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Characters of *Nummulites multiplicutiospiralis* n. sp. from the Qarara Formation, Maghagha, Nile Valley, Egypt

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Abstract: *Nummulites multiplicutiospiralis* n. sp. is described and illustrated for both generations from a claystone of Lutetian age in the Middle Eocene Qarara Formation, Maghagha, Nile valley, Egypt. Previously considered to be *Nummulites gizehensis*, we describe this form as a new species based on diameter of the test and protoconch sizes, septal shape and granulations. The primary feature of this species is spiral multiplication, seen in spiral section. The species is also characterized morphologically by lenticular to flat tests with rounded periphery, wrinkled to broadly meandering septal filaments and few granules on the periphery in microspheric forms. The granules are spirally arranged on the septal filaments in megalospheric forms. Chambers are longer than high and the spire is irregular. The new taxon belongs to the *Nummulites partschi* Group, Subgroup *N. gizehensis*. Reflexive coiling in the spiral may develop through ontogeny as in *N. rollandi*, the species which was considered to be an index species in the southern Tethys (Boukhary et al., 1982 and Boukhary et al. 2010). The characters of the new species, as well as its retrogenesis and reflexive coiling, should be further studied in general in *Nummulites* spp., to understand the importance of such characters phylogenetically.

Key words: invertebrate paleontology, foraminifera, *Nummulites*, Eocene, Nile Valley, Egypt

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1 Introduction

Hussein et al. (2008) recorded two subgroups of morphotypes related to the *Nummulites* gizehensis Group from the Middle Eocene sequence of the Citadel area, east of Cairo, and also from west of the Fayoum depression. Boukhary et al. (2010) also studied the Middle Eocene larger foraminifers of the Mokattam Formation exposed at the Citadel section, north of Gebel Mokattam and they also differentiated two additional morphotypes (*Nummulites lyelli* d'archiac and the Haime (1853) morphotypes 1 and 2), based on the nature of their septa.

When examining the *Nummulites* assemblages in samples collected from the Qarara Formation in the Qarara area of the Nile valley (Fig. 1), we found a morphotype that does not fit previous species descriptions. A new taxon is described here from the Nile Valley facies.

2 Geological Background

The Eocene succession of the Geabel Qarara Section in the Nile valley, east of Maghagha, Egypt, consists of two main units: the Qarara Formation at the base and the El Fashn Formation at the top. Based on *Nummulites* specimens found in the section, Bishay (1966) and Omara et al. (1977) assigned the succession at Maghagha to the Late Lutetian and showed that this stage is represented by the Qarara Formation and part of El Fashn Formation. The stratigraphy and geology of the Qarara Formation has been reported in several studies (Boukhary and Abdulla 1985; Moulin, 2011, Lorraine, 2012, Boukhary et al., 2012). Boukhary and Abdulla (1985) that combined paleontological and petrological examination of the Eocene rocks at Maghagha and revealed that the succession belongs to the Nummulites gizehensis gizehensis Zone.

The stratigraphic section of the Qarara Formation is ~140 m thick and of Middle Lutetian to Bartonian in age (Boukhary, 1988). As noted above, this formation is commonly divided into the Qarara Formation succeeded by the El Fashn Formation (Fig. 1). The lithologies of the Qarara Formation consists of marl and shale intercalations at the base and marly limestone at the top. The *Nummulites* spp. of the Qarara Formation are distributed in two successive horizons: taxa of the lower horizon comprise *N. depressus* Kenawy, 1978, *N.* gr. *striatus* and N. gr. *laevigatus* of Middle Lutetian age; and those of the upper horizon comprise N. gr. champollioni, N. gr. gizehensis, N. depressus and *N.* gr. *striatus*, an assemblage which denotes a middle–late Lutetian age.

The El Fashn Formation consists of white hard bryozoan limestone with flint bands and contains members of the *Nummulites* gr. *beaumonti* of Bartonian age.

3 Materials, Methods and Depository

Thirteen *Nummulites* specimens, collected from the Qarara section, were analyzed for diameter, thickness,

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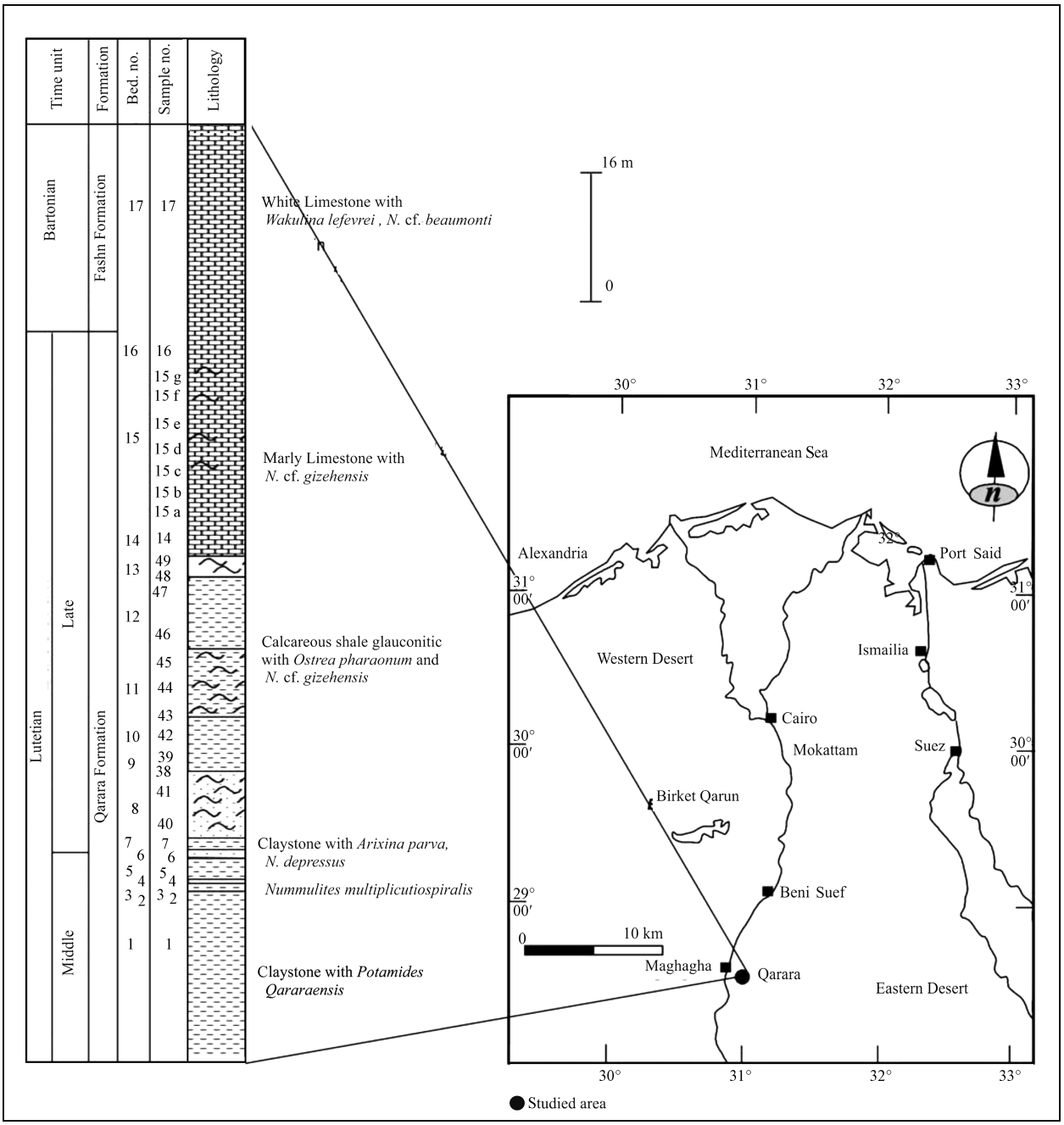

Fig. 1. Location map and stratigraphic succession of the studied section measured at the Qarara Section (after Boukhary et al., 2012).

number of whorls per radius, and minimum and maximum values of test radii and height. The *Nummulites* specimens were heated, soaked in water and then split along the equatorial plane into two halves using a needle, to examine the nature of spire.

The material described here is deposited in the collection of Safia Gaber Al Menoufy, Ain Shams University, Faculty of Education, Geological Museum, Department of Biological & Geological Sciences, Cairo, Egypt (Q31– Q3 32.).

4 Systematic Paleontology

Order Foraminiferida Eichwald, 1830
Superfamily Nummulitacea de Blainville, 1827
Family Nummulitidae de Blainville, 1827
Genus *Nummulites* Lamarck, 1801

Group *Nummulites partschi* de la Harpe, 1880
Subgroup *Nummulites gizehensis* Forskäl, 1775

Nummulites multiplicutiospiralis n. sp.

(Figs. 3.1–13, 4.1–19)

Holotype: Q31, Fig.4.4.

Paratypes: 30 specimens: Q32– Q3 32.

Etymology: This species is named after the character of multiplication in the test spiral.

Locus typicus*:* This species is recorded from the Qarara Formation at Maghagha, Nile valley, Egypt (31° 8' 20" N, 28° 18' 20" E).

Stratum typicum: Sample no. 2, Bed no. 3, Qarara Formation, Nile valley.

Stratigraphic Distributio*n*: Eocene, Late Lutetian.

Diagnosis: Test lenticular to flat, rounded periphery; chambers quadrate; test surface granulate and with spiral multiplication.

Measurements: Holotype dimensions in the microspheric form, the diameter is 20 mm, and the thickness is 5 mm. Paratype dimensions in the microspheric forms, diameter ranges from 7.5–21 mm, thickness ranges from 2.5–5.8 mm (Fig. 2). In megalospheric forms, the diameter ranges from 4.0–5.6 mm, thickness ranges from 1.4–3 mm.

Description: The microspheric (B-form) test has a rounded margin with a regular spire, and a thick and irregular marginal cord. Septal filaments are meandering in shape and a few granules are found on the periphery. In the equatorial section, the steps of coiling are lax to tight. The base of the septa is straight and septa become inclined towards the periphery. The chambers are quadrate. The number of whorls in relation to the radius is 10 in a radius of 2.2 mm and 30 whorls in a radius of 9.65 mm. The characteristic feature is spiral multiplication, seen in spiral section of the test (Fig. 4)

The megalospheric (A-form) test is much smaller. The surface has sinuous septal filaments at the middle portion of the spire and the filaments become radiate to falciform. They are densely granulated; granules are coarser on the polar regions spreading outwards in juvenile tests, becoming spirally arranged in adults. In the equatorial

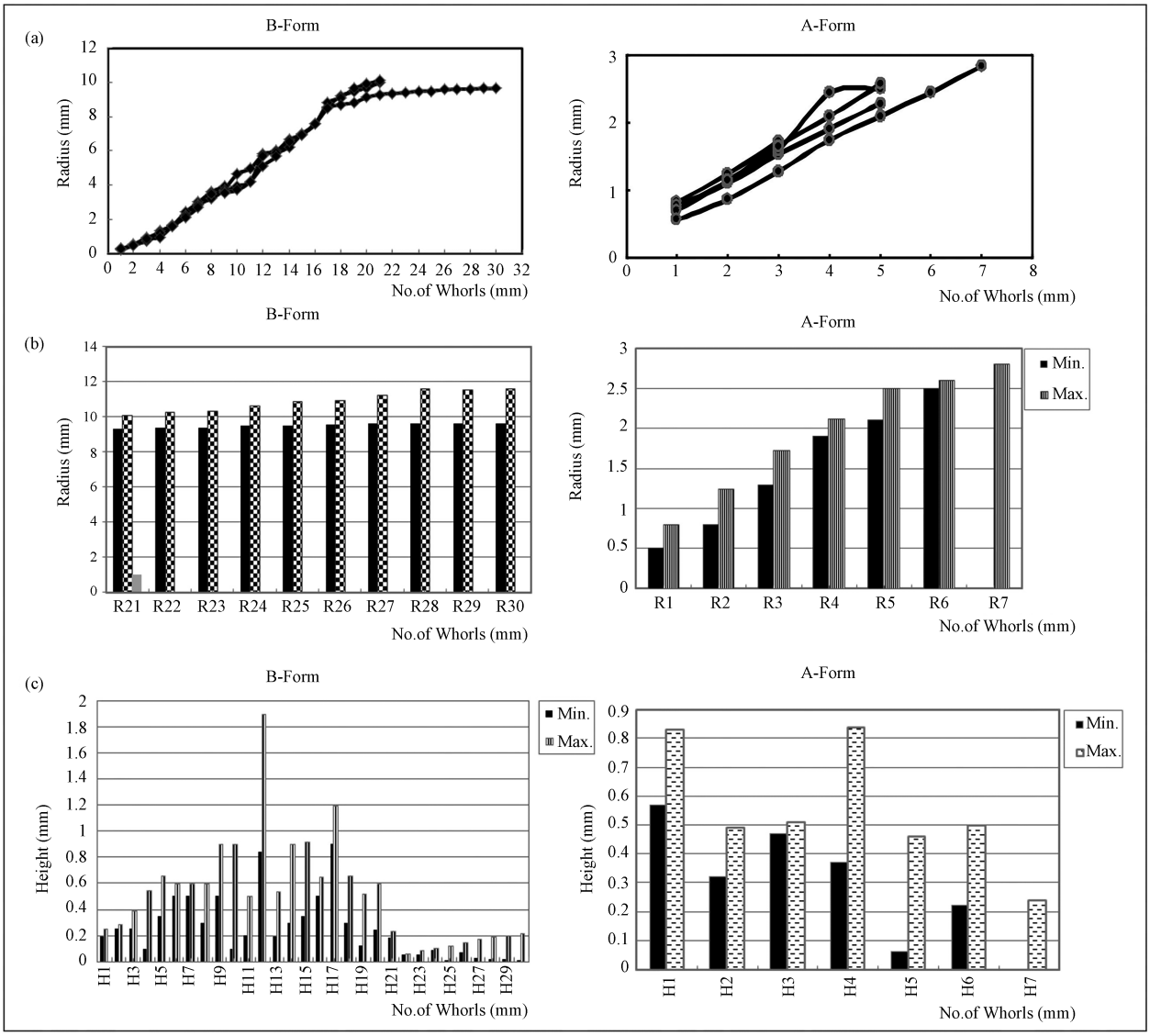

Fig. 2. Morphometric data for *Nummulites multiplicutiospiralis* n. sp. (B- & A-forms), sample 2, Qarara Fm., Nile valley: A, test radius plotted against number of whorls; B, test radii (minimum and maximum); C, height (minimum−maximum).

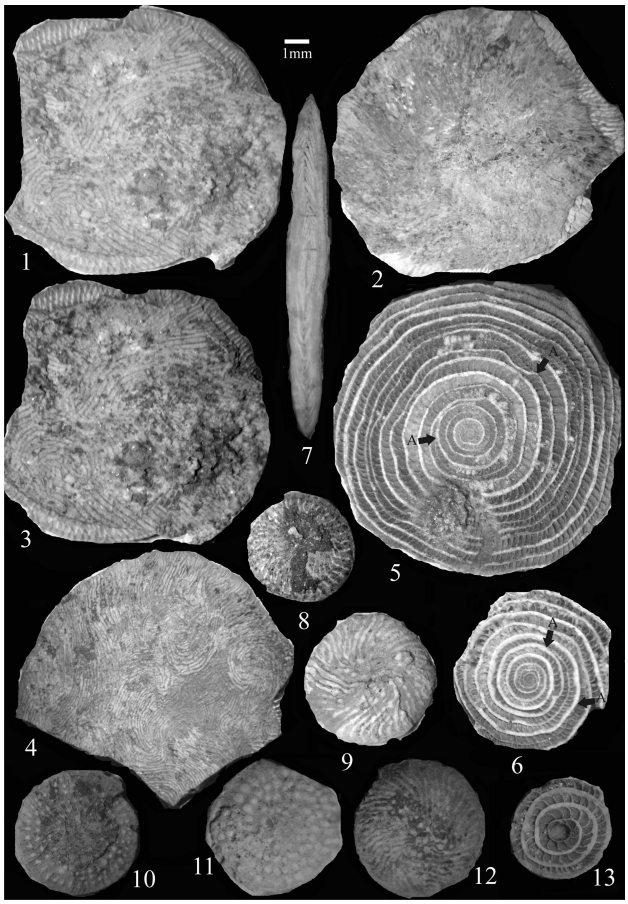

Fig. 3. *Nummulites multiplicutiospiralis* n. sp. from sample 2, Qarara Section: 1–7, microspheric forms: 1–4, external view, 5-6, equatorial sections, 7, axial section; 8–13, megalospheric forms: 8–12, external view, 13, equatorial section. Q3 1– Q3 32).

Fig. 4. *Nummulites multiplicutiospiralis* n. sp. from sample 2, Qarara Section: 1–5 microspheric forms: 1–5 equatorial sections,; 6–19 megalospheric forms: 6–11 external view, 12–16 equatorial section, 17–19 axial sections. Q3 1– Q3 32.

section, the septa begin as perpendicular at the base and then become inclined at the top. The number of whorls in relation to the radius is four in a radius of 1.9–2.4 mm and seven in a radius of 2.9 mm. The ontogeny is from lax to tight. Protoconch diameter ranges from 0.45–0.75 mm.

5 Discussion

The assessment given here is based on the scheme for the identification of *Nummulites* given by Blondeau (1972) and Schaub (1981).

The multispiral growth in Eocene *Nummulites* was previously recorded in some species by Wielandt (1991), Boukhary et al. (2010) and Ferràndez-Canadell (2012). This character, and other poorly understood characters such as reflexive coiling and retrogenesis are in need of further investigation in the *Nummulites* lineages. When *Nummulites* specimens are heated, soaked in water and then split along the equatorial plane into two halves using a needle, the multispiral nature of spire, if present, can be readily seen from the equatorial plane, Blondeau,1972.

Differences between *Nummulites multiplicutiospiralis* and similar species are listed in Table 1. The margin of *N. multiplicutiospiralis* is parallel, as seen in axial section (Fig. 3) and the spire grades from lax to tight (Fig. 3), similar to that of members of the *N. partschi* group. The test is loosely coiled. Septa are typically similar to those found in the *N. partschi* group. In addition, the megalospheric forms of *N. multiplicutiospiralis* have spirally arranged granules, also typical of members of the *N. partschi* group. However, *N. multiplicutiospiralis* is larger and flatter than previously described members of the *N. partschi* group and has spiral multiplication, which does not appear in the *N. partschi* group. *N. multiplicutiospiralis* differs from other species of the *N. partschi* group in characteristics such as spiral duplication, the thick, irregular marginal cord and the quadrate chambers.

N. multiplicutiospiralis differs from *N. gizehensis* (Fig. 5) in being smaller in size; the new species is flatter and with characteristic spiral multiplication, which is not seen in *N. gizehensis*. Both show lax to tight spires (Table 1, Fig. 5). The new species also differs from *N. gizehensis* in that the test has a parallel margin in axial form, is more lax in the center in microspheric forms, and has densely arranged granules. *N. gizehensis* has a more lenticular test with scattered granules on the surface and a thick-lenticular axial section. The protoconch diameter of *N.*

Table 1 Comparision of measurements *Nummulites multiplicutiospiralis* n.sp. with those of similar species

Characters	*Nummulites praegizehensis* (Boukhary and Hussein-Kamel, 1993)	*Nummulites gizehensis* (Forskäl, 1775) (after Boukhary and Hussein-Kamel, 1993)	*Nummulites remissus* (Boukhary et al., 2000)	*ummulites fayumensis* (Al Menoufy and Boukhary, 2018)	*Nummulites multiplicutiospiralis* n.sp. Present study
	N. gizehensis group	*N. gizehensis* group	*N. laevigatus* group	*N. gizehensis* group	*N. partschi* group
B-form					
Diameter	7 –22.8 mm	10.2–32.1 mm	8–19.4 mm	10.2–26.9 mm	7–21 mm
Thickness	1.8–5.1 mm	2.3–6.5 mm	0.8–3 mm	1.0–2.55 mm	2–5.8 mm
Granulation	Scattered all over the test on the filament	Scattered all over the septalfilament	Granules arranged near the periphery	Scattered all over the septalfilament	Few granules on the priphery
Steps of coiling	Lax to tight, laxer than *gizehensis*	Lax to tight in the large tests	Tight to lax	Tight to lax	lax to Tight
Whorls vs radius	25 whorls in 8.19–12.53 mm; 27 whorls in 12.6 mm and 29 whorls in 10.36 mm	20 whorls in 7. 3 mm; 30 whorls in 11.1 mm and 36 whorls in 14. 6 mm	12 whorls in 6.9 mm; 14 whorls in 7.9 mm and 18 whorls in 8 mm	12 whorls in 7-8 mm; 18 whorls in 12.9 mm and 23 whorls in 15.6 mm	10 whorls in 2.2 mm; 20whorls in 6.55 mm and 30 whorls in 9.65 mm
A-form					
Diameter	1.81 mm	2.8–8. 1 mm	4.0–8.0 mm	3–6.2 mm	4.0–5.6 mm
Thickness	1.4–3.1 mm	1.1–3.6 mm	0.6–1.6 mm	0.6–1.1 mm	1.4–3 mm
Granulation	Granulation concentrate on the center and become spread out on the septalfilaments with different denesities	Granulation is spread out on the surface following the behavior of the spire	fine granules arranged on the external whorls	granules spread out on the surface	Coarser on the polar regions to spirally arranged in juveniles whereas rare or the surface is erased in adults
Test form	Lenticular	Lenticular,with swelling center in small tests and apex in juvinel	flat	flat	Lenticular
Whorls vs radius	4 whorls in 1.5–2.2 mm; 5 whorls in 2.58 mm and 6 whorls in 3.2 mm	5 whorls in 2.5 mm and 7 whorls in 3.0 mm.	4 whorls in 2.8 mm to 3.37 mm; 6 whorls in 3.4 mm to 3.6 mm and 7 whorls in 3.8 mm	4 whorls in 2.0–2.5 mm; 5 whorls in 3.2 mm and 6 whorls in 3.66 mm	4whorls in 1.9–2.4 mm; 6 whorls in 3.2 and 7 whorls in 4 mm
Size of protoconch	0.49–0.91 mm	0.49–1.0 mm	0.2–0. 5 mm	0.22–0.50 mm	0.45–0.75 mm

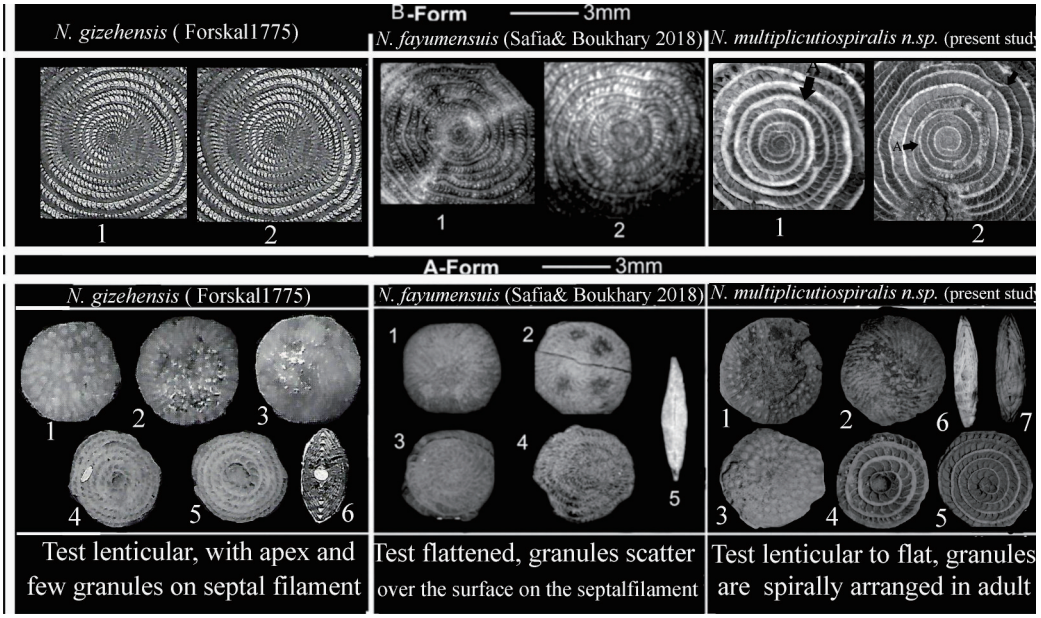

Fig. 5. Comparison between *Nummulites multiplicutiospiralis* n. sp., *N. fayumensis* and *N. gizehensis*.

multiplicutiospiralis (0.45–0.75 mm) is smaller than that of *N. gizehensis* (0.49–1.0 mm). The steps of coiling in other species of the *N. gizehensis* group (36 whorls) are laxer than those of *N. multiplicutiospiralis* (30 whorls). The ontogeny of *N. multiplicutiospiralis* is from lax to tight and it develops more or less loose spires, which are similar to those of *N. praegizehensis* Boukhary and Hussein-Kamel, 1993 and *N. gizehensis* Boukhary and Hussein-Kamel, 1993. The marginal cord in *N. multiplicutiospiralis* is thicker and the proloculus smaller than in *N. gizehensis*. In addition, *N. multiplicutiospiralis* is flatter and possesses chambers longer than high compared with those in *N. gizehensis* and *N.praegizehensis*.

N. multiplicutiospiralis also differs from *N. fayumensis*

Al Menoufy and Boukhary, 2018 (Fig. 5) and *N. remissus* Boukhary, Strougo and Merdas, 2000 in having a smaller test, tighter spire in the microspheric form and a protoconch diameter larger than that of *N. fayumensis* and *N. remissus*.

Nummulites multiplicutiospiralis differs from *N. remissus* in having fewer granules on the surface in the microspheric form, and is coarser on the polar regions to spirally arranged in juveniles whereas rare or the surface is in adults in megalospheric form, both species belong to two different lineages in *Nummulites partschi* group. Worth mentioning that Boukhary et al. 2000 considered *N. remissus* as the descendant of *N.gracilis* Schaub, 1981, originally described from Libya.

6 Conclusions

Samples from the Middle Eocene section measured at Qarara, Egypt, revealed a previously undescribed species, *Nummulites multiplicutiospiralis* n. sp. Biometrical analyses demonstrate that *N. multiplicutiospiralis* has a relatively thick marginal cord, a proloculus larger than the deuteroconch, and a specific character of spiral multiplication.

Another distinctive character, reflexive coiling, which reportedly persisted in *Nummulites rollandi* Ficheur, 1890, as recorded in Tunisia by Schaub (1981) and in Egypt by Boukhary et al. (2010), might be phylogenetically controlled. Based on observations from our study and previous reports regarding reflexive coiling, we suggest that spiral multiplication, retrogenesis and reflexive coiling, may be important in phylogeny and deserve much more detailed investigation.

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Appendix

Taxonomic List of *Nummulites* taxa considered in this paper according to the scheme for the identification of *Nummulites* is that given in Blondeau (1972) and Schaub (1981).

Order Foraminiferida Eichwald, 1830
Superfamily Nummulitacea de Blainville, 1827
Family Nummulitidae de Blainville, 1827
Genus *Nummulites* Lamarck, 1801
Nummulites multiplicutiospiralis n. sp.