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TERTIARIUS HIDALGENSIS SP. NOV., A NEW DIATOM SPECIES FROM NEOGENE DEPOSITS IN CENTRAL MÉXICO

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Se describe una nueva especie que fue estudiada con microscopio de luz y con microscopio electrónico de barrido, encontrada en sedimentos lacustres del Plioceno provenientes del centro de México: *Tertiarius hidalgensis* (Bacilariophyta: Stephanodiscaceae). Esta especie tiene alvéolos simples y complejos, formados por bandas hialinas engrosadas, una rimoportula elevada localizada dentro de una de las cámaras alveolares, 4 a 10 fultoportulae en la cara valvar rodeadas por 2 o por 2 y 3 poros stelitales, fultoportulae en el manto con 2 poros satelitales, localizadas al extremo de los costae gruesos interiores, sobre la pared. *T. hidalgensis* es una especie aparentemente extinta, de importancia bioestratigráfica, que extiende la distribución geográfica del género hacia latitudes tropicales y es una nueva evidencia de la gran diversidad que alcanzaron las especies de agua dulce de la familia Stephanodiscaceae durante el Neogeno.

A new species, *Tertiarius hidalgensis* (Bacillariophyta: Stephanodiscaceae), studied with light (LM) and scanning electron microscopy (SEM), is described from Pliocene sediments in central Mexico. This species possesses simple and complex alveolae formed by thickened hyaline strips, a single raised rimoportula located within one of the alveolar chambers, 4 to 10 valve face fultoportulae bounded by 2 or by 2 and 3 satellite pores, and mantle fultoportulae with 2 satellite pores positioned above thick internal costae on the surrounding wall. *T. hidalgensis* is apparently an extinct species of biostratigraphic significance; it extends the geographic distribution of this genus into tropical latitudes and gives further evidence of the great diversity that the freshwater Stephanodiscaceae reached during the Neogene.

INTRODUCTION

Tertiarius Håkansson *et* Khursevich was erected as a new genus (Håkansson & Khursevich 1997) after detailed study of *Cyclotella pygmaea* Pantocsek, *C. transilvanica* Pantocsek var. *transilvanica* and *C. transilvanica* var. *disseminatepunctata* Pantocsek from

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the type locality at Köpecz, Transylvania in Romania. These taxa are found in Miocene to Pliocene deposits. Later *Tertiarius baicalensis* Khursevich *et* Fedenya was reported from the middle-upper Pliocene sediments of Lake Baikal, Russia (Khursevich *et al.* 2001, 2003), and four new species of *Tertiarius* were described from upper Miocene to Pliocene diatomaceous rocks from western U.S.A. (Khursevich & Kociolek 2002) (Fig. 1).

The genus *Tertiarius* may also include specimens identified as "*Cyclotella hannaites*" from Miocene diatomites of Harney and Malheur Counties, Oregon, U.S.A. (Van Landingham 1967), "*Cyclotella* sp. aff. *C. pygmaea* or *C. hannaites* Van Landingham" from the Glenns Ferry Formation, Owyhee County, Idaho, U.S.A. (Bradbury & Krebs 1982), "*Cyclostephanos pygmaea* (Pantocsek) Khursevich" from Pliocene deposits of the Black Sea (Khursevich 1989) and "*Cyclotella macedonica* Jurily" from the Pliocene uppermost part of the lacustrine sequence in Mariovo Basin in Macedonia (Ognjanova-Rumenova 2001), but further detailed SEM observations are needed.

Tertiarius hidalgensis sp. nov. was identified from Pliocene sediments in central Mexico. This find extends the geographic distribution of the genus into tropical latitudes of the North American continent (Fig. 1) and adds further evidence of the high diversity that the freshwater Stephanodiscaceae reached during the Neogene.

MATERIALS AND METHODS

The investigated material was collected from the Sanctorum locality, in the state of Hidalgo, in central Mexico (Fig. 1). The Sanctorum outcrop is part of the lacustrine sequence of the Atotonilco el Grande Formation (Segerstrom 1961, Arellano-Gil *et al.* 2005). This formation is covered by volcanic rocks that were dated as 2.5 and 2.3 Ma (Cantagrel & Robin 1979), suggesting an early-middle Pliocene age for the sediments.

The studied material was cleaned with HCl (10%) and concentrated hydrogen peroxide (30%), and aliquots of the clean material were air-dried on individual coverslips. For light microscopy observation coverslips were mounted using Naphrax; mounted slides were viewed with an Olympus BX50 with interdifferential phase contrast. For scanning electron microscopy, coverslips were attached to aluminum stubs with two sided carbon tape, coated with gold and observed using a JSM 5600-LV.

RESULTS

***Tertiarius hidalgensis* Caballero, Khursevich & Velasco, sp. nov.** (Figs 2–19).

Valvae circularis, 8–32 μm in diametro. Frons paene plana. Areolae, interne cribris tholiformibus instructae, 10–15 in 10 μm secundum radium ab centro valvae, locatae sunt in serie brevi vel longa singular. Area hyaline aream areolatam in centro frontis cingens. Areolas ad marginem frontis cum interne cribris plana subtiliores areolas area centralis. In fronte annulus fultoportularum (ab 4 ad 10) prope centrum valvae. In parte faciali interna valvae fultoportulae habent 2 aut 3 poros satellitos, externe habent poros parvos. Limbum striatum, divisa est in claros sectores, ex 5–6 serie puncta subtilis constantes. Sectores limbus disiuncti sunt striis hyalinosis, (6)8–10 in 10 μm. In basi striarum hyalinarum sunt aperturas externi fultoportulas limbi. In facie interna valvae annulus marginalium alveoli simplices et complex cum plica vel striis hyalinosis adest. Fultoportulas limbi cum 2 poris satellitis dispositae above costis vel in pariete prope marginem valvae. Una rimoportula adest in alveoli. Bumps in frons paene adest; limbum valvae esse posset tecta granulis.

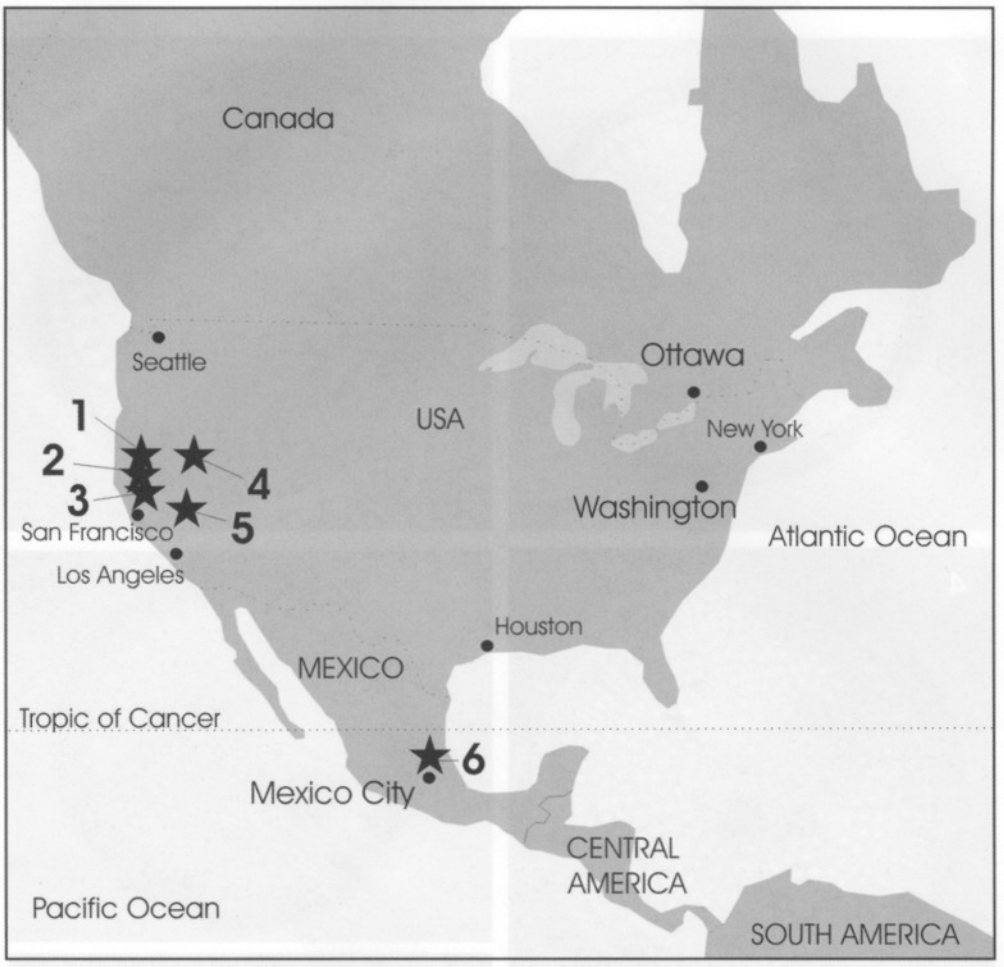
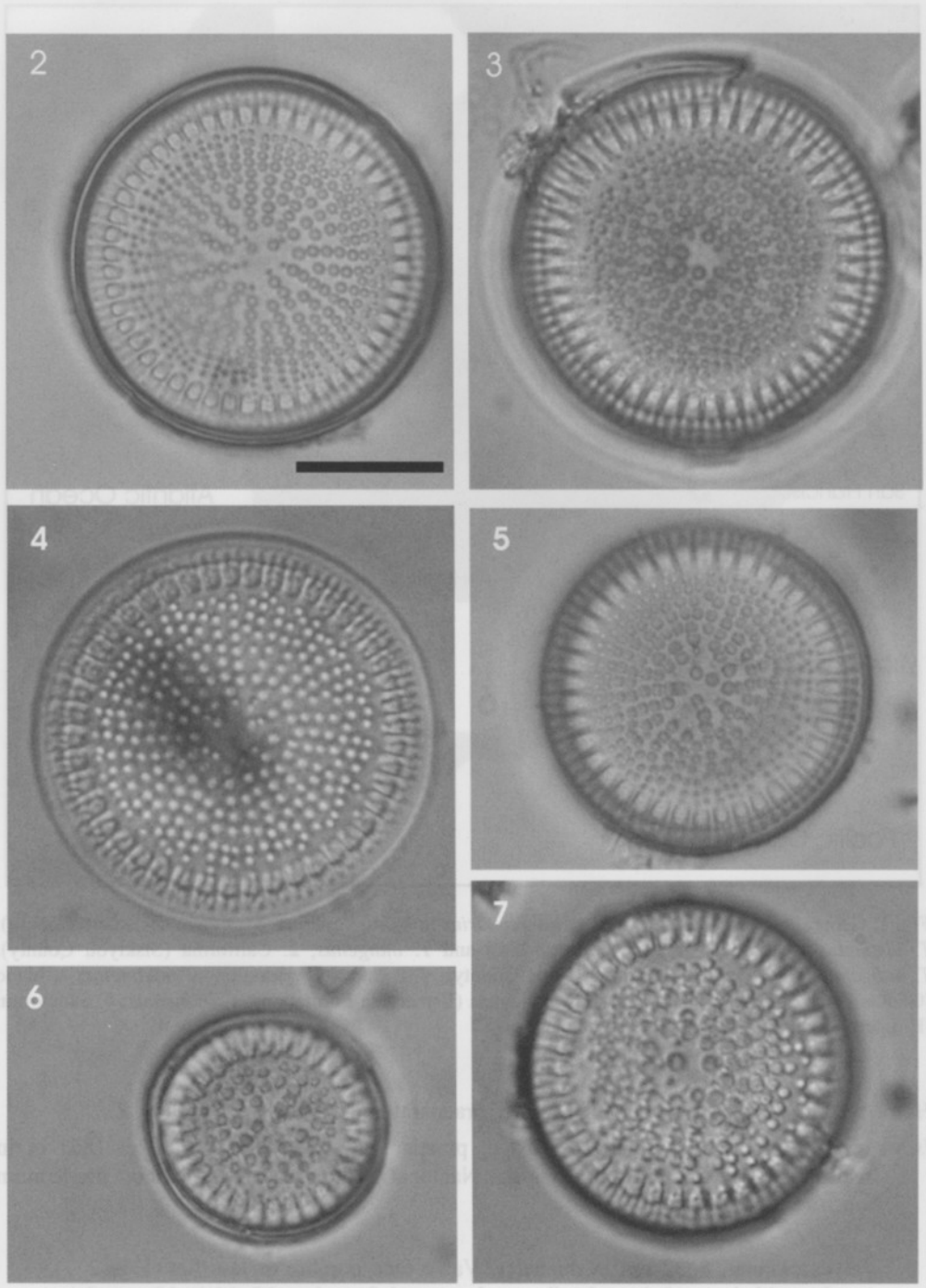


Fig. 1. Geographic distribution of the genus *Tertiarius* in North America. **1**. Oregon, (Klamath County): *T. distinctus* (type loc.), *T. porosus* (type loc.) and *T. indigenus*; **2**. California (Siskiyou County): *T. indigenus* (type loc.); **3**. California (Napa County): *T. roddai* (type loc.) and *T. distinctus*; **4**. Idaho (Glenns Ferry Formation): *T. indigenus*; **5**. Nevada (Esmeralda Formation): *T. indigenus*; **6**. Sanctorum (Hidalgo, Mexico): *T. hidalgensis* (type loc.).

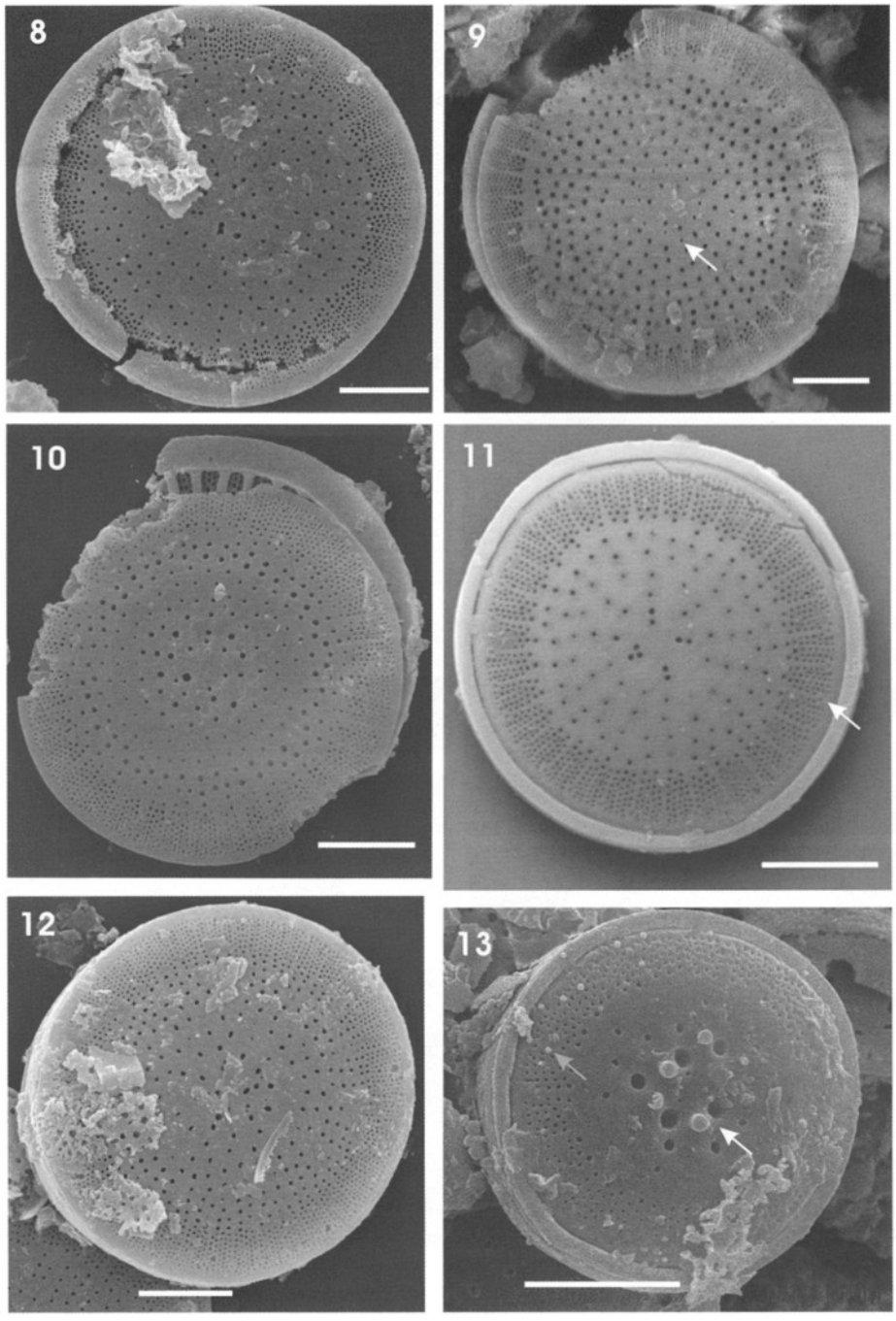
Holotypus: in Herbario Nacional de Mexico, praeparatum No. MEXU 1859, Fig. 2.

Isotypus: in Herbario Nacional de Mexico, praeparatum No. MEXU 1860 et 1861 et in Instituto de Geofísica, Universidad Nacional Autónoma de México, preparatum Sanctorum 5.

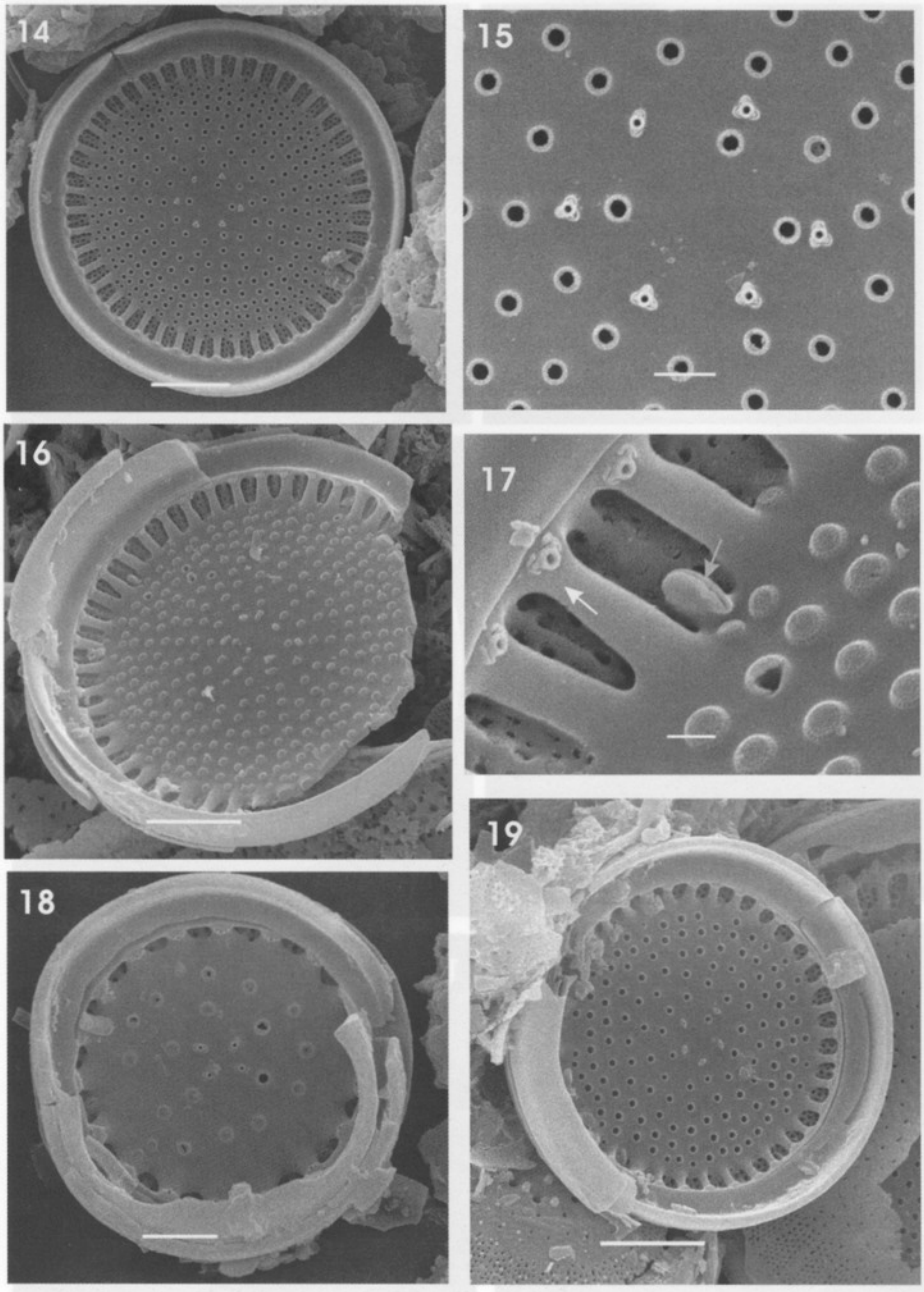
Valves circular, 8–32 μm in diameter. Valve face is more or less flat (Figs 2–7). Areolae with internal domed cribra and external foramina, 10–15 in 10 μm along the valve radius, are arranged in short and long radial rows (Figs 8–19). A narrow hyaline ring surrounding the central ornamentation is usually present, but sometimes absent, on the valve face surface. Marginal areolae have internal flat cribra that can be seen within alveolar chambers (Fig. 17). Four to ten valve face



Figs 2–7. *Tertiarius hidalgensis* (LM), Sanctorum outcrop, Hidalgo, Mexico. Scale bar = 10 μm.



Figs 8–13. *Tertiarius hidalgensis*, external views of valve (SEM), Sanctorum outcrop, Hidalgo, Mexico. Scale bars = 5 µm. All valves demonstrate more or less large central areolae and smaller perforations in multiseriate rows extending to the margin. **Fig. 9.** Note external small openings of valve face fultoportulae (arrow), which form a ring near the valve centre. **Fig. 11.** External small openings of mantle fultoportulae (arrow) located at the base of narrow hyaline strips. **Fig. 13.** Valve view with large areolae and bumps (white arrow) in the central area and small granulae (grey arrow) on the mantle.



Figs 14–19. *Tertiarius hidalgensis*, internal views of valve (SEM), Sanctorum outcrop, Hidalgo, Mexico. Scale bars = 5 μm (Figs 14, 16, 19), 1 μm (Fig. 15), 0.5 μm (Fig. 17), 2 μm (Fig. 18). **Fig. 15.** Fragment of valve (Fig. 14) showing valve face fultoportulae with 2 and 3 satelite pores near the valve centre. **Figs 16, 18, 19.** Specimens showing valve face fultoportulae only with 2 satellite pores near the valve centre. **Fig. 16.** Specimen shows internal domed cribra of central areolae and a marginal ring of complex alveolae formed by thickened hyaline strips or folds. **Fig. 17.** Fragment of valve (Fig. 16) showing internal flat cribra in marginal areolae, a raised rimoportula within alveolar chamber (grey arrow), as well as mantle fultoportulae with two satellite pores (white arrow).

fultoportulae with only 2 satellite pores or with 2 and 3 satellite pores internally are arranged in a ring near the valve centre (Figs 14–16, 18, 19); they open externally as small apertures (Fig. 9). The valve mantle is finely striated (Figs 8–13). Every 5–6 rows of small perforations are separated by narrow hyaline strips, (6)8–10 in 10 μm. The mantle fultoportulae are found at the base of the narrow hyaline strips (Fig. 11). On the internal valve surface a marginal ring of simple or complex alveolae formed by thickened hyaline strips or folds within the alveolae can be observed (Figs 14, 16–19). Alveolae are divided by thicker costae. Mantle fultoportulae with two satellite pores are placed at the end of every thicken internal costa on the wall near the valve edge (Fig. 17). A single sessile rimoportula is positioned within one of the internal alveolar chambers (Fig. 17). External opening of the rimoportula is difficult to discern. Bumps can be present on the valve face, and granulae on the valve mantle (Fig. 13).

Holotype: deposited in Herbario Nacional de Mexico (MEXU), Instituto de Biología, Universidad Nacional Autónoma de México, apartado postal 70–367, Coyoacán, CP 04510, México D.F., México; slide MEXU 1859, Fig. 4.

Isotype: deposited in Herbario Nacional de Mexico (MEXU), slides MEXU 1860 and MEXU 1861. Also in Laboratorio de Paleolimnología, Instituto de Geofísica, Universidad Nacional Autónoma de México, Slide Sanctorum 5.

Type Locality: México, Hidalgo, Municipio de Atotonilco el Grande, Atotonilco el Grande Formation, Sanctorum outcrop (12 km east of Atotonilco el Grande), 20° 18.290'N, 98° 46.865'W, 1,650 m asl, in the laminated sediments of early-middle Pliocene age at the base of the Sanctorum outcrop.

Etymology: Named after Hidalgo, the name of the state in central Mexico where the type locality is; the state is named after Miguel Hidalgo y Costilla, the leader of the Mexican independence war of 1810.

Comments:

This species differs from *Tertiarius distinctus* Khursevich & Kociolek (2002: 333, figs 1–5, 12–22) (Table 1) mainly by the larger size of valves, by the bigger numbers of hyaline strips / internal costae in 10 μm on the valve mantle, as well as by the different internal structure of rimoportula (it is raised in *T. hidalgensis* and sessile in *T. distinctus*). *T. hidalgensis* differs from *T. roddai* Kociolek & Khursevich (Khursevich & Kociolek 2002: 340, figs 33–47) (Table 1) by the greater number of areolae in 10 μm on the valve face (10–15 in 10 μm in *T. hidalgensis* against 6–10 in 10 μm in *T. roddai*) and by the different placement of rimoportula (it is located within alveolar chamber in *T. hidalgensis* and in the submarginal zone of the valve face in *T. roddai*).

Tertiarus hidalgensis was present only in the finely laminated sediments at the base of the Sanctorum outcrop, where it was the dominant taxa (80 to 90% relative abundance); it was associated only with two other diatom species: a small *Fragilaria* (s. l.) and *Aulacoseira granulata* (López-Trejo 2007).

DISCUSSION

Comparative analysis of morphological characters of eight species within the genus *Tertiarius,* which are presented in Table 1, resulted in a key for species determination within *Tertiarius*.

Table 1. Morphological characteristics of the *Tertiarius* species.

Species	Valve diameter (μm)	Number of areolae in 10μm along valve radius	Structure of alveolae	Structure and position of rimoportula(e)	Structure and position of valve face fultoportulae	Structure and position of mantle fultoportulae	Number of internal costae in 10 μm on valve mantle	Presence or absence of spines, granulae and bumps
T. pygmaeaus (Pantocsek) Håkansson & Khursevich	8–14(16)	15–20	simple	1 sessile, located at the base of one of the internal thick costae	with 2 satellite pores; 1–7 forming a ring near the valve centre	with 2 satellite pores, located above every thick internal costa on the wall near the valve edge	8–10	spines present on every costa, granulae on the mantle, bumps on the valve face
T. transilvanicus (Pantocsek) Håkansson & Khursevich	22–36	11–12	simple	1 sessile, on the thickened hyaline strip within alveolar chamber	with 2 satellite pores; form a ring in the submarginal zone of the valve face	with 2 satellite pores, located above every thick internal costa on the wall near the valve edge	8 – 10	granulae present on the valve face and mantle, some-times absent
T.baicalensis Khursevich & Fedenya	6–18	10–15	only simple	1 to 4 sessile, located in the sub-marginal zone of the valve face	with 2 satellite pores; 3 to 17 located near the valve centre, replacing 1 to 3 areolae in every radial row	with 3 satellite pores, located on every thick internal costa or on the wall near the valve edge	6–8	bumps can be present on the valve surface
T. distinctus Khursevich & Kociolek	4.5–14	10–20	simple and complex formed by thickened hyaline strips	1 sessile, on the thickened hyaline strip within alveolar chamber	with 2 satellite pores; 1–5 located near the valve centre	with 2 satellite pores, located on every thick internal costa	6–8	bumps present on the valve face
T. indigenus Khursevich & Kociolek	5–27.5	up to 20 in larger specimens; scattered in central area in smaller specimens	simple and complex	1 to 4 sessile, on the thickened hyaline strips within elongated alveolar chambers	absent	with 2 satellite pores, located above every thick internal costa on the wall near the valve edge	6–8	granulae present on the valve mantle, sometimes absent
T. porosus Khursevich & Kociolek	10–60	4–10	simple or complex	1 to 4 sessile, at the base of elongated alveolar chambers	with 2 satellite pores; 3 to many located near the valve centre	with 2 satellite pores, located on every thick internal costa	5–7	bumps present on the valve face
T. roddai Kociolek & Khursevich	6–45	6–10	simple or complex	1 sessile, large, in the submarginal zone of the valve face	with 2 satellite pores; 3 to 6 located near the valve centre	with 2 satellite pores, located on every thick internal costa; externally open by small tubes	6–10	bumps can be present on the valve surface
T. hildalgensis Caballero, Khursevich & Vázquez	(8)10–31	10–15	simple and complex formed by thickened hyaline strips	1 sessile, located within alveolar chamber	with 2–3 satellite pores; 4 to 10 form a ring near the valve centre	with 2 satellite pores, located above every thick internal costa on the wall near the valve edge	8–10	spines absent, bumps can be present on the valve face, granulae can be pesent on the valve mantle

Key for the taxonomic determination of *Tertiarius* species

I. Alveolae simple.

1. Mantle fultoportulae with two satellite pores.
   - A. One sessile rimoportula located at the base of an internal thick costa ..... *T. pygmaeaus*
   - B. One sessile rimoportula within alveolar chamber. ..... *T. transilvanicus*
2. Mantle fultoportulae with three satellite pores. One to four sessile rimoportulae located in the submarginal zone of the valve face ..... *T. baicalensis*

II. Alveolae simple and complex formed by folds or narrow ridges of silica.

1. One to several sessile rimoportulae.
   - A. Number of areolae 4–10 in 10 μm. Sessile rimoportulae located at the base of elongated alveolar chambers .....*T. porosus*
   - B. Number of areolae 10–20 in 10 μm. Sessile rimoportulae located on the thickened hyaline strips within alveolar chambers.
     - a. Valve face fultoportulae are located near the valve centre ..... *T. distinctus*
     - b. Valve face fultoportulae are absent ..... *T. indigenus*
2. One sessile rimoportula with large labium
   - A. Number of areolae 6–10 in 10 μm. Raised rimoportula located in the submarginal zone of the valve face ..... *T. roddai*
   - B. Number of areolae 10–15 in 10 μm. Raised rimoportula located within alveolar chamber ..... *T. hidalgensis*

The morphological features of all known species of *Tertiarius* (Table 1) allows to differentiate them from the members of *Stephanodiscus*, *Cyclotella*, *Cyclostephanos*, *Pliocaenicus*, *Tertiariopsis* and *Punticulata* (Round 1982, Theriot *et al.* 1987, Round & Håkansson 1992, Håkansson 2002, Khursevich *et al.* 2002, Stachura-Suchoples & Khursevich 2007).

Generally, the genus *Tertiarius* is characterized by a more or less flat valve face divided in a central and a marginal area by a wide or narrow hyaline ring. The central area has loculate areolae with domed internal cribra, arranged in radial rows or sometimes scattered, and valve face fultoportulae (from one to several) with 2–3 satellite pores. The marginal area of the valve face is striated, and it is distinguished from that on the mantle. Internally a marginal ring of simple and complex alveolae formed by wider hyaline strips (not usually raised) or folds can be seen (which differs from *Cyclotella* complex alveolae that have both internal thick and thin recessed and slightly raised costae). Mantle fultoportulae with 2, rarely 3, satellite pores are positioned at or above every thick internal costa on the wall near the valve edge. One to four sessile rimoportulae occur either at the base of one of the thick internal costae, or inside one of the alveolar chambers, or in the submarginal zone of the valve face.

The genus *Tetiarius* differs from the genus *Stephanodiscus* Ehrenberg (Håkansson 2002) first of all by the presence of alveolae in the marginal zone of the valve, by the absence of distinct areolar fascicles divided by hyaline interfascisles, sometimes externally raised, on the valve face surface, and by the absence of rimoportula having a stalked labium.

The genus *Cyclostephanos* Round (Round 1982, Theriot *et al.* 1987), unlike *Tertiarius*, has valves that range from flat to distinctly concentrically undulate; areolar fascicles separated

by costae towards the margin; only simple alveolae on the valve mantle and a single sessile rimoportula, lacking an external tube, located always on one of the costae on the valve mantle.

The genus *Cyclotella* (Kützing) Brébisson (Håkansson 2002), as compared with *Tertiarius,* is distinguished by various shapes of valves (from circular-round to rhomboid-elliptical); by the presence of valves with a flat to tranversely undulate and even to radially undulate central area; by the presence not only of areolae, but also of papillae and depressions within the central area, sometimes the central area is structureless; by the position of mantle fultoportulae both on internal thick and thin (recessed but slightly raised) costae; by the various locations of rimoportula(e) on the valve surface including on the costa(e).

In contrast to the genus *Tertiarius,* the genus *Pliocaenicus* (Round & Håkansson 1992, Håkansson & Khursevich 1997, Stachura-Suchoples & Khursevich 2007) has in most cases a transverse undulation on the valve face surface; it lacks the wide or narrow hyaline ring that divides the valve face into two differently structured areas; it has mantle fultoportulae with 2 or 3 satellite pores on either internal thick or thin recessed costae (in *Tertiarius* the mantle fultoportulae are at or above every internal thick costa on the surrounding wall).

The genus *Puncticulata* Håkansson (2002) is characterized by the presence of only complex alveolae (with thin and thick costae) around the marginal area, while the species of *Tertiarius* (Håkansson & Khursevich 1997, Khursevich & Kociolek 2002) have simple and complex alveolae formed by thickened hyaline strips, which are much thinner than the costae. Besides, the placement of rimoportula(e) is always on the valve face surface in the species of *Puncticulata,* while it is variable in the members of *Tertiarius*: either at the base of internal thick costa, or within internal alveolar opening, or in the submarginal zone of the valve face.

The genus *Tertiariopsis* Khursevich & Kociolek (Khursevich *et al.* 2002), compared with the genus *Tertiarius,* has no marginal alveolae, possesses mantle fultoportulae only with 3 satellite pores, covered internally by a marginal lamina, and has one or two rimoportulae located on the valve mantle.

Tertiarius, closely related to the abovementioned genera, is apparently an extinct genus with a stratigraphic distribution restricted to upper Miocene and Pliocene sediments; this distribution is consistent with the age of the deposits where it was found in Mexico, and therefore it can be useful as stratigraphic marker in Mexican sediments. For the moment the geographical range of this genus is extended into lower latitudes but as more research is done on the abundant Neogene lacustrine deposits in Mexico, the number of fossil species in this or other related genera may increase.

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