

SEM Observations on some species of genus *PALMULA* Lea 1883 (benthic foraminifera) and the Identification of a new genus *HANENOPALMULA*

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Abstract: The morphological features, inner and outer surface structures, and ultrastructure of the shell walls of *Palmulawoodi* Nakkady 1950, *P. pilulata* Cushman, 1938, *P. ansaryi* Anan 1994, *P. suturalis* Loetterle 1937, *P. mokattamensis* and unknown *Palmula. sp.* Aly *et al.*, 2011 species of genus *Palmula* Lea 1883 are studied carefully by using a scanning electron microscope (SEM) techniques. The studied specimens of these species of genus *Palmula* Lea 1883 were collected from Kharga Shale Member (upper part of the Dakhla Shale Formation) early Paleocene at Naqb Refuf, Kharga Oasis, Western Desert; Esna Shale Formation, early Paleocene at the North Gunna section, Western Desert and from El Fashn Formation late middle Eocene at Bayad El Arab section, Beni Suef area, Nile Valley Egypt. The analysis of the examined specimens led to identification of a new benthic foraminiferal genus *Hanenopalmula* n. gen., of the Family Vaginulinidae Reuss, 1860. The new genus differs from the *Palmula* Lea 1883 in a number of ways. Its wall structure is made from one solid layer, in which prismatic calcite crystals extend from the inner to the outer surface. The proloculus portion is bullate, rises up to the shell surface. Chambers are coiled around the early stage in an arch-like manner. The widest point is very close to the primordial chambers. Finally, the outer shell surface is smooth and glistening. Furthermore, this study identifies the *Hanenopalmula dabbosensis* n. species. This species differs from the *Hanenopalmula woodi* Nakkady, *Hanenopalmula bignoti* Anan 2002 in possessing wide and thick raised suture lines.

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1. Introduction

Genus *Palmula* Lea 1833 is well-known stratigraphically and geographically in Egypt and in different parts of the World. Stratigraphically, genus *Palmula* has a very long stratigraphic distribution. Loeblich and Tappan 1988 (p. 409) mentioned that the age of genus *Palmula* is ranging from Paleocene to Middle Miocene. It has been recorded from Lower Cretaceous to Middle Miocene. Holbourn and Kaminski (1995) recorded unknown *Palmula* species from lower Cretaceous ODP Site 766 (Leg 123), Indian Ocean; Valchev *et al.*, 2013 recorded *Palmula budensis* (Hantken, 1875) from upper Eocene to lower Oligocene at Republic of Macedonia.

Geographically, on the other hand, the genus seems to have a wide geographical distribution as well. It was recorded in Egypt by Nakkady (1950); Le Roy (1953); Ansary, (1955); Anan (1994); Aly *et al.* (2011) and others. Furthermore, it has been recorded from different parts of the World. It was recorded from New Jersey, USA by Rufus Bagg (1898); from Algeria by Dam and Sigal (1950); from Tunisia by Berggren *et al.* (1974) and Salaj *et al.* (1976); from Poland by Walkiewicz (1977); from Slovenia by Cimerman *et al.* (2006); from Macedonia by Valchev *et al.* (2013) and others. The *Palmula woodi* Nakkady 1950, *Palmula pilulata* Cushman 1938 and

Fronidularia bignoti Anan 2002 those species under genus *Palmula* Lea are sufficiently morphologically distinct to warrant assignment to another genus as in (Text-fig. 2). This study proposes a new genus and assigns these *Palmula* species to this new taxon based on the morphological characters, inner and outer shell structure and shell wall ultrastructure.

2. Studied areas

The foraminiferal samples for this study it has been collected from three different localities in Egypt. The first is North Gunna section. This section is located in Farafra Oasis, Western Desert, about 10 kilometers northeast of Qasr El Farafra, just to the right of the main road (27° 51' N, 28° 05' E). The second location is the Bayad El Arab section, Beni Suef area, Nile valley. This section is located along the eastern bank of the Nile Valley, about 20 km northeast of Beni Suef City and about 110 km southeast of Cairo (29° 05' N, 31° 15' E). The third location is Naqb Refuf, Kharga Oasis, Western Desert (25° 55' N, 30° 59' E) (Text-fig. 1).

3. Material and methods

The specimens selected for this study are two specimens of *Palmulawoodi* (Nakkady, 1950) and *Palmula pilulata* (Cushman, 1938) respectively. These

specimens were collected by the current author in 2002 during the field work for his Ph.D. study from North Gunna section, Farafra Oasis, Western Desert (Text-fig. 1). In addition, three specimens from each of *Palmula suturalis* Loetterle 1937, *Palmula ansaryi* Anan 1994, *Palmula mokattamensis* Tadros, 1968 and unknown *Palmula* sp. Aly *et al.*, 2011 were selected from Northeast, Beni Suef, Nile Valley. Furthermore, two specimens of *Palmula woodi* Nakkady, 1950 from, Naqb Refuf, Kharga Oasis, Western Desert, Egypt were kindly provided by Professor Dr. Hewaidy, to whom the author is deeply thankful, were selected for further comparisons. One specimen from each species that mentioned above to use in this study was broken for a detailed examination of the inner and outer shell structure. Observation on the shell and wall ultrastructure of the studied specimens was carried out under magnifications from 80 to 16000 times by scanning electron microscope suits at both Leeds University, United Kingdom and at the Nuclear Material Authority (NMA), Cairo, Egypt.

4. Results

Genus *Palmula* was first identified and described by Lea (1833) as being “characterized by palmate shells, with angular striae that are indicates on the interior chambers” (Lea 1883, p. 219, pl. 6, fig. 228). Throughout this period, the literatures are rich by images of species under this genus name, but some of them do not carry out the same morphological characteristics as Lea’s description. The following paragraphs will introduce some of these forms to answer this question: how much that forms are concerned with the original description of Lea 1883.

Lea 1833 described a *Palmula sagittaria* as a new species that is characterized by depressed shell, being rounded on the edges, with six angular striae, and sublunate oval aperture (Text-fig.2; 1a, b). Unfortunately, the figure of this species in Lea’s work is not clear. The present author made several attempts to track the holotype in USA museum depositories for further examination but none of these attempts was successful.

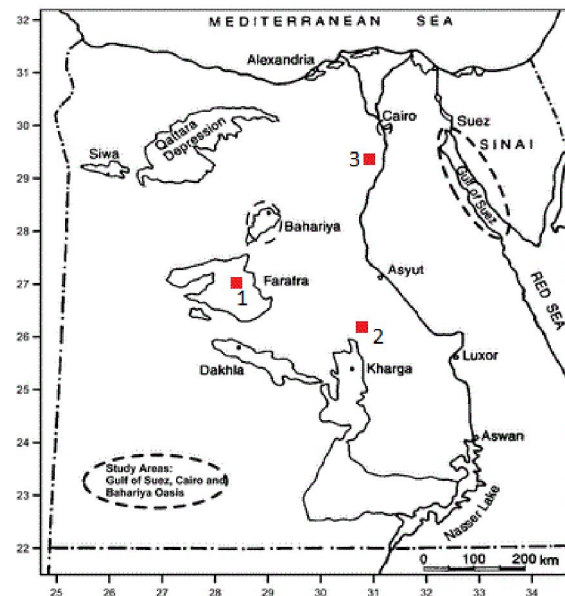
Nakkady (1950, p. 684) identified *Palmula woodi* as a new species that is characterized by its compressed test, coiled an early stage with rises above the general level of test (Text-fig. 2; 3). This species differs from Lea’s form in its having arched chambers in adult stage and its widest point closer to the proloculus portion. Nakkady (p. 685), also defined *Palmula undulata* (Text-fig. 2; 4) which differs from the *Palmula sagittaria* in having an inflated test with about 8 chambers in an early stage, which represents about half or slightly more of the test size. Nakkady

demonstrated that the test of this latter species is slightly arched and characterized by highly curved sutures in its early stage, the possession of 2-3 chambers in its latest stage, and radiate, terminal, and short necked aperture.

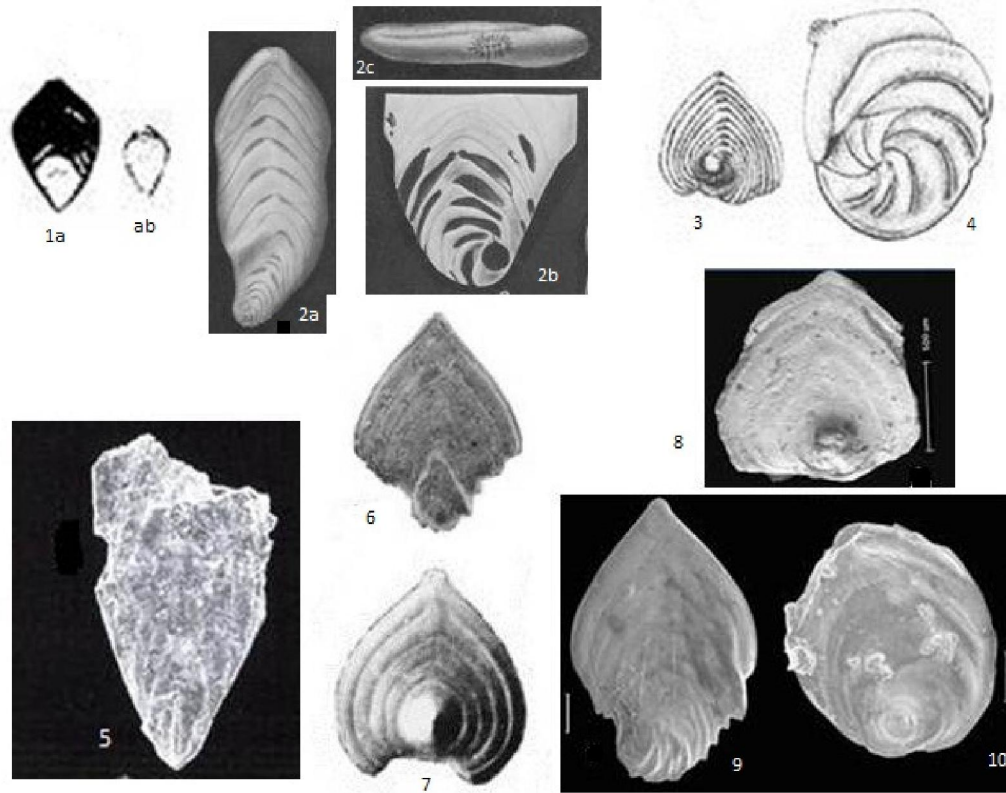
Loeblich and Tappan (1988, p. 409) considered the *Palmula sagittaria* Lea (Text-fig. 2; 2a-1c) a type species for the *Palmula* genus. They described that type species as a large, elongate test; flattened; with planispiral at an early stage with an uncoiled and rectilinear later portion. They described the chambers of their species as being broad and low strongly arched or chevron shaped. This species differs from the *P. sagittaria* Lea in its early stage is planispiral, elongated and contains on about 12 chambers. Its dimension is not the same and has no neck. Adult stage is rectilinear shape.

Anan (1994, p. 222) identified *Palmula ansaryi* (Text-fig. 2; 6) as a new species and indicated that its maximum height and width is exhibited in the uniserial stage. This form differs from Lea’s *Palmula* in its widest point is closer to the proloculus portion and its periphery is lobulate in early stage.

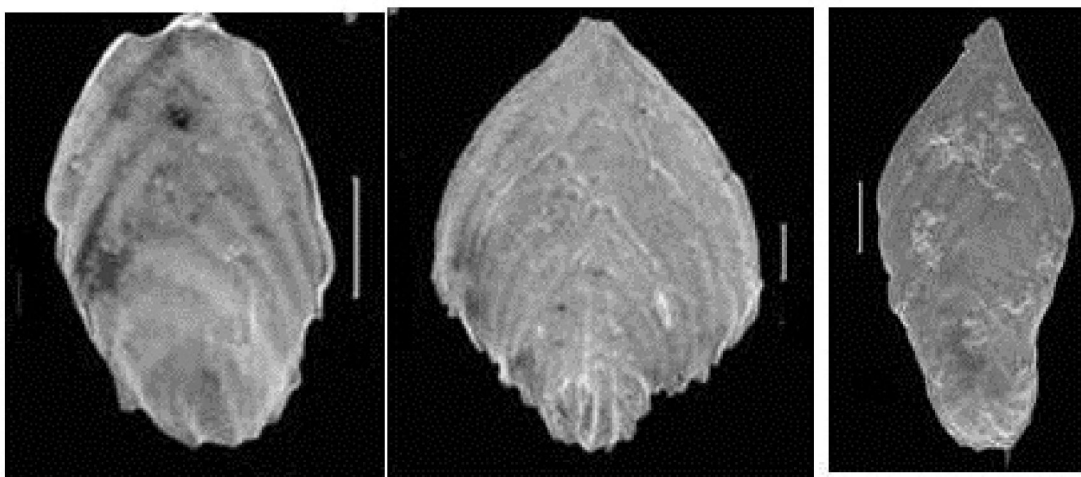
Anan 2002 attributed some of *Palmula* species to the genus *Fronicularia* (e.g., *Froniculariabignoti* Anan 2002 (Text-fig. 2; 7); *Froniculariawanneri* Nakkady, 1950; *Fronicularia nakkadyi* Futyan, 1976; and *Fronicularia phosphatica* Russo, 1934.



Text-fig. 1: Location map of selected samples; (1) North Gunna section, (2) Naqb Refuf section and (3) Bayad El Arab section.



Text-fig. 2: 1 a, b *Palmula sagittaria* Lea; after (Lea 1833, p. 219, pl. 6, fig. 228) (Diam. 1-20th, Length.2, Breadth.1, of an inch.). 2. a-c *Palmula sagittaria* Lea; after (Loeblich and Tappan 1988, p. 409, pl. 447, figs. 1-3) (2a, b side and apertural view x8 and 2c early stage view x20). 3. *Palmula woodi* Nakkady; after (Nakkady 1950, p. 684, pl. 89, fig. 24) (x6.8). 4. *Palmula undulate* Nakkady; after (Nakkady 1950, p. 685, pl. 89, fig. 25) (x42). 5. *Palmula bundensis* (Hantken); after (Horvath 2003, p. 18, pl. 4, fig. 7) (x98). 6. *Palmula ansaryi* Anan; after (Anan 1994, p. 222, fig. 8/14-15). 7. *Fronicularia bignoti* Anan; after (Anan 2010, p. 29, pl. 1, fig. 7) (x50). 8. *Palmula woodi* Nakkady; after (Aly 2007, p. 86, pl. 8, fig. 1). 9. *Palmula suturalis* Loetterle; after (Aly *et al.* 2011, p. 94, pl. 3, fig. 12). 10. *Palmula pilulata* Cushman; after (Aly *et al.* 2011, p. 94, pl. 3, fig. 11).



Text-fig. 3: 1 *Palmula cushmani* (Morrow); after Aly, *et al.* (2011, p. 94, pl. 3, fig. 9) 2. *Palmula ansaryi* Anan; after Aly *et al.* (2011, p. 94, pl. 3, fig. 8). 3. Unknown *Palmula* sp. after Aly *et al.* (2011, pl. 3, fig. 14).

The *Frondicularia* genus is characterized by thickened in the region of the aperture and its sutures are highly arched to angle at the midline of the test (Loeblich & Tappan, 1988, p. 400, pl. 440, figs. 21-23). The *Frondicularia bignoti* of Anan not thickened in the region of the aperture, also, its proloculus portion is bullate, and rises above the test level.

Horvath (2003, p. 18, pl. 3, fig. 7 and pl. 4, fig. 7) described the *Palmula bundensis* (Hantken) as strongly flattened test, the proloculus is fusiform followed by a few astacolone chambers and the midline is elevated (Text-fig. 2; 5). This form is broken and differs from the *P. sagittaria* in its later portion nearly rectilinear, highly perforate and the sutures are raised.

The *Palmula woodi* Nakkady after Aly (2007, p. 86, pl. 8, fig. 1) is very similar to the Nakkady's form. Aly *et al.* (2011, p. 94, pl. 3, figs. 11, 12) they listed two species of genus *Palmula* with their distinctive morphological features; *Palmula suturalis* Loetterle (Text-fig. 2; 9) and *Palmula pilulata* Cushman, 1938 (Text-fig. 2; 10). The former species is characterized by large inflation in its early stage and inverted V shaped chambers in its later stage. The latter species *Palmula pilulata* Cushman, 1938 is distinguished by highly arched proloculus chambers that are rise above the test and begin and end around the proloculus.

The uncoiled part in (Text-fig. 2; 3,7,8 and 10) is built surrounding and including the proloculus. In other words, the early chamber is representing a nucleolus to the rest of the test. In the other forms, the proloculus is preceding the rest of the test not included in it.

5. Discussions

The morphological differences between the *Hanenopalmula* new genus and *Palmula* Lea 1833 can be easily recognized by careful examination of the ultrastructure of their walls and apertures. The studied specimens are differentiated into two morphologically distinctive groups (Text-fig. 2). The first group that is referred to as group A here includes specimens attributable to genus *Palmula* (Text-fig. 2; 1, 2, 5, 6, 9 and Text-fig. 3; 1-3). Members of this group are characterized by their large, elongated, flattened test with coiled and more inflated early stage. Furthermore chambers in late stage are numerous, 12-18 and of an inverted V shape. Sutures are distinctive and raised. **Aperture is terminal and radiate. Outer surface of shells are perforate.** The second group, referred to here as group B, includes specimens that are proposed as the new genus *Hanenopalmula* (Text-fig. 2; 3, 7, 8 and 10). This group is characterized by; palmate, compressed test. Early stage is closed coil, bullate, rising over the level of test. Chambers in late stage are numerous 8-12 arched in shapes. Sutures are narrow

and slightly depressed. Outer surface of shells are smooth. Seven morphological features including inner & outer shell surface and the wall ultrastructure are diagnostic features of this genus and will be discussed in details as well. The following paragraphs present a comparison between the most diagnostic features that led to the proposal of the new genus *Hanenopalmula*.

A- Early stage:

One of the most distinct features of genus *Palmula* is the inflation of an early coiled stage that is rise over the outer surface of the test. Careful examination of these features in group A (Pl. 1, figs. 4, 5) shows that the early stage in group A is wider than in group B and are showing a higher inflation and biconvex (Pl. 2, figs. 3, 4). The transvers section of group A shows that the early stage is planispiral (Text-fig. 4; 1, 2 and Pl. 1, fig. 6), keeled, gradually increasing in size as added (Text-fig. 4, 1, 2). The inner shell surface displays that these early stage consist of 8 interior chambers (Pl. 1, fig. 6), fine to dense perforate (Pl. 1, fig. 5). In contrast, the proloculus chambers in group B are rises over the test and are coiled, bullate and rounded. More details by SEM images of the broken specimens shows that the early part is consists of 2-3 interior chambers; the first chamber is frustule or cavity (Pl. 1, fig. 3); ornamented by 2-3 short and thick straight ribs (Pl. 1, figs. 1 & 2). Under (X645) magnification by ESM on the side view (Pl. 2, fig. 2), it is observed that the overgrowth on the outer shell surface are unequal on both sides. These pores do not seem to have any impact on the internal structure and in inner shell surface that generally retained at smooth texture (Pl. 1, fig. 3).

B- Test form:

Furthermore, the shape of test in group A is large, elongate, sub rhomboidal in outline, inflated and with a variable position of its widest point from one species to another. This widest point could be located closer to the proloculus (Text-fig. 3; 1 and Pl. 1, fig. 4) to the middle of test (Text-fig. 3; 2) or closer to the apertural margin (Text-fig. 3; 3). In group B, on the other hand the test is palmate, elliptical, compressed and with its widest point on a straight line with the proloculus (Text-fig. 2; 3, 7, 8 and Pl. 1, fig. 1).

C- Shape of chambers:

Another diagnostic feature in both of foraminiferal groups of this study is the presence of two types of chambers within the same form; proloculus chambers and uncoiled chambers. In group A the proloculus portion is consist of eight planispiral, curved chambers (Pl. 1, fig. 6). The adult chambers are starting from side and ending on the other side (Text-fig. 3; 1-3). Its shape are inverted V shaped, broadening towards the proloculus and narrowing towards the apertural end (Pl. 1, fig. 4). In group B, on

the other hand, the proloculus part is comprised of two or three strongly arched chambers (Pl. 1, fig. 3) that rising above the level of outer shell surface (Pl. 1, figs. 1, 2). The adult chambers are arched and gradually

increasing in size as added. It's beginning and ending is located around the proloculus portion (Text-fig. 2; 3, 7, 8 and 10) and (Pl. 1, figs. 1, 2).

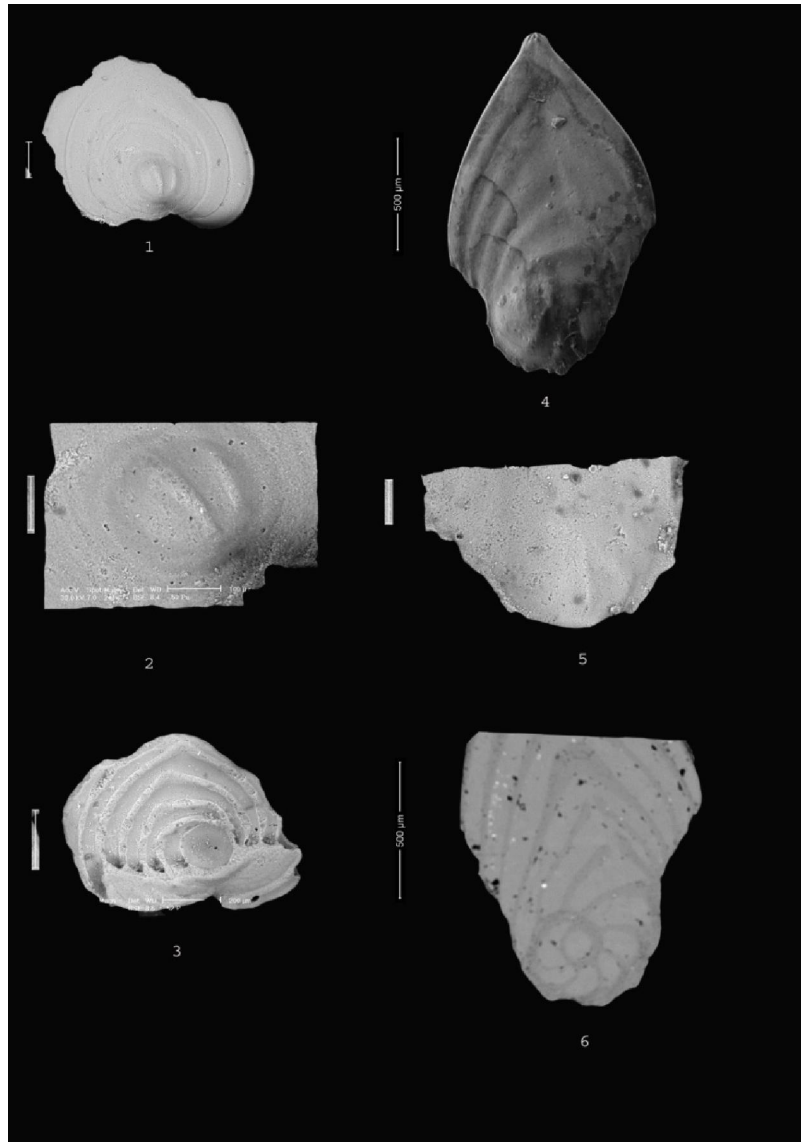


Plate 1

Fig.

1. Outer view of the whole shell of *Hanenopalmula woodi* Nakkady, 1950. Dakhla Formation, Kharga Oasis. Paleocene age. (X 80).
2. Early stage of *Hanenopalmula woodi* Nakkady, enlarged (X 241); note, the hole presumably made by some predator.
3. Internal structure of *Hanenopalmula woodi* Nakkady enlarged (X 80); note the inner aperture in proloculus chambers and in latest chambers.
4. Outer view of the whole shell of *Palmula suturalis* Loetterle, 1937. El Fashn Formation, Beni Suef area. Late middle Eocene age (X168).
5. Early stage of Fig. 4 enlarged (X 190); note, the raised sutures and wall perforate.
6. Thin section of unknown *Palmula* Aly, 2011; note, the early stage is planispiral and some pores was presumably made by some predators.

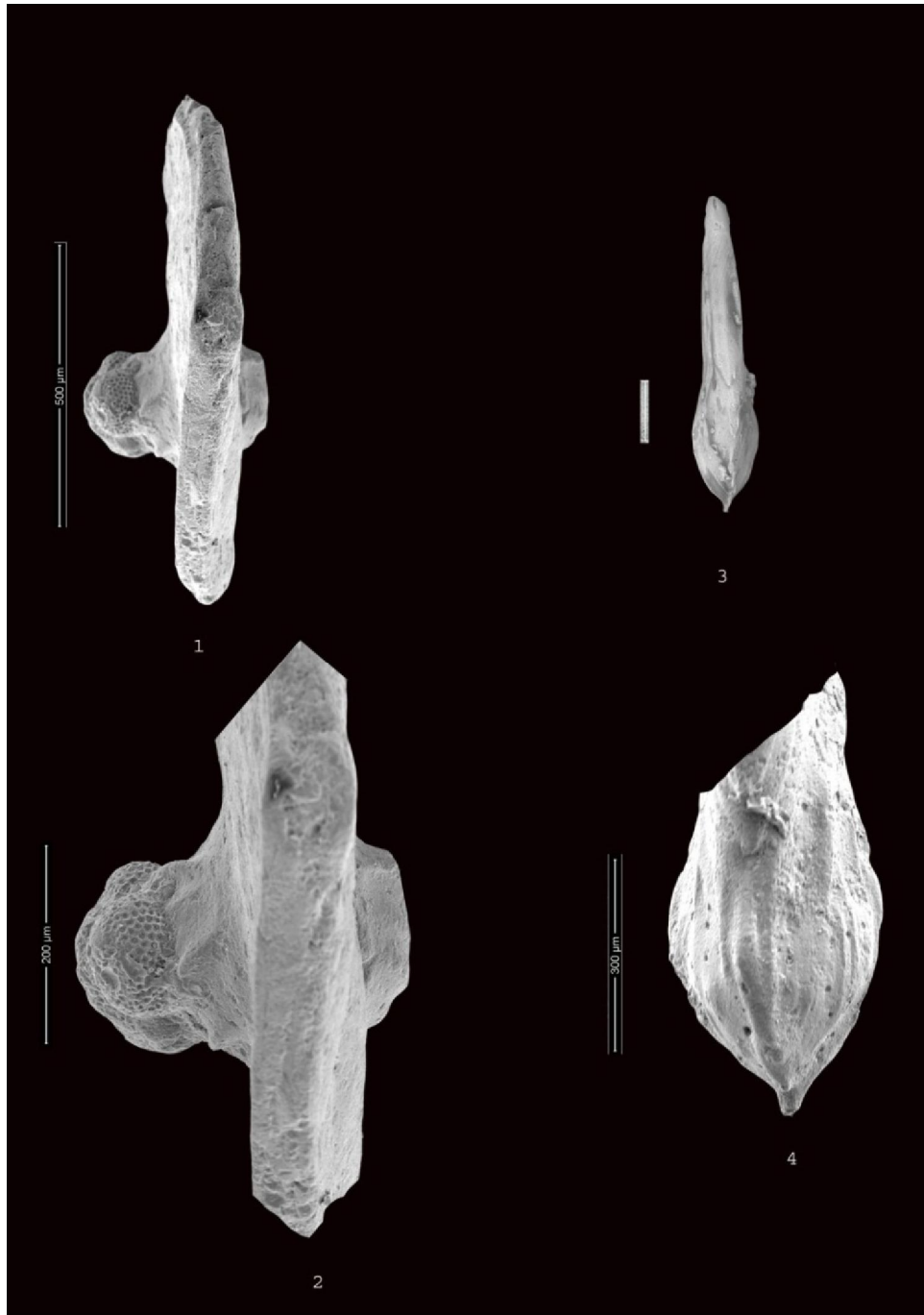


Plate 2

Fig.

1. Lateral view of *Hanenopalmula woodi* Nakkady, (X367); note, the proloculus chambers are rise up the test level and the size of the test is uniform.
2. Enlarged of *Hanenopalmula woodi* Nakkady (X645), note, the some planktic might be attached on the shell.
3. Lateral view of *Palmula suturalis* Loetterle, 1937; showing the periphery of early stage is keeled.
4. The early stage of figure 3 enlarged (X718); showing its biconvex, keeled and the perforate of wall shell.

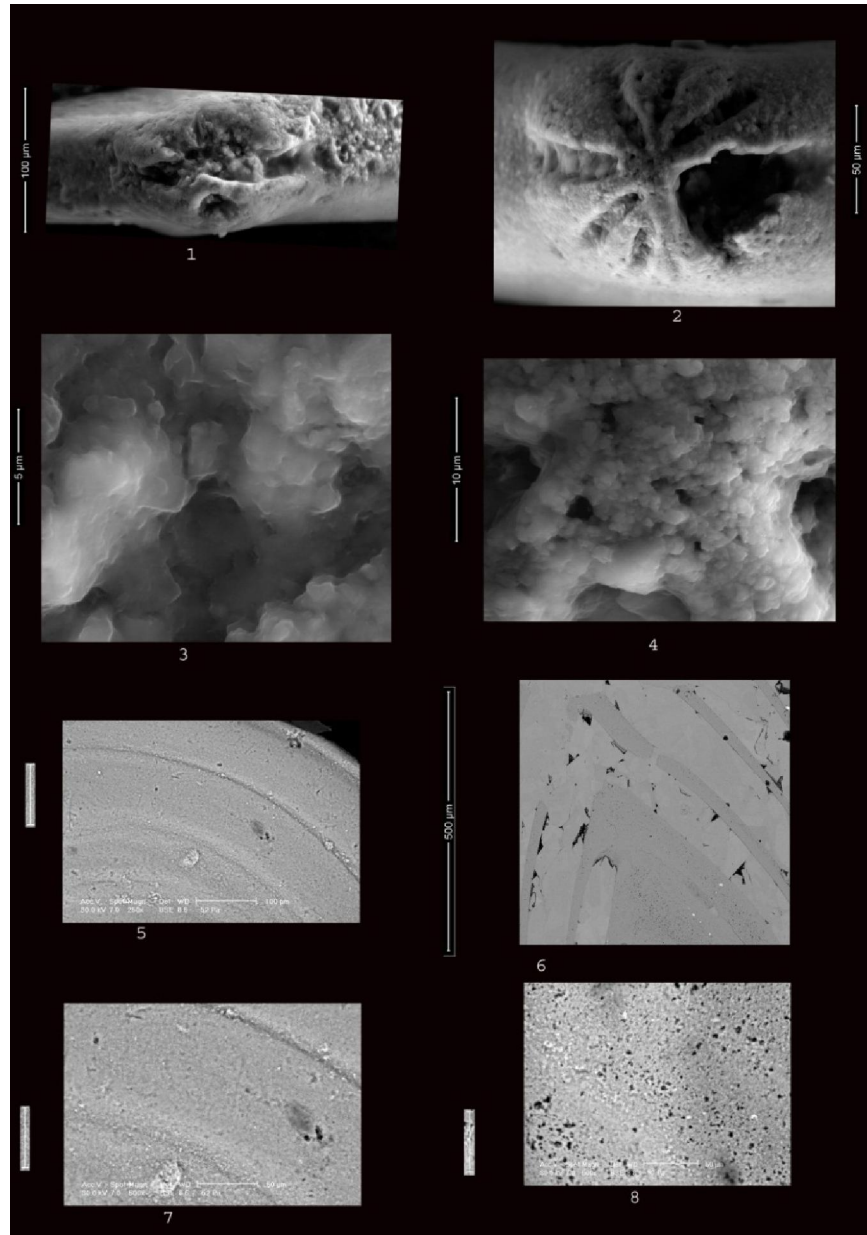


Plate 3

Fig.

- 1- Apertural view of *Hanenopalmula woodi*, Nakkady (X1000).
- 2- Apertural view of *Palmula suturalis* Loetterle (X1500).
- 3- The same of Fig. 1 enlarged (X16000); note, the pores openings are very rare; it's hard to see some of them.
- 4- The same of Fig. 2 enlarged (X14000); note, the pores openings are easy to see it.
- 5- Outer surface of *Hanenopalmulawoodi* Nakkady (X250); note, the shape of sutures is arched.
- 6- Transvers break of the wall of unknown *Palmula* Aly (X500); note, the shape of chambers and sutures are inverted V shape.
- 7- Enlarged of Fig. 5; note, the outer surface is micro perforate with some pores might be made by some predators (X500).
- 8- Outer surface of *Palmula suturalis* Loetterle; note, its surface are highly perforate (X500).

D- Sutures:

The suture lines in group A sutures are wide, raised and thicker at an early stage, flush to raised at

the adult stage in other forms (Text-fig. 2; 9 and Text-fig. 3; 1-3). In group B the sutures are slightly depressed, narrow and arched (Text-fig. 2; 3, 7, 8, 10

and Pl. 3, figs. 5, 7). Inner shell sutures “septa” are raised and thick (Pl. 1, fig. 3 and Pl. 5, fig. 3).

E- Wall

The outer wall of the specimens studied in group A is usually seen as having a soother finishing (Text-fig. 3; 1-3 and Pl. 1, fig. 4). Seen under high magnification (x190, x415 and x500), the specimen is highly perforate with irregularly distributed openings of irregular forms (Pl. 1, fig. 5, Pl. 2, fig. 4 and Pl. 3, fig. 6). However, the outer shell surface of group B is smooth (Pl. 3, figs. 4, 5) with some small pseudopores opening are randomly distributed, unequal in size and depth and are irregular in their shape (Pl. 1, figs. 1, 2). The size and position of these openings do not reflect the canaliculi openings (Pl. 5, figs. 1). Some of these pseudopores are seen on the inner surface (Pl. 1, fig. 3), which may have been caused by predators. The inner shell surface of group B is consisting of flatty packed, slight rough sand particles in their shape.

F- Aperture

The internal aperture is shifted eccentrically in relation to medial axis of test in the early part, and then moved to the medial axis in following uncoiled stage (Pl. 1, fig. 3).

Wall ultrastructure

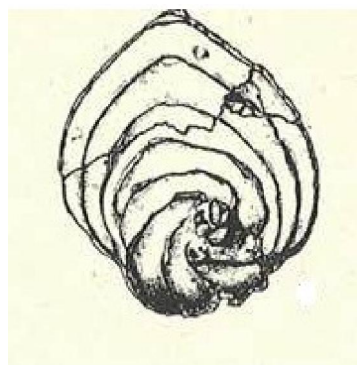
Transverse breaks of the wall of both groups A and B (Pl. 4, figs. 1-7 and Pl. 5, figs. 1, 2) and the surface of the inner aperture (Pl. 1, figs. 3, 6) also provide other means of differentiation between these forms. It is apparent that the thickness of shell wall in group A is 169μ (Pl. 4, fig. 5) whereas it is much less in group Bis 62.2μ (Pl. 4, fig. 1). This thickness variation in both groups may indicate that the test of group A is more inflated and in group B is more compressed. The chambers in group A have a semi rounded shape (Pl. 4, fig. 5), while those of group B have elliptical and elongated shape (Pl. 4, figs. 2 & 3). The wall in group A is consisting of thin lamellae of prismatic calcite crystals (Pl. 4, figs. 6 & 7). The calcite crystals are arranged from the inner and outer surfaces inward in two opposite directions, with inner empty spaces that appears as dark holes between the crystals (Pl. 4, fig. 7). These empty spaces are not observed on the inner layer (Pl. 5, fig. 2). The calcite crystals vary in their shape and size between the inner and outer layer. In addition, the calcite crystals on the outer layer are more granular than prismatic (Pl. 5, fig. 2). The wall in group B consists of distinct, long, opaque, radial, calcite crystals that extend from the inner to outer surface of test (Pl. 4, figs. 3, 4). The size of these crystals is volumetric and there is no pore openings observed between the crystals (Pl. 4, figs. 3, 4). Furthermore, additional to there is anorganic inner lining that cover the inner wall (Pl. 4, fig. 4). The inner shell surface of group A is rougher (Pl. 5, fig. 1) than the inner surface in group B (Pl. 5, fig. 2).

The above mentioned discussion indicates that, group A is easily distinguishable from group B because of the variation in their morphological features, the internal structure and wall surface. The author is strongly convinced that features in the group A are typically describing the *Palmula* Lea 1883 genus and those of group Bis to be regarded as a new genus, *Hanenopalmula* Aly 2017.

Stratigraphy

The *Hanenopalmula* Aly 2017 and *Palmula* Lea 1883 specimens were collected from three different stratigraphic rock units from different localities Kharga Shale Member (upper part of the Dakhla Shale Formation), Esna Shale Formation, and El Fashn Formation.

The Dakhla Shale Formation was measured for this study at Naqb Refuf section, Kharga Oasis. The age of this formation is Maastrichtian-Paleocene (Tantawy, *et al.* 2001). The Dakhla Formation is divided into three members; Mawhoob Shale Member at the base, Beris Mudstone Mband Kharga Shale Mb at the top (Awad and Ghobrial, 1966). The Dakhla Formation is of the Maastrichtian-early Paleocene age (Tantawy *et al.* 2001). The Kharga Member is divided into lower and upper parts respectively. The lower part lies above the Beris Mudstone Member of the late Maastrichtian age, below the upper Kharga Shale Member. The studied specimens were collected from the upper part of the Kharga Shale Member at Naqb Refuf, Kharga Oasis. This Member is consists of grey to greenish grey shales, intercalated with calcareous and pebbly.

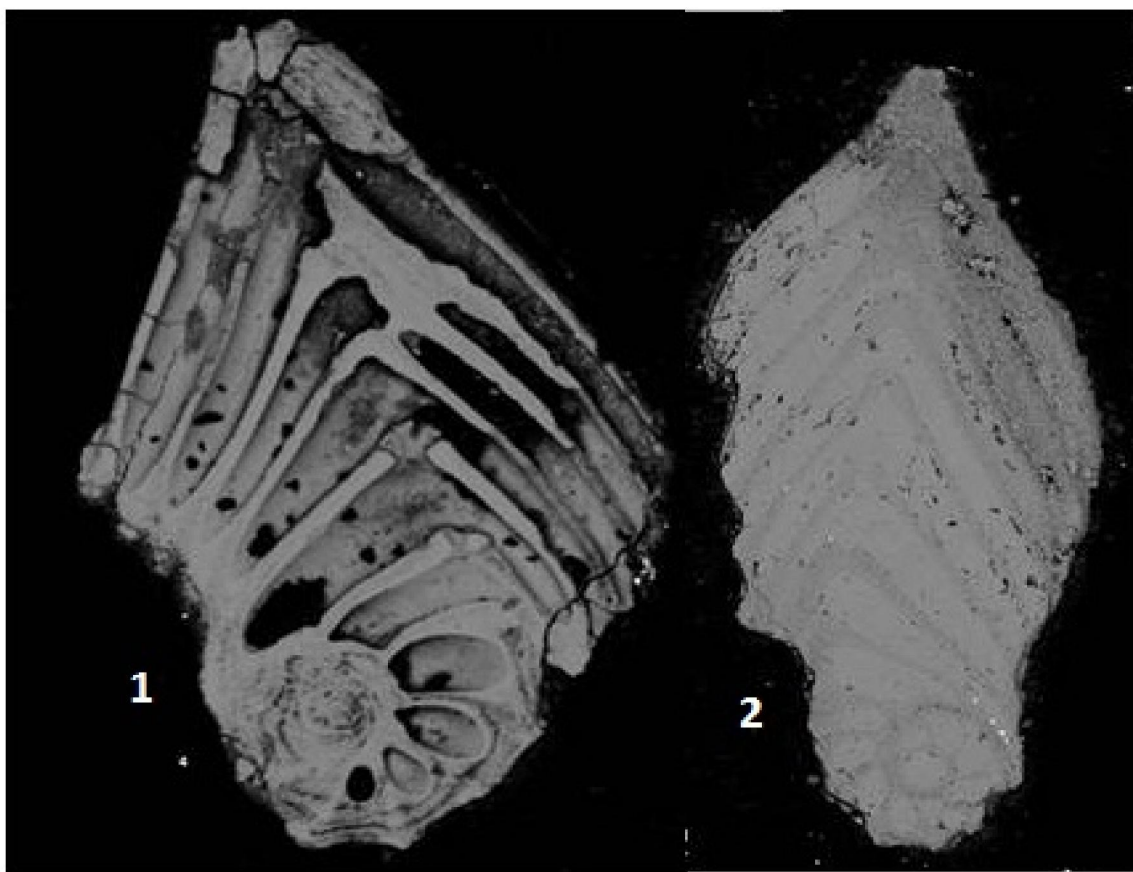


Text-fig. 4: *Palmula pilulata* Cushman, 1938, after Frizzell 1954, p. 97, pl. 5, figs. 5 & 6

Mudstone beds that mark the beginning of early Paleocene (Tantawy *et al.* 2001). The second stratigraphic unit is the Esna Shale Formation, which is measured from North Gunna section, Farafra Oasis, Western Desert. The Esna Shale Formation is conformably overlying the Tarawan Formation of Paleocene age and underlying unconformably the Oligo-Miocene fresh water stromatolitic limestones.

The Esna Shale Formation is 18 m thick and it is made of greyish green shale, in the basal part and dark green papery shale in the top part. This Formation is rich by planktic and benthic foraminiferal content. The third stratigraphic unit is El Fashn Formation that was measured at Bayad El Arab section, Beni Suef area, Nile Valley. El Fashn Formation conformably overlies the Qarara Formation of middle Eocene age and conformably underlies the Beni Suef Formation of upper Eocene age (Aly et al. 2011). The formation in

the area is about 28 m thick and is made up of yellowish to greyish white, moderately hard, fossiliferous limestones, intercalated with yellowish white, fossiliferous marls. The limestone is well-bioturbated and contains abundant bivalves and echinoids assemblage near the base. On the basis of planktic and benthic foraminifera, this unit can be assigned to the late middle Eocene (Bartonian) (Abdel-Gaied and Abdel-Aziz 2005).



Text-fig.5: Transverse section photographed by SEM show the internal shells structure of *Palmula* spp.

Taxonomy

The classification of Loeblich and Tappan 1987 are follows here for the rank of genera.

Suborder **Lagenina** Delage & Hérouarad, 1896.

Superfamily **Nodosariacea** Ehrenberg, 1838.

Family **Vaginulinidae** Reuss, 1860.

Subfamily **Palmulinae** Saidova, 1981.

Genus **Hanenopalmula** Alyn. gen.

Type species: *Palmula woodi* Nakkady, 1950.

Etymology: The name is dedicated to Dr. Hanan Awad and Miss Hanin Aly.

Holotype: The specimens illustrated here (plate 5, fig. 4).

Paratype: The specimens illustrated here (plate 5, fig. 5).

Type locality: North Gunna section, Farafra Oasis, Western Desert, Egypt.

Occurrence: *Hanenopalmula* genus is abundant in Esna Shale Formation and Paleocene part of the Dakhla Shale formation in Egypt.

Age: Paleocene.

Diagnosis: Test compressed, palmate; proloculus portion bullate; early chambers rises above level of the test; laterchambers arched; widest point very close to the proloculus portion; surface of test smooth; apertural terminal, radiate.

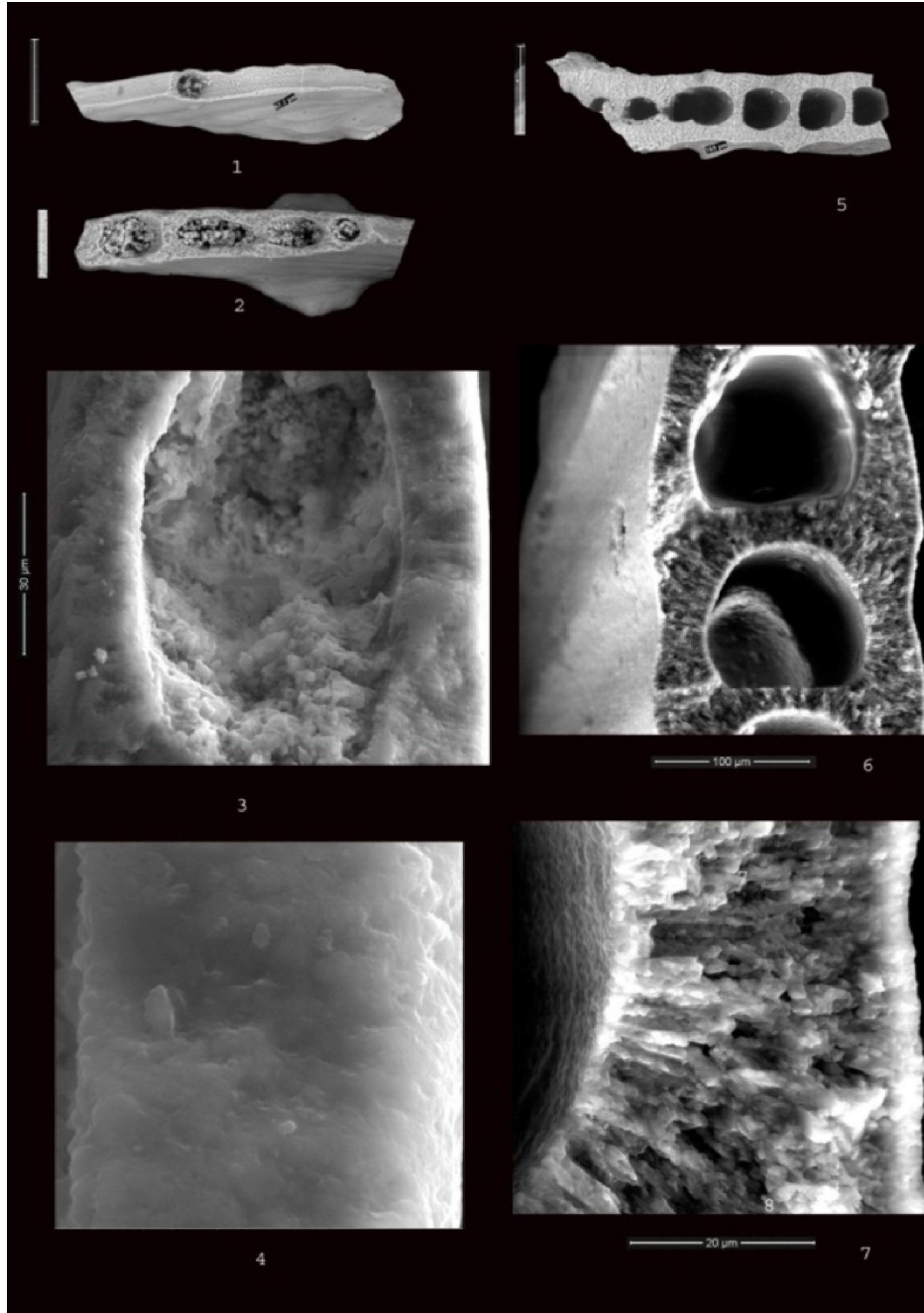


Plate 4

Fig.

1. Side view of *Hanenopalmula woodi*; note, the thickness of the wall is 62.2 μ .
2. Transverse break of the wall of Fig. 1; note, shape of the internal chambers is elliptical (X253).
3. Enlarged of Fig. 1; note, the calcite crystals is volumetric size and the inner chambers are filled out by sediments (X3500).
4. Enlarged of one wall layer of Fig. 3; note, the wall is consist of one layer (X14000).
5. Transverse break of the wall of *Palmula cushmani* (Morrow); note, the thickness of the wall is 169 μ (X168).
6. Transverse break of the wall of Fig. 5; note, the wall is consists of two thin layer (X3500).
7. The same of Fig. 6 enlarged; note the prismatic calcite crystals and the pore openings (X6000).

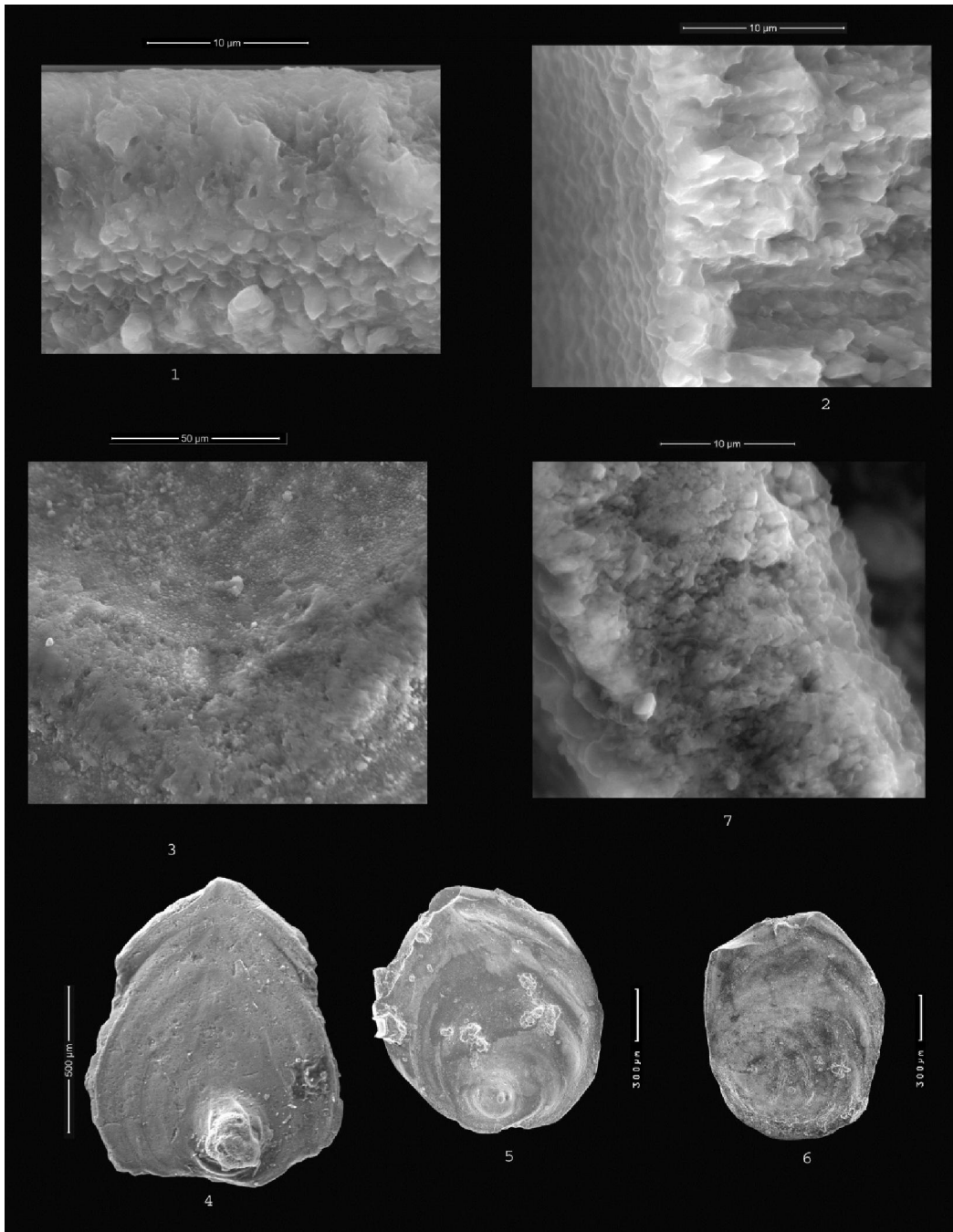


Plate 5

Fig.

- 1- The inner shell surface of *Hanenopalmula woodi*; note, its rough (X12000).
- 2- The inner shell surface of sample 7, plate 4; showing the inner wall surface is rough but by lesser degree than the Fig. 1(X12000).
- 3- The inner surface of Fig. 1; note, thickness of the septa it's thick, raised and wide(X2500).
- 4- *Hanenopalmula woodi* Nakkady, 1950; note, the widest point and the proloculus portion are on the straight line (X218).
- 5- *Hanenopalmula dabbousensis* Aly, 2017 (X195).
- 6- Para type of Fig. 5 (X 175).
- 7- The inner surface of *Palmula cushmani*; note, the thickness of septa is raised and wide (X10000).

Description:

Test is palmate or heart-shaped, compressed except in early stage (Pl. 1, figs. 1, 2). Proloculus portion is bullate, rising up the general level of the test (Pl. 1, figs. 1 & 2) and representing a nucleolus to the rest of the test (Text-fig. 2; 3, 7, 8 & 10). Later stage is uniserial contains on 12 elongate, arched chambers, gradually increasing in size as added (Pl. 1, fig. 1 and Pl. 5, figs. 4, 5 & 6), broadening towards the proloculus portion and narrowing towards the apertural end. The beginning and ending chambers in late stage are located around the early chambers (Pl. 1, fig. 1 and Pl. 5, figs. 4, 5 & 6). The widest point is on a straight line with a proloculus part in its position (Pl. 5, fig. 4) or close to its early chambers (Pl. 5, figs. 5 & 6). Sutures at early stage are distinct, raised and straight. Sutures at the uniserial stage raised, wide and arched. The periphery is rounded (Pl. 5, fig. 6). Aperture terminal, radial carried on small neck (Pl. 1, fig. 4). Wall is calcareous, smooth and glistening.

Remarks:

The *Hanenopalmula* Aly 2017 a new genus differs from *Palmula* Lea 1883 in possessing compressed, palmate to heart shape test. Early chambers are representing nucleolus to the rest of the test. Chambers in late stage are strongly arched, and its beginning and its ending are located around the proloculus chambers. The widest point is located at an early stage. The wall ultrastructure is consist of one layer of solid, volumetric size calcite crystals, there are no pores opening are observed between the calcite crystals.

Hanenopalmula dabbousensis n. species Aly.

Plate 5, fig. 5 & 6.

Palmula pilulata Cushman, 1938; Aly et al. 2011, pl. 3, fig. 11.

Etymology: in the honor of Dr. Saad Dabbous, Dalhousie University, Canada.

Type species: new species.

Type locality: Beni Suef area, Nile Valley, Egypt.

Type section: Bayad El-Arab section.

Type stratum: El Fashn Formation.

Holotype: Plate 5, figure 5.

Paratype: plate 5, figures 6.

Stratigraphic range: Late Middle Eocene.

Description: Test is rounded and compressed. Early stage growth up on the shell surface, bullate. Surface at early stage is smooth. Uniserial chambers are about seven, rounded and strongly arched. Sutures are thick, wide and raised. Periphery is keeled. Apertural is terminal. Wall calcareous, ornamented by very small nodes and very fine perforate.

Remarks:

This species is differs from other *Hanenopalmula* spp. In its early stage is smoothly finishing. Surface is

ornamented by micro perforate. Uniserial chambers are wide, rounded in shape. The sutures are wider and thicker than other *Hanenopalmula* spp. Periphery rounded and keeled.

Hanenopalmula woodi (Nakkady 1950).

Plate 5, fig.4.

Palmula woodi Nakkady 1950, p. 1950, p. 684, pl. 89, fig. 24.

Palmula woodi Nakkady 1950; Anan 2010, p. 30, pl. 1, fig. 11.

Description

Test is palmate, compressed broad towards the proloculus portion and narrowing towards the apertural end. Early stage is rising up the general level of the test. Uniserial chambers are about 10, arched and wide. Surface is finely perforate. The widest point is on a straight line with the proloculus portion. Sutures slightly depressed. Aperture is radial and terminal. Wall is calcareous.

Remarks: This species differs from the others *Hanenopalmula* spp. In its sutures at early stage are rounded and thick. Sutures in late stage are narrow and slightly depressed.

Conclusions

A Scanning Electron Microscope study of *Hanenopalmula* shells reveals the details of wall ultrastructure and the aperture characters. The shell ultrastructure indicated that the wall is formed of volumetric layer of crystalline calcite crystals. Such an ultrastructure is characteristic of one lamellar. The inner shell surface is rough. The early stage is close and coiled. Uniserial chambers are coiled and arched. The widest point of the shell is very close to the proloculus chambers.

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