

Miocene echinoids from the Sadat area, south Gebel Ataqa, NW Gulf of Suez, Egypt: systematics, palaeobiogeography

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Abstract The echinoid fauna from the Miocene sedimentary succession cropping out south Wadi Tweirig, and Wadi Hommath, south Gebel Ataqa, NW Gulf of Suez, has been examined with the aim to know their stratigraphic and paleogeographic distribution. The Miocene succession includes two formations: Sadat Formation, unconformably overlying the middle/upper Eocene rocks at the base and Hommath Formation at the top. Twenty-eight echinoid species (8 regular and 20 irregular) belonging to 18 genera, 13 families, and 7 orders have been identified, systematically described, and illustrated in this work. Eleven species are recorded for the first time from Egypt: ten of these came from the Hommath Formation (*Schizechinus* cf. *serresii* Desor (1856), *Schizechinus pentagonus* Kier 1972, *Clypeaster* cf. *martini* des Moulins 1837, *Scutella checchiaie occidentalis* Desio 1934, *Scutella melitensis* Airaghi 1902, *Echinodiscus desori* Duncan and Sladen 1883, *Echinolampas* cf. *zeitensis* Fourtau 1920, *Schizaster lovisatoi* Cotteau 1895, *Agassizia* (*Agassizia*) *powersi* Kier 1972, and *Hemipatagus ocellatus* Defrance (1827)), and one from the Sadat Formation (*Clypeaster campanulatus* Schlotheim (1820)). The identified fauna shows a strong affinity with the Mediterranean bioprovince.

Keywords Miocene · Echinoids · Paleobiogeography · Sadat area · Gulf of Suez · Sadat and Hommath formations

Introduction

The Sadat area lies 30 km to the southwest of Suez City (Fig. 1). It consists mainly of Miocene rocks forming a low land, flanked from the north and south by Eocene highs (Gebel Ataqa and El-Galala El-Bahariya, respectively). The Miocene rocks of the Sadat area are highly fossiliferous, including echinoids, bivalves, gastropods, corals, algae, bryozoans, and foraminifers.

Several authors have studied the stratigraphy and paleontology of the Sadat exposures and adjacent areas (e.g., Depéret and Fourtau 1900; Blanckenhorn 1901; Barron 1907; Sadek 1926, 1959; Shukri and Akmal 1953; Said 1962, 1971, 1990; Said and Metwalli 1963; Abdallah and Abd El-Hady 1966, 1971; Cherif 1966, 1972; Hamam 1966; Ghorab and Marzok 1967; Farag and Sadek 1969; Barakat and Aboul Ela 1970; Youssef et al. 1971; NCGS 1976; Abbass 1977; Cherif and Yehia 1977; El-Heiny 1982; Ali 1984; Abdel Wahab and El-Belassy 1987; Szczechura and Abd-El-shafy 1988; Abou Khadrah et al. 1993; Ismail and Abdelghany 1999; El-Shazly and Saber 1999; Abdelghany and Piller 1999; El-Azabi 2000; Mandic and Filler 2001; Abdelghany 2002; Nebelsick and Kroh 2002; Abou-El-Anwar and El-Gohary 2003; Kroh and Nebelsick 2003; Elattaar 2003; El-Sorogy et al. 2005; EL-Hedeny 2005; Strougo et al. 2006; Hamad 2009 and Tawfik et al. 2015).

Two authors studied the echinoids of the Sadat area; Fourtau (1900, 1901, 1920) identified two species from the Sadat Formation (*Schizaster legraini* Gauthier 1900, in 1900, and *Brissopsis fraasi* Fuchs 1883, in 1901, 1920), and Elattaar (2003) identified 15 species from the Sadat Formation, north Wadi Tweirig (*Pseudarbacina fraasi* (Gauthier 1901), *Tripneustes* sp., *Psammechinus fuchsi* Gauthier 1901, *Clypeaster acclivis* Pomel 1887, *C. deperti* Fourtau 1901, *C. fakhryi* Gauthier 1901, *C. geneffensis* Fourtau 1899,

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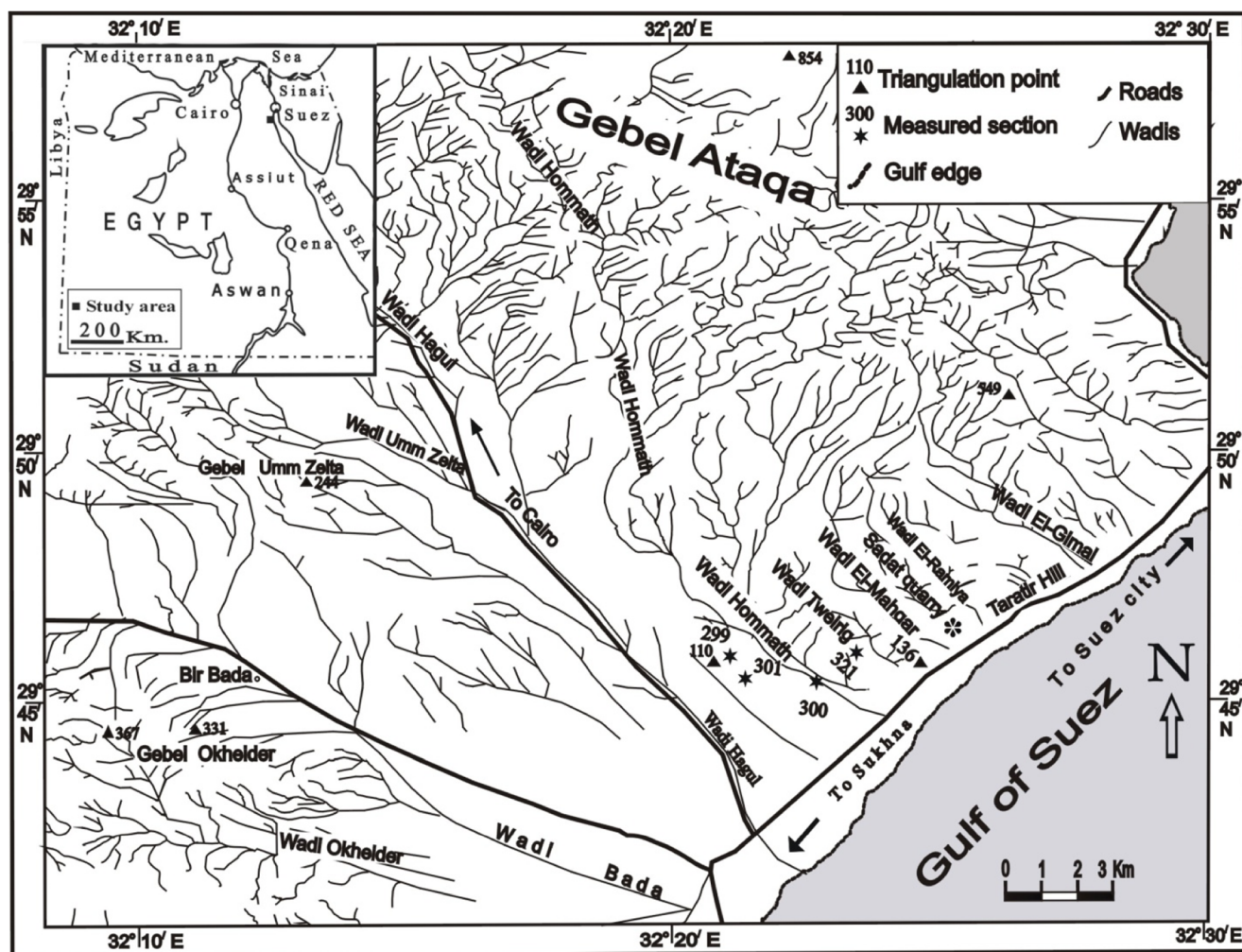


Fig. 1 Location map of the Sadat area and its surroundings showing places of the studied sections in northwestern coast of Gulf of Suez, Egypt. Section 299 at 29° 45' 41" N, 32° 21' 14" E. Section 300 at 29°

45' 10" N, 32° 22' 24" E. Section 301 at 29° 45' 23" N, 32° 21' 21" E. Section 321 at 29° 45' 52.6" N, 32° 23' 34.8" E

C. isthmicus Fuchs 1883, *C. libycus* Desio 1929, *C. martini* des Moulins 1837, *C. subplacunarius* Fuchs 1883, *Pliolampas pioti* Fourtau 1899, *Pericosmus* (*Pericosmus*) *latus* L. Agassiz 1847, *Schizaster* (*Paraster*) *legraini* Gauthier 1900, and *Brissopsis fraasi* Fuchs 1883).

The echinoids of the area south Wadi Tweiwig and the Hommath Formation are studied herein for the first time.

The main objective of this work is to present a systematic and stratigraphic study of the Miocene echinoids of the Sadat area, south Wadi Tweiwig, and their paleobiogeographic affinity.

General stratigraphy

The stratigraphic succession exposed in the Sadat area is subdivided by Abdallah and Abd El-Hady (1966) as follows, from top to base:

1. Hagul Formation (Late Miocene), non-marine deposits (out of study).
2. Hommath Formation (Middle Miocene), marine deposits.
3. Sadat Formation (Early Miocene), marine deposits.
4. Upper or Middle Eocene sequence, marine deposits (out of study).

The Sadat Formation is cropping out along both sides of Wadi El-Ramiya in the northern part of the Sadat area and extends to the southern flank of Wadi Tweiwig in the south and at the hills of Barabir. The Miocene outcrops of the Sadat area, north of Wadi Tweiwig, combined only the Sadat Formation and do not exist for Hommath Formation. It consists mainly of clastics at the base, followed by carbonates (limestone) at the top; the beds are inclined toward the SW with a dip angle of about 4–5°. Stratigraphically, this formation unconformably overlies the middle/upper Eocene rocks, with a distinct conglomeratic bed between them, and conformably underlies the Hommath Formation. The Miocene Sadat/

Hommath formation contacts appeared only at the southern flank of Wadi Tweirig.

The Hommath Formation is cropping out in the area under investigation and extending from the southern flank of Wadi Tweirig in the north to both sides of Wadi Hommath in the south (Fig. 1). It consists mainly of clastics intercalated by carbonates. The lower part of the Hommath Formation (Early Miocene) includes a complete thickness of sections 300 and 301, which inclined toward the SW with a dip angle of about 4–5°. The upper part of the Hommath Formation (Middle Miocene) includes a complete thickness of section 299 at triangulation point (110) still horizontal.

The echinoids studied herein have been collected from four stratigraphic sections, exposed between Wadi Tweirig in the north and the southern flank of Wadi Hommath in the south (Fig. 1). Section 321 located at the southern flank of Wadi Tweirig (29° 45' 52.6" N, 32° 23' 34.8" E) contains three echinoid beds (E1, E2, E3) and represents the total thickness of the Sadat Formation, where the Eocene sediments in the base and the Hommath Formation in the top bound it. Sections 300, 301, and 299 located at the southern flank of Wadi

Hommath. Section 300 lies near the entrance of Wadi Hommath (29° 45' 10" N, 32° 22' 24" E), where it represents the oldest strata of the Hommath Formation; it contains three echinoid beds (E4, E5, E6). Section 301 lies (29° 45' 23" N, 32° 21' 21" E) north of section 300; it contains three echinoid beds (E7, E8, E9) and a microfossil horizon (Upper Burdigalian according to Strougo et al. 2006) in its upper part. Section 299 represents the type section of the Hommath Formation described by Abdallah and Abd El-Hady (1966) at triangulation point (110) (29° 45' 41" N, 32° 21' 14" E); it contains four echinoid beds (E10, E11, E12, E13) and actually it represents the upper half only of the formation, which contains *Borlis* sp. horizon in its upper part (Middle Miocene by Strougo et al. 2006), whereas the older beds are lying exposed downstream of Wadi Hommath, to the southwest of the stratotype, near to Suez-Ain Sukhna asphalt road, which are represented in this study by sections 300 and 301 (Fig. 1). Stratigraphic details of the measured sections are shown in Figs. 2 and 3.

The age of the Sadat Formation is given as *Early Miocene* (*Burdigalian*) by Sadek (1926), Souaya (1961; 1963),

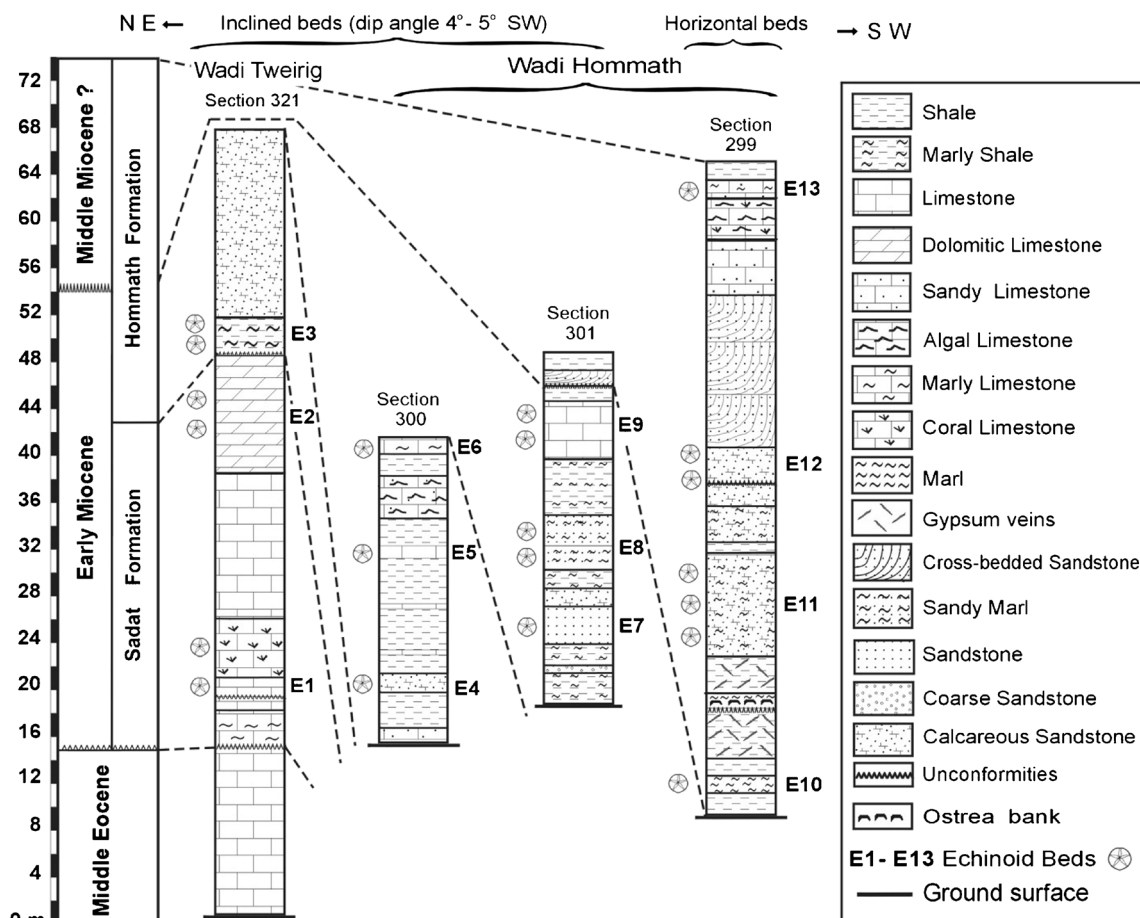


Fig. 2 Correlation chart of the studied sections of the Lower-Middle Miocene outcrops (Hommath and Sadat formations) in the Sadat area, south Wadi Tweirig, NW Gulf of Suez, Egypt. Section 299 at 29° 45' 41"

N, 32° 21' 14" E. Section 300 at 29° 45' 10" N, 32° 22' 24" E. Section 301 at 29° 45' 23" N, 32° 21' 21" E. Section 321 at 29° 45' 52.6" N, 32° 23' 34.8" E

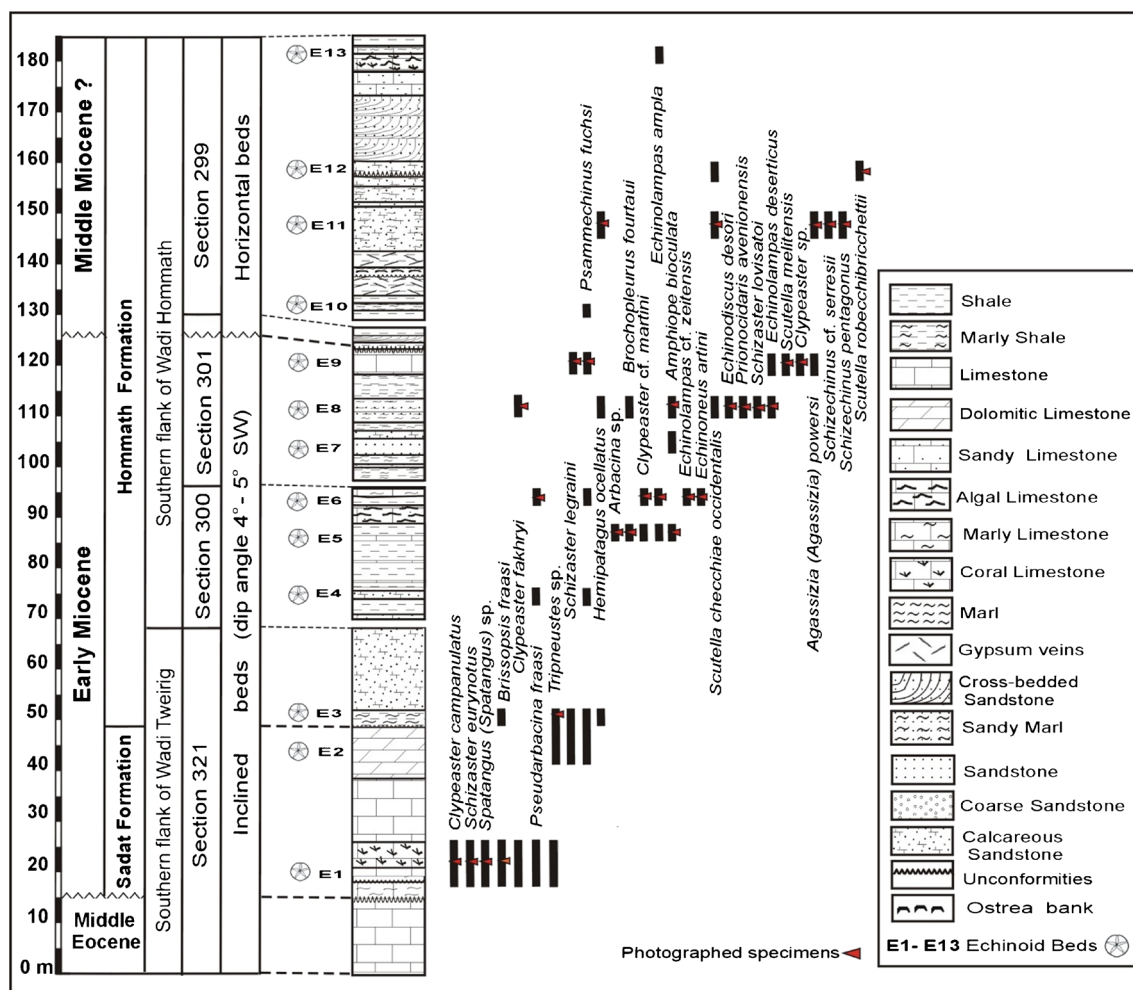


Fig. 3 Distribution chart of the Lower-Middle Miocene echinoids within the studied columnar sections of the Sadat area (Hommath and Sadat formations), south Wadi Twehrig, NW Gulf of Suez, Egypt; 28 species (1–28) of the present study (not to scale) (coordinates of sections in Figs. 1 and 2)

Abdallah and Abd El-Hady (1966), Ghorab and Marzok (1967), NCGS (1976), Cherif and Yehia (1977), El-Heiny (1982), Said (1990), El-Safari (1994), Abdelghany and Piller (1999), El-Azabi (2000), Abou-El-Anwar and El-Gohary (2003), Hamad (2009), and the present study and *Early-Middle Miocene* by Youssef et al. (1971), Cherif and Yehia (1977), Hermina and Lindenberg (1989), Abd-Elshafy and Abd-Elmoneim (1992), El-Safari (1994), Ouda (1998), El-Sorogy and Ziko (1999), and Elattaar (2003).

The age of Hommath Formation is given as *Early-Middle Miocene* by Strougo et al. (2006) and the present study; *Middle Miocene* by Sadek (1926), Abdallah and Abd El-Hady (1966, 1971), Ghorab and Marzok (1967), NCGS (1976), El-Heiny (1982), Hermina and Lindenberg (1989), Said (1990), Hamza (1992), Abd-Elshafy and Abd-Elmoneim (1992), El-Safari (1994), El-Azabi (2000), and Abou-El-Anwar and El-Gohary (2003); *Middle-Late Miocene* by Cherif and Yehia (1977) and Cherif (1980); and *Upper Miocene* by Youssef et al. (1971).

Age of the studied formations

Biostratigraphic data obtained from calcareous nannofossils and planktic foraminifera indicate that the main lower part of the Hommath Formation belongs to the late (but not the latest) Burdigalian, and suggest that the younger part of the formation at the type locality which contains *Borelis* sp. may belong to the Middle Miocene (Strougo et al. 2006). Abdelghany and Piller (1999) found some planktic forams in the uppermost part of the Sadat Formation in the studied area indicative of a Burdigalian age. Also, Hamad (2009) studied the coralline red algae and foraminifera of the Sadat Formation, and attributed this formation to the Early Miocene. In addition, there is an angular unconformity surface between the lower part (inclined beds) of the Hommath Formation (sections 300 and 301) of Early Miocene age and its upper part (horizontal beds of section 299). This surface is represented sedimentologically by cross-bedded sandstone.

The stratigraphic distribution of the studied echinoid species in the present work (28 species) is as follows (Figs. 3 and 4 and Table 1): 19 echinoid species are recorded only in the Early Miocene of both Sadat Formation and the lower part of the Hommath Formation; three of them characterize the Early Miocene of Egypt (*Prionocidaris avenionensis* (des Moulins 1837), *Amphiope bioculata* (des Moulins 1835), *Echinolampas*

deserticus Desio 1929); three species are recorded in the Middle Miocene of the upper part of the Hommath Formation at its type locality and characterize the Middle Miocene of Egypt (*Schizechinus pentagonus* Kier 1972, *Schizechinus* cf. *serresii* (Desor 1856), *Scutella robecchibricchettii* Desio 1929); and five species are recorded in both Early and Middle Miocene of the Sadat and Hommath formations and two of them characterize the

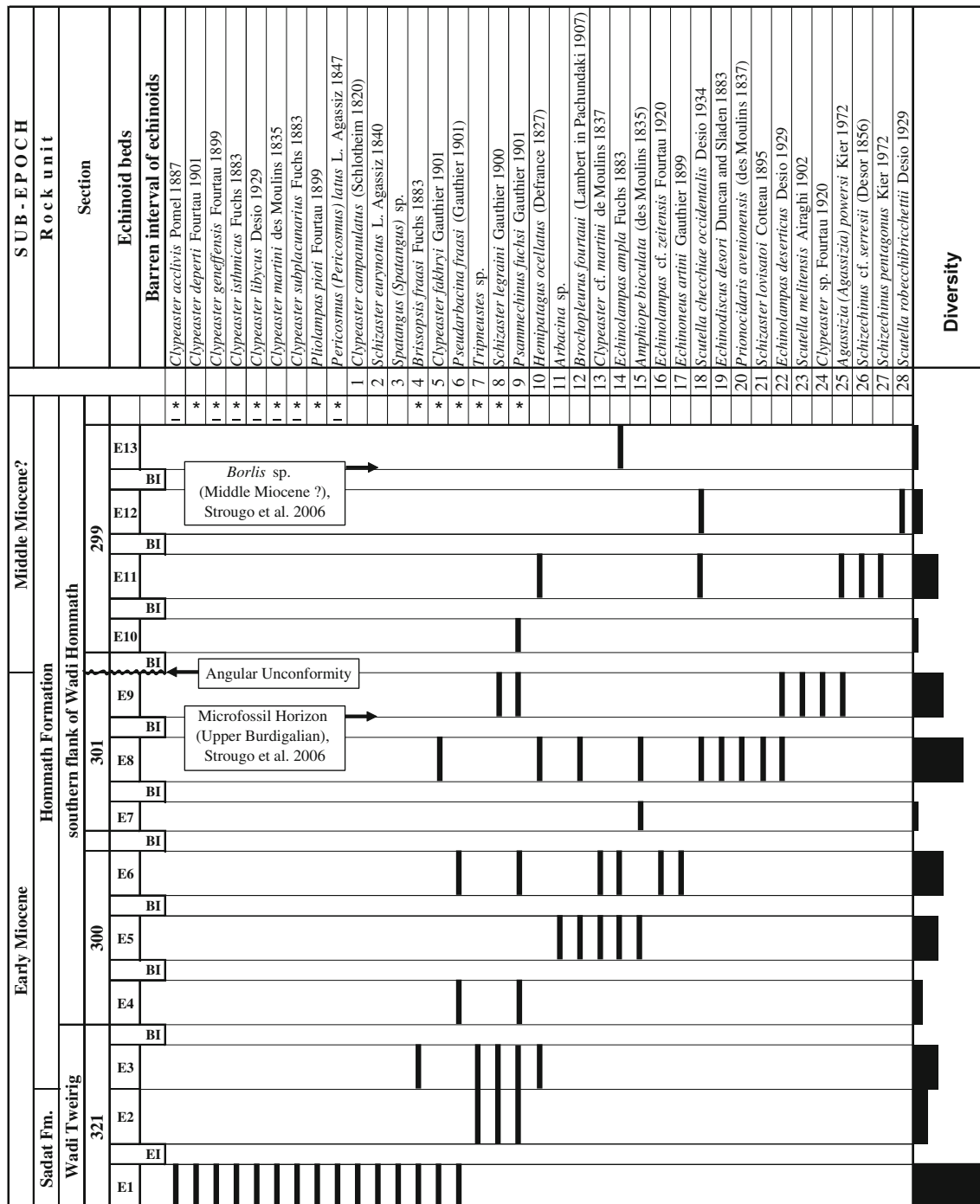


Fig. 4 Distribution chart of the Lower-Middle Miocene echinoids of Sadat area, NW Gulf of Suez, Egypt (Hommath and Sadat formations); 28 species (1–28) of the present study and 15 species

(asterisk) were recorded by Elattaar (2003) from the Sadat Formation, north Wadi Tweirig (not to scale). (Coordinates of sections in Figs. 1 and 2)

- (*Schizechinus pentagonus* Kier 1972, *Echinodiscus desori* Duncan and Sladen 1883, *Agassizia* (*Agassizia*) *powersi* Kier 1972) are Indo-Pacific, Asia (Saudi Arabia, Iran, and India and Pakistan), and one of them *Amphiope bioculata* (des Moulins 1835) is known in both of the two regions (Mediterranean and Indo-Pacific) (Table 1).
8. Among 25 echinoid species recorded from the Middle Miocene of Egypt (Table 1, species nos. 3, 5, 7, 15, 16, 18, 20, 21–28), only two species (*Schizechinus pentagonus* Kier 1972 and *Agassizia* (*Agassizia*) *powersi* Kier 1972) are known from the Early Miocene of the Indo-Pacific Region. This suggests the possibility that there is no connection between the Mediterranean and Indo-Pacific regions during the Middle Miocene.
 9. Several authors detected mixed fauna in the Miocene of Egypt between the Mediterranean and the Indo-Pacific regions (Cox 1927, 1936; Sadek 1959; Ali 1983; Ali and Cherif 1987; Ziko et al. 1994; El-Shazly and Abdelhamid 2001).

Consequently, the paleobiogeographic distribution of the identified echinoid species in the studied area indicates strong affinity to the Mediterranean region.

Systematic paleontology

Measurements have been carried out with a vernier caliper and are given in millimeters. The material of the present study is deposited in the Museum of Geology Department, Faculty of Science, Sohag University (SUSGM). For the classification of the echinoids treated in this paper, the scheme of Durham et al. (1966) in Moore (ed.) *Treatise on Invertebrate Paleontology* has been followed.

Specimens in the plates of this work were photographed using a digital camera, and for more detailed views of the important morphological features, some photomicrographs were taken using a binocular microscope, and they are whitened and coated with ammonium chloride.

Abbreviations: *a*, distance of apical disc from anterior margin; BI, barren interval of echinoids; *D*, test diameter in regular echinoids; (E), echinoid bed; Gebel, mountain; *H*, test height; *L*, test length in irregular echinoids; Lpr, length of periproct; Lps, length of peristome; Lpt, length of petals; L1, distance between posterior border of the periproct to posterior margin of test; L2, distance between posterior border of peristome to posterior margin of test; Npp, number of pore pairs; *W*, test width; Wa, width of ambulacral area at ambitus; Wadi, Valley; Wi, width of interambulacral area at ambitus; Wpr, width of periproct; Wps, width of peristome; Wpt, width of petals; I, petal I; II, petal II; III, petal III; IV, petal IV; V, petal V.

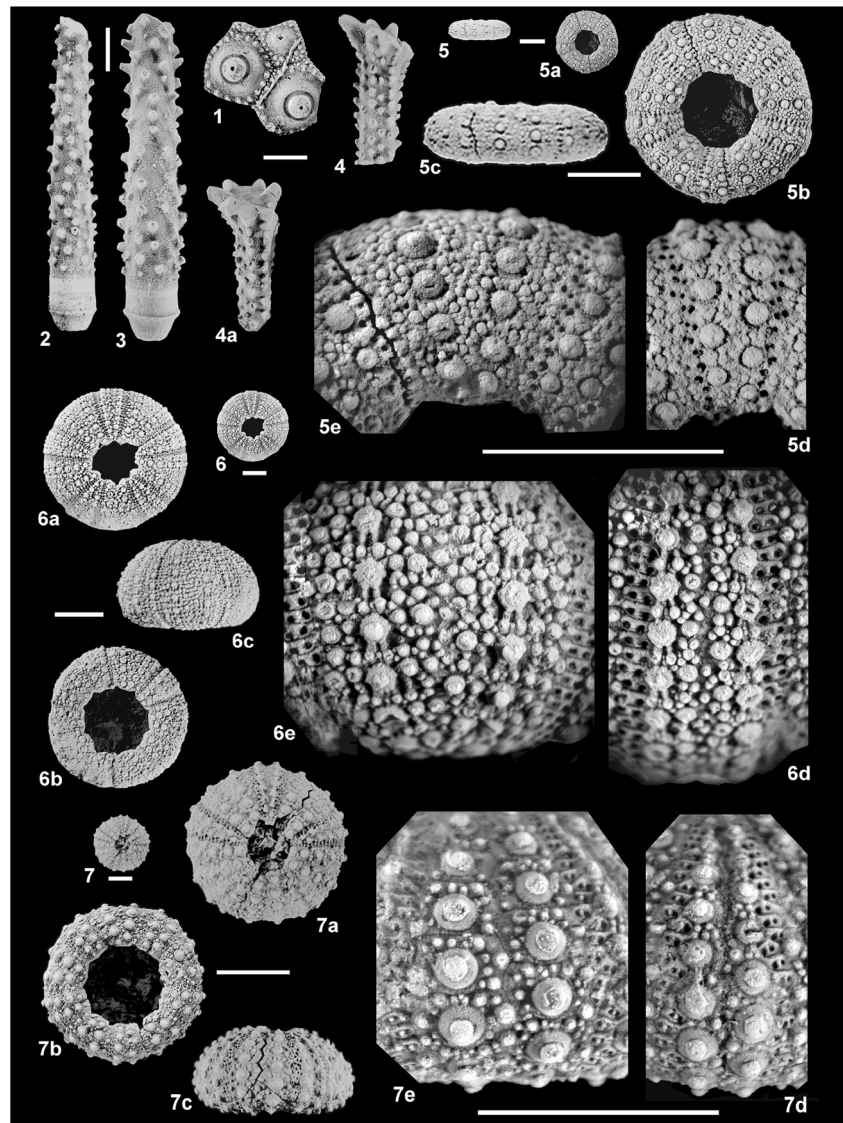
- Class Echinoidea Leske 1778.
 Subclass Perischoechinoidea McCoy 1849.
 Order Cidaroida Claus 1880.
 Family Cidaridae Gray 1825.
 Subfamily Rhabdocidarinae Lambert 1900.
 Genus *Prionocidaris* A. Agassiz 1863.
Prionocidaris avenionensis (des Moulins 1837)
 (Pl. 1, figs. 1–4a).
 1858 *Cidaris avenionensis*, Desor, p. 17, pl. 7, figs. 7, 8.
 1877 *Cidaris avenionensis*, Cotteau, p. 229, pl. 8, figs. 3–7.
 1917 *Cyathocidaris avenionensis*, Checchia Rispoli, p. 56, 57, pl. 5, fig. 1.
 1987 *Cyathocidaris avenionensis*, Mączyńska, p. 148, pl. 1, figs. 1–7, pl. 2, figs. 1a–1d.
 1993 *Cyathocidaris avenionensis*, Mączyńska, p. 106, pl. 1, fig. 4, pl. 6, fig. 1c.
 2005 *Prionocidaris avenionensis*, Kroh, p. 13.
 2003 *Prionocidaris avenionensis*, Kroh and Nebelsick, p. 161–169, figs. 3/e–h, figs. 7/b–e.
 2010 *Prionocidaris avenionensis*, Pereira, p. 206.
 2016 *Prionocidaris avenionensis*, Borghi and Stara, p. 18, figs. 2/A, B.
 2016 *Prionocidaris avenionensis*, Mancosu and Nebelsick, p. 145, fig. 4/c.

Material Attached interambulacral plates and many spines (SUSGM 018-10-101), section 301 (E8), Hommath Formation, Wadi Hommath, Early Miocene.

Description Each interambulacral plate bears one large, deep perforated, noncrenulated primary tubercle, almost occupying the entire surface of plate with complete circular scrobicular ring; mamelon large, raised and swollen. Primary spines are cylindrical to flattened with circular or slightly ovoid cross section, with a fine ornament of small thorns, coarse and serrated ribs, with toothed and wide end.

Discussion The spines of this species are distinguished from those of *P. bispinosa* (Lamarck 1816) in Nisiyama (1966) from the Pleistocene of Japan by their small size, non-tapered toward the flange, with subconical granules and smaller thorns on all sides, with cup and wide ends, instead of big thorns on one side and granules on the other in *P. bispinosa*. Its spines are also distinguished from *P. sismondai* (Mayer in Hartung 1864) in Loriol 1896 (p. 5, pl. 1, figs. 5, 5a) (*Rhabdoocidaris sismondai*) and Lambert 1907 (p. 19, pl. 1, figs. 1–6) (*Leiocidaris sismondai*) by having least robust, thinner, homogeneous, condensed and arranged in rows smaller thorns on all sides, with cup and wide ends, instead of big thorns on one side and granules on the other one in de Loriol forms, and scattered, longer, stronger and irregular thorns in Lambert forms.

Plate 1 1–4a, *Prionocidaris avenionensis* (des Moulins 1837) (SUSGM 018-10-101). 1, portion of interambulacrum near peristome. 2, 3, spines base. 4, 4a, spine tip; face adapical (4), profile (4a); Early Miocene, Hommath Formation, section 301 (E8). 5–5e, *Arbacina* sp. (SUSGM 018-10-102); 5, 5a, side and oral views (original size); 5c same as 5, enlarged; 5b same as 5a, enlarged; 5d, 5e, oral views and close-up of peristomal ambulacrum and interambulacrum; Early Miocene, Hommath Formation, section 300 (E5). 6–6e, *Brochopleurus fourtaui* (Lambert in Pachundaki 1907) (SUSGM 018-10-103); 6, aboral view (original size), 6a, 6b, 6c, aboral, oral and side views; 6a, same as 6, enlarged; 6d, 6e, details of ambital ambulacrum and interambulacrum; Early Miocene, Hommath Formation, section 300 (E5). 7–7e, *Pseudarbacina fraasi* (Gauthier 1901) (SUSGM 018-10-104); 7, aboral view (original size); 7a, 7b, 7c, aboral, oral, and side views; 7a, same as 7, enlarged; 7d, 7e, details of ambital ambulacrum and interambulacrum; Early Miocene, Hommath Formation, section 300 (E6). Scale bar = 5 mm



Occurrence and age Early Miocene, Hommath Formation, Wadi Hommath, section 301 (E8).

Geographic distribution In Egypt, it is recorded from the Early Miocene of Gebel Gharra, Eastern Desert (Kroh and Nebelsick 2003). Outside of Egypt, it is recorded from the Miocene of Portugal, Spain, France, Corsica, Sardinia, Middle Miocene of Switzerland and Poland, and Early-Middle Miocene of Italy (Cotteau 1877; Mączyńska 1987, 1993; Pereira 2010; Borghi and Stara 2016).

Subclass Euechinoidea Bronn 1860.

Superorder Echinacea Claus 1876.

Order Temnopleuroida Mortensen 1942.

Family Temnopleuridae A. Agassiz 1872.

Genus *Arbacina* Pomel 1869.

Arbacina sp.

(Pl. 1, figs. 5–5e).

Material Two specimens (one was measured) (SUSGM 018-10-102), section 300 (E5), Hommath Formation, Wadi Hommath, Early Miocene.

<i>D</i>	<i>H</i>	<i>H/D</i>	<i>Wa</i>	<i>Wi</i>	<i>Wa/Wi</i>	<i>Wps</i>	<i>Wps/D</i>
12.2	–	–	2.9	5.0	0.57	4.8	0.39

Description Test small, low, sub-spherical, with slightly raised ambulacral areas. Each interambulacral plate bears one central imperforate and non-crenulated primary tubercle, not occupying the entire surface of plate, with incomplete circular scrobicular ring; mamelon relatively large, adradial and interradial tracts with additional secondaries and miliaries closely packed. Each ambulacral plate has three pore pairs, arranged in arc shape, barely oblique and distinct primary tubercle close to the pore zone, and a smaller secondary

toward the perradius; primary tubercles separated in column by a row of miliaries; similar in size to interambulacral primary tubercles, no true pits on test. Poriferous zone rather broad, little depressed, forming almost a single vertical series of pore pairs. Apical disc small and less than one-third test diameter. Peristome of moderate size, with shallow buccal notches.

Discussion This species differs from *A. catenata* var. *orientalis* Fourtau 1920, from the Miocene of Sinai, Egypt, in having smaller and lower test, and different pattern of granules and tubercles around the principal primary tubercles in ambulacral and interambulacral areas. Our specimens closely resemble *A. mutellaensis* de Loriol 1896 (p. 8, pl. 1, fig. 10) from the Miocene of Portugal (de Loriol 1896) but differs in having relatively lower test and narrower peristome. On the other side, *A. mutellaensis* has been synonymized with *Psammechinus dubius dubius* (Agassiz 1840) by Pereira 2010 based on the re-examination of the holotype.

Occurrence and age Early Miocene, Hommath Formation, Wadi Hommath, section 300 (E5).

Genus *Brochopleurus* Fourtau 1920

Brochopleurus fourtaui (Lambert in Pachundaki 1907).

(Pl. 1, figs. 6–6e).

1907 *Opechinus fourtaui* Lambert in Pachundaki, p. 4, 14, pl. 2, figs. 2a–f.

1920 *Brochopleurus fourtaui*, Fourtau, p. 26, pl. 2, fig. 5.

2003 *Brochopleurus fourtaui*, Kroh and Nebelsick, p. 163, fig. 3j.

Material Thirteen specimens (11 were measured); section 300 (E5) (SUSGM 018-10-103) and section 301 (E8) (SUSGM 018-10-103/a), Hommath Formation, Wadi Hommath, Early Miocene.

<i>D</i>	<i>H</i>	<i>H/D</i>	<i>Wa</i>	<i>Wi</i>	<i>Wa/Wi</i>	<i>Wps</i>	<i>Wps/D</i>
7.6	4.4	0.58	2.1	2.9	0.72	3.1	0.41
8.2	4.5	0.55	2.0	2.9	0.69	3.5	0.43
8.4	4.6	0.54	2.3	3.0	0.77	3.9	0.46
8.5	5.7	0.67	2.2	3.0	0.73	3.8	0.44
9.4	4.5	0.48	2.7	3.2	0.83	4.1	0.44
10.0	6.2	0.62	2.5	3.6	0.68	4.2	0.42
10.0	4.7	0.47	2.5	3.6	0.69	4.3	0.43
10.1	5.6	0.56	2.6	3.5	0.75	4.2	0.42
10.5	6.0	0.57	2.3	3.7	0.63	4.0	0.38
12.1	7.4	0.61	3.0	4.7	0.65	4.6	0.38
13.9	8.2	0.59	3.3	5.2	0.63	5.8	0.42

Description Test small, subcircular, sub-hemispherical, slightly sunken toward peristome orally, aboral surface weakly domed, ambitus a little below mid-height. Apical disc small with not preserved plates. Ambulacral plates ranging from 11 to 16 in each column, whereas there are 11–15 in the interambulacral one; pore-pairs arranged in three weak arcs; pore zone a little sunken, primary tubercle lies in contact with poriferous zone. Poriferous zone straight, a little depressed, forming almost a single vertical series of pore pairs. Primary tubercles imperforate, non-crenulate with two radial ribs reaching to the two lower granules. Interambulacral plates with central primary tubercle, two radial ribs and complete circular scrobicular ring; there are five small depressions discontinuously developed around the primary tubercles, the primary and large secondary tubercles form five vertical series on the interambulacral area at the ambital region. Peristome of moderate size, with insignificant gill slits.

Discussion This species is easily distinguished from *B. sadeki* Fourtau 1920, from Gebel Zeit, Gulf of Suez, Egypt, in having larger and smaller number of secondary tubercles. Our specimens closely resemble *B. pulcherrimus* Nisiyama 1966, from probably Lower Pliocene or Miocene of Japan, but are distinguished from that species by having narrower peristome ($Wps/D = 0.38–0.46$, instead of 0.50 in *B. pulcherrimus*), and the primary and large secondary tubercles form five vertical series at the ambital region, instead of three or four in *B. pulcherrimus*. It is also distinguished from *B. stellulatus* Duncan and Sladen 1882 (*Temnechinus stellulatus*), from the Miocene of India by having five vertical series of primary and large secondary tubercles of interambulacral area at the ambital region, instead of very small and scattered secondary tubercles over the plate in *B. stellulatus*. It is also distinguished from *B. gajensis* Duncan and Sladen 1882 (*Temnechinus gajensis*), from the Miocene of India by having larger primary and secondary tubercles of ambulacral and interambulacral areas, especially at the ambital region.

Occurrence and age Early Miocene, Hommath Formation, Wadi Hommath, sections 300 (E5) and 301 (E8).

Geographic distribution *B. fourtaui* is endemic to Egypt. It is recorded from the Middle Miocene of Marsa Matrouh, Western Desert (*Opechinus fourtaui* Lambert in Pachundaki 1907), and Early Miocene of Egypt, Gebel Gharra, Eastern Desert (Kroh and Nebelsick 2003).

Genus *Pseudarbacina* Fourtau 1920

Pseudarbacina fraasi (Gauthier 1901).

(Pl. 1, figs. 7–7e).

1901 *Arbacina fraasi* Gauthier in Fourtau, p. 91, pl. 6, figs. 9–13.

1907 *Arbacina fraasi*, Lambert in Pachundaki, p. 21.

1913 *Prionechinus fraasi*, Cottreau, p. 47.

1913 *Prionechinus lyonsi*, Cottreau, p. 48.

1920 *Pseudarbacina fraasi*, Fourtau, p. 23, pl. 2, fig. 4.

2003 *Pseudarbacina fraasi*, Elattaar, p. 214, pl. 2, fig. 7, pl. 3, figs. 1–4, text—fig. 4a.

Material Three specimens (two were measured); section 300 (E4, E6) (SUSGM 018-10-104), Early Miocene, Wadi Hommath, Hommath Formation.

<i>D</i>	<i>H</i>	<i>H/D</i>	<i>Wa</i>	<i>Wi</i>	<i>Wa/Wi</i>	<i>Wps</i>	<i>Wps/D</i>
11.0	5.7	0.52	2.9	3.7	0.77	5.0	0.46
12.6	5.5	0.51	3.1	4.0	0.78	–	–

Description Test hemispherical, with raised ambulacral areas, ambitus a little below mid-height. Specimen 11 mm in diameter has 11 ambulacral plates and 9 interambulacral ones in each column. Each interambulacral plate bears three imperforated, noncrenulated tubercles, the largest one in the middle, lies in contact with adoral suture, with incomplete circular scrobicular ring. Ambulacral plate has two tubercles; the largest one lies in contact with poriferous zone, and three pore-pairs; arranged in arc shape. Peristome wide with shallow buccal notches. Apical disc small with no preserved plates in fossil material.

Discussion *Pseudarbacina* is distinguished from *Arbacina* by its homogeneous miliary granulation which is a little less regular and by the absence of specialized granules beneath and above the primary tubercles (Fourtau 1920, p. 22). Elattaar (2003) identified *P. fraasi* from the Early Miocene rocks of the Sadat Formation, Sadat area (north Wadi Tweirig) with very faintly crenulated primary tubercles. Our specimens are collected from the same area (at and south Wadi Tweirig), but from the Hommath Formation; they have noncrenulated primary tubercles. This species needs to be further studied, when more samples are available.

Occurrence and age Early Miocene, Hommath Formation, Wadi Hommath, sections 300 (E4, E6). Early Miocene, Sadat Formation, Sadat area, from beds equivalent to (E1) of section 321, Wadi Tweirig (Elattaar 2003).

Geographic distribution *P. fraasi* is endemic to Egypt. It is recorded from Miocene; Upper Burdigalian-Middle Miocene, Gebel Geneifa (Fourtau 1901, p. 92), (Burdigalian-Langhian) of Gebel Geneifa and Sinai (Fourtau 1920, p. 25), Lower-Middle Miocene, Western Desert (Ali 1984, p. 162), and Early Miocene, Sadat Formation, Sadat area (north Wadi Tweirig) (Elattaar 2003).

Family Toxopneustidae Troschel 1872.

Genus *Schizechinus* Pomel 1869.

Schizechinus cf. *serresii* (Desor 1856).

(Pl. 2, figs. 1–1c).

Material A single incomplete specimen (*Wa* = 9.1 mm, *Wi* = 14.6 mm), (SUSGM 018-10-105), section 299 (E11), Hommath Formation, Wadi Hommath, Middle Miocene.

Description Test high and sub-hemispherical, convex above and quite depressed around the peristome. Primary tubercles subequal, forming regular vertical series, imperforate and noncrenulate, reach to three in ambulacral plate and seven in interambulacral one at ambitus. Peristome moderately large, in a slightly depressed area, with moderately deep gill slits.

Discussion In general appearance, our specimen appears quite different from *S. duciei* (Wright 1855) in Cottreau 1913, p. 83, 84, text—figs. 10, 11; pl. 1, figs. 15–16, from the Miocene of Malta and Algeria and *S. pentagonus* Kier 1972 in the present work and Kier 1972, p. 89, fig. 47; pls. 55, 56, from Burdigalian of Saudi Arabia in having more primary tubercles in each ambulacral and interambulacral plates; seven in interambulacral and three in ambulacral at ambitus, whereas, five in interambulacral and two in ambulacral in *duciei*, five in interambulacral and three in ambulacral in *pentagonus*. Our specimen has wider peristome than the two species, and higher test than *duciei* and comes closest to *S. serresii* (Desor 1856) in Kroh and Smith (2006) in general shape, but differs in having moderately deeper gill slits and more tubercles in interambulacral plates (seven in each plate at ambitus, instead of 6 in *S. serresii*). It differs from *S. sahelensis* (Pomel 1887) (*Anapesus sahelensis*) p. 301, pl. 3, figs. 1–7, *S. serialis* (Pomel 1887) (*Anapesus serialis*), p. 303, pl. 4, figs. 1–7, and *S. tuberculatus* (Pomel 1887) (*Anapesus tuberculatus*), p. 298, pl. 5, figs. 1–6, pl. 13, figs. 4–6 from Lower Pliocene of Algeria in having more primary tubercles in each ambulacral and interambulacral plates; seven in interambulacral and three in ambulacral at ambitus, instead of four in interambulacral and two in ambulacral in *sahelensis*, six in interambulacral and three in ambulacral in *serialis*, and five in interambulacral and two in ambulacral in *tuberculatus*, and it has a higher test than *sahelensis* and *tuberculatus*.

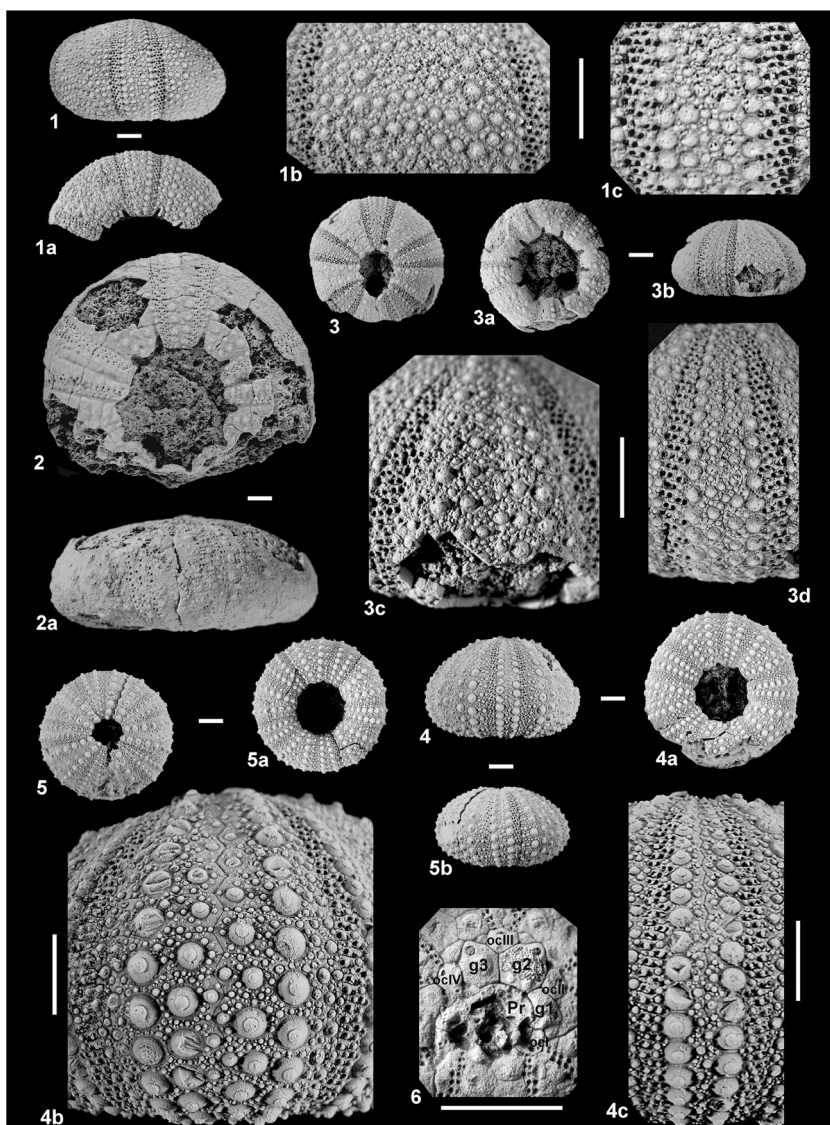
Occurrence and age Middle Miocene, Hommath Formation, Wadi Hommath, section 299 (E11).

Schizechinus pentagonus Kier 1972

(Pl. 2, figs. 3–3d).

1972 *Schizechinus pentagonus* Kier, p. 89, pl. 55, figs. 1–6, pl. 56, figs. 1–6.

Plate 2 1–1c, *Schizechinus* cf. *serresii* (Desor 1856) (SUSGM 018-10-105); 1, 1a, side and oral views; 1b, 1c, details of ambital interambulacrum and ambulacrum; Middle Miocene, Hommath Formation, section 299 (E11). 2, 2a, *Tripneustes* sp. (SUSGM 018-10-106); oral and side views; Early Miocene, Hommath Formation, Wadi Tweirig, section 321 (E3). 3–3d, *Schizechinus pentagonus* Kier 1972 (SUSGM 018-10-107); 3, 3a, 3b, aboral, oral, and side views; 3c, 3d, details of ambital interambulacrum and ambulacrum; Middle Miocene, Hommath Formation, section 299 (E11). 4–6, *Psammechinus fuchsi* Gauthier, 1901. 4–4a, side and oral views; 4b, 4c, details of ambital interambulacrum and ambulacrum (SUSGM 018-10-108). 5, 5a, 5b, aboral, oral and side views (SUSGM 018-10-109). 6, apical disc (SUSGM 018-10-110) (Pr = periproct; ocular plates indicated by “oc” and genital plates by “g” and their respective number according to the Lovenian system; Early Miocene, Hommath Formation, section 301 (E9). Scale bar = 5 mm



Material Three specimens (one was measured) (SUSGM 018-10-107), section 299 (E11), Hommath Formation, Wadi Hommath, Middle Miocene.

D	H	H/D	Wa	Wi	Wa/Wi	Wps	Wps/D
29.0	15.5	0.54	7.3	10.3	0.71	12.4	0.43

Description Test medium, high and subconical to hemispherical shape, with slightly subpentagonal marginal outline, slightly depressed at oral surface, ambitus a little below mid-height. Each column of ambulacral area has 25 plates and 17 in interambulacral one. Primary tubercles imperforate and nonrenulate, forming regular vertical series; three in each ambulacral plate and five in interambulacral one at ambitus; nearly equal in size, decreasing in number toward both apex and peristome, decreasing in size from peristome toward

apical disc, with complete scrobicular ring in interambulacral plates. Peristome of moderate size, with perpendicular moderately deep gill slits.

Discussion Paratype of *S. pentagonus* Kier 1972 (pl. 56, figs. 4, 5, 6) has subpentagonal marginal outline, instead of pentagonal outline in (pl. 55, fig. 6). In general appearance, our specimen appears quite different from *S. duciei* (Wright 1855) in Cottreau 1913, p. 83, 84, pl. 1, figs. 15–16, from the Miocene of Malta and Algeria, and in Kier 1972, pl. 57, fig. 1 in having more primary tubercles in ambulacral plates (3 instead of 2 in *duciei*), wider peristome, deeper gill slits and slightly higher test. It differs from *S. sahelensis* (Pomel 1887) (*Anapesus sahelensis*) p. 301, pl. 3, figs. 1–7; *S. serialis* (Pomel 1887) (*Anapesus serialis*), p. 303, pl. 4, figs. 1–7; and *S. tuberculatus* (Pomel 1887) (*Anapesus tuberculatus*), p. 298, pl. 5, figs. 1–6, pl. 13, figs. 4–6 from Lower

Pliocene of Algeria in having more primary tubercles in each ambulacral and interambulacral plates; five in interambulacral and three in ambulacral at ambitus, instead of four in interambulacral and two in ambulacral in *saheliensis*, 6 in interambulacral in *serialis*, and two in ambulacral in *tuberculatus*, and it has a higher test than all.

Occurrence and age Middle Miocene, Hommath Formation, Wadi Hommath, section 299 (E11).

Geographic distribution The type of *S. pentagonus* originally described from the Early Miocene (Burdigalian) of Saudi Arabia.

Genus *Tripneustes* L. Agassiz 1841

Tripneustes sp.

(Pl. 2, figs. 2, 2a).

Material Two incomplete specimens (one was measured) (SUSGM 018-10-106), Wadi Tweiwig, section 321; (E2), Sadat Formation, and (E3), Hommath Formation, Early Miocene.

<i>D</i>	<i>H</i>	<i>H/D</i>	<i>Wa</i>	<i>Wi</i>	<i>Wa/Wi</i>	<i>Wps</i>	<i>Wps/D</i>
57.6	24.0	0.42	15.6	20.3	0.77	20.0	0.35

Description Test large, low and subspherical in shape. Ambulacral areas with three vertical series of nonconjugate equal pore pairs (the middle series of pore pairs not straight) and three vertical series of primary tubercles, unequal in size per column, reduced in number toward apical disc and peristome; ambulacral plates trigeminate with three pore pairs in each plate of triad, arranged in arc three. Interambulacral areas wide; each plate corresponds to two plates (six or more pore pairs) in adjacent ambulacral area and has four primary tubercles at ambitus, reduced in number toward apical disc and peristome. Peristome of moderate size, with perpendicular to slightly oblique and moderately deep gill slits.

Discussion Our specimens appear quite different from *T. proavius* (Duncan and Sladen 1885) (*Hipponoe proavia* Duncan and Sladen 1885, p. 310, pl. 48, figs. 1–4a, pl. 49, fig. 1) and *T. antiquus* (Duncan and Sladen 1855) (*Hipponoe antiqua* Duncan and Sladen 1885, p. 313, pl. 49, figs. 2–4) from the Miocene of Pakistan by having lower test, wider peristome and less number of tubercles in interambulacral plates at ambitus (four instead of seven in *proavia* and five in *antique*). It also differs from *T. gahardensis* (Seunes 1896) in each of Lambert (1906), p. 75, pl. 5, figs. 12, 13, and Bajo and Borghi (2009, p. 14, pl. 1, figs. 1a–1c, pl. 2, figs. 1a–1c), from the Miocene of Spain by having wider peristome, shallower gill slits, and less number of tubercles in interambulacral plates at

ambitus (four instead of six in *T. gahardensis*). Agassiz 1846, p. 364, did not provide any description on *T. Parkinsoni*, except the sentence “Tubercles large enough inside the poriferous areas.” Figure 17, pl. 1 of *T. Parkinsoni* of Cottreau 1913 unclear. Our specimens differ also from *T. magnificus* Nisiyama (1966) (I), p. 243, pl. 6, figs. 2, 7, 8, pl. 7, fig. 1 from the Lower Miocene of Japan in having a smaller, lower and more flattened test, wider ambulacral area relative to interambulacral one ($Wa/Wia = 0.77$, instead of 0.81 in *T. magnificus*). It differs also from *T. planus* (Agassiz, 1847) in Bongrain 2013, p. 610, 613, 614, 618, 625, Fig. 9/A, from Early Miocene of France by having wider peristome.

Occurrence and age Early Miocene, Wadi Tweiwig, section 321; (E2), Sadat Formation, and (E3), Hommath Formation. *Tripneustes* sp. was recorded from the Sadat Formation, Sadat area, of beds equivalent to (E2) of section 321, north Wadi Tweiwig (Elattaar 2003). Except this record, there is no *Tripneustes* species was recorded from Egypt.

Order Echinoidea Claus 1876.

Family Echinidae Gray 1825.

Genus *Psammechinus* L. Agassiz and Desor 1846

Psammechinus fuchsi Gauthier 1901.

(Pl. 2, figs. 4–6).

1901 *Psammechinus fuchsi* Gauthier in Fourtau, p. 89, pl. 6, figs. 4–7.

1920 *Psammechinus fuchsi*, Fourtau, p. 14.

2003 *Psammechinus fuchsi*, Elattaar, p. 215, pl. 6, figs. 1–6.

Material Thirty specimens (seven were measured), section 321; (E2), Sadat Formation, (E3), Hommath Formation, Wadi Tweiwig, (SUSGM 018-10-109), section 300 (E4, E6) (SUSGM 018-10-109/a) and section 301 (E9) (SUSGM 018-10-108), Early Miocene, and section 299 (E10) (SUSGM 018-10-110), Middle Miocene, Wadi Hommath, Hommath Formation.

<i>D</i>	<i>H</i>	<i>H/D</i>	<i>Wa</i>	<i>Wi</i>	<i>Wa/Wi</i>	<i>Wps</i>	<i>Wps/D</i>
34.3	21.0	0.61	7.3	13.5	0.54	11.8	0.34
28.4	16.0	0.56	6.4	10.4	0.62	10.0	0.35
28.2	15.0	0.53	6.1	10.3	0.59	9.3	0.33
27.5	15.6	0.57	6.4	10.1	0.63	9.9	0.36
26.1	13.4	0.51	6.2	9.8	0.63	9.7	0.37
21.3	10.6	0.50	4.7	8.2	0.57	–	–
19.5	11.1	0.57	4.2	6.8	0.62	7.4	0.38

Description Test medium, high, subpentagonal, subspherical and slightly depressed at oral surface, ambitus a little below mid-height. In specimen 34.3 mm in diameter, each column of ambulacral area has 28 plates and 20 in interambulacral one. Primary tubercles forming regular vertical series,

imperforate and noncrenulate, 3 in each ambulacral plate and 5 in interambulacral at ambitus; decreased in number toward apex and peristome, with incomplete scrobicular ring. In each ambulacral plate, the principal primary tubercle lies adjacent to poriferous zone and larger than the secondary tubercle which lies adjacent to perradial suture. Peristome of moderate size, in slightly depressed area, with moderately shallow gill slits. Apical disc hemicyclic and not complete; ocular I in contact with periproct.

Discussion Our specimens of *P. fuchsi* are distinguished from *P. coronalis* Lambert 1910 in Cottreau (1913, p. 81, pl. 1, figs. 10–14) from the Miocene (Upper Aquitanian) of France by its higher test and narrower peristome.

Occurrence and age Early-Middle Miocene. Early Miocene, Wadi Twehrig, section 321 (E2), Sadat Formation, and (E3), Hommath Formation. Early Miocene, sections 300 (E4, E6),

and section 301 (E9), and Middle Miocene, section 299 (E10), Hommath Formation, Wadi Hommath. Sadat Formation, Sadat area, from beds equivalent to (E2) of section 321, Wadi Twehrig (Elattaar 2003).

Geographic distribution *P. fuchsi* is endemic to Egypt. It is recorded from the Miocene (Langhian-Serravallian) of Gebel Geneifa (Fourtau 1901, p. 91; 1920, p. 15), and from the Early Miocene Sadat Formation, Sadat area, north Wadi Twehrig (Elattaar 2003).

Superorder Gnathostomata Zittel 1879.

Order Holoctypoida Duncan 1889.

Suborder Echinoneina Clark 1925.

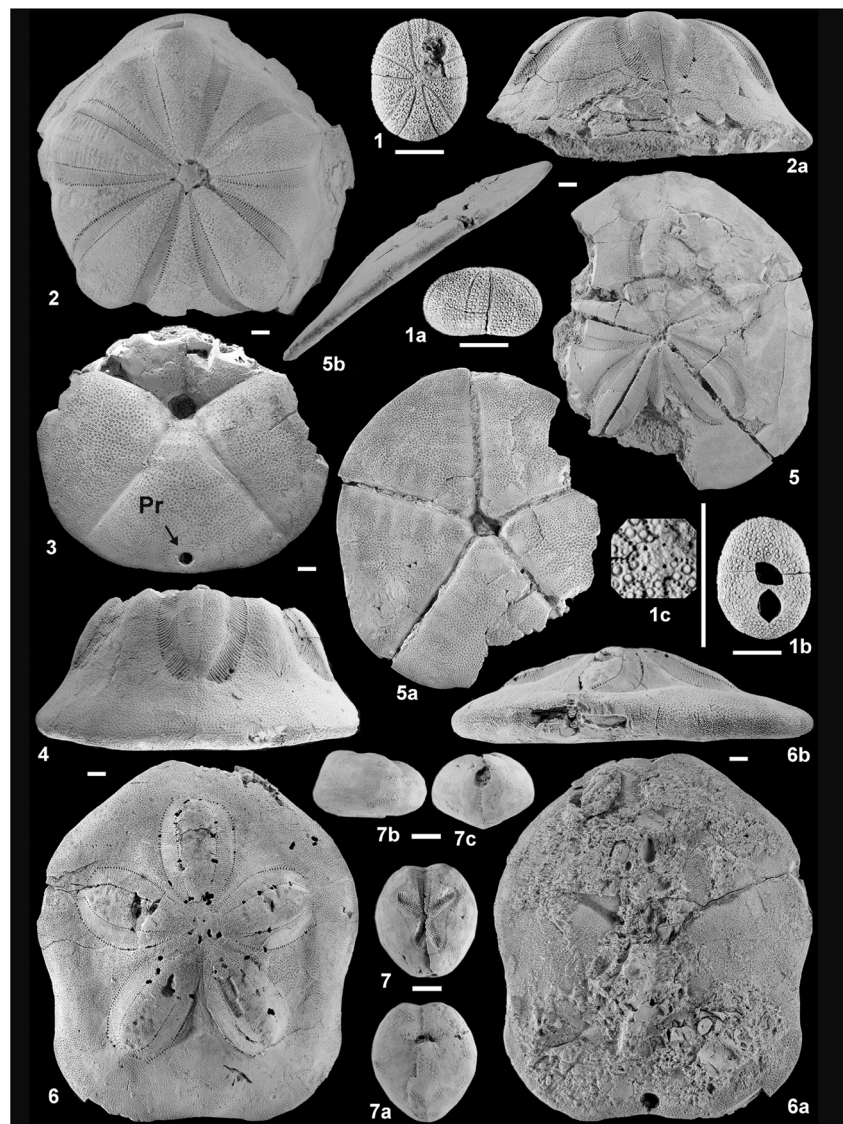
Family Echinoneidae L. Agassiz and Desor 1847.

Genus *Echinoneus* Leske 1778.

Echinoneus artini Gauthier 1899.

(Pl. 3, figs. 1–1c).

Plate 3 1–1c, *Echinoneus artini* Gauthier, 1899 (SUSGM 018–10–111); 1, 1a, 1b, aboral, left side and oral views; 1c, apical disc of the same; Early Miocene, Hommath Formation, section 300 (E6). 2–4, *Clypeaster campanulatus* (Schlotheim 1820) (SUSGM 018–10–112); 2, 2a, aboral and right side views. 3, oral view (combined periproct = Pr). 4, left side view; Early Miocene, Sadat Formation, Wadi Twehrig, section 321 (E1). 5–5b, *C. fakhryi* Gauthier 1901 (SUSGM 018–10–113); 5, 5a, 5b, aboral, oral and right side views; Early Miocene, Hommath Formation, section 301 (E8). 6–6b, *C. cf. martini* des Moulins 1837 (SUSGM 018–10–114); 6, 6a, 6b, aboral, oral and left side views; Early Miocene, Hommath Formation, section 300 (E6). 7–7c, *Brissopsis fraasi* Fuchs 1883 (SUSGM 018–10–115); 7, 7a, 7b, 7c, aboral, oral, right side, and posterior views; Early Miocene, Sadat Formation, Wadi Twehrig, section 321 (E1). Scale bar = 5 mm



1899 *Echinoneus artini* Gauthier in Fourtau, p. 695, pl. 2, figs. 7–8.

1913 *Echinoneus artini*, Cottreau, p. 62, 106.

Material Two specimens were measured, section 300 (E6) (SUSGM 018-10-111), Hommath Formation, Wadi Hommath, Early Miocene.

<i>L</i>	<i>W</i>	<i>H</i>	<i>W/L</i>	<i>H/L</i>	<i>Lpr</i>	<i>Wpr</i>	<i>Wpr/Lpr</i>	<i>Lps</i>	<i>Wps</i>	<i>Wps/Lps</i>
9.0	7.0	4.7	0.78	0.52	–	–	–	–	–	–
13.3	10.3	7.3	0.77	0.55	3.55	2.7	0.76	2.9	3.1	1.07

Description Our specimens of *E. artini* are characterized by an elliptical outline of test, aboral surface strongly convex and swollen, oral surface slightly depressed and concave, slightly arched in the antero-posterior direction. Ambulacral areas have wide interporiferous zones relative to very narrow and slightly depressed poriferous ones, with tubercles of the same size as in interambulacral areas, arranged in groups of two; pore pairs uniserial adapically. Apical disc centrally located, tetrabasal with four small genital pores; genital pore 2 has posterior position relative to the posterior left one (Fig. 1c, Pl. 3). Periproct inframarginal, oval, longitudinally elongate, just 3 mm behind peristome, with acute anterior and posterior ends. Peristome lies subcentral, oval, oblique and wider than long with straight horizontal posterior edge. Bourrelets absent.

Discussion *E. artini* is easily distinguished from *E. thomasi* Cotteau in Peron and Gauthier 1891, p. 133, from the Miocene of Algeria, by having higher and more elongated test and less prominent ambulacral areas. It differs from *E. cyclostomus* (Leske, 1778) (Recent species) in Cottreau (1913, p. 106, pl. 12, figs. 1–2b) by having higher test, broader anterior and posterior ends of test, lower ambulacral areas, wider periproct and peristome, fewer primary tubercles on each ambulacral plates at ambitus (two only, instead of three—four in *cyclostomus*). It differs also from *E. melitensis* (Wright, 1864), Lower Miocene, Malta (The Echinoid Directory) by having higher, wider, and more swollen test, wider ambulacral areas, especially ambulacrum III, larger and more posterior apical disc and more raised ambulacral areas.

Occurrence and age Early Miocene, Hommath Formation, Wadi Hommath, section 300 (E6).

Geographic distribution *E. artini* is endemic to Egypt and recorded for the first time from the studied area. It is recorded from Miocene (Langhian-Serravallian) of Gebel Geneifa (Fourtau 1899).

Order Clypeasteroidea A. Agassiz 1872.

Suborder Clypeasterina A. Agassiz 1872.

Family Clypeasteridae L. Agassiz 1835.

Genus *Clypeaster* Lamarck 1801.

Clypeaster campanulatus (Schlotheim 1820). (Pl. 3, figs. 2–4).

1913 *Clypeaster campanulatus*, Cottreau, p. 29, 30, 57, 58, 105.

1960 *Clypeaster campanulatus*, Roman, p. 78, pl. 3, fig. 3; pl. 4, figs. 1–1a.

2010 *Clypeaster campanulatus*, Pereira, p. 206, 207.

Material Four incomplete specimens (two were measured) (SUSGM 018-10-112), section 321 (E1), Wadi Tweirig, Sadat Formation, Early Miocene.

<i>L</i>	<i>W</i>	<i>H</i>	<i>Wpt</i> (IV)	<i>Wpt</i> (IV)/ <i>W</i>
–	100.4	51.0	27.9	0.28
–	100.5	44.0	25.0	0.25

Discussion *C. campanulatus* is easily distinguished from other *Clypeaster* species in this work by having higher test, wider petals with raised interporiferous zones, swollen and broad aboral surface, which begins to rise at the edge to form inflatable test.

Occurrence and age Early Miocene, Sadat Formation, Wadi Tweirig, section 321 (E1).

Geographic distribution *C. campanulatus* is recorded for the first time from Egypt. It is recorded from the Middle Miocene of France, Corsica, Spain, Sardinia and Turkey; Langhian to Serravallian of Hungary (Roman 1960, p. 79). Cottreau (1913, p. 57) adds a number of areas, including in Asia, Cilicia (southern (Mediterranean) coast of Turkey), and Syria. Miocene of Portugal (Pereira 2010).

Clypeaster fakhryi Gauthier 1901.

(Pl. 3, figs. 5–5b).

1901 *Clypeaster fakhryi* Gauthier in Fourtau, p. 99, pl. 5, figs. 1–3.

1913 *Clypeaster fakhryi*, Cottreau, p. 58.

1920 *Clypeaster fakhryi*, Fourtau, p. 49, pl. 8, fig. 2.

2003 *Clypeaster fakhryi*, Elattaar, p. 218, pl. 3, figs. 5–7; text—fig. 5c.

Material Three incomplete specimens (SUSGM 018-10-113), section 301 (E8), Hommath Formation, Wadi Hommath, Early Miocene.

Discussion *C. fakhryi* is characterized by low and thin test with thin margin, nearly flush petals and well developed food grooves. Our specimen photographed in Fig. 5b, Pl. 3 shows an exaggerated thickness because the specimen,

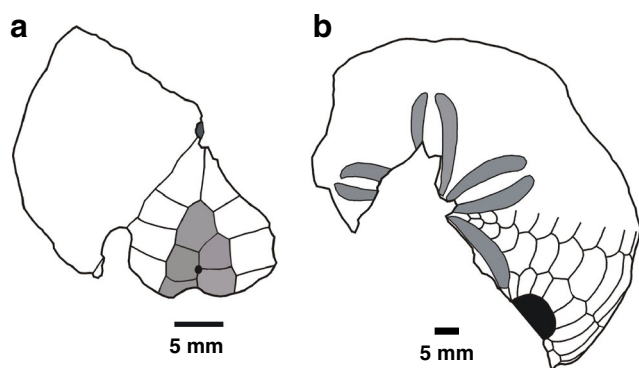


Fig. 5 Plate pattern of oral side of *Echinodiscus desori* Duncan and Sladen of Pl. 5, fig. 5a (a) and aboral side of *Amphiope bioculata* (des Moulins) of Pl. 5, fig. 2 (b)

exposed to deformation and sediment distortion, became wrapped. It slightly resembles *C. martini* des Moulins 1837, in Fourtau (1920, p. 52, pl. 8, fig. 3; pl. 9, fig. 1) from the Middle Miocene of Marsa Matrouh, Western Desert, Egypt, but differs in having thinner test and thinner margin, less indented margin in interambulacrum 1 and 4, more developed food grooves, and longer petals than in Fourtau (1920, pl. 8, figs. 3, 3a).

Occurrence and age Early Miocene, Hommath Formation, Wadi Hommath, section 301 (E8). Early Miocene of Sadat Formation, Sadat area, from beds equivalent to (E1) of section 321, Wadi Tweiwig (Elattaar 2003).

Geographic distribution *C. fakhryi* is endemic to Egypt. It is originally described from Miocene (Langhian-Serravallian) of Gebel Geneifa (Fourtau 1901, p. 100 and 1920, p. 49); Early-Middle Miocene of the Eastern Desert (Ali 1984, p. 163).

Clypeaster cf. *martini* des Moulins 1837. (Pl. 3, figs. 6–6b).

Material Two specimens were measured (SUSGM 018-10-114), section 300 (E5, E6), Hommath Formation, Wadi Hommath, Early Miocene.

L	W	H	W/L	H/L	Lpt			a	a/L
					I	II	III		
114.0	101.5	25.5	0.89	0.22	39.5	36.5	40.0	60.0	0.53
117.0	103.5	27.5	0.88	0.23	42.5	37.5	41.0	62.0	0.53

Description Test subpentagonal, elongated and low; margin thicker anteriorly than posteriorly, petals raised oral surface nearly flush. Maximum width lies anterior to mid-length of test. Maximum height lies posterior to apical

disc on petals I, V. Petal III the longest and petals II, IV the shortest. Apical disc excentric anteriorly. Periproct circular and close to margin.

Discussion It is easily distinguished from *C. fakhryi* Gauthier 1901, in having higher and thicker test, more raised petals, different outline and more flattened oral surface, and from *C. campanulatus* (Schlotheim 1820) in having lower and thinner test, more flattened oral surface and different outline. Our specimens differ from *C. latirostris laganoides* Desio 1929, in (Cottreau 1913, p. 24, 143, pl. 8, figs. 3–5), from the Miocene of the Mediterranean Basin, by having thicker margin, wider and longer petals, different outline of test (subpentagonal outline, instead of rounded in Cottreau), and indented posterior end, instead of rounded in Cottreau. It differs also from *C. intermedius* des Moulins 1837, in Michelin 1861, p. 128, pl. 31 (from Lower Miocene (Burdigalian) of France) by having more elongated and lower test, and more anterior apical disc. It differs from *C. martinianus* des Moulins 1837, in Michelin (1861, p. 134, pl. 35, fig. 1) by having more elongated test, and more forward periproct. Our specimens closely resembling *C. martini* des Moulins 1837, in Fourtau 1920, p. 52, pl. 9, fig. 1) from the Middle Miocene of Marsa Matrouh, Western Desert, Egypt, but differs in having a slightly higher and more elongated test, and more indented test at interambulacrum 1, 4 and the posterior end, whereas it differs from figs. 3, 3a, pl. 8 in Fourtau (op. cit.) and (Elattaar 2003, p. 226, pl. 5, figs. 4–6) from the Early Miocene of Sadat area, Egypt in having longer petals, more indented test at interambulacrum 2, 4, and the posterior end of test.

Occurrence and age Early Miocene, Hommath Formation, Wadi Hommath, section 300 (E5, E6).

Clypeaster sp. Fourtau 1920 (Pl. 4, figs. 1–1b).

1920 *Clypeaster* sp. Fourtau, p. 58, pl. 11, figs. 2, 2a.

Material Single incomplete specimen (SUSGM 018-10-116), section 301 (E9), Hommath Formation, Wadi Hommath, Early Miocene.

Discussion *Clypeaster* sp. has low test, long petals; petal III the longest and II, IV the shortest.

Occurrence and age Early Miocene, Hommath Formation, Wadi Hommath, section 301 (E9).

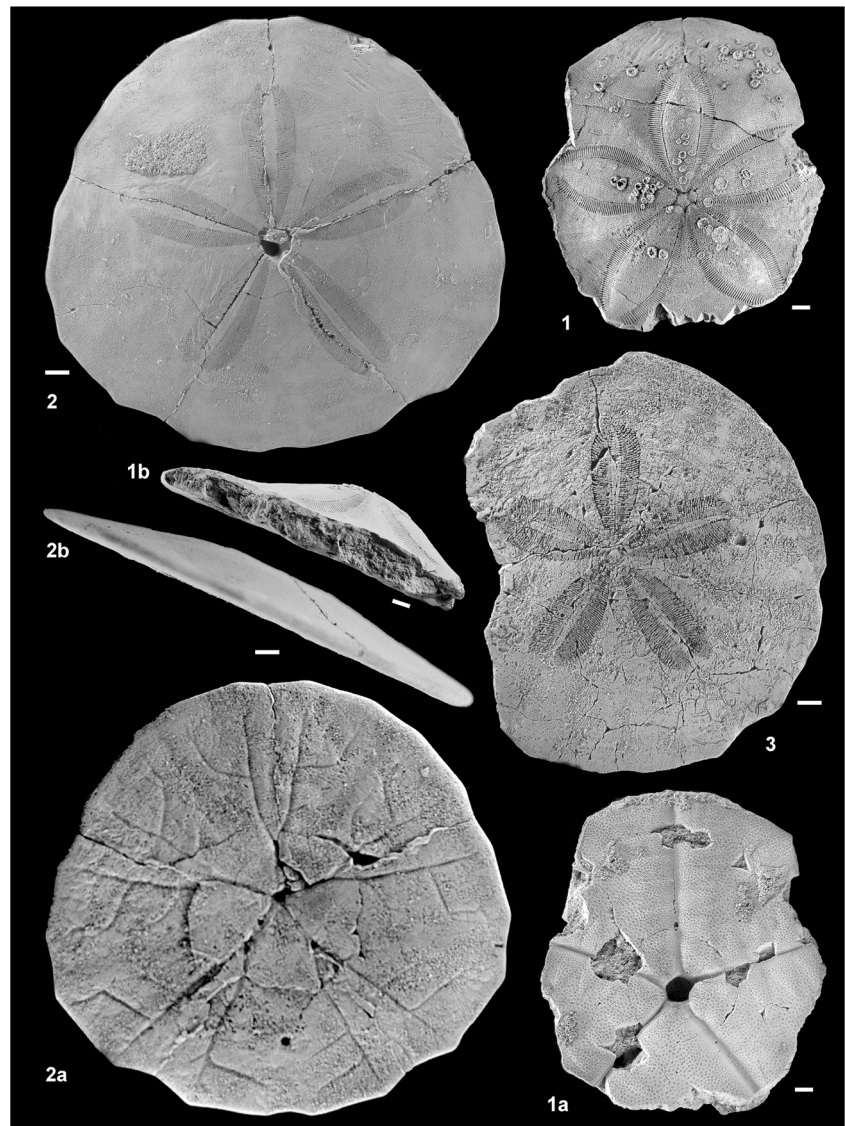
Geographic distribution *Clypeaster* sp. Fourtau 1920 was recorded from the Middle Miocene of Marsa Matrouh, Western Desert, Egypt (Fourtau 1920).

Suborder Scutellina Haeckel 1896.

Family Scutellidae Gray 1825.

Genus *Scutella* Lamarck 1816.

Plate 4 1–1b, *Clypeaster* sp. Fourtau 1920 (SUSGM 018-10-116); 1, 1a, 1b, aboral, oral and left side views; Early Miocene, Hommath Formation, section 301 (E9). 2–2b, *Scutella robecchibricchettii* Desio 1929 (SUSGM 018-10-117); 2, 2a, 2b, aboral, oral and right side views; Middle Miocene, Hommath Formation, section 299 (E12). 3, *S. checchiaie occidentalis* Desio 1934 (SUSGM 018-10-118); aboral view; Middle Miocene, Hommath Formation, section 299 (E11). Scale bar = 5 mm



Species *Scutella checchiaie* Desio 1929

Scutella checchiaie occidentalis Desio 1934

(Pl. 4, fig. 3).

1934 *Scutella Checchiaie* var. *occidentalis* Desio, p. 193, text—Fig. 8, pl. 17, fig. 1.

Material Four incomplete specimens (one was measured), section 301 (E8), Early Miocene (SUSGM 018-10-118/a), section 299; (E11, E12) (SUSGM 018-10-118), Middle Miocene, Hommath Formation, Wadi Hommath.

L	W	H	W/L	Lpt			a	a/L
				I	II	III		
94.0	2 × 45.5	–	0.97	25.0	24.7	26.2	47.0	0.50

Description Test subcircular, longer than wide, marginal outline indented at posterior ambulacral areas, narrowly indented at anterior one and at posterior interambulacrum 5, greatest width of test posterior to center. Petal III the longest and II, IV the shortest. Oral surface covered by sediments matrix. The dimensions of the specimen of Desio 1934 (Pl. 17, fig. 1 are $L = 111.5$ mm, $W = 99.5$ mm, $W/L = 0.89$) are matched with our specimens.

Discussion This species was recorded from the Miocene of Libya (Desio 1934) as a variety of *S. checchiaie* Desio 1929, p. 305, pl. 33, fig. 1, pl. 38, fig. 2. It is easily distinguished from the latter by having more elongated test, thinner anterior margin and periproct placed more forward than in specimens of Desio 1929.

Occurrence and age Early-Middle Miocene, Wadi Hommath, Hommath Formation. Section 301 (E8), Early Miocene and section 299 (E11, E12), Middle Miocene.

Geographic distribution *S. checchiaie occidentalis* is recorded from the Miocene of Libya (Desio 1934), and it is recorded here for the first time from Egypt.

Scutella robecchibricchettii Desio 1929

(Pl. 4, figs. 2–2b).

1929 *Scutella robecchi-bricchettii* Desio, p. 309, text—fig. 30, pl. 38, figs. 1a–b.

1934 *Scutella bricchettii*, Desio, p. 195.

2015 *Scutella robecchibricchettii*, Kroh (World Echinoidea Database).

Material Ten specimens (five were measured) (SUSGM 018-10-117), section 299 (E12), Middle Miocene, Wadi Hommath, Hommath Formation.

L	W	H	W/L	W/H	Lpt			a	a/L
					I	II	III		
89.0	94.5	–	1.06	–	32.0	30.0	33.0	46.0	0.52
96.0	103.0	9.5	1.07	0.10	–	–	–	–	–
97.0	109.0	9.3	1.12	0.10	32.0	31.5	32.0	49.5	0.51
102.5	110.0	11.0	1.08	0.11	35.0	34.5	35.5	52.5	0.51
125.0	130.0	14.5	1.04	0.12	42.0	41.0	45.0	63.5	0.51

Description Test subcircular, wider than long, marginal outline indented at posterior ambulacral areas, narrowly indented at anterior one, greatest width of test lies posterior to center. Petal III the longest and II, IV the shortest. Peristome circular, centrally located, narrow (3 mm width, 3.3% of test Length), periproct circular, narrow (2 mm width), lies at 16.5 mm from the posterior margin (L1 33% to radius and L1 16% of test Length), in specimen 103.5 mm length.

Discussion In our specimens, the ridges between the pore pairs of the poriferous zones carry one row of tubercles near and toward the apical disc, and two rows toward the extremities of petals. It differs from *S. sardica* Lambert 1907, p. 44, pl. 2, figs. 24, 25, from the Miocene of Sardinia in having wider test, longer petals, different manner of indentation in posterior margin, periproct lies at different distance from the posterior margin (L1 16% of L, while L1 13% of L in *S. sardica*). It is easily distinguished from *S. checchiaie occidentalis* Desio 1934, by having wider test than long, longer and wider petals, while in *S. checchiaie occidentalis* the test is longer than wide.

Our specimens have more forward periproct than in *S. ammonis* Fuchs 1883 (p. 48, pl. 14, figs. 1–4), and *S. rostrata* Fuchs 1883 (p. 48, pl. 17, figs. 4–6), *S. ammonis* var. *rostrata* Fuchs 1883 in (Fourtau 1920, p. 32, pl. 3, fig. 1), all from the Middle Miocene of Siwa and Gebel Geneifa, Egypt, and *S. paulensis* Agassiz 1841, p. 83, pl. 19, figs. 8–

10. Also, in our specimens, the periproct is placed closer to the posterior margin than in each of *S. paulensis* Agassiz 1841, in Cottreau (1913, p. 131, pl. 3, fig. 1a) from the Lower Burdigalian, France, *S. lovisatoi* Lambert 1907, p. 44, pl. 3, fig. 3; pl. 4, figs. 1, 2, from the Miocene, Sardinia, *S. deflersi* Gauthier in Fourtau 1901, p. 93, pl. 3, figs. 3–4, from the Middle Miocene, Eastern Desert, Egypt, *S. zitteli* Beyrich 1882, in Fourtau (1901, p. 94, pl. 3, figs. 1–2) from Miocene (Upper Burdigalian), Egypt, *S. stefaninii* Desio 1929, p. 307–309, fig. 29, pl. 40, figs. 3a–b, from Miocene of Libya, *S. forumjuliensis* Stefanini 1916, in Desio (1934, p. 193, fig. 9, pl. 17, fig. 2) from Early Miocene of Libya, *S. isidis* Fourtau 1919, in Fourtau (1920, p. 34, pl. 3, fig. 3) from Middle Miocene, Egypt, and *S. isidis* var. *bardiensis* Desio 1929, p. 304–305, pl. 39, figs. 1a–b, from the Middle Miocene, Libya. Accordingly, these species belongs to or must be transferred to genus *Parascutella*.

Occurrence and age Middle Miocene, Hommath Formation, Wadi Hommath, section 299 (E12).

Geographic distribution *S. robecchibricchettii* is recorded from the Miocene of Giarabub Oasis, Libya (Desio 1929, 1934); Middle Miocene (Helvetian) of Libya and Western Desert of Egypt (Ali 1984, p. 164).

Scutella melitensis Airaghi 1902.

(Pl. 5, figs. 1–1b).

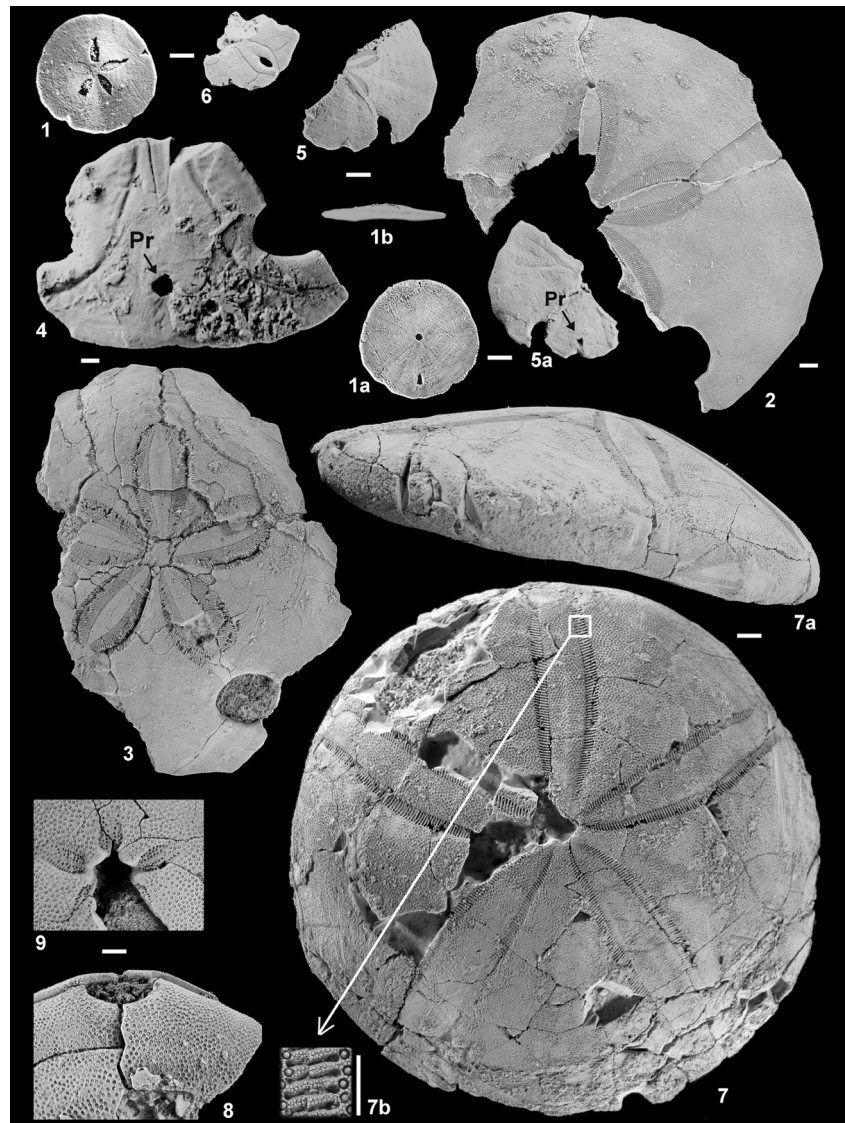
1913 *Scutella melitensis*, Cottreau, p. 53, 54, 87–89, pl. 4, figs. 7, 7a.

Material Seven complete specimens (four were measured) (SUSGM 018-10-119), section 301 (E9), Hommath Formation, Wadi Hommath, Early Miocene.

L	W	H	W/L	W/H	a	a/L
5.7	5.4	0.9	0.95	0.16	2.7	0.47
6.7	6.2	1.0	0.93	0.15	3.1	0.46
8.5	8.0	1.1	0.94	0.13	3.8	0.45
26.0	25.7	2.6	0.99	0.10	12.0	0.46

Description Test low, longer than wide, with thin margin and nearly flush to slightly concave oral surface, marginal outline indented at the posterior ambulacral areas and narrowly indented at anterior ones, greatest width of test lies posterior to center. Petals I, V the longest and II, IV the shortest; length of petals in a specimen 26 mm length (I or V = 5.8 mm, II or IV = 5.2 mm, III = 5.4 mm). Apical disc lies slightly anterior to the center of test (a = 46% L). Food grooves recognized only near and around peristome. Peristome narrow, circular and centrally located. Periproct circular, lies just 4 mm from posterior margin in

Plate 5 1–1b, *Scutella melitensis* Airagi 1902 (SUSGM 018-10-119); 1, 1a, 1b, aboral, oral and right side views (periproct is broken in fig. 1a); Early Miocene, Hommath Formation, section 301 (E9). 2–4, *Amphiope bioculata* (des Moulins 1835) (SUSGM 018-10-120); 2, 3 aboral views; 4, oral view of posterior part of test (combined periproct = Pr); Early Miocene, Hommath Formation, (2, 4 from section 300 (E5), and 3 from section 301 (E8)). 5–6, *Echinodiscus desori* Duncan and Sladen 1883 (SUSGM 018-10-121); 5, 5a, aboral and oral views (combined periproct = Pr); 6, oral view of left posterior part of test; Early Miocene, Hommath Formation, section 301 (E8). 7–9, *Echinolampas ampla* Fuchs 1883 (SUSGM 018-10-122); 7, 7a, aboral and right side views; 7b, enlarged poriferous zone (branch b) of petal III of 7. 8, oral view of posterior part of test (combined periproct). 9, oral view (combined peristome and phyllodes); Early Miocene, Hommath Formation, section 300 (E6). Scale bar = 5 mm



specimen 26 mm length, at distance from peristome (L1 31% of L2) and of total length of test (L1 15% of L).

Discussion Genus *Scutella* has a periproct closer to peristome than to posterior margin of test, whereas *Parascutella* has a periproct immediately adjacent to posterior end. The periproct of our specimens has a position in-between the two genera. *S. melitensis* Airaghi 1902 in Cottreau 1913 differs from *S. roquettei* de Loriol 1896, p. 13, pl. 3–3b, from the Miocene of Portugal in having longer test and circular periproct, instead of elongated longitudinally in latter and more forward periproct; periproct in *S. roquettei* placed closer to the posterior margin. It differs also from *S. hunteri* Fourtau in Pachundaki 1907, p. 24, pl. 2, figs. 3a, b, from the Middle Miocene of Marsa Matrouh, Egypt, in having longer test, shorter petals, and more backward position of periproct, while the periproct placed at mid-length between peristome and posterior margin in *S. hunteri*.

Occurrence and age Early Miocene, Hommath Formation, Wadi Hommath, section 301 (E9).

Geographic distribution *S. melitensis* is recorded for the first time from Egypt. It is recorded from Early Miocene (Aquitanian) of Gozo, Malta (Cottreau 1913).

Family Astriclypeidae Stefanini 1912.

Genus *Amphiope* L. Agassiz 1840.

Amphiope bioculata (des Moulins 1835).

(Pl. 5, figs. 2–4; text—Fig. 5b).

1841 *Amphiope bioculata*, L. Agassiz, p. 75, pl. 11, figs. 1–5.

1895 *Amphiope Lovisatoi*, Cotteau, p. 16, pl. 3, fig. 15.

1907 *Amphiope bioculata*, Lambert, p. 46.

1913 *Amphiope bioculata*, Cottreau, p. 135, text—fig. 23/4, pl. 5, figs. 1–8; pl. 6, figs. 1–12.

1934 *Amphiope bioculata*, Desio, p. 190, pl. 15, figs. 1a–b.

2003 *Amphiope bioculata*, Kroh and Nebelsick, p. 163, fig. 3b.

2010 *Amphiope bioculata*, Garilli et al., p. 91, text—fig. 3, pl. 1, figs. 1–6.

2010 *Amphiope bioculata*, Pereira, p. 208, fig. 1/i.

Material Four incomplete specimens (SUSGM 018-10-120), section 300 (E5) and section 301 (E7, E8), Hommath Formation, Wadi Hommath, Early Miocene.

Description Marginal outline indented broadly at the anterior ambulacral areas and narrowly at posterior interambulacrum 5, greatest width of test lies posterior to center; lunules large, closed, oval and slightly elongated transversely. Petal III the longest and II, IV the shortest; the ridges between pore pairs of the poriferous zones of petals carry one row of tubercles.

Discussion The lunules of *A. bioculata* are highly variable in shape in figures of Cottreau (1913), Desio (1934), Kroh and Nebelsick (2003), and Garilli et al. (2010); this reflects intra-specific variation in the shape of the lunules. Stara (2014), Stara and Borghi (2014), Stara and Fois (2014), and Stara and Sanciú (2014) provided a good revision on both genera *Amphiope* and *Echinodiscus* based on the plating pattern characteristics and morphological description of these genera and their related species. According to Stara and Sanciú (2014, p. 304, 306), “the sample of “*Amphiope bioculata*” (des Moulins 1835) described by Cottreau (1913) (Plate 7, Figs. 1–11) likely belongs to the genus *Amphiope* L. Agassiz 1840. However, it is not possible to attribute these specimens to *Amphiope bioculata*, since their plate structure was not reported by Cottreau (1913) and, on the other hand, the type species of *Amphiope bioculata* still needs defining. The plate pattern of our specimens is not exactly identical with those found and studied in Stara and Sanciú (2014), while they are morphologically similar to *Amphiope bioculata* (des Moulins 1835) described by Cottreau (1913).

Occurrence and age Early Miocene, Hommath Formation, Wadi Hommath, section 300 (E5) and section 301 (E7, E8).

Geographic distribution *A. bioculata* is recorded from the Miocene: (Aquitanian to Serravallian) of Spain, Corsica (France), Sardinia (Italy), Germany, and Austria (Cottreau 1913, p. 54, 188), Burdigalian to Serravallian of the eastern Mediterranean, Libya (Desio 1934), Miocene of Portugal (Pereira 2010), Early Miocene of Egypt (Kroh and Nebelsick 2003), Serravallian of Italy, late Burdigalian to early Serravallian of Austria and Hungary, Burdigalian of Iran, Burdigalian to Serravallian of Turkey and Middle-Upper? Miocene of Italy (Sicily) (Garilli et al. 2010).

Genus *Echinodiscus* Leske 1778.

Echinodiscus desori Duncan and Sladen 1883

(Pl. 5, figs. 5–6; text—Fig. 5a).

1883 *Echinodiscus desori*, Duncan and Sladen, p. 60, pl. 12, figs. 7–10.

1885 *Echinodiscus desori*, Duncan and Sladen, p. 328, pl. 51, figs. 1–6, 8.

1948 *Echinodiscus desori*, Mortensen, p. 414.

1972 *Echinodiscus desori*, Kier, p. 92, text—fig. 48, pl. 60, figs. 2–6; pl. 61, figs. 1, 2.

2014 *Echinodiscus desori*, Stara and Sanciú, p. 299, pl. 6, figs. 1–6; p. 306, 318.

Material Five incomplete specimens and several fragments (SUSGM 018-10-121), section 301 (E8), Hommath Formation, Wadi Hommath, Early Miocene.

Description In our materials, the lunules are closed in specimen and open due to breakage in others, greatest width of test posterior to center, petals I, V are the shortest, periproct lies just 3 mm from posterior margin, ambulacral food grooves bifurcating just outside basicoronal plates and commonly again near margin of test. There are two pairs of plates between the petal tip and the corresponding lunules on the aboral side. The lunule is surrounded by four couples of plates arranged in a linear manner. In the oral interambulacrum 5, there are only the post-basicoronal Pl. 2a, b and 3a, b, all of them large and paired; periproct opens between Pl. 2a/3b.

Discussion In genus *Amphiope*, the lunules are elongated transversely while they are elongated longitudinally in *Echinodiscus* (Durham 1966, U489). Kier (1972, p. 94) discussed the description of both genera *Amphiope* and *Echinodiscus*, and he noticed that considerable emphasis has been placed on the shape of the lunules. He noticed variability in the lunules of the Arabian species (*E. desori* Duncan and Sladen 1883); lunules are long and narrow in some specimens, wide in others, and in some, the lunules are notches opening posteriorly. Smith and Kroh (2011) stated that *Amphiope* have roundish-ovoid transverse lunules, while *Echinodiscus* have ovoidal axial lunules or notches. Stara and Sanciú (2014) produced a good revision on the plating pattern characteristics of the two genera which belong to the family Astriclypeidae Stefanini, 1912 (*Amphiope* L. Agassiz, 1840 and *Echinodiscus* Leske, 1778). They (op. cit.) proposed institution of two genera; *Sculpsitechinus* n. g. and *Paraamphiope* n. g., as a result of this, some species previously attributed to *Amphiope* and *Echinodiscus* are transferred into these two new genera, and two new species of Astriclypeidae are established; *Echinodiscus andamanensis* n. sp. and *Paraamphiope raimondii* n. sp. According to them, in the aboral face of *Echinodiscus*, there are one to two pairs of plates between the petal tip and the corresponding lunules, but the plates surrounding the lunules are arranged in a linear manner. Finally, they (op. cit.) found that the *Echinodiscus*

desori Duncan and Sladen 1883 belongs to genus *Echinodiscus*, these description is match with our specimens. *E. desori* differs from *E. ginauensis* Clegg 1933, in (Kier 1972, p. 91, pl. 66, figs. 4, 5) from Eocene-Oligocene? of Saudi Arabia, in having narrower and more elongated lunules, and shorter petals.

Occurrence and age Early Miocene, Hommath Formation, Wadi Hommath, section 301 (E8).

Geographic distribution *E. desori* is recorded here for the first time from Egypt. It is recorded from the Miocene of Asian region; Saudi Arabia, Pakistan and India (Duncan and Sladen 1883; Kier 1972).

Superorder Atelostomata Zittle 1879.

Order Cassiduloidea Claus 1880.

Family Echinolampadidae Gray 1851a.

Genus *Echinolampas* Gray 1825.

Echinolampas ampla Fuchs 1883

(Pl. 5, figs. 7–9).

1883 *Echinolampas amplus*, Fuchs, p. 45, pl. 9, figs. 5–8.

1899 *Echinolampas amplus*, Fourtau, p. 711.

1900 *Echinolampas amplus*, Fourtau, p. 59.

1907 *Echinolampas amplus*, Fourtau in Pachundaki, p. 25.

1913 *Echinolampas amplus*, Cottreau, p. 63, 109.

1920 *Echinolampas amplus*, Fourtau, p. 65.

1929 *Echinolampas amplus*, Desio, p. 331.

1984 *Echinolampas amplus*, Ali, p. 164.

2003 *Echinolampas ampla*, Kroh and Nebelsick, p. 163, fig. 3c.

Material Four incomplete specimens (one was measured), section 300 (E5, E6) (SUSGM 018–10–122), Early Miocene, and section 299 (E13), Middle Miocene, Wadi Hommath, Hommath Formation.

L	W	H	W/L	H/L	Lpt			a	a/L
					I	II	III		
112.5?	111.5	28.0	0.99	0.25	50	45	46	51.5	0.46

Discussion In *E. ampla*, the poriferous zones of all petals have equal branches (a and b), and the ridges between pore pairs carry one row of small tubercles toward the apical disc, and two rows toward the extremities of petals (Pl. 5, fig. 7b).

Occurrence and age Early–Middle Miocene. Early Miocene, section 300 (E5, E6), and Middle Miocene section 299 (E13). Wadi Hommath, Hommath Formation.

Geographic distribution *E. ampla* is recorded from the Middle Miocene of Algeria, Libya, and Tunisia (Fourtau 1899; Cottreau 1913; Desio 1929; Ali 1984); Early–Middle

Miocene of Eastern and Western Deserts of Egypt (Fuchs 1883; Fourtau 1899, 1900, 1920; Fourtau in Pachundaki 1907; Desio 1929; Ali 1984; Kroh and Nebelsick 2003).

Echinolampas deserticus Desio 1929

(Pl. 6, figs. 1–2a).

1929 *Echinolampas (Hypsoclypus) deserticus* Desio, p. 332, pl. 37, figs. 2a–b.

1984 *Echinolampas deserticus*, Ali, p. 164.

Material Ten specimens (two were measured) (SUSGM 018–10–123), section 301(E8, E9), Early Miocene, Wadi Hommath, Hommath Formation.

L	W	H	W/L	H/L	Lpt			a	a/L
					I	II	III		
86.0	84.0	–	0.98	–	42.5	39.5	37.0	38.0	0.44
103.0	99.5	43.5	0.97	0.42	56.5	47.5	45.5	45.5	0.44

Discussion In this species, the poriferous zones of petals (I, V, III) have equal branches (a, b), and unequal ones in petals (II, IV); whereas in *E. ampla*, the poriferous zones of all petals have equal branches, and the ridges between pore pairs of poriferous zones carry one row of small tubercles. It is easily distinguished from *E. ampla* in having a higher test, smoothly convex aboral surface and in lacking the second row of the small tubercles in the ridges between the pore pairs toward the extremities of petals.

Occurrence and age Early Miocene, Hommath Formation, Wadi Hommath, section 301 (E8, E9).

Geographic distribution *E. deserticus* is recorded from Miocene: (Burdigalian) of Giarabub Oasis, Libya (Desio 1929), (Burdigalian, Helvetian) of Libya and Early Miocene of Western Desert, Egypt (Ali 1984, p. 164).

Echinolampas cf. zeitensis Fourtau 1920

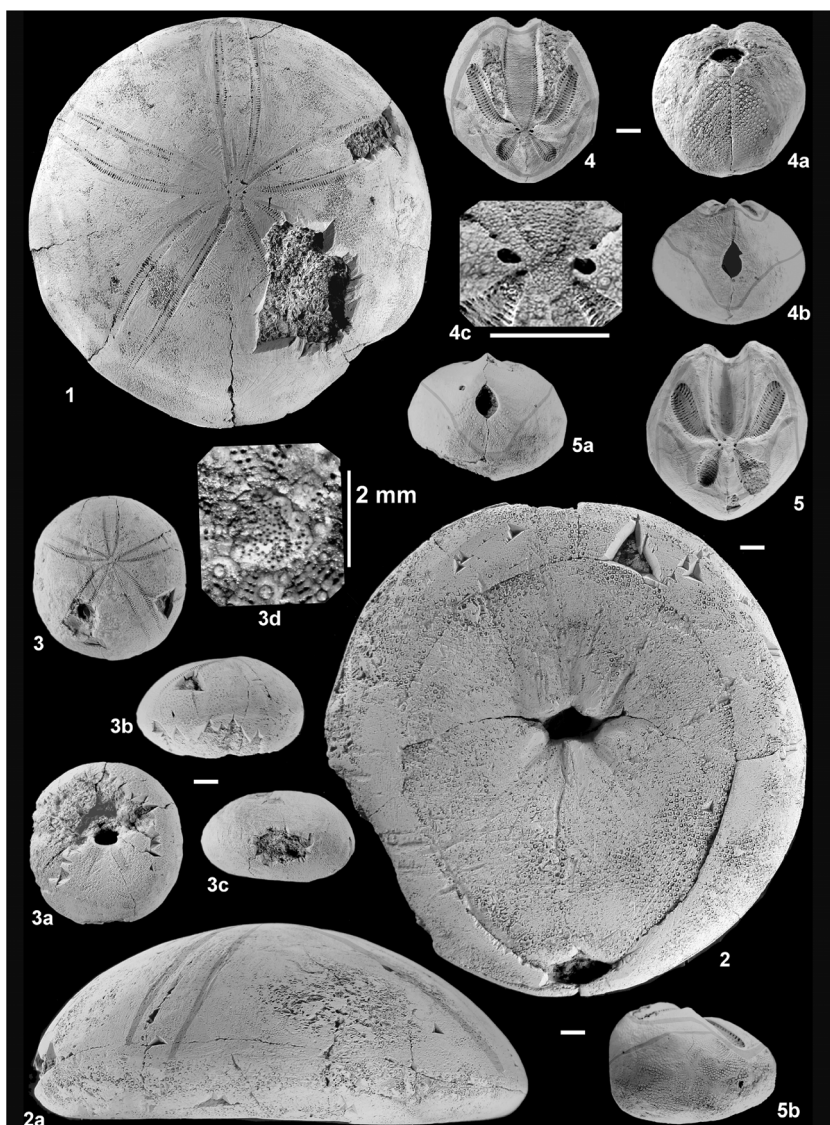
(Pl. 6, figs. 3–3d).

Material One specimen was measured (SUSGM 018–10–124), section 300 (E6), Early Miocene, Wadi Hommath, Hommath Formation.

L	W	H	W/L	H/L	a	a/L
34.5	31.5	18.5	0.91	0.54	15.0	0.44

Discussion In general appearance, our specimen appears somewhat similar to *E. zeitensis*, described from the Miocene (Burdigalian–Middle Miocene) of Gebel Zeit,

Plate 6 1–2a, *Echinolampas deserticus* Desio 1929 (SUSGM 018-10-123). 1, aboral view. 2, 2a, oral and left side views (inked poriferous zones); Early Miocene, Hommath Formation, section 301 (E8). 3–3d, *E. cf. zeitensis* Fourtau 1920 (SUSGM 018–10-124); 3, 3a, 3b, 3c, aboral, oral, right side and posterior views (periproct broken); 3d, enlarged apical disc of 3; Early Miocene, Hommath Formation, section 300 (E6). 4–5b, *Schizaster legraini* Gauthier 1900 (SUSGM 018-10-125) (inked fascioles, same size). 4, 4a, 4b, aboral, oral, and posterior views, 4c, enlarged apical disc of 4, 5, 5a, 5b, aboral, oral and right side views; Early Miocene, Hommath Formation, section 301 (E9). Scale bar = 5 mm unless otherwise shown



Eastern Desert, Egypt (Fourtau 1920, p. 71, pl. 10, figs. 3, 4) but differs in having slightly wider test, more smoothly rounded aboral surface and monobasal apical disc without any genital pores (see Pl. 6, fig. 3d in this work), instead of four genital pores in *E. zeitensis*. *E. zeitensis* Fourtau 1920 is endemic to Egypt.

Occurrence and age Early Miocene, Hommath Formation, Wadi Hommath, section 300 (E6).

Order Spatangoida Claus 1876.

Suborder Hemiasterina Fischer .1966

Family Schizasteridae Lambert 1905.

Genus *Schizaster* L. Agassiz 1836.

Schizaster eurynotus L. Agassiz 1840.

(Pl. 7, figs. 1–2).

1907 *Schizaster eurynotus*, Lambert, p. 67, pl. 5, figs. 6, 7.

1913 *Schizaster eurynotus*, Cottreau, p. 68, 114, text—fig. 29, pl. 14, figs. 1–6.

1920 *Schizaster eurynotus*, Fourtau, p. 78.

2003 *Schizaster eurynotus*, Kroh and Nebelsick, p. 167, fig. 5d.

2007b *Schizaster eurynotus*, Kroh, p. 190, figs. 3/r-s.

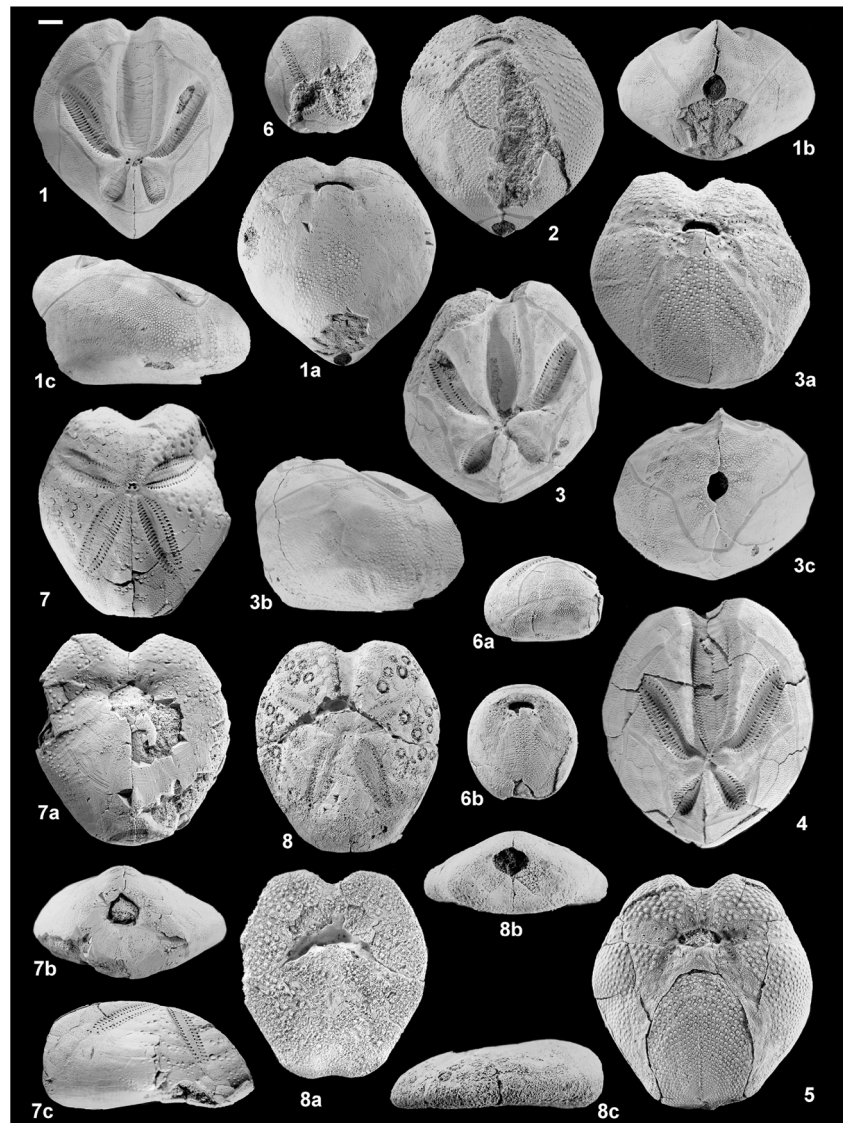
2010 *Schizaster eurynotus*, Pereira, p. 207, fig. 1 j.

2016 *Schizaster eurynotus*, Mancosu and Nebelsick, p. 149, fig. 8/A.

Material Two specimens were measured (SUSGM 018-10-127), section 321 (E1), Wadi Tweirig, Sadat Formation, Early Miocene.

L	W	H	W/L	H/L	Lpt			a	a/L
					I	II	I/II		
46.8	41.8	27.3	0.89	0.58	–	–	–	30.0	0.64
49.0	45.3	29.0	0.92	0.59	9.5	19.5	0.49	31.0	0.63

Plate 7 1–2, *Schizaster eurynotus* Agassiz 1840 (SUSGM 018-10-127); 1, 1 a, 1b, 1c, aboral, oral, posterior and right side views. 2, oral view. (1a, 2 oral views, tilted forward) (inked fascioles, same size); Early Miocene, Sadat Formation, Wadi Tweirig, section 321 (E1). 3–5, *S. lovisatoi* Cotteau 1895 (SUSGM 018-10-128); 3, 3a, 3b, 3c, aboral, oral, right side, and posterior views. 4, aboral view (inked fascioles, same size). 5, oral view; Early Miocene, Hommath Formation, section 301 (E8). 6–6b, *Agassizia (Agassizia) powersi* Kier 1972 (SUSGM 018-10-129); 6, 6a, 6b, aboral, left side, and oral views (inked fascioles, same size); Middle Miocene, Hommath Formation, section 299 (E11). 7–7c, *Spatangus (Spatangus) sp.* (SUSGM 018-10-130); 7, 7a, 7b, 7c, aboral, oral, posterior and right side views; Early Miocene, Sadat Formation, Wadi Tweirig, section 321 (E1). 8–8c, *Hemipatagus ocellatus* (Defrance 1827) (SUSGM 018-10-131); 8, 8a, 8b, 8c, aboral, oral, posterior and left side views; Middle Miocene, Hommath Formation, section 299 (E11). Scale bar = 5 mm



Discussion Our specimens have four large, circular genital pores in the apical disc, arranged in trapezoid shape; the two anterior pores are smaller. They differ from *S. scillae* (des Moulins 1837) in de Loriol (1896, p. 43, pl. 12, figs. 3–4) from the Miocene of Portugal in having a wider anterior end, wider anterior groove of ambulacrum III, wider anterior and posterior paired petals, wider apical disc, and different shape of both peripetalous and lateroanal fascioles. Also, it is easily distinguished from most of the fossil species of genus *Schizaster* by its more oblique backward posterior truncation. Apical disc of this species has two genital pores according to Lambert (1907, p. 68), two, three, or four according to Cottreau (1913), and four according to Fourtau (1920, p. 79). These differences in number of genital pores in apical disc of this species may reflect intra-specific variation. Hence, the development of the apical disc through growth of this species needs more study in the future.

Occurrence and age Early Miocene, Wadi Tweirig, Sadat Formation, section 321 (E1).

Geographic distribution *S. eurynotus* is recorded from the Miocene of Sardinia, Italy (Helvetian, Langhian by Lambert 1907, and Early Miocene by Mancosu and Nebelsick 2016). Miocene of Portugal, Spain, Corsica (France), Sardinia (Italy), Malta, Switzerland, Austria, Greece and Asia (Armenia) (Cottreau 1913; Ali 1984; Pereira 2010). Middle Miocene of Marsa Matrouh, Egypt (Fourtau 1920).

Schizaster legraini Gauthier 1900.

(Pl. 6, figs. 4–5b).

1900 *Schizaster legraini*, Gauthier in Fourtau, p. 60, pl. 3, figs. 9, 10.

1913 *Schizaster legraini*, Cottreau, p. 68.

1920 *Schizaster legraini*, Fourtau, p. 79, pl. 5, fig. 2.

1929 *Schizaster legraini*, Desio, p. 335, pl. 40, figs. 4a, b.

2003 *Schizaster (Paraster) legraini*, Elattaar, p. 234, text—fig. 7a; pl. 10, figs. 1–6.

Material Fifteen specimens (four were measured), section 321 (E3), Hommath Formation, Wadi Tweirig (SUSGM 018-10-126), section 301 (E9) (SUSGM 018-10-125), Hommath Formation. Early Miocene.

L	W	H	W/L	W/H	Lpt			Npp			a	a/L
					I	II	I/II	I	II	I/II		
32.3	30.0	22.5	0.93	0.70	6.6	12.3	0.54	17	27	0.63	19.0	0.59
35.0	33.2	24.0	0.95	0.69	6.8	13.2	0.52	19	30	0.63	21.0	0.60
36.0	33.3	27.3	0.93	0.76	6.8	13.3	0.51	20	31	0.65	22.0	0.61
37.2	35.5	27.0	0.95	0.73	6.9	–	–	–	–	–	24.5	0.66

Description Our specimens are characterized by wide and deep groove in ambulacrum III, vertical posterior truncation and wider apical disc than long, with two large oval genital pores.

Discussion Apical disc of our specimens has two large oval genital pores, whereas there are four large, circular genital pores in material collected by Elattaar (2003) from the Early Miocene, Sadat Formation, Sadat area, north Wadi Tweirig. This indicates that this species has two or four genital pores in its apical disc. Fourtau (1920, p. 80) mentioned that the *S. legraini* is similar to *S. sardiniensis* Cotteau 1895 from the Miocene of northern Sardinia. Our specimens differs from the latter species in (Lambert 1907, p. 71, pl. 4, figs. 8–10) from the Miocene of Sardinia by having higher and wider test, wider and more elongated anterior paired petals, more deeper and wider ambulacrum III, deeper anterior sinus, and wider apical disc.

Occurrence and age Early Miocene. Wadi Tweirig, section 321 (E2), Sadat Formation, and (E3), Hommath Formation, and Wadi Hommath, section 301 (E9), Hommath Formation. Early Miocene, Sadat Formation, Sadat area, north Wadi Tweirig, from beds equivalent to (E2) of section 321 (Elattaar 2003).

Geographic distribution *S. legraini* is recorded from Early-Middle Miocene of Libya (Desio 1929), Sardinia (Cottreau 1913), Burdigalian-Helvetian of several Mediterranean regions; Spain, Corsica, Sardinia, Malta, Libya, Algeria (Ali 1984, p. 165). It is recorded also from the Miocene of Egypt: Langhian-Serravallian of Gebel Ramlich, Sadat area (Fourtau 1900), Middle Miocene, Marsa Matrouh, Western Desert (Fourtau 1920; Ali 1984, p. 165).

Schizaster lovisatoi Cotteau 1895

(Pl. 7, figs. 3–5).

1895 *Schizaster lovisatoi* Cotteau, p. 45, pl. 5, figs. 9, 10.

1907 *Schizaster calceolus* Lambert, p. 69, pl. 5, fig. 8.

1913 *Schizaster lovisatoi*, Cottreau, p. 118, text—fig. 32, pl. 13, figs. 2–7.

Material Six specimens (three were measured), section 301 (E8) (SUSGM 018-10-128), Hommath Formation, Early Miocene.

L	W	H	W/L	H/L	Lpt			Npp			a	a/L
					I	II	I/II	I	II	I/II		
34.0	30.0	25.0	0.88	0.74	6.4	12.8	0.50	18	32	0.56	20.4	0.60
45.0	41.2	32.5	0.92	0.72	9.0	17.2	0.52	21	36	0.58	28.0	0.62
46.5	42.0	–	0.90	–	10.0	18.5	0.54	21	36	0.58	29.5	0.63

Discussion *S. lovisatoi* has two genital pores in its apical disc in this study. It differs from *S. legraini* described here in having deeper and narrower frontal sinus, smaller periproct, more oblique backward posterior truncation and a greater number of pore pairs in posterior petals relative to anterior ones (Npp: I/II = 0.56–0.58, instead of 0.63–0.65 in *S. legraini*). It differs from *S. eurynotus* Agassiz 1840, in having a higher test, wider posterior end, less oblique backward posterior truncation, smaller periproct, and different shape of peripetalous fasciole on interambulacral 2, 4 (see Pl. 7, figs. 1, 3, 4).

Occurrence and age Early Miocene, Hommath Formation, Wadi Hommath, section 301 (E8).

Geographic distribution It is recorded for the first time from Egypt. It is recorded also from Langhian, Italy (Cotteau 1895), = *S. calceolus* from Burdigalian-Helvetian of Sardinia (Lambert 1907), Burdigalian of France and Spain, Langhian of Sardinia (Cottreau 1913, p. 118, 119).

Genus *Agassizia* Valenciennes 1846.

Subgenus *Agassizia (Agassizia)* Valenciennes 1846.

Agassizia (Agassizia) powersi Kier 1972

(Pl. 7, figs. 6–6b).

1972 *Agassizia (Agassizia) powersi* Kier, p. 97, pl. 64, figs. 1–8; pl. 65, figs. 1, 2.

Material Six specimens (three were measured), section 301 (E9) (SUSGM 018-10-129/a), Early Miocene, section 299 (E11) (SUSGM 018-10-129), Middle Miocene, Wadi Hommath, Hommath Formation.

L	W	H	W/L	H/L	a	a/L
18.9	17.6	14.1	0.93	0.75	12.3	0.53

23.3	21.4	17.0	0.92	0.73	10.5	0.56
24.5	23.0	17.7	0.94	0.72	14.5	0.57

Description Test of small size, globular, wider than height. Maximum height slightly posterior of center. Aboral surface strongly convex and swollen, both peripetalous and lateroanal fascioles are present; peripetalous fasciole indented opposite petals (II, IV), and passing anteriorly down ambitus. Anterior ambulacrum (III) nonpetaloid, weakly sunken becoming flush at ambitus. Anterior paired petals (II, IV) long, almost not reaching to the ambitus, slightly sunken and slightly curved backward; posterior poriferous zone with subequal pyriform and large pore pairs, whereas the anterior poriferous zones composed of minute pore pairs aborally, gradually decreasing in size to mid length of petal. Peristome with reniform shape and anteriorly situated.

Discussion *A. (Agassizia) powersi* Kier 1972 is characterized by anterior paired petals (II, IV) with anterior poriferous zones composed of minute pore pairs aborally, gradually decreasing in size to mid length of petals, while *A. (Anisaster) arabica* Kier 1972, p. 96, pl. 65, figs. 3–8, pl. 66, figs. 1–3, and *A. arabica* Kier 1972, in Kroh et al. 2011, p. 431, text—fig. 9 is characterized by having anterior poriferous zones of the anterior paired petals with minute pore pairs aborally, gradually increasing in size distally until they reach about the same size as those of the posterior poriferous zones in the distal half of the petals, more elongated test and more anterior apical disc. It is distinguished from *A. zitteli* Fuchs 1883, p. 44, pl. 6, figs. 5–8, from the Miocene of Egypt by having wider and higher test and more anterior apical disc. According to Kier (1972), *A. (Agassizia) powersi* is easily distinguished from most of the fossil species of genus *Agassizia* by its more anterior apical disc.

Occurrence and age Early–Middle Miocene. Early Miocene, section 301 (E9) and Middle Miocene, section 299 (E11). Wadi Hommath, Hommath Formation.

Geographic distribution It is recorded for the first time from Egypt. It is recorded also from the Miocene of Asia; Saudi Arabia (Kier 1972) and Early Miocene Mishan Formation of Iran (Kroh et al. 2011).

Suborder Micrasterina Fischer 1966

Family Brissidae Gray 1855.

Genus *Brissopsis* L. Agassiz 1840.

Brissopsis fraasi Fuchs 1883

(Pl. 3, figs. 7–7c).

1883 *Brissopsis Fraasii* Fuchs, p. 43, pl. 17, figs. 4, 5.

1899 *Brissopsis Fraasi*, Fourtau, p. 714.

1901 *Brissopsis Fraasi*, Fourtau, p. 106, pl. 3, figs. 5, 6.

1920 *Brissopsis crescenticus*, Wright, var. *Fraasi*, Fourtau, p. 74.

2003 *Brissopsis fraasi*, Elattaar, p. 237, pl. 11, figs. 1–12; text—fig. 7b.

Material Five specimens (three were measured), section 321 (E1), Sadat Formation (SUSGM 018-10-115), and (E3), Hommath Formation (SUSGM 018-10-115/a), Wadi Tweirig, Early Miocene.

L	W	H	W/L	H/L	Lpt			Npp			a	a/L
					I	II	I/II	I	II	I/II		
19.0	17.3	11.7	0.91	0.62	4.6	5.4	0.85	14	17	0.82	8.9	0.47
21.2	19.5	14.0	0.92	0.66	4.8	5.7	0.84	14	17	0.82	10.0	0.47
25.0	22.0	16.0	0.88	0.64	5.7	6.8	0.84	15	18	0.83	12.0	0.48

Discussion Elattaar (2003) recorded 32 specimens of *B. fraasi* from the Sadat Formation, Sadat area, north Wadi Tweirig. He wrote: “There are two forms of *B. fraasi*; Form A is different from Form B in having a larger size, more depressed petals, sunken marginal outline at interambulacral areas, larger periproct, more raised interambulacral areas aborally and curved to sunken posterior truncation.” I think that there is gradually change in the shape of the test, occur throughout growth, this explains why there is a difference in the shape of test between the small and large specimens. Fourtau (1899, 1901) identified *B. fraasi* as a separate species. *B. fraasi* differs from *B. crescentica* in Mancosu and Nebelsick (2016, p. 149, 152, fig. 8/B) by having shorter and wider test, wider ambulacrum III, and slightly longer petals.

Occurrence and age Early Miocene, Wadi Tweirig, section 321 (E1), Sadat Formation and (E3), Hommath Formation.

Geographic distribution *B. fraasi* is endemic to Egypt. It is recorded from Miocene of Egypt: Helvetian, Gebel Geneifa (Fuchs 1883; Fourtau 1899); and from the study area: (upper Burdigalian), Gebel Ramiya, (Fourtau 1901); (Burdigalian–Middle Miocene), Wadi Hagul, south Gebel Ataqa, and Gebel Tanka, Wadi Withr, Abou Zenima area, Sinai (Fourtau 1920); and from Early Miocene, Sadat Formation, Sadat area, north Wadi Tweirig (Elattaar 2003), Western Desert of Egypt (Ali 1984, p. 165).

Family Spatangidae Gray 1825.

Genus *Spatangus* Gray 1825.

Spatangus (Spatangus) sp.

(Pl. 7, figs. 7–7c).

Material One complete specimen was measured (SUSGM 018-10-130), section 321 (E1), Sadat Formation, Wadi Tweirig, Early Miocene.

L	W	H	W/L	H/L	Lpt			Npp			a	a/L
					I	II	I/II	I	II	I/II		
41.6	38.0	22.5	0.91	0.54	17.5	15.9	1.10	27	23	1.17	17.0	0.41

Description Test heart-shaped, domed aboral surface, wide anterior end, and deep frontal groove at ambitus; becoming shallower to flat near apical disc. Apical disc ethmolytic and has four gonopores. Posterior end narrow and truncated vertically to slightly oblique forward. Periproct rounded, slightly wider than long with acute upper end. Primary tubercles are arranged in rows aborally, on all interambulacral areas (in first and second series of plates) and slightly smaller on interambulacrum 5. Peristome wider than long. Plastron region is eroded. Subanal fasciole well developed and bilobed.

Discussion Two species belonging to genus *Spatangus* were recorded from the Miocene of Corsica: *S. simplex* Agassiz 1847, and *S. corsecus* Agassiz and Desor 1847, both in (Cotteau 1877, p. 331, pl. 16, figs. 1–3, and p. 333, pl. 16, figs. 4–7, respectively). Our specimen differs from the first species in having a lower and wider test and different outline, and from the second in having a narrower and higher test, vertical posterior truncation, instead of oblique backward in *S. corsecus*. It differs from *S. delphinus* Defrance 1827 in (Stara et al. 2012, p. 32, pl. 1, figs. 1a, b; 2a, b c) in having narrower test, smoothly convex aboral surface, less divergent anterior paired petals, more posteriorly apical disc and different shape of posterior end. It differs also from *S. subconicus* Mazzetti 1881, *S. destefanii* Stefanini 1908, and *S. fabianii* Lambert 1924, all in (Borghini 2012, p. 51–52, pl. 1–4, and figs. 5, 6) in having different shape and elongation of test, depth and width of anterior groove, width of anterior end of test, convexity of aboral surface and position of apical disc.

Occurrence and age Early Miocene, Wadi Tweirig, Sadat Formation, section 321 (E1).

Family Loveniidae Lambert 1905.

Genus *Hemipatagus* Desor 1858 in Kroh 2007a

Hemipatagus ocellatus (Defrance 1827).

(Pl. 7, figs. 8–8c).

2005 *Hemipatagus ocellatus*, Kroh, p.191–194, Fig. 94, pl. 81, figs 1–4, pl. 82, figs 1–2.

2007a *Hemipatagus ocellatus*, Kroh, p. 163–192, pl. 1, figs. 11–14, fig.2/b, fig. 3/b, pl. 3, figs 5, 7.

2010 *Hemipatagus ocellatus*, Pereira, p. 207.

Material Seven fragments and broken specimens (one was measured), section 321 (E3), Wadi Tweirig, and section 301 (E8), Wadi Hommath (SUSGM 018-10-131/a), Early Miocene, section 299 (E11) (SUSGM 018-10-131), Middle Miocene, Wadi Hommath, Hommath Formation.

L	W	H	W/L	H/L	Lpt			a	a/L
					I	II	I/II		
44.0	39.3	15.3	0.89	0.35	15.7	15.3	1.03	21.0	0.48

Description Test ovate and low, with highest point posteriorly on interambulacrum 5. Scattered coarse primary tubercles occur on aboral surface on all interambulacral areas, except 5; they occur only on the posterior series of plates of interambulacral 2, 4. Periproct elongated transversally and lies high on vertical truncated and slightly concave posterior end. Test eroded posteriorly, so that subanal fasciole is invisible. It is without a peripetalous fasciole.

Discussion de Loriol (1880, p. 85, pl. 11, fig. 5) described *Euspatangus tuberosus* Fraas 1867, from Wadi El-Tih, Egypt. Fourtau (1901, p. 111, text—fig. 5, pl. 6, fig. 4; 1920, p. 86, pl. 11, figs. 3, 4) identified *Sarsella tuberosa* (Fraas 1867) and *Maretia tuberosa* (Fraas 1867), respectively from the Miocene (Burdigalian) of Gebel Geneifa, Egypt. The last author relied on a fragment or incomplete specimens, which casts doubt on the characters of this species. Kroh (2007a, p. 191) wrote on *Euspatangus tuberosus* Fraas 1867, and in de Loriol 1880 “Doubtful; the holotype is a fragment of the aboral side preserving a petal (I, or more likely IV) and the adjoining interambulacra which bear camelate tubercles; currently impossible to decide whether it is a *Lovenia*, *Hemipatagus* or something else.” Kroh (op. cit.) treated genus *Hemipatagus* as a subjective synonym of the extant genus *Maretia*. According to him, *Hemipatagus* is not close to *Maretia*, but it is closely related to *Lovenia* and should be placed in the Loveniidae. According to the summary of the differential diagnostic features and taxonomic revision of *Hemipatagus* and morphologically similar genera (*Lovenia*, *Breynia*, *Maretia*, and *Eupatagus*), which were produced by him (p. 169, Table 1), our specimens should be placed in genus *Hemipatagus*. Our specimens of *Hemipatagus* differs from that found in Mancosu and Nebelsick (2017, p. 341, fig. 5/D) by having more elongated test, more elongated anterior paired petals, narrower anterior sinus, greater number of tubercles in the interambulacral 1 and 4 (nine tubercles, instead of seven in Mancosu and Nebelsick form). Our specimen (measured and photographed here) is similar to that found in Kroh (2007a, p. 165, pl. 1, figs. 11–14) in all characters, except it is smaller in size and possess less number of tubercles

in interambulacral 1, 2, 3, 4. These differences in number of tubercles in the interambulacral areas could be size/age related. Specimens of Kroh (op. cit.) have length up to 60 mm, whereas, our specimen has length 44 mm. The difference in test height could easily be an effect of sediment compaction and distortion of the specimens.

Occurrence and age Early-Middle Miocene. Early Miocene, Wadi Tweirig, section 321 (E3), and Wadi Hommath, section 301 (E8), Hommath Formation. Middle Miocene, Hommath Formation, Wadi Hommath, section 299 (E11).

Geographic distribution Early Miocene; Late Early Burdigalian of Austria, and Burdigalian of France and Switzerland (Kroh and Menkveld-Gfeller 2006; Kroh 2007a). Miocene of Portugal (Pereira 2010).

Summary and conclusions

Twenty-eight echinoid species (eight regular and 20 irregular) have been collected from Lower-Middle Miocene rocks exposed in the Sadat area; they have been identified, systematically described and illustrated in this work. Eleven species are recorded for the first time from Egypt. Ten of them came from the Hommath Formation (*Schizechinus* cf. *serresii* (Desor 1856), *Schizechinus pentagonus* Kier 1972, *Clypeaster* cf. *martini* des Moulins 1837, *Scutella checchiaie occidentalis* Desio 1934, *Scutella melitensis* Airaghi 1902, *Echinodiscus desori* Duncan and Sladen 1883, *Echinolampas* cf. *zeitensis* Fourtau 1920, *Schizaster lovisatoi* Cotteau 1895, *Agassizia* (*Agassizia*) *powersi* Kier 1972, and *Hemipatagus ocellatus* (Defrance 1827)), and one from the Sadat Formation (*Clypeaster campanulatus* (Schlotheim 1820)).

The paleogeographic distribution of the studied echinoid fauna showed that (1) six species are endemic to Egypt (*Brochopleurus fourtaui* (Lambert in Pachundaki 1907), *Pseudarbacina fraasi* (Gauthier 1901), *Psammechinus fuchsi* Gauthier 1901, *Echinoneus artini* Gauthier 1899, *Clypeaster fakhryi* Gauthier 1901, *Brissopsis fraasi* Fuchs 1883 (Table 1)); (2) 15 species are reported outside of Egypt, 11 of them from the Mediterranean Region only (Table 1, species nos. 1, 6, 10, 14–17, 22, 23, 25, 28), three of them from Indo-Pacific Region only (Table 1, species nos. 12, 24, 27) (Saudi Arabia, Iran, and India and Pakistan), and one of them *Amphiope bioculata* (des Moulins 1835) is known in both of the two regions (Mediterranean and Indo-Pacific).

The paleobiogeographic distribution of the identified echinoid species in the studied area indicates strong affinity to the Mediterranean Region. Among 25 species recorded from the Middle Miocene of Egypt, only two species (*Schizechinus pentagonus* Kier 1972 and *Agassizia* (*Agassizia*) *powersi* Kier 1972) are known from the Early Miocene of Indo-

Pacific Region. This suggests the possibility that there is no connection between the Mediterranean and Indo-Pacific Regions during the Middle Miocene.

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