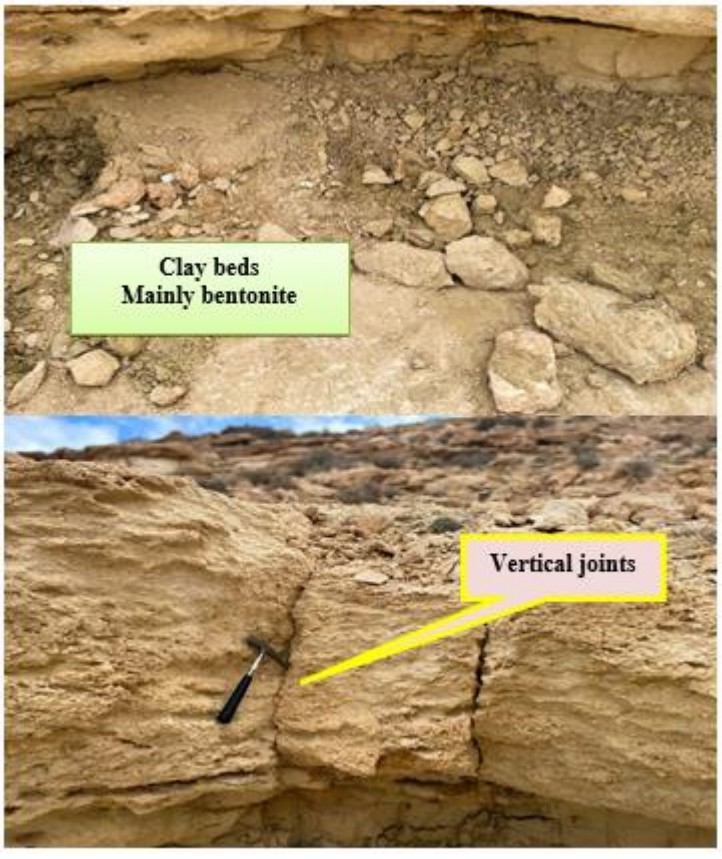

Figure (11): The Sharp Contact between the Al khowymat Shale and Al kowymat Dolomite of Al khowymat Formation in Wadi Abou Gomel.

Figure (12) shows schematic representation of the structural pattern and stratigraphic sequence of both Al khowymat Formation and Al Faidyah Formation in the investigated area.

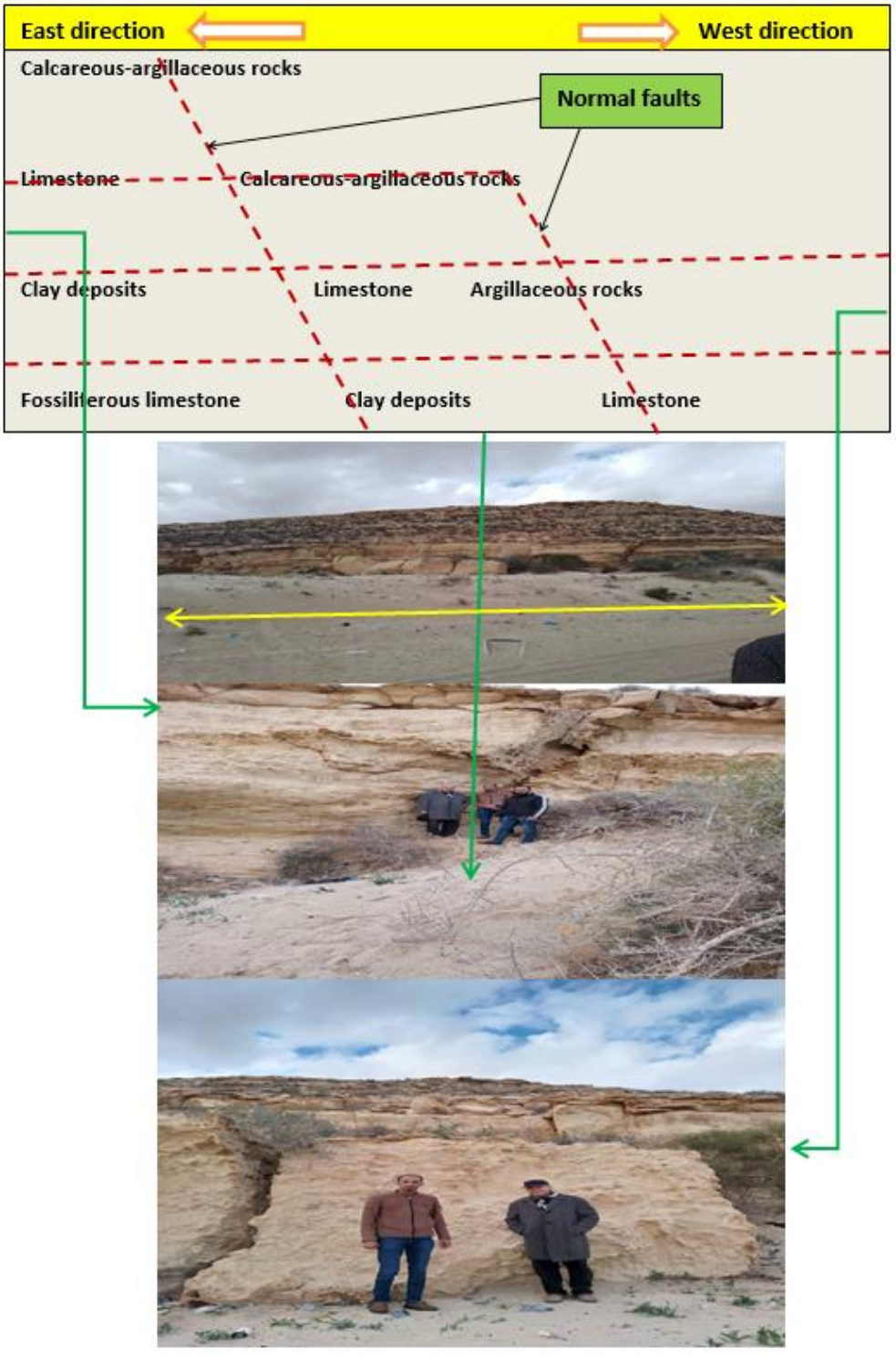

Figure (12): Schematic Representation of Structural Pattern and Stratigraphic Sequence in the Area.

Geological Structures

The structural patterns of Wadi Abou Al Gomel area are mainly determined by tensional forces that lead to the formation of normal faults patterns (Syamadas, 1980). Faults planes are steep form60˚ to 70˚ and their extension widely varied from one to another. It seems that the investigated area has been exposed to high tectonic movement and tension forces, and suffers from high stresses. The tectonic movement led to the formation of different structural patterns represented by faulting, folds, joints, fractures and rock cracks Figure (13). On the other hand, other geologic structures were formed later through depositional younger strata to yield cracks, joints and unconformity structures Figure (14).

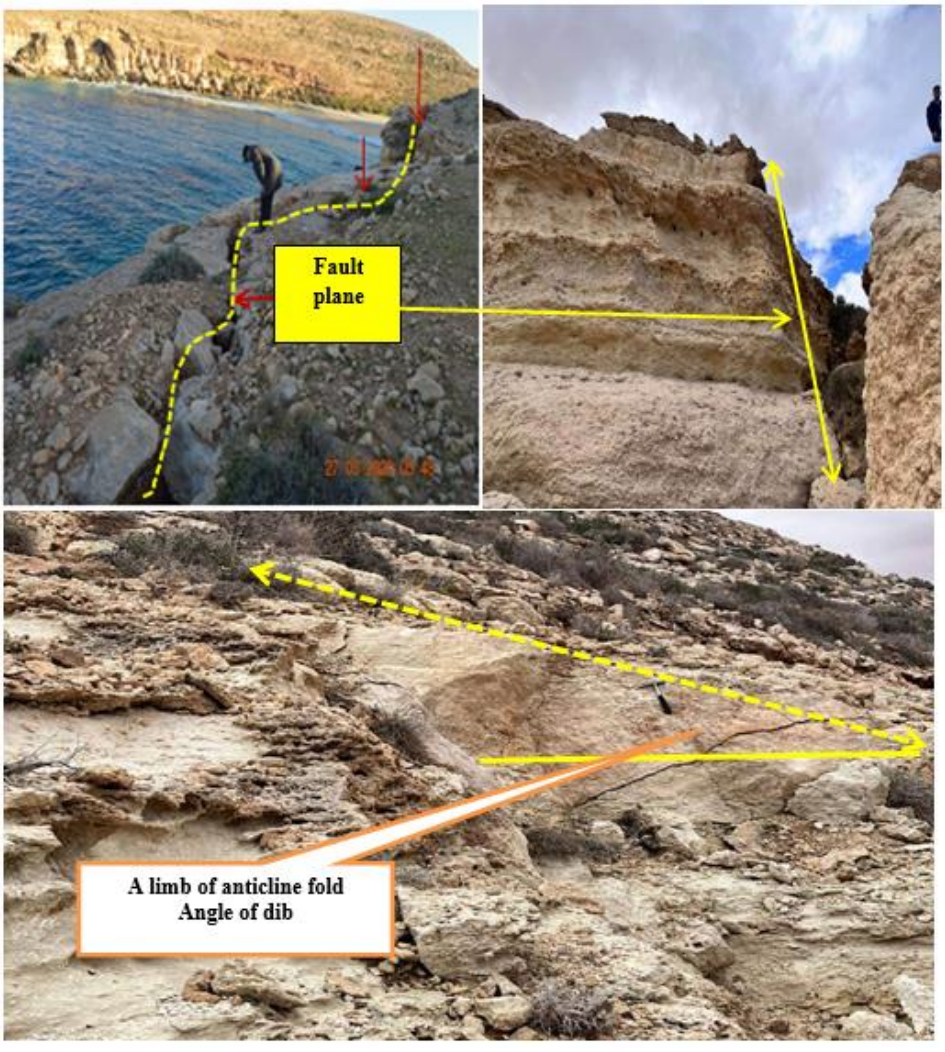

Figure (13): Faults and Folds Structures in Wadi Abou Al Gomel Area.

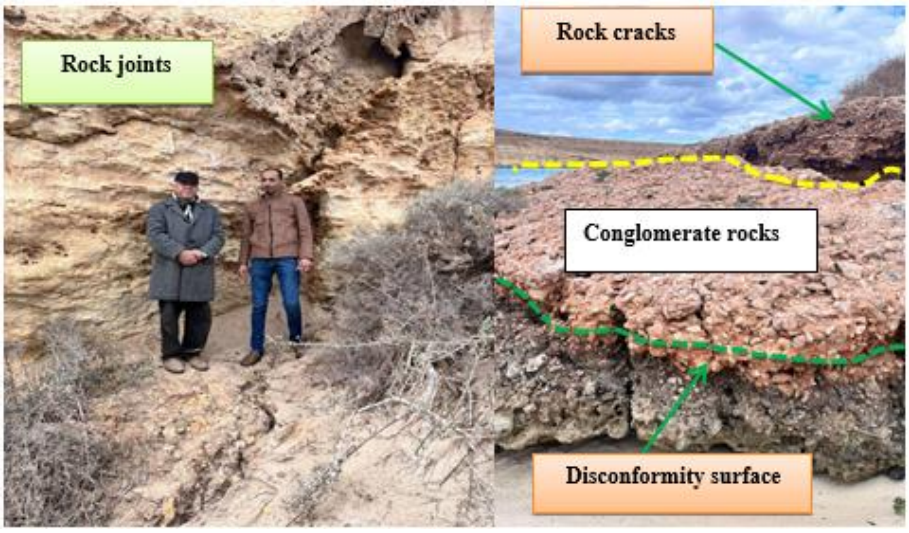

Figure (14): Rock Cracks, Joints and Disconformity Structural Features.

Geomorphological Features

The morphological aspects of the coast of the studied area vary due to the factors involved in lithology variation and the weathering results from wave's action. Rocks are mainly formed of calcareous and soft rocks, which are highly affected by the chemical and physical weathering resulting from the formation of different types of geomorphological features.

1. Weathering Pits

These pits outcrops at rocks exposures on the slopes are formed by calcareous rocks all over the area and usually associated with joints and cracks what called taffonispits that arise due to solubility Figure (15).

Figure (15): Weathering Pits.

2. Coastal Cliffs

The edges overlooking the sea are called coastal cliffs and they slope from 45-90˚ depending on waves motion. These geomorphological aspects are associated with an elevation ranging from 60 to more than 100 m Figure (16).

Figure (16): Coastal Geomorphotypes: Plunging Cliff; Wadi Abou Al Gomel.

3. Coastal Caves

The coastal caves and voids are spread in the area, which highlights the active erosion process at cliffs feet due to wave action depictss and weathering process. These caves range from 1.5 to 5.0 m with an average of 2 m, while their elevations range from 0.75 to 4.0 with an average of 0.50 to 4.0 m. Figure (17) shows the different types of cliffs in the investigated locations.

Figure (17): Coastal Caves.

4. Shore Platform

From horizontal to a sub-horizontal rock surface (0°–5°) spreads along the shore because of the action of marine processes (wave erosion, biogeochemical dissolution and other weathering processes) and the retreat of the cliff in the intertidal zone Figure (18).

Shore platforms can be observed at the intertidal level or at 5–10 m above sea level. The latter was developed on bedding planes, following their slope. They are never submerged but are affected by wave action and marine spray. Usually, a deeply carved abrasional notch occurs at the low sea level.

Figure (18): Coastal Geomorphotypes: Shore Platform and Rock Failure.

5. Ripple marks on Sand Dunes

Ripple marks suggest wave activity related to the oscillatory patterns of water movement near the water-sediment interface (Allen, 1968). Ripple marks that formed by wind process appear on the coastal line from north to south direction in some places and in regular in another as shown in Figure (19 A). On the other hand, sand dunes formation occurs along the coast in some of the investigated locations as shown in Figure (19 B).

Figure (19): (A): Ripple Marks with Regular Shape (B): Sand Dune.

Conclusion

The geology of the exposed rocks in Wadi Abou Al Gomel area dates back to the Late Eocen-Early Oligocene times. The deposits of the area correlates with Al Khowymat Formation and Al Faidiyah Formation. They exhibit similarities between lithology, stratigraphy, structures and fauna distribution.

The area has been affected strongly by tectonic movements such as the compressive and tension forces that led to the formation of normal faults, anticline folds and joints that show variable trends.

Al Faidiyah Formation shows a major anticline north-south trend. The unconformable relationship between Al Khowymat and the overlying Al Faidiyah is also marked by different joints sets observed in both units.

The area deposits show more or less a variation in the lithological distribution that reflects the variation of the marine environment under the oscillation of sea level.

The results of the study revealed that the investigated area was exposed to several factors that affected its geomorphological features, which vary from on location to another depending on these factors. These features have been identified and classified into different categories.

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