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New Radiolarian Species of the Genus *Carpocanium* Ehrenberg, 1847, emend. nov. in the Surface Sediments of the Emperor Seamount Chain, Pacific Ocean

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Abstract—The diversity of radiolarian species of the family Carpocaniidae Haeckel, 1881, emend. Riedel, 1967, from the surface sediments of the Emperor Seamount Chain (Nintoku, Jingū, Ojin, Koko and Yuryaku guyots) is analyzed. Five new species of the genus *Carpocanium* Ehrenberg, 1847, emend. nov.: *C. rotundum* sp. nov., *C. fragaria* sp. nov., *C. alabastrum* sp. nov., *C. tulipa* sp. nov., and *C. fungus* sp. nov. are described. The identification of the new species is based on their morphology, which differs from that of other species of the genus *Carpocanium*. It is proposed to restore *Carpocanarium* Haeckel, 1887 to a valid genus, and transfer it back into the family Carpocaniidae, based on the overall correspondence of its morphology to the diagnosis of this family.

Keywords: Radiolaria, family Carpocaniidae Haeckel, 1881, emend. Riedel, 1967, status of the genus *Carpocanarium* Haeckel, 1887, taxonomy, revision, Pacific region, modern sediments

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INTRODUCTION

The family Carpocaniidae Haeckel, 1881, emend. Riedel, 1967 represents a diverse group of radiolarians, widespread in the Cenozoic plankton and in the modern oceans. Due to the small size of their skeletons (70–120 μm) and, for the most part, the subdominant position of their species in the Cenozoic deposits, representatives of this group are often listed in open nomenclature in the literature. This is due to the difficulty of identifying not only species but also genera of Carpocaniidae. One of the criteria for determining the generic affiliation of species of this family is the location of the cephalis (uppermost segment), which is not always clearly visible during microscopic examination.

According to Petrushevskaya (1981), characters considered diagnostic for genera of the family Carpocaniidae are extremely unreliable, suggesting the possibility of many synonyms among these genera. For instance, the genera *Cyrtocalpis* Haeckel, 1861, *Carpocanobium* Haeckel, 1887 and *Asecta* Popofsky, 1913 are subjective synonyms of the genus *Carpocanium* Ehrenberg, 1847; the genus *Sethamphorus* Burma, 1959 is considered a subjective synonym of the genera *Cystophormis* Haeckel, 1887 and *Carpocanistrum* Haeckel, 1887; and the genus *Carpocanarium* Haeckel, 1887 is a subjective synonym of the genus *Tricolocapsa* Haeckel, 1881, etc.

O'Dogherty et al. (2009, 2021) published a major taxonomic revision of Mesozoic and Cenozoic radiolarians and concluded that it was necessary to combine taxa, especially those with large lists of synonyms:

— The Mesozoic genera *Diacanthocapsa* Squinabol, 1903, *Carpocryptocapsa* Petrushevskaya, 1981, *Myllocercion* Foreman, 1968 and *Tricolocapsa* Haeckel, 1881 were excluded from the family Carpocaniidae and re-assigned to other families (O'Dogherty et al., 2009);

— The Cenozoic genera *Carpocanarium* Haeckel, 1887 and *Carpocanistrum* Haeckel, 1887 are considered by O'Dogherty et al. (2021) to be synonyms of the genus *Carpocanium* Ehrenberg, 1847;

— Other genera, *Anthocyrturium* Haeckel, 1887, *Artobotrys* Petrushevskaya, 1971 and *Tripterocalpis* Haeckel, 1882, which were not previously included in the family Carpocaniidae, were included in it (O'Dogherty et al., 2021).

Thus, according to O'Dogherty et al. (2021), the family Carpocaniidae Haeckel, 1881, emend. Riedel, 1967 includes five genera: *Anthocyrturium* Haeckel, 1887; *Artobotrys* Petrushevskaya, 1971; *Carpocanium* Ehrenberg, 1847; *Carpocanopsis* Riedel et Sanfilippo, 1971, and *Tripterocalpis* Haeckel, 1882.

While studying radiolarians in surface sediments collected in the area of the southern guyots of the

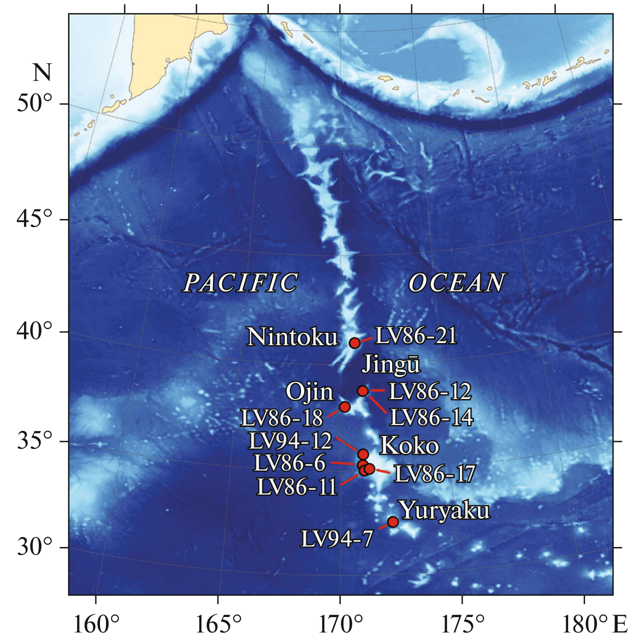

Fig. 1. Study area and location of sampling stations.

Emperor Seamount Chain (Fig. 1), the authors of this work discovered diverse representatives of Carpocaniidae (Vasilenko and Dautova, 2021; Khmel et al., 2023), the species identification of which caused difficulties due to taxonomic discrepancies in the literature. To solve this problem, we analyzed the diagnoses of the genera included in the studied family (according to Ehrenberg, 1846, 1847; Haeckel, 1887; Riedel, 1967; Petrushevskaya, 1981; O'Dogherty et al., 2021) and identified their main morphological features.

Table 1. Location and depths of the studied samples on the guyots of the Emperor Seamount Chain, collected during the 86th (2019) and 94th (2021) cruises of the R/V *Akademik M.A. Lavrentyev*

Guyot	Station	Locations	Depth, m
Nintoku	LV86-21	40°59.952′ N 170°43.482′ E	1161
Jingū	LV86-12	38°46.416′ N 171°5.232′ E	1935
	LV86-14	38°45.744′ N 171°5.142′ E	1446
Ojin	LV86-18	38°1.998′ N 170°12.834′ E	1531
Koko	LV86-6	35°47.04′ N 171°3.894′ E	1995
	LV86-11	35°4.35′ N 171°17.304′ E	1880
	LV86-17	35°5.67′ N 171°19.092′ E	1440
	LV94-12	35°47′20″ N 171°2′53″ E	2231–2242
Yuryaku	LV94-7	32°31′48″ N 172°18′0″ E	1249

This paper reviews the distinctive characteristics of some genera and species of Carpocaniidae for subsequent revision and describes five new species assigned by the authors to the genus *Carpocanium* Ehrenberg, 1847.

MATERIAL AND METHODS

The material represents surface sediments (0–3 cm) and short sediment cores (0–27 cm) collected by the National Scientific Center for Marine Biology (NSCMB) jointly with the P.P. Shirshov Institute of Oceanology of the Russian Academy of Sciences (IO RAS) during integrated expeditions on cruises 86 and 94 of the R/V *Akademik M.A. Lavrentyev* (2019, 2021) under the leadership of T.N. Dautova (NSCMB).

Geological samples were collected in the southern part of the Emperor Seamount Chain on the Nintoku, Jingū, Ojin, Koko and Yuryaku guyots using the Comanche 18 remotely operated submarine vehicle equipped with manipulators and samplers for collecting bottom sediments (Galkin et al., 2020) (Table 1).

The samples were processed according to the methods of Lipman (1979), Tochilina (1985), Abelmann (1988): (1) weighing the samples on high-precision scales (WAGA TORSYJNA–WT); (2) disintegration of the sediment in distilled water for several days; (3) boiling with the addition of tripolyphosphate and H_2O_2; (4) washing the samples through a 40 μm sieve; (5) preparing permanent preparations using Canada Balsam DC, refractive index = 1.520–1.523.

The radiolarian skeletons were studied using the Mikmed 6 (×300 magnification) and IMAGER.A1 (×300 magnification) microscopes. The skeletons were photographed using a Touptek photonics FMA050 camera. Scanning electron micrographs were obtained using a Tescan Lyra 3 XMH dual-beam scanning electron microscope (SEM-FIB) in the laboratory of micro- and nanoresearch of the Analytical Center of the Far Eastern Geological Institute Far Eastern Branch, Russian Academy of Sciences (FEGI FEB RAS).

The paper follows the system of higher taxa of radiolarians developed by M.S. Afanasieva and E.O. Amon using types, subtypes and classes (Afanasieva et al., 2005; Afanasieva and Amon, 2006). The age of species of the genus *Carpocanium* Ehrenberg, 1847 is given according to O'Dogherty et al. (2021).

Radiolarian collections nos. 86 and 94 are housed in the Marine Micropaleontology Laboratory of the V.I. Il'ichev Pacific Oceanological Institute of the Far Eastern Branch of the Russian Academy of Sciences (POI FEB RAS).

ON THE PROBLEM TAXONOMIES CARPOCANIIDAE HAECKEL, 1881, EMEND. RIEDEL, 1967

The difficulties in identifying representatives of Carpocaniidae lie in the great morphological diversity of this family, generic characteristics for which have not yet been clearly defined. To avoid errors, we examined diagnoses of the genera of Carpocaniidae published in classical works (Ehrenberg, 1846, 1847; Haeckel, 1887; Riedel, 1967; Riedel and Sanfilippo 1971; Petrushevskaya, 1981) and identified the following features of some Cenozoic genera that were part of this family previously and at present.

(1) Species of the family Carpocaniidae have a mainly two-segmented skeletal structure (cephalis—first segment and thorax—second segment), except for the genera *Carpocanopsis* Riedel et Sanfilippo, 1971 and *Artobotrys* Petrushevskaya, 1971, which have a third segment—the abdomen. In the first genus, it mainly passes into long basal teeth, in the second it is an elongated tube and is often transformed into a short peristome, with a small number of pores or lacking them altogether.

(2) One of the main features of the difference between genera in the family Carpocaniidae is the location of the cephalis in the skeletons:

- genus *Carpocanium* Ehrenberg, 1847 is characterized by a cephalis mostly included or half included in the thorax, which is separated from the thorax by a transverse septum;
- genus *Carpocanistrum* Haeckel, 1887 is characterized by an internal cephalis, which is mostly simplified and not separated from the thorax by a septum;
- genus *Carpocanarium* Haeckel, 1887 is characterized by an external cephalis with a distinct septum, as well as the presence of fairly large pores on the thorax;
- genus *Carpocanopsis* Riedel et Sanfilippo, 1971 is characterized by an external or half immersed in the thorax cephalis with a distinct septum; the abdomen is also present;
- genus *Anthocyrturium* Haeckel, 1887 is characterized by an external spherical cephalis, separated from the thorax by a distinct septum and teeth converging toward the center, framing the aperture;
- genus *Artobotrys* Petrushevskaya, 1971 is characterized by an elongated, complex cephalis, and an abdomen is also present;
- genus *Tripterocalpis* Haeckel, 1882 is characterized by a skeleton consisting of one section and having lateral wing-shaped spines.

Based on the above differences, separating the genera *Carpocanium* and *Carpocanistrum* is quite difficult, since the presence or absence of an internal septum is not always clearly visible under a microscope. Other genera have specific, well-defined features that facilitate their identification.

The affiliation of the genus *Tripterocalpis* to the family Carpocaniidae is questionable. The morphological features of the skeleton sharply distinguish this genus from other genera of the family. This genus is not discussed in this paper, since there is not yet enough evidence to revise its position; therefore the question of the affiliation of the genus *Tripterocalpis* to the Carpocaniidae remains open.

In addition, the exclusion of the genus *Carpocanarium* from the family is, in our opinion, unfounded. The morphology of its best-known representative, *Carpocanarium papillosum* (Ehrenberg, 1872) fully corresponds to the diagnosis of the family Carpocaniidae, and the external position of the cephalis distinguishes it from other genera. Also, Haeckel (1887) assigned to this genus the species *Carpocanium (Carpocanarium) calycothes* Stöhr, 1880, the type species, which has morphology similar to that of *C. papillosum* (Ehrenberg, 1872).

The genus *Tricolocapsa* Haeckel, 1881, which according to Petrushevskaya (1981), is a senior synonym of *Carpocanarium* Haeckel, 1887, is characterized by a skeleton consisting of three segments. *Tricolocapsa* is possibly an evolutionary predecessor of *Carpocanarium*, but not a synonym.

Thus, we propose to return the genus *Carpocanarium* Haeckel, 1887 to the family Carpocaniidae, since it fully corresponds to the diagnosis of this family and has distinctive morphological characters to be treated as a genus in its own right.

CARPOCANIIDAE IN THE SEDIMENTS OF THE EMPEROR SEAMOUNT CHAIN AND THEIR MORPHOLOGY

Having studied the surface sediments of the southern guyots of the Emperor Seamount Chain, we discovered a rich fauna of radiolarians (Vasilenko and Dautova, 2021; Khmel et al., 2023), including species of the genera Carpocaniidae constituting 2–6%. In total, we identified 10 species of the genera *Carpocanarium* and *Carpocanium*, characteristic of the transition zone from a tropical to a boreal fauna. We describe five new species of the genus *Carpocanium*.

Carpocanarium papillosum (Ehrenberg, 1872) (Pl. 1, figs. 23–26) is one of the representatives of Carpocaniidae found in the sediments of the Nintoku, Ojin, Jingū, and Koko guyots (Fig. 1). A characteristic feature of this species is the pear-shaped skeleton with large pores and a well-defined external spherical cephalis.

Carpocanium ruesti (Dreyer, 1890), which is found in the sediments of the Ojin, Jingū, Koko, and Yuryaku guyots (Fig. 1; Pl. 1, figs. 5–8) is also common. This species has a nearly spherical shape with a very narrow, elongated ring pylome without teeth.

Another very common species is *Carpocanium prunoides* (Popofsky, 1913), found in the sediments of the Nintoku, Jingū, Koko, and Yuryaku guyots (Fig. 1; Pl. 1, figs. 15–17). It is characterized by an oval, slightly irregular skeleton and a narrowed aperture without teeth.

The species *Carpocanium pachydermicum* Chen et Tan, 1996 and *Carpocanium flosculum* (Haeckel, 1887) were found in the sediments of all the guyots studied (Fig. 1; Pl. 1, figs. 1–4 and 20–22, respectively). The former is large (90–100 μm), nearly spherical, ending in a slightly narrowed peristome with small parallel or converging teeth. The latter is characterized by an oval skeleton, slightly inflated in the central part of the thorax with small, nearly parallel teeth.

Five species occur singly and are not found in all guyots (Fig. 1).

The species *Carpocanium acephalum* (Haeckel, 1887) was found in the sediments of the Koko and Yuryaku guyots (Fig. 1; Pl. 1, figs. 12, 13). A characteristic feature of this species is the elongated-oval shape of the skeleton with small pores, an internal (immersed in the thorax) cephalis and numerous slightly curved, almost parallel teeth on a wide peristome.

The species *Carpocanium acutidentatum* (Takahashi, 1991) was found in the sediments of the Jingū, Koko, and Yuryaku guyots (Fig. 1; Pl. 1, figs. 10, 11). This species is similar to *C. acephalum* in the shape of the skeleton, small pores, and internal cephalis. It is mainly different in the narrowed aperture, as well as deeply set pores, arranged in even vertical rows and giving the thorax a ribbed appearance.

The species *Carpocanium nigriniae* Kruglikova, 1978 was found in the sediments of the Koko Guyot (Fig. 1; Pl. 1, fig. 14). It is characterized by a nearly cylindrical skeleton, with small pores and a cephalis completely immersed in the thorax.

The species *Carpocanium obliquum* (Haeckel, 1862) is found in the sediments of the Jingū and Koko guyots (Fig. 1; Pl. 1, figs. 18, 19). Its peculiarity is the nearly spherical shape of the skeleton with an expanded smooth aperture, without teeth.

The species *Carpocanium favosum* (Haeckel, 1887) was found as a single specimen in the sediments of the Jingū Guyot (Fig. 1; Pl. 1, Fig. 9). It has a spindle-shaped skeleton with deeply set pores, giving the thorax a ribbing appearance, which passes onto an elongated, tapering peristome without teeth.

SYSTEMATIC PALEONTOLOGY

PHYLUM RADIOLARIA

SUBPHYLUM POLYCYSTINA

CLASS NASSELLARIA

Order Cyrtidinata

Family Carpocaniidae Haeckel, 1881, emend. Riedel, 1967

Genus *Carpocanium* Ehrenberg, 1847, emend. Vasilenko et Khmel nov.

Type species. *Lithocampe solitaria* Ehrenberg, 1839, Sicily Island (Caltanissetta), Miocene—present.

Diagnosis. Carpocaniidae, consisting of two segments, the cephalis and thorax, without thoracic ribs. Cephalis spherical or flattened, located inside thorax or half immersed in it; separated from thorax by a transverse septum. Apical horn weakly expressed or absent. Thorax ellipsoidal, subspherical, subcylindrical or fusiform. Peristome narrow or expanded, ending in a smooth or ribbed ring or in numerous processes of different sizes and shapes. Pores small, rounded,

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Explanation of Plate 1

All: Emperor Seamount Chain, modern sediments: Nintoku Guyot (Sample LV86-21, 0–3 cm, depth 1161 m: Fig. 22); Jingū Guyot (Sample LV86-12, 0–3 cm, depth 1935 m: figs. 8, 16, 20; Sample LV86-14, 0–3 cm, depth 1446 m: figs. 9, 11, 15, 24); Ojin Guyot (Sample LV86-18, 0–3 cm, depth 1531 m: text-figs. 25, 26); Koko Guyot (Sample LV86-6, depth 1995 m: fig. 3; Sample LV86-17, 0–3 cm, depth 1440 m: Fig. 13; core LV94-12-K2, depth 2231–2242 m: Sample LV94-12-K2-2, 1–2 cm: figs. 1, 2, 5, 10, 12, 17, 21, 23; Sample LV94-12-K4-2, 4–5 cm: figs. 4, 18, 19; sample LV94-12-K2-6, 6–7 cm: text-fig. 6, 14); Yuryaku Guyot (Sample LV94-7-K7-2, 1–2 cm, depth 1249 m: Fig. 7). Scale bar 100 μm.

Figs. 1–4. *Carpocanium pachydermicum* Chen et Tan, 1996: (1) specimen POI, no. 94/12.2-138; (2) specimen POI, no. 94/12.2-137; (3) specimen POI, no. 86/6-159: (3a) focus on pores, (3b) focus on skeleton outline; (4) specimen POI, no. 94/12.4-75.

Figs. 5–8. *Carpocanium ruesti* (Dreyer, 1890): (5) specimen POI, no. 94/12.2-141; (6) specimen POI, no. 94/12.6-94: (6a) focus on pores, (6b) focus on skeleton outline; (7) specimen POI, no. 94/7.2-29; (8) specimen POI, no. 86 /12.1-69.

Figs. 9. *Carpocanium favosum* (Haeckel, 1887), specimen POI, no. 86/14.1-73.

Figs. 10, 11. *Carpocanium acutidentatum* (Takahashi, 1991): (10) specimen POI, no. 94/12.2-136; (11) specimen POI, no. 86/14.1-76.

Figs. 12, 13. *Carpocanium acephalum* (Haeckel, 1887): (12) specimen POI, no. 94/12.2-135; (13) specimen POI, no. 86/17.1-110.

Fig. 14. *Carpocanium nigriniae* Kruglikova, 1978, specimen POI, no. 94/12.6-105.

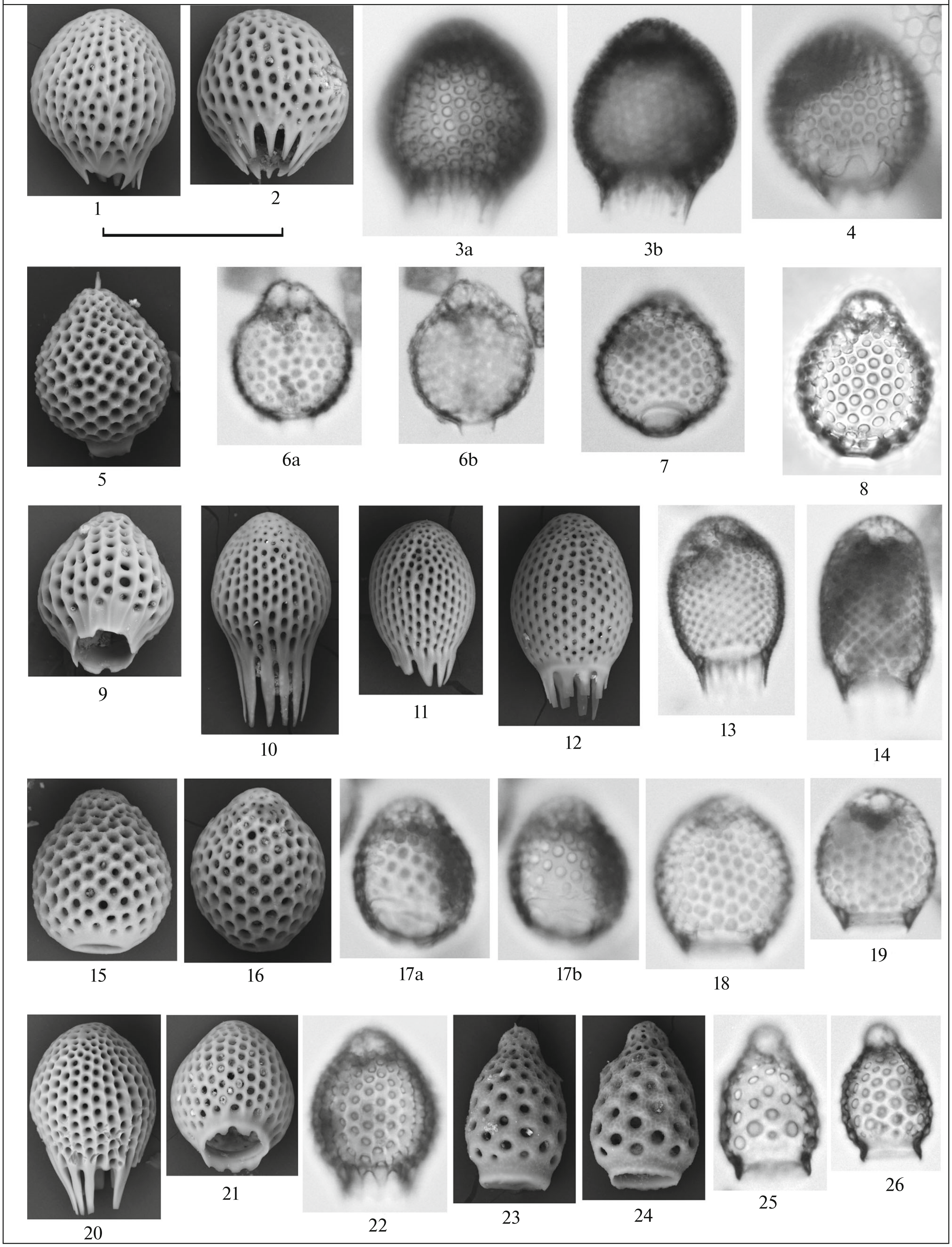
Figs. 15–17. *Carpocanium prunoides* (Popofsky, 1913): (15) specimen POI, no. 86/14.1-72; (16) specimen POI, no.86 /12.1-82; (17) specimen POI, no. 94/12.2-124: (17a) focus on pores, (17b) focus on skeleton outline.

Figs. 18, 19. *Carpocanium obliquum* (Haeckel, 1887): (18) specimen POI, no. 94/12.4-77; (19) specimen POI, no. 94/12.4-78.

Figs. 20–22. *Carpocanium flosculum* (Haeckel 1887): (20) specimen POI, no. 86/12.1-81; (21) specimen POI, no. 94/12.2-149; (22) specimen POI, no. 86/21-33.

Figs. 23–26. *Carpocanarium papillosum* (Ehrenberg, 1872): (23) specimen POI, no. 94/12.2-133; (24) specimen POI, no. 86/14.1-77; (25) specimen POI, no. 86/18.1-79; (26) specimen POI, no. 86/18.1-78.

Plate 1



1 2 3a 3b 4

5 6a 6b 7 8

9 10 11 12 13 14

15 16 17a 17b 18 19

20 21 22 23 24 25 26

arranged in rows or in a checkerboard pattern, sometimes randomly.

Species composition. 53 species: *C. prunoides* (Popofsky, 1913), Recent, South Atlantic Ocean; *C. acephalum* (Haeckel, 1887), Pleistocene-present, North Pacific Ocean; *C. acutidentatum* (Takahashi, 1991), Recent, Hawaiian Islands; *C. azyx* (Sanfilippo et Riedel, 1973), Middle Eocene, Gulf of Mexico; *C. brevispina* (Vinassa de Regny, 1900), Early Miocene, Adriatic Sea; *C. evacuatum* (Haeckel, 1887), Pleistocene, Central Pacific Ocean; *C. flosculum* (Haeckel, 1887), Recent, equatorial Atlantic Ocean; *C. novenum* (Haeckel, 1887), Recent, South Atlantic Ocean; *C. blastogenicum* Chen et Tan, 1996, Holocene, South China Sea; *C. coronatum* Ehrenberg, 1859, Middle Eocene, Caribbean Sea (Barbados Island); *C. diadema* Haeckel, 1861, Recent, Mediterranean Sea, Atlantic, Indian and Pacific Oceans; *C. ensigerum* Tan et Su, 1982, Holocene, East China Sea; *C. hexagonale* Haeckel, 1887, Recent, tropical Atlantic Ocean; *C. irregulare* Haeckel, 1887, Recent, Central Pacific Ocean; *C. kinugasense* Nishimura, 1990, Middle Miocene, Japan (Kanagawa Prefecture); *C. microdon* Ehrenberg, 1859, Holocene, Caribbean Sea (Barbados Island); *C. nigriniae* Kruglikova, 1978, Pleistocene, Equatorial Pacific Ocean; *C. pachydermicum* Chen et Tan, 1996, Holocene, South China Sea; *C. peristomium* Haeckel, 1887, Pleistocene, Atlantic, Indian and Pacific Oceans; *C. petalospyris* Haeckel, 1887, Pleistocene, Central Pacific Ocean; *C. praecursor* Kruglikova, 1978, Pleistocene, equatorial Pacific Ocean; *C. pulchrum* Carnevale, 1908, Pleistocene, Italy (Bergonzano); *C. rubyae* O'Connor, 1997, Early Miocene, Cyprus, New Zealand; *C. verecundum* Haeckel, 1887, Pleistocene-Holocene, North Pacific Ocean; *C. virgineum* Haeckel, 1887, Pleistocene, Central Pacific Ocean; *C. obovatum* (Tan et Su, 1982), Holocene–Recent, East China Sea; *C. plutonis* (Ehrenberg, 1854), Holocene, Atlantic Ocean; *C. polyptera* (Ehrenberg, 1873), Holocene, Indian Ocean; *C. amphora* (Haeckel, 1861), Recent, Mediterranean Sea, Atlantic and Pacific Oceans; *C. butschlii* (Vinassa de Regny, 1900), Early Miocene, Adriatic Sea; *C. micropora* (Stöhr, 1880), Late Miocene, Mediterranean Sea (Sicily); *C. obliquum* (Haeckel, 1862), Recent, Mediterranean Sea, Atlantic and Pacific Oceans; *C. ovulum* (Haeckel, 1887), Pleistocene, Mediterranean Sea, Atlantic and Pacific Oceans; *C. urceolus* (Haeckel, 1887), Recent, Mediterranean Sea; *C. gargantua* (Renaudie et Lazarus 2012), Early–Middle Miocene, Southern Ocean (Kerguelen Plateau); *C. petrushevskayae* (Renaudie et Lazarus, 2016), Late Oligocene–Early Pleistocene, Southern Ocean; *C. crassus* (Carnevale, 1908), Early–Middle Miocene, Italy (Bergonzano); *C. ruesti* (Dreyer, 1890), Early–Middle Miocene, Sicily (Caltanissetta); *C. cryptoprora* (Ehrenberg, 1861), Holocene, Caribbean Sea (Barbados Island); *C. setosum* (Ehrenberg, 1876), Late–Middle Eocene, Caribbean Sea (Barbados Island); *C. solitarium* Ehrenberg, 1854, Late–Middle Miocene, Sicily (Caltanissetta); *C. favosa* (Haeckel, 1887), Pleistocene, Western Tropical Pacific Ocean; *C. hexapleura* (Haeckel, 1887), Pleistocene, Central Pacific Ocean; *C. microstoma* (Haeckel, 1887), Pleistocene, Western Tropical Pacific Ocean; *C. bussoni* (Carnevale, 1908), Early–Middle Miocene, Italy (Bergonzano); *C. cristatum* (Carnevale, 1908), Early–Middle Miocene, Italy (Bergonzano); *C. pacificum* (Nishimura, 1990), Holocene—Recent, tropical Pacific Ocean; *C. uburex* Renaudie et Lazarus, 2012, Neogene, Southern Ocean; *C. rotundum* sp. nov., Recent, Emperor Seamount Chain; *C. fragaria* sp. nov., Recent, Emperor Seamount Chain; *C. alabastrum* sp. nov., Recent, Emperor Seamount Chain; *C. tulipa* sp. nov., Recent, Emperor Seamount Chain; *C. fungus* sp. nov., Recent, Emperor Seamount Chain.

Comparison. The genus *Carpocanium* is distinguished:

— from *Carpocanarium* Haeckel, 1887—by cephalis internal or half-immersed in the thorax and smaller pores;

— from *Carpocanistrum* Haeckel, 1887—by the presence of a septum between the cephalis and the thorax;

— from *Carpocanopsis* Riedel et Sanfilippo, 1971—by the absence of an abdomen;

— from *Anthocyrturium* Haeckel, 1887—the location of the cephalis and a thinner and smaller apical horn or its absence;

— from *Artobotrys* Petrushevskaya, 1971—by the shape of the skeleton, also a thinner and smaller apical horn or its absence and the absence of an abdomen;

— from *Tripterocalpis* Haeckel, 1882—the presence of a cephalis separated from the thorax by a septum, the absence of lateral pterygoid spines.

Remarks. An analysis of the diagnosis of the genus *Carpocanium* (Ehrenberg, 1846, 1847)[1] showed that the original description of this genus is very conditional, since it does not reflect the main morphological features necessary for its identification. The refined diagnosis of the genus *Carpocanium* Ehrenberg, 1847, emend. nov. is based on the authors own analysis of the skeletal morphology of the species included in it. The emended diagnosis contains information on the number of segments in the skeletons and their shape, the presence and location of the

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[1] Original description of the genus *Carpocanium* (Ehrenberg, 1846): "Apertura testac duplex opposita. Testa simplex, stricturis articulisve nullis" (translation from Latin: aperture of the test double, opposite. Test simple, with neither strictures nor segments). Original addition to the description of the genus *Carpocanium* (Ehrenberg, 1847): "Testae simplex continua, non constricta, postremo fine lobato aut fibriato" (translation from Latin: Test simple, continuous, without strictures, lobed or fibrous at the terminal end).

cephalis, the nature of the porosity, as well as possible variants of the morphology of the peristome.

Carpocanium rotundum Vasilenko et Khmel, sp. nov.

Plate 2, figs. 1–7

Etymology. From the Latin *rotundus* (round).

Holotype. POI, no. 86/14.1–70, modern sediments, Jingū guyot (Emperor Seamount Chain), Sample LV86-14, 0–3 cm.

Description. The skeleton is subspherical or subcylindrical in shape and consists of two segments. The apical horn is absent. The cephalis is horizontally elongated, flattened, divided by a radial structure into three distinct chambers, slightly shifted to the side and half immersed in the thorax. The skeletal wall is thin, with small pores. The thorax is subspherical, sometimes subcylindrical, in some specimens it is slightly swollen in the middle part. The pores are rounded, of the same size, arranged in a checkerboard pattern, with a tendency to be in rows (8–11 pores diagonally). The aperture terminates in a ring-like peristome surrounded by 6–10 small conical teeth about 1/5 or 1/6 the length of the skeleton.

Dimensions in µm:

Specimen no.	SH	Hc	Ht	Wc	Wt	Wa
86/14.1-70 (holotype)	77	13	55	35	72.5	45
86/12.1-77	87	12.5	65	37	72.5	40
86/12.1-78	77	12.5	62.5	37	73	45
86/12.1-63	82	12.5	58	35	69	40

Note: SH—height of skeleton with teeth, Hc—height of cephalis, Ht—height of thorax, Wc—width of cephalis, Wt—width of thorax, Wa—width of aperture.

Comparison. *C. rotundum* sp. nov. resembles *C. pachydermicum* Chen et Tan, 1996 in the general shape of the skeleton, but differs in the smaller size of the skeleton and larger pores. Also, in the general shape of the skeleton, it is close to *C. hexagonale* Haeckel, 1887, differing in rounded, smaller, sparse pores, while the latter has large, hexagonal, closely spaced pores. The morphology is similar to then of *C. flosculum* (Haeckel, 1887), mainly in the general shape and basal teeth, but differs in the larger size of the skeletons in *C. rotundum* sp. nov. and larger pores.

Material. 18 specimens: one specimen from surface sediments of Nintoku Guyot, nine specimens from surface sediments of Jingū Guyot, eight specimens from surface sediments of Koko Guyot.

Carpocanium fragaria Vasilenko et Khmel, sp. nov.

Plate 2, figs. 8, 9

Etymology. From the Latin *fragaria* (strawberries).

Holotype. POI, no. 86/12.1-89, modern sediments, Jingū guyot (Emperor Seamount Chain), sample LV86-12, 0–3 cm.

Description. The skeleton is subspherical with a wide aperture, slightly expanded downwards and consists of two segments. The apical horn is absent. The cephalis is divided by a radial structure into three distinct chambers and is immersed in the thorax by half. The skeletal wall is thin, with small pores. The thorax is subspherical, slightly expanded towards the aperture. The pores are small, rounded, arranged in a checkerboard pattern (8–11 pores diagonally), but some vertical rows are observed (6–8 pores in a row on the thorax). The aperture is wide, ending in a ring-shaped smooth peristome without teeth.

Dimensions in µm:

Specimen no.	SH	Hc	Ht	Wc	Wt	Wa
86/12.1-89 (holotype)	72.5	9	54	31	60	37
94/12.2-131	72	9	56	31	58	38
94/12.7-75	73	10	56	30	58	37

Comparison. *C. fragaria* sp. nov. is close to *C. hexagonale* Haeckel, 1887 in the general shape of the skeleton, but differs in small, rounded, sparse pores. *C. fragaria* sp. nov. is also similar to *C. rotundum* sp. nov. in the rounded shape of the skeleton, but differs in its smaller size, wider aperture without teeth, and smaller pores.

Material. Three specimens: One from the surface sediments of the Jingū guyot, two from the surface sediments of the Koko guyot.

Carpocanium alabastrum Vasilenko et Khmel, sp. nov.

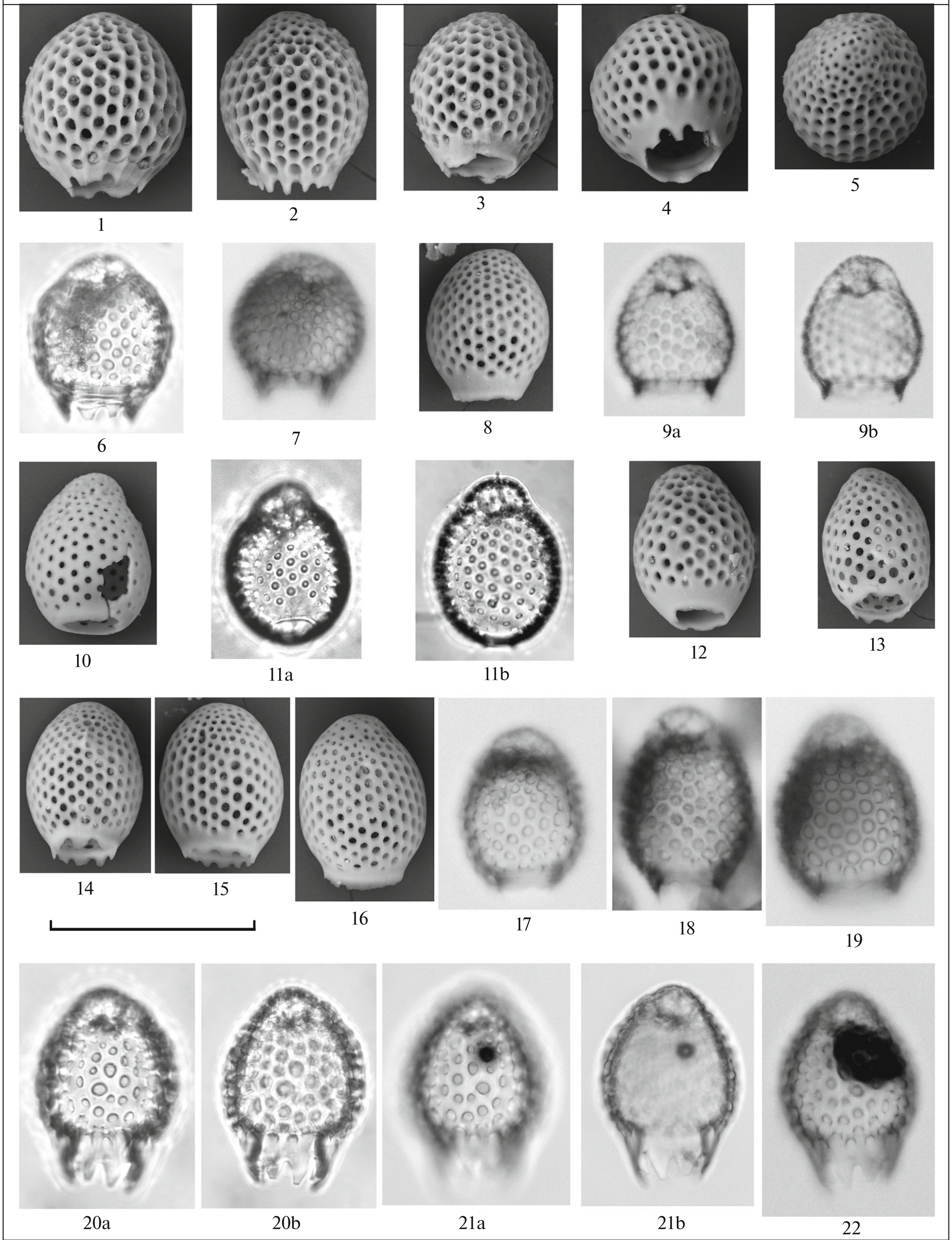
Plate 2, figs. 10–13

Etymology. From the Latin *alabastrum* (alabaster).

Holotype. POI, no. 86/12.1-87, modern sediments, Jingū guyot (Emperor Seamount Chain), Sample LV86-12, 0–3 cm.

Description. The skeleton is ovoid and consists of two segments. The apical horn is absent or manifests as a small thin needle. The cephalis is divided by a radial structure into three distinct chambers, two of which are located above the thorax, and the third is immersed in it. The wall of the skeleton is thin, smooth, with small sparse pores. The thorax is ovoid. The pores are rounded, located in a checkerboard pattern (7–9 pores diagonally), but some vertical rowing is observed (8–9 pores in a row on the thorax). The aperture ends in a narrow smooth peristome without teeth, or they are weakly expressed.

Plate 2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20a
20b
21a
21b
22

Dimensions in µm:

Specimen no.	SH	Hc	Ht	Wc	Wt	Wa
86/12.1-87 (holotype)	73	16	57	39	61	31
86/14.1-47	75	17	58	37	60	32
86/17.1-83	75	17	60	38	60	30

Comparison. *C. alabastrum* sp. nov. is similar to *C. butschlii* (Vinassa de Regny, 1900) in its porosity and lack of teeth around the peristome but differs in the shape of the cephalis and the ovoid shape of the thorax, whereas in *C. butschlii* it is fusiform. In addition, the new species is similar to *C. amphora* Haeckel, 1862 in its clearly discernible cephalis, but differs in its fewer, smaller, more sparse pores.

Material. Four specimens: three from surface sediments of Guyot Jingū, one specimen from surface sediments of Guyot Koko.

Carpocanium tulipa **Vasilenko et Khmel, sp. nov.**

Plate 2, figs. 14–19

Etymology. From the Latin *tulipa* (tulip).

Holotype. POI, no. 94/12.2-148, modern sediments, Guyot Koko (Emperor Seamount Chain), Sample LV94-12-K2-2, 1–2 cm. Guyot Koko (Emperor Seamount Chain), Sample LV94-12-K2-2, 1–2 cm.

Description. The skeleton is elongated-oval and consists of two segments. The apical horn is absent. The cephalis is horizontally elongated, flattened, divided by a radial structure into three distinct chambers; it is located evenly or with a slight offset and is immersed in the thorax by about half. The skeletal wall is thin, with deep pores. The thorax is ovoid. The pores are rounded, located in a checkerboard pattern (8-12 pores diagonally). The aperture ends in a ring-shaped peristome, surrounded by thin conical teeth, which are barely noticeable in some specimens.

Dimensions in µm:

Specimen no.	SH	Hc	Ht	Wc	Wt	Wa
94/12.2-148 (holotype)	85	20	60	45	67.5	42
86/12.1-65	86	21	59	45	67	30
94/12.2-129	91	20	60	39	63	35
94/12.2-128	92	22	63	43	68	38
86/12.1-64	91	22	61	47	72	43
86/6-170	92	23	62	46	72	42
86/6-171	88	20	60	45	66	32

Comparison. *C. tulipa* sp. nov. is most similar to *C. praecursor* Kruglikova, 1978 but differs in having a smaller number of larger and more sparse pores arranged in a checkerboard pattern. There is also some similarity with the species *C. micropora* (Stöhr, 1880), mainly in the general shape of the skeleton, but differs in having a smaller number of larger pores arranged in a checkerboard pattern, a horizontally elongated flattened cephalis and the presence of small teeth framing the aperture.

Material. 25 specimens: two specimens from surface sediments of Guyot Jingū, 23 specimens from surface sediments of Guyot Koko.

Carpocanium fungus **Vasilenko et Khmel, sp. nov.**

Plate 2, figs. 20–22

Etymology. From the Latin *fungus* (fungus).

Holotype. POI, no. 86/12.1-74, modern sediments, Jingū Guyot (Emperor Seamount Chain), Sample LV86-12, 0–3 cm.

Description. The skeleton is oval-mushroom-shaped and consists of two segments. The apical horn is absent. The cephalis is almost spherical, immersed in the thorax by half. The thorax is rounded-conical, slightly widened towards the mouth. The wall of the thorax is medium, with deep pores of different sizes. The pores on the thorax are randomly spread, in some

←

Explanation of Plate 2

All: Emperor Seamount Chain, modern sediments: Jingū Guyot (Sample LV86-12, 0–3 cm, depth 1935 m: figs. 2, 3, 5, 8, 10, 12, 17, 19–22; Sample LV86-14, 0–3 cm, depth 1446 m: figs. 1, 4, 6, 7, 11); Koko Guyot (core LV94-12-K2, depth 2231–2242 m: Sample LV94-12-K2-2, 1–2 cm: figs. 9, 13–16, 18). Scale bar 100 µm.

Figs. 1–7. *Carpocanium rotundum* sp. nov.: (1) holotype POI, no. 86/14.1-70; (2) specimen POI, no. 86/12.1-77; (3) specimen POI, no. 86/12.1-78; (4) specimen POI, no. 86/14.1-71; (5) specimen POI, no. 86/12.1-79; (6) specimen POI, no. 86/12.1-63; (7) specimen POI, no. 86/12.1-60.

Figs. 8, 9. *Carpocanium fragaria* sp. nov.: (8) holotype POI, no. 86/12.1-89; (9) specimen POI, no. 94/12.2-131(9a) focus on pores, (9b) focus on skeleton outline.

Figs. 10–12. *Carpocanium alabastrum* sp. nov.: (10) holotype POI, no. 86/12.1-87; (11) specimen POI, no. 86/14.1-47: (11a) focus on pores, (11b) focus on skeleton outline; (12) specimen POI, no. 86/12.1-88.

Fig. 13. *Carpocanium* cf. *alabastrum* sp. nov., specimen POI, no. 94/12.2-142.

Figs. 14–19. *Carpocanium tulipa* sp. nov.: (14) holotype POI, no. 94/12.2-148; (15) specimen POI, no. 94/12.2-146; (16) specimen POI, no. 94/12.2-144; (17) specimen POI, no. 86/12.1-65; (18) specimen POI, no. 94/12.2-128; (19) specimen POI, no. 86/12.1-64.

Figs. 20–22. *Carpocanium fungus* sp. nov.: (20) holotype POI, no. 86/12.1-74: (20a) focus on pores, (20b) focus on skeleton outline; (21) specimen POI, no. 86/12.1-75: (21a) focus on pores, (21b) focus on skeleton outline; (22) specimen POI, no. 86/12.1-75.1.

specimens they resemble a checkerboard pattern. The peristome is elongated, ending in eight wide conical teeth, slightly widening in the middle part and narrowing towards the end, about half or a third of the height of the skeleton.

Dimensions in μm:

Specimen no.	SH	Hc	Ht	Wc	Wt	Wa
86/12.1-74 (holotype)	96	16	57	44	72	30
86/21-39	97	14	60	40	70	35
86/12.1-75	96	15	59	42	72	35
86/12.1-75.1	96	16	60	43	72	35

Comparison. *C. fungus* sp. nov. has a characteristic mushroom-shaped form, which distinguishes it from other species of the genus *Carpocanium*. The greatest similarity of the new species is observed with *C. pulchrum* Carnevale, 1908, which also has a close mushroom-shaped form due to the almost spherical thorax and long parallel teeth around the relatively narrow aperture. *C. fungus* sp. nov. differs from *C. pulchrum* Carnevale, 1908 in the chaotic arrangement of pores of different sizes, while in the latter the pores are arranged in even vertical rows and are of the same size. Some similarity is also observed with the species *C. verecundum* Haeckel, 1887, but the new species differs in a smaller number of larger pores, spaced randomly, and in wider basal teeth.

Material. Five specimens: one from surface sediments of Nintoku guyot, four specimens from surface sediments of Jingū Guyot.

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This work does not contain any studies involving human or animal subjects.

CONFLICT OF INTEREST

The authors of this work declare no conflict of interest.

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