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Two new *Mesodictyopsis* species, *M. akitaensis* sp. nov. and *M. miyatanus* sp. nov., from a Late Miocene to Pliocene freshwater sediment, Japan

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Two new *Mesodictyopsis* species, *M. akitaensis* sp. nov. and *M. miyatanus* sp. nov., are described from freshwater sediment of the Late Miocene to Pliocene Miyata Formation, northern Honshu, Japan. The species are characterized by small size, veluma on inner side of areolae, one fultoportula (sometimes two in *M. akitaensis*) on central valve face with two (in rare cases three in *M. miyatanus*) satellite pores, mantle fultoportulae with three satellite pores located on upper mantle close to valve face/mantle junction. Single rimoportula located in a row of areolae on marginal valve face near valve face/mantle junction in *M. akitaensis* or valve face/mantle junction on a strip in *M. miyatanus*. The veluma of *M. akitaensis* are cribra in inner view and sometimes volae on marginal valve face in outer view while those of *M. miyatanus* are cribra in both inner and outer view. The two species are compared with two similar reported *Mesodictyopsis* taxa.

Key words: fossil, diatom, *Mesodictyopsis*, ultrastructure, Lake Tazawa, Miyata Formation, Japan

Introduction

The Miyata Formation is located in the eastern part of Akita Prefecture, northern Honshu, Japan and is known to contain plant fossils (HUZIOKA and UEMURA 1973). The formation also contains freshwater diatoms and two reports have been published (TANAKA and NAGUMO 2002, TANAKA 2007).

Recently, the authors found two small centric diatoms characterized by velum on the inner side of areolae, one fultoportula (sometimes two in *M. akitaensis*) with two (in rare cases three in *M. miyatanus*) satellite pores on the central valve face and mantle fultoportulae with three satellite pores. The authors concluded that the taxa belong to the genus *Mesodictyopsis* proposed by KHURSEVICH et al. (2004) with seven species, six species found from upper Miocene–lower Pliocene deposits of Lake Baikal and one species from Miocene sediments of the Transbaikal area. It was not possible, however, to match the two

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new taxa with any of the seven *Mesodictyopsis* species reported thus far. The authors, therefore, propose the two new species as *Mesodictyopsis akitaensis* H.Tanaka et Nagumo and *Mesodictyopsis miyatanus* H.Tanaka. The two species described here are the first finding in the genus *Mesodictyopsis* outside the Lake Baikal area.

Materials and methods

Samples were collected from an outcrop on the northeast shore of Lake Tazawa in Senboku City (former Tazawako Town), Akita Prefecture (Fig. 1). All samples are laminated siltstone of the Miyata Formation estimated to be Late Miocene, according to the plant fossils (UEMURA 1988), or Pliocene by K-Ar and fission track methods (TSUCHIYA 1999).

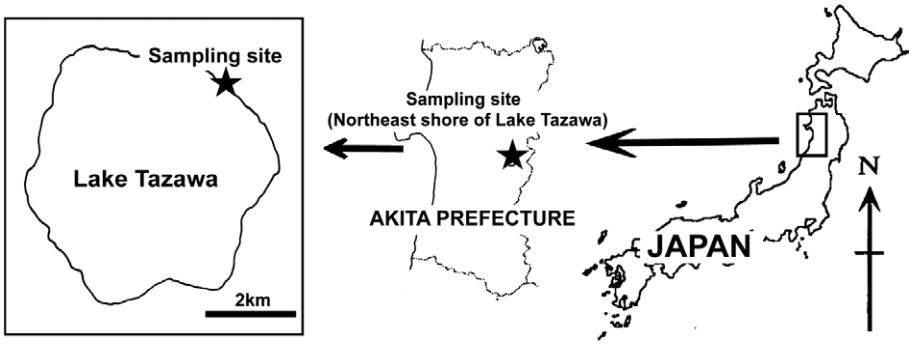


Fig. 1. Location of sampling site, Lake Tazawa, Senboku City, Akita Prefecture, Japan.

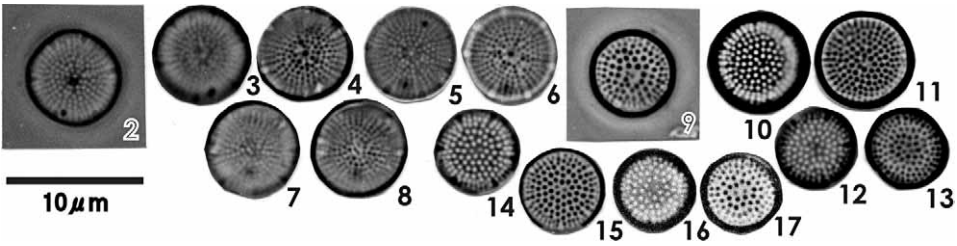
Samples were boiled in a 30% H_2O_2 solution to separate the sediment particles from the diatom valves. After cooling, the sediment was washed several times with distilled water, hydrochloric acid and nitric acid were added, then the solution was boiled to dissolve the calcium salts in the sample and washed again 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 plan-apochromat 100× oil immersion objective lens (NA = 1.4). SEM observations were made using a Hitachi S-4000 field emission microscope.

Terminology used is that of ROSS et al. (1979) and KHURSEVICH et al. (2004).

Descriptions of new species

***Mesodictyopsis akitaensis* H. Tanaka et Nagumo sp. nov. (Figs. 2–8, 18–29)**

Valves circular, flat valve face, ranging from 6.5–8.0 μm in diameter. Punctae rows ca. 24 in 10μm at valve margin. Vela located on inner side of areolae sometimes forming volae in outer view. One fultoportula (sometimes two) with two satellite pores located near the valve center. Mantle fultoportulae located on thickened strips of upper mantle, 6–8 in each valve, each with a short tube externally and three satellite pores internally. Single rimoportula lacking outer tube, internal sessile labia, within a row of areolae on marginal valve face near valve face/mantle junction. Valve mantle shallow, consisting of two or three areolae in a vertical row.



Pl. 1. *Mesodictyopsis akitaensis* and *Mesodictyopsis miyatanus* (Figs 2–17). **Figs. 2–8** – *Mesodictyopsis akitaensis* LM. **Fig. 2** – holotype, MPC-003017, National Museum of Nature and Science, Japan. **Figs. 3–8** – the same valves shown at different focal planes. **Figs. 9–17** – *Mesodictyopsis miyatanus*. LM. **Fig. 9** – holotype, MPC-003018, National Museum of Nature and Science, Japan. **Figs. 10–17** – the same valves shown at different focal planes.

Holotype: MPC-003017, Micropaleontology Collection, National Museum of Nature and Science, Japan.
Type locality: Northeastern shore of Lake Tazawa, Senboku City, Akita Prefecture, Japan (39° 44' N, 140° 41' E).
Type material: TAZ-F03, siltstone of Miyata Formation, Late Miocene to Pliocene, collected by one of authors (H. Tanaka) on 26 September 1992.
Etymology: The species name refers to the type locality, Akita Prefecture.

LM observation of *Mesodictyiopsis akitaensis* shows a small circular valve face with radiating rows of single punctae from valve center to margin (Figs. 2–8). Short, dark (or bright) lines appear on valve margin (mantle fultoportulae in SEM observation).

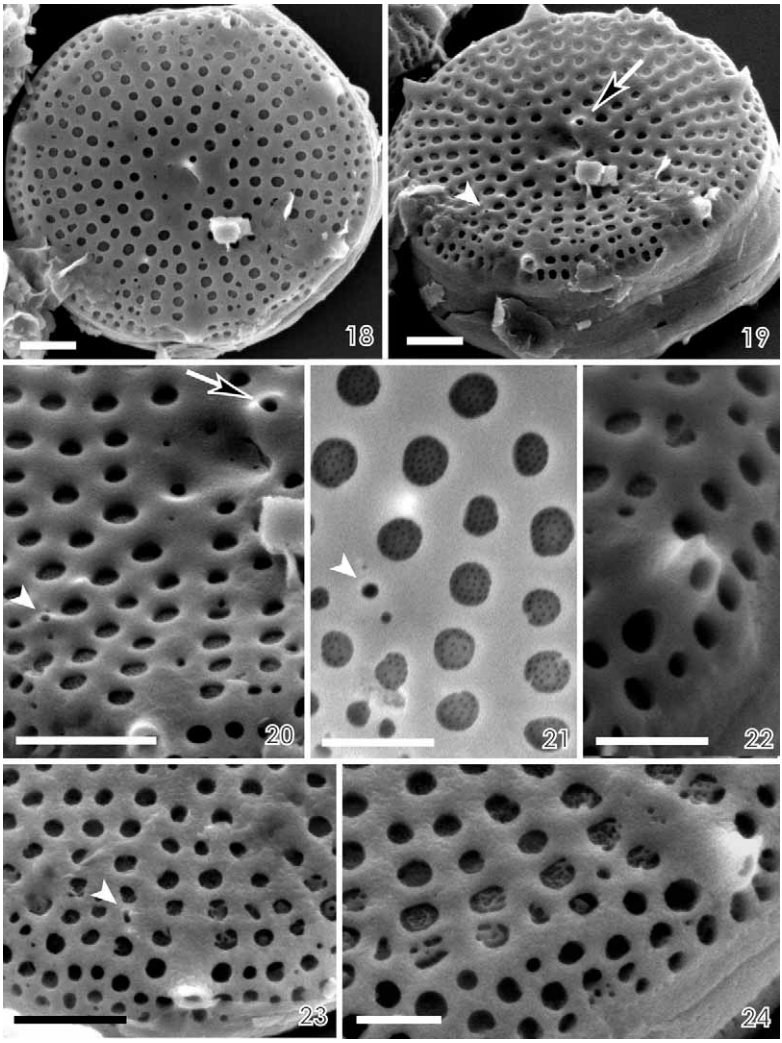
External SEM observation shows flat circular valve face with radiating areolae rows (Figs. 18, 19). Areolae of valve face are usually from round to oval in shape. Sometimes vela are volae in the outer view of marginal valve face (Figs. 23, 24), but always cribra in the inner view (Figs. 25–29). One opening of fultoportula (sometimes two) located near valve center (Figs. 18, 19). A small depression near valve center corresponds with a valve face fultoportula of sibling valve (Figs. 19, 20), as in *Cyclostephanos invisitatus* (M. H. Hohn et Hellerman) Theriot et al. (KOBAYASI and INOUE 1985). Mantle fultoportula openings with short tubes are located high on the mantle at the end of a costa (Fig. 19). A rimoportula opening, shaped round to slit, is located in a row of areolae on marginal valve face near valve face/mantle junction (Figs. 19–21, 23).

Internal SEM observation shows cribra located inside of areolae (Figs. 26–29), a valve face fultoportula (sometimes two) with two satellite pores (Figs 26, 28, 29), the mantle fultoportulae with three satellite pores each (Figs. 27, 28) located every four to eight costa, and a single sessile rimoportula located on the marginal valve face near valve face/mantle junction in a row of areolae (Figs. 28, 29). Areolae of marginal valve face are generally quadrilateral or polygon in shape.

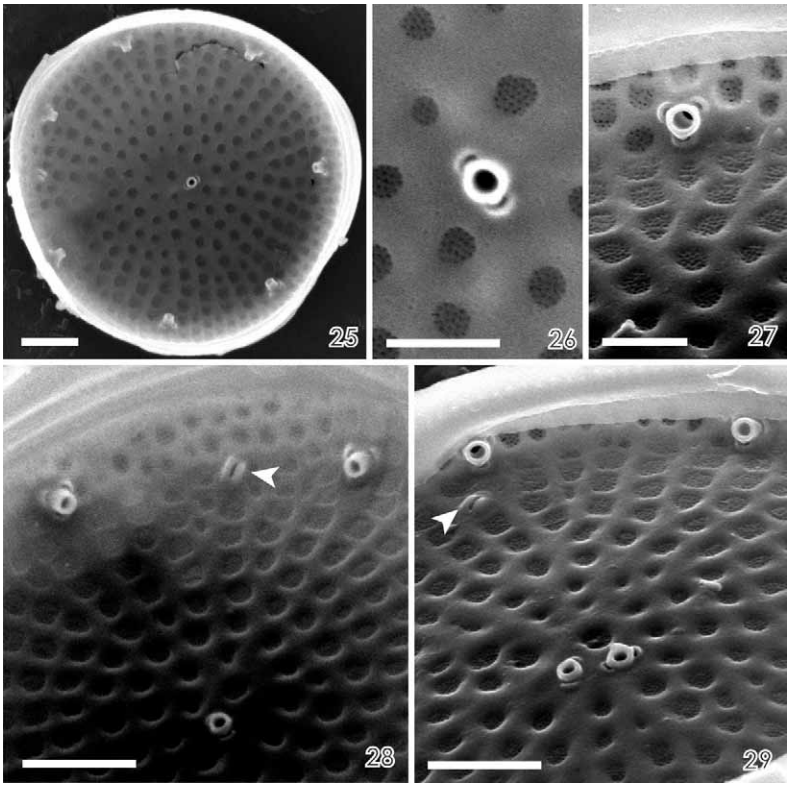
***Mesodictyopsis miyatanus* H. Tanaka sp. nov. (Figs. 9–13, 30–39)**

Valves circular, flat valve face, ranging from 4.0–8.0 μm in diameter. Punctae rows ca. 20 in 10 μm at valve margin. Cribra located on inner side of areolae. One fultoportula with two (in rare cases three) satellite pores occurs near the valve center. Mantle fultoportulae

located at the end of the costa of the upper mantle, 5–7 in each valve, each with a short tube externally and three satellite pores internally. Single rimoportula lacking outer tube, internal sessile labia, on valve face/mantle junction. Valve mantle shallow, consisting of two or three areolae in a vertical row.



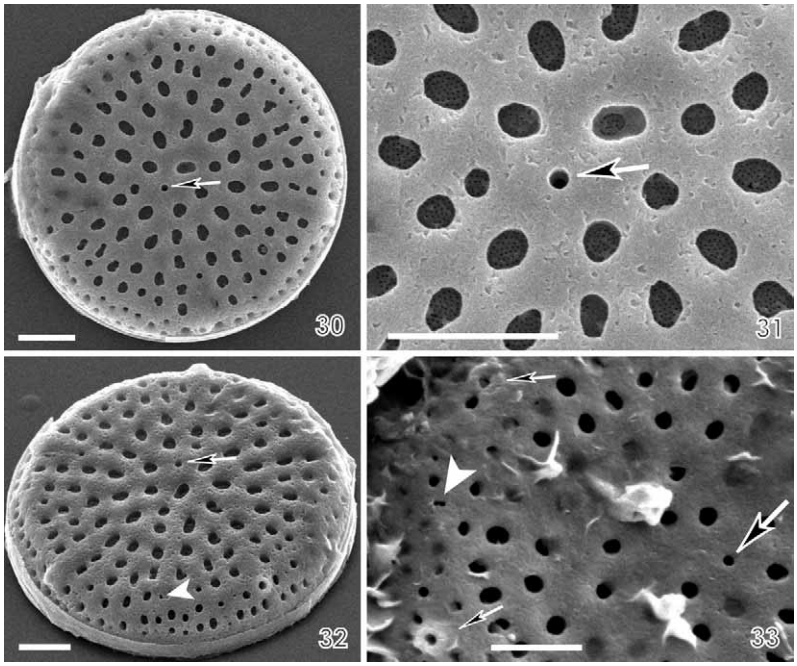
Pl. 2. *Mesodictyopsis akitaensis*. SEM, external views (Figs. 18–24). **Fig. 18** – Whole valve. **Fig. 19** – oblique view of figure 18 showing opening of valve face fultoportula (arrow), opening of rimoportula (arrowhead). **Fig. 20** – enlarged view of figure 19 showing opening of valve face fultoportula (arrow), opening of rimoportula (arrowhead) and central depression. **Fig. 21** – detailed view of figure 18 showing cribra and opening of rimoportula (arrowhead). **Fig. 22** – detailed view of opening tube of mantle fultoportula. **Fig. 23** – valve margin showing volae and opening of rimoportula (arrowhead). **Fig. 24** – enlarged view of valve margin showing volae. scale bars = 1 μm (Figs. 18–20, 23), and 0.5 μm (Figs. 21, 22, 24).



Pl. 3. *Mesodictyopsis akitaensis*. SEM, internal views (Figs. 25–29). **Fig. 25** – whole valve. **Fig. 26** – detailed view of a valve face fultoportula with two satellite pores and areolae with cribra inside. **Fig. 27** – detailed view of mantle fultoportula with three satellite pores and areolae with cribra inside. **Fig. 28** – enlarged oblique view of figure 25 showing rimoportula (arrowhead) in an areolae row and cribra. **Fig. 29** – enlarged view showing two valve face fultoportulae with two satellite pores each and rimoportula (arrowhead) located in an areolae row. Scale bars = 1 μm (Figs. 25, 28, 29) and 0.5 μm (Figs. 26, 27).

Holotype: MPC-003018, Micropaleontology Collection, National Museum of Nature and Science, Japan.
Type locality: Northeastern shore of Lake Tazawa, Senboku City, Akita Prefecture, Japan (39° 44' N, 140° 41' E).
Type material: TAZ-F03, siltstone of Miyata Formation, Late Miocene to Pliocene, collected by one of the authors (H. Tanaka) on 26 September 1992.
Etymology: The species name refers to the Miyata Formation where the new species was found.

LM observation of *Mesodicyiopsis miyatanus* shows a small circular valve face with approximately radiating rows of single punctae from valve center to margin but having a slightly irregular arrangement at the valve center (Figs. 9–17). Short dark (or bright) lines are located on the valve margin (mantle fultoportulae in SEM observation). External SEM observation shows flat circular valve face with radial areolae rows (Figs. 30, 32). Areolae



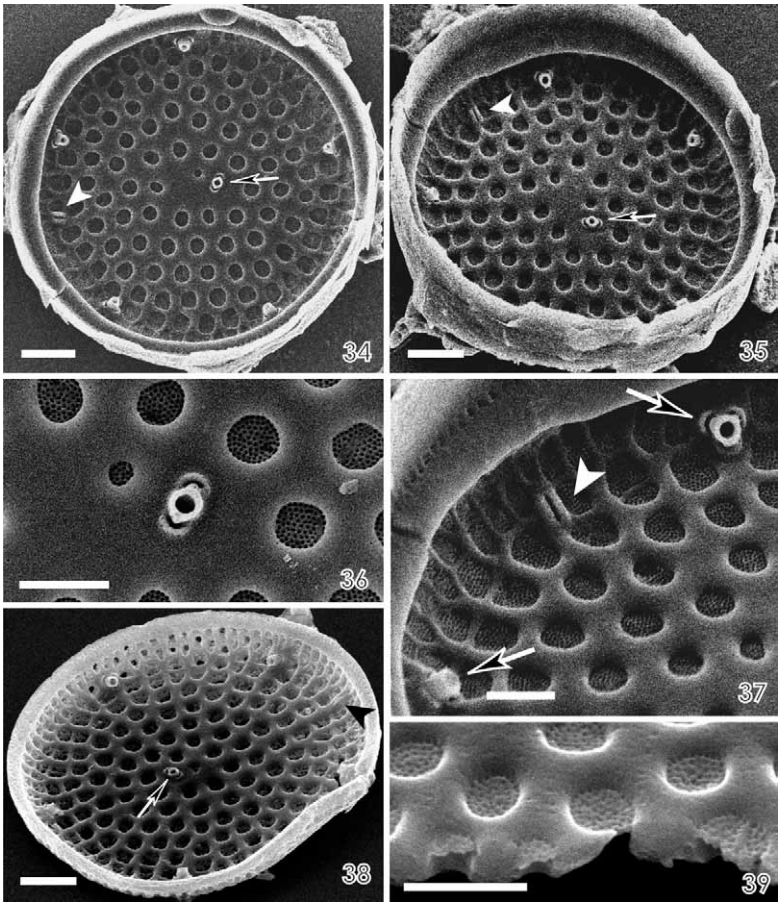
Pl. 4. *Mesodictyopsis miyatanus*. SEM, external views (Figs. 30–33). **Fig. 30** – whole valve (arrow: opening of valve face fultoportula). **Fig. 31** – enlarged view of figure 30 showing opening of valve face fultoportula (arrow). **Fig. 32** – oblique view of figure 30 showing opening of valve face fultoportula (arrow) and opening of rimoportula (arrowhead). **Fig. 33** – detailed view of valve face showing opening of valve face fultoportula (large arrow), openings of two mantle fultoportulae (small arrows) and opening of rimoportula (arrowhead). Scale bars = 1 μm.

of valve face and mantle are from round to oval in shape. Diameters of central valve face areolae are usually slightly larger than those of margin. Vela are always cribra. A valve face fultoportula opening located near valve center (Fig. 30). Mantle fultoportulae openings with short tubes are located high on the mantle atop every (four) five to eight (nine) costa (Fig. 32). A rimoportula opening is located on valve face/mantle junction on a costa (Figs. 32, 33).

Internal SEM observation shows the cribra located inside of areolae (Fig. 39), one valve face fultoportula with two (rarely three) satellite pores (Fig. 36), mantle fultoportulae always with three satellite pores each (Fig. 37), and a single sessile rimoportula located on valve face/mantle junction on a costa (Figs. 37, 38). Areolae of internal valve face are usually from round to oval in shape but generally quadrilateral in marginal valve face.

Discussion

The presence of cribra within the areolae is a characteristic shared by both the freshwater genera *Mesodictyon* and *Mesodictyopsis* of Stephanodiscaceae Makarova (KHURSEVICH et al. 2004). However, mantle fultoportulae with three satellite pores each and fulto-



Pl. 5. *Mesodictyopsis miyatanus*. SEM, internal views (Figs. 34–39). **Fig. 34** – whole valve (arrow: valve face fultoportula, arrowhead: rimoportula). **Fig. 35** – oblique view of figure 34 showing valve face fultoportula (arrow) and rimoportula (arrowhead). **Fig. 36** – detailed view of figure 34 showing valve face fultoportula with two satellite pores and areolae with cribra inside. **Fig. 37** – enlarged view of figure 35 showing rimoportula (arrowhead) and two mantle fultoportulae with three satellite pores (arrows). **Fig. 38** – oblique view of valve (arrow: valve face fultoportula, arrowhead: rimoportula). **Fig. 39** – cross section of valve face showing cribra inside the areolae. Scale bars = 1 μm (Figs. 34, 35, 38) and 0.5 μm (Figs. 36, 37, 39).

portula(e) on the valve face are characteristic of *Mesodictyopsis* (KHURSEVICH et al. 2004). *Mesodictyon* has no valve face fultoportulae and its mantle fultoportulae have two satellite pores (THERIOT and BRADBURY 1987). The two new species described here belong to *Mesodictyopsis* because they both have cribra inner sides of the areolae, one valve face fultoportula (*M. akitaensis*: sometimes two) with two (*M. miyatanus*: in rare cases three) satellite pores and mantle fultoportulae always with three satellite pores.

KHURSEVICH et al. (2004) reported three morphological groups in *Mesodictyopsis.* The first group is characterized by the location of a single rimoportula at the valve face/mantle

junction or in the submarginal zone of the valve face. This puts both *M. akitaensis*, single rimoportula on marginal valve face close to valve face/mantle junction, and *M. miyatanus*, single rimoportula on valve face/mantle junction, in this first morphological group.

Mesodictyopsis akitaensis

Mesodictyopsis akitaensis differs from the other two members of the first morphological group in KHURSEVICH et al. (2004), *Mesodictyopsis singularis* Khursevich, Iwashita et Fedenya and *Mesodictyopsis peculiaris* Khursevich, Kociolek et Fedenya, in significant ways. First, *M. akitaensis* has only one (rare cases, two) valve face fultoportulae with two satellite pores while *M. singularis* may have one to several with three satellite pores. Also, the mantle fultoportulae of *M. akitaensis* are fewer with one every five to eight strips and those of *M. singularis* every two to rarely three strips (Tab. 1). *M. peculiaris* has a rimoportula located between two closely placed mantle futoportulae while the others are widely spaced. *M. akitaensis,* on the other hand, has mantle fultoportulae always located every five to eight strips.

Mesodictyopsis has cribra inside of the areolae (KHURSEVICH et al. 2004) and while this is true of *M. akitaensis*, it sometimes has volae, especially on marginal valve face in external views.

Mesodictyopsis miyatanus

M. miyatanus differs from *M. singularis* in that it has a higher density of punctae rows and more punctae in each row, only one valve face fultoportula usually with two satellite pores and mantle fultoportulae located every five to eight strips. *M. miyatanus* is distinguished from *M. peculiaris* by mantle fultoportulae located on every five to eight costae and its rimoportula is located between two of these spaced mantle fultoportulae, not close together as in *M. peculiaris*.

With the exception of the vela inside the areolae, other similar species such as *Thalassiosira dispar* (Perag. et Hérib.) Serieyssol (SERIEYSSOL et al. 1998) exist having a valve face fultoportula with two or three satellite pores, mantle fultoportulae with three satellite pores and a rimoportula at the valve face mantle border. The presence of vela inside the areolae then is the defining characteristic of *M. miyatanus*.

In Japan, TANAKA and NAGUMO (2006) reported *Mesodictyon* sp. from the Late Miocene Mitoku Formation, Tottori Prefecture. The species, however, has vela inside the areolae, one valve face fultoportula located near center and mantle fultoportulae with three satellite pores, actually features of *Mesodictyopsis*. *Mesodictyopsis* taxa therefore have been found in two formations in Japan, the Mitoku Formation and the Miyata Formation.

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Tab. 1. Comparison of *Mesodictyopsis akitaensis, M. miyatanus, M. peculiaris, M. singularis*.

Characteristics		*M. akitaensis*	*M. miyatanus*	*M. peculiaris*	*M. singularis*
Valve face					
diameter (μm)		6.5–8.0	4.0–8.0	3.0–9.5	4.0–17.2
punctae rows (in 10 μm)		ca. 24	ca. 20	15–20	14–18
punctae (in 10 μm)		ca. 24	ca. 20	ca. 20	12–16
Fultoportulae					
valve face	location	near valve center	near valve center	near valve center	near valve center
	number	1(2)	1	1	1-several
	satellite pores	2	2(3)	2	3
mantle	location	every 4–8 strip	every (4)5–8(9) strip	two are placed close to one another, the rest widely spaced	every 2(3) strip
	number (/valve)	6–8	5–7	4–6	ca. 18
	satellite pores	3	3	3	3
Rimoportula					
	position	marginal valve face (near, valve face/mantle junction), on punctae row	valve face/mantle junction, on strip	marginal valve face (near valve face/mantle junction), between two closely located mantle fultoportulae	marginal valve face (near valve face/mantle junction)
	number	1	1	1	1
References		this paper	this paper	KHURSEVICH et al. (2004)	KHURSEVICH et al. (2004)

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