

## The type material of *Tetracyclus japonicus* (Petit) Temp. & H. Perag. and *Tetracyclus eckhardii* Ehrenb. (Bacillariophyceae)

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**Abstract** — This paper illustrates type material for both *Tetracyclus japonicus* (Petit) Temp. et Perag. (= *Stylobibulum japonicum* Petit) (Sendai, Japan, Fossil, possibly Miocene) and *Tetracyclus eckhardii* Ehrenberg (Ostheim, Germany, Fossil, age unknown). While it remains possible to confuse the two species, the latter (*Tetracyclus eckhardii*) has not been recorded since Ehrenberg's description in 1848.

**Diatoms / Type material / *Tetracyclus***

**Résumé** — Le matériel type de *Tetracyclus japonicus* (Petit) Temp. et H. Perag. et de *Tetracyclus eckhardii* Ehrenb. (Bacillariophyceae). Cet article illustre le matériel type de *Tetracyclus japonicus* (Petit) Temp. et Perag. (= *Stylobibulum japonicum* Petit) (Sendai, Japon, Fossile, probablement Miocène) et de *Tetracyclus eckhardii* Ehrenberg (Ostheim, Allemagne, Fossile, d'âge inconnu). Tandis qu'il reste possible de confondre les deux espèces, *Tetracyclus eckhardii* n'a pas été enregistrée depuis la description d'Ehrenberg en 1848.

**Diatomées / matériel type / *Tetracyclus***

### INTRODUCTION

*Tetracyclus japonicus* (Petit) Temp. et H. Perag. is a distinctive fossil diatom, displaying a characteristic 12-pointed star shaped valve that may superficially suggest that it is a centric diatom with radial symmetry rather than a pennate diatom with bilateral symmetry. In a revision of species originally described for the genus *Stylobibulum* Ehrenb., Williams gave a detailed account of the valve and girdle morphology of *Tetracyclus japonicus* from some exceptionally well preserved material from its type locality in Sendai, Japan (Williams, 1989). The specimens examined clearly demonstrated a central, bilateral sternum, confirming its 'pennate' symmetry, and a series of transapical ribs and septate girdle bands, confirming its placement in the genus *Tetracyclus* Ralfs. In addition, the

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material was so well preserved that the extremely delicate pleural band was discovered *in situ* on a number of specimens.

*Tetracyclus japonicus* is not widespread; it is distributed around the Pacific Ocean, particularly occurring in Japan and USA (California) (Williams, 1989). While it might be difficult to mis-identify *T. japonicus*, a number of less well known species, all with 'star'-shaped valves, can be distinguished from *T. japonicus* and have been described as separate species. From the perspective of the palaeobiogeography of the genus, it was important to separate out these rather similar species and establish both their identity and geographic range. Williams (1997) established that *Tetracyclus castellum* (Ehrenb.) Grun., from Oregon, should be recognised and a new species, *Tetracyclus pseudocastellum* Williams, from China, was identified. Thus, the 'star'-shaped species in the genus *Tetracyclus* were all considered as extinct Pacific rim species.

Rather surprisingly, when type specimens of *Tetracyclus eckhardii* (Ehrenb.) F.W. Mills were examined, they initially appeared to represent European specimens of *T. japonicus*. While Ehrenberg described *T. eckhardii* (Ehrenberg 1848), he never published any of his illustrations. On closer examination of Ehrenberg's specimens, it became apparent that *T. eckhardii* only superficially resembled *T. japonicus*, primarily differing in the numbers of 'points' to the star outline of the valve and, more significantly, in the structure of the central sternum.

Since the publication of Williams (1989), Petit's slides of *T. japonicus* have been identified and examined and figures of Petit's holotype specimens are presented. In addition, details of Ehrenberg's specimens and drawings of *T. eckhardii*, a distinct species, are presented based on material in his collections.

## OBSERVATIONS

*Tetracyclus japonicus* (Petit) Temp. et H. Perag. 1909: 185.

**Basionym:** *Stylobibulum japonicum* Petit 1890: 47, fig. 1 a-c. *non Stylobibulum japonicum* Pant. 1892 = *S. carinatum* Pant. 1905.

**Type locality:** "Lignites du Sendai, Japon".

**Type slides:** There are three slides in PC, all of which have a number of selected specimens (PC Petit, 'Japon', box 27, Slides 1-3; lectotype indicated with 'type' label; D.M. Williams, 28/6/2002). Slide 1, selected here as the lectotype, has 5 specimens in valve view and 5 in girdle view; slide 2 has 7 specimens in valve view and c.20 in girdle view plus a few girdle fragments; slide 3 has 2 specimens in valve view, 1 girdle fragment and 1 specimen in girdle view. In spite of slide 2 having more specimens, those on slide 1 are orientated better for microscopy (they lie flatter) and hence that slide is the best of the three. Three specimens have been illustrated (Figs 1-4) of which the specimen illustrated on figures 1-2 is best designated as lectotype. All specimens from the three slides have the characteristic 12-'pointed' star-shaped outline. The type material from 'Sendai' is widely dispersed in various diatom herbaria and all specimens so far examined (see below) have the 12-pointed 'star' outline.

**Description:** Valves circular, 35-60  $\mu\text{m}$  in diameter; valves with characteristic 12-pointed 'star' outline, each tip curving at the margin. Ribs primary, secondary and tertiary, usually extending into each point of the 'star', meeting the

sternum, 2-4 in 10  $\mu\text{m}$ . Striae in equidistant rows, 20-45 in 10  $\mu\text{m}$ , sometimes scattered towards the central sternum. Sternum central, distinct, sometimes appears less distinct towards the poles. Rimoportulae present on valve margin, obscure, not visible in LM, usually situated near a transapical rib. Cingulum consisting of four distinct components, all open ligulate bands. Valvocopula without ligula; pars interior consisting of 2-4 poroids appearing as simple apertures, internally. Septum extending from above pars interior; small pores penetrating the ligula; no pars exterior ornamentation. Primary copulae consisting of 10-12 elements, possessing an advalvar ligula. Secondary copulae usually three bands, lacking a pore area within the ligula; pars interior consisting of a single row of poroids. Single pleura lacking both ornamentation and septum. (For SEM details see Williams, 1989).

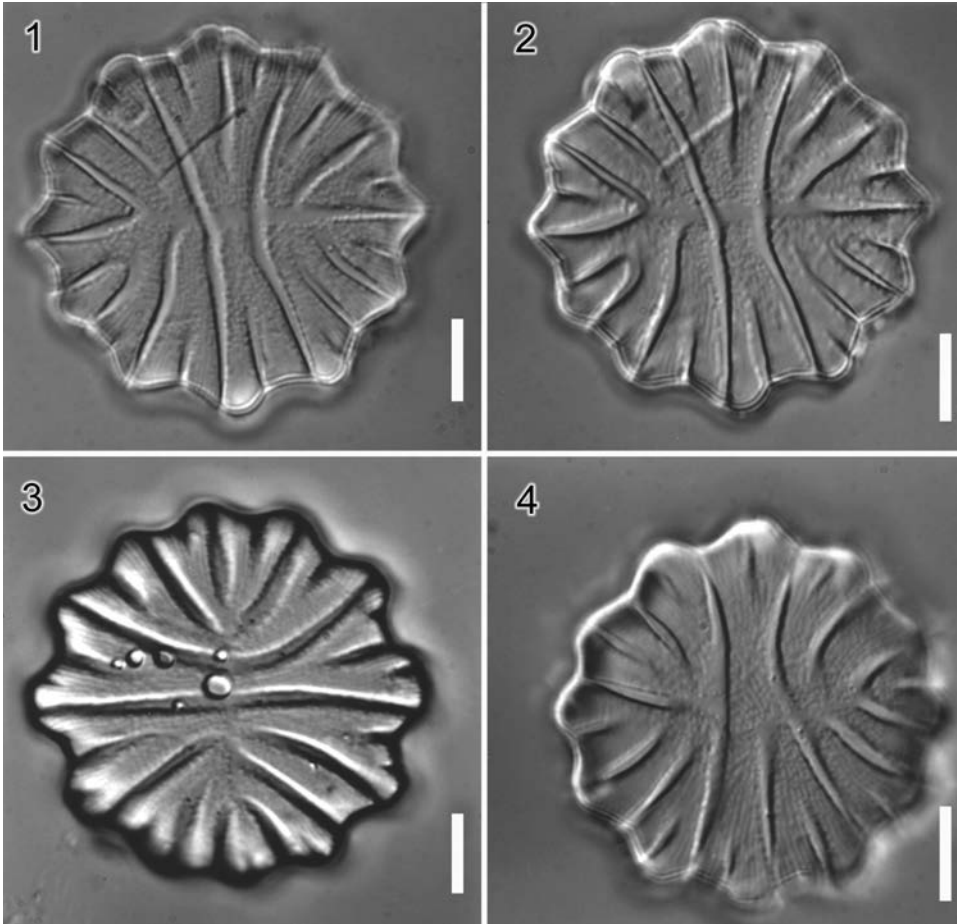
**Notes:** This species is usually identified by its characteristic shape, the 12-pointed star outline. The valve's shapes appears to remain rather constant in all specimens examined so far: from the fossil deposit found in the Kettleman Hills, California, USA (Lohman, 1938; Williams, 1989) and the type material from Sendai. Its distribution appears restricted to Japan (Sendai), on the East coast of the Pacific, and the USA (California and Oregon) on the West coast. Tschermissovna (1973) has reported this species from the Miocene deposit of Tunka Ridge, Lake Baikal, Siberia, Russia although she published no illustrations and the occurrence of this species in Siberia has yet to be confirmed.

**Nomenclature:** Some early confusion arose as the specific epithet *japonicus* was used in two different senses. Pantocsek (1892) applied the name *Stylobibulum japonicum* for a circular species he discovered in a portion of the Sentenai fossil deposit. Although Pantocsek eventually noticed the prior usage of the epithet *japonicus* (see also Baxter, 1893: 54) and proposed the substitute name *S. carinatum*, the incorrect usage of *Stylobibulum japonicum* is still occasionally used for the diatom *Tetracyclus excentricum* (Ehrenb.) D.M. Williams (Williams, 1989; see Van Landingham, 1967; Li, 1982, for example).

#### **Distribution (specimens):**

**JAPAN:** Lignites, Sendai. It is not clear exactly where this material comes from. Tsumura (1967) suggests that it may be from the Miyagi Prefecture, where Sendai City is located, as there are some freshwater fossils deposits found here. BM 7455, BM 7456 (= "Lignite, Thiergarten, Japan Berlin." The probability that this is a Germany deposit is doubtful. Examination of material from 'Thiergarten, Berlin' [BM 58949 and BM 54713] has a somewhat dissimilar flora to that on BM 7456, leading to the suspicion that the 'Berlin' part of the label is erroneous. The slide is labelled "*Tetracyclus* var?" and, according to Kitton, who received the slides, identified as "*Tetracyclus* abnormal". This is probably a reference to the unusual shape, which may have been new to Kitton. The specimen is not *T. emarginatus* f. *abnormis* Fontell [Fontell, 1917:63, pl. 2, fig. 54]), BM 7457, BM 7458, BM 8004-5, BM 8007-10, BM 14331, (Tempère & Peragallo, *Diat. monde entier*, 1st edn, no. 79), BM 15393, BM 54900, BM 56432, BM 58945, BM 60462-3, BM 64153, BM 68690-1 (Tempère & Peragallo, *Diat. monde entier*, 2nd. edn nos 344, 345), BM 71372, BM 71402, BM 74204-5, BM 747C, BM B 441, BM GC 1660, BM J 585-6, BM TS 319.

**USA:** California, Kettleman Hills, Tulare Formation, 36° 48' 25" N, 118° 35' 42" W, Upper Pliocene (USGS 2213), (see Lohman, 1938: 83; Williams, 1989), BM s.n., CAS 362003; Oregon, Linn. Co. North Santian Highway, CAS 434003-4.



Figs 1-4. *Tetracyclus japonicus* (Petit) Temp. et H. Perag. Lectotype slide PC Petit, 'Japon', box 27, Slide 1 (lectotype indicated with 'type' label; D.M. Williams, 28/6/2002). Figs 1 and 2 (same specimen), 45  $\mu\text{m}$  in diameter, Fig. 3, 35  $\mu\text{m}$  in diameter, Fig. 4, 55  $\mu\text{m}$  in diameter (measured along sternum). Bar = 10  $\mu\text{m}$ .

**Distribution (Illustrations):**

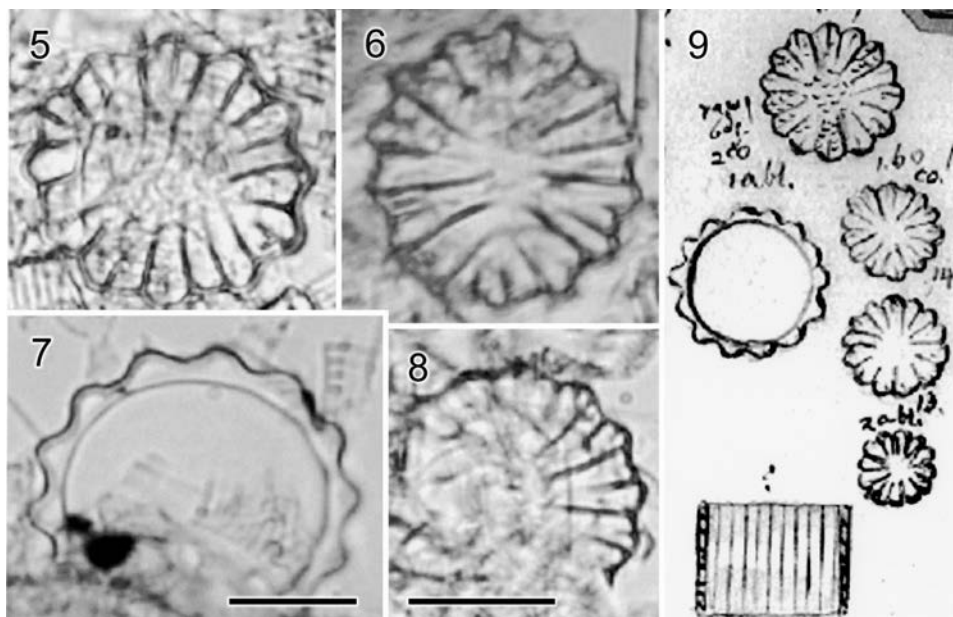
JAPAN: Petit 1890: 47, fig. 1; Hustedt in A. Schmidt 1912: Taf. 282, Figs 1-2, "Senday (Japan), f.S. (Reichelt)"; Williams 1989: Figs 25, 26, Sendai Lignites, Japan".

??RUSSIA: Tscheremissinova 1973:30 [no illustration];

USA: Williams 1989: Figs 24, 27, 28, 29-32, "Kettleman Hills, Fresno, California".

**Erroneous identifications:**

Lupikina 1965: pl. 3, Figs 1-3; Khursevich & Loginova 1980: pl. 17, Fig. 13; Khursevich 1982:pl. II, fig. 7; Temniskova-Topalova & Ognjanova-Rumenova 1994: l. I, fig. 12 = *Tetracyclus castellum* (Ehrenb.) Grun. (see Williams, 1997).



Figs 5-9. *Tetracyclus eckhardii* ('eckhardtii') (Ehrenb.) F.W. Mills Type specimens, Ehrenberg collection, Museum für Naturkunde, Humboldt Universität zu Berlin (BHUMP). Fig. 5: Tray 476 (L), case 42, book 2, 1<sup>st</sup> mica (blue ring) (1-3), 'Tripel von Ostheim...', lectotype; Figs 6 and 8: Tray 476 (L), case 42, book 2, 5<sup>th</sup> mica, "Tripel von Ostheim 2", lectotype; Fig. 7: Tray 476 (L), case 42, book 2, 4<sup>th</sup> mica, "Tripel von Ostheim 4", 4<sup>th</sup> mica. Bar = 25  $\mu$ m. Fig. 9: Reproduction of part of Ehrenberg sheet 2346, illustrating specimens of *Tetracyclus eckhardii*.

Li 1982: pl. II, figs 1-5 = *Tetracyclus clypeus* (Ehrenb.) Li (see Williams, 1989).

Huang *et al.* 1983: pl. 7, Figs 1-2. Huang *et al.*'s specimens are not easily identified. They have the characteristic valve outline of *T. japonicus* but also have an extremely diffuse central sternum suggesting a relationship with *T. eckhardii* (see below).

***Tetracyclus eckhardii* ('eckhardtii')** (Ehrenb.) F.W. Mills 1935 (February):1601.

**Basionym:** *Stylobibulum eckhardii* Ehrenb. 1848: 13.

**Type locality:** "...Kieselguhr von Ostheim..." (Ehrenb. 1848: 13).

**Lectotype:** Ehrenberg collection, Museum für Naturkunde, Humboldt Universität zu Berlin (BHUMP). Tray 476 (L), case 42, book 2, 1<sup>st</sup> mica (blue ring) (1-3), 'Tripel von Ostheim...' (Fig. 5); additional specimens, Tray 476 (L), case 42, book 2, 5<sup>th</sup> mica, "Tripel von Ostheim 2" (Figs 6, 8), 1<sup>st</sup> mica, "Tripel von Ostheim 3", 4<sup>th</sup> mica; "Tripel von Ostheim 4" (Fig. 7). (Ostheim probably refers to the small town near Bayern in Germany [50.28N, 10.14E]). All specimens c.50  $\mu$ m in diameter, measured along sternum.]

Several micas exist in the Ehrenberg collection with marked specimens of *T. eckhardii*. Ehrenberg labelled some of these micas with an alternative name,

'*Stylobibulum pellatan*' *nom. herb.*, a name he never published, evidently favouring *eckhardii*. Ehrenberg's manuscript drawings contain one sheet of illustrations for the "Ostheim" material (sheet 2346), which includes 6 illustrations of *T. eckhardii*, five of valve views (four valves, one girdle band), one in girdle view (Fig. 9). The specimens illustrated by Ehrenberg were located on the appropriate micras, a selection of which have been photographed.

**Description:** Valves circular, 35-50  $\mu\text{m}$  in diameter, most with a 14 pointed star, some with 12 or 13 points, each point of the star curving gently. Ribs primary, secondary and tertiary, usually extending into each point of the 'star', meeting an ill-defined sternum, 2-4 in 10  $\mu\text{m}$ . Striae rather indistinct but possibly parallel to the margins (Figs 5-6). Sternum central, ill-defined. Rimoportulae not observed; one girdle noted (Fig. 7), appears as a closed band but specimen obscured by other material so confirmation not possible (but see Fig. 7, Ehrenberg's illustration of a girdle band).

**Notes:** The only specimens of *T. eckhardii* observed so far are those from Ehrenberg's original material; no illustrations of this taxon have been discovered or any other specimens found. In total 9 specimens were found and examined. Of these, 5 had 14 points to the outline, of the remaining four, three had 12 points and one had 13 points (compare with the drawings on Fig. 9 where 3 have 14 points, the remaining two having 13 and 12 apiece). It is quite possible that this taxon has not, and was not, observed by any other diatomist since Ehrenberg provided its description. Ehrenberg (1848: 13) noted its distinct outline, commenting on its 'star' shape and noting its distinctive girdle bands. It remains a puzzle as to why he never published his drawings. The most distinctive feature of this diatom is the diffuse central sternum compared to the regular and rather better defined sternum of *T. japonicus*, which serves to distinguish the two species. In this respect, two published illustrations may be specimens of *T. eckhardii*. The first is an illustration of a single valve in Ozornina (1993: plate 1, fig. 29), a study on Pleistocene diatoms from Kamchatka. The second is a single valve and a single girdle band in Huang *et al.* (1983: pl. 7, figs 1-2) from China, "...Changbai, Yongji, Hunjiang and Jiaohe, Jilin Province." The specimen from China is somewhat unusual and it cannot be definitely associated with *T. eckhardii*, while the specimen from Kamchatka is more convincing. Regardless, both specimens have the diffuse central sternum and are evidently not *T. japonicus*.

De Toni (1892: 750) noted *Stylobibulum eckhardii* (as *Stylobibulum 'eckhardtii'* Ehrenb.), adding: 'Species mihi omnino ignota...Hab. Fossile in stratis epochae tertiariae in Hassia "Bergtesgaden" (Ehrenberg).' The alternative spelling used by De Toni appeared in Peragallo (1897: 864, *Stylobibulum 'eckhardtii'* Ehrenb.), Hustedt (1914:103, *Tetracyclus (Stylobibulum) eckhardti'* Ehrenb., 'Nomina nuda.'). Mills (1935:1504, *Stylobibulum 'eckhardtii'* Ehrenb. 'non. [sic] nud.') and Van Landingham (1978: 3793, *Stylobibulum eckhardi ('eckhardtii')* Ehrenb. 'Ehrenberg 1845 [sic, 1848], p. 13'; corrected to 1848 on p. 3982).

## DISCUSSION

The two species discussed herein, *T. japonicus* and *T. eckhardii*, can be separated relatively simply by the more or less regular sternum in the former, and the diffuse and irregular sternum of the latter. *T. japonicus* remains a circum-

Pacific diatom, while *T. eckhardii* has a European distribution, extending to Kamchatka and possibly China. A more detailed examination of other specimens supposedly of *T. japonicus* may assist with elucidating the distribution of species in this genus, especially as so many of the fossil representatives are either distributed around the Pacific rim or are within the Northern boreal (Williams, Accepted).

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