

## A study of Different Classes and Genera of Macrofossils of the An Naggazah Member, the Al Khums Formation, North-West Libya

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### دراسة عن فئات وأجناس مختلفة من الأحافير الكبيرة لعضو النقازة، تكوين الخمس، شمال غرب ليبيا

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Received: September 19, 2025 | Accepted: December 03, 2025 | Published: December 20, 2025

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#### Abstract:

This study investigates the paleontological characteristics of Miocene deposits exposed in the Al Khums area, northwestern Libya, with particular emphasis on the An Naggazah Member of the Al Khums Formation. The primary objective is the systematic classification, detailed description, and taxonomic evaluation of selected fossil assemblages. A total of fourteen rock samples were collected from a well-defined stratigraphic section and subjected to comprehensive paleontological analysis. The examined fauna from the lower to middle Miocene comprises two species belonging to the class Echinozoa, ten species of the class Bivalvia, and two species of the class Gastropoda. Notably, several of the identified taxa have been rarely documented within the Al Khums Formation or in Libya more broadly. These include *Echinolampas amplus* Fuchs, *Lima* (*Lima*) *Linnaeus*, *Chlamys varia* (*Linnaeus*), *Chlamys scabrella* Lamarck, *Pecten subarcuatus* Tournouer, and *Turritella* (*Torquesia*) cold Abbass, among others. The findings contribute new paleontological data that enhance the understanding of Miocene marine biodiversity and faunal distribution in northwestern Libya.

**Keywords:** Miocene deposits; Paleontology; Fossil assemblages; Al Khums Formation; Northwestern Libya.

#### المخلص:

تهدف هذه الدراسة إلى استقصاء الخصائص الحفرية لرواسب العصر الميوسيني المكشوفة في منطقة الخمس شمال غرب ليبيا، مع التركيز بشكل خاص على عضو النقازة من تكوين الخمس. ويتمثل الهدف الرئيس للدراسة في التصنيف المنهجي والوصف التفصيلي والتقييم التصنيفي لمجموعة مختارة من التجمعات الحفرية. وقد جُمعت أربع عشرة عينة صخرية من قطاع طبقي واضح المعالم، وأخضعت لتحليل حفري شامل. وتضم الفونة المدروسة من الميوسين الأدنى إلى الأوسط نوعين ينتميان إلى طائفة شوكيات الجلد (Echinozoa)، وعشرة أنواع من طائفة ذوات المصراعين (Bivalvia)، ونوعين من طائفة بطنيات القدم (Gastropoda). ويلاحظ أن عددًا من الأصناف المحددة نادر التسجيل في تكوين الخمس أو في ليبيا بصفة عامة، ومن بينها *Echinolampas amplus* Fuchs و *Lima* (*Lima*) *Linnaeus* و *Chlamys varia* (*Linnaeus*) و *Chlamys scabrella* Lamarck و *Pecten subarcuatus*.

البيانات الحفرية، وتعزيز فهم التنوع الحيوي البحري وتوزيع الفونة خلال العصر الميوسيني في شمال غرب ليبيا. و *Taurnouer*، و *Turritella (Torquesia) cold* Abbass، وغيرها. وتسهم نتائج هذه الدراسة في إثراء قاعدة

**الكلمات المفتاحية:** رواسب الميوسين؛ علم الحفريات؛ التجمعات الحفرية؛ تكوين الخمس؛ شمال غرب ليبيا.

## Introduction:

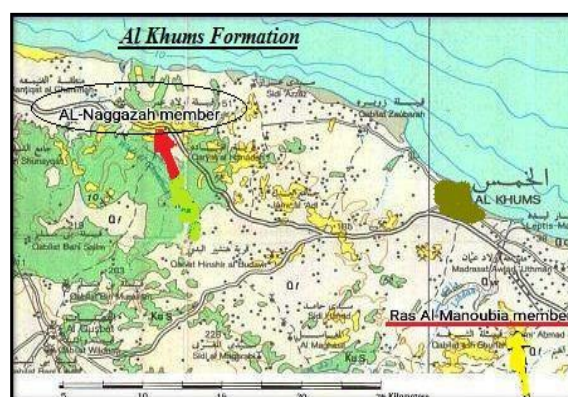
The Sirte Basin underwent significant tectonic development during the Late Miocene, representing a southern extension of the Tethyan geodynamic system. By the Miocene epoch, the basin and its associated gulf were largely infilled by extensive carbonate and siliciclastic sedimentary successions deposited under conditions of sustained marine transgression, as documented by Seeley (1971, 1985). Within this regional framework, the Miocene deposits exposed in the Al Khums area, situated along the northwestern margin of the Sirte Basin, are predominantly composed of marine transgressive–regressive carbonate and siliciclastic sediments. The observed lithological and facies variability is primarily governed by differential erosion patterns and the paleotopography of the underlying Upper Cretaceous substratum.

The fossil assemblages investigated in this study were recovered from multiple stratigraphic horizons within the Lower and Middle Miocene formations exposed in the Al Khums area of northwestern Libya. The identified fauna includes several taxa belonging to the phylum Echinodermata, a diverse and abundant representation of the class Bivalvia, and a more limited number of species attributed to the class Gastropoda, consistent with previous regional paleontological observations (Moore et al., 1969).

Geographically, the study area is located in northwestern Libya, within the Al Khums region, extending between latitudes 32°–33° N and longitudes 13°13′–15° E. The Miocene sedimentary succession occupies an area of approximately 3,000 km<sup>2</sup>, as summarized in Table 1. Al Khums lies along the Libyan Mediterranean coastline, approximately 100 km east of the capital city, Tripoli, and to the west of the city of Misurata (Figure 1). The stratigraphic framework of the study area, as established by Mann (1975), provides the geological context for the depositional history and fossil distribution discussed in this study.

**Table (1):** The Stratified sequence of geology of the study area (Mann, K. 1975).

AGE	FORMATION	MEMBER	THICKNESS(m)	DESCRIPTION
Middle Miocene	Al-Khums Formation	Ras Al Mannubiyah Member	60 m	Limestone, Marly-limestone
		An Naggazah Member	110 m	Limestone, Marly-limestone, Sandstone, Siltstone



**Figure (1):** The Locations of the study area (Mann, K. 1975).

## Aims of the Present Work

The present study aims to conduct a comprehensive taxonomic analysis and detailed morphological description of selected fossil assemblages belonging to the phyla Coelenterata and Echinodermata, as well as the phylum Mollusca, from the Miocene deposits of the Al Khums area, northwestern Libya. In addition, the study seeks to critically evaluate and interpret selected fossil taxa in order to enhance the understanding of their paleoecological significance and stratigraphic distribution within the Miocene succession of the region.

## Geology of the Study Area

The Miocene succession exposed in the Al Khums area has been extensively investigated by numerous researchers, including Florida (1939), Desio (1971), Hinnawy and Chestitev (1975), Francis and Issawi (1977), Salem and Spreng (1980), Sherif (1984, 1991), and El-Waer (1991). Most of these studies concentrated primarily on regional stratigraphy and lithostratigraphic correlations, whereas comparatively limited attention was given to paleontological and micropaleontological aspects. Collectively, these authors assigned a Middle Miocene age to the Al Khums Formation and subdivided the Miocene succession into two principal formations: the upper Al Khums Formation (Late Miocene) and the underlying Marada Formation (Early to Middle Miocene).

The Al Khums Formation was further subdivided into the Wadi Yunis Member, overlain by the Qwerat Jibs Member, which has been attributed to the Late Tortonian–Early Messinian interval. Detailed faunal investigations were deemed necessary to refine stratigraphic correlations and validate age assignments. Sediments of the Al Khums Formation exposed in the Awlad Omar area (Section 1 of the present study), located at latitude 32°40' N and longitude 14°06' E, yielded diverse microfaunal assemblages, particularly ostracods, indicating a Late Tortonian–Early Messinian age. Comparable age assignments have been proposed for the Al Khums Formation exposed on the El Aqayah Plateau, as well as for the Sahabi Formation farther east, both of which are considered to belong to the Late Miocene.

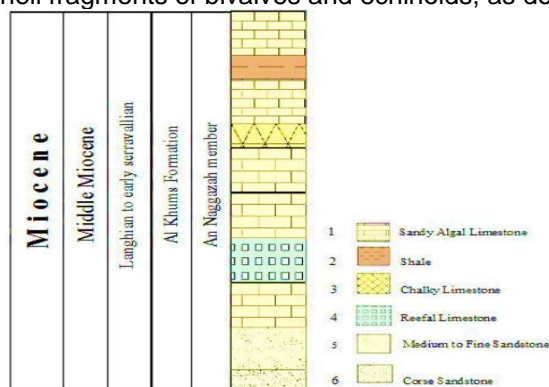
### An Naggazah Member

The upper part of the An Naggazah Member is characterized by interbedded fossiliferous mudstones and dolomitic limestones, typically yellow to grayish-gray in color, with varying fossil content. These lithologies are locally intercalated with layers of dolomitic limestone and green gypsum-bearing oil shale. Figure 2 (a) illustrates the stratigraphic succession of the Al Khums Formation, while Figure 2 (b) presents corresponding field photographs of the An Naggazah Member within the study area.

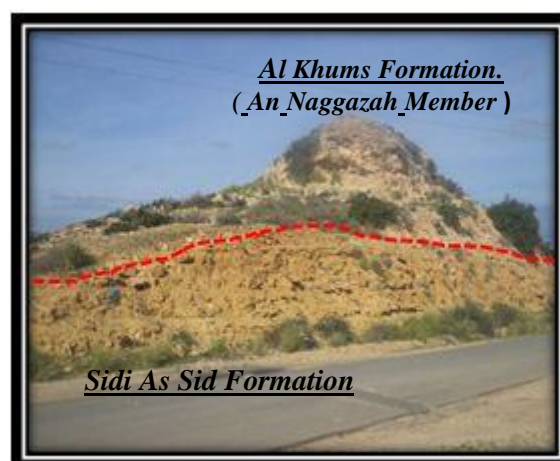
The lower part of the Al Khums Formation in the Al Khums area, as described by Salem and Spreng (1980), consists predominantly of multilayered conglomerates composed mainly of carbonate clasts with chert fragments embedded in a sandy carbonate matrix. This basal unit is overlain by pebbly to coarse-grained sandstones that progressively grade upward into medium- to fine-grained, poorly sorted, fossiliferous calcareous sandstones containing abundant shell fragments of gastropods and crustaceans. Above this sequence lies a yellowish-brown, irregular to massive, ridge-forming coralline-algal limestone unit. This limestone is porous to locally hard, sandy in texture, and exceptionally rich in fossils, including corals, coralline algae, bivalves (notably oysters), bryozoans, and echinoids.

These biogenic accumulations commonly thicken laterally to form reefal bodies of variable thickness, particularly concentrated in the central part of the unit. Numerous branching reef complexes have been observed along Wadi Zaqlum, where coral patch reefs developed locally on submerged paleo-highs associated with an uneven Late Cretaceous substrate. These reefal limestones are massive and highly fossiliferous, hosting a diverse assemblage that includes calcareous red algae, echinoids, bryozoans, macrobenthic foraminifera, bivalve shell fragments, and algal rhodoliths. Colonial corals constitute the dominant biogenic component of these deposits.

The composition of this faunal assemblage indicates deposition under clear, shallow-marine conditions characterized by normal marine salinity and open water circulation. Representative macrofossils identified within this basin include *Pycnodonte virleti* Deshayes, *Ostrea frondosa* Fuchs, *Pecten cristato-costatus* Sacco, *Pecten zizinae* Blanckenhorn, *Strombus bonelli* Brongniart, *Chlamys submalvinae* Blanckenhorn, *Clypeaster* sp., and *Flabellum pecten burdigalensis* Lamarck. This coralline limestone unit is overlain by a younger layer of muddy, yellow-brown algal limestone that is partially fossiliferous and contains shell fragments of bivalves and echinoids, as documented by Hamad (2013).



**Figure (2) a:** Sedimentary Sequence Layers of Min Al Khums Formation (An Naggazah Member).



**Figure (2) b:** Photographs Show the red Line separates between the An Naggazah Formation and The Sidi as Sid Formation in Jabil An Naggazah Al Khums area.

### Methodology

The methodological framework of this study integrates systematic field investigations with detailed laboratory analyses to ensure accurate documentation and interpretation of the Miocene fossil assemblages. Accordingly, the methodology is structured into two principal components: fieldwork and laboratory work.

Field investigations focused on the collection of fossil-bearing materials from exposed Miocene strata within the Al Khums Formation, specifically the An Naggazah Member. A stratigraphic interval with a total thickness of approximately 110 m, representing the earliest exposed Miocene succession in the study area, was examined and documented. The investigated section is geographically located between latitude 32°40'44" N and longitude 14°04'42" E. Fourteen representative rock samples were systematically collected from this section, which constitutes the An Naggazah Member and corresponds to the basal part of the Al Khums Formation. These samples were selected to capture lithological variability and fossil content across the stratigraphic succession.

The fossil specimens analyzed in this study were collected during multiple field campaigns conducted at the An Naggazah Member in the Qabilat Celine area over several days, specifically on 12, 13, 17, and 21 February 2025. All collected samples were carefully labeled, documented, and prepared for subsequent laboratory examination, where taxonomic identification and descriptive analyses were carried out using standard paleontological techniques.

### Results and Discussion

The fossil assemblages examined in this study were recovered from multiple stratigraphic horizons within the Lower and Middle Miocene successions exposed in the Al Khums area of northwestern Libya. Systematic paleontological analysis led to the identification of a total of fourteen species, comprising two species assigned to the class Echinodermata, ten species belonging to the class Bivalvia, and two species attributed to the class Gastropoda. This taxonomic composition reflects a predominantly marine assemblage characteristic of shallow to moderately shallow depositional environments during the Miocene.

Representative specimens of the identified taxa are illustrated and systematically described, with emphasis placed on their diagnostic morphological features. Comparative taxonomic assessments were undertaken to evaluate their affinities and relationships with closely related and previously documented taxa from both regional and global Miocene successions. These comparisons contribute to refining species-level identifications and to elucidating patterns of faunal similarity and biogeographic distribution within the Mediterranean–Tethyan realm.

The systematic framework adopted in this study follows the classification scheme proposed by Moore et al. (1966, 1969) in *A Treatise on Invertebrate Paleontology*, which remains a foundational reference for invertebrate paleontological taxonomy. This classification system was applied consistently, particularly for the classes Echinodermata and Bivalvia, ensuring taxonomic rigor and facilitating meaningful comparison with earlier paleontological studies conducted in Libya and adjacent regions.



By studying the lengths of the fossils, measured in millimeters for the studied specimens, these echinoderm fossils were classified, as shown in Table (2). Table (3) presents the most prominent previous studies on this type of echinoderm fossil, *Echinolampas amplus*. Table (4) shows the measurements of the specimens in terms of length, width, and weight. Table (5) illustrates how species of the bivalve phylum were classified in terms of family, genus, and species. Tables (6, 8, 10, and 12) are previous studies of the names of fossils from the bivalve phylum. Tables (7, 9, 11, and 13) show the measurements of these fossil specimens. Table (14) shows the classification of gastropod fossil species. Table (15) presents previous studies. Table (16) shows measurements in terms of shell height, elevation angle, and spiral width.

**Table (2):** The classification of echinoderm fossils in terms of phylum, class, order, and family.

<b>Phylum</b>	ECHINODERMATA
<b>Subphylum</b>	ECHINOZOA Haechel (In Zittle) 1895.
<b>Class</b>	ECHINOIDA Leske, 1778.
<b>Super order</b>	ECHINACEA Claus, 1876.
<b>Order</b>	CASSIDULOIDA Claus, 1880.
<b>Family</b>	ECHINOLAMPADIDAE Gray, 1851.

Genus *Echinolampas* Gray, 1825.

Type species *Echinus oviformis* (Gmelin), 1789.

*Echinolampas amplus* Fuchs, 1883.

**Table (3):** Some types of echinoderm fossil, *Echinolampas amplus*.

<b>1983</b>	<i>Echinolampas amplus</i> Fuchs: p. 27, pl. IX,
<b>1920</b>	<i>Echinolampas amplus</i> Fuchs Fourtau: p. 65.
<b>1929</b>	<i>Echinolampas amplus</i> Fuchs Desio: p. 331.
<b>1954</b>	<i>Echinolampas amplus</i> Fuchs Said and Tallouze: p. 77, pl. V,
<b>1972</b>	<i>Echinolampas amplus</i> Fuchs Mansour: p. 108, pl. XXVI.
<b>1990</b>	<i>Echinolampas amplus</i> Fuchs El – Hedeny: p. 17, pl. II.
<b>1996</b>	<i>Echinolampas amplus</i> Fuchs El – Hedeny: p. 60, pl. I,

**Material:** tow well-presented shells.

**Table (4):** The measurements of the specimens in terms of length, width, and weight.

<b>L</b>	<b>W</b>	<b>H</b>
81.3mm	75.7mm	32.9mm
86.1mm	88.3mm	30.2mm

#### **Description:**

The test is large and subcircular in outline, with a distinctly convex apical surface and a slightly concave oral surface. The apical disc is monobasal and positioned precentrally. The petals are moderately tumid, with the posterior lateral petals noticeably longer than the anterior ones. The poriferous zones of the anterior petals are shorter than those of the posterior petals. The periproct is oval in shape and located in a submarginal position, whereas the peristome is precentral and pentagonal in outline. The ornamentation consists of irregularly distributed, imperforate miliariid tubercles covering the test surface.

#### **Remarks:**

The examined specimens exhibit close morphological affinity to *Echinolampas amplus* Fuchs, as described and illustrated by Mansour (1972, p. 108, pl. XXXVI), and show strong correspondence with specimens documented by El-Hedeny (1996, p. 60, pl. I). These similarities support the taxonomic assignment of the studied material to this species.

#### **Age and Occurrence:**

Lower to Middle Miocene. The specimens were recovered from the Al Khums Formation, specifically from the coral-bearing deposits of Jabal An Naggazah, Al Khums area, northwestern Libya.



**Figure (3):** *Echinolampas amplus* Fuchs, 1883.

Lower to middle Miocene of Al Khums Libya. Miocene corals from Jabal An Naggazah, Al Khums, Libya.

**Table (5):** illustrates how species of the bivalve phylum were classified in terms of family, genus, and species.

<b>Superfamily</b>	LIMACEA	Rafinesque. 1851.
<b>Family</b>	LIMIDAE	Rafinesque. 1851.

Genus *Lima* Bruguiere. 1797.

Type species *Lima Alba* Cuvier, 1797.

(= *Ostrea Lima* Linne', 1758).

*Lima (Lima) lima* (Linne'), 1758.

**Table (6):** Previous studies of this type of bivalve.

<b>1758</b>	<i>Ostrea lima</i> (Linne'): p. 699.
<b>1819</b>	<i>Lima squamosa</i> (Linne'): Lamarch: p. 156.
<b>1912</b>	<i>Radula lima</i> (Linne'): Pallary: P. 152.
<b>1969</b>	<i>Lima (Lima) lima</i> (Linne'): in Moore: p. 368, Fig. 104, 3.
<b>1974</b>	<i>Lima (Lima) lima</i> (Linne'): Toni: p. 50, pl. II, Fig. 9.

**Material:** Three Moderately preserved shells.

**Table (7):** The measurements of these fossil specimens.

L	H	T
30 mm	32 mm	20.7 mm
30.9 mm	31.4 mm	21 mm
32.2 mm	32.5 mm	22 mm

**Description:** Shell oval, inequilateral, slightly convex, slightly higher than long, umbo terminal. Ornament consists of radial ribs which are fine and separated by smooth interspaces the radial ribs as wide as the intervals between them.

**Remarks:** The present specimens are quite similar to *Lima (Lima) lima* (Linne') described and figured by Moore (1969. p. 368, Fig.104. 3) and to that illustrated by Toni (1974, p. 50, Pl. II).

**Age:** Lower – middle Miocene of Gabal An Naggazah. This species is found in all the tropical seas. It is recorded from the Miocene deposits up to the Recent where it lives in the Mediterranean Sea and Atlantic and Indian oceans (Dollfus and Dautzenberg, 1920).



**Figure (4):** *Lima (Lima) lima* (Linne') 1758.

Lower middle Miocene of Gabal, An Naggazah Al Khums, Libya.

*Chlamys varia* (Linné), 1758.

**Table (8):** type of bivalve.

<b>1758</b>	<i>Ostra varia</i> (Linne'): P. 698.
<b>1931</b>	<i>Chlamys varia</i> (Linne'): Dautzenberg: P. 34.

1939	<i>Chlamys varia</i> (Linne): Roger: P. 157, Pl. XXII.
1971	<i>Chlamys varia</i> (Linne): Toni: P. 47, Pl. II.

**Material:** Three well preserved internal casts.

**Table (9):** The measurements of these fossil specimens.

L	H	T
49 mm	53 mm	12 mm
51 mm	58 mm	12.3 mm
52 mm	64 mm	12 mm

**Description:** Shell subovoidal in outline, slightly in equilateral. Beaks orthogyral. Ornament consists of 21 – 26 radial ribs as wide as the interspaces. Intervals between the radial ribs smooth and concave.

**Remarks:** The described specimens are quite similar to *Chlamys varia* (Linne) studied and figured by Roger (1939, P. 157, Pl. XXII). *Chlamys multistrita* Poli differs from the present species in having supplementary ribs where secondary ribs and found in the interspaces between the radial ribs.

**Age:** Lower – middle Miocene of AN Naggazah Al Khums Formation, Libya.



**Figure (5):** *Chlamys varia* (Linne). 1758.  
Lower middle Miocene of AN Naggazah,  
Al Khums Formation, Libya.

#### ***Chlamys scabrella* Lamarck.**

**Table (10):** Type of bivalve.

1939	<i>Chlamys scabrella</i> Lamarck: Roger: p. 104, pl. IIX, Figs. 8. 9- 9a. 10-. 10a, pl. IIIX, Figs. 3 – 13.
1972	<i>Chlamys scabrella</i> Lamarck: Hamza: p. 93, pl. II, Fig. 5- 5a – 5b, pl. III. Figs. 1 – 1a – 1b.
1976	<i>Chlamys scabrella</i> Lamarck: Metwally: P. 157, pl. VII, Fig. 6, pl. VIII, Figs. 1.

**Material:** One complete shell.

**Table (11):** The measurements of these fossil specimens.

L	H	T
27 mm	24 mm	0.57 mm

**Description:** Shell of moderate size auricles unequal: anterior one of the valves longer than posterior one. Wing – shaped ornamented with 5 slightly strong costules: posterior one triangular. With 16- 18 costae equal rounded in cross section. Separated by equal width the intercostals spaces with 2 fine costules.

**Remarks:** The studied species is similar to *Chlamys scabrella* Lamarck, described and figured by Hamza (1972, p. 93, pl. II, and pl. III).

**Age:** Lower and middle Miocene of Libya and Egypt. (Hamza 1972, Metwally 1976).



**Figure (6):** *Chlamys Scabrella* Lamarck.  
Lower and middle Miocene of Libya.

#### ***Pecten subarcuatus* Tournouer, 1873.**

**Table (12):** Type of bivalve.

1902	<u>Pecten subarcuatus</u> Tournouër: Déperet and Roman: p. 11, pl. I.
1920	<u>Pecten subarcuatus</u> Tournouër: Dollfus and Dautzenberg: p. 401, pl. XXXVI.
1972	<u>Pecten subarcuatus</u> Tournouër: Mansour: p. 142, pl. XXI.
1990	<u>Pecten subarcuatus</u> Tournouër: El-Hedeny: p. 28, pl. III.

**Material:** three well preserved shells.

**Table (13):** The measurements of these fossil specimens.

L	H	T
24 mm	22 mm	2.7 mm
27.2 mm	24 mm	3.6 mm
26.4mm	25mm	3.1

**Description:** Shell subtriangular, equilateral, posterior lateral margin longer than anterior lateral margin. Right valve moderately convex, left valve slightly concave. Beaks incurved and pointed. Ornament consists of 19-20 radial ribs, rounded in cross- section. Interspaces between tie radial ribs are more wider than the width of the ribs. The radial ribs have high relief in the ventral portion than in the dorsal part.

**Remarks:** Pecten subarcuatus Tournouër resembles those described and figured in Depéret and Roman (1902, p. 11, pl. I, Figs. 1-4) but the latter are characterized by less curved cross-section of their radial ribs and the intervals wider than that of the above described species. The present specimens exhibit great similarity to Pecten subarcuatus Tournouër described and figured by El-Hedeny (1990, p. 28, pl. III, Figs. 3-4) that described and figured by Mansour (1972, p. 142, pl. XXI).

**Age:** Lower -middle Miocene of AN Naggazah, and Wadi Kreim in AL Khums area.



**Figure (7):** Pecten subarcuatus Tournouër, 1873.  
Lower -Middle Miocene of AN Naggazah, Is of east Formation  
Al Khums and Wadi Kreim Al Khums area.

**Table (14):** The classification of gastropod fossil species.

<b>Class</b>	GASTROPODA	Cuvier, 1797.
<b>Order</b>	MESOGASTROPODA	Thiele, 1929.
<b>Family</b>	TURRITELLIDAE	Clark, 1851.

**Genus** Turritella Lamarck, 1799.

**Type species** Turritella terebra Linnaeus, 1758.

**Subgenus** Torquesia Douville, 1929.

**Type species** Turritella granulata Sowerby, 1957.

Turritella (Torquesia) coxi Abbass, 1963.

**Table (15):** presents previous studies.

1963	<u>Turritella (Torquesia) coxi</u> Abbass: p. 33, pl. II,
1996	<u>Turritella (Torquesia) coxi</u> Abbass: El-Hedeny: p. 134, pl. X.

**Material:** Two well preserved internal casts.

**Table (16):** Measurements of shell height, elevation angle, and spiral width.

Height of The shell	Height of the whorle	Width of the whorle	Spiral Angle
49 mm	10 mm	9 mm	24°
51 mm	12 mm	13 mm	24°

**Description:** Shell large, the whole outline straight, spire narrow, width of the whorle slightly higher than height. The sutures superficial. Ornament consists of about eight spiral cords separated by wider interspaces and crossed by growth lines. The growth line chord prosocline.



**Remarks:** The present species resembles *Turritella* (*Torquesia*) *coxi* Abbass described and figured (1963, p. 33, pl. II).

**Age:** Middle Miocene of An Naggazah Al Khums formation, Libya.



**Figure (9):** *Turritella* (*Torquesia*) cold Abbass, 1963.  
Middle Miocene of An Naggazah, Al Khums, Libya.

## Discussion

The fossil assemblages examined in this study were recovered from multiple stratigraphic horizons within the Lower and Middle Miocene successions exposed in the Al Khums area of northwestern Libya. Systematic paleontological analysis led to the identification of a total of fourteen species, comprising two species assigned to the class Echinodermata, ten species belonging to the class Bivalvia, and two species attributed to the class Gastropoda. This taxonomic composition reflects a predominantly marine assemblage characteristic of shallow to moderately shallow depositional environments during the Miocene. Representative specimens of the identified taxa are illustrated and systematically described, with emphasis placed on their diagnostic morphological features. Comparative taxonomic assessments were undertaken to evaluate their affinities and relationships with closely related and previously documented taxa from both regional and global Miocene successions. These comparisons contribute to refining species-level identifications and to elucidating patterns of faunal similarity and biogeographic distribution within the Mediterranean–Tethyan realm. The systematic framework adopted in this study follows the classification scheme proposed by Moore et al. (1966, 1969) in *A Treatise on Invertebrate Paleontology*, which remains a foundational reference for invertebrate paleontological taxonomy. This classification system was applied consistently, particularly for the classes Echinodermata and Bivalvia, ensuring taxonomic rigor and facilitating meaningful comparison with earlier paleontological studies conducted in Libya and adjacent regions.

## Conclusion

This study provides a systematic paleontological assessment of macrofossil assemblages from the An Naggazah Member of the Al Khums Formation in northwestern Libya, offering new insights into the composition and diversity of lower to middle Miocene marine faunas. Based on detailed analysis of fourteen stratigraphically constrained rock samples, the identified assemblages, comprising representatives of the classes Echinozoa, Bivalvia, and Gastropoda, reflect a diverse and well-established marine ecosystem. The documentation of several taxa that are rarely reported from the Al Khums Formation or from Libyan Miocene deposits more broadly significantly expands the regional fossil record and improves taxonomic resolution for this stratigraphic unit. These findings contribute to a more refined understanding of Miocene paleoecological conditions, biogeographic patterns, and faunal evolution in the southern Mediterranean realm. Overall, the study underscores the paleontological importance of the Al Khums Formation and highlights the need for further detailed investigations to support stratigraphic correlation, paleoenvironmental reconstruction, and conservation of Libya's geological heritage.

## Recommendations

- The Al Khums Formation, which is composed primarily of clay, limestone, and gypsum, is notably rich in carbonaceous and biogenic fossil content. This formation warrants focused paleontological attention due to its scientific and stratigraphic significance.
- Detailed investigation of fossil assemblages preserved within the stratigraphic units of the Al Khums Formation is recommended to improve interpretations of depositional environments, paleoenvironmental conditions, and relative energy regimes during sediment accumulation.
- Further systematic paleontological studies are strongly recommended to enhance the identification, classification, and formal taxonomic description of fossil groups within the formation, with particular emphasis on bivalves, which represent a dominant and diverse component of the assemblages.
- Fossil evidence should be more extensively utilized to reconstruct depositional settings and paleoecological frameworks, thereby strengthening regional stratigraphic correlations and environmental interpretations.

- The application of Geographic Information Systems (GIS) is recommended for the precise identification, spatial documentation, and mapping of fossil occurrences within the Al Khums Formation, facilitating the development of an integrated paleontological database.
- Comprehensive fossil distribution maps of the Al Khums Formation should be prepared and made available to engineering consultancies and geotechnical laboratories. These maps should be accompanied by clear guidelines and mandatory recommendations for fossil conservation, to be included in soil investigation and geotechnical reports submitted for construction projects, road development, and other infrastructure works.
- Specialized training programs should be organized for engineers and technical staff in engineering offices and laboratories to build capacity in fossil identification, documentation, and protection methods during site investigations and construction activities.
- Recovered fossils should be preserved under suitable and controlled conditions following excavation to prevent erosion, weathering, and physical damage, recognizing their importance for reconstructing Earth's geological history, understanding past biodiversity, and establishing the relative ages of sedimentary rock units.
- Enhanced collaboration between geologists and professional diving specialists is recommended, with trained divers actively participating as technical experts in the exploration and documentation of submerged or underwater fossil occurrences along the coastal and nearshore environments associated with the Al Khums Formation.

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