Miocene Scutellina (Echinoidea) from the northern part of the Western Desert, Egypt

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Six *Scutella,* one *Parascutella* and three *Amphiope* species are recorded from four Miocene (Burdigalian and Langhian-Serravallian) sections: Gebel West El Migahhiz, Gebel El Takrur (Siwa Oasis), Wadi Um El Ashtan (Mersa Matruh) and Wadi Aqrab (El Salum), all in the northern part of the Western Desert of Egypt. These species are *Scutella aegyptiaca* Ali, *S. ammonis* Fuchs, *S. checchiae* Desio, *S. conica* Ali, *S. robecchibricchettii* Desio, *S. rostrata* Fuchs, *Parascutella stefaninii* (Desio), *Amphiope miocenica* Ali*, A. arcuata* Fuchs, and *A. fuchsi* Fourtau.

Considering Durham's diagnosis of the genus *Scutella*: 'periproct located midway between the peristome and the posterior margin of the test', all the species described from the Central Paratethys (Vienna Basin, Hungary, Poland, Romania, Austria and Ukraine) and referred to *Scutella* by earlier authors appear to be congeneric with either *Parascutella* (periproct submarginal). This means that no occurrences of the genus *Scutella* in the Central Paratethys during Miocene times are known to date.

Key words: Siwa Oasis, Mersa Matruh, El Salum, *Scutella, Parascutella, Amphiope,* Paratethys.

قنفذيات الميوسين لتحت رتبة Scutellina من الجزء الشمالى للصحراء الغربية، مصر

ستة أنواع تتبع جنس *Scutella* ، نوعا واحدا يتبع جنس *Parascutella* وثلاثة أنواع تتبع جنس *Amphiope* تم جمعهم من صخور الميوسين [الميوسين المبكر (Burdigalian) والميوسين الأوسط (Langhian-Seravallian)] لأربعة قطاعات جيولوجية هى : جبل غرب المجهز وجبل التكرور (واحة سيوة)، وادى أم الأشطان (مرسى مطروح)، ووادى عقرب (السلوم)، وجميعهم يقعوا فى لبجزء الشمالى من الصحراء الغربية0 هذه الأنواع هى:

Scutella aegyptiaca Ali, *S. ammonis* Fuchs, *S. checchiae* Desio, *S. conica* Ali, *S. robecchibricchettii* Desio*, S. rostrata* Fuchs; *Parascutella stefaninii* (Desio); *Amphiope miocenica* Ali, *A. arcuata* Fuchs, *A. fuchsi* Fourtau.

طبقا لوصف Durham للصفات المميزة لجنس *Scutella* فإن مكان الحولأست يقع فى وسط المسافة بين الحولفم والحافة الخلفية للدرقة، وعلى ذلك فإن كل الأنواع التى تم تعريفها على انها تنتمى لجنس *Scutella* والمعروفة بمنطقة وسط الباراتيثيس Paratethys (فيينا، المجر، بولندا، رومانيا، النمسا واوكرانيا) تنتمى إلى جنس *Parascutella* حيث يوجد الحولأست تحت الحافة الخلفية للدرقة مباشرة، وهذا يعنى أن جنس *Scutella* لم يدخل منطقة الباراتيثيس مطلقا اثناء الميوسين المعروف هناك حتى الآن.

Introduction

The Miocene rocks in the northern part of the Western Desert of Egypt have yielded a well-preserved echinoid fauna rich in number of genera as well as species. Large numbers of specimens have been collected from three areas: Mersa Matruh, El Salum (both on the Mediterranean coast) and Siwa Oasis more to the South.

No monographic papers were published ever since the work of Fourtau (1920) on the Miocene echinoids of Egypt and only few have appeared on the echinoid fauna of the area under consideration. The Egyptian genera of Scutellina were first recorded by Fuchs (1882) who introduced four new species in the genera *Scutella* and *Amphiope* from the middle Miocene of the Siwa Oasis, *Scutella ammonis, S. rostrata, Amphiope truncata* and *A. arcuata*. Gregory (1898, p. 153) described *Scutella subrotunda* var. *paulensis* Agassiz, 1841, from the 'Helvetian' of Siwa. Fourtau (1899) recognized the four species previously recorded by Fuchs (1882) from the 'Helvetian' of Siwa, and additionally *Scutella zitteli* Beyrich, 1882, and *S. innesi* Gauthier, 1889, from the 'Helvetian' of the northern part of the Eastern Desert of Egypt. Blanckenhorn (1901) listed the same species described by Fuchs (1882) from the middle Miocene of Siwa. Again Fourtau (1907) described the new species *Scutella hunteri*, as well as *Amphiope* cf. *arcuata* Fuchs, 1882, from the middle Miocene of Mersa Matruh.

In 1920, Fourtau published his most important paper on the Neogene echinoids of Egypt. He added the following species to those mentioned previously: *Amphiope fuchsi* Fourtau, 1902, from the 'Vindobonian' of Mersa Matruh, *A. palpebrata* Pomel, 1887 from the Burdigalian of Sinai and *A. arcuata* Fuchs, 1882, from the Burdigalian of Moghra, east of Siwa.

Stratigraphy

A large part of the northern Western Desert is covered by thick deposits of Miocene rocks. Excellent outcrops of these rocks are observed at Siwa Oasis, Qattara Depression, and also along the Mediterranean Sea from Mersa Matruh to El Salum in the west and extending to Libya (Fig. 1).

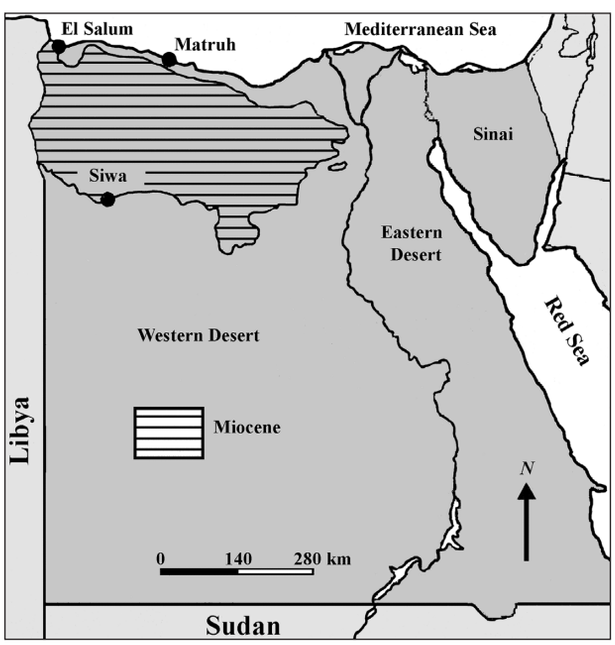

Figure 1. Location map of the studied sections and the distribution of Miocene rocks in the northern part of the Western Desert, Egypt.

According to Said (1962), the Miocene beds of the Western Desert belong to two formations. The upper Marmarica Formation consists entirely of marine deposits of middle Miocene (Langhian-Serravallian) age. The lower Moghra Formation, of early Miocene (Burdigalian) age, is of marine character in the West, grading to estuarine and fluvial in the East.

The Moghra Formation is a thick clastic sequence carrying a mixed fluviomarine fauna. This is shown by the presence of vertebrate remains and marine macro- and micro-fossils described by Blanckenhorn (1901). According to Said (1990), the Moghra Formation seems to have been deposited in a high-energy, wave-dominated delta. However, Abdallah (1966) declared that the Moghra Formation was made up of sandy limestone, sandstone, claystone, shale and marlstone. Sedimentary rocks of late Miocene are absent in the Western Desert area (Gindy & El Askary, 1969).

The echinoids discussed herein were collected from four sections, Wadi Um El Ashtan near Mersa Matruh, Wadi Aqrab at El Salum, Gebel west El Migahhiz and Gebel El Takrur, both at Siwa Oasis (Figs 2).

Wadi Um El Ashtan – This section is located 16 km west of Mersa Matruh (31°20' N, 27°06' E). The total thickness of the Miocene beds is about 63.5 m. It is composed mainly of chalky limestone and marlstone. Only one species, *Scutella checchiae*, has been recorded from the Marmarica Formation (Fig. 2).

Wadi Aqrab section – Located about 2 km south of El Salum (31°33' N, 25°07' E), close to the Egyptian-Libyan border. The middle Miocene Marmarica Formation mainly consist of limestone and sandy limestone, and contains *Scutella robecchibricchettii*, whereas the early Miocene Moghra Formation is composed of limestone, claystone and sandstone with *Parascutella stefaninii* (Fig. 2).

Gebel West El Migahhiz – Located about 7.5 km northwest of Siwa (29°15' N, 25°30' E). Total thickness of the Miocene beds is about 76.8 m. The Marmarica Formation consists mainly of limestone and sandy limestone. Seven species have been recorded from this formation. These are: *Scutella aegyptiaca*, *S. ammonis*, *S. robecchibricchettii*, *S. rostrata*, *Amphiope arcuata*, *Amphiope fuchsi* and *A. miocenica*. The Moghra Formation is composed of marly limestone, shale, claystone and sandy limestone.

Gebel El Takrur – Situated about 3.5 km south-east of Siwa (29°11' N, 25°33' E). The thickness of the Miocene beds is about 148.3 m. The sequence resembles that of Gebel West El Migahhiz. The following species have been recorded from the middle Miocene Marmarica Formation: *Scutella ammonis*, *S. conica*, *S. robecchibricchettii, S. rostrata, Amphiope arcuata* and *A. miocenica* (Fig. 2).

Scutellina palaeoecology

The three Scutellina genera described herein are extinct. The species discussed occur associated with species of the genera *Clypeaster, Echinolampas* and *Agassizia* that include species still living today. Living species of *Clypeaster* and *Echinolampas* are shallow burrowers in sand (Kier, 1975) and largely confined to medium to coarse-grained sand in shallow water (McNamara & Kendrick, 1994). *Agassizia* has two extant species, both of which are found only in tropical waters (Kier, 1980). Also, many *Clypeaster* and *Echinolampas* now live in tropical or subtropical regions, such as in the Red Sea. Likewise, the fauna recorded herein is considered to have been living in shallow and warm waters. *Amphiope* is very similar to the Recent genus *Echinodiscus,* which is presently living in the Red Sea.

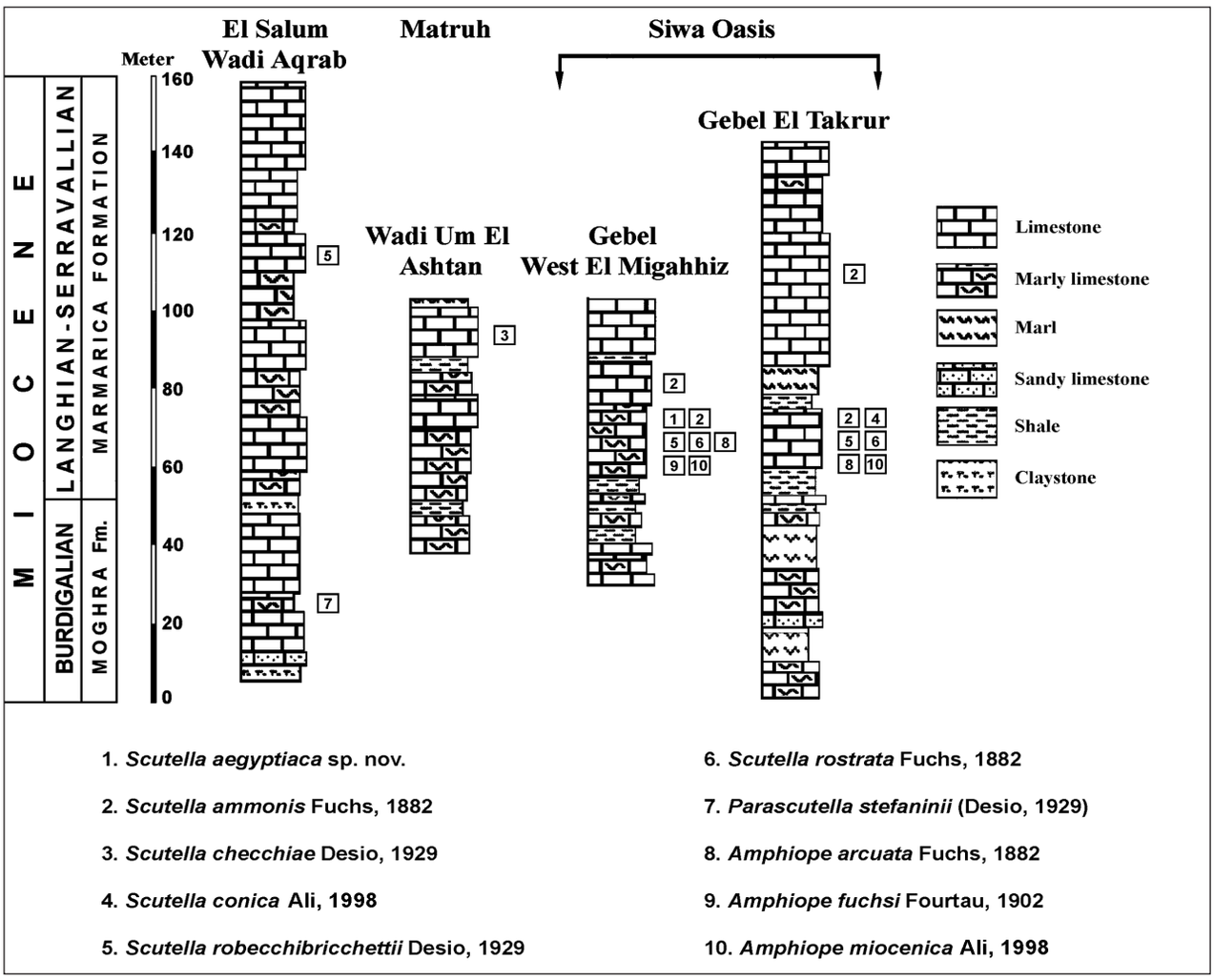

Figure 2. Stratigraphic columns of the studied sections, and distribution of *Scutella* and *Amphiope* species.

Did *Scutella* enter the Paratethys region during Miocene times?

During identification of the present material, it was noticed that many of the European and North African Miocene species which have been referred to *Scutella* have a submarginal periproct, not situated midway between the peristome and the posterior margin, as in the *Scutella* type species *S. subrotunda* Lamarck, 1816. Durham (1953, 1955) established a new genus, *Parascutella* (type species *Scutella leognanensis* Lambert, 1903), including those individuals referred to *Scutella* that have a submarginal periproct.

Ali (1998) discussed this problem, he agreed with the view of Durham because the position of the periproct is considered to be an important diagnostic character at generic level. The following is a summary of his comparison between the genera *Scutella* and *Parascutella*. According to Durham (1953, 1955, 1966), the main diagnostic characters of the two genera are:

Scutella – Type species: *Scutella subrotunda* Lamarck, 1816. Periproct about midway on oral surface between posterior margin and peristome, at suture between first pair of post-basicronal interambulacral plates. Petals closed, about one-half length of corresponding radius, anterior petal longest (Fig. 3A).

Parascutella – Type species: *Scutella leognanensis* Lambert, 1903. Periproct submarginal along suture between

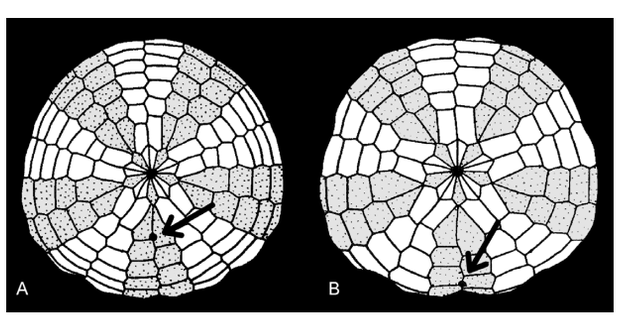

Figure 3. Schematical oral views of (A) *Scutella* Lamarck, 1816, and (B) *Parascutella* Durham, 1953, showing the location of the periproct (arrows) (modified after Durham, 1955, fig. 18a, 18b).

third pair of post-basicronal interambulacral plates, often with a groove to anal notch in posterior margin of test. Petals nearly closed, about two-third as long as corresponding radius, anterior petal shortest (Fig. 3B).
According to these characteristics Miocene echinoid species from the Paratethyan region previously referred to the genus *Scutella* (Agassiz, 1841: Switzerland; Kühn, 1936: Austria; Laube, 1869: north Italy; Laube, 1871: Austria and Hungary; Mihály, 1985: Hungary; Mitrovic-Petrovic, 1969: Poland; Schaffer, 1962: Austria; Szöreńyi, 1953: Ukraine) all belong to *Parascutella*.
In conclusion, *Scutella* and *Parascutella* species are found in the Mediterranean region (southern Europe and North Africa), while *Scutella* is not found in the Paratethys region. This means that *Scutella* did not enter into the Paratethys Sea during Miocene times at all. The same conclusion was attained by Kroh (2005) during his study of the Neogene echinoids of Austria.

Systematic palaeontology

During the identification of the species belonging to the genera *Scutella* and *Amphiope* described herein, it was difficult to find distinguishing characteristics for the various species of each genus. To solve this problem and to facilitate the identification process, specimens were drawn at the same test length (differing magnifications) in which way the main characters, such as shape of the test, poriferous as well as interporiferous zones and location and size of the apical system, became obvious (Figs 4,5).
Type and illustrated specimens of taxa described herein are housed in the Cairo Geological Museum, Invertebrate division (CGM Inv. registration numbers). Additional specimens are housed in the Geological Museum of the Geology Department, Faculty of Science, Minia University, Minia, Egypt, (MUGM)
The classification of Kroh & Smith (2010), Smith & Kroh (2014), is adopted.

Abbreviations used: L= length of test; W= width of test; H= height of test; %T.L.= percentage of maximum test length; P.Z.= poriferous zone; I.P.Z.= Interporiferous zone. Some further abbreviations are given in the captions of Tables 1 and 2.

Class Echinoidea Leske, 1778
Subclass Euechinoidea Bronn, 1860
Superorder Microstomata Smith, 1984
Order Clypeasteroida A. Agassiz, 1872
Suborder Scutellina Haeckel, 1896
Infraorder Scutelliformes Haeckel, 1896
Family Scutellidae Gray, 1825
Genus *Scutella* Lamarck, 1816

Type species – *Scutella subrotunda* Lamarck, 1816, by subsequent designation of Agassiz (1841, p. 5).

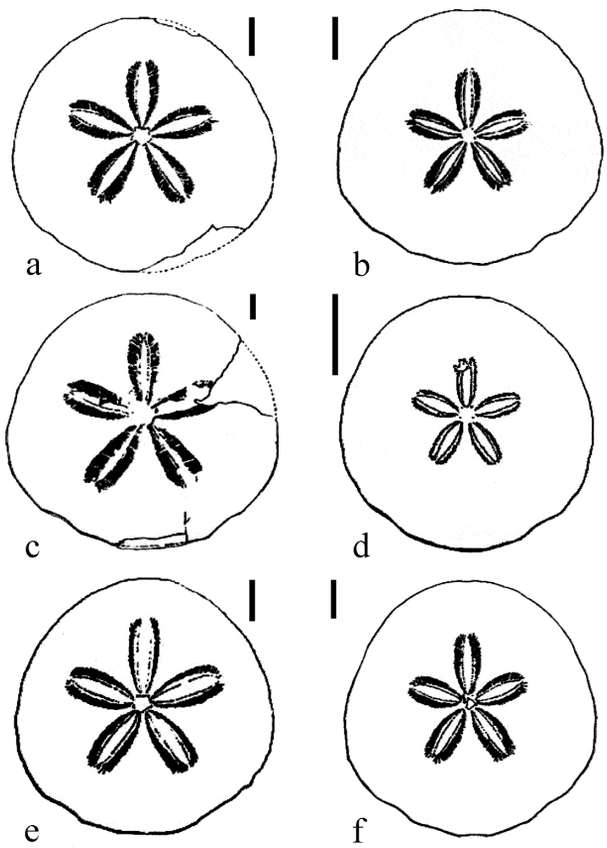

Figure 4. Schematic aboral views of *Scutella* species studied herein, showing test shape, length of petals, width of poriferous and interporiferous zones, and location and size of the apical disc; **a**: *Scutella aegyptiaca* Ali, 1998 (**holotype** CGM Inv. 531); **b**: *S. ammonis* Fuchs, 1882; **c**: *S. checchiae* Desio, 1929; **d**: *S. conica* Ali, 1998 (**holotype** CGM Inv. 536); **e**: *S. robecchibricchettii* Desio, 1929; **f**: *S. rostrata* Fuchs, 1882.
Drawings are resized to same test length. Bars represent 10 mm.

***Scutella aegyptiaca* Ali, 1998**
Fig. 4a; Pl. 1, figs 1a-b, 2a-b; Pl. 5, fig. 1

*1998 *Scutella aegyptiaca* Ali, p. 543-544, fig. 3A.

Holotype – Fig. 4a, Pl. 1, fig. 1a-b, registration number CGM Inv. 531.

Paratype – Pl. 1, fig. 2a-b, registration number CGM Inv. 532, from the type locality.

Additional material – Three well preserved specimens (MUGM 2014E119, 2014E120 and 2014E121), from the type locality are housed in the Geological Museum, Minia University Collection.

Type locality – Gebel west El Migahhiz, Siwa Oasis; Marmarica Formation (middle Miocene, Langhian-Serravallian).

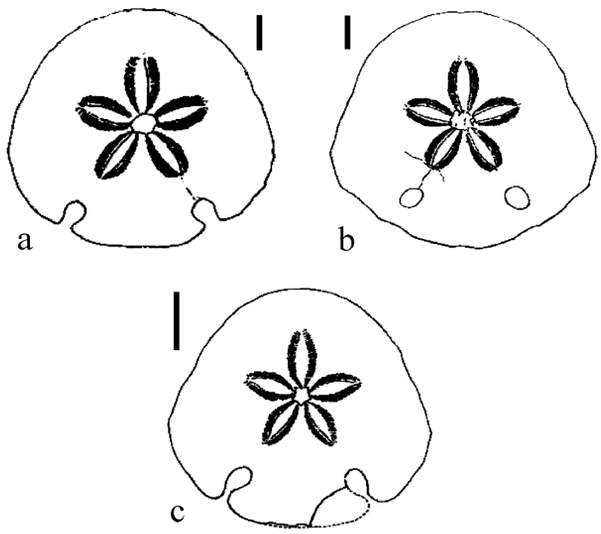

Figure 5. Schematic aboral views of *Amphiope* species studied herein, showing test shape, length of petals, width of poriferous and interporiferous zones, and location and size of the apical disc; **a**: *Amphiope miocenica* Ali, 1998 (**holotype** CGM Inv. 542); **b**. *A. arcuata* Fuchs, 1882; **c**: *A. fuchsi* Fourtau, 1902.
Drawings are resized to same test length. Bars represent 10 mm.

Diagnosis – Test wider than long, large apical system, more extending petals toward margin of test**,** extending between 55.5-61.1% distance from apical system to margin, with swollen interporiferous zones.

Description (based on the holotype) – **Shape and size:** test nearly circular, of medium size, L: 63.8 mm, slightly wider than long (101.7% T.L.), greatest width slightly posterior of centre, at about 4.9% T.L. from centre; greatest height at apical system, height 10.8 % T.L. Aboral surface subconical; oral surface flat. Margin thickest anteriorly (4.5% T.L.), thinning posteriorly to 2.9% T.L. **Apical disc:** slightly anterior of centre, distance from anterior margin 47.5% T.L. **Ambulacra:** petals nearly closed, extending between 55.5-61.1 % of distance from apical system to margin; anterior and postero-lateral petals of same length, slightly longer than antero-lateral petals, length of petals III and I 27.4% T.L., length of petal II 25.4% T.L.; petals III and II of same width, slightly narrower than petal I, width of petals III and II 12.1% T.L., width of petal I 13% T.L. Petals closing slightly. Interporiferous zones swollen, greatest width of I.P.Z. slightly wider than single P.Z. in petals III and II, of same width in petal I; I.P.Z. of petal III wider than other petals where 5% T.L., width of I.P.Z. of petal II 4.5% T.L., 4.1% T.L. in petal I. Poriferous zones slightly depressed, greatest width 4.5% T.L. in petal III, 3.8% T.L.in petal II, 4.1% T.L.in petal I. **Peristome:** slightly anterior of centre, distance from anterior margin 47.6% T.L., circular, small, diameter 3.1% T.L. **Periproct:** situated at a distance from posterior margin 30.4% T.L. and 60.1% of distance from peristome to posterior margin, opening between first pair of post basicoronal interambulacral plates. Opening circular to slightly elongated longitudinally, very small, width 1.3% T.L. **Food grooves:** Bifurcates at distance from peristome 7.8-11.1 % T.L., each branch of grooves with outward small branch extending nearly at right angles to it before curving to margin.

Discussion – *Scutella aegyptiaca* slightly resembles *S. robecchibricchettii* Desio. It is easily distinguished by its test being wider than long, proportionally shorter petals (Table 1, fig. 4a), petals extending toward the margin and by its swollen interporiferous zones. It is characterized from the other *Scutella* species by higher test, swollen interporiferous zones and less central apical system.

Distribution – Only known from the type locality.

***Scutella ammonis* Fuchs, 1882**
Fig. 4b; Pl. 2, fig. 2a-b; Pl. 5, fig. 2

*1882	*Scutella Ammonis* Fuchs, p. 48, pl. 14, figs 1-4.
1899	*Scutella ammonis* Fuchs, 1882 – Fourtau, p. 698.
1913	*Scutella Ammonis* Fuchs – Cottreau, p.53.
1974	*Scutella ammonis* Fuchs – Rose, p.344.

Material examined – Fig. 4b; Pl. 2, fig. 2a-b, registration number CGM Inv. 535, from Gebel west El Migahhiz; Siwa Oasis. Ten well preserved additional specimens, (MUGM 2014E122 - E131), from the same locality and thirteen, (MUGM 2014E132 – E144), from Gebel El Takrur, all Marmarica Formation (middle Miocene, Langhian-Serravallian) are housed in the Geological Museum, Minia University.

Discussion – *Scutella ammonis* is distinguished from *S. rostrata* by its test being lower and wider than long, subcircular outline, shorter petals, narrower interporiferous zones and the periproct being farther from the peristome (Table 1, fig. 4b). It is distinguished from the other *Scutella* species recorded herein by having thinner test, narrower interporiferous zones and with periproct more approached to the posterior margin than the other species.

Distribution – Oasis of Jupiter Ammon, near Siwa Oasis (Fuchs, 1882) and Gebel Ndefer, surrounding Siwa (Fourtau, 1889), Egypt. Lybia (Rose, 1974). All middle Miocene.

***Scutella checchiae* Desio, 1929**
Fig. 4c; Pl. 2, fig. 1; Pl. 5, fig. 3

*1929	*Scutella Checchiae* Desio, p. 305, pl. 33, fig. 1.
1934	*Scutella Checchiae* Desio – Desio, p. 192.
1974	*Scutella checchiae* Desio – Rose, p.344.

Material examined – Fig. 4c; Pl. 2, fig. 1, registration

number CGM Inv. 534, and one broken specimen (MUGM 2014E145), oral surface covered with limestone, housed in the Geological Museum, Minia University. Both specimens from Wadi Um El Ashtan, Mersa Matruh. Marmarica Formation (middle Miocene, Langhian-Serravallian).

Discussion – This species was erected by Desio (1929) for specimens from Libya. It is differentiated from all other species recorded herein in having the test wider than long, longer and wider petals, a narrower interporiferous zone and wider poriferous zones (Table 2, fig. 4c). In the present material only a single specimen is available, in which the apex and a part of the petals near the apical system are missing and its oral surface is covered by a thick mass of limestone.

Distribution – El Giarabub Oasis, Libya, 150 km west of Siwa Oasis at the border between Egypt and Libya; middle Miocene (Desio, 1929, 1934; Rose, 1974).

***Scutella conica* Ali, 1998**
Fig. 4d; Pl. 2, fig. 3a-b; Pl. 5, fig. 4

*1998 *Scutella conica* Ali, p. 544, figs 3B-C

Holotype – Fig. 4d, Pl. 2, fig. 3a-b, registration number CGM Inv. 536.

Paratypes – Two specimens from the type locality were deposited in the Geological Museum, Minia University (MUGM 2014E146 – E147).

Type locality – Gebel El Takrur, Siwa Oasis; Marmarica Formation (middle Miocene, Langhian-Serravallian).

Diagnosis – Test small, circular, greatest width at centre, aboral surface clearly conical at petaliferous area; margin very thin; apical system slightly anterior of centre; petals short; periproct with opening slightly elongated longitudinally.

Description (based on the holotype) – **Shape and size:** Test small, length 30.7 mm, marginal outline almost circular, with two small indentations posteriorly where posterior ambulacra cross margin; width 98% T.L., greatest width nearly at centre, posterior of centre by about 2.6% T.L.; test low, greatest height at apical system, height 9.1% T.L. Aboral surface clearly conical at petaliferous area. Oral surface flat. Margin very thin, thickness 3.1 % T.L. in all directions. **Apical disc:** Slightly anterior of centre, distance from anterior margin 46.9 % T.L. **Ambulacra:** Petals relatively short, extending between 39-45 % distance from apical system to margin; petal III longest, length 18.6 % T.L., petals I and II of same length, length 17.9 % T.L.; petal III slightly narrower, width 6.8 % T.L., width of petal II and I 7.8 % T.L. Petals closing slightly with both poriferous and interporiferous zones, narrower distally. Interporiferous zones of same width where 3.3 % T.L., wider than single P.Z. Poriferous zone of petal III narrower, width 1.6 % T.L., 2.6 % T.L. in petals I and II. **Peristome:** Anterior of centre, distance from anterior margin 46.9 % T.L. Opening circular, diameter 3.6 % T.L. **Periproct:** Situated a distance from posterior margin 29 % T.L. and 58.6 % of distance from peristome to posterior margin, opening between the first pair of post basicoronal interambulacral plates touching one of 2nd coronal plate. Opening slightly elongated longitudinally, very small, width 1.8 % T.L. **Food Grooves:** Bifurcates at distance from peristome between 8.1 and 9.8 % T.L.

Discussion – This species differs from all other species studied herein by its very short and narrow petals, the conical shape of its petaliferous area, very thin margin, petals extending little from apical system toward margin, greatest width of test nearly at centre and the periproct closer to the peristome (Table 1, fig. 4d).

***Scutella robecchibricchettii* Desio, 1929**
Fig. 4e; Pl. 3, fig. 2; Pl. 5, fig. 5

*1929 *Scutella Robecchi-Bricchettii* Desio, p. 309, pl. 38, fig. 1.
1934 *Scutella Bricchettii* Desio – Desio, 195.
1974 *Scutella robecchi-bricchettii* Desio – Rose, p. 344.

Material examined – Fig. 4e; Pl. 3, fig. 2, registration number CGM Inv. 538. Gebel west El Migahhiz, Siwa Oasis. Marmarica Formation (middle Miocene Langhian-Serravallian).
Three additional specimens from the same locality and four from Gebel El Takrur, all Marmarica Formation (middle Miocene, Langhian-Serravallian), are housed in the Geological Museum, Minia University (MUGM 2014E148, E149, E150).
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Discussion – This species was established by Desio (1929), based on a specimen collected from the middle Miocene of Libya. It slightly resembles the new species *Scutella aegyptiaca* in the test height, the width of the petals, the width of the interporiferous zones and the locations of the peristome and periproct, but it differs by having longer and more extended petals, and a more central apical system.
Scutella robecchibricchettii is readily distinguished from *S. aegyptiaca* in having the test longer than wide, greatest width of the test being farther posterior from the centre, longer petals extending farther to the margin, flush interporiferous zones and in having more central apical system (Table 1, fig.4e).

Occurrences – Middle Miocene of Libya (Desio, 1929, 1934; Rose, 1974).

***Scutella rostrata* Fuchs, 1882**
Fig. 4f; Pl. 1, fig. 3a-b; Pl. 5, fig. 6

*1882 *Scutella rostrata* Fuchs, p. 48, pl. 17, figs 4-6.

1899 *Scutella Rostrata* Fuchs – Fourtau, p. 698.
1913 *Scutella rostrata* Fuchs – Cottreau, p. 53.
1920 *S. ammonis rostrata* Fuchs – Fourtau, p. 32, pl. 3, fig. 1.
1929 *S. ammonis rostrata* Fuchs – Desio, p.301.
1974 *S. ammonis rostrata* Fuchs – Rose, 344.

Material examined – Fig. 4f; Pl. 1, fig. 3a-b, registration number CGM Inv. 533. Gebel west El Migahhiz, Siwa Oasis. Marmarica Formation (middle Miocene Langhian-Serravallian). Five additional specimens from the same locality and nine specimens from Gebel El Takrur, all Marmarica Formation (middle Miocene, Langhian-Serravallian) are housed in the Geological Museum, Minia University (MUGM 2014E151 – E155).

Discussion – Fourtau (1920) considered *Scutella rostrata* to be a subspecies of *S. ammonis* Fuchs. Although S. *rostrata* slightly resembles *S. ammonis* indeed, it appears to be consistently different from *S. ammonis*, predominantly by its test being longer than wide and higher, with rostrate posterior margin, the petals proportionately broader, wider interporiferous zones and narrower poriferous zones. Finally, the periproct is situated farther forward from the posterior margin than in *S. ammonis* (Table 1, Fig. 4f).

Occurrence – Middle Miocene of Siwa Oasis (Fuchs, 1882) and Libya (Desio, 1929, 1934; Rose, 1974).

	Test length mm	Test width %	Distance GW-CT %	Test height %	Petals length %	Petals width %	I.P.Z. width %	P.Z. width %	AS-AM %	Peristome -AM %	Periproct -PM %	Petals extension %
S. ammonis	60.7	101.2	6.9	8.7	21.3-22.6	9.1-9.9	2.0-2.5	3.5-3.6	48.8	49.8	28.5	47.3-47.9
S. rostrata	65.0	95.0	4.9	9.8	20.6-24.3	9.8-10.8	3.2-3.5	3.1-3.5	48.2	49.2	31.1	48.7-54.3
S. robecchi-bricchettii	60.0	99.2	7.7	10.5	27.5-30.2	11.6-13.2	4.5-5.0	3.3-4.0	49.2	47.7	31.0	58.1-65.1
S. aegyptiaca	63.8	101.7	4.9	10.8	25.4-27.4	12.1-13.0	4.1-5.0	3.4-4.1	47.5	47.6	30.4	55.5-62.2
S. conica	30.7	98.0	2.6	9.1	17.9-18.6	6.8-7.8	3.3	1.0-2.6	46.9	46.9	29.0	39.0-45.0
S. checchiae	122.5	104.3	4.5	9.6	30.2-31.8	12.4-13.1	2.5-2.7	4.6-5.3	48.0	--	--	64.8-65.8

Table 1. Comparison between some parameters of the *Scutella* species studied (all parameters are expressed in percentages of test length).
Distance GW-CT = distance of greatest width from centre of test; AS-AM = apical system from anterior margin; Peristome -AM = peristome from anterior margin; Periproct-PM = periproct from posterior margin.

Key of *Scutella* species discussed herein:

1a	Test longer than wide, longest petals (30.2-31.8 % T.L.)	*Scutella checchiae*
1b	Test wider than long	2
2a	Petals very short (19.9-18.6% T.L.), petaliferous area conical	*Scutella conica*
2b	Petals longer (25.4 – 27.4% T.L.)	3
3a	Test high (10.3 – 10.8% T.L.)	*Scutella aegyptiaca*
3b	Test lower	4
4a	Posterior margin of test rostrate	*Scutella rostrata*
4b	Posterior margin of test rounded	5
5a	Test of medium height (10.5 % T.L.); greatest width of test more posterior of center (7.7 % T.L.), broad petals (11.6-13.2 % T.L.), broad interporiferous zone (4.5-5.0 % T.L.)	*Scutella robecchibricchettii*
5b	Test low (8.7 % T.L.), greatest width of test closer to center (6.9 % T.L.); narrower petals (9.1-9.9 % T.L.); narrower interporiferous zone (2.0 – 2.5 % T.L.)	*Scutella ammonis*

Genus *Parascutella* Durham, 1953

Type species – *Scutella leognanensis* Lambert, 1903, by original designation.

***Parascutella stefaninii* (Desio, 1929)**
Pl. 3, fig. 1a-c; Pl. 5, fig. 7

*1929 *Scutella Stefaninii* Desio, p. 307, pl. 40, fig. 3.
1934 *Scutella Stefaninii* Desio – Desio, p. 194, pl. 18, fig. 1.

Material examined – Pl. 1, fig. 1a-c, registration number CGM Inv. 537. A broken specimen is housed in the Geological Museum, Minia University (MUGM 2014E156). Both specimens from Wadi Aqrab, El Salum; Moghra Formation (early Miocene, Burdigalian).

Discussion – Desio (1929) erected this species as *Scutella stefaninii* from middle Miocene rocks of Libya. It is characterized, according to Desio, by having a submarginal periproct situated at a distance from posterior margin 8.9% T.L. According to the diagnostic features of the genus as discussed above, this species has to be assigned to *Parascutella*. The periproct must have been situated in the missing broken part of the posterior margin and, therefore, is supposed to have been submarginal. Hence, this specimen is considered to represent a *Parascutella* species.

Occurrence – Middle Miocene of Giarabub Oasis, Libya (Desio, 1929, 1934).

Family Astriclypeidae Stefanini, 1911
Genus *Amphiope* Agassiz, 1840

Type species – *Scutella bioculata* DesMoulins, 1835, by subsequent designation of Lambert (1907, p. 49).

***Amphiope miocenica* Ali, 1998**
Fig. 5a; Pl. 4, fig. 4a-b; Pl. 5, fig. 10

*1998 *Amphiope miocenica* Ali, p. 545-546, fig. 3D.

Holotype – Fig. 5a, Pl. 4, fig. 4a-b, registration number CGM Inv. 542.

Paratype – One specimen is housed in the Geological Museum, Minia University (MUGM 2014E157), from Gebel west El Migahhiz, Siwa Oasis; Marmarica Formation (middle Miocene, Langhian-Serravallian).

Type locality – Gebel El Takrur, Siwa Oasis; Marmarica Formation (middle Miocene, Langhian-Serravallian).

Diagnosis – Test with subcircular outline; wider than long, greatest width more anterior of test centre; with two subrounded distally opened lunules in posterior paired ambulacra; test relatively higher than other species described herein; petals long, wide; poriferous zones wide; apical disc more central than other species described herein; peristome slightly posterior of test centre.

Description of holotype – **Shape and size:** Test of medium size, length 65 mm, wider than long, width 107.2% T.L. Marginal outline subcircular, with two subrounded, distally opened lunules situated in posterior paired ambulacra, lunule diameter 7.7-8.9% T.L. Greatest width of the test posterior to centre, distance between centre and line of maximum width 11.5% T.L. Greatest height anterior to centre at point in front of extreme of anterior petal. Aboral surface asymmetrically convex, sloping anteriorly more than posteriorly from apex. Oral surface slightly convex near peristome. Margin of test thick anteriorly (4.9% T.L.), thin posteriorly (92.9% T.L.) **Apical disc:** missing, apparently anterior of centre, distance from anterior margin 48.6% T.L. **Ambulacra:** Petals lanceolate, closed distally, extending between 47-58.4% of distance from apical system to margin; petal III and I of same length, longest, length 25.6% T.L., length of petal II 22.6% T.L.; anterior petals wider than posterior ones, width of petals III and II 13.3% T.L., width of petal I 11.7% T.L. Interporiferous zone wider than single poriferous zone in petal III, of same width in petal II, narrow in petal I, width of I.P.Z. 5.8% T.L. in petal III, 4.3% T.L. in petal II and 3.5% T.L. in petal I. Poriferous zones of approximately same width, width 3.5% T.L. in petal III, 4.3% T.L. in petal II and 4.2% T.L. in petal I. **Peristome:** Missing, apparently posterior of centre, distance from anterior margin 52.3% T.L. **Periproct:** Submarginal, distance from posterior margin 10.7% T.L., bounded by first pair of post-basicoronal interambulacral plates. Opening subcircular to elongate longitudinally, length 3.1% T.L., width 2.3% T.L. **Food grooves:** Bifurcate near peristome, branches slightly diverging, each one with small branch near margin.

Discussion – Amphiope miocenica is easily distinguished from *A. arcuata* Fuchs and *A. fuchsi* Fourtau by its higher test, greatest height just anterior of anterior petal, less marked indentations opposite the antero-lateral ambulacra, longer and wider petals, petals with wider poriferous zones, petals extending toward the margin (Table 3, fig. 5a).

***Amphiope arcuata* Fuchs, 1882**
Fig. 5b; Pl. 4, fig. 1; Pl. 5, fig. 8

*1882 *Amphiope arcuata* Fuchs, p. 49, pl. 16, figs 4-6.
1899 *Amphiope Arcuata* Fuchs, 1882 – Fourtau, p. 698.
1920 *Amphiope arcuata* Fuchs – Fourtau, p. 38, pl. 4, figs 1-2.
1929 *Amphiope arcuata* Fuchs – Desio, p. 311.
1934 *Amphiope arcuata* Fuchs – Desio, p. 191.

Material examined – Fig. 5b; Pl. 4, fig. 1, registration number CGM Inv. 539 from Gebel El Takrur, Siwa Oasis.

One well preserved further specimen from the same locality and two from Gebel west El Migahhiz (Siwa Oasis) are housed in the Geological Museum, Minia University (MUGM 2014 E158, E159, E160 respectively). All Marmarica Formation (middle Miocene, Langhian-Serravallian).

Discussion – This species is distinguished from *A. miocenica* and *A. fuchsi* in having more developed indentations opposite the antero-lateral ambulacra, its petals longer and wider than in *A. fuchsi*, but shorter and narrower than in *A. miocenica;* periproct situated at a relatively larger distance from posterior margin, and by having wider lunules (Table 2, Fig.5b).

Occurrence – Middle Miocene of Siwa Oasis (Fuchs, 1882; Fourtau, 1899, 1920); middle Miocene of Libya (Desio, 1929, 1934).

***Amphiope fuchsi* Fourtau, 1902**

Fig. 5c; Pl. 4, figs 2, 3a-b; Pl. 5, fig. 9

1899 *Amphiope Truncate* Fuchs, 1882 – Fourtau, p. 697.
*1902 *Amphiope fuchsi*, Fourtau, p. 626.
1906 *Amphiope truncate* Fuchs – Lambert, p. 10.
1920 *Amphiope fuchsi* – Fourtau, p. 40, pl. 4, figs 3-4.
1929 *Tretodiscus Fuchsi* (Fourtau) – Desio, p. 313, pl. 33, fig. 2.
1934 *Tretodiscus Fuchsi* (Fourtau), – Desio, p. 192, pl. 16, fig. 2.

Material examined – From Gebel west El Migahhiz, Siwa: one specimen, Fig. 5c; Pl. 4, fig. 2, registration number CGM Inv. 540, and three well preserved additional specimens housed in the Geological Museum, Minia University (MUGM 2014E161, E162, E163). From Gebel El Takrur: one specimen, Pl. 4, fig. 3a-b, registration number CGM Inv. 541, and three well preserved additional specimens housed in the Geological Museum, Minia University (MUGM 2014E164, E165, E166). All Marmarica Formation (middle Miocene, Langhian-Serravallian).

Discussion – This species differs from *Amphiope arcuata* in having a subtriangular test outline; of the test, its maximum width is nearer to the centre of the test, the distance between the line opposite to the greatest width and the centre of the test is 10% T.L. (15.3% T.L. in *A. arcuata*), the petals approach the margin, the periproct is located closer to the posterior margin, and in having narrower lunules. It differs from *Amphiope miocenica* sp. nov. in having shorter petals, anterior petal extending closer to the margin and having narrower petals (Table 2, fig. 5c).

Occurrence – Gebel Ndefer (surrounding Siwa), middle Miocene, (Fourtau, 1889), Miocene of Libya (Desio, 1929, 1934).

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	Test length mm	Test width %	Distance GW-CT %	Test height %	Petals length %	Petals width %	I.P.Z. width %	P.Z. width %	AS-AM %	Peristome -AM %	Periproct -PM %	Petals extension %
A. miocenica	65.0	107.2	11.5	11.2	22.6-25.8	11.7-13.4	3.5-4.3	3.5-4.3	48.6	52.3	11.1	47.0-58.4
A. arcuata	70.7	107.5	10.8	9.8	20.5-23.5	11.2-12.0	4.0-5.1	3.4	47.0	49.2	12.2	41.2-53.4
A. fuchsi	40.1	107.0	10.0	9.65	19.5-23.9	9.5-11.5	3.7-5.5	3.0	45.9	49.0	8.1	37.7-55.1

Table 2. Comparison between some parameters of the *Amphiope* species studied (all parameters are expressed in percentages of test length).
Distance GW-CT = distance of greatest width from centre of test; AS-AM = apical system from anterior margin; Peristome -AM = peristome from anterior margin; Periproct-PM = periproct from posterior margin.

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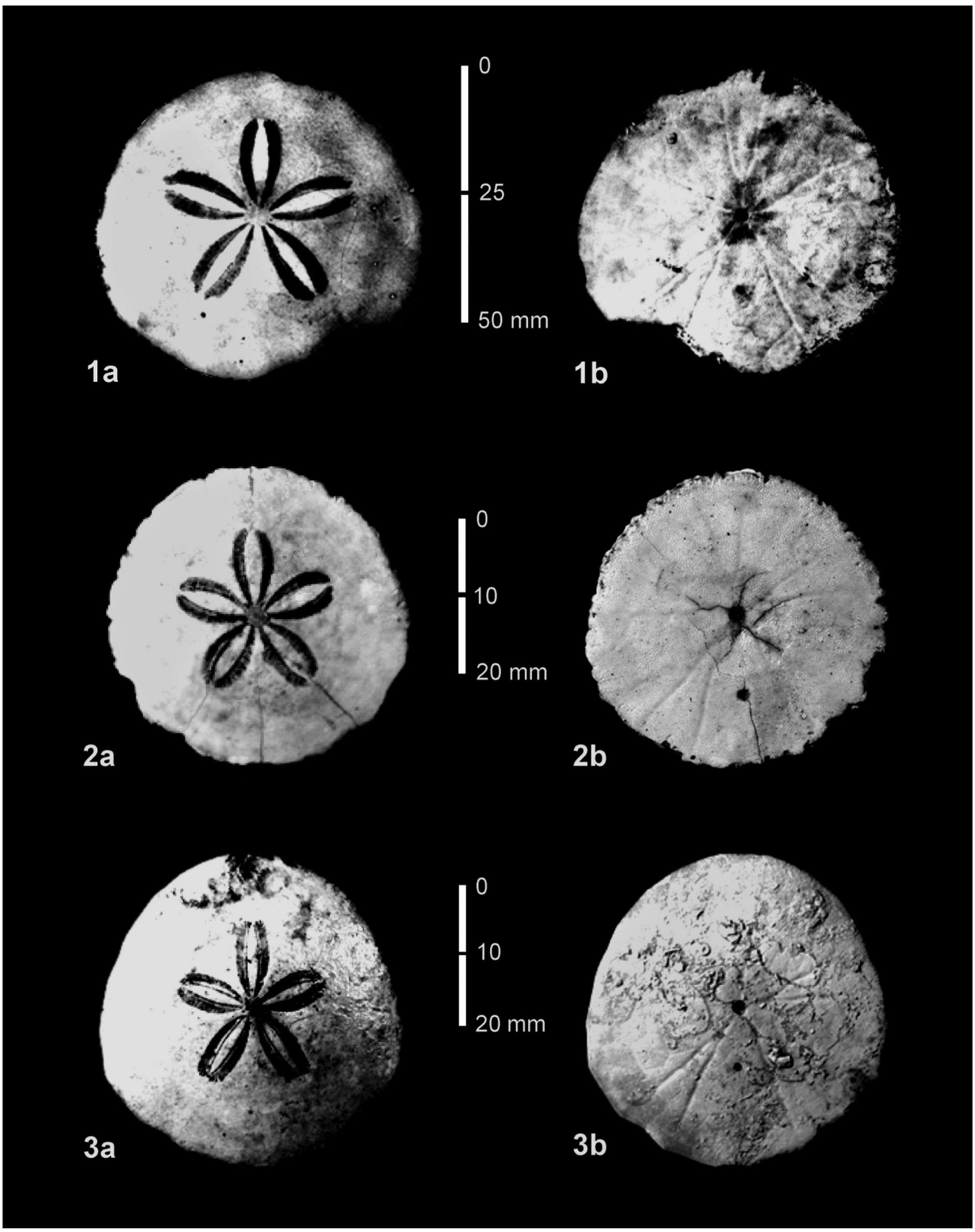

Plate 1

1a-b. *Scutella aegyptiaca* Ali, 1998; **holotype**, CGM Inv. 531; a. aboral view, b. oral view. Gebel west El Migahhiz, Siwa.
2a-b. *Scutella aegyptiaca* Ali, 1998; **paratype**, CGM Inv. 532, a. aboral view, b. oral view. Gebel west El Migahhiz, Siwa.
3a-b. *Scutella rostrata* Fuchs, 1882; CGM Inv. 533, a. aboral view, b. oral view. Gebel El Takrur, Siwa.

All specimens Marmarica Formation (middle Miocene, Langhian-Serravallian).

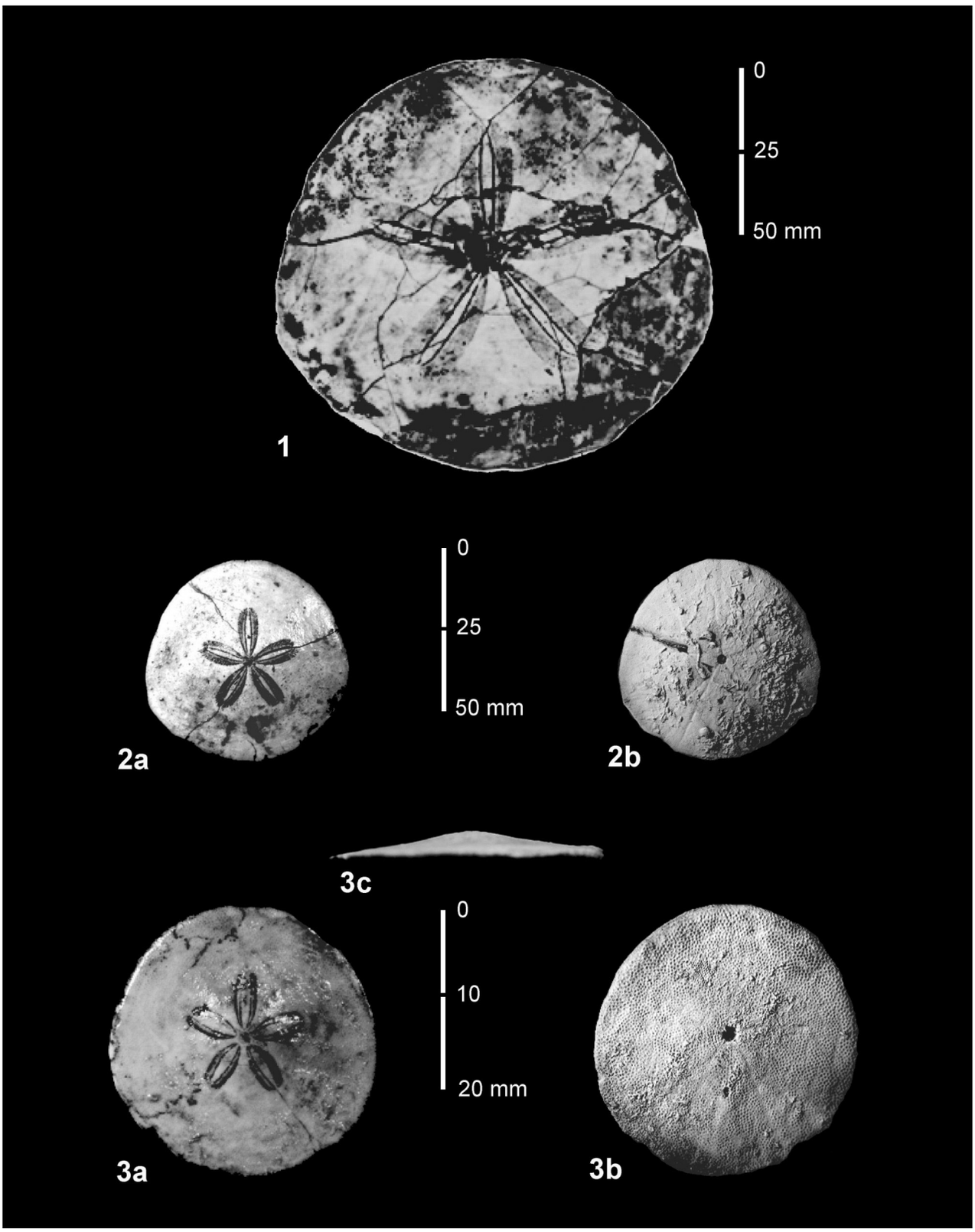

Plate 2

1. *Scutella checchiae* Desio, 1929; CGM Inv. 534; 1. aboral view. Wadi Um El Ashtan, Mersa Matruh.
2a-b. *Scutella ammonis* Fuchs, 1882; CGM Inv. 535; a: aboral surface, b: oral surface. Gebel west El Migahhiz, Siwa.
3a-c. *Scutella conica* Ali, 1998, **holotype** CGM Inv. 536; a: aboral view, b: oral view, c: side view. Gebel El Takrur, Siwa.

All specimens Marmarica Formation (middle Miocene, Langhian-Serravallian).

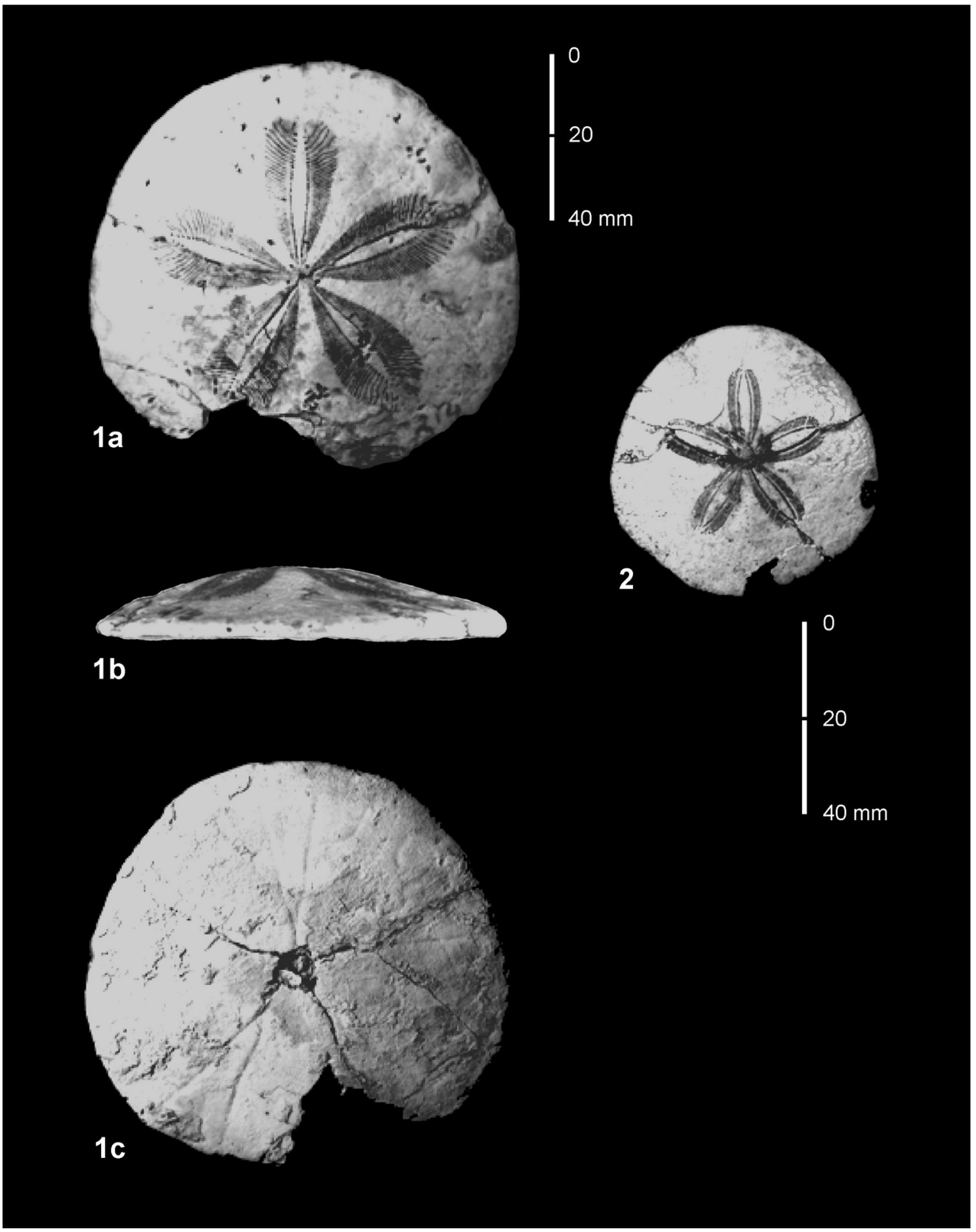

Plate 3

1a-c. *Parascutella stefaninii* (Desio, 1929); CGM Inv. 537; a: aboral view, b: lateral view, c: oral view. Wadi Aqrab, El Salum, Moghra Formation (early Miocene, Burdigalian).

2. *Scutella robecchibricchettii* Desio, 1929; CGM Inv. 538; aboral view. Gebel west El Migahhiz, Marmarica Formation (middle Miocene, Langhian-Serravallian).

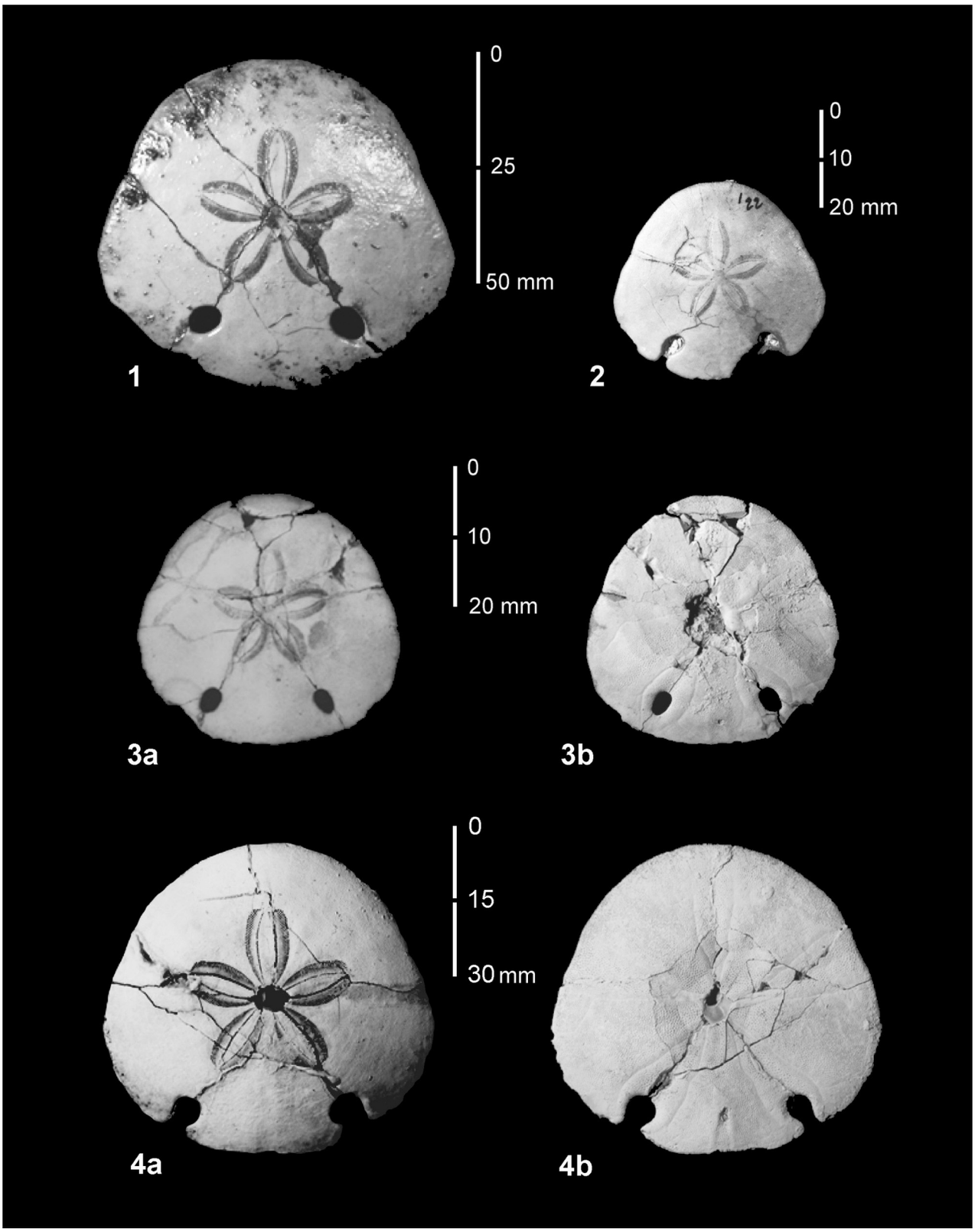

Plate 4

1. *Amphiope arcuata* Fuchs, 1882; CGM Inv. 539; aboral view. Gebel west El Migahhiz, Siwa.

2, 3a-b. *Amphiope fuchsi* Fourtau, 1902; CGM Inv. 540; **2**: aboral view. Gebel west El Migahhiz, Siwa. **3**: CGM Inv. 341; 3a: aboral view, 3b: oral view. Gebel El Takrur, Siwa.

4a-b. *Amphiope miocenica* Ali, 1998, **holotype** CGM Inv. 542; a: aboral view, b: oral view. Gebel El Takrur, Siwa.

All specimens Marmarica Formation (middle Miocene, Langhian-Serravallian).

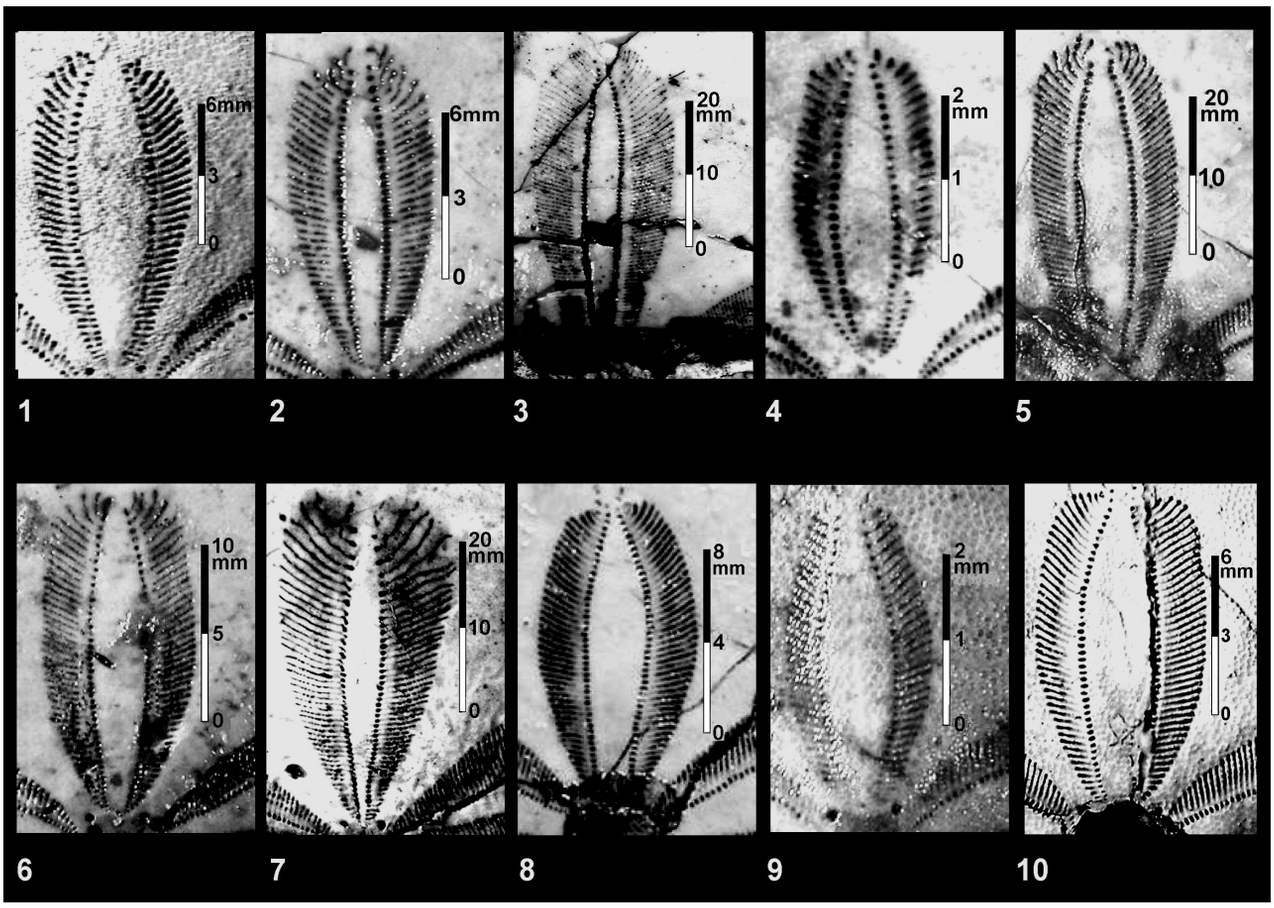

Plate 5

1. *Scutella aegyptiaca* Ali, 1998; **paratype**, CGM Inv. 532: anterior petal III. Gebel west El Migahhiz, Siwa, Marmarica Formation (middle Miocene (Langhian-Serravallian).
2. *Scutella ammonis* Fuchs, 1882; CGM Inv. 535: anterior petal III. Gebel west El Migahhiz, Siwa, Marmarica Formation (middle Miocene, Langhian-Serravallian).
3. *Scutella checchiae* Desio, 1929; CGM Inv. 534: anterior petal III. Wadi Um El Ashtan, Mersa Matruh, Marmarica Formation (middle Miocene, Langhian-Serravallian).
4. *Scutella conica* Ali, 1998; **holotype** CGM Inv. 536: antero-lateral petal IV. Gebel El Takrur, Siwa, Marmarica Formation (middle Miocene, Langhian-Serravallian).
5. *Scutella robecchibricchettii* Desio, 1929; CGM Inv. 538: anterior petal III. Gebel west El Migahhiz, Siwa, Marmarica Formation (middle Miocene, Langhian-Serravallian).
6. *Scutella rostrata* Fuchs, 1882; CGM Inv. 533: anterior petal III. Gebel El Takrur, Siwa, Marmarica Formation (middle Miocene, Langhian-Serravallian).
7. *Parascutella stefaninii* (Desio, 1929); CGM Inv. 537: anterior petal III. Wadi Aqrab, El Salum, Moghra Formation (early Miocene, Burdigalian).
8. *Amphiope arcuata* Fuchs, 1882; CGM Inv. 539: antero-lateral petal IV. Gebel west El Migahhiz, Siwa, Marmarica Formation (middle Miocene, Langhian-Serravallian).
9. *Amphiope fuchsi* Fourtau, 1902; CGM Inv. 540: anterior petal III. Gebel west El Migahhiz, Siwa, Marmarica Formation (middle Miocene, Langhian-Serravallian).
10. *Amphiope miocenica* Ali, 1998; CGM Inv. 542: anterior petal III. Gebel El Takrur, Siwa, Marmarica Formation (middle Miocene, Langhian-Serravallian).