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Revisiting Late Pennsylvanian (Kasimovian) corals of Egypt: New perspectives and contributions

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THE BASAL calcareous/dolomitic mudstone beds of the Kasimovian lower member of the Aheimer Formation in the Northern Galala Plateau (western side of the Gulf of Suez) harbour a distinctive assemblage of rugose corals, marking the youngest Carboniferous coral fauna from the southern margin of the western Palaeotethys, that is to say along the northern margin of western Gondwana. This study presents new taxonomic insights into this unique coral fauna, describing three species from the Antiphyllidae and Plerophyllidae families. They include *Monophyllum maxima* sp. nov. and two yet unnamed species of *Monophyllum* sp. and *Ufimia* sp. The coral retrieved association are generally simple structured and non-dissepimented. Colonial rugosa are missing and tabulate corals are very rare. Comparisons with global taxa and palaeogeographic considerations suggest connections with northern Spain and the Cordilleran–Arctic–Uralian realm.

Keywords: Cornute rugosa, *Monophyllum*, Carboniferous, Northern Galala, Gulf of Suez.

1. Introduction

Carboniferous deposits in Egypt are distributed as scattered and discontinuous outcrops on both sides of the Gulf of Suez (Fig. 1A). On the eastern side of the gulf, these deposits are exposed in west-central Sinai at Um Bogma, Wadi Feiran and Abu Durba areas. On the west, they can be found in the Northern Galala (Fig. 1 B), Abu Darag, Wadi Araba and at Wadi El-Dakhel (Said, 1971; Issawi and Jux, 1982; Klitsch, 1990; Kora, 1998; Ernst et al., 2020; El-Desouky et al. 2023 and references therein). Pennsylvanian rugose corals are found in the exposed strata on both sides of the Gulf of Suez. However, they are scarcely found in the upper Moscovian Abu Durba Formation in the Abu Durba area to the east. Conversely, they are more prevalent in strata along the eastern and southern scarps of the Northern Galala Plateau to the west (Fig. 1 B). Notably, the rugose corals from the Abu Durba area have not yet been investigated, whereas those of the upper Moscovian Rod El Hamal Formation from the southern rim of the Northern Galala Plateau in Wadi Araba have been thoroughly studied by Kora et al. (2019). Additionally, the Kasimovian rugosa were investigated by Kora and Mansour (1991) and recently by El-Desouky et al. (2023) from the eastern cliffs of the Northern Galala Plateau. Generally, limited research has been conducted on the rugose corals encountered in the eastern cliffs of the Northern Galala Plateau.

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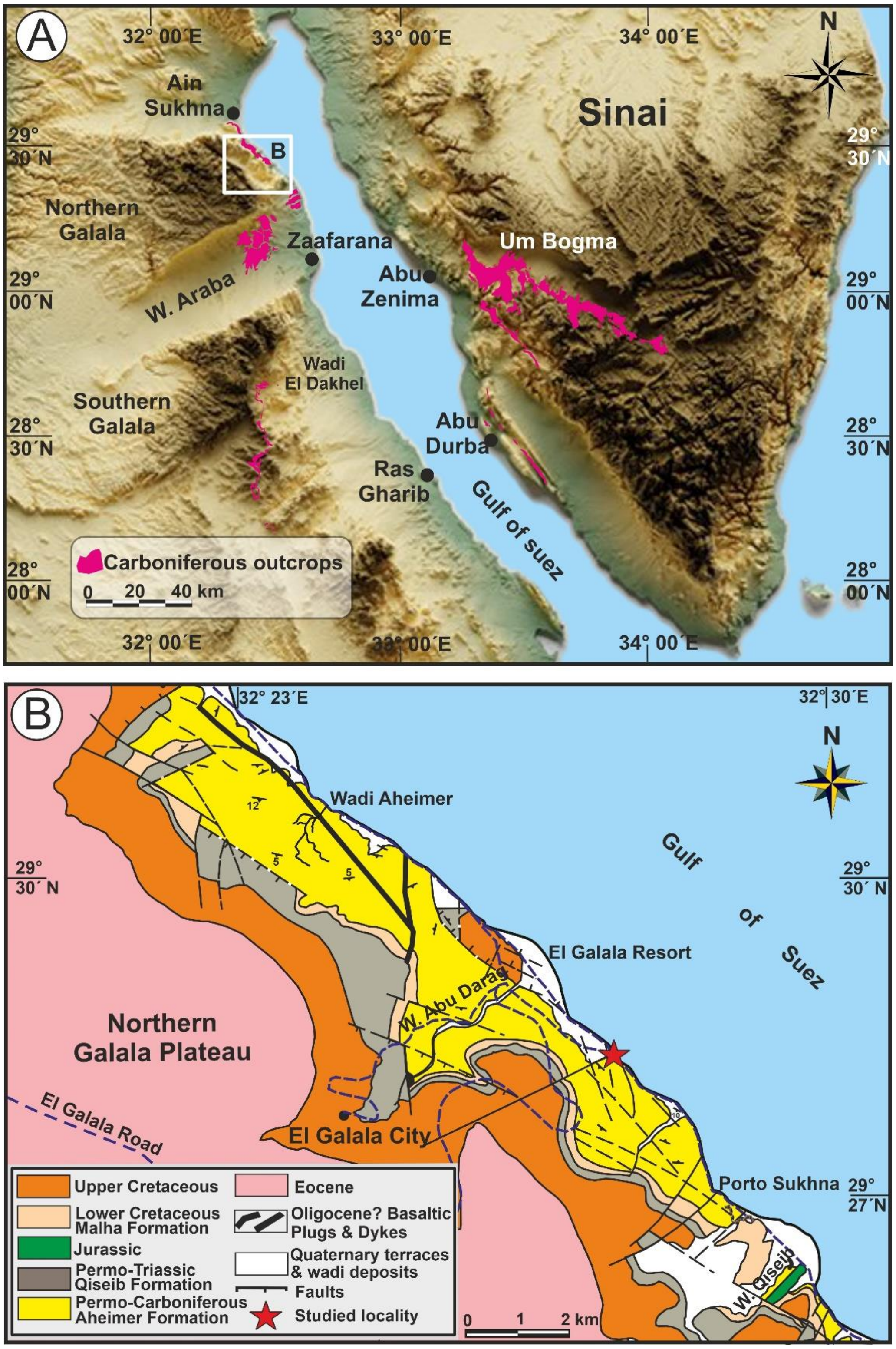

Fig. 1. A. Distribution of the Carboniferous outcrops in the Gulf of Suez area (adapted from Kora, 1998). B. Geological map of the eastern cliffs of the Northern Galala Plateau (modified after Abdallah and El Adindani (1965).

In 1965, Abdallah and El Adindani made initial observations that only acknowledged the presence of corals without providing a detailed investigation or description. Decades later, Kora and Mansour (1991) studied these corals in more detail, using one transverse section below the calice and a longitudinal thin section. They identified 17 species belonging to 13 genera and 5 families. However, most of their identifications have been revised and compared with the recently acquired material by El-Desouky et al. (2023), who have identified 10 taxa belonging to 4 families, including four new species.

Herein, the author presents new findings from a newly conducted sampling of rugose corals from the Kasimovian lower member of the Aheimer Formation, which is exposed at the Eastern foothills of the Northern Galala Plateau (Fig. 1B); 2 km south of El Galala Resort and about 3 km north of Porto Sukhna (Lat. 29°28′ 01″ N and Long. 32°27′36″ E). However, it is important to note that the landscape has undergone significant transformations due to industrial, domestic, and tourism projects in recent years. Consequently, many fault blocks in the area have been partially destroyed. Despite these changes, the type section, which hosted the identified species by El-Desouky et al. (2023), as well as the herein newly studied materials, remains largely intact, albeit with partial coverage at its base in certain locations.

2. Geological and stratigraphic setting

Recent comprehensive studies by El-Refaiy et al. (2023) provided detailed insights into the stratigraphic context of the studied succession. The Permo-Carboniferous Aheimer Formation is exclusively documented along the eastern foothills of the Northern Galala Plateau, situated on the western side of the Gulf of Suez (Figs. 1A, B). It is typically exposed at Wadi Aheimer; approximately 10 km SSE of Ain Sukhna (Abdallah and Adindani, 1965). At its type locality, it is unconformably overlain either by the Permo-Triassic red beds of the Qiseib Formation or by the Lower Cretaceous pebbly sandstone beds of the Malha Formation (Said 1990; Abdallah and Adindani 1965). While the base of the Aheimer Formation remains unexposed southward, it has been suggested to either rest conformably over or interfinger with the Abu Darag Formation (Awad and Said, 1966; Klitzsch, 1990) or the Rod El Hamal Formation (Said, 1971).

The stratigraphic context of the Aheimer Formation was initially introduced by Abdallah and Adindani (1965), who documented a roughly 250-meter-thick succession at its type locality, followed by subsequent studies by several authors (e.g., Abd El-Azeam, 1990; Kora and Mansour, 1992 and El-Desouky et al., 2023). Recently, the formation has been subdivided by El-Refaiy et al. (2023) into four informal units (see Fig. 2A), correlating them with the previous subdivisions by other researchers (refer to Table 2 therein).

Unit I of El-Refaiy et al. (2023) termed the "*Tisoa*-bearing unit", corresponds to the lower member of Kora & Mansour (1992) and the *Lophophyllidium*-bearing shale unit of Abdallah and El Adindani (1965). According to Kora and Mansour (1992) and El-Refaiy et al. (2023), this unit reaches a thickness of approximately 40 m. Its basal 32-34 m consists of dark grey shales, intercalated with ca. 0.1 to 0.5 m- thick reddish brown ferruginous hard siltstone, sandstone and sandy dolomite interbeds (see Fig. 2A, C). These layers are richly fossiliferous with various macro and microfauna, including small rugose corals, bryozoans, disarticulated crinoidal columnals, brachiopods, agglutinated foraminifers, ostracods, and conodonts (Fig. 2C). The upper part of the unit is composed of variegated fissile shale, interbedded with thin-bedded siltstones and sandstones (Figs. 2A, D). These beds exhibit significant bioturbation, characterized by simple deep and vertical burrows of the *Glossifungites* ichnofacies (*Tisoa* ichnotaxon)

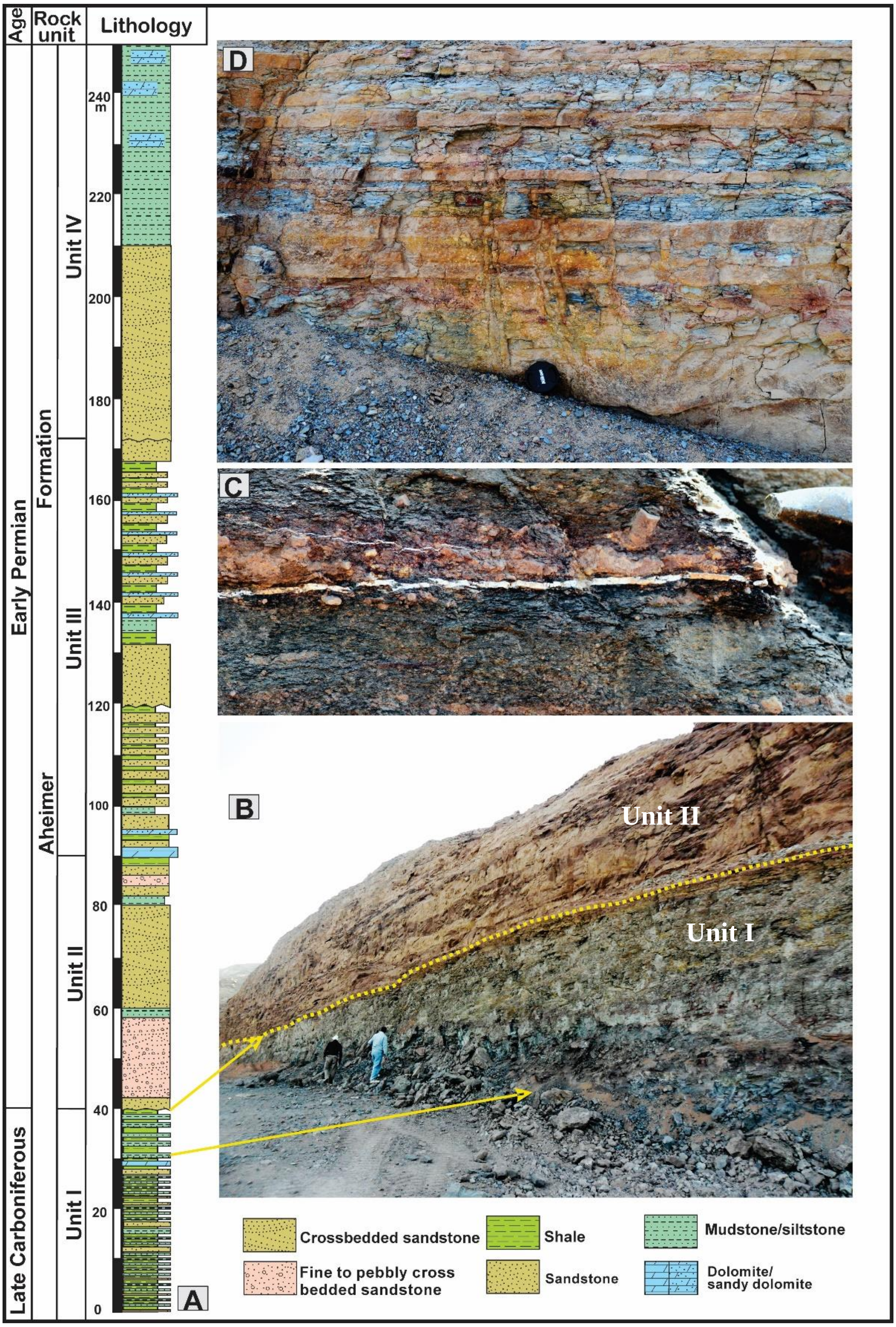

Fig. 2. A. Lithostratigraphic succession of the Aheimer Formation studied at Wadi Aheimer, on the eastern cliffs of the Northern Galala (adapted from El-Refaiy et al., 2023). B. Field photograph shows the upper shaly part of unit I, overlain uncomformably by the lower sandstones of unit II. C. Fossiliferous shales intercalated with thin bands of ferruginous dolomitic limestone. Note the abundance of fossil fragments of corals and crinoids. D. Close-up view of the uppermost part of uint I, showing the vertical, long burrows of *Tisoa siphonalis* penetrating through the alternating shales and sandy dolostone beds.

(Fig. 2D). In their study of the Wadi Aheimer and Abu Darag areas, El-Refaiy et al. (2023) did not mention the high occurrence of the rugose corals in the lower part of this unit, which has been previously recorded by Abdallah and El Adindani (1965), Kora and Mansour (1991), El-Desouky et al. (2023) and the current study. Consequently, they disregarded the *Lophophyllidium*-bearing shale nomenclature attributed to the rocks of Unit I by Abdallah and El Adindani (1965). Instead, they adopted the name "the *Tisoa*-bearing unit" due to the prevalence of the *Tisoa* ichnotaxon in its upper part. This nomenclature had previously been contested by Kora and Mansour (1991) and El-Desouky et al. (2023) due to the absence of the *Lophophyllidium* corals in these strata. Notably, in our study area, this unit is most prominently exposed near Wadi Abu Darag (El Galala Resort). Based on the previous age dating using its macro- and microfaunal content and its stratigraphic position relative to the underlying upper part of the Rod EL Hamal Formation (Kora et al., 2019), El-Desouky et al. (2023) assigned this unit to the Kasimovian age.

Unit II of El-Refaiy et al. (2023) correlates with the lower beds of the middle limestone-sandstone series of Abdallah and Adindani (1965) and the lower horizon of the middle member of Kora and Mansour (1992). It is best exposed at Wadi Aheimer, with an approximate thickness of 50 m. This unit primarily consists of yellowish-brown cross-bedded sandstones intercalated with siltstones (Figs. 2A, B). El-Refaiy et al. (2023) recorded plant remains (*Calamites* sp.) and occasional trace fossils within these rocks, and assigned it Early Permian age based on the sharp stratigraphic discontinuity with the underlying unit I.

Unit III of El-Refaiy et al. (2023) corresponds to the upper beds of the middle limestone-sandstone series of Abdallah and Adindani (1965) and the upper beds of the middle member of Kora and Mansour (1992), with a thickness of ca. 82 m in Wadi Aheimer. This unit is composed mainly of sandstones, partially kaolinitic siltstones, and variegated shale interbeds, intercalated with two to three thin fossiliferous sandy dolomite beds that become more abundant towards the top of the unit (Fig. 2A). El-Refaiy et al. (2023) reported plant remains from the shale beds in the lower part of this unit, in addition to brachiopods, crinoid fragments, and foraminifers from the dolomite layers, confirming an Early Permian age, as previously suggested by Kora & Mansour (1992) for these rocks.

Unit IV by El-Refaiy et al. (2023) correlates with the sandstone series of Abdallah and El Adindani (1965) and the upper member of Kora and Mansour (1992). It predominantly consists of thick-bedded sandstones, siltstones, and shales, with an average thickness of about 78 m at Wadi Aheimer (Fig. 2A). El-Refaiy et al. (2023) noted rare brachiopod imprints and trace fossils from the sandstones of the topmost part of this unit. They extended the Early Permian age to include this unit based on the rare fossil content and the stratigraphic continuity with the underlying unit III.

3. Materials and Methods

A renewed sampling effort targeting the Pennsylvanian corals from the basal shales of the Aheimer Formation yielded a limited association consisting of five rugose coral specimens and a poorly preserved tabulate coral. The apparent scarcity of the corals in this succession can be attributed mainly to ongoing construction and development activities in the region, which have resulted in the covering of most of the basal shales bearing the corals.

Two of the rugose specimens, along with the tabulate coral, exhibit significant deterioration (Fig. 3), with their internal parts almost entirely dolomitized and ferruginized, hindering proper identification. The collected specimens underwent cleaning and photographic documentation using ammonium chloride whitening. Subsequently, the corallites were saturated with resin under vacuum conditions to facilitate the preparation of transverse serial thin sections. These thin sections were then photographed and examined using the microscope. All diameter measurements of the sections represent alar diameters. The abbreviation "n:d" represents the ratio of the number of septa (n) to corallite diameter (d).

The studied material is currently housed at the Geology Department, Faculty of Science, Mansoura University, Mansoura, Egypt.

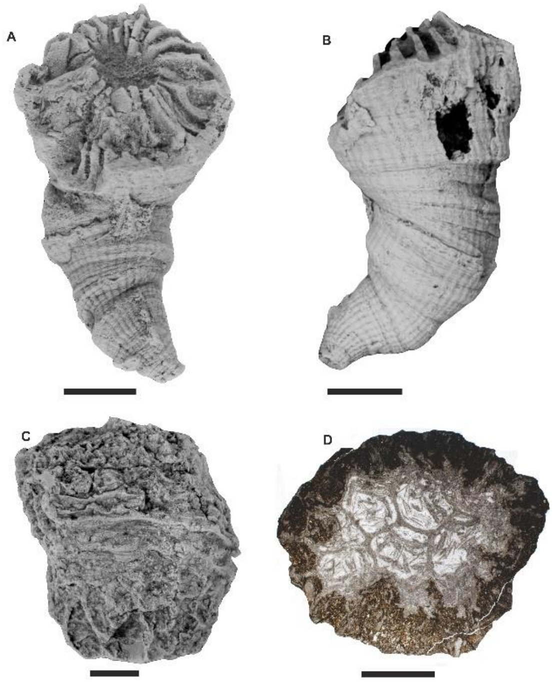

Fig. 3. Impact of diagenesis on two coral specimens: A–B. External views of an antiphyllid rugose coral specimen (*Rotiphyllum*? sp.), displaying well-preserved epithecal wall showcasing septal furrows, growth lines, constrictions, and rejuvenations. Additionally, apparently well-preserved septa are observed at the base of the eroded calyx. Despite the apparent preservation of outer features, internal dolomitization and ferrugination have resulted in hollow portions within the corallite (B). C–D. A tabulate coral (*Michelinia* sp.), showing relatively well-preserved colony morphology (C) however, internal structures exhibit significant damage (D).

4. Systematic Palaeontology

Order: **Stauriida Verrill, 1865**

Suborder: **Stereolasmatina Hill, 1981**

Family: **Antiphyllidae Ilina, 1970**

Genus: ***Monophyllum* Fomichev, 1953**

Type species: *Monophyllum sokolovi* Fomichev, 1953.

Diagnosis: Small solitary corals, without dissepimentarium. Major septa arranged radially and may retreat slightly from the corallite center as it matures, while minor septa underdeveloped. Alar septa slightly elongated at least in part of growth. Cardinal septum tends to short from early maturity, while counter septum is strongly and permanently elongated towards the corallite axis (after Fedorowski, 1987, p. 67).

Geographic and stratigraphic range: The genus *Monophyllum* exhibits a wide geographic (Fig. 8) and stratigraphic distribution. It has been recorded from various spatial and temporal windows, including the Bashkirian of the Donets Basin (Fomichev, 1953; Kossovaya, 1996 and Fedorowski, 2022), the Moscovian of the same region (Fomichev, 1953; Kossovaya, 1996 and Ogar, 2012), and of Novaya Zemlya (Fedorowski, 1981 and Wang et al., 2022) as well as the Kasimovian of Egypt (El-Desouky et al., 2023 and materials described herein). Additionally, it is identified from the Pennsylvanian-Permian transition, and the Wolfcampian (Asselian–middle Artinskian) of southwest Texas (Fedorowski, 1987).

***Monophyllum maxima* sp. nov.**

(Fig. 4 A1 – G)

Etymology: Derived from Latin *maxima*, meaning "greatest", referring to the lager n:d ratios observed in this species compared to other species of the genus.

Holotype: Only one specimen (RCA 1), shown in Figs. 4 (A1–G). Six transverse thin sections are available for study. No other paratypes are available.

Type locality: Eastern scarps of the Northern Galala plateau (Lat. 29°28′ 01″ N and Long. 32°27′38″ E), northern Eastern Desert, western side of the Gulf of Suez, Egypt.

Type horizon and age: Basal shale beds of the lower member of the Aheimer Formation; Upper Pennsylvanian (Kasimovian).

Diagnosis: *M. maxima* sp. nov. exhibits a maximum n:d ratio (26:13) at calice base. The cardinal septum is shortened late in ontogeny and thinner than all other major septa. The counter septum is elongated from the immature stage up to the calice floor.

Description:

External Features: Moderately well-preserved small solitary coral (Figs. 4 A1–A3). Slightly curved, trochoid in shape, measuring approximately 3 cm in length on its convex side. The well-preserved epitheca (ca. 0.8 mm in thickness) bears distinct septal furrows and concentric lines. The calyx and the apical tip are not preserved. There is a remnant node in the apex flank, possibly indicating an attachment scar. The cardinal fossula is situated on the concave side of the corallite.

Internal features: The earliest preserved ontogenetic stage shows 19 septa in approximately 5.8 mm of the corallite alar diameter (Fig. 4B). In this stage, major septa are pinnately arranged and exhibit a zaphrentoid arrangement. They are thick and dilated adaxially, with the cardinal septum thinner but retaining a dilated base. The counter septum is slightly thicker than the adjacent major septa, and relatively longer. The cardinal fossula is evident with a long, thin cardinal septum that reaches the corallite axis, and merges with other major septa forming a stereocolumn. At this stage, the alar fossular breaks are marked. However, there are no minor septa present. The section above is made at a diameter of 6.3 mm with 22 major septa (Fig. 4C). The number of septa increases rapidly in the counter quadrants. The septal arrangement and the shape of the alar and cardinal fossulae are very close to the lower, less mature, section. The counter septum becomes longer. In the counter quadrants, two incomplete rows of tabulae are observed. Minor septa are still absent.

In the subsequent section, the corallite diameter measures 9.4 mm, hosting 25 septa (Fig. 4D). At this stage of maturity, major septa exhibit a trend towards thinning, with the cardinal septum appearing the thinnest, while the counter septum develops a rhopaloid end. The pinnate arrangement of septa transitions to a semiradial type. Within the corallite lumen, there are five incomplete rows of tabulae, forming incomplete concentric circles around the axial stereocolumn. Minor septa are rudimentary, primarily confined to the left cardinal quadrant (Fig. 4D). Continuing into further maturity, at diameters of 12 mm and 12.3 mm, the corallite hosts 26 radially arranged major septa (Figs. 4E, F). Minor septa remain underdeveloped.

The counter septum elongates further, with a more pronounced rhopaloid end extending slightly beyond the central part of the stereocolumn. The alar fossulae are less conspicuous, while the cardinal fossula assumes a triangle shape and open adaxially. The long cardinal septum begins to retract, becoming shorter compared to the other major septa. Five incomplete concentric rows of tabulae persist, along with a pronounced biform reduction of minor septa is well developed. The last mature stage sectioned below the calice base (Fig. 4G), records 26 septa in a diameter of 13 mm. Major septa in the left cardinal quadrant are somewhat crooked and broken due to the compression of the calical part of the corallite. Around the central stereocolumn, there are 2 incomplete rows of tabulae, predominantly visible in the counter quadrants. The cardinal septum becomes shorter and is confined to the corallite wall.

Remarks:

On a generic level, *Monophyllum maxima* sp. nov. differs from *Actinophrentis* Ivanovski, 1967 in the arrangement of septa with maturity. While major septa in *Actinophrentis* are pinnately arranged up to the calice floor, this character is not observed in *M. maxima* sp. nov., where septa transition from sub-radial to radial arrangement with maturity (Figs. 4E–G). Furthermore, *M. maxima* sp. nov. cannot also be allocated to *Lytvolasma* Soshkina, 1925, due to the absence of the deep, key-hole cardinal fossula which often bordered by half aulos in the counter quadrants, a notable diagnostic feature of the *Lytvolasma*. Similarly, *M. maxima* sp. nov. also cannot be related to *Rotiphyllum* Hudson, 1942, as *Rotiphyllum* exhibits a longer cardinal septum that reaches the corallite centre along the cardinal fossula in all growth phases, a feature absent in *M. maxima* sp. nov.

On the species level, *Monophyllum* represents a rare taxon, with only five species hitherto known worldwide. In addition to the type species (*Monophyllum sokolovi* Fomichev, 1953); there are *M. parvum* Fomichev, 1953; *M. cassum* Fedorowski, 1987, *M.* sp. Fedorowski, 1987and *M. galalaensis* El-Desouky et al., 2023.

The current species varies from *Monophyllum sokolovi* in the stronger formation of the stereocolumn, which constitutes up to two-thirds of the corallite diameter in *M. sokolovi*, whereas in *M. maxima* sp. nov., it is loose and accounts for only one-third of the corallite diameter. Additionally, it exhibits larger n:d ratios than *M. sokolovi* (Fig. 6, Table 1). It also differs from *M. parvum* from the Bashkirian of the Donets Basin by its larger n:d ratios (Fig. 6, Table 1); (26:13 vs. 22:8.3, respectively) at the last preserved mature part. Comparison with *M. cassum* Fedorowski, 1987 from the Lower Wolfcampian (Lower Permian) of southern Texas reveals a completely different species, *M. maxima* sp. nov., with higher n:d ratios (Fig. 6, Table 1). Furthermore, the loose stereocolumn expressed in the current species is not found in the *M. cassum*. Additionally, *M. maxima* sp. nov. lacks the free axial area, a feature that distinguishes the *M. cassum* in the late neanic/early ephebic and even to the last ephebic stage, a feature potentially present in the most mature part of the calice base, which is not preserved in *M. maxima* sp. nov. The studied species differs from the *Monophyllum* sp. recorded by Fedorowski, 1987 from the previous region in terms of the rhopaloid character of the major septa, more radial arrangement, smaller dimensions, and the absence of the stereocolumn in *M*. sp. Fedorowski, 1987.

M. maxima sp. nov. differs from the Egyptian *M. galalaensis* which is recovered from the same horizon by its greater n:d ratio (26:13 *vs*. 24:11) for the last preserved mature stage. At this stage, septa retreat from the axis and leave a narrow free axial area in *M. galalaensis* in contrast to the current species where septa are still joined together at the axial area.

***Monophyllum* sp.**

(Fig. 5 A–D)

Material: Only one specimen (RCA 2), illustrated in Figs. 5 A–D. Five transverse thin sections are available; 3 of them are well-preserved enough for description and illustrations, whereas the other two lower sections suffer from diagenesis that hinders better description and illustrations. The specimen is collected from basal beds of the lower member of the Aheimer Formation; Upper Pennsylvanian (Kasimovian).

Description:

External features: Moderately well-preserved small solitary coral (Fig. 5A). Trochoid in shape and 2.5 cm long on its convex side. Septal furrows are clearly preserved on the epitheca near the apex. Calyx is partly preserved, and apical part is not preserved.

Internal features: The three prepared sections of this species are made approximately in the mature part of

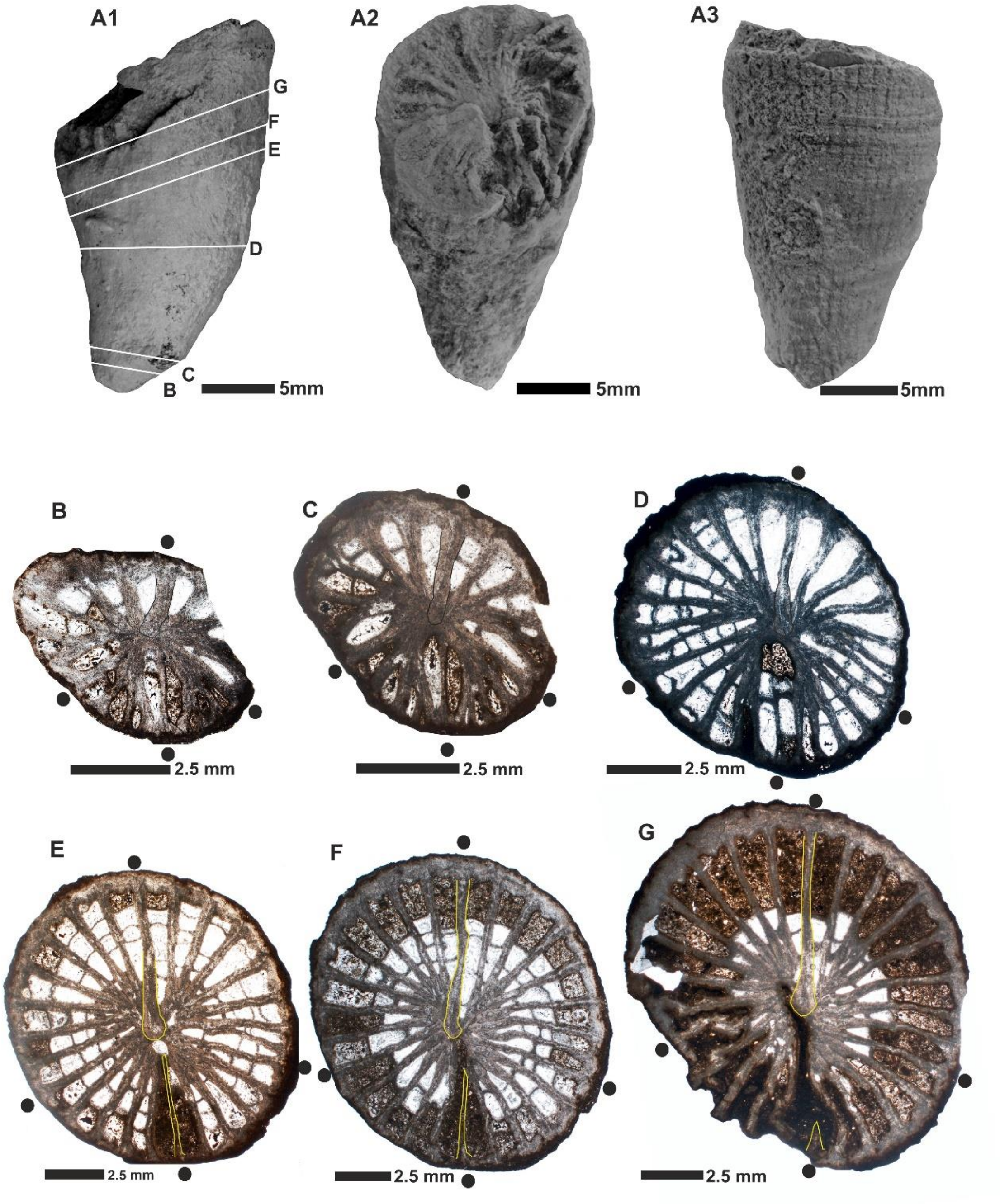

Fig. 4. The holotype of *Monophyllum maxima* sp. nov. A1–A3 External views of the holotype specimen (RCA 1), showing a trochoid corallite, with eroded calical rim and well-preserved epitheca exhibiting septal furrows and fine concentric growth lines. Positions of the thin sections are shown in A1. B–C. Two successive transverse thin sections in the early growth stages, showing the zaphrentoid arrangement of septa, long counter septum, and thin cardinal septum. D. Transverse section in the middle mature part of the corallite, showing the pinnate arrangement of septa. E–G. Three successive transverse sections in the late mature part of the corallite, showcasing radial arrangement of septa, elongated counter septum, thinning of the cardinal septum axially that shortens late with maturity in G, in addition to the triangular fossula. Black dots display the positions of cardinal septum (below), counter septum (above), and the two alar septa.

the corallum. In the lowest and least mature section (Fig. 5B), there are 25 septa in 11 mm alar diameter. In this section, major septa are radially arranged. Cardinal septum terminates with a tabula, which hinders it from reaching the centre. The counter septum is the longest and curved with its distal end, it invades beyond the corallite axis to enter the cardinal quadrants. Neither cardinal nor alar fossulae are marked in this section. Minor septa are not developed. Major septa are axially thickened to form a large stereocolumn, that constitutes up to half of the corallite diameter. One of the counter lateral septa, to the right of the counter septum is exceptionally, unusually elongated than other majors. One row of concentric tabulae is visible between septa, although some tabulae are not preserved due to the dolomitization of internal spaces between septa and even of septa. The section above (Fig. 5C) has the same n:d ratio (25:11). Major septa still form a strong stereoplasm, due to the thickening of the septa axially. Of them, the counter septum is still the longest with a rhopaloid end, that extends beyond the centre of the corallite. Cardinal septum is thinning axially unlike all other majors. The fossular breaks are still undetectable.

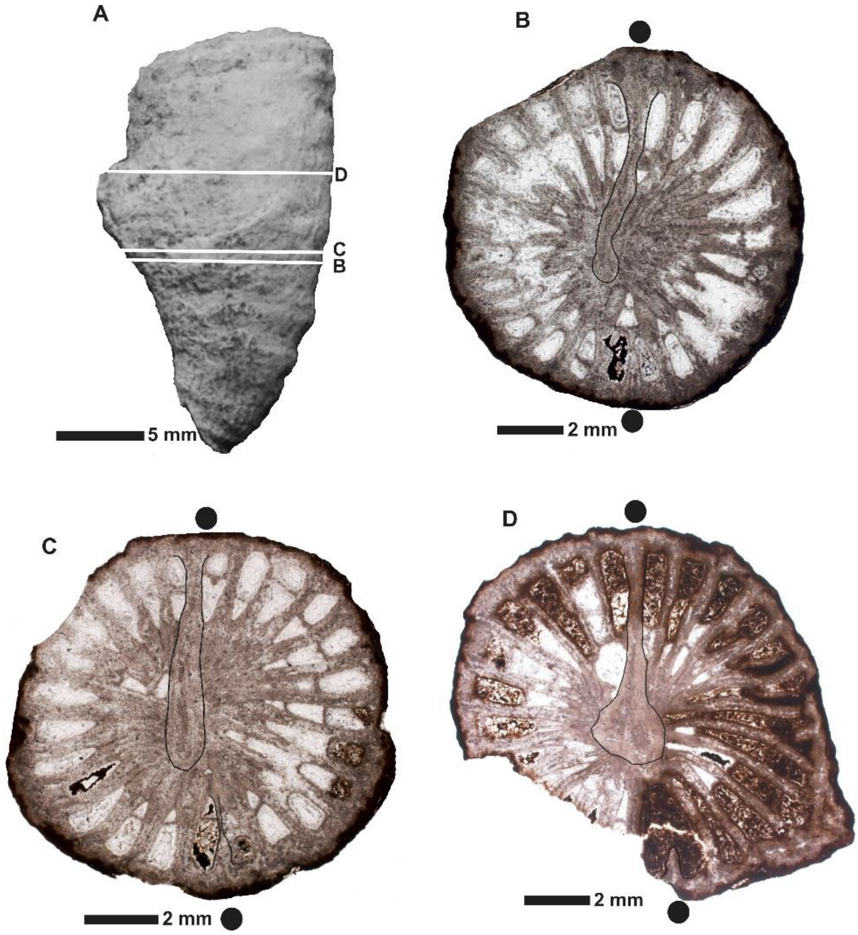

Fig. 5. *Monophyllum* sp. A. lateral view of the corallite (RCA 2) shows fairly eroded epitheca with faint septal furrows preserved near the apex. Positions of thin sections indicated. B–D. Two successive transverse thin sections in the mature part of the corallite, showing the domination of the counter septum with its rhopaloid end with maturity, in addition to thinning and reduction of the cardinal septum with maturity. Black dots display the positions of cardinal septum (below), counter septum (above).

The unusual manner of the lateral counter septum of the previous lower section is not found in this section, as it equals the other adjacent septa in length. Another unusual manner of the counter lateral septa on the left side with three adjacent major septa are shorter than the other majors and make a close hole in the stereocolumn. Two incomplete rows of tabulae are visible in the corallite lumen. The last mature section prepared below the calice base (Fig. 5D) is partly destroyed and slightly compressed, affecting the septa on the right side, that are crocked and partly broken. Counter septum is the longest with a remarkably enlarged or swollen end. In this stage the stereocolumn is moderately loose. Cardinal septum is short, forms a spike protrude from the corallite wall in a triangle cardinal fossula. Major septa in the three sections are radially to sub-radially arranged. Minor septa are not developed until this stage of maturity.

Remarks: The current species distinctly differs from any other species of *Monophyllum* with the domination of the counter septum with the club-shaped end, at least in the recorded mature part of the studied specimen. Comparisons with other species are listed in Table (1) and Fig. (6). The studied specimen definitely forms a new species. Nevertheless, more material and transverse thin sections in the immature part of the corallite would be necessary to exclude its open nomenclature.

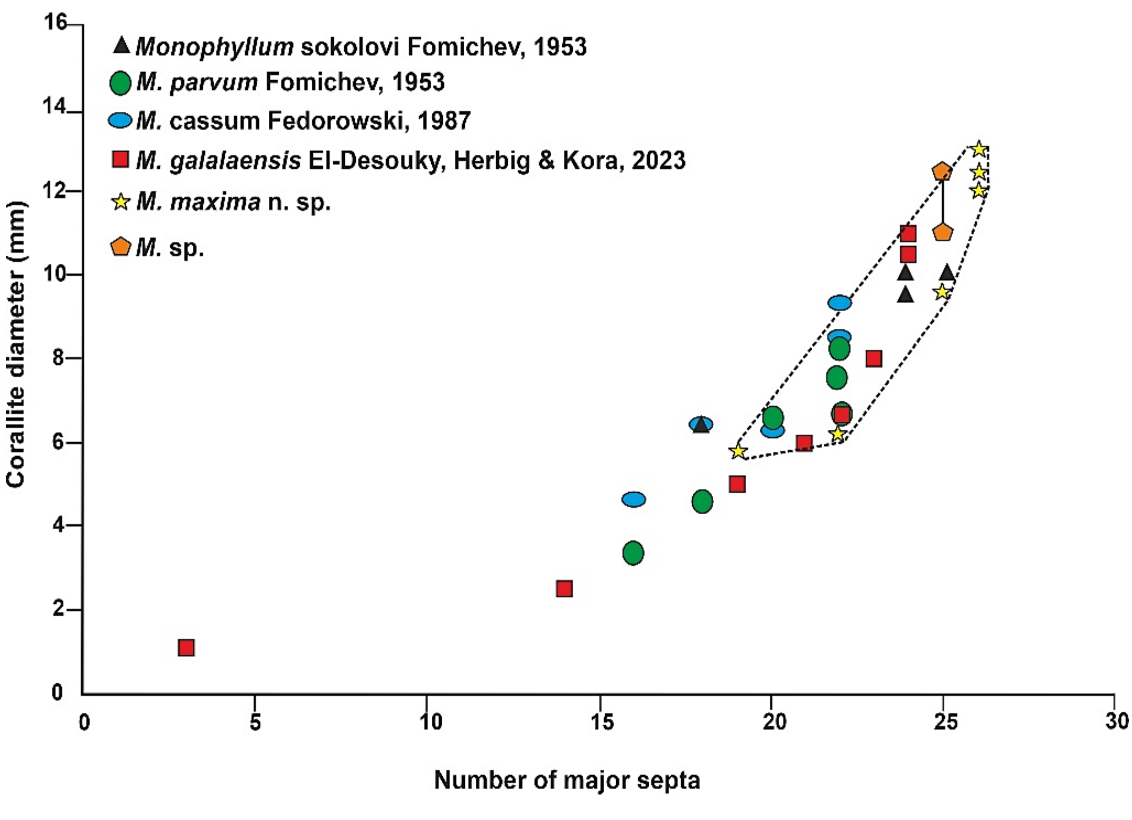

Fig. 6. Morphometric relationship between number of major septa and coralla alar diameters for the known species of *Monophyllum*. The cluster outlines the newly described *M. maxima* sp. nov.

Table 1. Morphological comparison of the worldwide record of *Monophyllum* species. * refers to new taxa described in this work.

Name of species	Major septa	Cardinal septum	Cardinal fossula	Counter septum	n:d ratio
***Monophyllum sokolovi* Fomichev, 1953**	Long, straight, thick, join with their inner ½ to 2/3 of their length to form a dense stereocolumn, retreat a little lately in maturity	Slightly shorted with maturity	Indistinct, narrow	Elongated from early ontogeny	21:6.3 to 25:10
***M. parvum* Fomichev, 1953**	Long, slightly curved to straight, reach the corallite axis, forming a stereocolumn, radially to sub-radially arranged	Shortened with maturity	Triangular	Longer than the others	16:3.3 to 22:8.3
***M. cassum* Fedorowski, 1987**	Their ends are mostly free, forming a small free axial area filled only by the elongated counter septum. Their arrangement shifts from radial to pseudoradial and then pinnate towards the progressively younger portion of the corallite	Moderately shortened, about half the length of the cardinal fossula, or less	Narrow, open, bounded by two major septa	With a rhopaloid thickened end, does not form an upstanding columella	16:4.7 to 22:9.3
***M.* sp. Fedorowski, 1987**	Rhopaloid septa with free ends, exactly radially arranged	Shortened with maturity	Open, triangular	Prominent, longer than other majors, but does not form a separate columella	21:8 at calice margin
***M. galalaensis* El-Desouky et al. 2023**	Their arrangement changes from pinnate, sub-radial to radial with ongoing maturity. They meet in the axis forming a stereocolumn; then retreat near the calice floor, forming a small free axial area occupied only by an incipient columella	Shortened with maturity	Triangular, open adaxially	Permanently long, surpasses all majors in the axial stereocolumn with its rhopaloid enlarged end, forms an upstanding columella in the calice	3:1.1 to 24:11
*** *M. maxima* sp. nov.**	Long, laterally contiguous over their inner third length, joined to form a loose stereocolumn. Their arrangement changes with maturity from Pinnate to sub-radial	Thinner than other major septa and shorten later in ontogeny	Well-marked, changes from open, parallel walls that bordered by slightly shorter septa to triangular that open adaxially with successive maturity	Elongated from the early mature stages up to calice floor	19:5.8 to 26:13
***Monophyllum* sp.**	Radially to sub-radially arranged, contiguous over their inner half of their length, forming a dense stereocolumn that begins to diminish with advanced maturity	Shortened late in ontogeny and thinner than all other major septa	Not conspicuous, but can be detected as a triangular near the calice	Permanently long, exceeds all major septa axially, with a club-shape end	25:11 to 25:13

Suborder: **Plerophyllina** Sokolov, 1960

Family: **Plerophyllidae** Koker, 1924

Subfamily: **Plerophyllinae** Koker, 1924

Genus: ***Ufimia*** Stuckenberg, 1895

Ufimia sp. El-Desouky et al. 2023

(Fig. 7, A–D)

2023 *Ufimia* sp., El-Desouky et al., p. 24, fig. 13 A1–A3.

Material: Only one small corallite (RAC 3), with four transverse thin sections shown in Figs. (7A–D). The specimen is collected from Kasimovian basal beds of the lower member of the Aheimer Formation.

External features: A small rugose corallite with compressed calice and eroded tip.

Internal features: Near the missing apical part, at the earliest ontogenetic preserved stage, there are 19 septa at 4.5 mm diameter (Fig. 7A). Septa are very thick. The corallite lumen is largely filled with stereoplasm. Alar septa are the longest. The subsequent mature section at a diameter of 6.3 mm reveals 20 septa with thick rhopaloid ends (Fig. 7B). Like in the previous less mature section, major septa slightly retreat from the centre, which is still filled with stereoplasm.

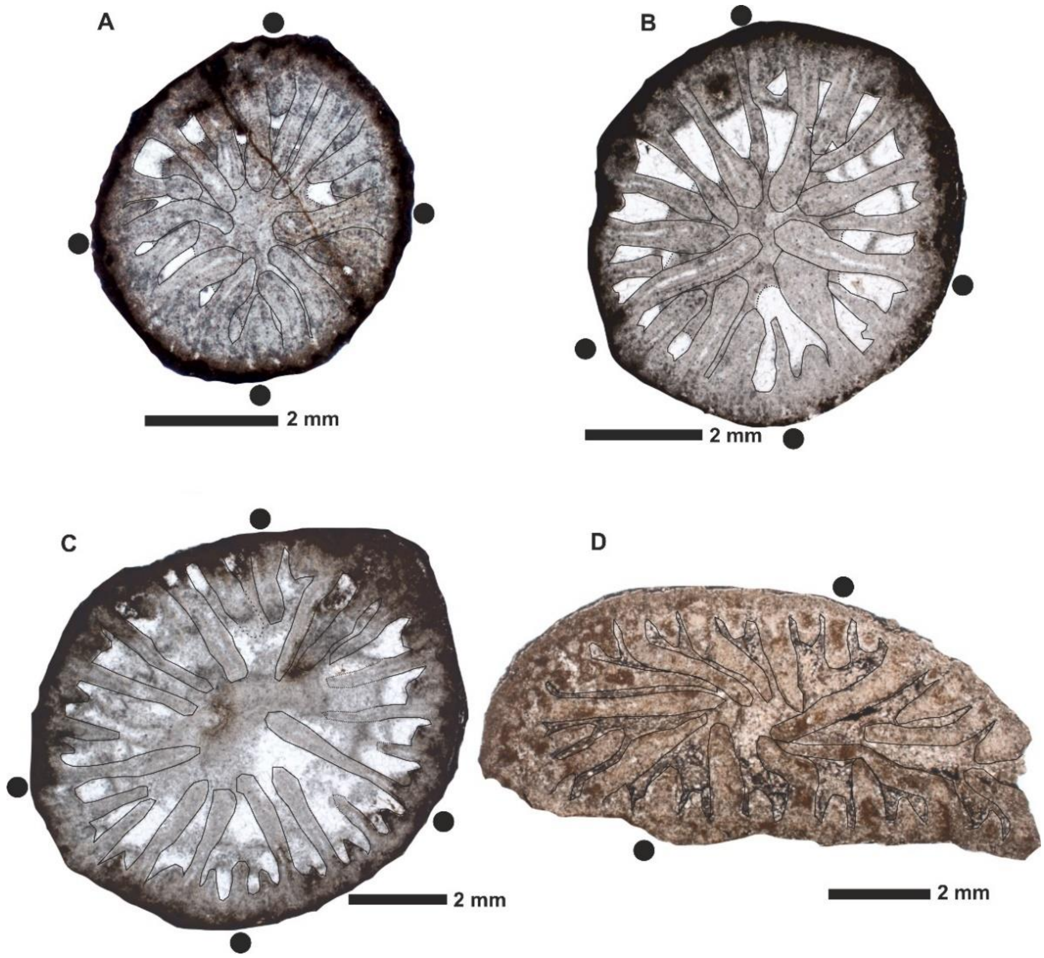

Fig. 7. A *Ufimia* sp. El-Desouky et al. 2023. A –D. Four successive transverse thin sections, show the rhopaloid thick septa withdraw from the axis with advanced maturity and thick stereocolumn in earlier stages (A, B). In all sections, alar septa are the longest, in contrast to the counter and cardinal septa which are constantly short. Black dots display the positions of the cardinal septum (below), the counter septum (above), and the two alar septa.

At this stage of maturity, the cardinal and the counter septa are getting shorter and thinner. Alar septa exceed all other major septa in length. Tabulae are observed between septa in one to two incomplete rows. Minor septa are observed at this stage of growth and are rudimentary. They occur as small spikes protruding from the fairly thick epitheca (up to 1 mm thick). The following mature section is made at 8.2 mm corallite diameter and is diagenetically highly altered by dolomitization and the septa could hardly be traced (Fig. 7C). In this section there are about 22 major septa, of which the cardinal and counter septa are shorter than the adjacent laterals. Minor septa are getting longer than in the previous section. The last mature section within the compacted calice is filled with mud (Fig. 7D). At this stage all major and minor septa are thick. Most majors are crooked due to the compression. Cardinal and counter septa are notably shorter than the laterals. Cardinal fossula is indistinct in all stages of maturity.

Remarks: Comparing the herein studied *Ufimia* sp. with that recorded by El-Desouky et al. (2023), it is obvious that they are reporting the same species. They exhibit the same septal pattern and n:d ratios at the same stages of ontogeny. *Ufimia* sp. El-Desouky et al. (2023), was described based on only two sections in the middle mature part of the corallite, whereas the present study adds two more sections in the latest mature part of the corallite (near the calice).

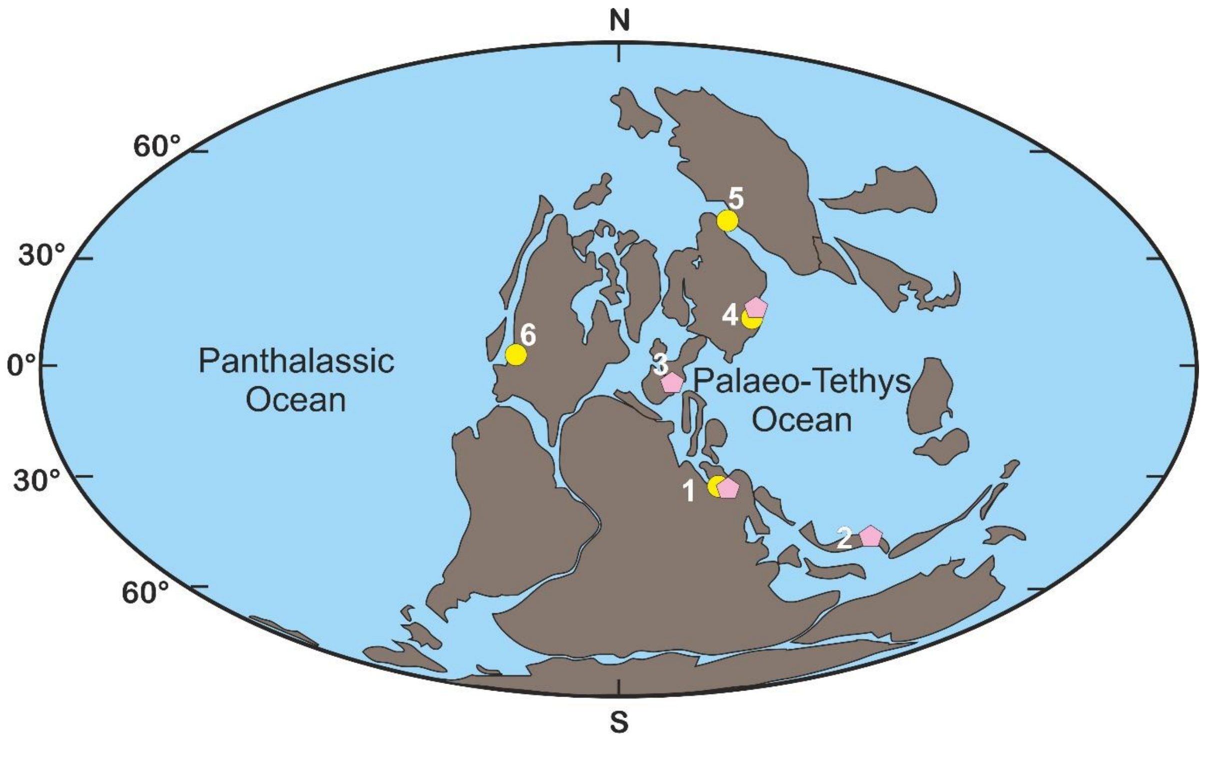

Fig. 8. Palaeobiogeographic map of the Pennsylvanian time, showing the distribution of the genera *Monophyllum* (yellow circle) and *Ufimia* (pink polygon) throughout the Pennsylvanian. The Palaeotethys realm; 1: Egypt (Gulf of Suez), 2: Iran, 3: northern Spain (Cantabrian Mts.), 4: Donets Basin. The Cordilleran-Arctic-Uralian realm; 5. Novaya Zelyma, 6. Western Texas. Base map is drawn from Abd-Elhameed et al. (2021) as modified from Kiessling et al. (1999).

These sections show the septa are separated, the central zone is empty, and the cardinal and counter septa are short, all these characters emphasise the attribution to the *Ufimai* genus.

5. Discussion and conclusions

The present study concerns the description of newly collected Kasimovian rugose coral specimens from basal beds of the lower member of the Aheimer Formation exposed on the eastern scarps of the Northern Galala. They represent the youngest Carboniferous coral fauna from the platforms that stretch along the southern fringe of the western Palaeotethys, along the northern Gondwana margin across North Africa, respectively (Kora & Mansour, 1991; El-Desouky et al. 2019, and El-Desouky et al. 2023). The study resulted in introducing of a new species of *Monophyllum* (*Monophyllum maxima* sp. nov.) and an unidentified species of *Monophyllum* sp., in addition to *Ufimia* sp. The studied monophyllid corals are compared with all recorded taxa of *Monophyllum*.

The coral bearing basal beds of the lower member of the Aheimer Formation consists of calcareous silty mudstones intercalated with thin silty dolostone and/or thin bands of calcareous siltstone. Small cornute rugose corals are the most common fossils despite their poor preservation. Associated fossil assemblages encompass bryozoans, clinoidal columns, brachiopods, and foraminifers, as well as *Glossifungites* ichnofacies. The obtained body and trace fossils suggest a sheltered, poorly circulated, sheltered shoreface shallow marine environment for the lower beds of the rock unit changing into firm ground foreshore “intertidal” condition in the upper part. This is in agreement with the previous interpretation of Kora and Mansour (1991).

El-Desouky et al. (2023) created a time-averaged ramp model for the upper part of the Rod El Hamal Formation (upper Moscovian) and the Kasimovian to Gzhelian (early Permian?) Aheimer Formation (Fig. 16 therein). They concluded a general cooling from the upper Rod El Hamal Formation to the middle-upper Aheimer Formation. The palaeogeographic affinities of the mostly non-dissepimented rugose corals recovered from the lower member of the Aheimer Formation had been widely discussed by El-Desouky et al. (2023). The herein recoded corals revealed a connection with N. Spain, that place Egypt in the western Palaeotethys. In addition to the connections with the Cordilleran–Arctic–Uralian realm that represents a cool water province during the Lower and Middle Permian through the Donets Basin and the southern Urals (Fig. 8).

The scarceness of dissepimented solitary and tabulate corals and the absence of colonial rugose corals may indicate inadequate conditions, such as a high amount of clastics, low temperature, or turbidity of water. The strong endemism shown in the present work and in the coral association of El-Desouky et al. (2023) is probably related to the deposition of the Pennsylvanian succession of the western side of the Gulf of Suez in an embayment at the southern margin of a broad shelf of the southern Palaeotethys that was named Proto-Clysmic Basin by Reynolds et al. (1997a, 1997b).

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Availability of data and materials

The reference fossil coral specimens and thin sections used in this study will be available at the Geology Department, Faculty of Science, Mansoura University, Mansoura, Egypt.

Declarations

Competing interests: The author declare that she has no competing interests.

References

Abdallah, A.M., and El Adindani A. (1965) Stratigraphy of Upper Palaeozoic Rocks, Western Side of the Gulf of Suez. *Geological Survey and Mineral Resource Department, Egypt*, **25** (1963), 18 pp.

Abd-Elhameed, S., Mahmoud, A., and Salama, Y. (2021) Late Moscovian phylloid algal-microbial mounds from Wadi Araba, north Eastern Desert, Egypt: a new construction model and paleogeographic distribution. *International Journal of Earth Sciences*, **110**, 3001–3013.

Awad, G. H. and Said, R. (1966) Egypt. - Lex. Stratigr. Internat., 4, Afrique, fasc. **4b**, 4 – 73; Paris

El Desouky, H., Herbig, H.-G. and Kora, M. (2019) Taxonomy, palaeoecology and palaeobiogeography of the Pennsylvanian rugose corals of Egypt – a rare view to the southern fringe of the Palaeotethys. In S. Hartenfels, H.-G. Herbig, M.R.W. Amler, & M. Aretz (Eds.), *19th International Congress on the Carboniferous and Permian, Cologne*, July 29–August 2, 2019, Abstracts. – *Kölner Forum Geol. Paläont.*, **23**, 85–86.

El-Desouky, H., Herbig, H.-G., and Kora, M. (2023) Kasimovian (late Pennsylvanian) cornute rugose corals from Egypt: taxonomy, facies and palaeogeography of a cool-water fauna from northern Gondwana. *Swiss Journal of Palaeontology*, **142**(1), 32.

El-Refaiy, A. A., El-Sabbagh, A. M., Hedeny, M. M. E., Mansour, A. S. and El-Barkooky, A. N. (2023) Stratigraphical, microfacies, and ichnological characteristics and depositional environments of the Permo–Carboniferous Aheimer Formation, western side of the Gulf of Suez, Egypt. *Facies*, **69**(2), 1–40.

Ernst, A., Kora M., El-Desouky, H., Herbig, H.-G., and Wyse Jackson, P.N. (2020) Stenolaemate bryozoans from the Carboniferous of Egypt. *Journal of African Earth Sciences*, **165**, 21 pp.

Fedorowski, J. (1981) Carboniferous corals: distribution and sequence. *Acta Palaeontologica Polonica*, **26**(2), 87–160.

Fedorowski J. (1987) Upper Palaeozoic rugose corals from southwestern Texas and adjacent areas: Gaptank Formation and Wolfcampian corals, Part 1. *Palaeontologica Polonica*, **48**, 1– 271.

Fedorowski, J. (2022) Bashkirian Rugosa (Anthozoa) from the Donets Basin (Ukraine). Part 12. Concluding considerations. *Acta Geologica Polonica*, **72**(3), 247–316.

Fomichev, V. (1953) Rugose corals and stratigraphy of Middle and Upper Carboniferous and Middle Permian deposits of the Donets Basin. *GeoI. Inst. (VESEGEI)*, 622pp.

Hill, D. (1981) Supplement 1, Rugosa and Tabulata. In C. Teichert (Ed.), *Treatise on Invertebrate Paleontology, Part F, Coelenterata*, F1–F762. Boulder/Colorado and Lawrence/Kansas. (Geological Society of America and University of Kansas Press).

Hudson, R.G.S. (1942) *Fasciculophyllum* Thomson and other genera of the "*Zaphrentis*" *omaliusi* group of Carboniferous corals. *Geological Magazine*, **79**(5), 257– 263.

Ilina, T.G. (1970). Some new Permian Rugosa from the South-Eastern Pamir. 146–151. In G.G. Astrova, & I.I. Chudinova (Eds.), *New species of the Palaeozoic bryozoans and corals*. Nauka, Moskva, 178 pp. (in Russian).

Issawi, B., & Jux U. (1982) Contribution to the stratigraphy of the Palaeozoic rocks in Egypt. *Geological Survey of Egypt*, **64**, 1–28.

Kiessling, W., Flügel, E., and Golonka, J. (1999) Paleoreef maps: evaluation of a comprehensive database on Phanerozoic reefs. *American Association of Petroleum Geologist, Bulletin*, **83**(10), 1552–1587.

Klitzsch, E. (1990) Paleozoic. In R. Said (Ed.), *The Geology of Egypt*. (pp. 393–406). Balkema, Rotterdam.

Koker, E.M.J. (1924) Anthozoa uit het Perm van het eiland Timor, I: Zaphrentidae, Plerophyllidae, Cystiphyllidae, Amphiastreidae. Jaarboek van het Mijnwezen in Nederlandsch Oost Indie (for 1922) **51**, 1–50.

Kora, M. (1998) The Permo- Carboniferous outcrops of the Gulf of Suez region, Egypt: stratigraphic classification and correlation. *Geodiversitas*, **20** (4), 701– 721.

Kora, M., and Mansour, Y. (1991) Late Carboniferous solitary rugose corals from the western side of the Gulf of Suez, Egypt. *Neues Jahrbuch für Geologie und Paläontologie Monatshefte*, **10**, 597– 614.

Kora, M., and Mansour, Y. (1992) Stratigraphy of some Permo-Caboniferous successions in the Northern Galala, Gulf of Suez region, Egypt. *Neues Jahrbuch für Geologie und Paläontologie Monatshefte*, , **185**(3), 377 – 394.

Kora, M., Herbig H.-G. and El Desouky H. (2019) Late Moscovian (mid-Pennsylvanian) rugose corals from Wadi Araba (Egypt, Eastern Desert): Taxonomy, palaeoecology and palaeobiogeography. *Geobios*, **52**, 1– 25.

Kossovaya, O.L. (1996) Correlation of uppermost Carboniferous and Lower Permian Rugose Coral Zones from the Urals to Western North America. *Palaios*, **11**(1), 71–82.

Ogar, V.V. (2012) Carboniferous buildups in the Donets Basin (Ukraine). *Geologica Belgica*, **15**(4), 340–349.

Reynolds, P.-O., Schandelmeier, H., Semtner, A.-K., and Klitzsch, E. (1997a) The early Carboniferous (late Tournaisian/early Viséan, ca. 350 Ma). In H. Schandelmeier, P.-O. Reynolds (Eds.), Palaeogeographic–palaeotectonic atlas of Northeastern Africa, Arabia, and adjacent areas, A.A. Balkema, Rotterdam, pp.29–33.

Reynolds, P.-O., Schandelmeier, H., Semtner, A.-K., and Klitzsch, E. (1997b) The late Carboniferous (Bashkirian, ca. 315 Ma). In H. Schandelmeier, & P.O. Reynolds (Eds.), Palaeogeographic–palaeotectonic atlas of Northeastern Africa, Arabia, and adjacent areas, A.A. Balkema, Rotterdam, pp. 35–38.

Said, R. (1971) Explanatory notes to accompany the geological map of Egypt. Geol. Surv. Egypt 56:1–123.

Said, R. (1990) The geology of Egypt. Rotterdam, AA Balkema, p 721.

Sokolov, B.S. (1960) Permian corals of the southeastern parts of the Omolon Massif (with general review of plerophylloid Rugosa). *Trudy Vsesoyuznogo neftyanogo nauchno geologicheskogo Instituta (VNIGRI)* **154**, 38–77. Leningrad (in Russian).

Stuckenberg, A.A. (1895). Korallen und Bryozoen der Steinkohlenablagerungen des Ural und des Timan. *Mémoires du Comité Géologique*, **10**(3), 244 p. (in Russian and German).

Verrill, A.E. (1865) Classification of polyps (extract condensed from Synopsis of the Polyps and Corals of the North Pacific Exploring Expedition under Commodore C. Ringgold and Captain John Rodgers, U.S.N.). *Communications of the Essex Institute 4*, 145–152.

Wang, X.D., Yang, S.R., Yao, L., Sugiyama, T., and Hu, K.Y. (2022). Carboniferous biostratigraphy of rugose corals. In S.G. Lucas, J.W. Schneider, X. Wang, S. Nikolaeva (Eds), *The Carboniferous timescale*. Geological Society, London, Special Publications. **512** (2022). 603–63.