New nummulitids from lower Eocene limestones of Egypt (Monastery of St. Paul, Eastern Desert)

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ABSTRACT: *Bassiounina sanctipauli* n. gen. n. sp. (Nummulitidae) together with *Nummulites praeatacicus* n. sp. are newly described from the upper nummulitic bearing sandy marls from Monastery of St. Paul, Eastern Desert, Egypt. According to Schaub's nummulitic time scale 1981, this interval is assigned to the Early Eocene (Early/Middle Ilerdian), since *Nummulites atacicus* Leymerie 1846 originally recorded from Mont Cayla (Herault), is a characterisitc species of the top part of the Middle Ilerdian. *Nummulites sahariensis* n. sp. is also described from a parallel stratigraphic section and is given an Early Eocene Age (Early Ilerdian 1/2); this age is confirmed from studies based on planktonic and benthonic foraminifera and matched well with Schaub's nummulitic scale. The sediments were deposited in small basins situated on a structural ramp that inclined gently towards the south.

INTRODUCTION

The Paleocene-Eocene strata of Egypt show a great variety of lithologies with clays, marls, and limestones formed in different paleogeographic settings of deep to shallow shelf environments. The Early Tertiary stratigraphic sequences of the Galala Plateaus (Eastern Desert of Egypt, text-fig. 1) are dominated by shallow water limestones with several siliciclastic intercalations. The carbonates contain large numbers of benthic foraminiferids, among them alveolines, which were used for biostratigraphic interpretations. Marly intercalations are less frequent and often strongly altered by diagenetic overprinting. In a few cases planktic foraminiferids were found and supported the biostratigraphic subdivisions.

The stratigraphic section of the Monastery of St. Paul is situated at the southern rim of the South Galala, and consisting of Late Cretaceous to Early Tertiary strata. The Late Maastrichtian sequence (G. gansseri-zone) with prevailing marls is conformably overlain by similar lithologies of Early Paleocene marls. The base of the sequence contains planktonics, including the recently identified *eugubina* - zone (Strougo et al. 1992). Dolomitic limestones are intercalated with the Middle Paleocene silty marls and no fossil remains of biostratigraphic value were found (280992/20; text-fig. 2). The limestone-unit marks the onset of a general lithologic change within the section that represents the Middle Paleocene - Early Eocene succession. The limestones are thick massive carbonates composed of synsedimentary reworked limestones, dolomites, and intercalated silt/sandstones and a few thin marly beds.

The Middle Paleocene - Lower Eocene carbonate-dominated sediments were formed in shallow shelf environments. Microfacies and sedimentary structures indicate a gently south dipping carbonate platform in the area of the two Galala Mountains during Early Tertiary times (Kuss and Leppig 1989). Based on several massive horizones of reworked debris, the carbonate sequence represents the distal part of a southward prograding platform that originally formed in age equivalent shallow-shelf environments north of the Galala Mountains.

Investigations of the early Tertiary column (Kulbrok, in prep.) give evidence to the composition of the carbonate-dominated sediments: limestone conglomerates, intercalated with quartzose limestones, siltstones, and marls. Within the limestone conglomerates, different intensities of intraformational reworking were observed as follows:

1. Wacke/rudstones, dominated by synsedimentary reworked limestones clasts and bioclasts (mainly larger foraminiferids) incorporated in a micritic groundmass (autochthonous) of nearly the same composition.

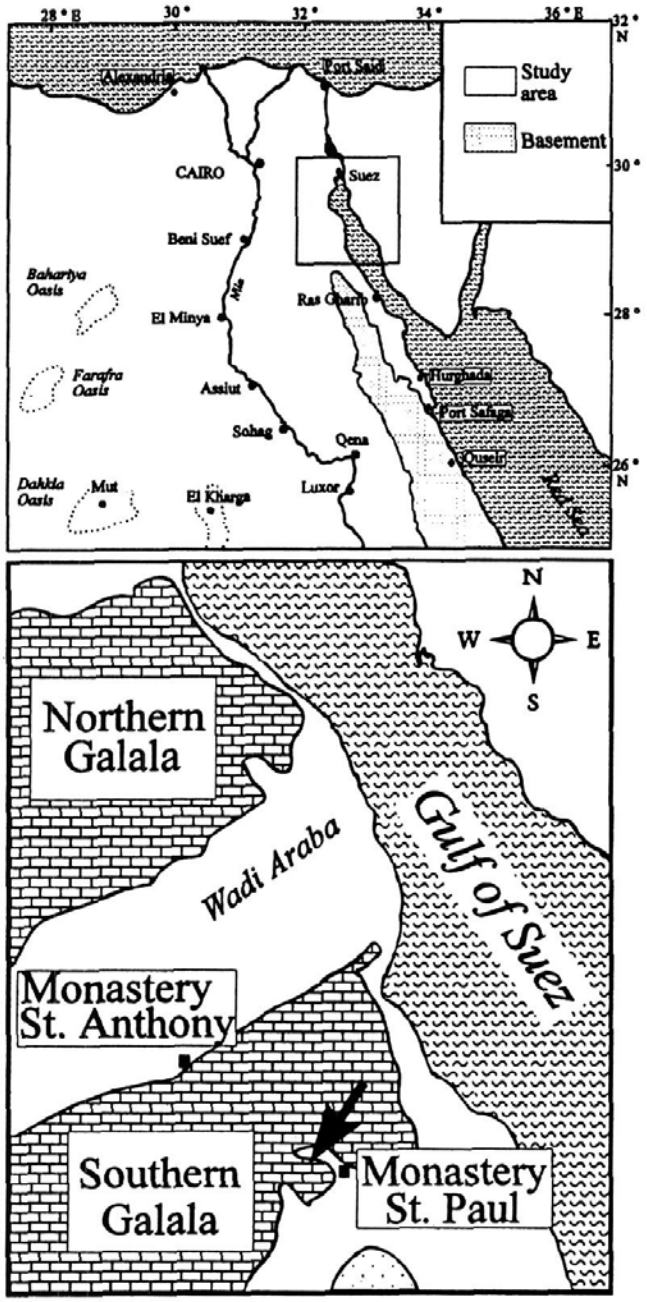
2. Increased contents of quartz and lithic fragments are due to intensive reworking and deeper erosion of older strata. These quartz wacke/packstones often hold large numbers of foraminiferids, which are nearly exclusively composed of eroded shells. In such cases, it is very difficult to estimate the proportion of "autochthonous" grains bioclasts.

3. Intraformational reworking expressed by conglomeratic nodules surrounding older alveolines within limestones of younger stratigraphic levels.

Current investigations (Kulbrok, in prep.) characterize the depositional development of the region as a gently south-dipping homoclinical ramp. The setting is an arrangement of small basins and highs formed from a previously developed morphology, that are overlain by siliciclastic input coming from a structural high to the north.

Stratigraphy of the Nummulite-bearing Intervals:

The nummulites described in this report were found within the Early Eocene portion of the stratigraphic section (text-fig. 2). The stratigraphic subdivisions used here are based on alveolines (Hottinger 1960) and planktonic foraminiferids (Bolli et al. 1985). Subdivisions summarized charts of benthic fora-



TEXT-FIGURE 1
Location of the stratigraphic section at the Monastery of St. Paul, along the southern rim of the South Galala.

miniferids/nannoplankton (Racey 1994) and planktic foraminiferids/ nannoplankton (Bolli et al. 1985).

The oldest Tertiary limestones in the studied section (20, 21) are underlain by marls and chalks with planktic foraminiferids of the *M. angulata* zone. Based on lithostratigraphic correlation with a section from the Monastery of St. Paul (Strougo et al. 1992) the sandy marls above were attributed to the basal *M. velascoensis* zone (*2 in text-fig. 2). The first limestones with

TABLE 1
A comparison between *N. praeatacicus* n. sp., *N. atacicus* Leymerie 1846 (Schaub 1981), and *N. praecursor* De La Harpe 1883, (Type locality, Farafra).

Microspheric B-Form

Characteristics	*N. praeatacicus* n. sp (Saint Paul) present work	*N. atacicus* Leymerie 1846 (after Schaub 1981)	*N. praecursor* De La Harpe, 1883 (after Schaub 1981)
Diameter (D)	6.3-8.19mm	11-19mm	9-14mm
Thickness (T)	2.8-4.27mm	3-7.5mm	2.5-4.5mm
Number of whorls per radius W/Rmm	7/1.89 8/3.4-3.99 9-10/5.39	12/6.4 14/8.3 16/8.8 17/9.5	9-15/4.5-6.5

Megalospheric A-Form

Diameter (D)	2.3-3.85mm	3- 5.5mm	3-4.5mm
Thickness (T)	1.4-2.2mm	1.3-2.5mm	1.4-2mm
Number of whorls per radius W/Rmm	2/1.75 3/1.8-2.1	4/1.8-2 5/2.2-2.4	4/1.7-2mm 5/2-2.5mm
Protoconch Diameter	0.21-0.25mm	0.4-0.65mm	0.3-0.5mm

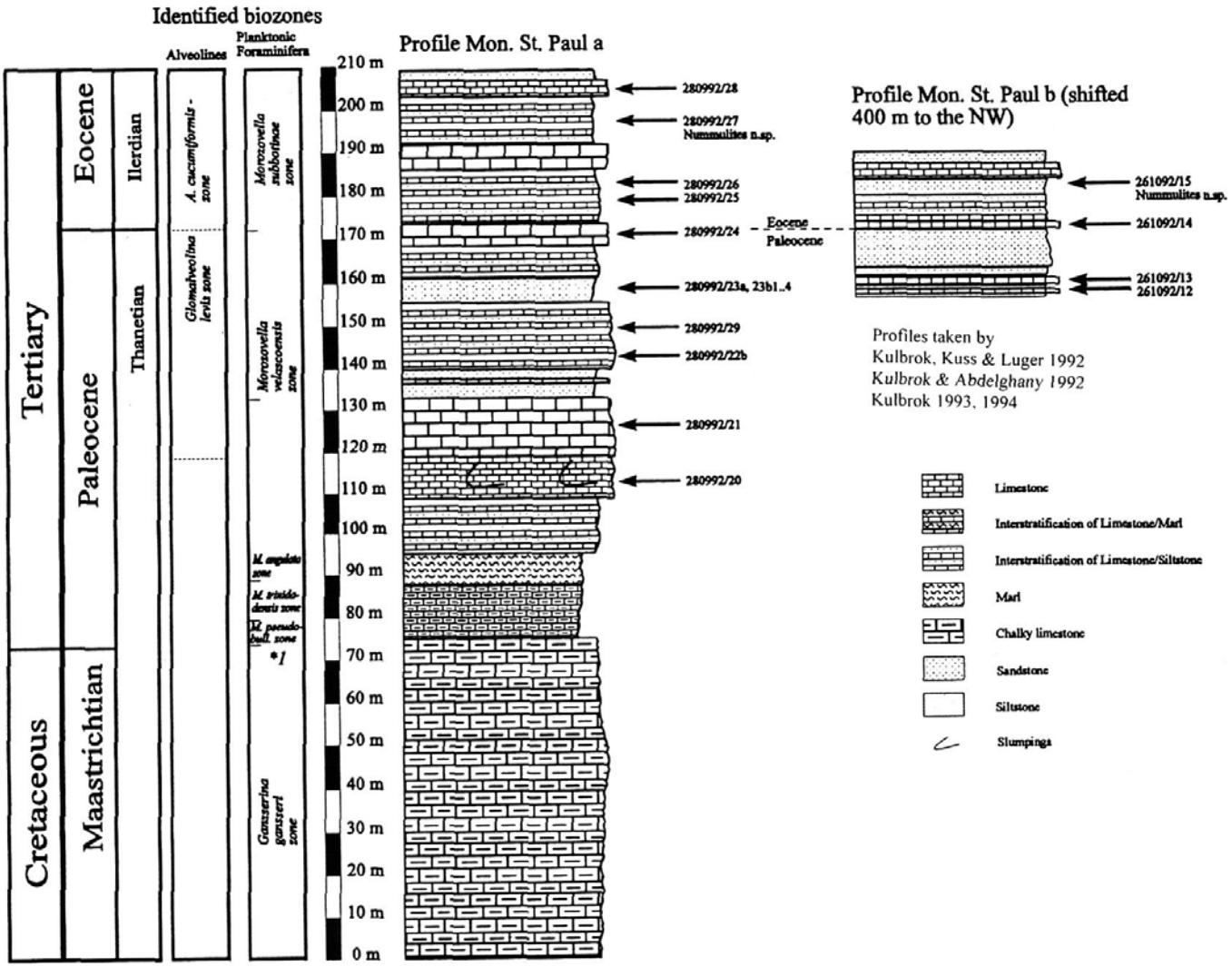
TABLE 2
Biometric values of *N. deserti* De La Harpe, 1883 (emend Schaub 1951), *N. sahariensis* n.sp., and *N. planulatus* (Lamarck 1804).

Microspheric B-Form

Characteristics	*N. deserti* De La Harpe 1883; Schaub, 1951	*N. sahariensis* n.sp.	*N. planulatus* (Lamarck, 1804) Schaub, 1981
Diameter (D)	2.6-4.4mm	4.76-9.8mm	4-10mm
Thickness (T)	1.2-2.0mm	1.82-2.66mm	1-1.5mm
Number of whorls per radius W/Rmm	5/1.3-1.5 6/1.7-2.1 6.5/2.2-2.3 7/2.5	6-7/3 8-9/4.9	6-7/2 8-9/4 9-10/5

Megalospheric A-Form

Diameter (D)	1.5-3 mm lectotype (D) = 2.6 mm	2.9-5.18 mm	1.5-5 mm
Thickness (T)	1-11/3 mm lectotype (T) = 1.3 mm	1.33-1.8 mm	1-2 mm
Number of whorls per radius W/Rmm	3/1.0-1.2 3.5/1.3-1.4 4/1.5-1.4	3/2.2-2.3	2-3/1 3/1.5-2.2 4/2.2
Protoconch Diameter	0.13-0.19 mm	0.14-0.25 mm	0.2-0.35 mm



TEXT-FIGURE 2
Stratigraphic section of the Late Cretaceous/Early Tertiary succession from the Monastery of St. Paul. The benthic and planktic foraminiferids are from Bulbrok (in prep.); stratigraphic datum obtained from Strougo et al. (1992) is indicated with an asterik; *(1) stands for the Early Paleocene eugubina-zone.

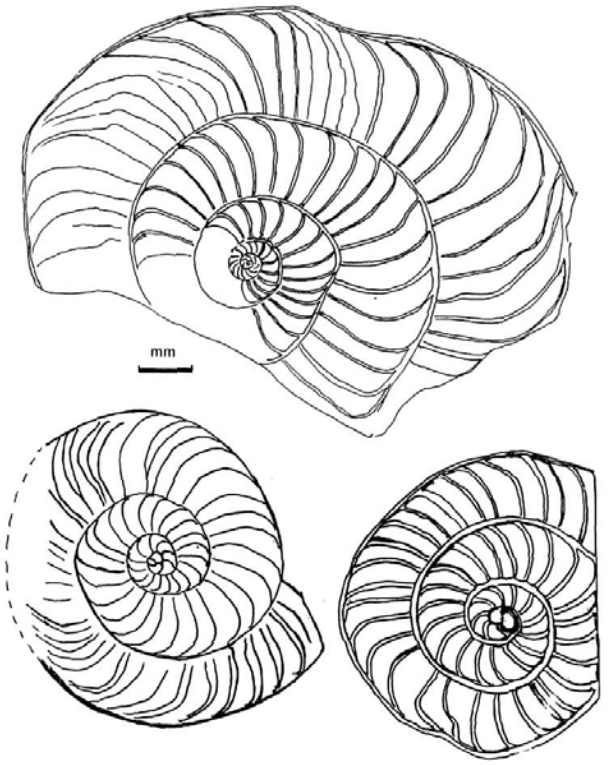
alveolines occur at 35m above the base of the silty marls of the *velascoensis* - zone (text-fig. 2) and yield an assemblage of A. (G.) *dachelensis, Miscellanea rhomboidea* and *Operculina* sp. indicating a late Thanetian age (*levis* - zone).

The marly siltstones above (25-26) contain planktic foraminiferids of the *M. subbotinae* - zone (Early Eocene); the basal Eocene *edgari* - zone could not be recognized until now. Because no younger planktic biozones were proved from the overlying interval, alveolines were used for the stratigraphic subdivision.

The lower nummulite-bearing marly limestones above (27) with containing *Nummulites sahariensis* n.sp.) are overlain by early Ilerdian *Alveolina* - bearing limestones of the *cucumiformis* - zone with *A. (G.) lepidula* and *A. cucumiformis* (28). Both planktic foraminiferids (below) and benthic foraminiferids (above) from the described stratigraphic section indicate an early Eocene age ("Lower Ilerdian 1/2" sensu Racey 1994) of *N. sahariensis* n.sp.

A second parallel profile comprising the Paleocene/Eocene boundary is located 400m to the east of the first section. Two conglomeratic limestone horizons at the base of the profile (samples 261092/12 and 261092/13; text-fig. 2) are mainly composed of reworked bioclasts with high contents of quartz and lithic fragments, indicating synsedimentary reworking. A Late Paleocene age is indicated by the occurrence of *A. (G) dachelensis* (*levis* - zone) and *Hottingerina lukasi* (Drobne 1994, pers. comm.). The overlying limestones of sample 281092/14, (text-fig. 2) are composed of wacke-/packstones with characteristic alveolines of the Lower Eocene *ellipsoidalis* - zone (*A. cf. pasticillata,* and *A. ellipsoidalis*).

The topmost part of Monastery of St. Paul (b) which is represented by the upper nummulite-bearing sandy marls yields *Nummulites praeatacicus* n. sp. together with *Bassiounina*



TEXT-FIGURE 3
A diagrammatic sketch of *Bassiounina sanctipauli* n. gen. n. sp. From Monastery of Saint Paul, South Galala, Eastern Desert.

sanctipauli n. gen., n.sp. Because younger biostratigraphic horizons are not currently to occur overlying the upper nummulite-bearing horizon, a Lower Eocene (Lower Ilerdian sensu Racey 1994) age is suggested for the nummulitic horizon. This bank of Nummulites carrying *Nummulites praeatacicus* n. sp. together with *Bassiounina sanctipauli* n. gen., n. sp. is older than that yielding *Nummulites atacicus* Leymerie, 1846, originally recorded from Mont Cayla (Herault).

Depository

All the types described in this work are deposited in the Department of Geology, Faculty of Science, Ain Shams University, Cairo, Egypt (collection of Boukhary)

Systematic Description of the New Nummulitids

Order Foraminifera
Family Nummulitidae De Blainville 1825
Genus *Nummulites* Lamarck 1801
Type species: *Nummulites laevigatus* (Bruguire 1789) (=*Camerina laevigata* Bruguire 1789)

Nummulites praeatacicus Boukhary and Kuss **n. sp.**
Plate 1, figures 1-27

Etymology: Prior to *Nummulites atacicus* Leymerie 1846 to which the species is phylogenetically linked.

Holotype: Inv. N/261092015, plate 1, figure 5.

Paratypes: 30 specimens (megalospheric and microspheric)

Type Locality: Monastery of St. Paul (Eastern Desert, Egypt)

Stratum Typicum: Bed no. 26092/15 Early Eocene (lower/Middle Ilerdian *cucuiformis*-zone)

Typical Association: Together with the new genus *Bassiounina sanctipauli* n.gen., n.sp.

Microspheric Form: The test is lenticular. A central boss is seen in the juvenile test, while in the adult forms, the center becomes flat. In the juvenile tests, the septal filaments are S-shaped at the center, then become radial towards the outer edge, showing a slight wrinkle. In the adult forms, the septal filaments are more or less meanderine at the center, then becoming radial towards the outer edge, showing a bifurcation along their route. The periphery is rounded and circular. The equatorial diameters (D) of the test range from 6.3 to 8.19mm. The thickness (T) of the tests ranges from 2.8 to 2.47mm.

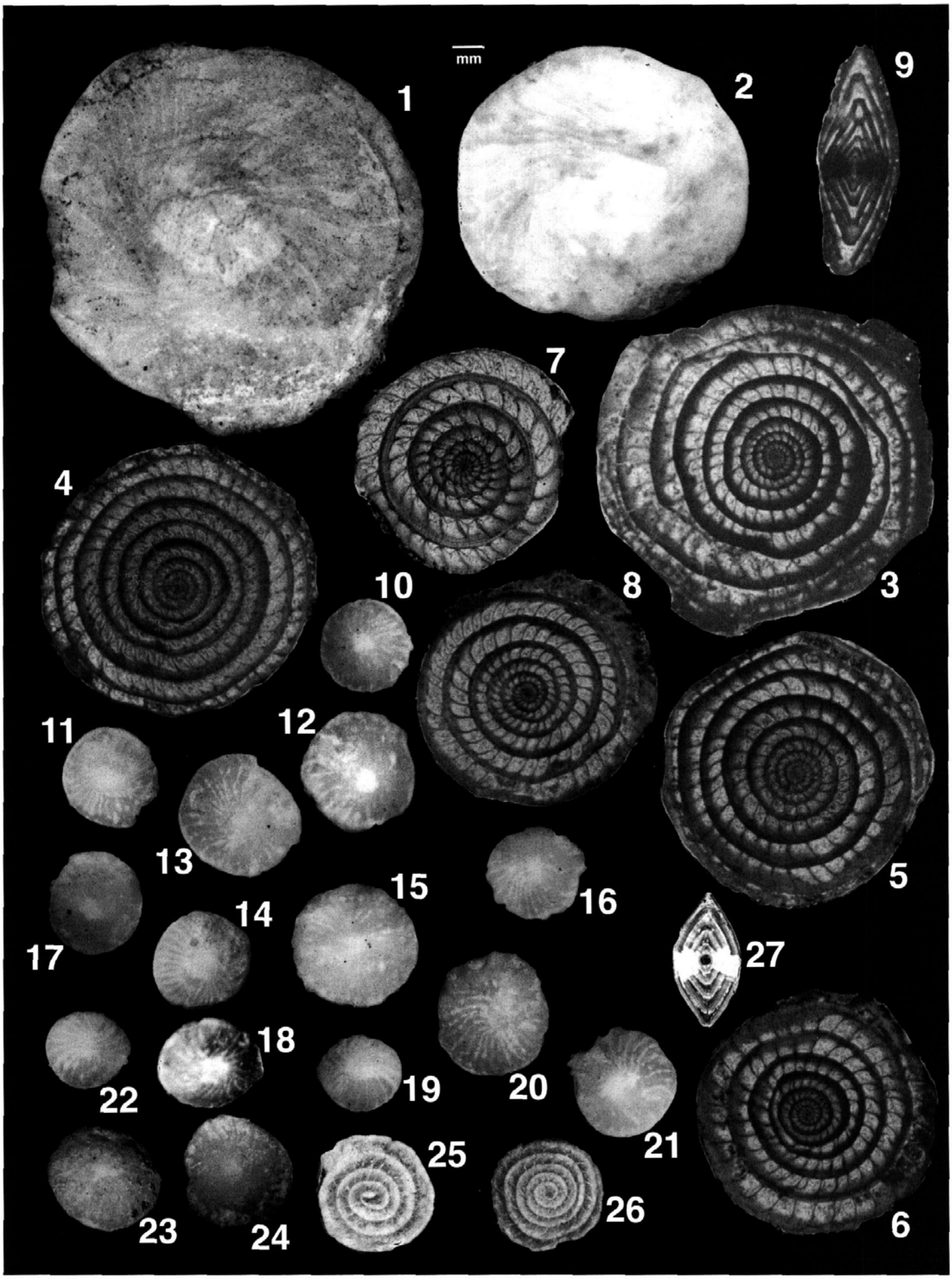
Equatorial Section: Steps of coiling show regular rate of growth. The chambers are more or less quadrate in the early whorls, while in the last 3 whorls, the length of the chambers increases so that these chambers become more or less rectangular. The marginal cord is thick. The septa are straight yet inclined to the right-hand side. Numbers of whorls per radius are: 7 whorls in a radius of 1.89mm; 8 whorls in radii of 3.4 to 3.99mm; 9-10 whorls in a radius of 5.39mm.

Axial Section: The axial section of the test (pl. 1, fig. 9) shows a rudimentary polar pustule that appear on the surface of the test as a boss; however, in the large specimens, the pustule becomes buried.

PLATE 1
Figs. 1-27 *Nummulites praeatacicus* n. sp. Scale bar = 1mm.

1-9 microspheric generation: 1, 2 external views; 3-8 equatorial section, (3, holotype), axial section

10-27 megalospheric generation: 10-24, external views; 25, 26, equatorial section; 27 axial section. Holotype: Pl. 1, Fig. 5. Depository number: N/261092015 (1-27).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Megalospheric Form: The test is lenticular to semiglobular; the polar pile in the tests is divided into a number of granules throughout the center. In the moderate-sized tests, the polar pile appears as a well developed boss in the center with a few small granules surrounding it. In the large tests, the polar pustule changes into a flat area in the center. Radial septal filaments are slightly sinuous in the center, then become wrinkled or and crossed towards the outer edge. The test has a sharp edge. The diameters of the tests (D) range from 2.3 to 3.85mm. The thickness of the tests range from 1.4 to 2.2mm.

Equatorial Section: The cord is thick and shows regular steps of coiling. The septa are straight yet inclined to the right hand side. The chambers are quadrate in the early whorls, then they become more or less rectangular in the last 2 whorls. Numbers of whorls per radius are: 2 whorls in a radius of 1.75mm; 3 whorls in radius of 1.8 to 2.1mm. Protoconch diameters range from 0.21 to 0.25mm. The axial section of A-Form (pl. 1, fig. 27) shows the presence of a central polar pustule. Table 1 shows a comparison between *N. praeatacicus* n. sp., *N. praecursor* De La Harpe 1883 and *N. atacicus* Leymerie, 1846 (from Schaub 1981).

Remarks: There is an ancestral relationship between *N. praeatacicus* n. sp. and *N. atacicus* Leymerie, 1846 as expressed by the biometric values of Table 1. It is shown that the steps of coiling of this new species is opposite that of *N. praecursor* De La Harpe 1883. *N. praeatacicus* n. sp. is comparable with the so-called *N. aff. praecursor* Schaub 1981 in both A and B-forms, in their septal nature, steps of coiling, shape of chambers, and in their external appearances.

Occurrence and Stratigraphic Distribution

N. praeatacicus n. sp. occurs together with *Bassiounina sanctipauli* n. gen. sp. in marly siltstones of 50cm thickness that overlie a massive sandstone and shallow water limestone containing alveolines of the *A. corbarica* - zone. An Early Eocene (Middle/Late Ilerdian) age is estimated for the newly erected species based on its stratigraphic position prior to *N. atacicus* Leymerie.

Nummulites sahariensis Boukhary and Kulbrok **n. sp.**
Plate 2, figures 1-27

Etymology: After the Arabic nomenclature of desert, as this species was recognized from the northern mountains of the Eastern Desert.

Holotype: Inv. N/280992027; plate 2, figure 4.

Paratypes: 22 specimens (megalospheric and microspheric)

Type Locality: Monastery of St. Paul (Eastern Desert, Egypt)

Stratum Typicum: Bed No. 280992/27 Early Eocene (Lower Ilerdian)

Microspheric Form: The test is lenticular, flat, with a central polar pustule. The test rim is semicircular. The septal filaments are radially arranged; at the center they are S-shaped and wrinkled at the outer edge. The diameters of the tests (D) range from 4.76-9.8mm. The thickness of the tests (T) range from 1.82-2.66mm.

Equatorial Section: Coiling comparatively loose and the steps in the 5th and 6th whorls are twice as high as the rest of the whorls. The cord is thick and irregular. The septum grows from the lower cord in an upright position, then it shows a strong arch in its midway. Number of whorls per radius are: 6-7 whorls in a radius of 3mm and 8 whorls in a radius of 4.9mm. The chambers are higher than long.

Axial Section: The axial sections show rudimentary polar pustule.

Megalospheric Form: The test is lenticular with a central polar pile. The test rim is semicircular. The septal filaments are radial, S-shaped towards the polar center of the test, with a slight wrinkle towards the outer edge. The equatorial diameters of the tests (D) ranges from 2.87-5.18mm. The thickness of the tests (T) ranges from 1.33 to1.8mm.

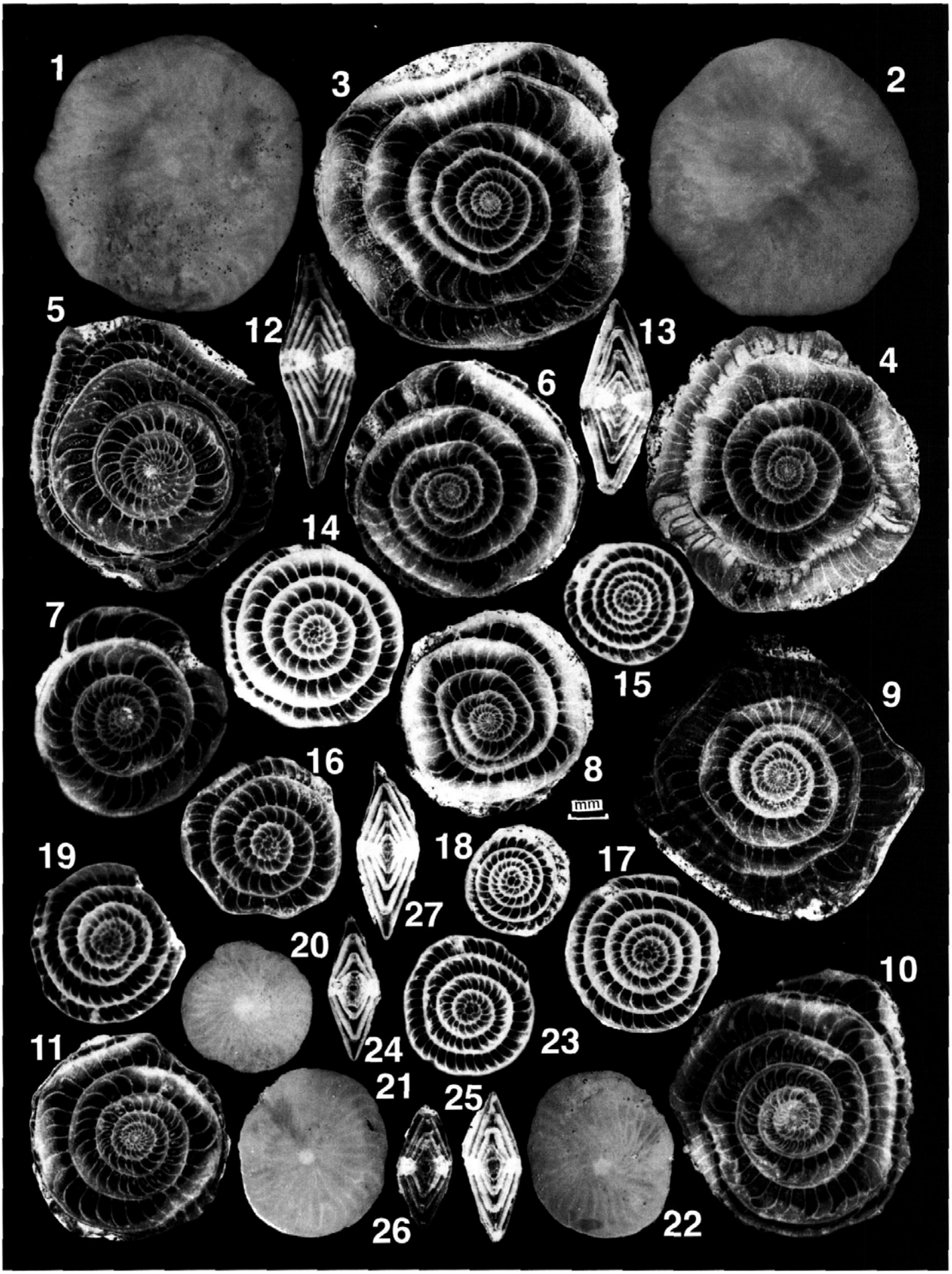
Equatorial Section: Coiling loose, chambers are higher than long. The cord is thick. The septa in A-form are similar to those in the B-forms. Number of whorls per radius is: 3 whorls in a radius of 2.2-2.3mm. Protoconch diameters range from 0.14-0.25mm. Table 2 shows a comparison between *N. sahariensis* n.sp., *N. planulatus* (De La Marck 1804), and *N. deserti* (De La Harpe 1883) in both A and B-forms.

Remarks: The authors believe that *Nummulites sahariensis* n.sp. belong to *Nummulites deserti* group. Although the two generations of *N. sahariensis* n.sp. are too large in size than those of *N. deserti,* both species are overlapped in the diameter of protoconch. In addition, the spire in *N. sahariensis* is loose much later than the spire in *N. deserti* De La Harpe 1883; (emend by Schaub 1951 and 1981). Although the dimensions of *N. sahariensis* and *N. planulatus* are overlapped, the protoconch diameter in *N. planulatus* is much larger than that in *N. sahari-*

PLATE 2
Figs. 1-27 *Baasiounina sahariensis* n.sp. Scale bar = 1mm.
Depository number: N/261092015 (1-27).

1-12 Microspheric generation . Holotype: figure 4.

13-27 Megalospheric generation.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ensis. Moreover, the last two species are found in different stratigraphic levels.

Occurrence and Stratigraphic Distribution: *N. sahariensis* n.sp. occurs within a marly unit (80cm thick), which contribute to an intercalation of marls and limestones (10m total thickness). This unit overlies marls of the *M. subbotinae* - zone and is overlain by shallow water limestones with alveolines of the *cucumiformis* - zone, clearly indicating an Early Eocene (Lower Ilerdian) age.

Superfamily: Nummulitacea
Family: Nummulitidae

Genus: *Bassiounina* Boukhary **n. gen.**
Type species: *Bassiounina sanctipauli* Boukhary n. sp., plate 3, figures 1-22

Etymology of the Genus: In honour of Mohamed El-Amin Ahmed Bassiouni, Professor of Micropalaeontology, Geology Department, Faculty of Science, Ain Shams University, Cairo, Egypt for his outstanding contributions to the Micropaleontology of Egypt and abroad.

Diagnosis of the Genus: The test is semi-involute, slightly asymmetrical (pl. 3, fig. 21). The genus is operculinoid of relatively medium size, flat, compressed, the marginal cord is thin, the spire is loose assilinoid, with transverse trabecules. In the axial section, the alar prolongation occurring in the *Nummulites* are absent in the newly erected genus: *Bassiounina*, the spiral lamina of each whorl is in direct contact with previous whorl. The septa of the adult B-form show a wrinkle in the upper part of the last whorls. Furthermore, they show a duplication thickness and a bifurcation in the last whorls, in both adult A and B-Forms, see diagrammatic sketch Fig. 3.

Bassiounina sanctipauli Boukhary **n.sp.**
Plate 3, figures 1-22

Etymology of the species: After the locality of Saint-Paul, Southern Galala, Eastern Desert, Egypt.

Type Locality: Monastery of Saint Paul (Eastern Desert, Egypt)

Type Section: Columnar section of text-fig. 2.

Stratum Typicum: Early Eocene (Lower/Middle Ilerdian - *corbarica* - zone)

Holotype: Inv. N/261092015, Pl. 3, Fig. 21.

Paratypes: 26 specimens (Two microspheric and 24 megalospheric)

Association: Together with the new species *Nummulites praeatacicus* n.sp.

Microspheric Form: The test is flat, thin rim, granulation is visible on the spiral and lateral structures; these granulations grow densely on the middle portion and in the distal part of each whorl, then grow faintly outward. In the large specimens, the granules are weakly developed. The equatorial diameters of the tests (D) range from 12 to13mm. The thicknesses of the test (T) average 0.75mm.

Equatorial Section: The spire is lax operculinoid, shows a rapid growth towards the periphery. The height of the chamber is three and a half times its length. The septum is erect in its lower third, then becomes slightly arched in its middle portion, and then strongly arched in its uppermost third in large tests. Numbers of whorls per radius are: 5-6 whorls in a radius of 7.0mm.

Megalospheric Form: The test is flat or discoid, the granulation is concentrated in the last distal portion of the whorls. The diameters of the tests (D) range from 5.32-8.19mm. The thicknesses of the tests (T) range from 0.7 to 1.19 mm.

Equatorial Section: The septa are similar to those in the B-form, so is the shape of the chambers and the steps of coiling. Numbers of whorls per radius are: 2 whorls in a radius 3.71-4.2mm. Protoconch diameters range from 0.21 to 0.35mm.

Remarks: The closest species comparable to *Bassiounina sanctipauli* n. gen. and sp. is *Operculina semiinvoluta* Nemkov and Barkhatova 1960; however, the latter is not considered as an *Operculina* in the present work because of the presence of transverse trabecules. This characteristic feature was observed by Hottinger1971, resulting in the new classification of this species as *Nummulites semiinvoluta* (Nemkov and Barkhatova).

The species described here belongs to the new genus *Bassiounina* because it is neither an *Operculina* because of the presence of transverse trabecules (pl. 3, fig. 21) nor is it a *Nummulites* because of the lack of the alar prolongation (pl. 3, figs. 2, 22). *Operculina semiinvoluta* Nemkov and Barkhatova 1960 shows the generic characteristics which is similar to the type species of *Bassiounina* n. gen., such as semiinvolute test, septa duplication, presence of trabecules and granulation development.

The authors believe that both *Operculina semiinvoluta* Nemkov and Barkhatova 1960, and *Bassiounina sanctipauli* n. gen.,

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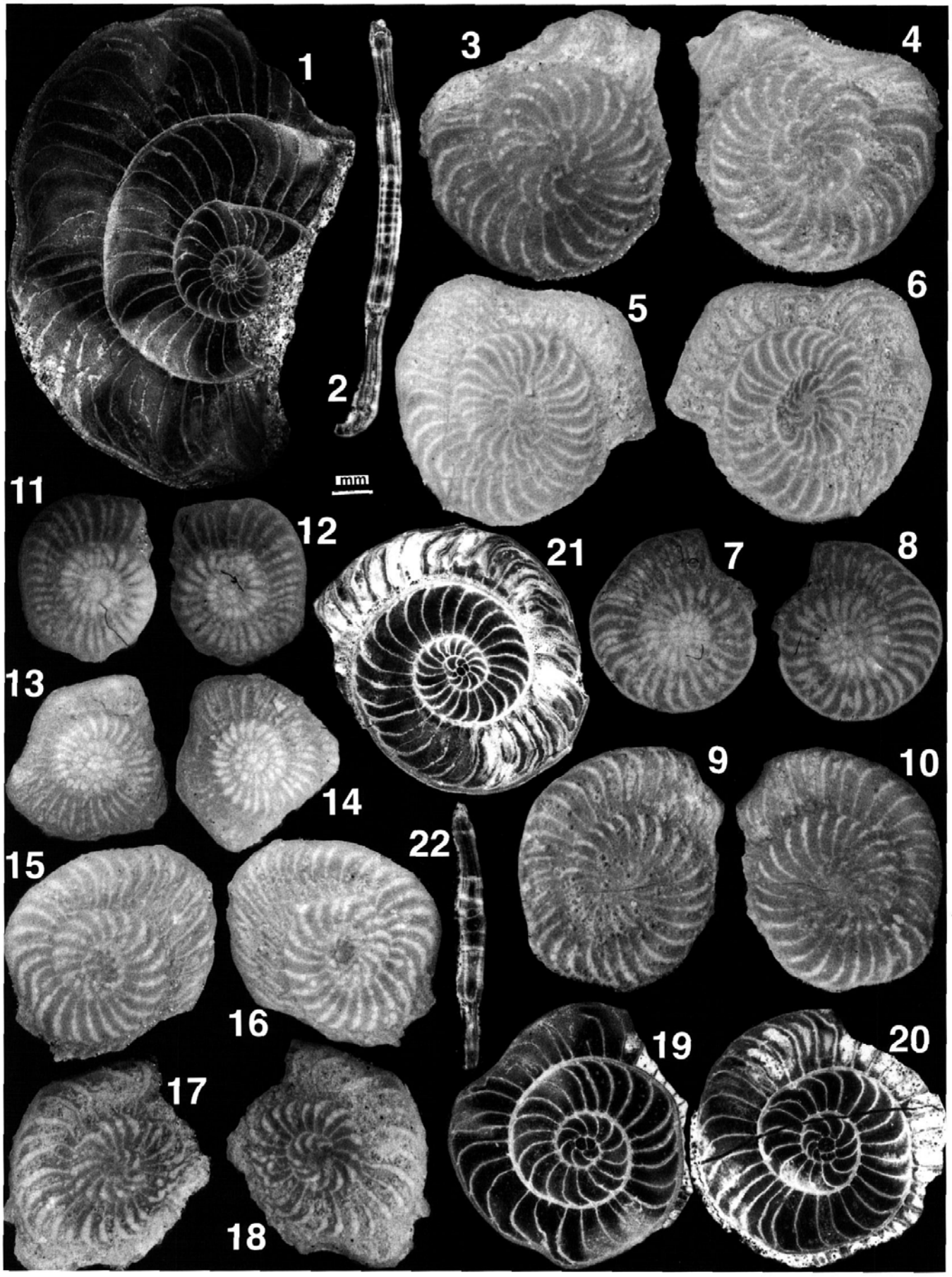
PLATE 3
Scale bar = 1mm.

1-22 *Bassiounina sanctipauli* n. gen. n.sp. 1, 2 microspheric generation; (1) equatorial section, and (2) axial section; Figs. 3-22 megalospheric generation, (3) equatorial section and (4) axial section. Holotype: fig. 21. Depository number: Inv. N/261092015 (36-39).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n.sp. belong to the same group of taxa which appeared simultaneously in two parallel lineages during that time.

Occurrence and Stratigraphic Distribution: Bassiounina sanctipauli n. gen., n.sp. occurs together with *N. praeatacicus* n.sp. in marly siltstones of 50cm thickness on top of a massive sandstone, overlying shallow water limestone with alveolines of the *A. ellipsoidalis* - zone. We suppose an Early Eocene (Lower/Middle Ilerdian) age.

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