



## ***Stephanodiscus* Ehr. species from Holocene sediments in the Faiyum Depression (Middle Egypt)**

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### **Abstract**

Lake Qarun in the Egyptian Faiyum Depression is the shrunken remnant of a much larger lake. To investigate the sedimentary history of the former lake, several continuous lacustrine sediment cores were collected from now terrestrial locations within the basin. The suitability of these sediments for reconstructing past environmental changes was first assessed by describing the gross stratigraphies of three core sequences and secondly by evaluating taxonomic issues concerning sedimentary diatom species within the genus, *Stephanodiscus* Ehr. The stratigraphic descriptions show basal sections comprised of either coarse sand or weathered Eocene limestone overlain by lacustrine sediments. Lower sections of the lacustrine sediments are diatom marls, and, in the two lakeside cores, these are laminated. These sections indicate that the lake initially formed by rapid in filling to a considerable depth with freshwater and the diatom-rich marls containing abundant *Stephanodiscus* and *Aulacoseira* Thwaites species. A new species and variety of *Stephanodiscus*, *S. neoaegypticus* and *S. neoaegypticus* var. *fekrii*, are described from the marl section in one core. Another species, *S. galileenis* Håkansson & Erhlich, was also present and is re-evaluated with reference to the published description. The importance of establishing a sound taxonomic foundation for palaeolimnological studies of Lake Qarun is stressed.

### **Introduction**

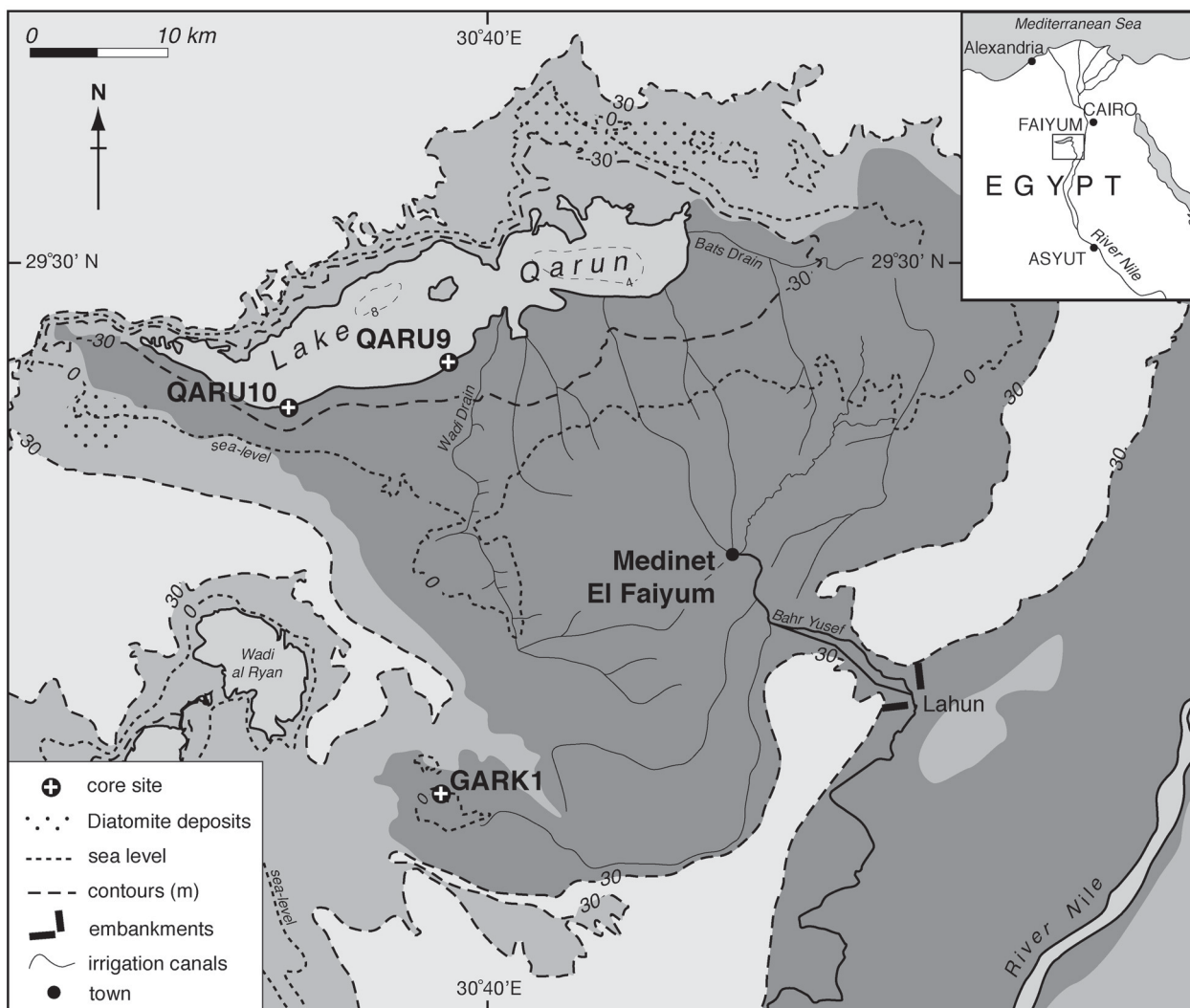
Egypt possesses few natural inland lakes but modern day Lake Qarun in the Faiyum Depression is the remnant of a much larger early Holocene lake (Caton-Thompson & Gardner 1934, Hassan 1986). Consequently, exploring sedimentary diatom records in Lake Qarun sediments can potentially help understand the environmental history of the lake. However, issues of sediment formation and dating, diatom preservation and diatom taxonomy all require careful evaluation before palaeolimnological information can be fully exploited (e.g. Flower *et al.* 2006). Previous work has described terrestrial diatomite exposures north-east of modern Lake Qarun (Aleem 1958) and later Przbylowska-Lang (1976) showed benthic diatom species of *Synedra* Ehrenberg (1830: 60) and *Epithemia* Kutzing (1844: 33) to be more abundant in upper diatomites from the region. Furthermore, Mueller-Wilmes (1988) found several unknown *Stephanodiscus* Ehrenberg (1845: 72) species in Lake Qarun sediment as well as *Stephanodiscus aegyptiacus* Ehrenberg (1854: pl. 33/1, fig. 16). *Stephanodiscus* species are of particular interest because they no longer grow in the lake today (Fathi & Flower 2003, Mansour 2008) and, being planktonic, are indicative of open lake conditions.

As part of a larger project to investigate the environment history of Lake Qarun (e.g. Keatings *et al.* 2010), several sediment augur cores were collected from the Lake Qarun basin. This paper firstly summarizes the gross stratigraphy of these cores and, secondly, evaluates some *Stephanodiscus* species present with in these cores.

## Site Description and Field Methods

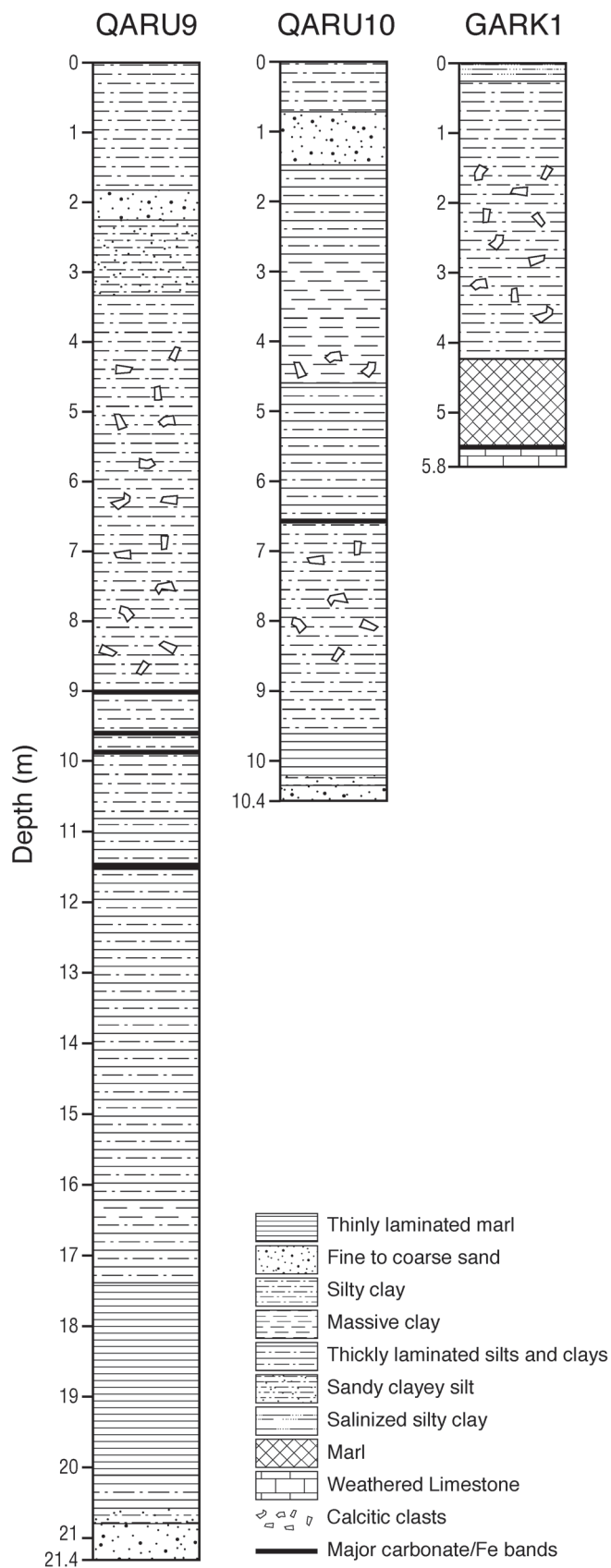
Modern Lake Qarun (29.487°N, 30.298°E) lies within the Faiyum Depression and the current surface lake water fluctuates around -43 m below sea level. It is sustained by drainage of Nile water delivered into the Depression through the Bahr Yusef (Fig.1)

*Field sampling:* In April–May 2008 augur coring (see Flower *et al.* 2012) was undertaken at six locations and three of these yielded lacustrine sediment sequences. The three cores containing diatom remains were QARU9 and QARU10, collected at the southern margin of Lake Qarun, and GARK1, collected from within the Gharak region in the south-western part of the Faiyum (Fig. 1).



**FIGURE 1.** Lake Qarun situated in northern part of the Faiyum Depression, Egypt. Three terrestrial sediment core locations are shown with QARU9 and 10 on the southern shore of the lake and GARK1 in the Gharak region of south west Faiyum. Note diatomite exposures are indicated to the west and northeast of the modern lake.

*Summary descriptions:* QARU9 (29.43447°N, 30.64213°E) was the longest core at 21.4 m and the upper sections consisted of a sandy layer and silty clays coloured dark brown to grey depending on depth (Fig. 2, left). Only below 1085 cm depth did the bulk sediment become coarsely laminated and below 1730 cm the white laminations became much thinner (at c. 1 mm thick) as the matrix changed to soft olive grey sediment. Below 2030 cm the sediment became silty and at c. 2080 cm coarse grey sand with small pebbles was present. QARU10 (29.40309°N, 30.50830°E) was 10.4 m long (Fig. 2, middle) had a lithology similar to QARU9 but



**FIGURE 2.** Gross sediment stratigraphies of the three cores, QARU9, QARU10 and GARK1 (see text for sediment descriptions). Note the basal sands below finely laminated diatom marl sediment in QARU9 & 10.

with shorter sections. At around 960 cm fine laminations appeared but this section was shorter than in QARU9 being only about 60 cm in depth and by 1030 cm brown coarse sands and gravel occurred. GARK1 (29.14840°N, 30.60976°E) was 5.80 m long (Fig. 2, right) and the upper sections comprised mainly silty clay but at 420 cm the sediment changed to a silty clayey grey marl which persisted to 570 cm with some feint irregular laminations. The sequence ended in light grey weathered limestone at 580 cm.

*Sample preparations:* Sub-samples for preliminary diatom analysis were taken at approximately 40 cm intervals in each core with sampling frequency varying according to changes in stratigraphy. Most samples were placed into Whirl Pac bags for transportation from the sites. The bulk cores were all archived in Egypt for further lithostratigraphic study while the sedimentary diatom sub-samples were transported to the UK for diatom analysis.

## Material and Methods

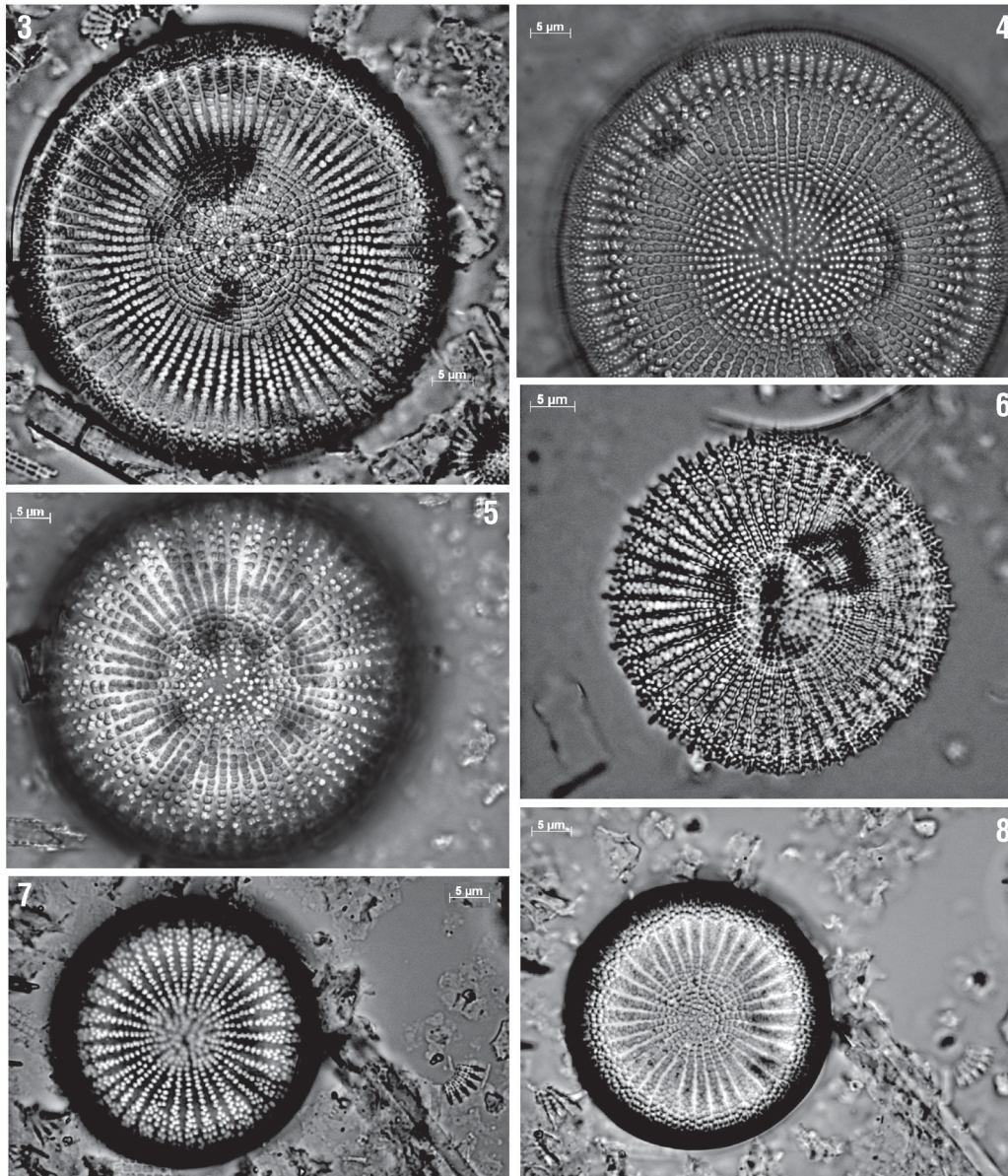
Initial low power microscopical examination of the down core diatom strews indicated that species of *Cyclostephanos* Round ex Theriot, Håkansson, Kociolek, Round & Stoermer (1987: 346), *Stephanodiscus* and *Aulacoseira* Thwaites (1848: 167) and were common in many samples. In QARU9 at least some whole diatom valves were present in all samples between 160 cm and 2030 cm depth, in QARU10 between 260 and 1005 cm depth and in GARK1 between 60 cm and 580 cm. Consequently, all samples were prepared for diatom analysis. After initial freeze drying, diatom analysis was undertaken after sample treatment with hydrogen peroxide (organic matter was <10% of the dry sediment weight in all samples and little oxidation was needed). Hot 50% HCl, was used to remove carbonate minerals. After washing with distilled water, the resulting diatom suspensions were dried on to glass cover slips and mounted in Naphrax. Slide strews were examined at x1000 magnification in a Leitz Labrolux light microscope (LM) with a 1.3 N.A. objective so that diatom species could be assessed and taxonomic issues confronted. Because of the high degree of valve silicification, diatoms were usually viewed without phase contrast optics. Identification difficulties were soon encountered for species within the *Stephanodiscus* genus and appropriate treated samples from all three cores were used for taxonomic evaluation and photomicrography. LM microphotography used a Leica DM6000 LM with a x100 objective with a Zeiss AxioCam digital camera. Scanning electron microphotography was undertaken in a Jeol JSM-6480LV scanning electron microscope (SEM).

## Results

*Sediment core GARK1:* Although not thinly laminated, the deeper (4.2–5.6 m) sediment in this core contained abundant planktonic diatoms which, in addition to *Cyclostephanos dubius* (Fricke) Round in Theriot et al. (1987: 346), included a *Stephanodiscus* species with similarities to *S. aegyptiacus*. This latter species was reviewed by Håkansson & Locker (1981) and it is noteworthy that the type locality for *S. aegyptiacus* is the ‘See Garag, Fajum, Aegypten’. The unrecognized *Stephanodiscus* species in GARK1 marl sediment was initially thought to be co-specific with *S. aegyptiacus* but closer examination in both LM and SEM revealed significance differences.

In the LM valves were large (up to 70 µm in diameter) and weakly concentrically undulate so that frustules possessed only slightly differentiated convex and concave valves. No distinct sub-marginal hyaline silica ring was discernible at the valve face mantle junction (cf. *S. aegyptiacus*) although an indistinct ring (Fig. 3) is present in larger specimens (> c. 40 µm diameter). Interfascicle ribs (3–4 in 10 µm) were relatively broad and tended to narrow both distally and proximally giving a fine lanceolate appearance (Figs 3, 4). Spines were absent although valves showing marginal dissolution can appear to have spines (Fig. 6). The fascicles are composed of areolae which in LM often appear large and blocky (Fig. 4), especially in well

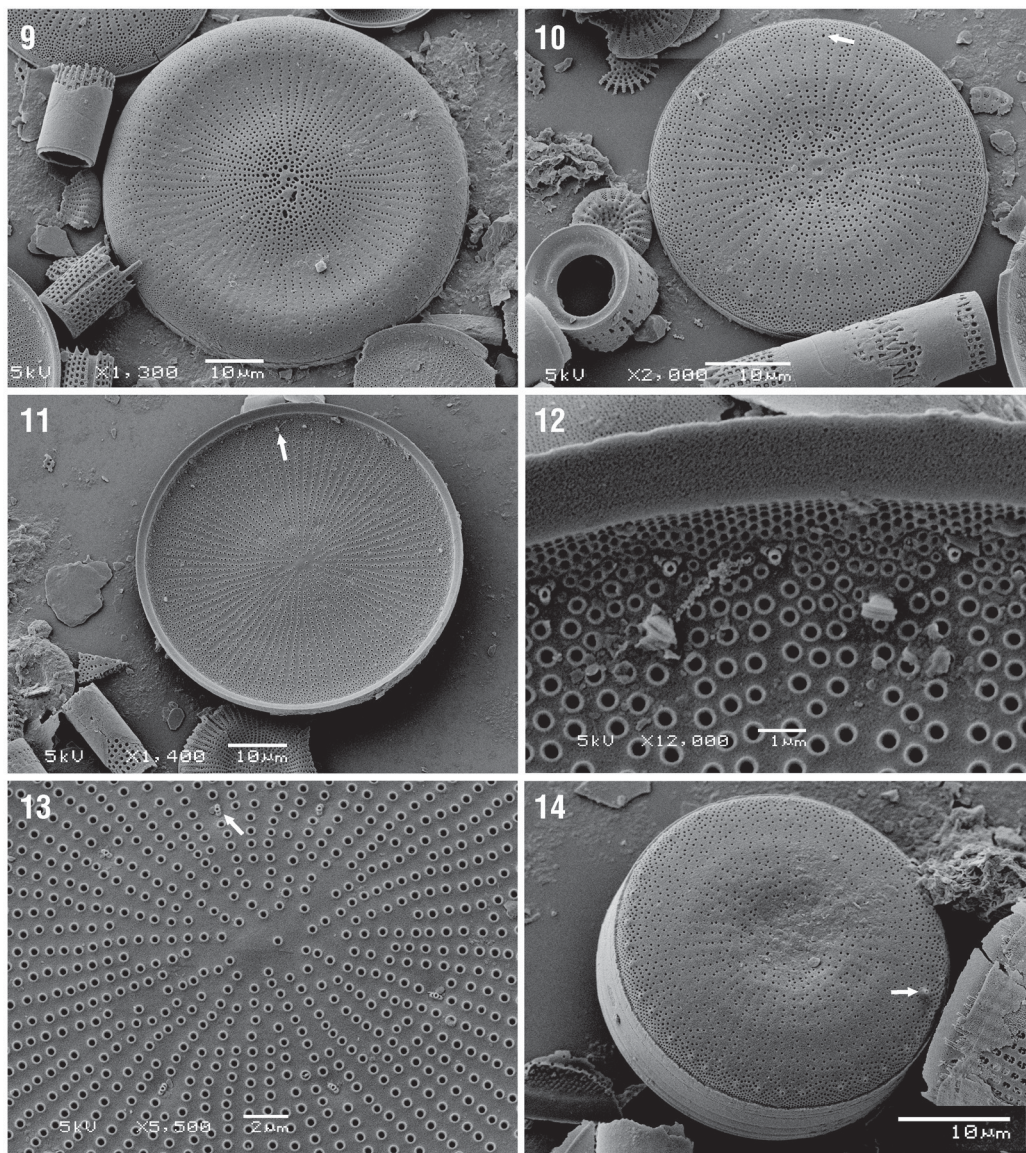
silicified specimens (Fig. 5). At the valve face-mantle junction (VFMJ), the interfascicles occasionally bifurcate (Figs 4 & 5). The fascicles are uniseriate for half to two thirds the length of the fascicle (dependant on valve size) and broaden at the VFMJ to include 3–4 areolae (Figs 4, 6–7). In smaller (< c. 40 µm diameter) valves (Figs 7–8) the interfascicles appear relatively more lanceolate, depending on the plane of focus (Figs 7–8) and, compared to larger valves, they more frequently bifurcate at the VFMJ (Fig. 8).



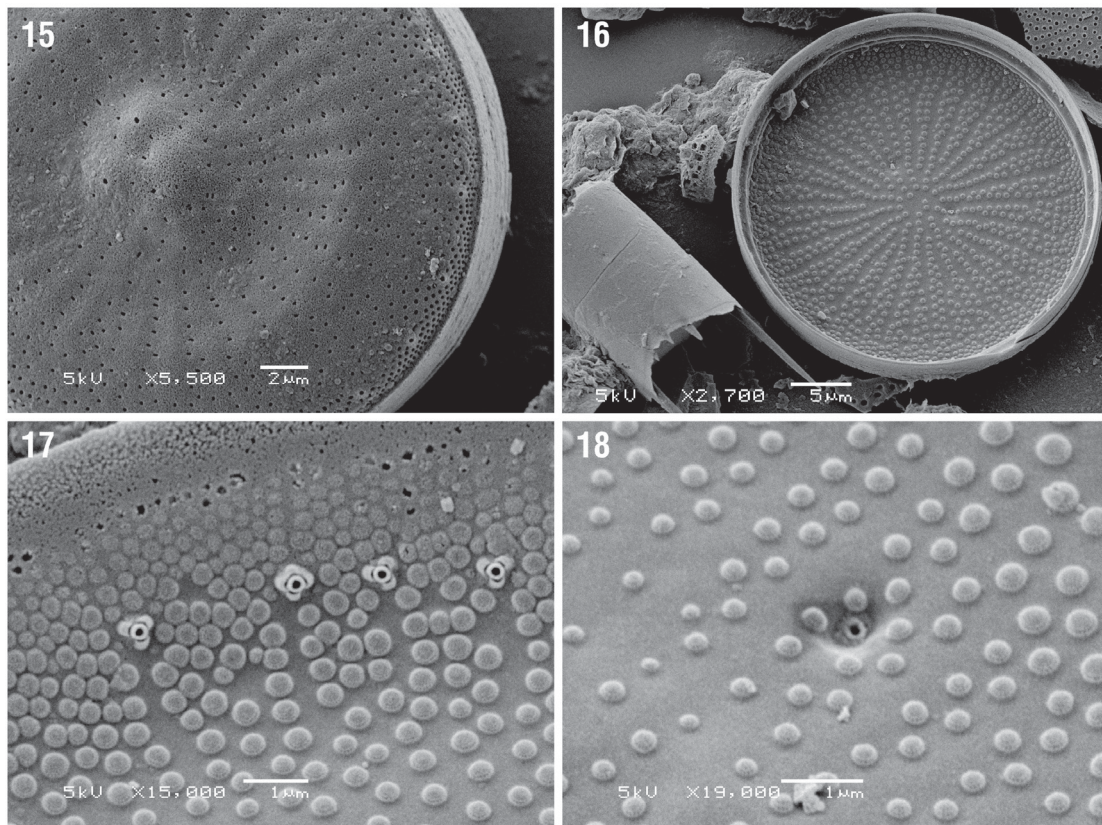
**FIGURES 3–8.** *Stephanodiscus neoegypticus*, LM. Fig. 3. Valve showing an indistinct sub-marginal hyaline ring and broad interfascicular ribs. Fig. 4. Valve focused to show the valve face-mantle zone with occasional bifurcating interfascicular ribs (arrowed). Fig. 5. A strongly silicified valve. Fig. 6. A part dissolved valve with eroded margin and diminished interfascicular ribs. Figs 7–8. *S. neoegypticus* v. *fekrii* LM. Fig. 7. Whole valve focused to show the broad interfascicular ribs and marginal bifurcations (arrowed). Fig. 8. The same whole valve (Fig. 7) focused to show the central area. Scale bars = 5 µm (Figs 3–8)

In SEM the external valve view confirms only a small degree of concentric undulation with valves being slightly convex (Fig. 9) or concave (Fig. 10). The latter clearly shows the fine lanceolate nature of the flat interfascicles which narrow distally to accommodate broadening of the fascicles as they become multiseriate. External openings of the valve face areolae (c. 14 in 10 µm) are small (< 1 µm in diameter, unless expanded by dissolution) and most interfascicles have external fultoportulae openings at the VFMJ (Fig. 10). External apertures of rimoportulae (Fig. 10, arrowed) are sub-marginal on interfascicles. Spines are absent. Internally,

rimoportulae (3–6) occur irregularly spaced in the sub-marginal zone (Fig. 11, arrowed), are almost sessile and oriented sub-obliquely (Fig. 12). The areolae become markedly smaller beyond the VMFJ (Fig. 12) and more closely spaced ( $>30$  in  $10\ \mu\text{m}$ ) compared to valve face areolae (c. 14 in  $10\ \mu\text{m}$ ). Marginal fultoportulae have three satellite pores and are subtended by short tubes (Fig. 12). The central area fultoportulae form a ring and each possesses two satellite pores (Fig. 13, arrowed). Smaller valves ( $< c. 20\text{--}40\ \mu\text{m}$  in diameter) are also either concave (Fig. 14) or convex (Fig. 15) and valve face areolae appear more coarsely spaced with very small apertures (but metrics are not significantly different from those of larger forms). At least one raised rimoportula aperture occurs submarginally (Fig. 14, arrowed). Internally, each valve has one, two or three marginal rimoportulae and a valve with two is indicated in Fig. 16. Marginal fultoportulae have three (sometimes four) satellite pores (Fig. 17). Central area fultoportulae are recessed with two satellite pores (Fig. 18, where well preserved domed cribra are also shown).



**FIGURES 9–14.** *Stephanodiscus neoegypticus*, SEM. Fig. 9. Iconotype, external valve showing small concentric convex undulation with out spines. Fig. 10. External valve showing small concentric concave undulation and external rimoportula opening (arrowed). Fig. 11. Internal valve showing sub-marginal rimoportulae (arrowed). Fig. 12. Detail of the same valve showing two sub-marginal rimoportulae and marginal ring fultoportulae. Fig. 13. Detail of the central ring of fultoportulae (each with two satellite pores). *Stephanodiscus neoegypticus* v. *fekrii* SEM. Fig. 14. Iconotype, external valve with a concave central area, marginal ring of fultoportula apertures and external opening of a rimoportula (arrowed). Scale bars =  $10\ \mu\text{m}$  (Figs 9–11, 14),  $1\ \mu\text{m}$  (Fig. 12), and  $2\ \mu\text{m}$  (Fig. 13).



**FIGURES 15–18.** *Stephanodiscus neoegypticus* v. *fekrui*, SEM. Fig. 15. External valve with a convex central area. Fig. 16. Internal valve showing two rimoportulae (arrowed). Fig. 17. Detail of internal marginal zone showing fultoportulae with either three or four satellite pores. Fig. 18. Internal central area fultoportula with two satellite pores. Scale bars = 2  $\mu\text{m}$  (Fig. 15), 5  $\mu\text{m}$  (Fig. 16), and 1  $\mu\text{m}$  (Figs 17, 18).

## New species descriptions

### Division Bacillariophyta

Class **Coscinodiscophyceae** F.E. Round & R.M. Crawford in Round *et al.* 1990 emend. Medlin & Kaczmarska 2004

Order **Thalassiosirales** Glezer & Makarova 1986

Family **Thalassiosiraceae** Lebour 1930

Genus *Stephanodiscus* Ehrenberg

### *Stephanodiscus neoegypticus* Flower *sp. nov.*

Cells circular, undulate, central areas weakly concave or convex, spines absent. Cell diameters c. 30–70  $\mu\text{m}$ . Fascicles radial, uniseriate striae occupy about 2/3 of the valve radius with 3–4 rows of areolae at valve face-mantle junction. Interfascicles distinct, not raised (compared to fascicles), circa 1.5  $\mu\text{m}$  wide around the mid radius, 4–5 areolae in 10  $\mu\text{m}$  at valve margin. External areolar openings small (1  $\mu\text{m}$  or less). Central area fultoportulae up to 6, near valve centre, with two satellite pores. Marginal fultoportulae with three satellite pores at termini of interfascicles. External openings of marginal fultoportulae slightly raised. Rimoportulae sub-marginal, 3–6, oblique, irregularly spaced.

**Type:**—EGYPT. Gharak: Faiyum Depression, 29.43447° N, 30.64213° E, Holocene lake sediment core (*GARK1*) material, sediment depth 450 cm, collected April–May 2008, (Circled specimen (Fig. 3) on slide *BM101659* (BM!), **holotype, designated here**).

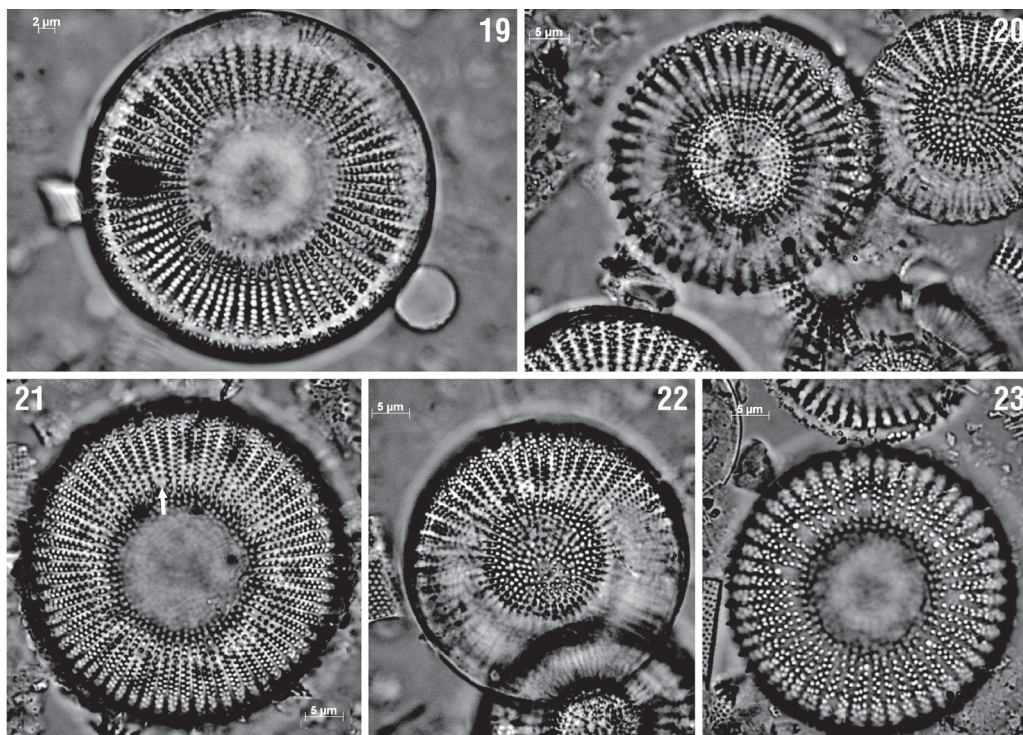
*Stephanodiscus neoegypticus* var. *fekrii* Flower var. nov.

Cell diameters ca. 20–40 µm. Fascicles radial, uniseriate striae occupy ca. 50% of the valve radius. Interfascicles often divide beyond the valve face-mantle junction and slightly widen in the mid-valve region. Central area fulloportulae 2–3. Rimoportulae sub-marginal, 2–3.

**Type:**—EGYPT. Gharak: Faiyum Depression, 29.14840° N, 30.60976° E, Holocene lake sediment core (*GARK1*) material, sediment depth 450 cm, collected April–May 2008, (circled specimen (Figs 8, 9) on slide BM101660, **holotype, designated here**).

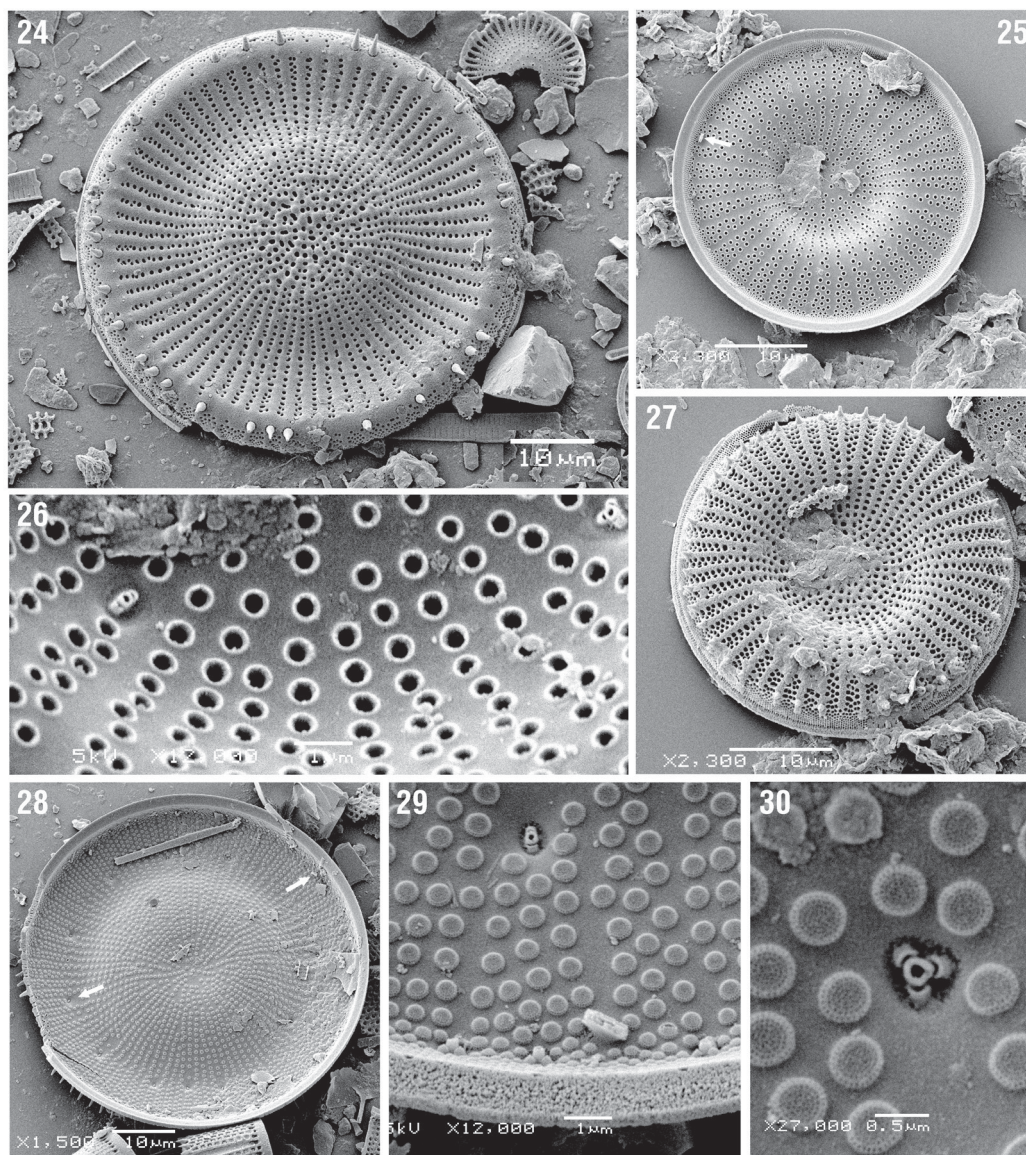
*Sediment cores QARU9 and QARU10:* In the thinly laminated sections of both QARU9 & 10 (see Fig. 2), a third common *Stephanodiscus* species was present that was not *S. neoegyptiacus* but much more similar to *S. galileensis* Håkansson & Ehrlich (1987: 20). The type locality for this species is sub-surface (fossil) sediment in Lake Kinneret (Israel). They reported a heterovalvic condition where the concave and convex valves differed with regard to fascicle arrangement and to location of fulloportulae. Since some of their material was evidently rather poorly preserved (see their Figs 3, 14 and 16), the species is re-examined here.

In LM, *Stephanodiscus galileensis* valves show strong concentric undulations according to the plane of focus either on the marginal or central areas (Figs 19 & 20). Valves range from 20–48 µm in diameter. The marginal area (Fig. 19) also displays a characteristic sub-marginal hyaline silica ring and broad interfascicles. Fascicles are c. 5 in 10 µm, proximally uniseriate with large blocky areolae becoming finer and bi- or triseriate in the distal third portion of the valve. Interfascicles are distinct and about 1.5 µm broad in the mid-radius area. Concave valves show a similarly strong undulation (Figs 21 & 22) with 5–6 hyaline areas (marking fulloportulae, see below) in the mid-radius position on the valve face (Fig 21, arrowed) and these are particularly obvious in well silicified specimens (Fig. 23). Fascicles on these valves (morphotype ‘B’ of Håkansson & Ehrlich 1987) appear to contain finer areolae and are biseriate for about half the valve distal radius. In this region, interfascicles are often about 1 µm broad but in strongly silicified specimens the width is similar to those in valves with hyaline sub-marginal rings.



**FIGURES 19–23.** *Stephanodiscus galileensis*, LM. Fig. 19. Convex valve showing a distinct sub-marginal hyaline ring in focus. Fig. 20. Similar showing marginal ring of spines and valve central area in focus. Fig. 21. Concave valve showing finer fascicle structure (see *S. galileensis* morphotype B, Håkansson & Locker 1987) and valve face fulloportulae (arrowed). Fig. 22. Similar showing valve central area in focus. Fig. 23. Similar, but valve is more strongly silicified. Scale bars = 5 µm (Figs 19–23).



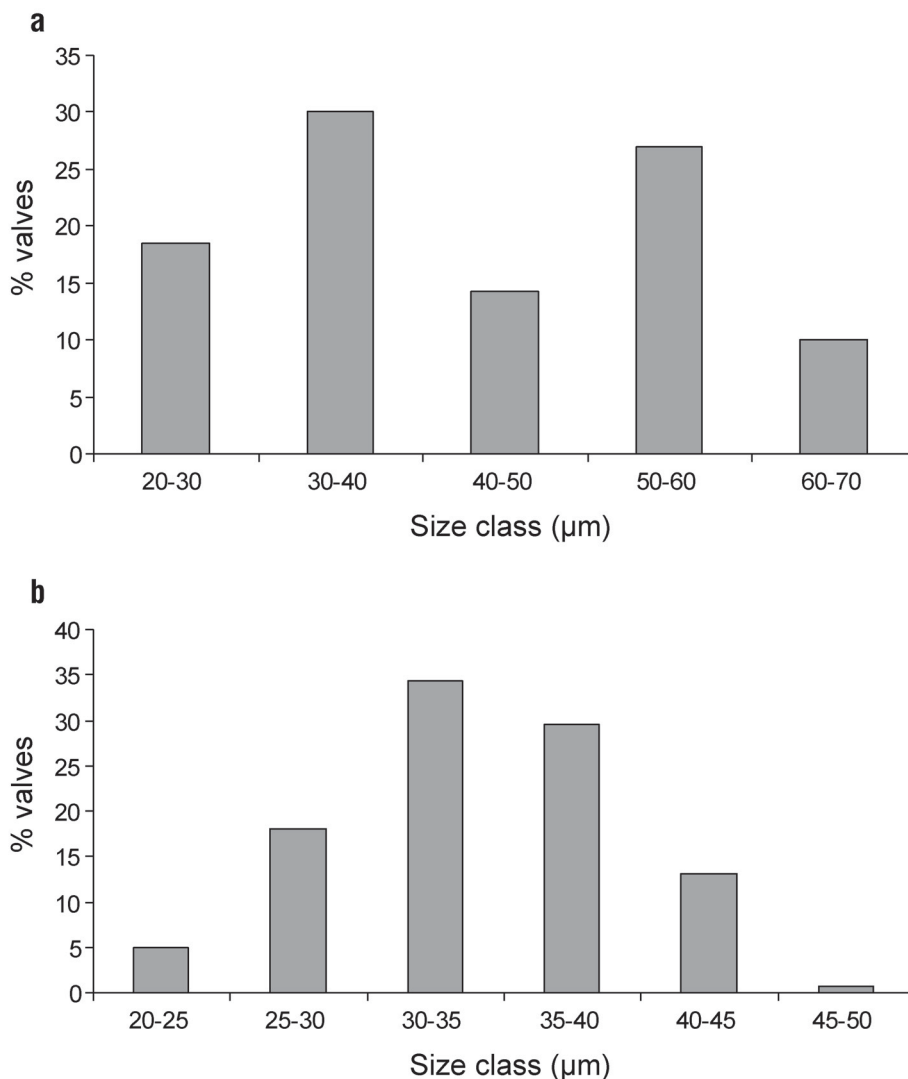


**FIGURES 24–30.** *Stephanodiscus galileensis*, LM. Fig. 25. External convex valve note irregular spines and sub-marginal silica ring. Fig. 25. Internal convex valve with rimoportula arrowed. Fig. 26. Detail of same valve showing central area ring of fultoportulae with two or three satellite pores. Fig. 27. External concave valve with ring of spines and raised interfascicular ribs. Fig. 28. Internal concave valve showing ring of sub-marginal fultoportulae and rimoportulae (arrowed). Fig. 29. Similar showing detail of a rimoportula, a sub-marginal fultoportula with two satellite pores and marginal fultoportulae. Fig. 30. Detail of a sub-marginal fultoportula with three satellite pores and surrounding domed cribra. Scale bars = 10 µm (Figs 24, 25, 27, 28), 1 µm (Figs 26, 29), and 0.5 µm (Fig. 30).

In SEM, the external view of convex valves of *S. galileensis* clearly shows the marked central undulation with irregularly spaced spines subtended from the sub-marginal silica ring (Fig. 24, note the similarity of this specimen with *S. aegyptiacus* as depicted in Fig. 63, Håkansson & Locker 1981). The fascicles are uniseriate becoming biseriate or triseriate near the valve face-mantle junction (VFMJ) with small areolae (12–13 in 10 µm). External areolar openings are generally < 1 µm in the mid valve face area and, consequently, the fascicles are narrower than the interfascicles. Internally, these convex valves (Fig. 25) show marginal fultoportulae on each interfascicle at the VFMJ, one or two sub-marginal rimoportulae (arrowed) and a ring of central area fultoportulae (Fig. 26) with either two or three satellite pores. The mantle areolae, cribra and fultoportulae are generally as in Håkansson & Ehrlich (1987) except in this material the number of central area processes is lower. The concave valves confirm heterovalvy (Fig. 27) with raised interfascicles each subtended by a spine, distinct external openings of central area fultoportulae (arrowed) and a greater degree of areolation (with distally extended bi- and triseriate fascicles) compared to convex valves. Internally, the

concave valves display a ring of sub-marginal fuloportulae (Fig. 28, arrowed) that initiate distally an usually biseriate fascicle (Fig. 29). There are typically three oblique sub-marginal rimoportulae (Figs 28–29). Central area fuloportulae possess two (Fig. 29) or three (Fig. 30) satellite pores and occur in depressions near finely porate domed cribra (Fig. 30).

**Size distributions:**—To help substantiate the two varieties of *S. neoegypticus*, diameters of 70 random valves (*S. neoegypticus* sensu lato) were assigned to size classes and the distribution plotted (Fig. 31a). These data show a bimodal size distribution with two modal size classes, 30–40  $\mu\text{m}$  and 50–60  $\mu\text{m}$ ; the larger class was always composed of *S. neoegypticus* valves and the smaller class was mainly *S. aegypticus* var. *fekrii*. For *S. galileensis*, diameters of 60 random valves were assigned to size classes and the distribution plotted (Fig. 31b). There were approximately equal numbers of convex and concave valves resulting in a unimodal size class distribution with 35% of valves in the 30–35  $\mu\text{m}$  size class.



**FIGURE 31.** Size distributions for diatom valve diameters (see text). Fig. 31a: *Stephanodiscus neoegypticus* sensu lato from material at 430 cm depth in core GARK1. Fig. 31b. *Stephanodiscus galileensis* Hakansson & Ehrlich from material at 1930 cm depth in core QARU9.

**Morphological comparisons:**—The morphological characteristics of *S. neoegypticus* and *S. neoegypticus* var. *fekrii* are summarized in Table 1 where valve size, extent of uniseriate areolae serve best to discriminate the latter in routine LM examination. Another small form, similar to *S. neoegypticus* var. *fekrii* but with distally wider (4/5 areolae) fascicles, was recognised in GARK1 and tentatively named as cf. *asteriodes* but this taxon requires further study. Comparable data for *S. aegyptiacus* from Hakansson & Locker 1981 are included in Table 1 to demonstrate differences between this species and the two newly

described *S. neoegypticus* taxa. The most discriminating features of the latter are a larger valve diameter range and differences in valve face areolar structure. Strongly concentric valve undulations a distinct marginal hyaline ring and marginal spines are all lacking in *S. neoegypticus* sensu lato. The morphological characteristics of *S. galileensis* obtained from the Qarun core material compare favourably with the published data for this species (Håkansson & Ehrlich 1987) shown in Table 2. The original description and the existence of heterovalvy is generally substantiated and only very minor differences were found in this study. The latter extends slightly the original description by increasing the valve size range and including more variation in the number of rimoportulae and in the arrangement of satellite pores around fultoportulae.

**TABLE 1.** Some morphological characteristics of *Stephanodiscus neoegypticus* Flower and *S. neoegypticus* v. *fekrii* Flower. Data for *S. aegyptiacus* Ehr. from Håkansson & Locker (1981) are also given for comparison; na indicates data not available, ? indicates inferred value.

	<i>S. neoegypticus</i>	<i>S. aegyptiacus</i> v. <i>fekrii</i>	<i>S. aegyptiacus</i>
Diameter (µm)	c. 30–70	c. 20–35	9–45
Concentric undulation	weak	weak	strong
Spines	none	none	yes
Interfascicles	hyaline, 4–5 in 10 µm	hyaline, 4 in 10 µm	hyaline, 3–5 in 10 µm
Fascicle areolae (proximal)	uniseriate	uniseriate	uniseriate
Fascicle areolae (distal)	2–4 rows	3–4 rows	2–4 rows
Uniseriate areolae extent	75–80% of valve	c. 50% of valve	c. 60% of valve
Marginal hyaline ring	indistinct or absent	absent	distinct
Interfascicle at mantle	rarely bifurcated	often bifurcated	na
Areolae on mantle	fine, 3–4 in 1 µm	fine, 3–4 in 1 µm	fine, 3 in 1 µm
Interfascicles	width, 0.5–1.5 µm, not raised	width 0.5–1.5 µm, not raised	width 0.4–0.9 µm, raised
External areolar pores	c. 0.2–1 µm, c. 14 in 10 µm	c. 0.2 µm, c.16 in 10 µm	>1 µm, 6–7 in 10 µm
Internal cribra	domed, c. 0.4 µm	domed, c. 0.4 µm	na
Central area fultoportulae	up to 6	2 or 3	5?
Marginal fultoportulae	interfascicle termini, raised	interfascicle termini, raised	interfascicle termini, below spines
Satellite pores	3 at margin, 2 centrally	3/4 at margin, 2 centrally	3 at margin, 2 centrally
Rimoportulae	3–6, sub-marginal	usually 2, sub-marginal	at least one, marginal

## Discussion

The presence of diatom-rich marl sediment in the basal sections of all three cores provide evidence of a lake that was formerly much more extensive than today. The planktonic diatoms in these sections were dominated by *Aulacoseira* and *Stephanodiscus* taxa and, while *A. granulata* (Ehrenberg) Simonsen (1979: 58) is common in the Nile River today (Talling *et al.* 2009), the latter is not. Sediment records show that species of the genus *Stephanodiscus* were formerly widespread and often very abundant in large East African lakes during the Plio-Pleistocene and Holocene (Gasse 1980, 1987). However, few species present in the Faiyum core sections appeared to be recognisable as previously described African endemics. Those *Stephanodiscus* species present in the Faiyum sediments appear to have developed within the lake rather than from populations brought northwards into the lake via Nile floods.

In the thinly laminated marl sections of cores QARU9 and 10, *Stephanodiscus galileensis* was fairly common; it has not been previously reported for the Faiyum but its locality corresponds to the fossil type material from Lake Kinneret (Håkansson & Ehrlich 1987). The species seems to have a very restricted Middle Eastern distribution although Krammer & Lange-Bertalot (2004) note that it is a planktonic form in eutrophic African freshwaters. Tuji *et al.* (2003) comment on the similarities of *S. akanensis* Tuji, Kawashima, Julius & Stoermer (2003: 2) (so far a Japanese endemic species) to *S. galileensis*. Mueller-Wilmes (1988) recorded 11 unidentified *Stephanodiscus* species in Lake Qarun sediment cores and *S. galileensis* probably occurred

within this unknown group. Other unidentified *Stephanodiscus* taxa could correspond to different dissolution states of this species where erosion of both the marginal and the broad interfascicle areas can alter markedly valve appearance in LM.

The marked heterovalvy in *S. galileensis* described by Håkansson & Erlich (1987) is supported in this investigation as are the characteristics of both the convex and concave valves. Failure to recognise this heterovalvic condition can also cause species identification problems in routine counting since the concave valve is distinctly more finely striated and has a higher density of fascicle areolae (cf. Table 2). As noted by Håkansson & Erlich (1987), the distinctive hyaline marginal ring is characteristic of the convex valve and, while not definitive of the species, it is a useful initial identification feature. The descriptions of both frustular valves of this species are extended slightly by reporting details ultra-structure features (cf. Table 2) associated with the valve processes and the valve size range is extended to smaller forms (to 20 µm valve diameter).

The other *Stephanodiscus* species of note found to date in the Faiyum sediment cores is described as a new species *Stephanodiscus neoegypticus*. This species occurred most commonly in GARK1, from a region that would have been partially isolated from the main lake in the early Holocene. Although the ‘See Garak’ area of the Faiyum is the type locality for *Stephanodiscus aegyptiacus* Ehr., this species appeared absent in Gharak sediment where only a few *S. galileensis* and the newly described species were common. Ehrenberg (1854) noted that *S. aegyptiacus* is an extinct form that also occurs in Atlantic Passat winds but the latter does not substantiate its occurrence as North African. Associated diatoms in his drawing (in Håkansson & Locker 1981) do however indicate a sedimentary source within the Faiyum. The only extant lake (Birket Abu Talib) in the Gharak is small and shallow and receives agricultural drainage so is most unlikely to support *S. aegyptiacus* today. While its occurrence in the Faiyum remains to be established, the latter species seems unreported in recent lakes except for several sites in Florida (Whitmore 1989).

Despite the genus name, *Stephanodiscus neoegypticus* is distinctive for its total lack of spines in all specimens examined in this study. While marginal spines are characteristic of the genus (e.g. Krammer & Lange-Bertalot 1991) many other characters of *S. neoegypticus* (fasciculate structure, arrangement of valve face and mantle areolae, the external rimoportula and the cribra) are all typical of *Stephanodiscus*. The new species has few characters in common with *S. galileensis* (cf. Tables 1 & 2). Similarly, it is clearly separated from *S. aegyptiacus* Ehr., a species for which heterovalvy is not confirmed (Håkansson & Erlich 1987). There are, however, issues with the description of *S. aegyptiacus*, the convex valve figured in SEM from the type material (Fig. 63 in Håkansson & Locker 1981) has a marginal hyaline ring, raised interfascicular ribs and fasciculate areolar structure exactly similar to *S. galileensis*. The internal valve image (Fig. 65 in Håkansson & Locker 1981) of *S. aegyptiacus* shows a central area ring of fuloportulae and sub-marginal rimoportulae in the same positions as in *S. galileensis*. Further, an external valve of *S. galileensis*, Fig. 87 in Håkansson (2002), and the external valve of *S. galileensis*, Fig. 63 in Håkansson & Locker (1981) seem identical. The diagnosis of *S. aegyptiacus* is also virtually the same as that for the convex valve of *S. galileensis* excepting a smaller size limit for the former. As noted by Håkansson & Locker (1981), other workers have expressed doubt in the validity of *S. aegyptiacus* (e.g. VanLandingham 1978) and while the species concept is valid, conspecificity with *S. galileensis* is suspected. If heterovalvy can be demonstrated in the original material of *S. aegyptiacus*, then *S. galileensis* may well be synonymous.

Validating and establishing diatom species in ancient lake sediments is often made difficult by poor preservation, but establishing a secure taxonomic foundation is essential to assure integrity for biostratigraphies within and between lakes. Furthermore, a secure taxonomy is needed for both extant and fossil species so that species distributions through time and space can be determined. Provenance of individual species as well as information about the diversity of either contemporary communities or fossil assemblages is needed to help understand how diatom diversity in ancient lakes developed and sometimes declined. Questions remain about the origin of the diatom species recorded in Lake Qarun sediments but it is already clear that the *Stephanodiscus* flora of the early Holocene deep lake arose and declined with some rapidity (cf. Flower *et al.* 2012). Until a secure chronology is developed for a continuous Holocene sequence for Lake Qarun, the precise timing of the major environmental changes in this once great lake remains elusive.

**TABLE 2:** Some morphological characteristics of *Stephanodiscus galileensis* Hakansson & Ehrlich according to material from lake sediment cores QARU9 and 10. CVV and CCV refer to the convex and to the concave valves of this species. *S. galileensis*<sup>1</sup> refers to data given in Hakansson & Ehrlich 1987; na indicates data not available, ? indicates inferred values, fp indicates fulcportulae.

	<i>S. galileensis</i> —CVV	<i>S. galileensis</i> —CCV	<i>S. galileensis</i> <sup>1</sup> —CVV	<i>S. galileensis</i> <sup>1</sup> —CCV
Diameter (µm)	20–48	20–48	32–48	32–48
Concentric undulation	strong	strong	strong	strong
Spines	irregular, small	regular, small	irregular ring at margin	irregular ring at margin
Interfascicles (in 10 µm)	5–6, raised	c. 6, markedly raised	c. 6, raised	c. 6, raised
Fascicle areolae (proximal)	uniseriate	uniseriate	uniseriate	uniseriate
Fascicles areolae (distal)	1–2, rarely 3, rows	2–4 rows	1–2 rows	2–3 rows
Uniseriate areolae extent	>80% of valve face	>70% of valve face	>80% of valve face	>70% of valve face
Marginal hyaline ring	distinct	not present	distinct	not present
Areolae on mantle	fine, 4 in 1 µm)	fine, c. 3 in 1 µm	c. 4 in 1 µm	na
Fascicles (width)	narrow, usually < 1 µm	wider, >2 µm especially distally	0.3–0.6 µm	c. 1.5 µm?
External areolar pores	12–14 in 10 µm	c. 15 in 10 µm	c. 12 in 10 µm	c. 15 in 10 µm
Internal cribra	domed, c. 0.6–0.7 µm	domed, c. 0.6–0.7 µm	domed, c. 0.6–0.7 µm	domed, c. 0.6–0.7 µm
Central fulcportulae	>10 in a central ring	c. 10 in sub-marginal ring	up to c. 20 in central ring(s)	up to c. 20 in submarginal ring
Marginal fulcportulae	every interfascicle below spines	every interfascicle below spines	every or every 2nd interfascicle	every or every 2nd interfascicle
Satellite pores	2 marginal fp, 2 central fp	2 marginal fp, 2/3 central fp	2	2
Rimoportulae	1 or 2 sub-marginal	usually 3, sub-marginal	1 or 2	1 or 2

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