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Stephanodiscus uemurae, a new Mio-Pliocene diatom species from the Miyata Formation, Akita Prefecture, northern Honshu, Japan

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Abstract

A recently found *Stephanodiscus* fossil, *S. uemurae* sp. nov., from Mio-Pliocene sediment of the Miyata Formation, Senboku City, Akita Prefecture, northern Honshu, Japan is described here. The new species is characterized by having a slightly double concentric undulation of the valve face, uniseriate fascicles at the valve center and biseriate or triseriate fascicles at the valve face/mantle junction. There is often a slight break between the rows of areolae on the valve face and mantle. Usually, there are no valve face fultoportulae. Spines are located on all interfascicles at valve face/mantle junction except in the case where openings of mantle fultoportulae are present, which is usually every two or three interfascicles. One tubular rimoportula replaces a spine and is located slightly above the ring of spines. The new species is illustrated with LM and SEM photographs.

Key index words: Akita Prefecture, fossil, Japan, Mio-Pliocene, Miyata Formation, *Stephanodiscus uemurae*

Introduction

The Miyata Formation is distributed in the eastern part of Akita Prefecture, northern Honshu, Japan. Huzioka & Uemura (1973) reported 65 plant fossils belonging to 43 genera from this formation, composed mainly of deciduous broad-leaved trees with a common association of conifers. Later, Usuda *et al.* (1985) reported *Aulacoseira italica*, *Cyclotella stelligera*, *Synedra ulna*, *Rhopalodia gibba* and *Epithemia turgida*, all identified by Dr. Itaru Koizumi, from the Miyata Formation. Uemura (1988) noted that the Miyata Formation contains fossil freshwater diatoms of the genus *Cyclotella* at a different locality studied in Usuda *et al.* (1985).

Recently, two taxonomic studies of the diatoms of the formation have since been published (Tanaka & Nagumo 2002, Tanaka 2007). The authors found a fossil diatom flora including an unknown *Stephanodiscus* taxon from an outcrop of the Miyata Formation on a tributary of the Hinokinai River at a different location from the previously reported sites. This taxon is possibly the oldest *Stephanodiscus* species ever found in Japan.

Detailed observations on the specimens revealed a unique combination of characteristics which could not be matched with any *Stephanodiscus* species heretofore reported. The authors therefore propose the new species as *Stephanodiscus uemurae*.

In this work, we describe the new species *S. uemurae* using light and electron microscope observations and compare it to related species, *Stephanodiscus kusuensis* Julius, H.Tanaka & Curtin, *Stephanodiscus alpinus* Hust. and *Stephanodiscus neoastraea* Håk. & B.Hickel.

Materials and methods

Two samples were collected from an outcrop

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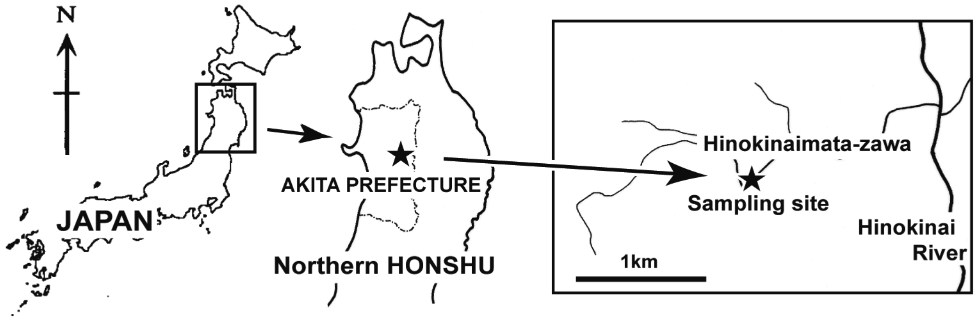


Fig. 1. Location of sampling site, Hinokinaimata-zawa, Senboku City, Akita Prefecture, Japan. ★: Sampling site.

along Hinokinaimata-zawa, a tributary of the Hinokinai River, in Senboku City, Akita Prefecture (Fig. 1). The samples are mudstone of the upper part of the Miyata Formation estimated to be Late Miocene based on the plant fossils (Uemura 1988). Radiometric (K/Ar) ages for andesite of the Miyata Formation, however, indicate Pliocene, though stratigraphic relations to the sediments are uncertain (Nakajima *et al.* 1995, Tsuchiya 1999). The age of the Miyata Formation is, therefore, assumed to be Mio-Pliocene in this paper.

The samples were boiled in a 30% H_2O_2 solution to separate the sediment particles from the diatom valves and to eliminate organic material, and then washed several times with distilled water. The cleaned material was mounted in Pleurax or Styrax. LM observations were made using a Nikon Apophot microscope with a Nikon plan-apochromat 100× oil immersion objective lens (NA = 1.4). SEM observations were made using a Hitachi S-4000 field emission microscope.

Terminology used was after Håkansson (2002).

Results

Description of new species

Stephanodiscus uemurae **H.Tanaka sp. nov. (Figs 2-22)**

Valves circular, diameter 19-28 μm, with a concave or convex valve center and a slightly double concentric undulation of valve face. Usually valve face fultoportula is absent. In rare cases, a fultoportula with two satellite pores is present near the center of valve, but it can only be discerned by internal observation using SEM. Fascicles are uniseriate areolae rows on valve center with an increase of two or three rows up to valve face/mantle junction. There is often a slight break between areolae rows of valve face and those of mantle. Interfascicles are 6-8 in 10 μm at the valve face/mantle junction. Mantle fultoportulae are located upper mantle or sometimes valve face/mantle junction on usually every second to third interfascicle. Spines are located on all interfascicles at valve face/mantle junction except in the case where openings of mantle fultoportulae and the rimoportula are present. Mantle is shallow. Each mantle fultoportula has three satellite pores. Single rimoportula with external tube is situated on valve face/mantle junction though external tube located at a slightly higher position from the ring of spines.

Holotype: MPC-03020. Micropaleontology Collection, National Museum of Nature and Science, Tokyo, Japan.

Type locality: Hinokinaimata-zawa, Senboku City, Akita Prefecture, Japan. 39°51′N, 140°34′E.

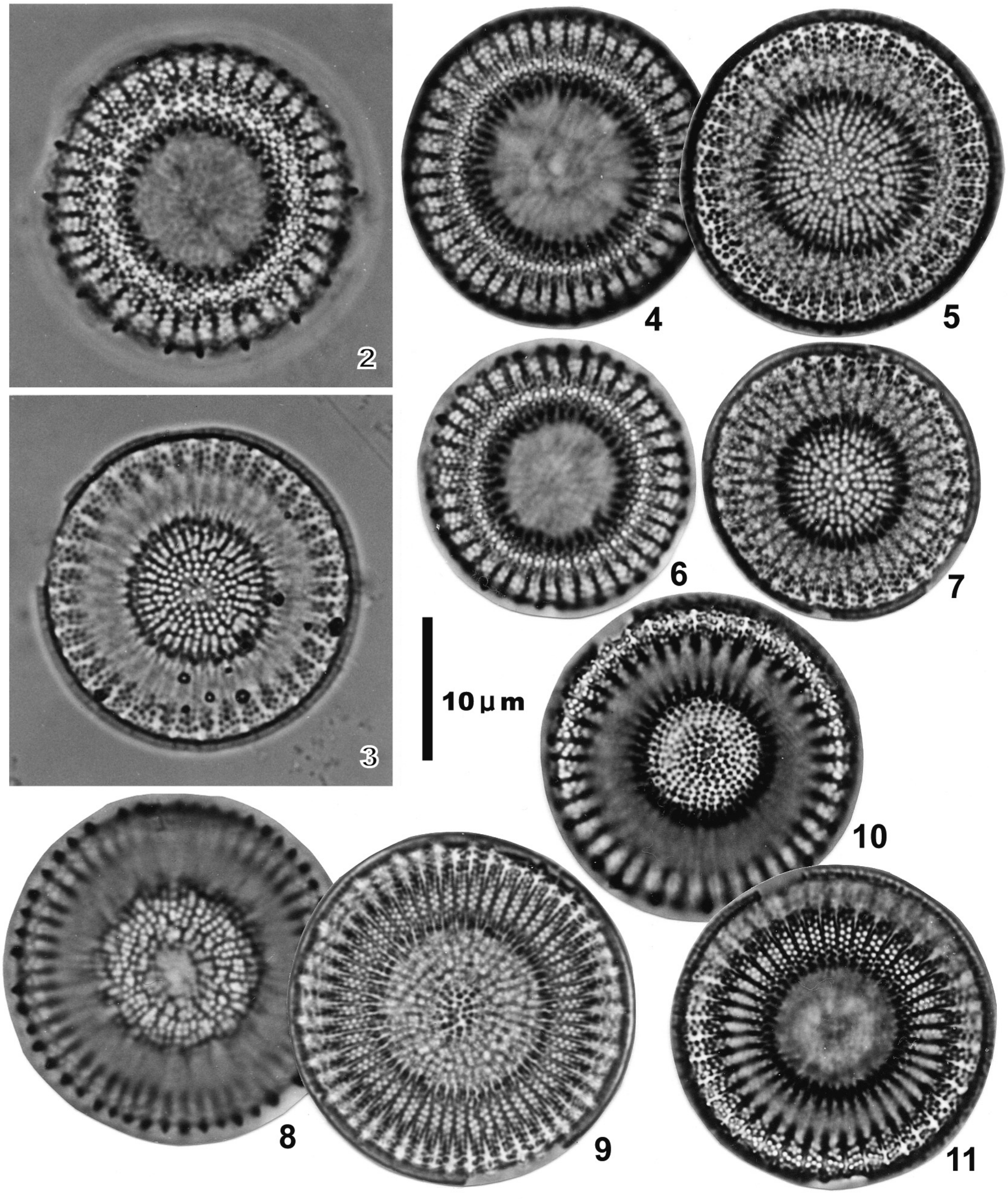
Type material: MIY-104, Coll. H. Tanaka on 6 June 2007. Mudstone of the Miyata Formation.

Etymology: The taxon is named in honor of Dr. Kazuhiko Uemura who is a researcher of plant fossils and who provided us with the information of the Miyata Formation.

Observations

LM shows valves having either a concave or a convex center. Fascicles are uniseriate on valve center and biseriate or triseriate at the valve face/mantle junction (Figs 2-11). One valve has 38-62 interfascicles.

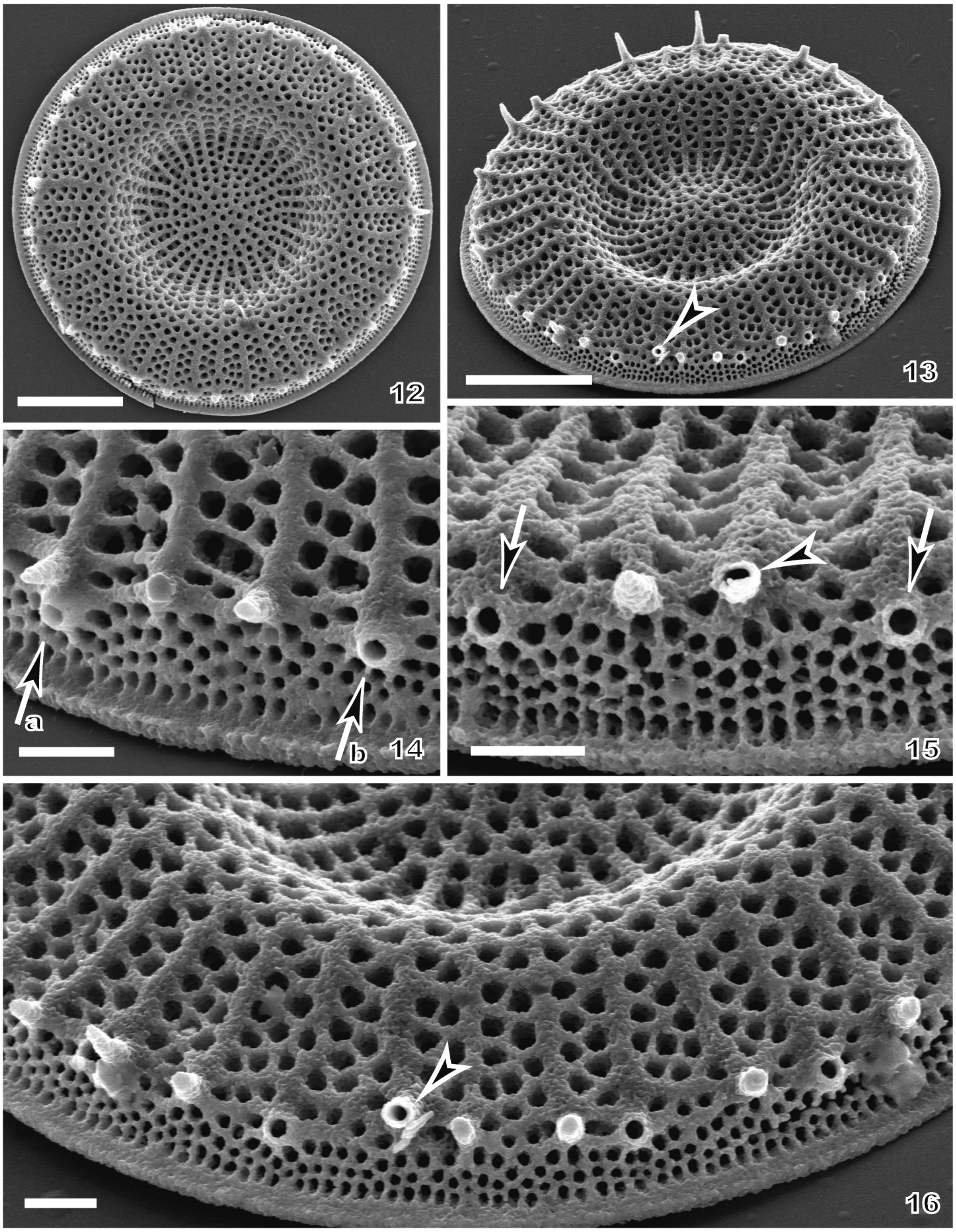
SEM external observation shows the valve face either concave or convex having a slightly double concentric undulation (Fig. 13). Mantle fultoportulae located upper mantle or sometimes



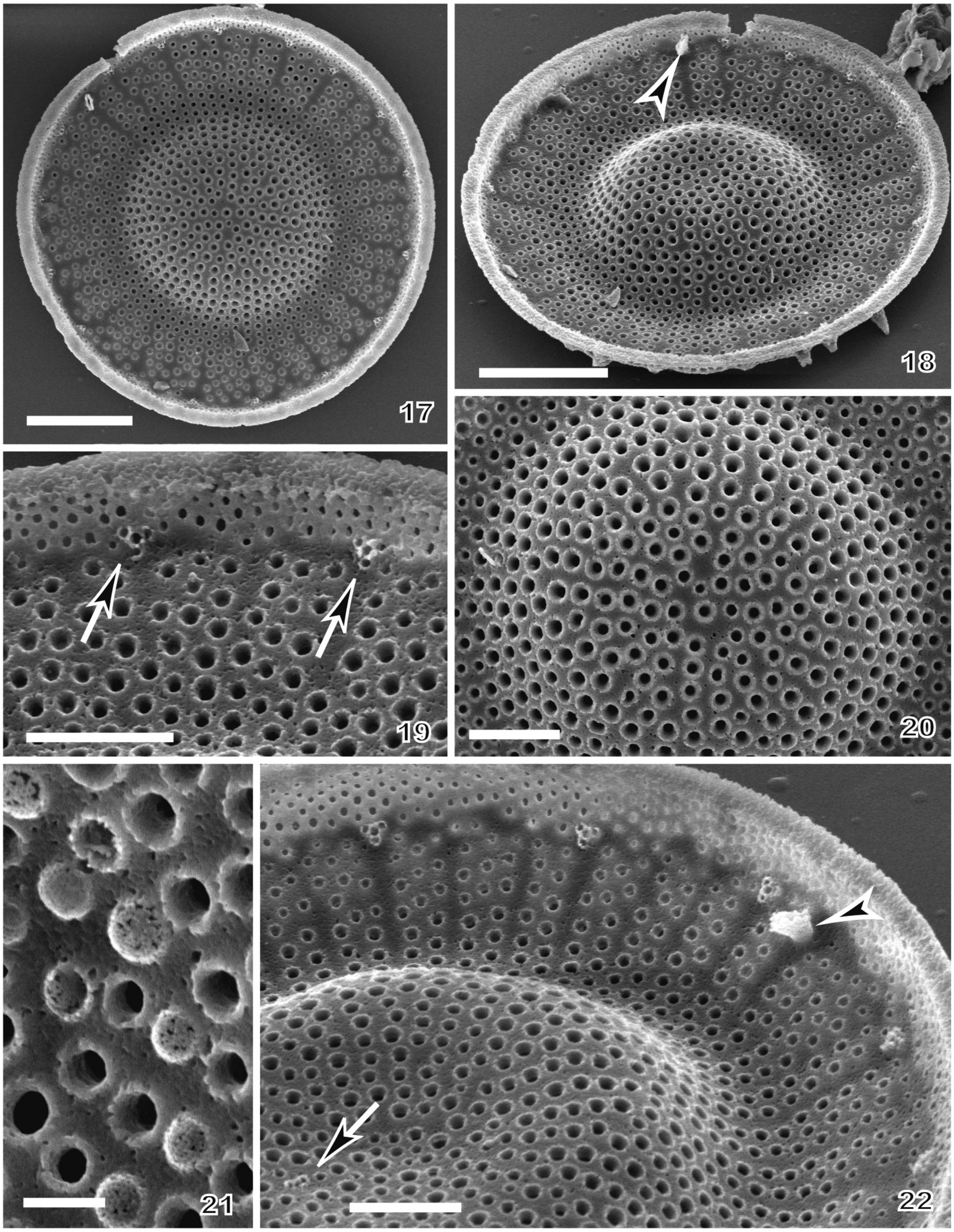
Figs 2-11. *Stephanodiscus uemurae*. LM. Scale bar = 10 μm. **Figs 2, 3.** Holotype, MPC-03020, National Museum of Nature and Science, Tokyo. Same valve shown at different focal planes. **Fig. 4/5, 6/7, 8/9, 10/11.** Same valve shown at different focal planes.

valve face/mantle junction on usually every second to third interfascicle, though in very rare cases mantle fultoportulae located on next interfascicle or on fourth interfascicle. When fultoportulae are located on valve face/mantle junction or near, spines were absent (Figs 14-16). Mantle is shallow with vertical areolae rows consisting of 2-4 areolae per row. One opening of rimoportula with external tubular projection (Figs 15, 16) is situated on valve face/mantle junction or slightly toward valve face side at the end of an interfascicle (Figs 15, 16).

SEM internal view shows areolae having domed cribra (Fig. 21) and usually no valve face



Figs 12-16. *Stephanodiscus uemurae*. SEM, external views. **Fig. 12.** Whole valve. **Fig. 13.** Oblique view of Fig. 12 (arrowhead : opening of rimoportula). **Fig. 14.** Valve margin showing two openings of mantle fultoportulae, one under the spine (arrow a) and the other with no spine (arrow b). **Fig. 15.** Valve margin showing opening of rimoportula with tube (arrowhead) and openings of mantle fultoportulae (arrows). **Fig. 16.** Enlarged view of valve margin of Fig. 13, showing opening of rimoportula (arrowhead). Figs 12, 13, scale bars = 5 μm ; Figs 14-16, scale bars = 1 μm.



Figs 17-22. *Stephanodiscus uemurae*. SEM, internal views. **Fig. 17.** Whole view of valve. **Fig. 18.** Oblique view of Fig. 17 (arrowhead : rimoportula). **Fig. 19.** Enlarged view of valve margin showing a slight break between valve face areolae rows and mantle areolae rows, and mantle fultoportulae with three satellite pores (arrows). **Fig. 20.** Enlarged view of valve center. **Fig. 21.** Detailed view of internal openings of areolae with domed cribra. **Fig. 22.** Oblique enlarged view showing rimoportula (arrowhead) and valve face fultoportula with two satellite pores (arrow). Figs 17, 18, scale bars = 5 μm ; Figs 19, 20, 22, scale bars = 2 μm ; Fig. 21, scale bar = 0.5 μm.

Table 1. Comparison of *Stephanodiscus uemurae* with *S. kusuensis*, *S. alpinus* and *S. neoastraea*.

Characteristics			*S. uemurae*	*S. kusuensis*	S. *alpinus*	*S. neoastraea*
Diameter (μm)			19-28	15-45	7.5-33	18-52
Valve face			slightly double concentric undulation	strongly double concentric undulation	strong concentric undulation	slightly double concentric undulation
Interfascicles (in 10μm) (at valve face/mantle junction)			6-8	7-10	8-11	7-9
Number of areolae rows in a fascicle			2-3	2-3	2	2(3)
Areolae in a fascicle (in 10μm)			ca. 20	ca. 20	ca. 18	ca. 20
Fultoportulae						
	valve face	position	near center	heterotopic position	near center	
		number	0(1)	5-22	1	0
		satellite pores	2	2(3)	2	
	mantle	position	every (1)2-3(4) interfas cicle; some at valve face/mantle junction	every 1-3 interfascicle; some at valve face/mantle junction	every 1-3 interfascicle; on the mantle	every 2-3 interfascicle; on the mantle
		satellite pores	3	3	3	3
Rimoportula						
		number	1	2-6	1	1 to several
		position	in the ring of spines or slightly higher than the ring of spines	in the ring or just out side the ring of spines	valve face/mantle junction in the ring of spines	concave valve: lower than the ring of spines between inter-fascicles, convex valve: at the end of an interfascicle in the ring of the spines
Spines			every interfascicle except when occupied by fultoportula	every 2 interfascicle except when occupied by fultoportula	every interfascicle	(usually) every 2-4 interfascicle
References			this paper	Julius *et al*. (2006) authors observation	Hickel & Håkansson (1993) partly Håkansson (2002)	Håkansson & Hickel (1986), Håkansson & Meyer (1994)

fultoportulae, or one near the center of valve with two satellite pores (Fig. 22). There is often a slight break between areolae rows of valve face and those of mantle (Fig. 19). Each mantle fultoportula has three satellite pores (Figs 19, 22).

Discussion

The most distinctive feature of *Stephanodiscus uemurae* is the mantle fultoportulae replacing spines when they are located near or at the valve face/mantle junction. This feature was formerly reported on *Stephanodiscus kusuensis*, a Middle Pleistocene fossil diatom from Kyushu, Japan in Julius *et al.* (2006). In addition, both species display a valve face with double concentric undulation, though *S. kusuensis* is strongly so and *S. uemurae* only slightly. The defining difference is that *S. kusuensis* has many valve face fultoportulae whereas *S. uemurae* usually has none.

The absence of valve face fultoportulae is a characteristic shared by *S. uemurae* and *Stephanodiscus neoastraea* (Håkansson & Hickel 1986). The two species, however, differ in the location of mantle fultoportulae; those of *S. neoastraea* always located on the mantle while those of *S. uemurae* sometimes on the valve face/mantle junction. Also, the mantle fultoportulae of *S. uemurae* sometimes replace spines while those of *S. neoastraea* do not. In addition, although it is possible that both species have only one rimoportula, *S. neoastraea* can have up to several (Håkansson & Hickel 1986, Håkansson & Meyer 1994) whereas *S. uemurae* always has just one.

The number and location of mantle fultoportulae of *Stephanodiscus uemurae* appear quite similar to those of *Stephanodiscus alpinus* in LM observation. Careful SEM observation, however, reveals that *S. alpinus* has spines on every interfascicle (Hickel & Håkansson 1993, Håkansson 2002), while the spines of *S. uemurae* are absent when the mantle futoportulae are located near or at the valve face/mantle junction. Other differences between *S. alpinus* and *S. uemurae* are as follows. The former always has one valve face fultoportula while the latter usually does not have one. The fascicles of the former are always biseriate at the valve/mantle junction while those of the latter may be triseriate.

Comparisons of characteristics of *S. uemurae* to *S. kusuensis*, *S. alpinus* and *S. neoastraea* are summarized in Table 1.

Except for the rarity of areolae on its central valve face, *Stephanodiscus raripunctatus* Khursevich & Loginova looks similar to *S. uemurae* in valve view under LM. Careful SEM observation, however, reveals that *S. raripunctatus* has a deep mantle, interfascicles each having a spine and a rimoportula opening at the same level of the ring of spines (Khursevich 1999): these characteristics are all different from those of *S. uemurae*.

As stated above, *S. uemurae* can be characterized by the combination of its morphological features. The combination is unique, although the individual characteristics displayed by *S. uemurae* can be shared with other *Stephanodiscus* species, such as the ones mentioned above and many others like *Stephanodiscus medius* Håk. or *Stephanodiscus transilvanicus* Pant. and so on.

In Japan, no *Stephanodiscus* species have been found from Miocene sediment, but several have been reported from Pliocene (e.g. Skvortzov 1937, Okuno 1952, Tanaka & Matsuoka 1985). The Miyata Formation is considered to be a Mio-Pliocene deposit, but the exact age of the sampling site is difficult to determine. If indeed the deposit is in the future determined to be Late Miocene, *S. uemurae* would be the oldest species of *Stephanodiscus* in Japan.

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