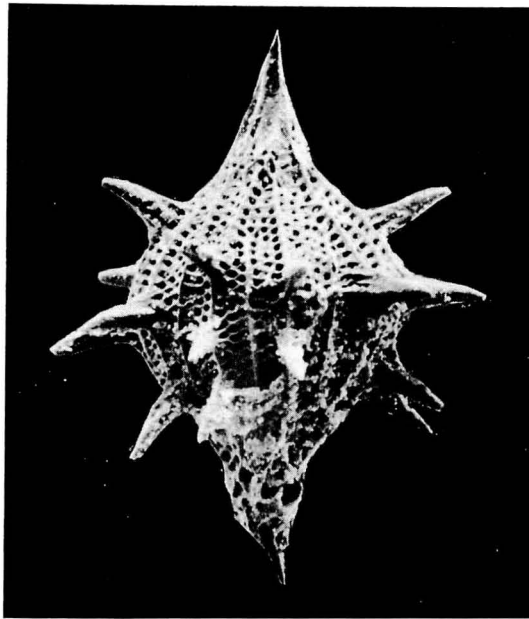


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The fossil on the cover is *Unuma (Spinunuma) echinatus* ICHIKAWA and YAO, a Middle Jurassic multisegmented radiolaria from Unuma, Gifu Prefecture, central Japan (photo by A. YAO, × 260).

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804. RECURRENT MOLLUSCAN ASSOCIATIONS OF THE OMMA-MANGANJI
FAUNA IN THE GOJOME-OGA AREA, NORTHEAST HONSHU
PART 2. SYSTEMATIC NOTES ON BIVALVE SPECIES*

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Abstract. Forty-seven species of bivalves from the Gojome-Oga area are described.

Systematic notes (continued from Part 1)

Nucula (Leionucula) niponica Smith, 1885

Pl. 31, Fig. 1.

Nucula niponica Smith, 1885, p. 226, pl. 18, figs. 8, 8a.

Nucula (Nucula) niponica Smith. Otuka, 1936, pp. 727, 728, pl. 41, figs. 1a—b, 2.

Locality: Og1-1 (CM16391, CM16392).

Acila (Acila) divaricata (Hinds, 1843)

Pl. 31, Fig. 2.

Nucula mirabilis Adams and Reeve. Yokoyama, 1920, pp. 180, 181, pl. 19, fig. 9.

Acila (Acila) divaricata (Hinds). Schenck, 1936, pp. 90—92, pl. 15, figs. 1—10, text-fig. 8 (1, 2).

Acila nakazimai Otuka. Takayasu, 1962, pl. 1, fig. 14.

Locality: Og2-2a (CM16393); Og2-4 (CM16394, CM16395).

Acila (Truncacila) nakazimai Otuka, 1939

Pl. 31, Fig. 3.

Acila (Truncacila) nakazimai Otuka, 1939, pp. 26, 27, pl. 2, figs. 9—11.

Locality: 1-1 (CM16396, CM16397); 2-2d (CM16398); 2-7 (CM16399); 4-3 (CM16400); 4-4 (CM16401); 4-5g (CM16402); 4-5h (CM16403); 5-5 (CM16404); 5-13b (CM16405); 23-2 (CM16406); 26-2c (CM16407); 34-1 (CM16408).

Acila (Truncacila) sp.

Pl. 31, Fig. 4.

Small form of *Acila (Truncacila)* appears in the sandy *Macoma tokyoensis* Association, and is similar to small individuals of *Acila nakazimai* in outline and surface ornamentation. The samples of *Acila nakazimai* listed above contain individuals larger than 20 mm long or in some cases than 30 mm long, and occur from the *Acila-Turritella*, *Nuculana* and *Thyasira bisecta* Associations, while *Acila sp.* in the *Macoma tokyoensis* Association is 11.6 mm long in the largest individual and usually smaller than 7 mm long. It can not be decided whether these specimens of *Acila* represent a distinct species differ from *nakazimai* or a dwarf ecophenotype of *nakazimai* in shallower sandy bottom.

Locality: 4-2a (CM16409, CM16410); 4-2b (CM16411); 5-1a (CM16412); 25-2 (CM16413).

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Nuculana sadoensis (Yokoyama, 1926)

Pl. 31, Figs. 5, 6.

Leda sadoensis Yokoyama, 1926b, p. 308, pl. 36, fig. 6.*Nuculana pernula sadoensis* (Yokoyama). Suzuki and Kanehara, 1936, pp. 179, 180, pl. 10, figs. 1-7; Takayasu, 1962, pl. 1, figs. 9a-b.*Nuculana (Nuculana) pernula sadoensis* (Yokoyama). Oyama, 1951, p. 148, pl. 6, figs. 3a-b.

Suzuki and Kanehara (1936), who examined the topotype specimens, noted that the surface of the species is concentrically very finely grooved, and that the small area below the umbo is ornamented by low and fine concentric ribs. Five specimens examined here have such ornamentation and other features also well agree with the description of Yokoyama (1926b), and Suzuki and Kanehara (1936). This species is very similar to *Nuculana pernula* in outline, but *pernula* has numerous and fine concentric ribs on the whole surface of the shell.

Locality: 2-8 (CM16414); 12-2 (CM16415, CM16416); Og2-1 (CM16417, CM16418).

Nuculana yokoyamai Kuroda, 1934

Pl. 31, Fig. 8.

Leda ramsayi Smith. Yokoyama, 1920, pp. 176, 177, pl. 19, figs. 3a-b.*Nuculana (Thestyleda) yokoyamai* Kuroda, 1934, p. 204; Kaseno and Matsuura, 1965, pl. 7, fig. 10; Kuroda, Habe and Oyama, 1971, p. 320, pl. 66, fig. 14; Ogasawara, 1977, pl. 5, fig. 2.

Locality: 2-2c (CM16419, CM16420); 20-1b (CM16421); 26-4 (CM16422); 26-7c (CM16423); Og2-4 (CM16424).

Nuculana (Robaia) robai (Kuroda, 1929)

Pl. 31, Fig. 7.

Leda robai Kuroda, 1929, app. 9, app. 6, figs. 6, 7.*Nuculana robai* (Kuroda). Suzuki and Kanehara, 1936, pp. 181, 182, pl. 10, figs. 8-15; Takayasu, 1962, pl. 1, figs. 10a-b; Chinzei, 1973, pl. 14, fig. 10.*Nuculana (Robaia) robai* (Kuroda). Habe, 1958a, p. 248.*Robaia robai* (Kuroda). Habe and Ito, 1965, p. 105, pl. 34, fig. 15.

One right valve and some fragmental shells are examined. They are characterized by nearly straight postero-dorsal margin, wide and round posterior margin and smooth surface of the shell. They are identical with *Nuculana (Robaia) robai* (Kuroda).

Locality: 5-11b (CM16425); 5-13c (CM16426); 28-2 (CM16427); Og1-1 (CM16428); Og2-7 (CM16429).

Saccella (Costanuculana) onoyamai
(Otuka, 1935)

Pl. 31, Figs. 9-11.

Nuculana onoyamai Otuka, 1935a, pp. 507, 508, figs. 3(b), 3(c); Otuka, 1935b, p. 881, pl. 55, figs. 105, 106; Itoigawa, 1958, pl. 1, fig. 2; Iwai, 1965, p. 23, pl. 14, figs. 3a-4b.

Description:—Shell small, subelliptical in outline, high and thick, attaining 1 mm thick in central part of adult shell. Postumbonal part occupies about 55-65% of total length of shell. Umbo blunt; postero-dorsal margin nearly straight. Two round-topped ridges run from umbo to posterior margin. The upper one borders escutcheon. On the area between two ridges, a very shallow depression runs from umbo to posterior margin, corresponding with a ridge of inner shell surface. Posterior margin of flat area roundly and obliquely truncated. Prominence and shape of concentric sculpture on shell surface varies specimen by specimen. Most of the specimens have round-topped concentric ribs numbering 5 to 6 in 1 mm distance on shell. Some have acute-topped concentric ribs around umbo, and shallow and fine striations on marginal part of shell. Others have only irregular and obscure striations. The concentric ribs obscure in escutcheon and area between two ridges. These varieties coexist at Locs. 17-1 and 23-3. Tooth v-shaped.

Remarks:—These characteristics well agree with *Saccella (Costanuculana) onoyamai* (Otuka),

reported from the Pliocene Nozaki Formation in the Noto Peninsula. This species is similar to *Nuculana fumosa* E. A. Smith, 1895, from Bay of Bengal, but the species is distinguishable from *N. fumosa* by larger size of shell and weaker surface concentric ornamentation. This species is somewhat similar to *Saccella (Costanuculana) husamaru* (Nomura, 1940) (UMUT RM16656, Pl. 31, figs. 14a, 14b), but *S. husamaru* has a higher shell and a more pointed umbo which is situated in the center of shell length than the species.

The species was assigned to *Nuculana* by Otuka (1935a, b). This is moved to *Saccella (Costanuculana)*, because of its high and thick shell, and concentric ornamentation.

Locality: 7-1 (CM16430, CM16431); 17-1 (CM16432, CM16433, CM16434); 23-3 (CM16435).

Portlandia hirosakiensis Iwai, 1959

Pl. 31, Fig. 12.

Yoldia scapha Yokoyama. Yokoyama, 1926b, p. 309, pl. 35, fig. 6.

Portlandia scapha hirosakiensis Iwai, 1959, pp. 53, 54, pl. 2, figs. 10–12.

Portlandia (Portlandella) hirosakiensis Iwai. Ogasawara, 1977, p. 88, pl. 5, fig. 3.

Locality: 2-2c (CM16436); 12-2 (CM16437); 26-5d (CM16438).

Portlandia toyamaensis (Kuroda, 1929)

Pl. 31, Fig. 13.

Yoldia toyamaensis Kuroda, 1929, app. 11, app. 6, figs. 14, 15.

Portlandia (Portlandella) toyamaensis (Kuroda). Uozumi, 1957, pl. 2, figs. 2, 2a–c.

Only one valve was collected. It is characterized by the inflated and high shell, and the umbo situated about center of shell length.

Locality: Og2-1 (CM16439).

Yoldia (Yoldia) kikuchii Kuroda, 1929

Pl. 31, Fig. 15.

Yoldia (Yoldia) kikuchii Kuroda, 1929, app. 10, app. 6, figs. 10, 11; Uozumi, 1957, pl. 5, figs. 6a–c.

Yoldia (s. str.) *kikuchii* Kuroda. Oyama, 1951, p. 149, pl. 6, figs. 5a–b.

Only one conjoined individual was collected. It is subelliptical in outline, posteriorly narrowed, and compressed. The umbo is very low and situated about the center of shell length. The specimen can be identified with *Yoldia (Y.) kikuchii* (Kuroda). *Yoldia (Y.) laudabilis* differs from the present species in having larger shell and a pair of weak lines running from the beak to the antero-ventral corner.

Locality: 41-2 (CM16440).

Yoldia (Cnesterium) johanni Dall, 1925

Pl. 31, Fig. 16.

Yoldia (Cnesterium) johanni Dall, 1925, p. 32, pl. 29, fig. 7; Habe and Ito, 1965, pp. 101, 102, pl. 33, fig. 6.

Yoldia johanni Dall. Kuroda, 1929, app. 12, app. 7, fig. 16.

Shell subelliptical, postero-dorsal margin slightly concave, which terminates a pointed posterior end; fine striations obliquely crossing growth lines. *Yoldia (Cnesterium) johanni* Dall is similar to *Yoldia (Cnesterium) notabilis* Yokoyama, 1922. The postero-dorsal margin of *notabilis* is, however, more concave than that of *johanni*. *Y. (C.) scissurata* Dall, 1898 and *Y. (C.) ensifera* Dall, 1897, which are also similar to the species, have lower shell than the species.

Locality: 1-1 (CM16441); 2-1a (CM16442); 2-1b (CM16443); 2-3 (CM16444, CM16445); 4-1b (CM16446); 4-1c (CM16447); 4-1d (CM16448); 4-4 (CM16449); 4-5a (CM16450); 5-13b (CM16451); 20-1a (CM16452); 21-1 (CM16453); 23-2 (CM16454); 25-3-5 (CM16455).

Yoldia (Megayoldia) thraciaeformis
(Storer, 1838)

Pl. 31, Fig. 17.

Yoldia thraciaeformis (Storer). Oldroyd, 1924,

p. 27, pl. 5, fig. 1.

Yoldia scapha Yokoyama, 1926a, p. 247, pl. 31, figs. 7-11.

Portlandia (Megayoldia) thraciaeformis (Storer). Uozumi, 1957, pp. 574-576, pl. 1, figs. 5, 5a, 7, 8, 8a, pl. 7, figs. 23, 28.

Yoldia (Megayoldia) thraciaeformis (Storer). Habe and Ito, 1965, p. 102, pl. 33, fig. 7; MacAlester in Moore, 1969, p. N241, fig. A9 (10).

Locality: 2-2a (CM16456); 2-6 (CM16457, CM16458); 2-7 (CM16459); 4-3 (CM16460); 4-4 (CM16461); 25-3-18 (CM16462); 25-3-41 (CM16463); 26-5g (CM16464); 26-7c (CM16465).

Acharax tokunagai (Yokoyama, 1925)

Pl. 31, Fig. 22.

Solemya tokunagai Yokoyama, 1925a, p. 31, pl. 6, figs. 1-3; Yokoyama, 1925b, p. 11, pl. 1, figs. 20, 21.

Solemya (Acharax) tokunagai Yokoyama. Kamada, 1962, pp. 37-39, pl. 1, figs. 1-3.

Acharax tokunagai (Yokoyama). Habe and Ito, 1965, p. 100, pl. 33, fig. 1.

Locality: 41-2 (CM16466, CM16640).

Anadara amicula (Yokoyama, 1925)

Pl. 32, Figs. 1, 2.

Arca amicula Yokoyama, 1925c, p. 19, pl. 7, figs. 2-4.

Anadara amicula (Yokoyama). Takayasu, 1961, pl. 1, figs. 13a-b; Kaseno and Matsuura, 1965, pl. 7, figs. 16, 17; Chinzei, 1973, pl. 14, fig. 1.

Locality: 4-1b (CM16467); 4-1c (CM16468, CM16469, CM16470); 4-1g (CM16471); 4-2a (CM16472); 21-1 (CM16473); 25-1 (CM16474).

Limopsis tokaiensis Yokoyama, 1910

Pl. 32, Figs. 4a, 4b.

Limopsis Tokaiensis Yokoyama, 1910, pp. 1, 2, pl. 9, figs. 1-3, 5-7.

Limopsis Tokaiensis var. *elongata* Yokoyama, 1910, pp. 2, 3, pl. 9, fig. 4.

Limopsis tokaiensis Yokoyama. Kanno, 1962, pl. 3, figs. 5a-b.

Locality: 5-11a (CM16475); 7-7a (CM16476); 7-8 (CM16477, CM16478).

Crenulilimopsis oblonga (A. Adams, 1860)

Pl. 32, Figs. 6a, 6b, 7a, 7b.

Limopsis oblonga A. Adams, 1860, p. 412.

Limopsis crenata A. Adams, 1863b, p. 230; Yokoyama, 1910, p. 3, pl. 9, figs. 8-11; Yokoyama, 1920, pp. 173, 174, pl. 18, figs. 17, 18; Habe, 1961a, p. 192, pl. 1, fig. 3.

Limopsis tumidula Thiele and Jaekel, 1931, p. 186, pl. 6, fig. 26.

Pectunculina oblonga (A. Adams). Habe, 1953, p. 204, pl. 29, figs. 12-14; Habe, 1961b, p. 112, p. 50, fig. 8.

Limopsis (Pectunculina) crenata A. Adams. Kaseno and Matsuura, 1965, pl. 6, fig. 13; Shikama and Masujima, 1969, pl. 7, figs. 10, 11.

Crenulilimopsis oblonga (A. Adams). Kuroda, Habe and Oyama, 1971, pp. 339, 340, pl. 71, figs. 13-15.

Immature shell of the species has obliquely subcircular outline, and mature shell becomes postero-ventrally elongated. Surface is ornamented by fine ridge-like concentric ribs, which are crossed by very fine radial furrows. Inner margin is crenulated. The crenulation is obscure or often disappears in anterior and posterior margins.

Locality: 20-1a (CM16483); 20-1b (CM16484, CM16485, CM16486).

Glycymeris derelicta (Yokoyama, 1928)

Pl. 32, Figs. 8a, 8b.

Pectunculus derelictus Yokoyama, 1928, p. 361, pl. 69, fig. 1.

?*Glycymeris nipponica* (Yokoyama). Nomura and Hatai, 1935, pp. 92, 93, pl. 9, figs. 10-13; Iwai, 1965, p. 26, pl. 14, figs. 15-17.

Glycymeris derelicta (Yokoyama). Nomura and Zimbo, 1935, pp. 157, 158, pl. 15, figs. 1, 2; Chinzei, 1959, pp. 122, 123, pl. 11, figs. 12-15.

?*Glycymeris* (s.s.) *nipponica* (Yokoyama). Hatai, Masuda and Suzuki, 1961, pl. 1, figs. 7a-b.

The species has very characteristic features, as noted by Chinzei (1959). It has unequilateral outline, opisthogyral beak, and asymmetric, duplivincular ligament grooves. These features are recognized either in adult and immature individuals. In specimens larger than about 25 mm high, the shell is ventrally or antero-ventrally elongated, and the posterior adductor muscle scar is slightly reduced. The immature individuals of the species is very similar to *Glycymeris rotunda* and *G. nipponica* in outline, but the latter two species have nearly symmetric ligamental grooves. Mature specimens of *rotunda* and *nipponica* are postero-ventrally elongated, and never reduce the posterior muscle scar.

Locality: 2-3 (CM16487); 4-4 (CM16488); 4-5g (CM16489); 23-2 (CM16490); 25-3-6 (CM16491); 25-3-7.5 (CM16492); 25-3-33 (CM16493); 25-3-34 (CM16494); 25-3-52 (CM16495); 26-5g (CM16496).

Glycymeris yessoensis (Sowerby, 1889)

Pl. 32, Figs. 9a, 9b.

Pectunculus yessoensis Sowerby, 1889, p. 570, pl. 28, fig. 19; Yokoyama, 1920, p. 168, pl. 18, figs. 1, 2; Yokoyama, 1922, p. 189, 190, pl. 16, figs. 6, 7.

Glycymeris yessoensis (Sowerby). Nomura and Hatai, 1935, pp. 93–95, pl. 9, fig. 14.

Glycymeris (Glycymeris) yessoensis (Sowerby). Ogasawara, 1977, pp. 93–94, pl. 5, figs. 14, 15, 18–22.

This species is similar to *Glycymeris derelicta* noted above. The former species, however, has antero-posteriorly elongated, less inflated, thinner shell than *derelicta*. The outline and ligamental area of *yessoensis* is nearly symmetrical. This species is restricted to the sandy bottom *Protothaca* Association, while *derelicta* occurs from the sandy silt facies as a common component of the *Acila-Turritella* Association. In other words, *yessoensis* was living in a shallower depth than *derelicta*. Similar congeneric species pairs in the genus *Glycymeris* are found in the other areas. In the continental shelf of the Pacific coast of southern Honshu, *Glycymeris*

vestita or *G. albolineata* is found in a shallower sandy bottom, and *G. rotunda* in a deeper muddy bottom. In the Pliocene of the Kakegawa area of the central Honshu, *G. totomiensis* or *G. nakamurai* and *G. rotunda* represent a similar pair of *Glycymeris* species (Chinzei, 1980).

Locality: 4-1a (CM16497); 4-1b (CM16498); 4-1c (CM16499); 4-1d (CM16500); 6-1 (CM16501); 25-1 (CM16502).

Solamen spectabilis (A. Adams, 1862)

Pl. 31, Fig. 18.

Crenella spectabilis A. Adams, 1862, p. 228.

Solamen spectabilis (A. Adams). Kuroda, Habe and Oyama, 1971, p. 342, pl. 74, figs. 7, 8.

Locality: 21-1 (CM16503, CM16641).

Chlamys islandica (Müller, 1776)

Pl. 31, Fig. 20.

Chlamys (s.s.) *islandicus* (Müller). Shikama and Ikeya, 1964, pp. 29–54, pls. 1–2.

Chlamys islandicus (Müller). Habe and Ito, 1965, p. 120, pl. 39, fig. 2.

Chlamys islandica (Müller). Abbott, 1974, p. 444, pl. 19, fig. 5147.

Locality: Og2-4 (CM16504).

Palliolium (Delectopecten) peckhami
(Gabb, 1869)

Pl. 31, Fig. 19.

Pecten tairanus Yokoyama, 1925b, pp. 8, 9, pl. 1, figs. 8, 9.

Palliolium (Delectopecten) peckhami (Gabb). Weaver, 1942, pp. 96–97, pl. 11, fig. 6, pl. 21, fig. 4; Shuto, 1960, pp. 123, 124, pl. 12, figs. 8, 9.

Delectopecten peckhami (Gabb). Masuda, 1962, pp. 158, 159, pl. 18, figs. 12–16.

Locality: Og1-3 (CM16505); Og1-5 (CM16506, CM16507).

Mizuhopecten poculum (Yokoyama, 1926)

Pl. 31, Fig. 21.

Pecten poculum Yokoyama, 1926a, pp. 245, 246, pl. 32, figs. 1–3.

Pecten kurosawaensis Yokoyama, 1926c, p. 388, pl. 45, fig. 3.

Patinopecten (Patinopecten) poculum (Yokoyama). Masuda, 1962, p. 209, pl. 24, fig. 1, pl. 25, fig. 5.

Mizuhopecten poculum (Yokoyama). Iwai, 1965, pp. 29, 30, pl. 15, figs. 11, 12.

Locality: 4-2b (CM16508); 6-1 (CM16509, CM16510).

Lucinoma acutilineata (Conrad, 1849)

Pl. 32, Fig. 10.

Lucina (Phacoides) borealis (Linné). Yokoyama, 1925a, p. 24, pl. 5, figs. 5–8; Yokoyama, 1925b, pp. 18, 19, pl. 1, fig. 2, pl. 3, figs. 1, 2.

Lucina acutilineata (Conrad). Weaver, 1942, pp. 143–144, pl. 34, figs. 8, 11, 16.

Lucinoma acutilineata (Conrad). Takayasu, 1961, pl. 1, fig. 15.

Lucinoma acutilineatum (Conrad). Kamada, 1962, pp. 95–97, pl. 9, figs. 10–16, pl. 10, figs. 1–3.

Locality: 2-1a (CM16511); 5-12a (CM16512); 7-6c (CM16513); 14-3 (CM16514); 20-1b (CM16515); 21-1 (CM16516); 23-1 (CM16517); 41-1 (CM16518).

Thyasira (Thyasira) tokunagai

Kuroda and Habe, 1951

Pl. 32, Fig. 11.

Thyasira gouldii (Philippi). Yabe and Nomura, 1925, p. 94, pl. 23, figs. 6a–b; Yokoyama, 1927a, p. 433, pl. 50, fig. 9; Yokoyama, 1927b, p. 457, pl. 52, figs. 3, 4.

Thyasira tokunagai Kuroda and Habe, 1951, p. 86; Habe, 1961b, p. 124, pl. 56, fig. 17; Takayasu, 1962, pl. 1, fig. 2; Kaseno and Matsuura, 1965, pl. 13, fig. 2.

Thyasira (Thyasira) tokunagai Kuroda and Habe. Habe, 1977, p. 131, pl. 24, figs. 17, 18.

Locality: 2-1a (CM16519, CM16520).

Thyasira (Conchocele) bisecta (Conrad, 1849)

Pl. 32, Fig. 12.

Thyasira bisecta Conrad. Oldroyd, 1924, p. 120, pl. 10, fig. 1; Yabe and Nomura, 1925, p. 84, pl. 23, figs. 2, 7–10; Yokoyama, 1926b, pp. 294, 295, pl. 35, figs. 2, 3; Takayasu, 1961, pl. 2, figs. 5, 6.

Thyasira bisecta var. *nipponica* Yabe and Nomura, 1925, pp. 84–92, pl. 23, fig. 3, pl. 24, figs. 2–4.

Conchocele bisecta (Conrad). Habe, 1977, p. 129, pl. 24, fig. 19.

Locality: 7-6c (CM16521); 7-6g (CM16522); 14-1 (CM16523); 14-4d (CM16524); 14-5a (CM16525, CM16526); 15-3 (CM16527); 29-1 (CM16528); 41-1 (CM16529).

Axinopsida subquadrata (A. Adams, 1862)

Pl. 33, Figs. 1a, 1b, 2a, 2b.

Cryptodon (Clausina) subquadratus A. Adams, 1862, p. 227.

Axinopsida subquadrata (A. Adams). Habe, 1955, p. 10, pl. 1, figs. 8, 9.

Shell small, less than 4 mm high, subquadrate in outline, inflated and thin. Some have a very weak depression passing from beak to postero-ventral corner. Antero-dorsal margin concave. A node-like tooth just below beak in right valve.

The characteristics well coincide with *Axinopsida subquadrata* (A. Adams).

Locality: 4-1c (CM16530); 4-2a (CM16531, CM16532); 4-2b (CM16533); 6-3 (CM16534).

Felaniella usta (Gould, 1861)

Pl. 33, Fig. 3.

Diplodonta usta (Gould). Yokoyama, 1920, pp. 130, 131, pl. 9, figs. 14–16; Yokoyama, 1922, p. 159, pl. 13, fig. 3.

Felaniella usta (Gould). Habe, 1955, p. 10, pl. 6, figs. 8, 9.

Locality: 4-1b (CM16535); 4-1c (CM16536); 4-1d (CM16642); 4-1e (CM16537, CM16538); 4-1f (CM16539); 4-1g (CM16540); 4-1h (CM16541).

Cyclocardia aomoriensis (Chinzei, 1961)

Pl. 33, Figs. 4a, 4b, 5.

Venericardia (Cyclocardia) aomoriensis Chinzei, 1961, p. 110, pl. 1, figs. 9—11.

The species is characterized by large and thick shell, nearly circular outline, and low and broad ribs numbering 21 (Chinzei, 1961). More than ten abraded specimens examined here are rather small, less than 26 mm high, although the holotype is 4 cm. The large specimens have thick and circular shell. Smaller ones not exceeding 20 mm high is somewhat variable in outline; some are circular, and the others are trigonally subcircular. The radial ribs are 19—23 in number.

Locality: 6-1 (CM16542, CM16543, CM16544).

Cyclocardia ferruginea (Clessin, 1888)

Pl. 33, Fig. 7.

Venericardia ferruginea (Clessin). Chinzei, 1958, pl. 7, fig. 6.

Cyclocardia ferruginea (Clessin). Habe and Ito, 1965, p. 128, pl. 43, fig. 9.

Locality: 20-1b (CM16545, CM16546); 21-1 (CM16547); Og2-1 (CM16548).

Cyclocardia sp.

Pl. 33, Fig. 8.

Three specimens examined here are small in size, 5 mm high or lower. The shells are similar to *Venericardia (Cyclocardia) ferruginea complexa* Ogasawara (1977, pp. 107—109, pl. 11, figs. 3a—b, pl. 12, fig. 4) in outline, but have only fifteen or sixteen radial ribs. The interspace of radial ribs is wider in these specimens than in *complexa*.

Locality: 4-5d (CM16549); 25-3-27 (CM16550); M4B (CM16551).

Miodontiscus nakamurai (Yokoyama, 1923)

Pl. 33, Fig. 6.

Venericardia nakamurai Yokoyama, 1923a, pp. 5, 6, pl. 1, fig. 9.

Miodontiscus nakamurai (Yokoyama). Ogasawara, 1977, pp. 110, 111, pl. 10, figs. 3a—b, pl. 11, figs. 1a—b, 2a—b.

Locality: M3B (CM16552).

Tridonta borealis Schumacher, 1817

Pl. 33, Figs. 9a, 9b.

Tridonta borealis Schumacher. Habe and Ito, 1965, p. 127, pl. 43, fig. 2.

Astarte (Tridonta) borealis (Schumacher). Ogasawara, 1977, p. 105, pl. 11, figs. 8, 9, 13a—b.

Locality: 2-1b (CM16553); 2-2a (CM16554); 21-1 (CM16555); 25-3-51 (CM16556); Og2-1 (CM16557, CM16558); Og2-4 (CM16559).

Clinocardium chikagawaense Kotaka, 1950

Pl. 33, Fig. 11.

Clinocardium chikagawaense Kotaka, 1950, pp. 46—49, pl. 5, figs. 1—6.

Locality: 2-1a (CM16560); 2-2b (CM16561); 4-5a (CM16562); 4-5c (CM16563); 4-5e (CM16564); 4-5f (CM16565); 4-5g (CM16566); 4-5h (CM16567); 7-1 (CM16568); 20-1b (CM16569); 23-3 (CM16570); 25-3-1 (CM16571); 25-3-5 (CM16572); 25-3-35 (CM16573); 26-5e (CM16574).

Clinocardium fastosum (Yokoyama, 1927)

Pl. 33, Figs. 10a, 10b.

Cardium fastosum Yokoyama, 1927c, pp. 178, 179, pl. 48, fig. 5.

Clinocardium fastosum (Yokoyama). Kaseno and Matsuura, 1965, pl. 13, fig. 11; Ogasawara, 1977, pp. 115, 116, pl. 11, figs. 16, 19.

Locality: 6-1 (CM16575); 24-1a (CM16576).

Fulvia mutica (Reeve, 1844)

Pl. 33, Fig. 12.

Cardium muticum Reeve. Yokoyama, 1920, p. 128, pl. 9, figs. 11a—b; Yokoyama, 1922, pp. 154, 155, pl. 12, fig. 7.

Fulvia mutica (Reeve). Habe and Ito, 1965, p. 133, pl. 44, figs. 7, 8; Habe, 1977, p. 174, pl. 32, figs. 11, 12.

Locality: 4-1a (CM16577, CM16578).

Macoma calcarea (Gmelin, 1791)

Pl. 34, Fig. 2.

Macoma calcarea (Gmelin). Habe, 1955, p. 18, pl. 1, figs. 14, 15; Chinzei, 1959, pp. 126-128, pl. 11, fig. 11, text-fig. 3(1).

Locality: 2-3 (CM16579); 4-1a (CM16580); 4-1b (CM16581); 4-1h (CM16582); 4-2a (CM16583); 4-2b (CM16584); 4-2c (CM16585, CM16586); 4-2d (CM16587); 4-3 (CM16588); 5-1a (CM16589); 6-3 (CM16590); 7-6a (CM16591); 7-8 (CM16592); 7-9a (CM16593); 11-2 (CM16594); 12-1 (CM16595); 20-1b (CM16596); 23-1 (CM16597); 25-3-1 (CM16598); 26-5e (CM16599); 26-7c (CM16600); 28-2 (CM16601); Og2-4 (CM16602).

Macoma tokyoensis Makiyama, 1927

Pl. 34, Fig. 1.

Macoma dissimilis (Martens). Yokoyama, 1922, p. 143, pl. 10, fig. 4.

Macoma tokyoensis Makiyama, 1927, p. 50; Habe and Ito, 1965, p. 149, pl. 51, figs. 15,

16.

Locality: 4-1g (CM16603); 4-2a (CM16604); 4-2b (CM16605); 5-1b (CM16606, CM16607); 5-1f (CM16608); 5-2j (CM16609); 24-1a (CM16610).

Dosinia (Phacosoma) japonica (Reeve, 1850)

Pl. 34, Fig. 3.

Dosinia (Phacosoma) japonica (Reeve). Kira, 1959, p. 141, pl. 56, fig. 7.

Phacosoma japonicum (Reeve). Habe, 1977, p. 260, pl. 55, fig. 1.

Locality: 4-1e (CM16611).

Mercenaria stimpsoni (Gould, 1861)

Pl. 36, Fig. 5.

Venus (Mercenaria) stimpsoni Gould. Yokoyama, 1922, p. 148, pl. 11, figs. 11, 12.

Mercenaria stimpsoni (Gould). Habe, 1955, p. 13, pl. 5, figs. 10, 11; Habe and Ito, 1965, p. 137, 138, pl. 46, fig. 4; Chinzei, 1973, pl. 14, fig. 5.

Explanation of Plate 31

Fig. 1. *Nucula (Leionucula) niponica* Smith, ×2, Loc. 1-1 (CM16391).

Fig. 2. *Acila (Acila) divaricata* (Hinds), ×1, Loc. Og2-4 (CM16394).

Fig. 3. *Acila (Truncacila) nakazimai* Otuka, ×1, Loc. 1-1 (CM16396).

Fig. 4. *Acila (Truncacila)* sp., ×5, Loc. 4-2a (CM16409).

Figs. 5, 6. *Nuculana sadoensis* (Yokoyama), fig. 5, ×3, Loc. 12-2 (CM16415); fig. 6, ×2.5, Loc. Og2-1 (CM16417).

Fig. 7. *Nuculana robai* (Kuroda), ×2, Loc. Og2-7 (CM16429).

Fig. 8. *Nuculana yokoyamai* Kuroda, ×2, Loc. 2-2c (CM16419).

Figs. 9-11. *Saccella (Costanuculana) onoyamai* (Otuka), figs. 9, 10, ×2, Loc. 17-1 (fig. 9: CM16432, fig. 10: CM16433); fig. 11, ×2, Loc. 7-1 (CM16430).

Fig. 12. *Portlandia hirosakiensis* Iwai, ×2, Loc. 26-5d (CM16438).

Fig. 13. *Portlandia toyamaensis* (Kuroda), ×1, Loc. Og2-1 (CM16439).

Figs. 14a, 14b. *Saccella (Costanuculana) husamaru* (Nomura), ×2, off Jyogashima, Kanagawa Prefecture, Central Japan, 100 m in depth (RM16656).

Fig. 15. *Yoldia (Yoldia) kikuchii* Kuroda, ×1.5, Loc. 41-2 (CM16440).

Fig. 16. *Yoldia (Cnesterium) johanni* Dall, ×2, Loc. 2-3 (CM16444).

Fig. 17. *Yoldia (Megayoldia) thraciaeformis* (Storer), ×1, Loc. 2-6 (CM16457).

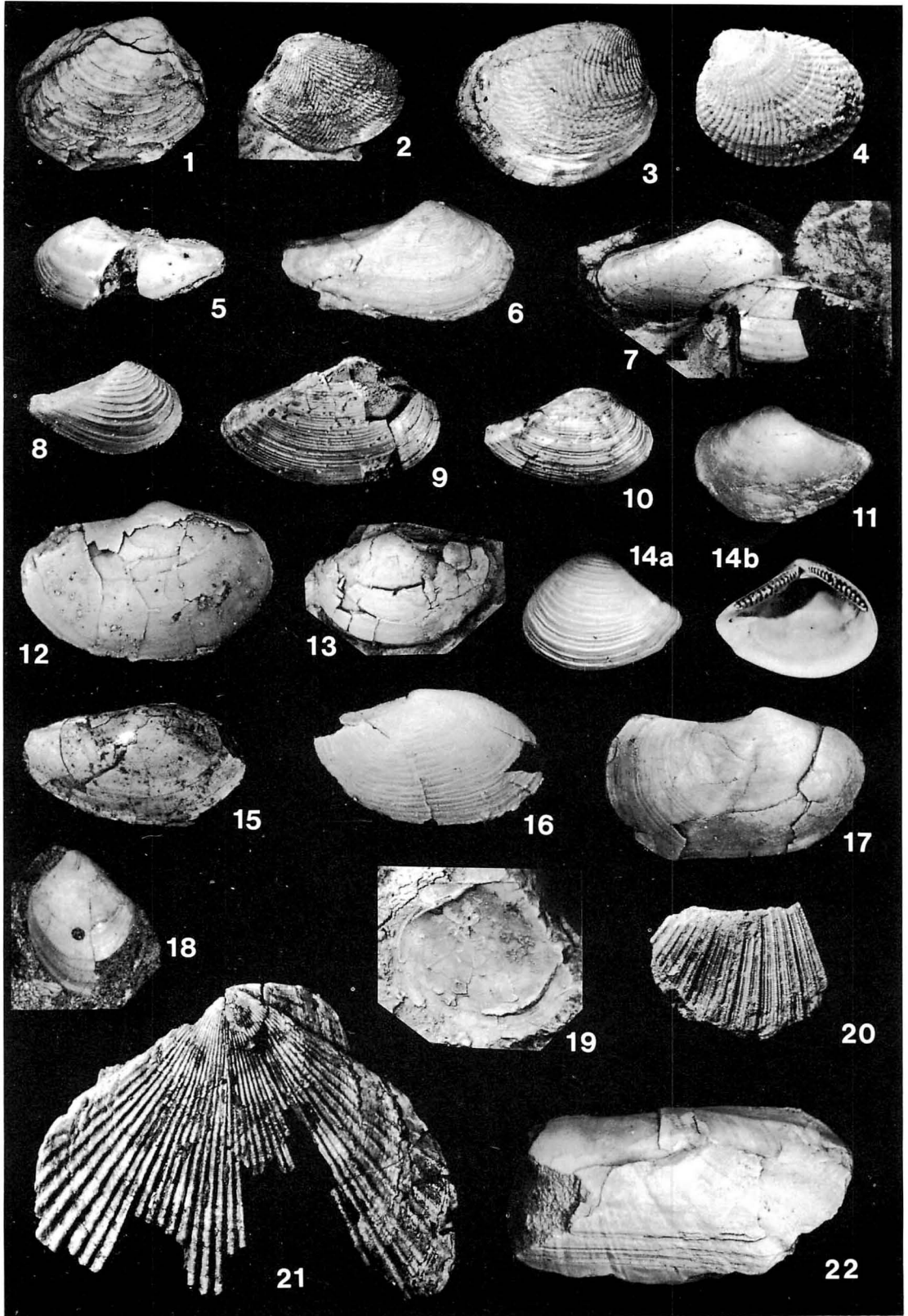
Fig. 18. *Solamen spectabilis* (A. Adams), ×2, Loc. 21-1 (CM16503).

Fig. 19. *Palliolulum (Delectopecten) peckhami* (Gabb), ×1.5, Loc. Og1-5 (CM16506).

Fig. 20. *Chlamys islandica* (Müller), ×1, Loc. Og2-4 (CM16504).

Fig. 21. *Mizuhopecten poculum* (Yokoyama), ×1/2, Loc. 6-1 (CM16509).

Fig. 22. *Acharax tokunagai* (Yokoyama), ×1, Loc. 41-2 (CM16466).



Locality: 4-1a (CM16612); 4-1c (CM16613).

Protothaca (Protocallithaca) adamsi
(Reeve, 1863)

Pl. 34, Fig. 4.

Venus rigida Gould. Yokoyama, 1927a, p. 430,
pl. 50, figs. 3, 4.

Protocallithaca adamsi (Reeve). Nomura, 1937,
p. 10, pl. 3, figs. 4a-b.

Callithaca (Protocallithaca) adamsi (Reeve). Habe,
1955, p. 14, pl. 5, figs. 1, 2.

Protothaca (Callithaca) adamsi (Reeve). Chinzei,
1961, p. 117, 118, pl. 1, fig. 8.

Locality: 4-1c (CM16614); 4-1e (CM16615);
4-1f (CM16616).

Mya (Mya) cuneiformis (Böhm, 1915)

Pl. 34, Figs. 6a, 6b.

Mya cuneiformis (Böhm). Fujie, 1957, pp.
395-397, pl. 3, fig. 5, pl. 4, figs. 1-6; Chin-
zei, 1973, pl. 14, fig. 15.

Mya (Arenomya) cuneiformis (Böhm). Kamada,
1962, pp. 141, 142, pl. 16, figs. 14-16.

Mya (Mya) cuneiformis (Böhm). MacNeil, 1965,
pp. G35-G37, pl. 7, figs. 2, 3, 5-8, 12, 15;
Honda, 1978, pl. 1, figs. 14a, 14b, 15.

Locality: 4-2c (CM16617); 4-3 (CM16618);
4-4 (CM16619); 4-5b (CM16620); 4-5c (CM
16621); 4-5d (CM16622); 4-5e (CM16623);
4-5g (CM16624); 20-1a (CM16625); 20-1b
(CM16626); 23-2 (CM16627); 24-4d (CM16628);
26-5g (CM16629).

Pandora (Pandorella) wardiana A. Adams, 1859

Pl. 34, Figs. 10, 11.

Pandora (Kennerlia) wardiana A. Adams. Habe,
1952, pp. 123, 124, pl. 18, figs. 1-3; Hatai,
Masuda and Suzuki, 1961, pl. 2, figs. 13a-b.

The specimens is referable to *Pandora wardiana*
A. Adams in having nearly straight postero-
dorsal margin and a fold running from beak to
antero-ventral margin. *Pandora pulchellus* has
concave postero-dorsal margin and more com-
pressed shell than the species. *Pandora pseudo-*
bilirata and *P. otukai* also have the fold, but

have angular postero-ventral corner.

Locality: 14-1 (CM16630); 26-4 (CM16631);
26-5g (CM16632); M10B (CM16633).

Myadora japonica Habe, 1950

Pl. 34, Fig. 7.

Myadora japonica Habe, 1950, p. 27, pl. 4, figs.
4-6.

Locality: 21-1 (CM16634, CM16635).

Periploma plane Ozaki, 1958

Pl. 34, Fig. 9.

Periploma plane Ozaki, 1958, p. 120, pl. 18,
figs. 3, 4.

This species is closely allied to *Periploma oto-*
himeae Habe, 1952 nomen nudum (= *P. ovata*
Kuroda and Horikoshi, 1952 non d'Orbigny,
1846; = *P. plane* Ozaki sensu Habe, 1977),
but has longer shell than the latter. The post-
umbonal part of *plane* forms about 56% (pl. 18,
fig. 3 of Ozaki, 1958) - 59% (a conjoined
specimen from Loc. 4-4) of the shell length,
while *otohimeae* forms about 44% (pl. 103,
fig. 2 of Kuroda, Habe and Oyama, 1971). The
posterior of this species is angular, while one of
otohimeae is rather rounded.

Locality: 4-4 (CM16636).

Periploma cf. besshoensis (Yokoyama, 1924)

Pl. 34, Fig. 8.

cf. *Tellina besshoensis* Yokoyama, 1924, p. 14,
pl. 2, figs. 1-5.

Four conjoined and deformed specimens are
examined. They are similar to *Periploma bessho-*
ensis in their large size (about 60 mm long or
less) and oval outline. They, however, have lower
shell than typical *besshoensis*, and seem not to
rostrate posteriorly. The shell torsion, which is
characteristic feature of the species, can not be
assessed in the specimens, because of deforma-
tion of the shells.

Locality: 41-2 (CM16637, CM16638).

Thracia kakumana (Yokoyama, 1927)

Pl. 34, Fig. 12.

Tellina kakumana Yokoyama, 1927c, pp. 177, 178, pl. 47, fig. 14.

Thracia kakumana (Yokoyama). Habe, 1955, p. 26, pl. 1, figs. 3, 4; Itoigawa, 1958, pl. 2, fig. 4; Ogasawara, 1977, p. 102, pl. 17, figs. 8, 13.

Locality: 5-1h (CM16639).

Acknowledgments

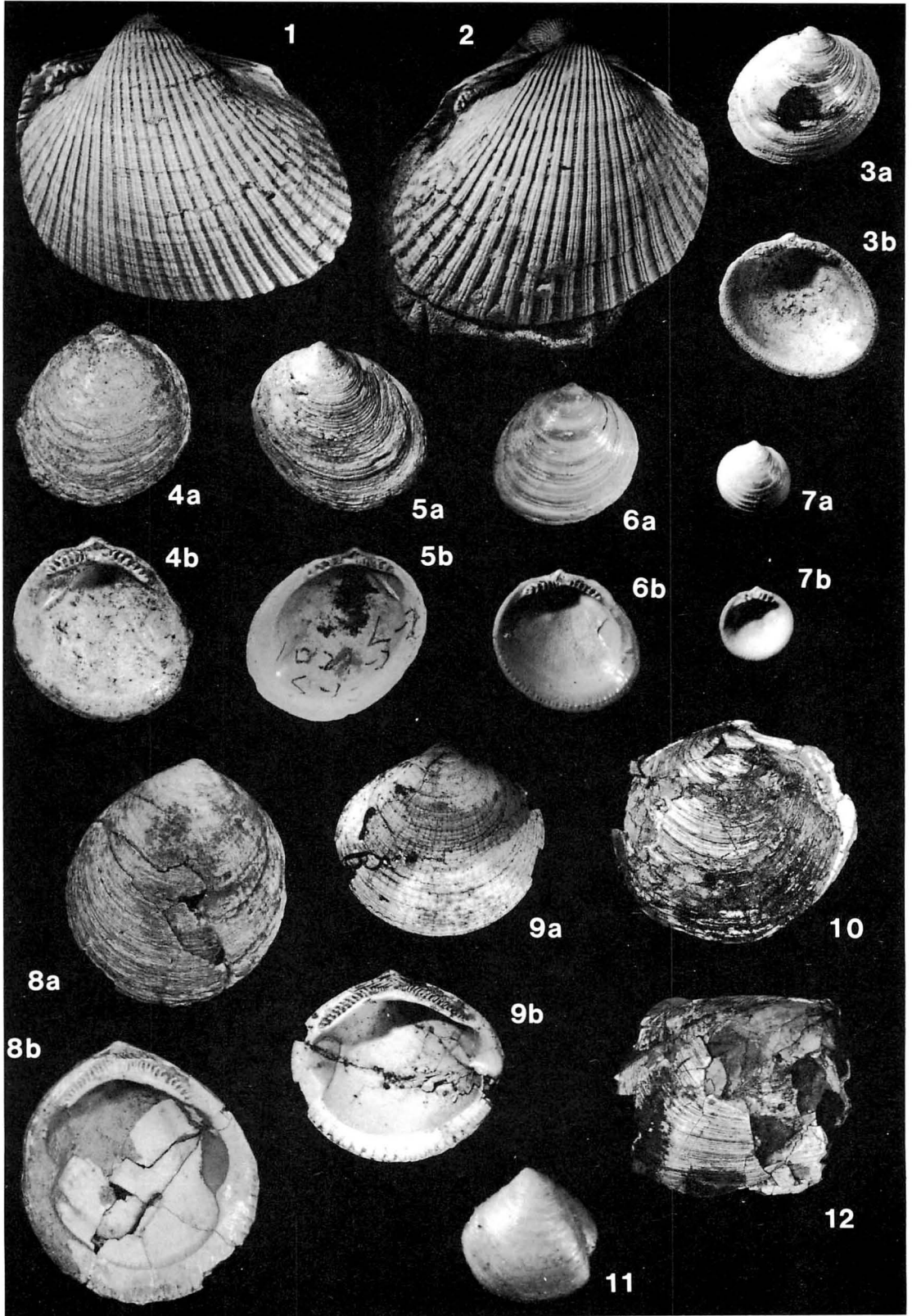
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Explanation of Plate 32

- Figs. 1, 2. *Anadara amicula* (Yokoyama), ×1, Loc. 4-1c (fig. 1: CM16468, fig. 2: CM16469).
- Figs. 3a, 3b. *Limopsis* sp. A, ×3, Loc. 26-7c (CM16479).
- Figs. 4a, 4b. *Limopsis tokaiensis* Yokoyama, ×2, Loc. 7-8 (CM16477).
- Figs. 5a, 5b. *Limopsis* sp. B, ×2, Loc. Og2-4 (CM16481).
- Figs. 6a, 6b, 7a, 7b. *Crenulilimopsis oblonga* (A. Adams), ×3, Loc. 20-1b (fig. 6: CM16484, fig. 7: CM16485).
- Figs. 8a, 8b. *Glycymeris derelicta* (Yokoyama), ×1, Loc. 4-4 (CM16488).
- Fig. 9a, 9b. *Glycymeris yessoensis* (Sowerby), ×1, Loc. 25-1 (CM16502).
- Fig. 10. *Lucinoma acutilineata* (Conrad), ×1/2, Loc. 14-3 (CM16514).
- Fig. 11. *Thyasira (Thyasira) tokunagai* Kuroda and Habe, ×3, Loc. 2-1a (CM16519).
- Fig. 12. *Thyasira (Conchocele) bisecta* (Conrad), ×1/2, Loc. 14-5a (CM16525).

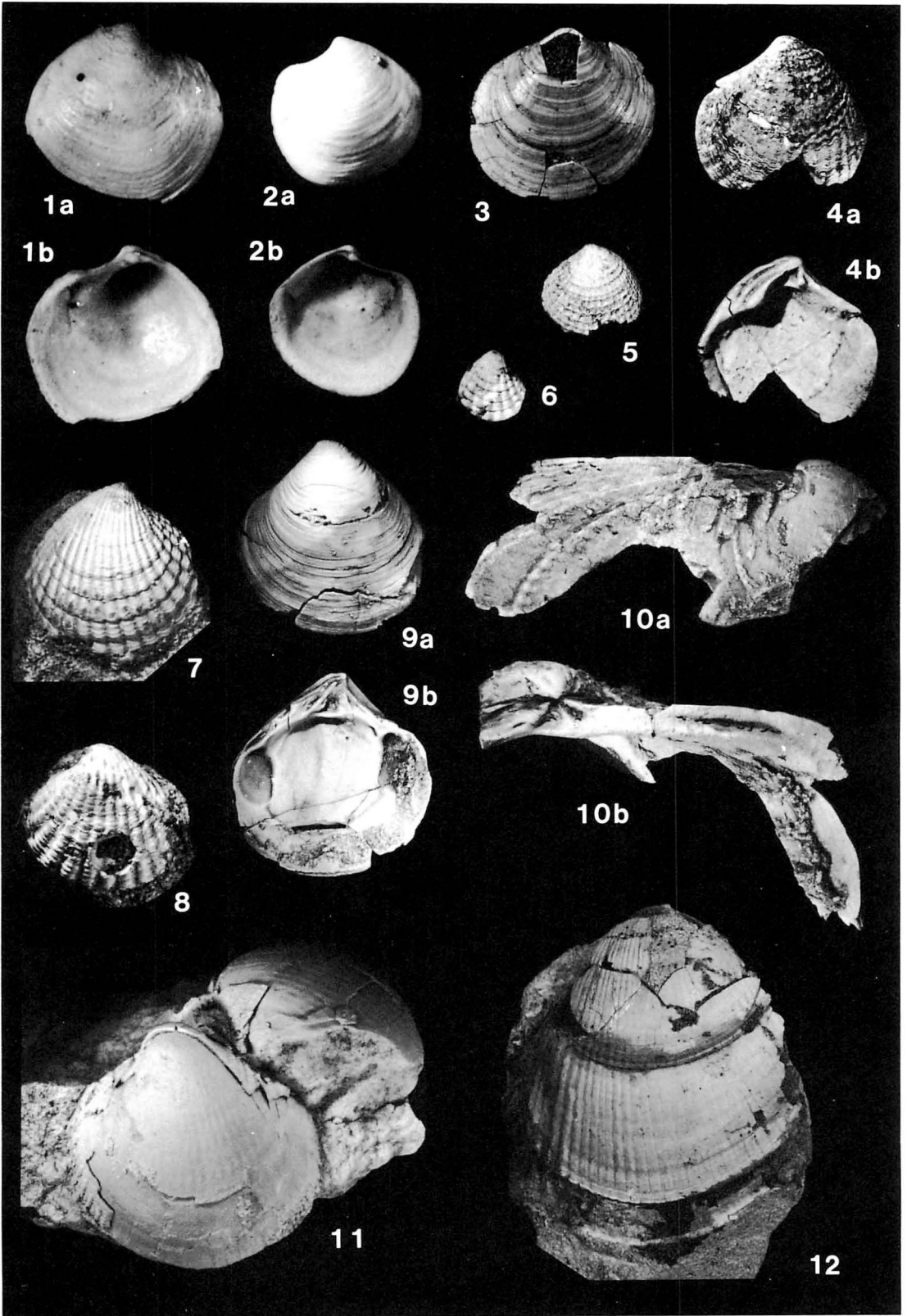


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Explanation of Plate 33

- Figs. 1a, 1b, 2a, 2b. *Axinopsida subquadrata* (A. Adams), ×10, figs. 1a, 1b, Loc. 4-2a (CM16531); figs. 2a, 2b, Loc. 6-3 (CM16534).
- Fig. 3. *Felaniella usta* (Gould), ×2, Loc. 4-1e (CM16537).
- Figs. 4a, 4b, 5. *Cyclocardia aomoriensis* (Chinzei), ×1, figs. 4a, 4b, Loc. 6-1 (CM16542); fig. 5, Loc. 6-1 (CM16543).
- Fig. 6. *Miodontiscus nakamurai* (Yokoyama), ×4, Loc. M3B (CM16552).
- Fig. 7. *Cyclocardia ferruginea* (Clessin), ×4, Loc. 20-1b (CM16545).
- Fig. 8. *Cyclocardia* sp., ×4, Loc. M4B (CM16551).
- Figs. 9a, 9b. *Tridonta borealis* Schumacher, ×1, Loc. 25-3-51 (CM16556).
- Figs. 10a, 10b. *Clinocardium fastosum* (Yokoyama), ×1, Loc. 24-1a (CM16576).
- Fig. 11. *Clinocardium chikagawaense* Kotaka, ×1, Loc. 7-1 (CM16568).
- Fig. 12. *Fulvia mutica* (Reeve), ×1, Loc. 4-1a (CM16577).

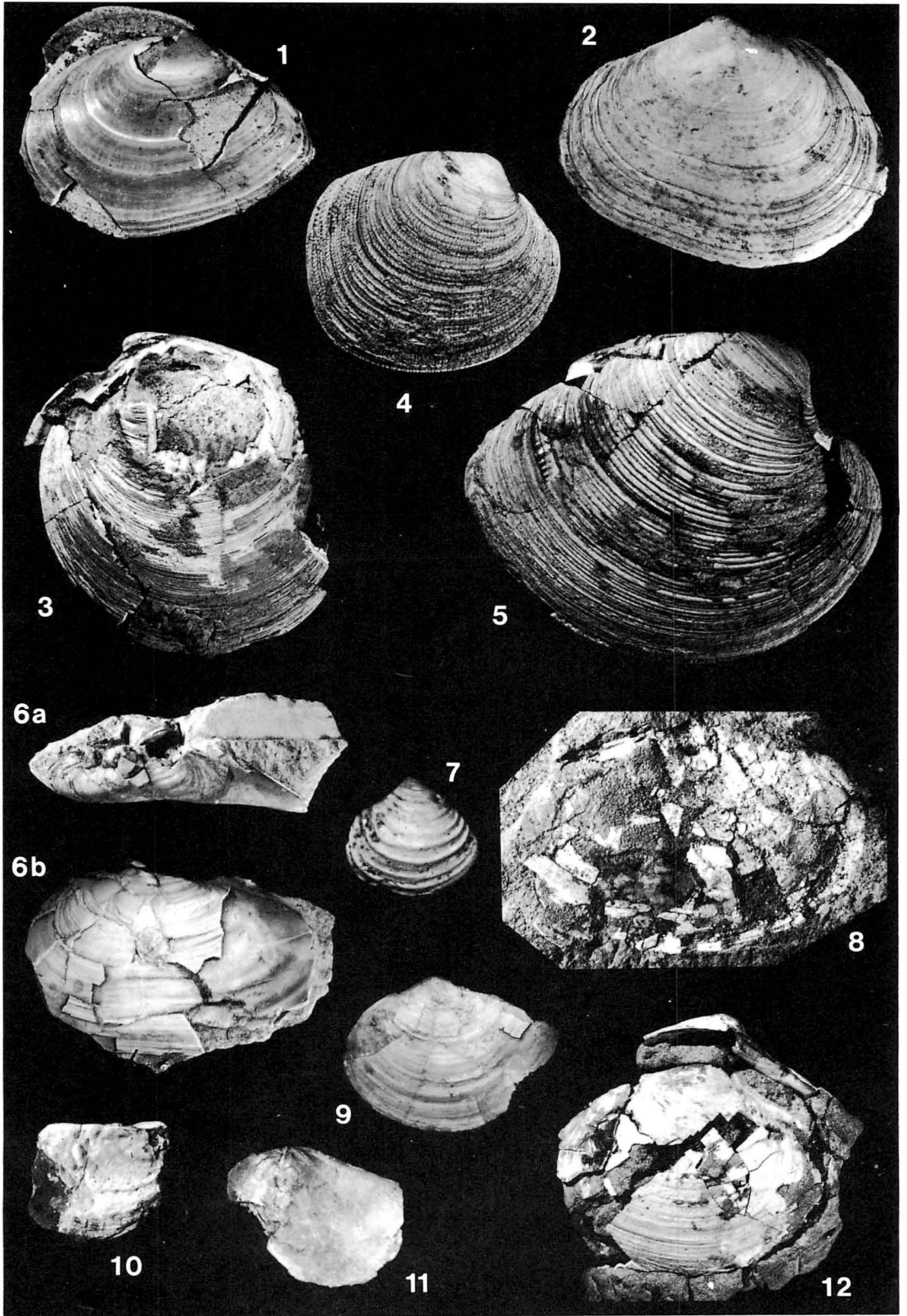


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Explanation of Plate 34

- Fig. 1. *Macoma tokyoensis* Makiyama, $\times 1$, Loc. 5-1b (CM16606).
- Fig. 2. *Macoma calcarea* (Gmelin), $\times 1$, Loc. 4-2c (CM16585).
- Fig. 3. *Dosinia (Phacosoma) japonica* (Reeve), $\times 1$, Loc. 4-1e (CM16611).
- Fig. 4. *Protothaca (Protocallithaca) adamsi* (Reeve), $\times 1$, Loc. 4-1f (CM16616).
- Fig. 5. *Mercenaria stimpsoni* (Gould), $\times 1$, Loc. 4-1a (CM16612).
- Figs. 6a, 6b. *Mya (Mya) cuneiformis* (Böhm), $\times 1/2$, Loc. 4-2c (CM16617).
- Fig. 7. *Myadora japonica* Habe, $\times 3$, Loc. 21-1 (CM16634).
- Fig. 8. *Periploma cf. besshoensis* (Yokoyama), $\times 1$, Loc. 41-2 (CM16637).
- Fig. 9. *Periploma plane* Ozaki, $\times 1$, Loc. 4-4 (CM16636).
- Figs. 10, 11. *Pandora (Pandorella) wardiana* A. Adams, $\times 1$, fig. 10, Loc. 14-1 (CM16630); fig. 11, Loc. M10B (CM16633).
- Fig. 12. *Thracia kakumana* (Yokoyama), $\times 1/2$, Loc. 5-1h (CM16639).



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五城目—男鹿地域産の47種の二枚貝類を記載した。

805. CYST AND THECATE FORMS OF *PYROPHACUS STEINII* (SCHILLER)
WALL ET DALE, 1971*

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Abstract. The cyst form of *Pyrophacus steinii* (Schiller) Wall et Dale is clarified as a result of both field and laboratory observations. Thecate forms germinated from living cysts identified as *Tuberculodinium vancampoe* (Rossignol) Wall are assignable to *Pyrophacus steinii* on the basis of detailed observation of their plate distribution. Furthermore, many thecate specimens of *P. steinii* including living cysts identical with *T. vancampoe* were found in the summer plankton of Omura Bay.

According to these data, *T. vancampoe* is regarded as a resting cyst of not only *P. vancampoe* (Rossignol) but also *P. steinii*, and *P. vancampoe* is concluded to be a subspecies of *P. steinii*.

Introduciton

Tuberculodinium vancampoe (Rossignol) Wall 1967 has a lenticular body and a hypocystal archeopyle. Owing to these characteristic features, this species is easily distinguishable from other fossil dinoflagellate cysts.

T. vancampoe is also regarded as an useful indicator of the tropical to warm temperate environment based on the modern distribution in the Atlantic (Wall and Dale, 1971; Harland, 1982) and in the Pacific (Matsuoka, 1985). In Japan, this species has been reported from the middle Miocene to Early Pleistocene sediments in the Niigata area (Matsuoka, 1983) and in the Kinki area (Harada, 1984; Matsuoka, 1976). These two evidences suggest that *T. vancampoe* has a possibility to be an useful fossil as a tropical to warm temperate marine environment since the Neogene in Japan.

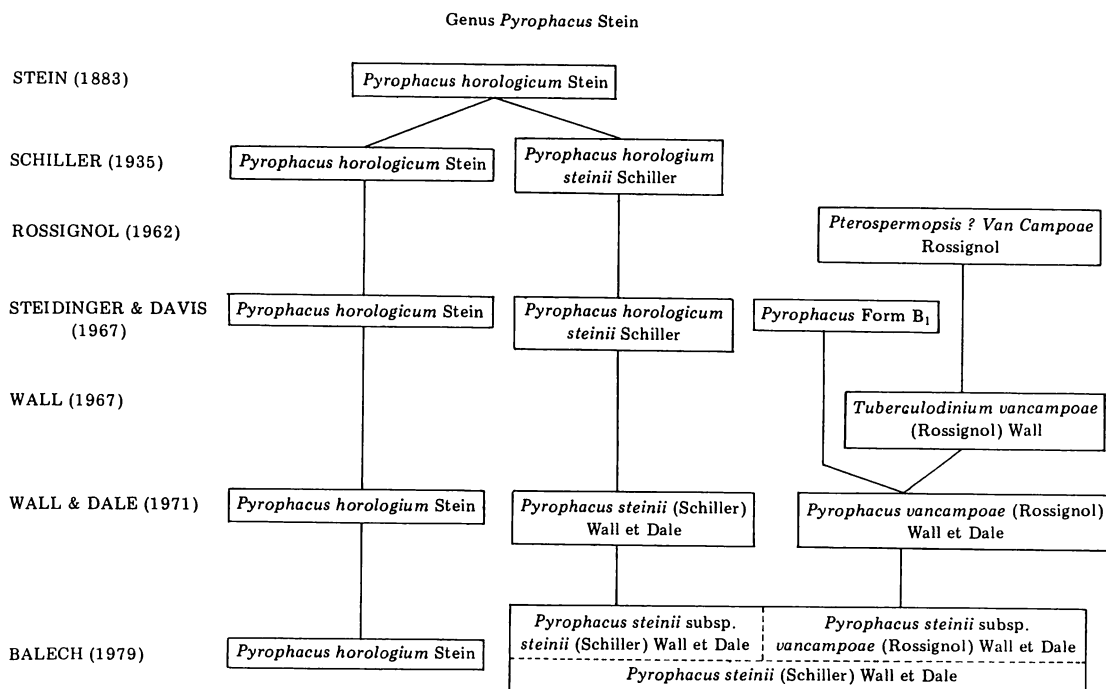
But the correlative thecate form of this cyst species have never been fixed until the present, because the plate formula (plate distribution pattern) which is the most important character for the thecate dinoflagellates is extremely variable in number and shape and is not useful in case of its parent thecate genus *Pyrophacus*. On the contrary, recent studies of modern dinoflagellate cysts reveal that the cyst morphotype (=cyst species) probably appear to be a natural species (Wall and Dale, 1968).

The present paper documents that the real taxonomic position of the thecate form of *T. vancampoe* is confirmed on the basis of the modern biological methodology and the paleontological account to be cyst form. And through the consideration about this species, the taxonomical significance in both modern and fossil dinoflagellate cysts will be clarified.

Historical review of study of *Pyrophacus* and *Tuberculodinium*

The genus *Pyrophacus* was first established

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Text-fig. 1. Taxonomic history of the genus *Pyrophacus*.

by Stein (1883) and at that time this genus contained only one species, *P. horologicum* Stein. Schiller (1935) recognized one species and one variety, *P. horologicum* Schiller and *P. horologicum* var. *steinii* Schiller based on difference of thecal plate formula in the genus.

Apart from plankton research, Rossignol (1962) found a peculiar fossil species from the Pleistocene sediments and named it *Pterospermopsis ? van campoae*. Later, Wall (1967) also obtained this species from deep sea core samples of the Caribbean Sea and erected the new cyst genus *Tuberculodinium* with emendation of *P. vancampoe*.

Steidinger and Davis (1967) noticed the presence of a characteristic form consisting of more plates than other varieties of *P. horologicum* and called this form *P. Form B₁*.

Wall and Dale (1971) carried out an incubation experiment of several cyst forms of the genus *Pyrophacus* and reexamined the classification of this genus. They concluded that *Tuberculodinium vancampoe* (Rossignol) is a cyst

form of living *P. Form B₁* of Steidinger and Davis, and as a result, they recognized the following three *Pyrophacus* species; *P. horologicum* Stein, *P. steinii* (Schiller) Wall et Dale and *P. vancampoe* (Rossignol) Wall et Dale. But they did not find a cyst form for *P. steinii* (Schiller) Wall et Dale.

Recently, Balech (1979) reexamined the plate morphology of the genus *Pyrophacus* and recognized two species and one subspecies. He concluded that *P. vancampoe* (Rossignol) Wall et Dale is a subspecies of *P. steinii* (Schiller) because the difference in plate distribution between these two is rather than minor.

The taxonomic history of these species, subspecies, and varieties is shown in Text-fig. 1.

Materials and method

Samples containing various dinoflagellate cysts were collected in gravity cores from Omura Bay (Lat. 32°53'N, Long. 129°54'E, water depth -18 m), Nagasaki Prefecture, west Japan

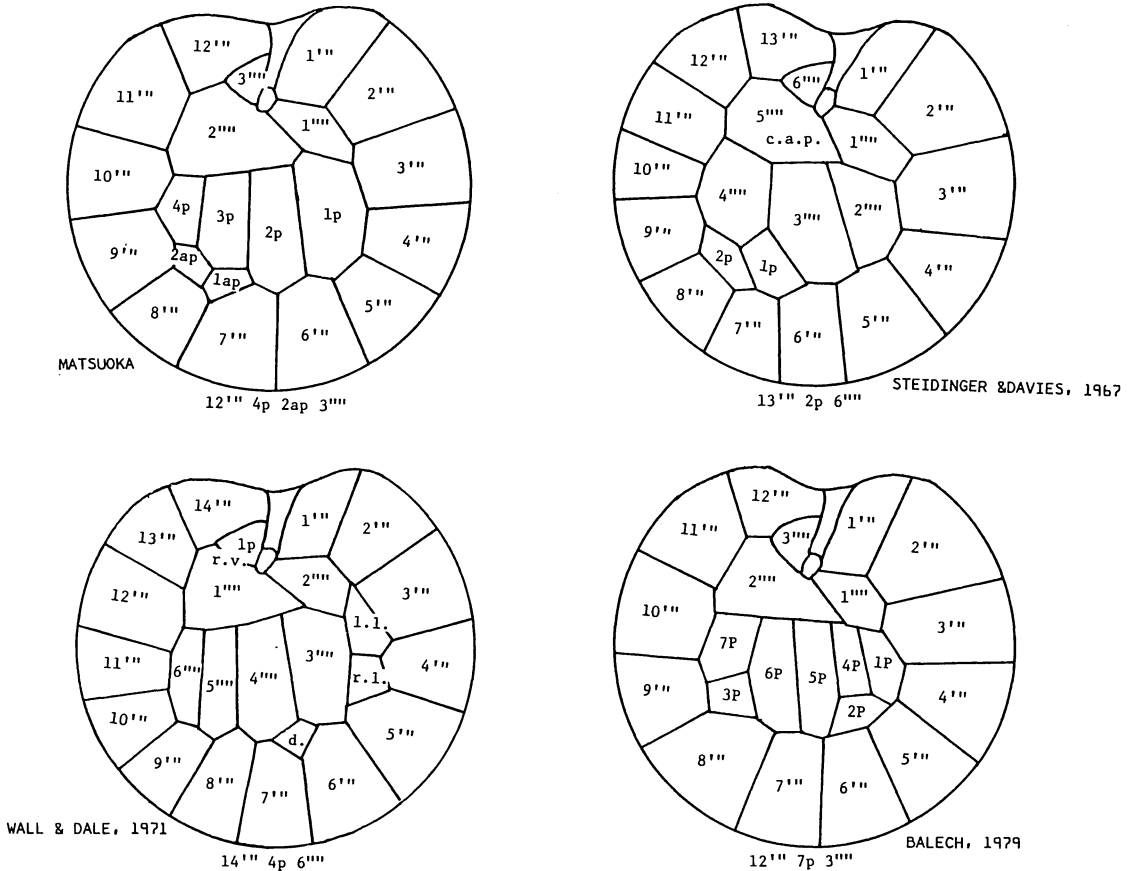
on 12 March, 1981. This bay is influenced by the warm Tushima Current, and its surface water temperature and chlorinity are as follows; $9 \pm 2^\circ\text{C}$ in winter, $30 \pm 2^\circ\text{C}$ in summer and 17.5–19‰ (Nagasaki Univ., 1976). The sediments are black and sapropelic mud sometimes containing small shell fragments.

Until the start of the incubation experiment, the samples were stored in the refrigerator for three to four months. The upper 2 cm of the core was provided for the investigation. Before incubation, the material (about 1.9 ml) was cleaned by sonification and sieved between 125 μm and either 37 μm or 20 μm stainless steel screen. The materials retained on the latter screens was washed in filtered sea water passed

several times through a Whatman GF/C glass filter.

The isolated cysts picked up by a capillary pipet were placed in a culture dish containing ca. 1 ml filtered sea water. The incubation was carried out under the following condition; temperature 20–22°C, fluorescent light about 4,000 lux, light-dark cycle 14–10 hours.

For small thecate forms described in detail later, a vegetative newly formed cell was individually placed into another chamber. This operation was repeated until the appearance of the small thecate forms. The materials remaining after the incubation experiment was used for the investigation of cyst morphology. For paleontological analysis, the usual procedure (Matsu-



Text-fig. 2. Hypothecal labeling systems of several authors and proposal of a new system. Abbreviation in Wall and Dale (1971) . . . r.v.; right ventral, l.l.; left lateral, r.l.; right lateral, d.; dorsal intercalary plate.

oka, 1985) was adopted.

Many vegetative cells included in surface plankton were also provided for the present study for taking the information of the plate formula in situ. These samples were collected from the surface water of Omura Bay (Lat. 32°54'N, Long. 129°52'E) in June of 1983 and July of 1984 by net haul. At that time, the surface temperature was 20°C and 33.5‰ in salinity.

Labeling on the antapical plates of the genus *Pyrophacus* —

Difference of labeling among several authors

Since Stein (1883) first described the genus *Pyrophacus*, the plate formula of this genus has not been fixed, because it has considerable variation in plate number. In the description of *Pyrophacus* Form B₁, Steidinger and Davis (1967) noticed that a large and nearly triangular plate is always present just below the sulcus, and named it coupling antapical plate (C.A.P.) (Text-fig. 2). Wall and Dale (1971) proposed a new labeling system and later Balech (1979) suggested another one. But there are major differences between these two in the antapical series (Text-fig. 2). According to Wall and Dale (1971), the distinctive and larger triangular plate which always contacts the small elliptical posterior sulcal platelet is the first antapical plate (1''), the plate which constantly occupies the left position of the 1'' plate is the second antapical plate (2'') and the plate placed above the 1'' plate is the right ventral posterior intercalary plate (r.v.p.). The plates which always contact the 1'' and 2'' plates are other antapical plates, and those between these and the postcingulars are posterior intercalary plates.

Balech's system is as follows; the antapical series consists of three plates which always surround the sulcal posterior platelet. The left plates is the first antapical plate (1''), the center is the second (2'') and the right is the third (3''). Other plates between these and the postcingular series are posterior intercalary plates.

A new nomenclature, especially in the hypotheca

In all species of *Pyrophacus*, three plates are always present around the small posterior sulcal platelet. These three plates are regarded as the first, second and third antapical plates. The second one is the same as C.A.P. of Steidinger and Davis (1976). One to five, or occasionally more plates occupy the position between the antapical and postcingular series. These are regarded as members of the posterior intercalary series.

In the cyst, two to four, occasionally five paraplates similar to these intercalary plates in shape and position form an archeopyle. This suggests that these intercalary plates are of one plate series.

In *P. steinii*, additional plates that are usually smaller than the posterior intercalaries are present between the posterior intercalary and postcingular series. In the present work, these plates are newly named as additional posterior intercalary plates (a.p.). They have never developed in other thecate dinoflagellates.

Similarity of the plate formula in related taxa

Fragilidium heterolobum Balech ex Loeblich, which is closely related to the genus *Pyrophacus* in having a similar plate distribution in the hypotheca. The plate formula of this species was first suggested by Balech (1979) as follows; Po, 4', 9'', 12c, 7'', 2'', 1p and 6s. But in the figure shown by Balech (1979, Fig. 3), the 12c platelet is different in shape from other cingular platelets and occupies the position between the cingulum and sulcus. If this platelet is not seen as a part of the cingulum but as a part of the sulcus, the 7'' plate which directly contacts this platelet is not a postcingular. Based on this viewpoint, three antapical plates surround the small sulcal posterior platelet and the plate formula in the hypotheca should be corrected as follows; 11c, 6'', 3'', 1p and 7s. This plate distribution around the sulcus is fundamentally the same in both *Fragilidium* and *Pyrophacus*.

Observation in unialgal culture

Many and various dinoflagellate cysts were recovered from the surface sediments of Omura Bay. Based on the morphological characteristics, mentioned later in detail, the cysts identifiable as *T. vancampoae* (Rossignol) were selected for unialgal culture. For morphological investigations, both living and empty cysts were observed under optical microscope. Living cysts were selected for germination and incubation experiments. Twenty living cysts were placed in a single chamber of the culture dish and then eighteen cysts were excysted and developed in thecate vegetative cells. Most of these vegetative cells were reproduced asexually, produced many vegetative daughter cells. Furthermore, several cells were continued to divide for about two weeks. After several divisions, these thecate cells became small spherical thecate cells.

Living cyst (Pl. 36, Figs. 4a, b):—Living cysts which are pale brown with many small spherical oil or starch particles and one large red pigmented body are selected for the germination experiment. Even cysts with breaks in the distal extremities of large processes or the autophragm are excysted and produced normal thecal plates.

The cysts are ca. 80 μm in lateral diameter and ca. 55 μm in length. They are flattened and nearly circular in apical-antapical view. Many large barrel-shaped processes ornament the cyst body. The paratabulation indicated by the processes and archeopyle is 5–8', 9–11'', 0c, 10–11'' and (4–5)'''' + 2–4@ (Table 1). The symbol (@) indicates the number of paraplates consisting of the operculum in the cyst, and is common in this text and figures. The morphological features closely resemble those of the empty cysts recovered from Omura Bay. Based on these features, the living cysts are clearly identified as *T. vancampoae*.

Thecate form (Pl. 37, Figs. 2–8, 10a–12; Pl. 38, Figs. 1, 3, 5–7, 10–13; Pl. 39, Figs. 2, 4, 5–7):—Most of the living cysts were germinated within two to five days. After excystment, only one thecate vegetative cell (=germinated cell) appeared in the culture chamber.

This cell was larger than any of the subsequent vegetative daughter cells. The plate formulae of many thecate specimens produced from living cysts were investigated. As compared with the same observations made of many thecate specimens collected from the plankton in Omura Bay.

As a result, the laboratory-excysted vegetative cells show a relatively wide variation in number of plates (Table 1). The cultured specimens have more plates than those obtained from the plankton. In vegetative cells derived from the plankton and excystment, however, the plates are arranged in the usual apical, precingular, cingular, postcingular and antapical series. The fundamental plate pattern in these specimens is as follows.

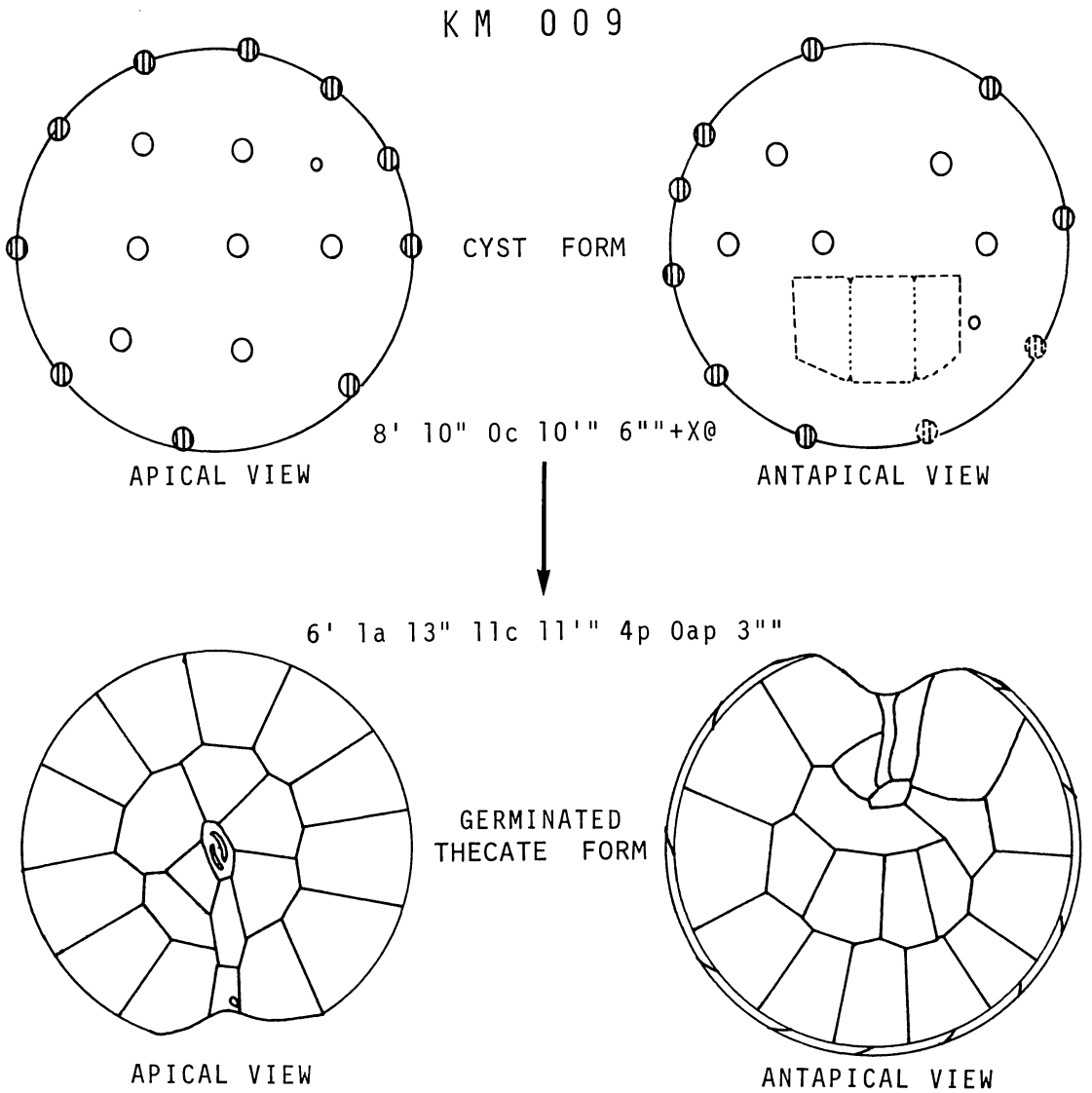
The apical pore platelet is roughly ellipsoidal, but polygonal in detail, and its longest axis is slightly oblique (Pl. 36, Fig. 7). The two apical pores are linear and arched in shape, and the dorsal one is larger than the other. The apical series consists of six to eight plates. The 1' plate was asymmetrical and antero-posteriorly rhomboidal in shape and bears a small pore, probably the "ventral pore", in its posterior part. Other apical plates are pentagonal or hexagonal in shape and similar in height. One to two intercalary plates, which are usually smaller than the apicals, are observed in some specimens. The precingular series is made up of nine to fourteen plates. The first (1'') and the last (9'', 10'', 11'', 12'', 13'' or 14'') plates are shorter and always trapezoidal. The other plates are trapezoidal or pentagonal in shape.

The cingulum is slightly indented and the number of platelets in it is basically the same as the number of postcingulars. They always remain connected to the hypotheca, when the theca splits into two hemispherical parts. Each plate has perforations arranged nearly parallel to the shallow cingular list. The postcingular series consists of ten to fourteen plates. The first (1''') plate is nearly orthogonal and the last (10''', 11''', 12''', 13''' or 14''') plate is roughly triangular but irregularly trapezoidal in detail. The ventral plates are usually shorter than the dorsal ones. The postcingular plates

Table 1. Paratabulation of living cysts used in incubation experiment and plate formula of germinated and subsequent daughter cells.

Speciman	Paratabulation of cyst	Plate formula of germinated cell	Plate formula of daughter cells
KM 001	not determined	7' 1a 13" 12c 12''' 2p 1ap 3''''	not produced
KM 002	not determined	8' 0a 13" 11c 11''' 4p 0ap 3''''	8' 0a 13" 11c 11''' 4p 0ap 3'''' 8' 0a 11" 11c 11''' 3p 0ap 3''''
KM 003	7' 9" 0c 10''' 4'''+X@	8' 0a 12" 11?c 11''' 3p 1ap 3''''	7' 0a 12" 12c 12''' 3p 0ap 3''''
KM 004	6? 10" 0c 10''' ?''''	not germinated	
KM 005	not determined	7' 0a 12" 12?c 12''' 4p 1ap 3''''	7' 0a 12" 12c 12''' 4p 0ap 3'''' 7' 0a 12" 12c 12''' 3p 1ap 3''''
KM 006	not determined	6' 1a 9" 10?c 10''' 2p 0ap 3''''	7' 0a 12" 10?c 10''' 4p 0ap 3'''' 7' 0a 12" 12?c 12''' 2p 0ap 3''''
KM 007	6' 10" 0c 10''' 5'''+2@	7' 1a 12" 12?c 12''' 3p 1ap 3''''	7' 1a 12" 12c 12''' 3p 1ap 3'''' 8' 0a 12" 12c 12''' 3p 0ap 3'''' 8' 2a 12" 12c 12''' 4p 0ap 3'''' 8' 2a 12" 12c 13''' 4p 1ap 3'''' 8' 2a 12" 12c 13''' 4p 1ap 3''''
KM 008	7' 10" 0c 11''' 4'''+3@	7' 0a 12" 12c 12''' 3p 0ap 3''''	7' 0a 12" 12c 12''' 3p 0ap 3''''
KM 009	8' 10" 0c 10''' 6'''+3@	6' 1a 13" 11c 11''' 4p 0ap 3''''	7' 0a 12" 12?c 12''' 3p 1ap 3'''' 7' 0a 11" 11?c 11''' 3p 0ap 3'''' 7' 0a 12" 12c 12''' 4p 0ap 3'''' 6' 1a ?" 12c 11''' 3p 0ap 3'''' 12c 12''' 5p 0ap 3'''' 11c 11''' 5p 0ap 3'''' 11c 11''' 5p 0ap 3'''' 11c 11''' 3p 1ap 3''''
KM 010	6' 11" 0c 10''' 4'''+3@	7' 0a 11" 11c 11''' 4p 0ap 3''''	7' 0a 12" 12c 12''' 3p 1ap 3'''' 7' 0a 11" 11?c 11''' 2p 0ap 3'''' 7' 0a 12" 12c 12''' 4p 0ap 3'''' 7' 0a 13" 13c 13''' 4p 0ap 3'''' 7' 0a 12" 13?c 13''' 4p 0ap 3'''' 11c 11''' 4p 0ap 3'''' 11c 11''' 3p 0ap 3'''' 12c 12''' 4p 0ap 3'''' 13c 13''' 3p 0ap 3''''
KM 011	5? 10" 0c 10''' 4'''+X@	7' 0a 11" 12c 12''' 2p 0ap 3''''	not produced
KM 012	6' 11" 0c 10''' 5'''+X@	7' 0a 11" 11c 11''' 3p 0ap 2''''	7' 0a 11" 11c 11''' 3p 0ap 3'''' 7' 0a 12" 12c 12''' 3p 0ap 3'''' 7' 1a 11" 11c 11''' 3p 0ap 3'''' 12c 12''' 3p 1ap 3'''' 12c 12''' 3p 0ap 2'''' 13c 13''' 3p 0ap 3'''' 10c 10''' 2p 0ap 3''''
KM 013	7' 10" 0c 10''' 5'''+3@	7' 1a 13" 14c 14''' 4p 1ap 3''''	7' 1a 13" 14c 14''' 4p 0ap 3'''' 7' 1a 13" 14c 13''' 4p 0ap 3'''' 12c 12''' 2p 1ap 3'''' 12c 12''' 3p 0ap 3'''' 14c 14''' 4p 1ap 3''''
KM 014	not determined	7' 2a 11" 10c 10''' 3p 0ap 3''''	not produced
KM 015	not determined 12c 12''' 3p 0ap 3'''' 12c 12''' 3p 0ap 3''''
KM 016	not determined	7' 0a 12" 12c 12''' 3p 0ap 3''''	7' 1a 12" 12c 12''' 3p 0ap 3'''' 7' 0a 12" 12c 12''' 3p 1ap 3'''' 7' 0a 12" 12c 12''' 2p 0ap 3'''' 12c 12''' 4p 1ap 3'''' 12c 12''' 4p 0ap 3''''
KM 018	6? 8" 0c 8''' 5'''+X@	7' 1a 12" 13c 13''' 3p 0ap 3''''	7' 1a 12" 12?c 12''' 3p 0ap 3'''' 6' 1a 12" 13c 13''' 3p 0ap 3''''
KM 019	not determined	7' 2a 13" 12c 12''' 4p 0ap 3''''	not produced
KM 020	7' 10" 0c 10''' 4?'''+X@	7' 0a 10" 10c 10''' 2p 0ap 3''''	7' 0a 10" 11c 11''' 2p 0ap 3'''' 7' 0a 12" 12c 12''' 3p 0ap 3'''' 6' 4a 12" 11c 11''' 3p 1ap 3'''' 7' 0a 11" 11c 10''' 2p 0ap 3'''' 11c 11''' 4p 0ap 3''''
Composite	5-8' 9-11" 0c 10-11''' 4-5'''+2-3@	6-8' 0-2a 9-14" 10-14c 10-14''' 2-4p 0-2ap 2-3''''	6-8' 0-4a 11-13" 10-14c 10-14''' 2-5p 0-1ap 2-3''''
C 949*	data not provided	7' 3a 15" Xc 13''' 2p 5''''	
C 955*	data not provided	7' 2a 13" Xc 13''' 1p 5''''	8' 0a 13"

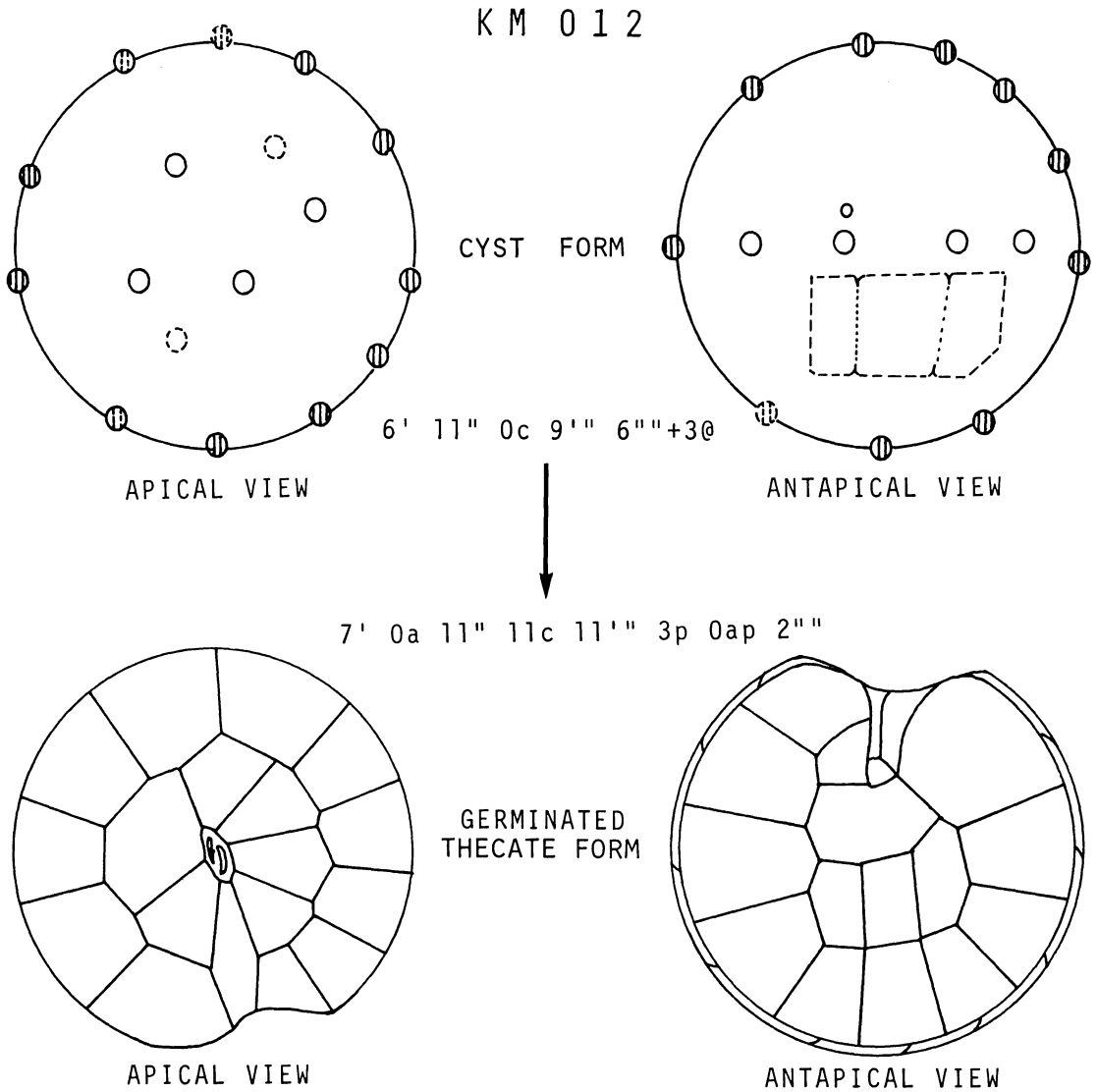
*Incubated specimens of Wall and Dale (1971)



Text-fig. 3a. Cyst-theca relationships of *Pyrophacus steinii* (Schiller) Wall et Dale based on incubation experiments. 3a; Specimen KM 009, 3b; Specimen KM 012, 3c; Specimen KM 013, 3d; Specimen KM 020.

are also covered with coarse granules and perforated many small pores linearly arranged near the cingulum. The plates possess distinct growth or intercalary bands in mature specimens. There are three antapical plates that always surrounded the small posterior sulcal platelet. The 1'' plate is an irregularly pentagonal to hexagonal shape equatorially expanded. The characteristic

2'' plate is the largest and is nearly triangular in shape. The triangular and smaller 3'' plates is also nearly in the sulcus and contacts the last postcingular plate and 2''. The posterior intercalary plates are also variable in number from two to five. The 1p plate is usually nearly trapezoidal and always contacts the 1'' and 2'' plates and a few postcingular plates. The

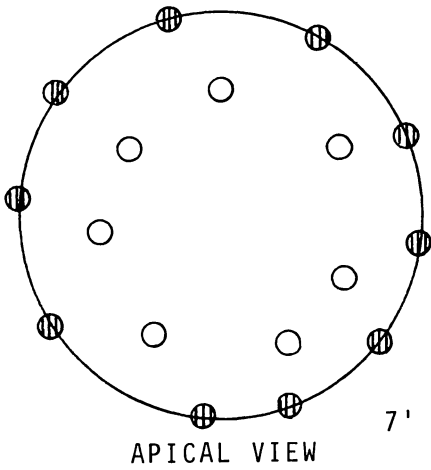


Text-fig. 3b.

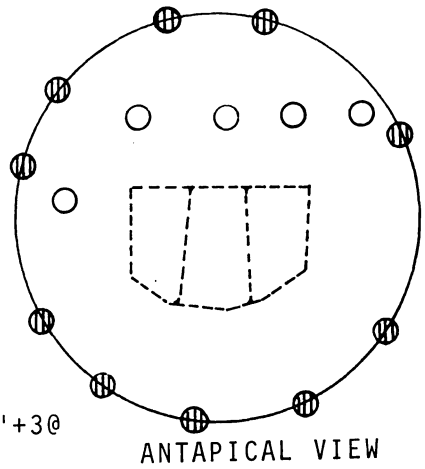
last posterior intercalary plate is irregularly hexagonal and occupies the position between the 2'' plates and dorsal postcingulars. The other plates are elongated trapezoids and are situated between the antapical and ventral postcingulars. There are a few additional plates between the posterior intercalary and/or antapical plates and the postcingulars. These additional posterior intercalary plates are usually smaller than the other posterior intercalaries and are variably pentagonal to hexagonal in shape. The

sulcal region consists of eight platelets (Pl. 36, Fig. 6; Text-fig. 4). The rectangular anterior sulcal platelet is the largest and obliquely contacted the first and last cingular platelets. The posterior sulcal platelet is roundly triangular to ovoid in shape, and consistently surrounded by three antapical plates. The left sulcal platelet is larger than the right one. Both platelets are situated just anterior sulcal platelet. The right sulcal accessory platelet is roundly rectangular, and larger, and is located between the last

K M 0 1 3



APICAL VIEW

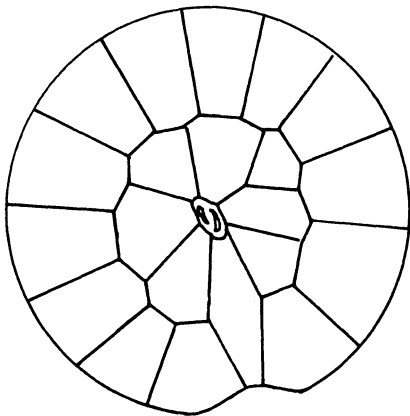


ANTAPICAL VIEW

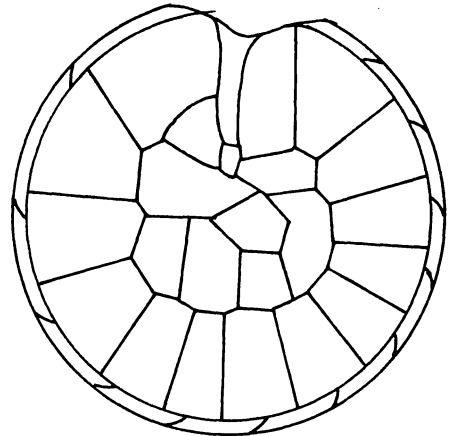
CYST FORM

7' 10" 0c 10' 5" +3@

7' 1a 13" 14c 14' 4p 1ap 3"



APICAL VIEW



ANTAPICAL VIEW

GERMINATED
THECATE FORM

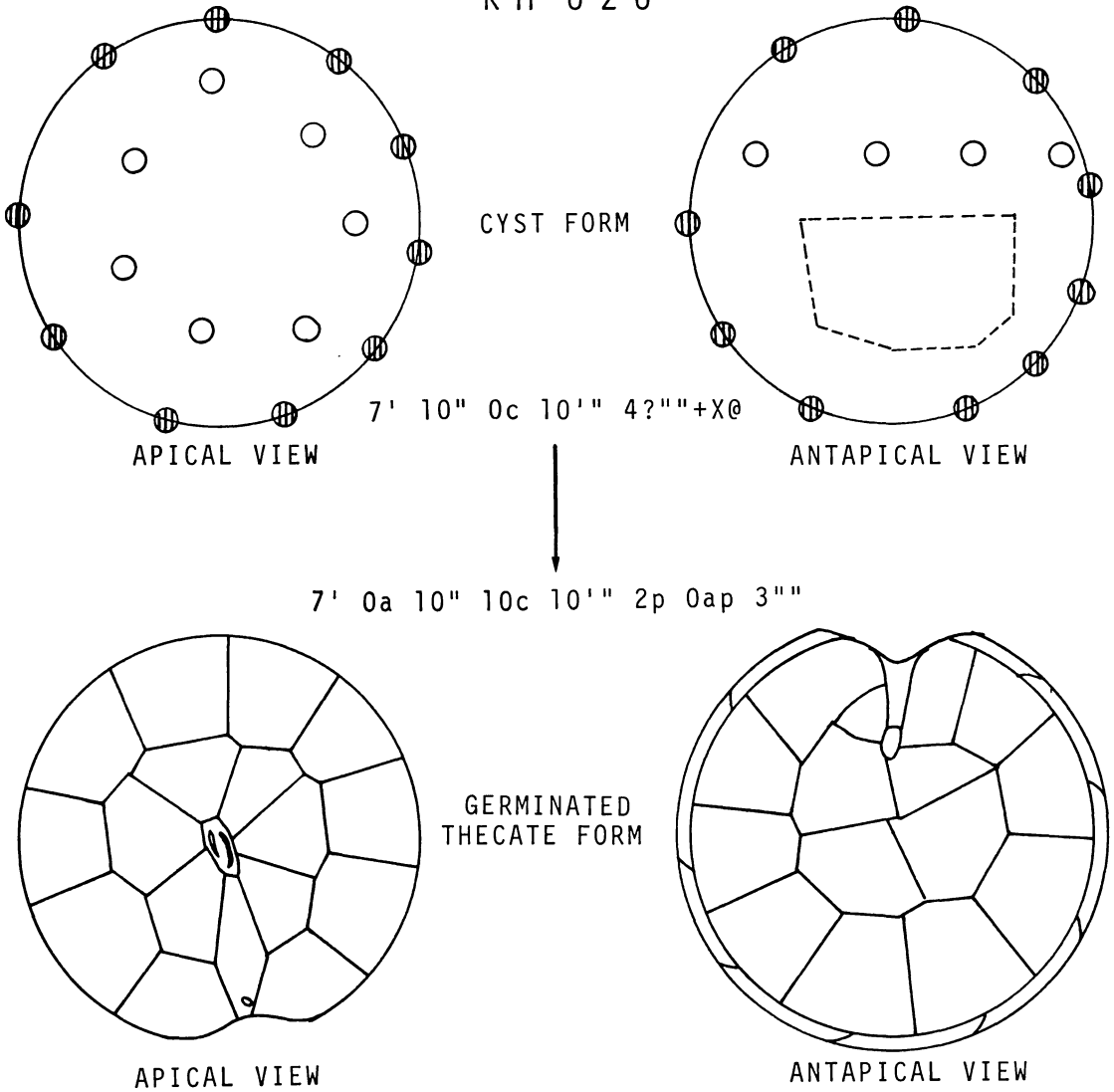
Text-fig. 3c.

cingular plate and the right sulcal platelet. The left sulcal accessory platelet has a round triangular shape. Two other small platelets are occurred in the middle of the sulcal region: median sulcal and anterior accessory platelets.

Small thecate form (Pl. 40, Figs. 1-12, Text-fig. 6):—The vegetative cell germinated from the incubated cyst becomes gradually smaller in diameter during asexual reproduction (Text-fig. 5). After six to eight divisions, the proto-

plasm is divided into four or eight smaller masses inside the parent theca (Pl. 36, Fig. 1). Subsequently, four or eight small cells appear in the culture chamber. These small forms are also covered with many thin thecal plates and platelets, but they are very different from the parent cells in size and shape. These small cells are ovoidal in shape, 36-37.2 μm long, 32-36 μm wide and 32-36 μm thick (dorso-ventrally) (Pl. 40, Figs. 1-4). Although there are slight

K M 0 2 0



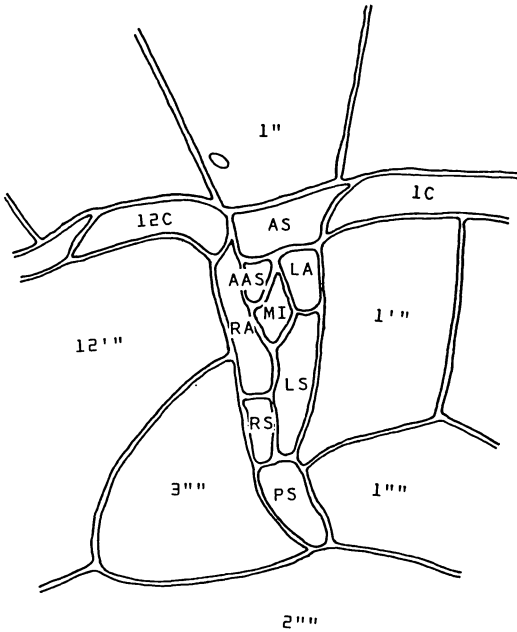
Text-fig. 3d.

variations in number of plates, they total 38 to 39, excluding the sulcal and apical pore platelets. The plates are smooth and transparent without any ornamentation under optical microscope.

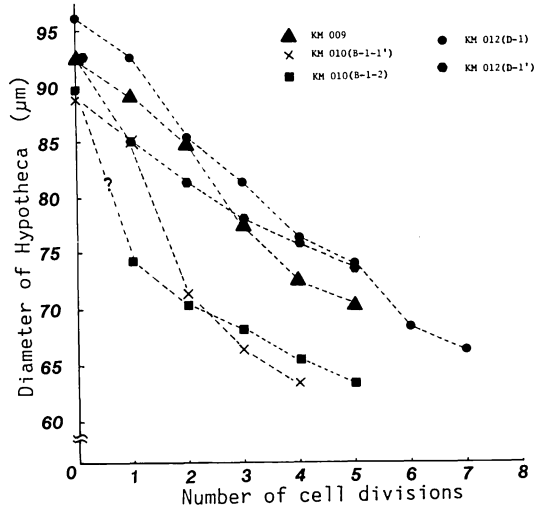
The apical pore plate is round hexagonal and has many very small perforations scattered around the margin, and two large arched slits in the centre (Pl. 40, Figs. 5, 10a, 11). The apicals consist of six to seven plates. The 1

plate is nearly pentagonal in shape, but strongly expands antero-posteriorly and has a small and elongate perforation, possibly "ventral pore" on its posterior part (Pl. 40, Figs. 5, 12). Other apical plates are irregularly pentagonal or hexagonal in shape and of similar height.

There are no anterior intercalary plates. The precingular series consists of nine plates of similar height. The 3", 4", 6" and 7" plates are pentagonal and others trapezoidal.



Text-fig. 4. Plate and platelet distribution in the sulcus.



Text-fig. 5. Decrease in thecal diameter in relation to number of cell divisions.

The cingulum is relatively wide (0.11 to 0.13 of the cell length), laevorotary (left handed) displacement of one cingular width. When the

Explanation of Plate 35

Figs. 1—3. *Tuberculodinium vancampoe* (Rossignol) Wall

Fig. 1. Fossil specimen from the Pleistocene upper Nishiyama Formation; apical view, showing apical and precingular barrel-shaped processes, Loc. Haizume, Niigata Prefecture, \times ca. 250.

Fig. 2. Fossil specimen from the Pliocene lower Nishiyama Formation, antapical view, showing attached operculum and antapical processes, and a somewhat damaged archeopyle (arrow), Loc. Haizume, Niigata Prefecture, \times ca. 250.

Fig. 3. Fossil specimen from the late Miocene Shiiya Formation, antapical view, showing attached operculum composed of three rectangular paraplates, Loc. Ishiji, Niigata Prefecture, \times ca. 250.

Figs. 4a—5b. *Pyrophacus steinii* (Schiller) Wall et Dale from plankton sample of Omura Bay.

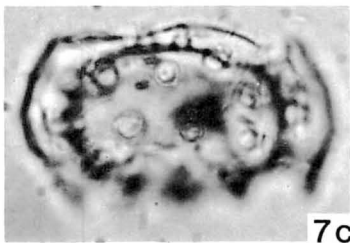
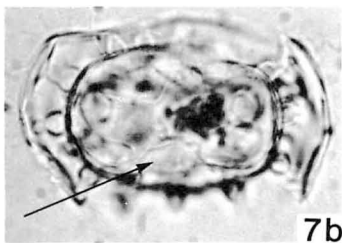
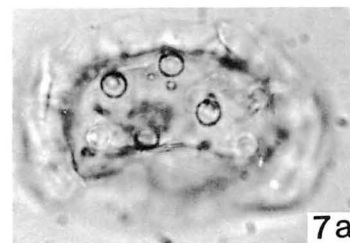
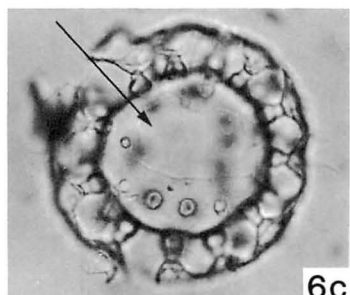
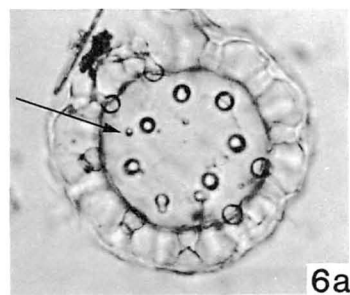
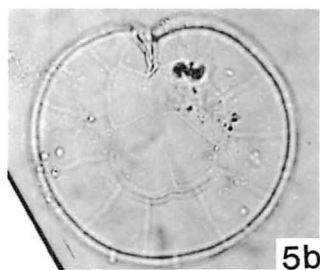
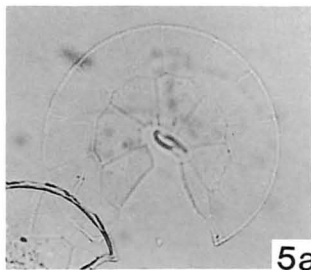
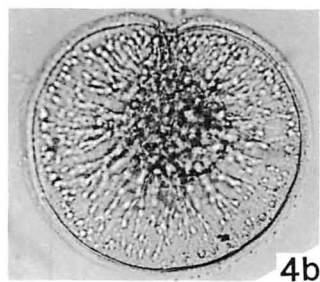
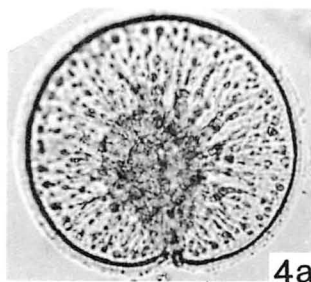
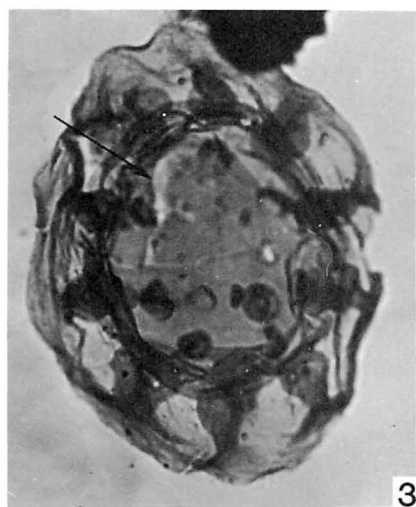
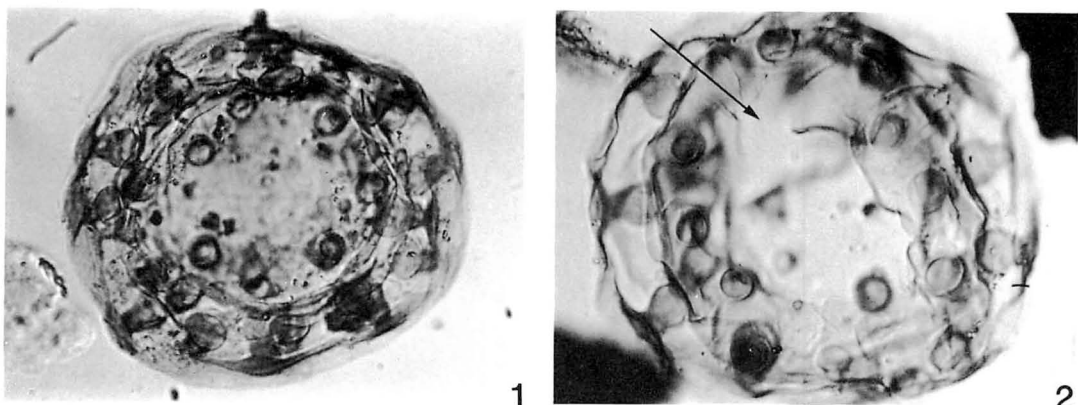
Figs. 4a—b. Living thecate vegetative cell containing a large nucleus, many chromatophores and food reserves. a; apical view, \times ca. 310, b; antapical view, \times ca. 310.

Figs. 5a—b. Vegetative cell theca, showing the distribution of major plates: 5a; apical view, 5b; antapical view; plate formula, Po, 7', 0a, 12'', 12c, 12''', 3p, 0ap and 3''', \times ca. 310.

Figs. 6a—7c. *Tuberculodinium vancampoe* (Rossignol) Wall from surface sediments of Omura Bay.

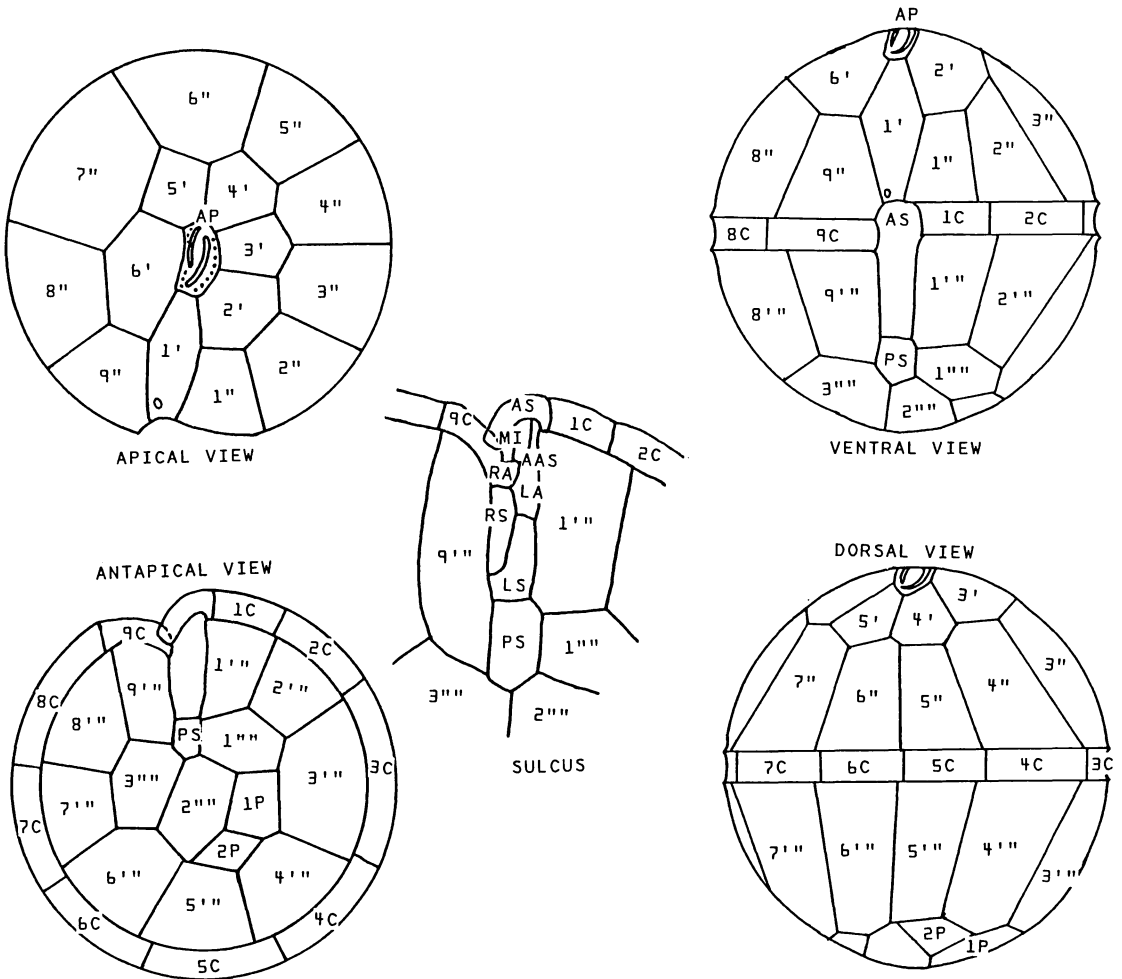
Figs. 6a—c. Polar view, 6a; apical view, showing large apical and precingular processes and additional small, spherical apical processes (arrow), \times ca. 235, 6b; optical cross section, 6c; antapical view, showing hypocystal archeopyle (arrow), \times ca. 235.

Figs. 7a—c. Lateral view, 7b; optical cross section, showing hypocystal archeopyle (arrow), \times ca. 235.



complete theca is broken and split into two the cingulum remained attaches to the hypotheca. The cingulum consists of nine rectangular platelets, wider than tall, and equatorially expanded. The 9c platelet somewhat invades the sulcus. The postcingulum also possesses nine plates. Some are trapezoidal, and similar in height to the precingulars. Other parts of the hypotheca are insufficiently clear in detail because it is easily deformed. Judging from relationships with the adjacent plates, there are one or two posterior intercalary plates. Three antapical plates always surround the posterior sulcal platelets, and these are variable in shape.

The sulcus is narrow and almost straight, and did not reach the centre of the hypotheca. This area comprises of eight platelets of various shapes and sizes. The anterior sulcal platelet is the largest in shallow U-shape. The posterior sulcal platelet is also large and irregularly hexagonal. This platelet contacts the 1''', 9''', 1''', 2'''' and 3'''' plates and the left sulcal platelet. The left sulcal platelet is large, L-shaped and occupies the position just anterior the posterior sulcal platelet. The elongated rectangular right sulcal platelet does not contact the posterior sulcal platelet. Four other small platelets are located between the left and right



Text-fig. 6. Diagram of the small thecate from of *Pyrophacus steinii* (Schiller) Wall et Dale. Specimen KM 012 D1-1.

sulcal and the anterior sulcal platelet.

The plate formula of these small thecate forms is interpreted as Po, 6-7', 9'', 9c, 9''', 1-2p, 3'''' and 8s.

Cyst and thecate forms obtained from net haul and sediment samples

Cyst form:—The polar view in *T. vancampoae* is very different from the equatorial view. In the polar view, in which orientation most cysts are observed, the cyst is circular to roundly

Table 2. Paratabulation of empty cysts recovered from the surface sediments of Omura Bay. The symbol @ indicates opercula in the hypocyst. 'S' means small spherical processes on the epicyst.

Paratabulation					Total number of processes
8"	12"	0c	12'''	5''''+3@	37 + 3@
7'+1s	10"	0c	10'''	4''''+3@	31 + 3@
7'+1s	10"	0c	12'''	4''''+3 or 4@	33 + 3 or 4@
6"	10"	0c	11'''	4''''+3@	31 + 3@
7"	10"	0c	9'''	3''''+3@	29 + 3@
14s	9"	0c	9'''	5-6''''+X@
7"	10"	0c	12'''	3''''+3@	32 + 3@
7"	9"	0c	12'''	3''''+3@	31 + 3@
6"	9"	0c	9'''	4''''+3@	28 + 3@
8"	11"	0c	11'''	5''''+3@	33 + 3@
7"	10''	0c	13'''	6''''+3@	35 + 3@
*6-8"	9-12"	0c	9-13'''	3-5(6)''''+3-4@	28-35+3-4@
**5-8"	8-13"	-	6-13'''	3-11''''	
(7"	10"		10'''	8''''	

*composite paratabulation of empty cysts of Omura Bay

**composite paratabulation of cysts of Ivory Coast (Wall & Dale, 1971)

reniform, while in the equatorial view, it is a slightly round rectangular with weakly developed shoulders. The cyst wall consists of a thin, smooth and nearly transparent autophragm. The processes are hollow, and intratabular of two types. One is large and barrel- to dumbbell-shaped, because it consists of two spherical parts with different diameters. In well-preserved specimens, the distal extremities of these processes are expanded to be flare-like and connected with adjacent ones. In this way, they often make an outer cyst wall. The other type of processes, a simple sphere, is rare. The walls of both types of processes are thin and smooth. These processes do not have any parasutural features at the proximal bases. These processes are regularly distributed in four latitudinal lines surrounded the cyst body. Judging from their position relative to the archeopyle and the plate distribution in the thecate form, these lines correspond to the apical, precingular, postcingular and antapical paraplate series. The apical area consists of six to eight large processes and sometimes a few small spherical processes as well. There is no process representing the apical pore platelet in the thecate form. The precingular area begins at the epicystal shoulder of the cyst body and includes eight to ten large processes. This area contained hardly any small spherical processes. The postcingulum is relatively variable in number of processes and is composed of nine

Explanation of Plate 36

Modern cyst and thecate forms of *Pyrophacus steinii* (Schiller) Wall et Dale collected from surface plankton of Omura Bay.

Figs. 1a-b. Gamete formation (?) showing eight small cells included within a normal vegetative cell, \times ca. 310.

Fig. 2. Hypnozygote (?), theca containing a living cyst identified as *Tuberculodinium vancampoae* (Rossignol) Wall showing archeopyle suture preparing for germination (arrow) (interference contrast optics), \times ca. 310.

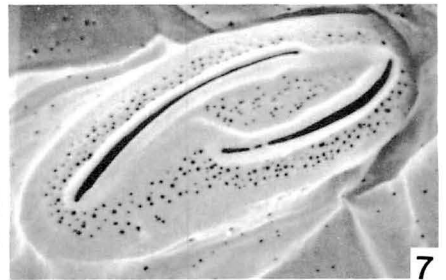
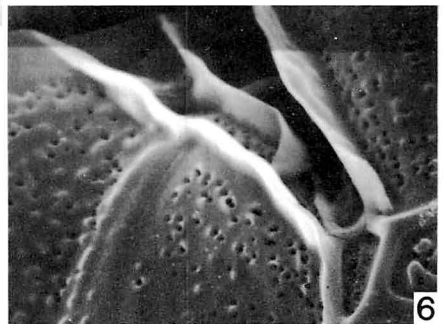
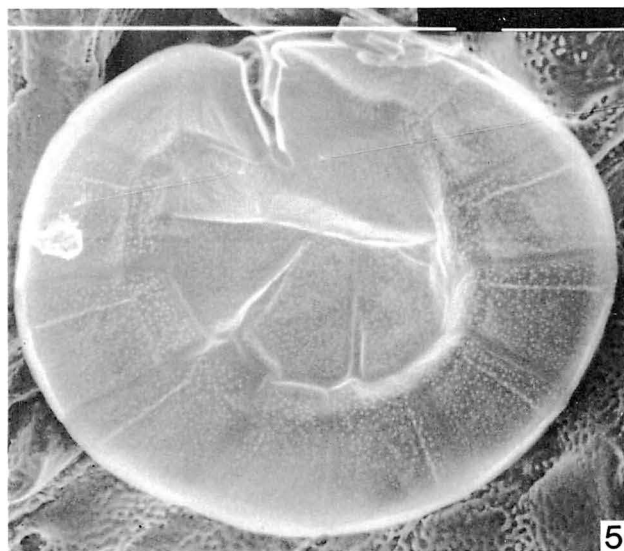
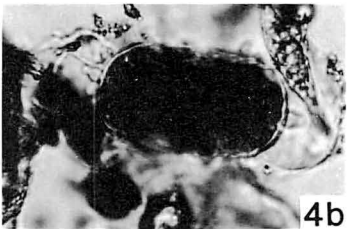
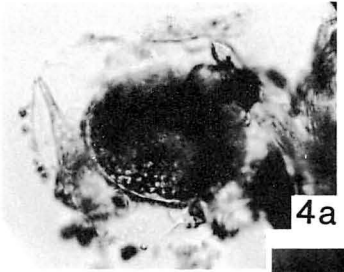
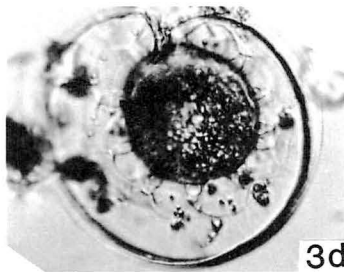
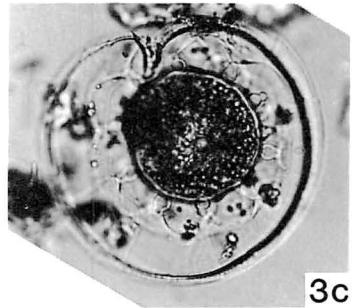
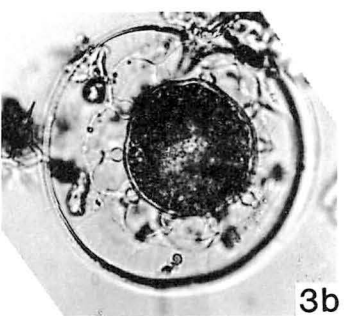
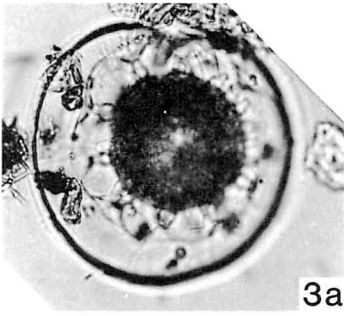
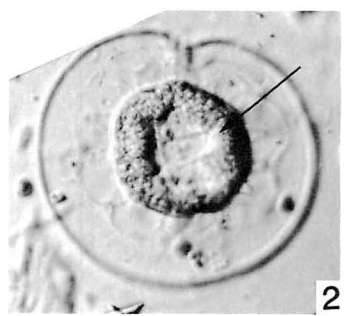
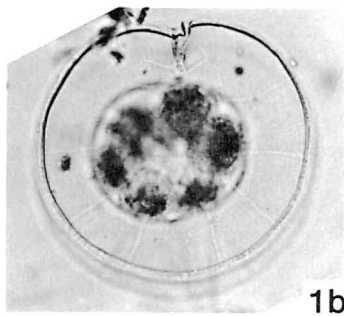
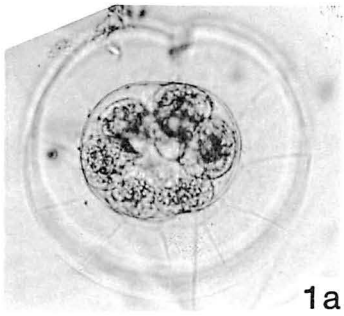
Figs. 3a-b. Hypnozygote (?), theca containing a living cyst, \times ca. 310.

Figs. 4a-b. Living cyst probably recently freed from its parent theca. 4a; apical-antapical view, \times ca. 310, 4b; lateral view, \times ca. 310.

Fig. 5. Hypotheca of vegetative cell, showing well developed growth band and many small surface granules. SEM photograph, \times ca. 700.

Fig. 6. Sulcus of the thecate cell. SEM photograph, \times ca. 2500.

Fig. 7. Apical pore platelet of thecate cell. SEM photograph, \times ca. 2500.



to thirteen large processes. These processes occur at another hypocystal shoulder. The antapical area has three to five large processes and the archeopyle, consisting of two to three, rarely four or five paraplates which are released at excystment. There are no processes or ornamentation between the pre- and post-cingular series. Therefore, the paracingulum is represented by the space between these two rows of processes. The parasulcal area is also not reflected by any morphological features.

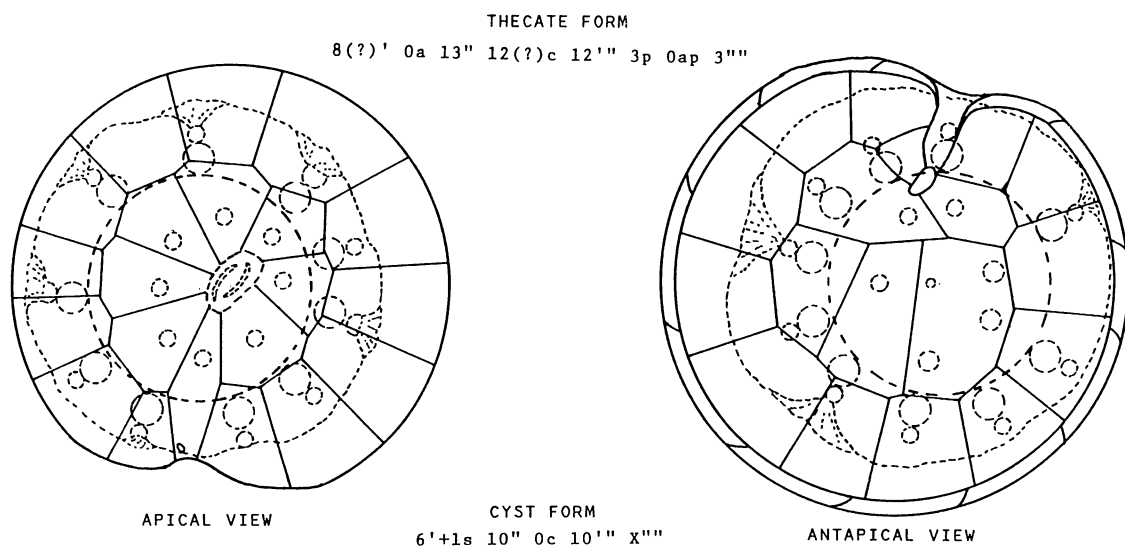
Based on this evidence, most cysts recovered from Omura Bay possess 27 to 37 processes, including large and small spherical types and two to five paraplates corresponding to the archeopyle.

Thecate cell bearing living cyst (Pl. 36, Figs. 2, 3; Text-fig. 7):—The plankton sample collected from Omura Bay in June, 1983 and July,

1984 contained not only many thecate specimens identifiable as *P. steinii* (Schiller) but also a few living forms of *T. vancampoae* (Rossignol). Furthermore, rare of thecate cells filled not with protoplasm as observed at the motile stage but with a cyst were found in it (Pl. 36, Figs. 2, 3). Two thecate specimens enclosing the living cysts were examined for thecal tabulation and cyst paratabulation. One consists of eight apicals, thirteen precingular, twelve cingulars, twelve postcingular, three posterior intercalaries, three antapical plates and one apical pore platelet. Its plate formula is 8', 0a, 13'', 12' ', 3p, 0ap and 3''' '. The paratabulation of the cyst included within the thecate cell is 6' with one small process, 10'', 0c, 10' '' and ?' '' , and its archeopyle is not clear. In another specimen, although the plate formula in the epitheca can not be determined, the hypotheca contains twelve

Table 3. Plate formulae of thecae and paratabulation of living cysts contained within, from plankton samples of Omura Bay in June, 1983.

Plate formulae of thecae	Paratabulation on living cyst
8(?)' 0a 13'' 12(?)c 12''' 3p 0ap 3''''	6'+1s 10'' 0c 10''' X''''
-----?----- 12''' 3p 0ap 3''''	8'+5(?)s 10'' 0c 10''' 6''''+3@



Text-fig. 7. Diagram of a theca containing a living cyst, collected from Omura Bay in June, 1983.

postcingulars, three posterior intercalaries and three antapicals. The paratabulation of the cyst is interpreted as 8' (+ a few small processes), 10'', 0c, 10'' and 4'' + 3@. The archeopyle consists of three nearly rectangular opercula, and has been already indicated by the boundary of three paraplates. Trabecula or small spherical processes are completely lacking. These paraplates are closely similar to the posterior intercalary plates in general shape, but smaller. Also, the orientation of the opercula is clearly different from that of the thecate form. The diameter of the cyst is nearly half of the thecate cell and resembles that of the temporary cyst produced by the usual asexual reproduction.

Morphological variation in thecate form

Variations in the cell shape and the plate pattern are seen in both field-collected and cultured specimens. Plates show wide variations in shape and number, while the cell shape was

relatively consistent.

Cell shape:—All field specimens and most cultured specimens are lenticular in dorso-ventral view and roundly reniform in polar view. This is one of the most stable characters in the thecate form. But in specimen labelled as KM 018 for example, all of the thecate cells derived from one cultured cyst are different from the progeny of the other cysts in cell shape (Pl. 38, Fig. 9). They have a normal-lenticular epitheca and a roundly conical hypotheca, and these features makes them longer than normal forms. On the other hand, the plate formula of these specimens 6—7', 1a, 12'', 13c, 12—13'', 3p, 0ap and 3'' with minor variability in number of plate; but this variation is quite similar to that of other cells.

Aberrant shape of plate:—The first apical plate is occasionally divided in the middle into two plates. In this case, the 1' plate does not reach the cingulum and the ventral pore appears on the 1'' plate (Pl. 37, Fig. 2a; Pl. 39, Fig. 2a).

Explanation of Plate 37

Modern cyst and thecate forms of *Pyrophacus steinii* (Schiller) Wall et Dale obtained in unialgal culture.

Figs. 1—5. *Pyrophacus steinii* (Schiller) Wall et Dale, Specimen KM 009.

Fig. 1. Cyst after germination, showing much compressed cyst body, \times ca. 330.

Figs. 2a—b. Newly germinated vegetative cell, 2a; epitheca, apical surface in antapical view, showing aberrant shape of the 1' plate (arrow), \times ca. 330, 2b; hypotheca, antapical surface in apical view, \times ca. 330.

Fig. 3. Hypotheca of daughter cell, antapical surface in antapical view, \times ca. 330.

Fig. 4. Epitheca of daughter cell, apical surface in antapical view, \times ca. 330.

Fig. 5. Hypotheca of daughter cell, antapical surface in antapical view, \times ca. 330.

Figs. 6—8. *Pyrophacus steinii* (Schiller) Wall et Dale, Specimen KM 010.

Fig. 6. Hypotheca of newly germinated vegetative cell, antapical surface in antapical view, showing additional small posterior sulcal platlet (arrow), \times ca. 330.

Fig. 7. Hypotheca of daughter cell, antapical surface in antapical view, \times ca. 330.

Fig. 8. Hypotheca of daughter cell, antapical surface in antapical view, \times ca. 330.

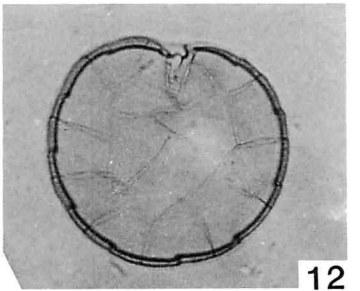
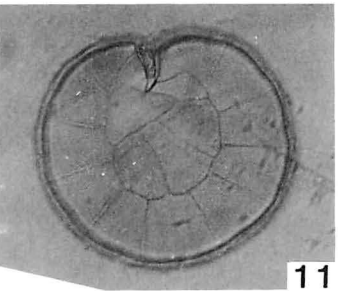
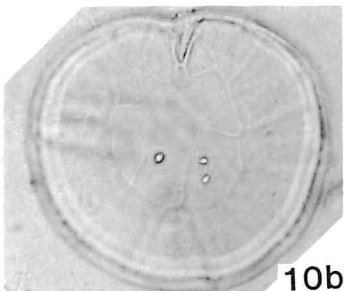
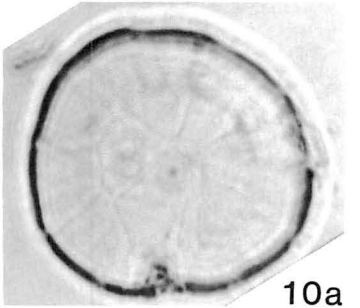
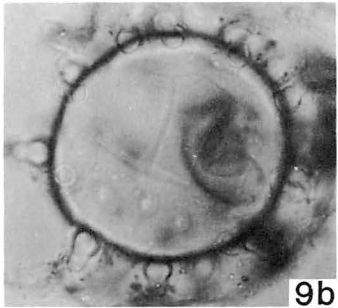
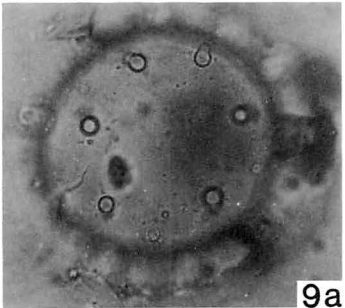
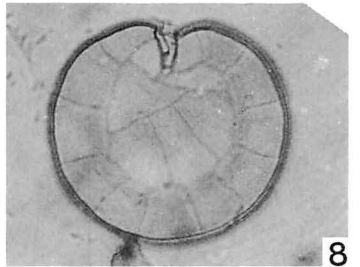
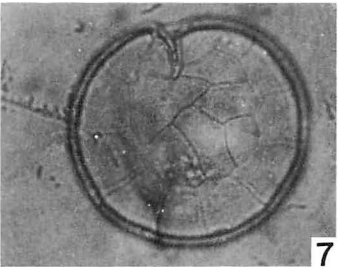
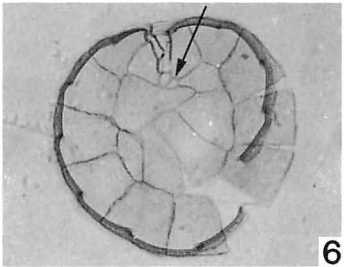
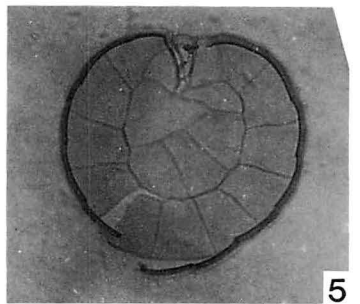
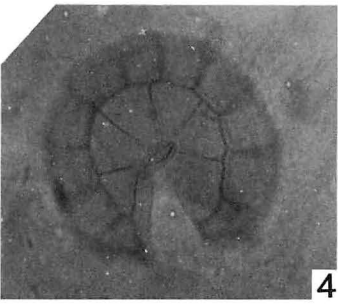
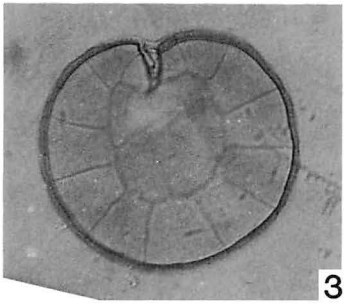
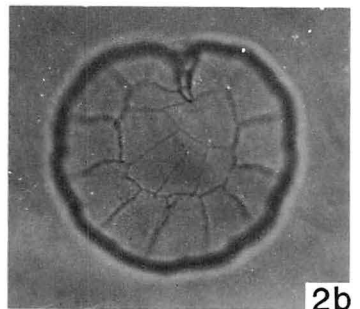
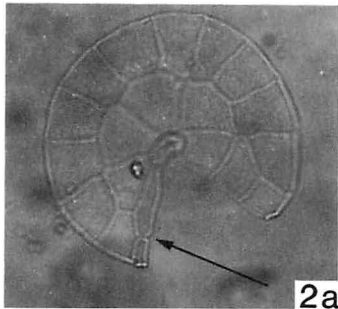
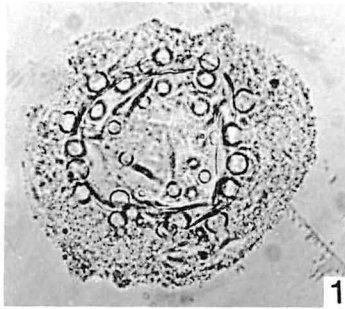
Figs. 9a—12. *Pyrophacus steinii* (Schiller) Wall et Dale, Specimen KM 012.

Fig. 9. Cyst after germination, 9a; apical surface, \times ca. 360, 9b; antapical surface, showing attached operculum corresponding to three rectangular paraplates, \times ca. 360.

Figs. 10a—b. Newly germinated vegetative cell, 10a; epitheca, apical surface in apical view, \times ca. 400, 10b; hypotheca, showing two antapical plates, antapical surface in apical view, \times ca. 400.

Fig. 11. Hypotheca of daughter cell, antapical surface in antapical view, \times ca. 330.

Fig. 12. Hypotheca of daughter cell, antapical surface in apical view, \times ca. 330.



The posterior intercalary plates are normally rectangular or elongatedly pentagonal. But this plate series occasionally consists of two large septagonal and one nearly triangular plates. Furthermore, in specimens possessing extra posterior intercalary plates, the shape of the posterior intercalary plates also becomes irregular (Pl. 38, Fig. 13).

The second antapical plate was rarely absent (e.g. specimen labelled as KM 011) and then the first postcingular plate touched the second antapical plate (Pl. 37, Fig. 10b).

These aberrant plates appeared only in cultured specimens.

Number of plates.—The number of major plates and cingular platelets is more variable than the cell shape. The total number of plates ranges from 31 to 41. The plate formulae of freshly germinated cells vary. The composite formula is 6–8', 0–2a, 9–14'', 10–14c, 10–14''', 2–4p, 0–2ap and 2–3'''. The most common pattern is 7', 0a, 11–12'', 12c, 12''', 3–4p, 0ap and 3'''.

The progeny of these first cell has composite plate formulae 6–7', 0–4a, 11–13'', 10–14c, 10–14''', 2–5p, 0–1ap and 2–3'''. The most common pattern is 7', 0a, 12'', 12c, 12''', 3p,

0ap and 3''' (52 out of 155 specimens). The total number of plates ranges from 31 to 43.

Clearly then, the plate formula of the daughter cells are frequently different from those of the first germinated cells. For example, in specimen labelled as KM 020, the first germinated cell has the formula 7', 2a, 11'', 10c, 10''', 2p, 0ap and 3'''. Within several days, more than ten daughter cells are produced with plate formula as follows: 7', 0a, 10'', 11c, 11''', 2p, 0ap and 3'''; 7', 0a, 12'', 12c, 12''', 3p, 0ap and 3'''; 6', 4a, 12'', 11c', 11''', 3a, 1ap and 3'''; 7', 0a, 11'', 11c, 10'' or 11'', 2p, 0ap and 3'''.

The composite formulae of field specimens are 6–7', 0a, 9–12'', 11–13c, 11–13''', 2–3p, 0ap and 3''', and the total number of plates ranges from 31 to 37. Among them, the most frequent formula is 7', 0a, 12'', 12c, 12''', 3p, 0ap and 3''' for a total of 37 plates (in 76 out of 83 specimens).

These data indicate that the cultured specimens are more in number of plates and variable than the field specimens.

Table 4. Variation in numbers of plate of germinated cells and subsequent daughter cells in incubation experiments and of normal vegetative cells in plankton sample.

Plate series	Germinated cells	Daughter cells	Cells in plankton
Apical plates	6–8 (7)	6–8 (7)	6–7 (7)
Anterior intercalary plates	0–2 (0)	0–4 (0)	0
Precingular plates	9–14 (11, 12)	11–13 (12)	9–12 (12)
Total plates in epitheca	16–22 (20)	17–22 (19)	16–19 (19)
Cingular platelets	10–14 (12)	10–14 (12)	11–13 (12)
Sulcal platelets	8	8	8
Postcingular plates	10–14 (12)	10–14 (12)	11–13 (12)
Antapical plates	2–3 (3)	2–3 (3)	3
Posterior intercalary plates	2–4 (3, 4)	2–5 (3)	2–3 (3)
Additional post. inter. plates	0–2 (0)	0–1 (0)	0
Total plates in hypotheca	15–21 (18)	15–21 (18)	16–19 (18)
Total plates	31–41 (39)	33–43 (39)	33–37 (37)
Number of specimens	17	155	83

Discussion

Cyst morphology:—Based on morphological characteristics, the living cysts provided for incubation experiments were clearly identified as *T. vancamptoeae*. In addition, several new morphological features are noted as a result of the present study.

As Wall and Dale (1971) have already mentioned, the number of paraplates corresponding to the operculum is variable in number. It ranges from two to five in the present cyst specimens. The fossil *Tuberculodinium rossignolae* Drugg is known to have two opercular paraplates which considered to be an important character (Drugg 1970). But the Miocene speci-

mens of this species shown by Williams and Brideaux (1975, pl. 34, figs. 2, 3) clearly has three opercular paraplates similar to those of *T. vancamptoeae*. Therefore, this character is not diagnostic for *T. rossignolae*.

Small spherical "processes" are also present on the fossil species *Tuberculodinium wallii* Drugg. But this species has these processes more densely not only on the apicals but also on the postcingulars, including the opercular paraplates, and the antapicals.

The paratabulation of the specimens collected from Omura Bay is as follows; 5-7', 9-10'', 10-11'' and 4-5'' + 2-3@. This is within the range of variation indicated by Wall and Dale (1971). In the specimens used in the in-

Explanation of Plate 38

Modern cyst and thecate forms of *Pyrophacus steinii* (Schiller) Wall et Dale obtained in unialgal culture.

Fig. 1. *Pyrophacus steinii* (Schiller) Wall et Dale, Specimen KM 012, hypotheca of daughter cell, showing aberrant shape of the 2'' plate (arrow), antapical surface in antapical view, \times ca. 330.

Fig. 2. *Pyrophacus steinii* (Schiller) Wall et Dale, Specimen KM 011, cyst after germination, lateral view, \times ca. 400.

Fig. 3. *Pyrophacus steinii* (Schiller) Wall et Dale, Specimen KM 009, hypotheca of newly germinated vegetative cell, antapical surface in antapical view, \times ca. 330.

Figs. 4a-6. *Pyrophacus steinii* (Schiller) Wall et Dale, Specimen KM 013.

Figs. 4a-c. Cyst after germination, 4a; apical surface, \times ca. 260, 4b; optical cross section of antero-posterior view, \times ca. 260, c; antapical surface showing attached operculum composed of three rectangular paraplates, \times ca. 260.

Fig. 5. Epitheca of newly germinated vegetative cell, apical surface in antapical view, \times ca. 260.

Fig. 6. Hypotheca of daughter cell, antapical surface in antapical view, \times ca. 260.

Fig. 7. *Pyrophacus steinii* (Schiller) Wall et Dale, Specimen KM 002, hypotheca of daughter cell, antapical surface in apical view, \times ca. 335.

Figs. 8-11. *Pyrophacus steinii* (Schiller) Wall et Dale, Specimen KM 018.

Fig. 8. Cyst after germination, showing somewhat damaged autophragm, \times ca. 325.

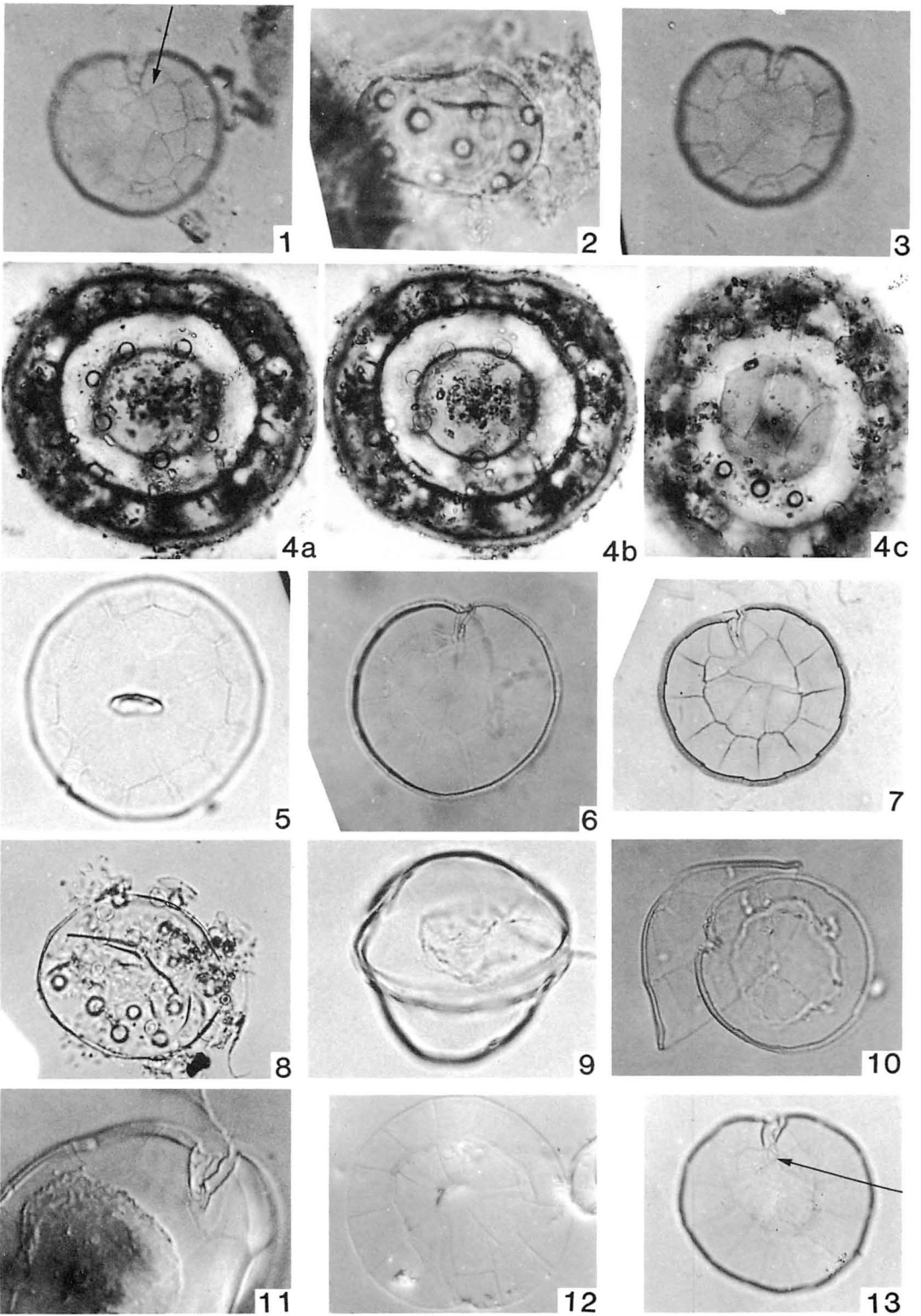
Fig. 9. Lateral view of newly germinated vegetative cell, showing relatively normal epitheca and subspherical aberrant hypotheca, \times ca. 325.

Fig. 10. Epitheca and hypotheca of daughter cell, showing lenticular epitheca, \times ca. 325.

Fig. 11. Sulcus of daughter cell, apical surface in oblique apical view (interference contrast optics), \times ca. 640.

Fig. 12. *Pyrophacus steinii* (Schiller) Wall et Dale, Specimen KM 003, epitheca of newly germinated vegetative cell, apical surface in antapical view, \times ca. 325.

Fig. 13. *Pyrophacus steinii* (Schiller) Wall et Dale, Specimen KM 006, hypotheca of daughter cell, showing additional sulcal posterior platelet (arrow), antapical surface in apical view, \times ca. 330.



cubation experiment, the paratabulation represented by the intratabular processes and the archeopyle corresponds only roughly to the tabulation of the thecate form, except for the cingulum and sulcus (which does not correspond at all). The number of processes plus opercular paraplates is usually fewer than the number of thecal plates. These facts suggest that such morphological information as the number and structure of plates and platelets in the thecate stage are poorly reflected in the cyst stage.

Plate formula of Pyrophacus steinii, and P. vancampoae:—There are three taxonomic units in the genus *Pyrophacus*, as several authors have agreed, but the taxonomic positions of these units are uncertain.

Steidinger and Davis (1967) recognized one species, one variety and one form as follows; *Pyrophacus horologicum*, *P. horologicum* var. *steinii* and *P. Form B₁*. According to their observations, the plate formula of *P. horologicum* var. *steinii* is 6–7', 0–1a, 11–13'', 11–13' ', 0–1p and 5–8' ' (6–7', 0–1a, 11–13'', 11–13' ', 2–5p, 0–1ap and 3' ' in my nomenclature), and *P. Form B₁* has 7–9', 2–8a, 13–15(16?)'', 13–16' ', 0–6p and 7–11' ' (7–9', 2–8a, 13–15(16?)'', 13–16' ', 4–8p, 0–6ap and 3' ' in my nomenclature). Based on these data, they suggested that *P. Form B₁* is

either another variety of *P. horologicum* or is an aberrant form.

Wall and Dale (1971) carried out a precise statistical study of the plate formulae of these three taxa, and divided them into three species; *P. horologicum*, *P. steinii*, and *P. vancampoae*. The plate formula of *P. steinii* is 6–7', 0a, 11–13'', 12c, 11–14' ', 1–2p and 4–6' ' (6–7', 0a, 11–13'', 12c, 11–14' ', 1–3p, 1–2ap and 3' ' in my nomenclature) plus an apical pore platelet with about eight sulcal platelets. *P. vancampoae* is more variable in plate number and its formula is 7–9', 0–9a, 13–15'', 12–16c, 12–17' ', 1–9p and 5–7' ' (7–9', 0–9a, 13–15'', 12–16c, 12–17' ', 2–4p, 1–9ap and 3' ' in my nomenclature) plus an apical pore platelet with eight sulcal platelets. Its most common formula is represented as 8', 0a, 14'', 14c, 14' ', 1p and 6' ' (8', 0a, 14'', 14c, 14' ', 3p, 1ap and 3' ' in my nomenclature). Although they recognized the presence of the morphologically intermediate forms between *P. steinii* and *P. vancampoae*, and furthermore the possibility that these two species may be biological ecotypes, they considered that these species are different enough to warrant separation.

Balech (1979) rearranged these three species described by Wall and Dale (1971) into two species, but with *P. vancampoae* reduced to a subspecies under the code of International

Table 5. Summarized plate formula of *Pyrophacus steinii* (Schiller) and its related taxa, according to several authors.

Taxon	Plate formula							Author or locality
<i>Pyrophacus Form B₁</i>	7–9'	2–8a	13–15(16)''		13–16'''	0–6p	7–11''''	Steidinger & Davis (1967)
						[4–5p	0–5ap 3'''']	
<i>Pyrophacus horologicum</i> var. <i>steinii</i>	6–7'	0–1a	11–13''		11–13'''	0–1p	5–8''''	
						[3–5p	0–1ap 3'''']	
<i>Pyrophacus vancampoae</i>	7–9'	0–9a	13–15''	12–16c	12–17'''	1–9p	5–7''''	Wall & Dale (1971)
	(8'	0a	14''	14c	14'''	1p	6'''')	
<i>Pyrophacus steinii</i>	6–7'	0a	11–13''	12c	11–14'''	1–2p	4–6''''	Balech (1979)
	(7'	0a	12''	12c	12'''	1p	6'''')	
<i>Pyrophacus steinii</i> subsp. <i>vancampoae</i>	8'		12–14''	12c	12–14'''		3''''	
<i>Pyrophacus steinii</i> subsp. <i>steinii</i>	7'		12''	12c	12'''	3p	3''''	
Present specimens	6–8'	0–4a	9–14''	10–14c	10–14'''	2–5p	0–2ap 3''''	From Omura Bay
	(7'	0a	12''	12c	12'''	3p	0ap 3'''')	

Zoological Nomenclature, because the differences between *P. steinii* and *P. vancampoae* are smaller than those between *P. horologium* and *P. steinii*. According to him, the normal plate formula of *P. steinii* is Po, 7', 12'', 12c, 12''', 3''', 3p and 8s, and that of *P. vancampoae* is basically Po, 8', 12–14'', 12–14c, 12–14''', 3''', 8s and 8–11p. Based on this, he considered that *P. vancampoae* is a subspecies of *P. steinii*.

In the specimens germinated from living cysts of Omura Bay, only a few may have formula like that of *P. vancampoae*; Specimen labelled as KM 002 was 8', 0a, 13'', 11c, 11''', 4p, 0ap and 3'''; specimen labelled as KM 013 was 7', 2a, 13'', 12c, 12''', 4p, 0ap and 3'''. These formulae do not agree with the most common formula of *P. vancampoae* indicated by Wall and Dale (1971). Furthermore, in the case of specimen KM 013, progeny of the first germinated cell had the formula 7', 1a, 13'', 13c, 13''', 4p, 0ap and 3'''. This formula is well within the range of *P. horologicum* var. *steinii* sensu Steidinger and Davis (1967), *P. steinii* sensu Wall and Dale (1971) and *P. steinii* subsp.

steinii sensu Balech (1979).

Cyst form of Pyrophacus steinii:—Based on the morphological characters, cysts used in the incubation experiments and those acquired by palynological method can all be assigned to *T. vancampoae*. There are not significant morphological differences between cysts from Phosphorescent Bay (Wall and Dale 1971) and from Omura Bay. Although the vegetative cells obtained from the incubation experiments showed greater individual variation in the plate formula, they were clearly identifiable as *P. steinii*. Furthermore, theca containing living *T. vancampoae* cysts were found in the plankton. These theca had the plate formula of *P. steinii*, as well only *P. horologium* and *P. steinii* motile cells were found in the plankton. No plankton cells could be identified as *P. vancampoae*. This means that *T. vancampoae* is also the cyst form of *Pyrophacus steinii*.

Based on their incubation experiments, Wall and Dale (1971) concluded that *T. vancampoae* is the cyst form of *P. vancampoae* but they did not discuss the cyst of *P. steinii*. Germinated

Explanation of Plate 39

Modern cyst and thecate forms of *Pyrophacus steinii* (Schiller) Wall et Dale obtained in unialgal culture.

Figs. 1a–2c. *Pyrophacus steinii* (Schiller) Wall et Dale, Specimen KM 009.

Figs. 1a–f. Cyst after germination, 1a; apical surface, \times ca. 285, 1b; optical cross section in antero-posterior view, \times ca. 285, 1c; antapical surface, showing attached operculum composed of three paraplates, 1d; enlargement of 1e, showing archeopyle, \times ca. 570, 1e and 1f; lateral surface, \times ca. 285.

Figs. 2a–c. Newly germinated vegetative cell, 2a; epitheca lacking the apical pore platelet, showing aberrant shape of the 1' plate (arrow), apical surface in apical view, \times ca. 285, 2b; epitheca, showing lenticular shape, oblique lateral view, \times ca. 285, 2c; hypotheca, antapical surface in apical view, \times ca. 285.

Figs. 3–7. *Pyrophacus steinii* (Schiller) Wall et Dale, Specimen KM 020.

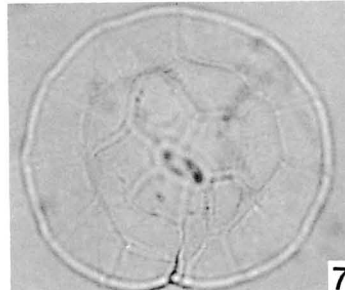
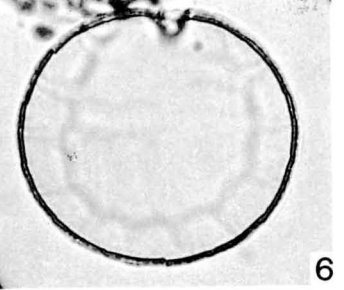
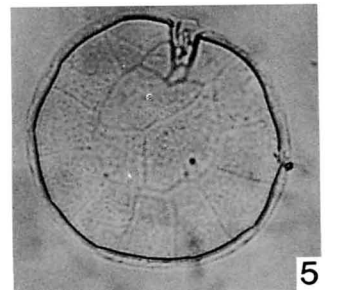
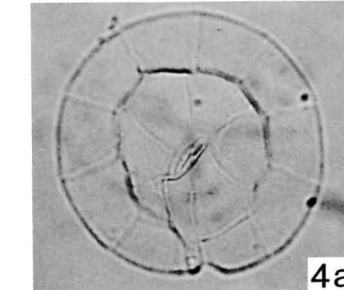
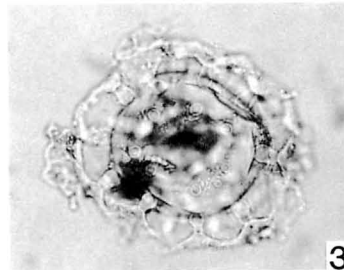
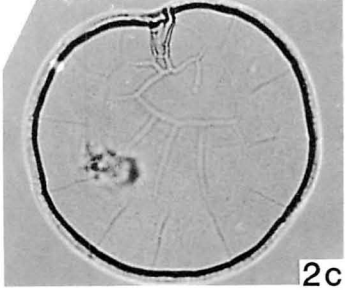
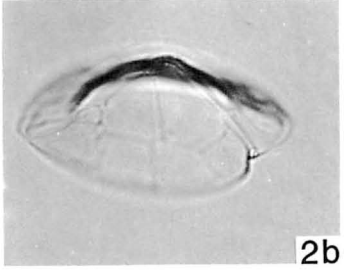
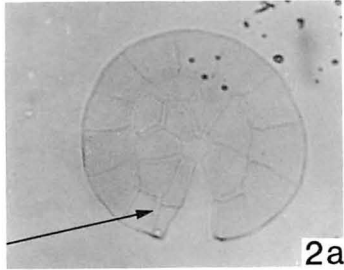
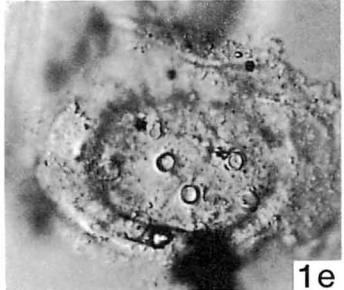
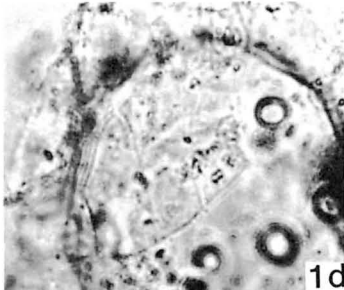
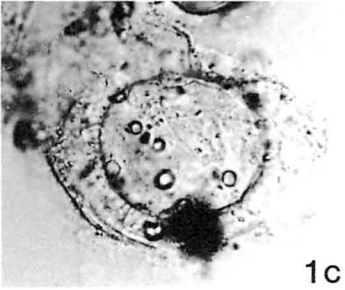
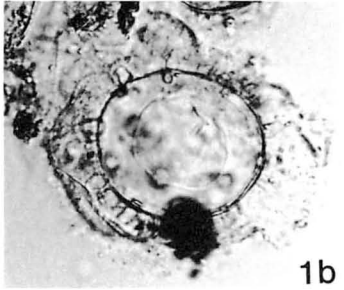
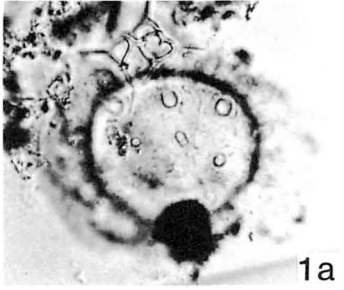
Fig. 3. Cyst after germination, apical surface, \times ca. 260.

Figs. 4a–b. Newly germinated vegetative cell, 4a; epitheca, apical surface in antapical view, \times ca. 260, 4b; hypotheca, showing the aberrant shape of the 1'' and 2'' plates, antapical surface in apical view, \times ca. 260.

Fig. 5. Hypotheca of daughter cell, showing only two antapical plates; antapical surface of antapical view, \times ca. 260.

Fig. 6. Hypotheca of daughter cell, showing cingular platelets, optical cross section in antero-posterior view, \times ca. 260.

Fig. 7. Epitheca of daughter cell, apical surface in apical view, \times ca. 260.

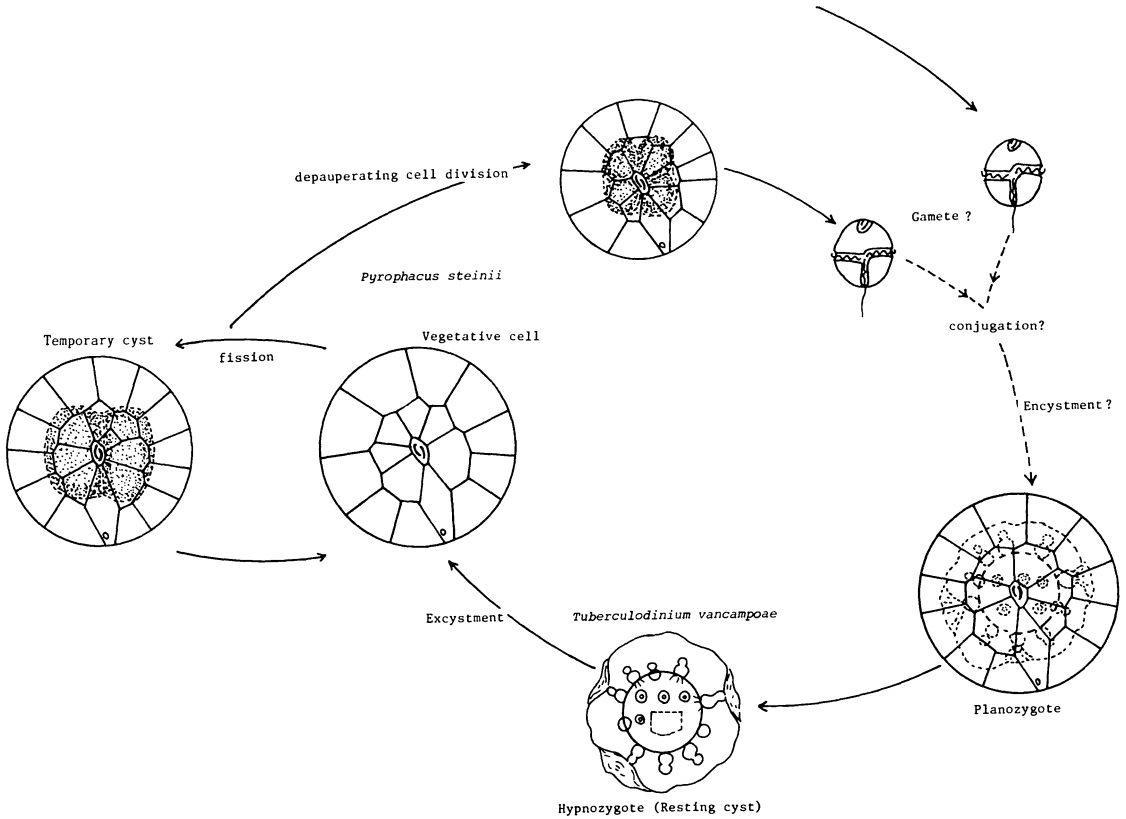


thecate cells obtained from Phosphorescent Bay have following plate formula; C949 ··· 7', 3a, 15'', 15'', 2p and 5'', and C955 ··· 7', 2a, 13'', 1p, and 5'', and 8', 0a, 13'' (hypotheca unknown) according to Wall and Dale (1971). The plate number of these specimens are larger than the normal form of *P. steinii*; but in my opinion, one of them, C955, is clearly included within the range of *P. steinii*. Therefore, no clear separation can be made based on vegetative cell plate formulae, between *P. steinii* and *P. vancampoe* obtained from Phosphorescent Bay and Omura Bay.

Significance of small thecate form in life cycle of Pyrophacus steinii (Text-fig. 8):—The small thecate form of *P. steinii* is different from normal vegetative cells of *P. steinii* (Schiller)

in plate formula and cell shape, and most closely resembles *P. horologicum* except for the number of apical plates. The latter species has only five to six plates, while the former form possesses six to eight.

Steidinger and Davis (1967) reported that *P. horologicum* is more spherical than *P. steinii* and that smaller cells are found. The small thecate forms derived from incubation are similar in shape to these small and spherical cells of *P. horologicum*, but they are distinguishable from the latter in being ovoid in cell shape and having a wider cingulum. This small forms also differ from *P. horologicum* in the plate and platelet distribution of the antapicals and sulcus. *P. horologicum* possesses three antapical plates surrounding the posterior sulcal plates, one of



LIFE CYCLE of *Pyrophacus steinii* (Schiller)

Text-fig. 8. Life cycle of *Pyrophacus steinii* (Schiller) Wall et Dale. Solid line; observed process, dotted line; hypothesized process.

which is characteristically large and triangular, and others having consistent shapes and positions. These characters are also found in *P. steinii*. Though this small thecate form also possesses three antapical plates, none are large and triangular. Furthermore, the structure of the sulcus is different in the two. The anterior sulcal platelet of the small thecate form is shallow U-shape, while this platelet of *P. horologium*, is nearly rectangular. The posterior sulcal platelet of the small thecate form is irregularly hexagonal, but the corresponding platelet of *P. horologium* is nearly ellipsoidal. In the former, the last cingular platelet clearly invades the sulcus, but the platelet of the latter does not.

Matzenauer (1933) reported the occurrence of *P. horologium* sensu lato from the Indian Ocean. The figured specimen (Matzenauer 1933,

p. 481, fig. 78) is noteworthy in no being lenticular but rather subspherical, with a theca composed of many plates and platelets as observed in normal vegetative cells. This spherical form is also smaller (57 μm in length and 59.5 μm in width) than normal cells and apparently resembles the present small thecate form. Unfortunately its plate formula is not clear and cannot be reconstructed in detail from his original figure, so we cannot determine which species of the genus *Pyrophacus* that specimen is assignable to. However, the species of Matzenauer differs from the small thecate form in being more spherical and in having a cingulum without displacement. With respect to the life cycle in *P. steinii*, it is significant that the small thecate form appeared in the unialgal culture. Stosch (1973) reported the appearance of smaller and light colored cells in cultures of the

Explanation of Plate 40

Small thecate form of *Pyrophacus steinii* (Schiller) Wall et Dale obtained in unialgal culture.

Figs. 1—2. Ventral surface in dorsal view, showing the displacement of the cingulum. Both specimens are somewhat elongated antero-posteriorly; 1, specimen KM 012-1, \times ca. 690; 2, specimen KM 012-2, \times ca. 550.

Figs. 3—4. Optical cross section in lateral view, showing the theca; 3, specimen KM 012-2, \times ca. 650; 4 specimen KM 012-2, \times ca. 600.

Figs. 5—6, 10a—b. Plate distribution on epitheca.

Fig. 5. Apical surface in antapical view, showing small ventral pore in the 1' plate (arrow), specimen KM 012-3, \times ca. 570.

Fig. 6. Apical surface in oblique apical view, specimen KM 012-4, \times ca. 660.

Figs. 10a—b. Apical surface in antapical view, showing the apical pore platelet and apical plates (10a), \times ca. 590, and precingular plates (10b), \times ca. 590, specimen KM 012-2.

Figs. 7—9. Plate distribution on hypotheca.

Fig. 7. Nearly optical cross section of hypotheca, showing the sulcus and postcingular plates, specimen KM 012-3, \times ca. 770.

Fig. 8. Antapical surface in oblique antapical view, showing the 6''', 7''' and 8''' plates, specimen KM 012-3, \times ca. 770.

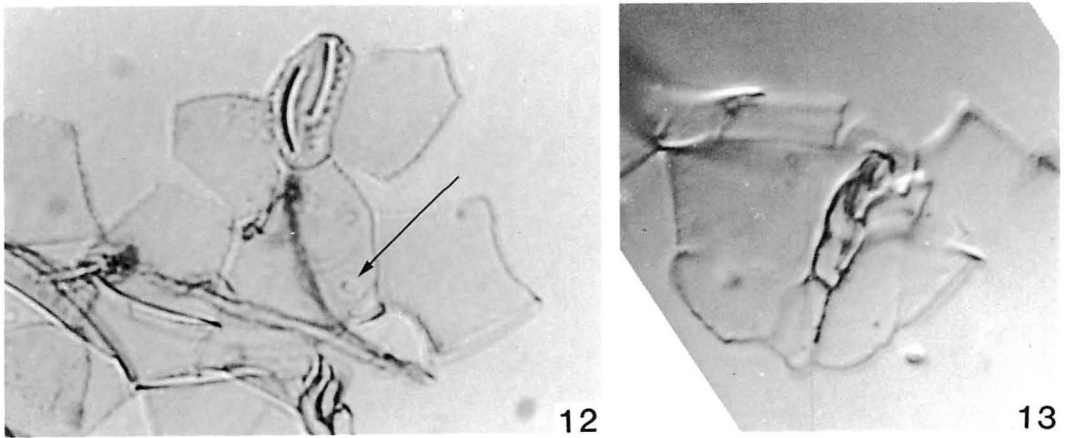
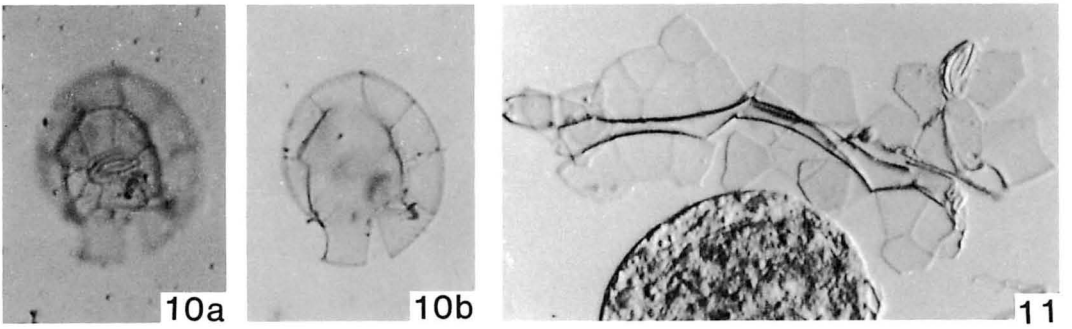
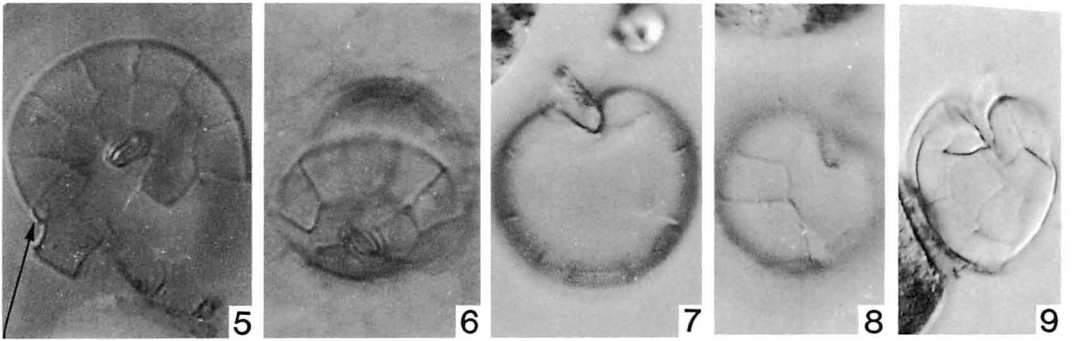
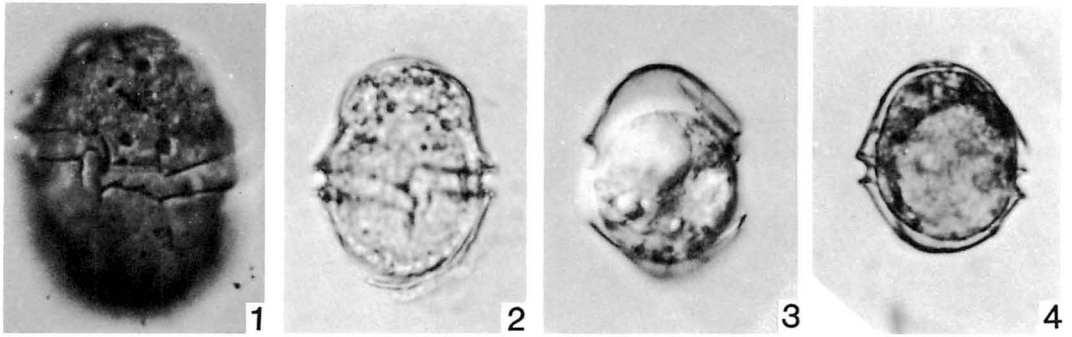
Fig. 9. Antapical surface in oblique antapical view, showing right precingular plates and some antapicals, specimen KM 012-2, \times ca. 630.

Figs. 11—13. Cell pressed under coverslip, ventral surface in dorsal view.

Fig. 11. Thecal plates and platelets constituting the theca, a few plates and platelets are missing, specimen KM 012-1, \times ca. 600.

Fig. 12. Enlargement of anterior ventral part, showing an apical pore platelet and the 1', 2', 7', 1'', 2'', 3'' (part) and 8'' plates, and a ventral pore on the 1' plate (arrow), specimen KM 012-1, \times ca. 1400.

Fig. 13. Enlargement of posterior ventral part, showing the distribution of sulcal platelets, specimen KM 012-1, \times ca. 1325.



freshwater gymnodinial species, *Gymnodinium pseudopalsutre* Schiller and concluded that this form was a gamete formed by depauperating cell division. Later, Dale (1977) also observed such smaller cells in the thecate species, *Peridinium faeroense*. The present smaller form is very different from the normal vegetative cell in its smaller size and more spherical shape. This strongly suggests that this smaller form may be a gamete of *P. steinii*, but confirmation of this will need to investigate on its nuclear phase and to observe a zygote formation.

Conclusion

Living cyst identical with the fossil dinoflagellate *Tuberculodinium vancampoe* (Rossignol) Wall produced the thecate species *Pyrophacus steinii* (Schiller) Wall et Dale in incubation experiments.

In the plankton of Omura Bay, thecate form of *Pyrophacus steinii* (Schiller) Wall et Dale contained living cysts assignable to *Tuberculodinium vancampoe* (Rossignol) Wall.

These facts indicate that *Tuberculodinium vancampoe* is also the cyst form of *Pyrophacus steinii* Wall et Dale.

Pyrophacus vancampoe (Rossignol) is concluded to be a subspecies of *P. steinii* as follows: *Pyrophacus steinii* (Schiller) Wall et Dale subsp. *vancampoe* (Rossignol) Balech.

In the unialgal culture of *Pyrophacus steinii* germinated from living cysts, a small thecate form appeared. This form is very different from the normal vegetative cell in being smaller and more ovoid. The plate formula of this form is more similar to that of *Pyrophacus horologium* than to that of *P. steinii*.

The morphological characteristics of this form strongly suggest that it is a gamete.

Acknowledgment

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Pyrophacus steinii (SCHILLER) WALL et DALE, 1971 のシストと游泳体: *Pyrophacus steinii* (SCHILLER) WALL et DALE のシストが室内及び野外観察の結果から明らかにされた。*Tuberculodinium vancampoae* (ROSSIGNOL) と同定される生シストから発芽した游泳・有殻体は、錯板配列の詳細な観察に基づいて *Pyrophacus steinii* に属するとされた。さらに *T. vancampoae* と同定され得る生シストを包含した *Pyrophacus steinii* の游泳・有殻体が大村湾の夏季のプランクトン群集から数多く得られた。これらの資料によると、*T. vancampoae* は *P. vancampoae* だけでなく *P. steinii* のシストでもあり、また *P. vancampoae* は *P. steinii* の亜種であると結論される。

松岡数充

806. A NOTE ON AN INOCERAMID SPECIES (BIVALVIA) FROM THE
LOWER CONIACIAN (CRETACEOUS) OF HOKKAIDO*

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Abstract. A large number of well preserved specimens from the limited thickness of fine-grained sandy siltstone in the lower part of the Coniacian sequence along the Pombets-Gono-sawa of the Mikasa [Ikushumbets] area, central Hokkaido, is regarded as representing a population of a single species which can be identified with *Inoceramus rotundatus* Fiege. We have examined statistically certain measurable characters on this sample (N=25) and described the extent of variation. The ratio of shell length to height is fairly constant, whereas that of breadth to height varies considerably. There is variation in the appearance and strength of major ribs and also in the distinctness of minor rings. Some specimens are thus fairly close to a form which has been called *I. waltersdorfensis hannourensis* Heinz, but as there is gradation from the typical form of *I. rotundatus*, they are included in the same species. *I. rotundatus* characterizes the lower part of the tripartite Coniacian in the sequence of the studied area. *I. uwajimensis* Yehara is occasionally found together with *I. rotundatus*, but it is more prolific in the middle part of the Coniacian sequence. The fossils associated with *I. rotundatus* include *Didymotis akamatsui* (Yehara), *Forresteria (Reesideoceras) petrocoriensis* (Coquand) and *Harleites* cf. *H. harlei* (Grossouvre).

Introduction

On the occasion of the Symposium on the Cretaceous Stage Boundaries in Copenhagen, 20th October 1983, one of us presented a paper on the so-called Turonian-Coniacian boundary in Japan. As has been described in that paper (Matsumoto, 1984), the outcrops along the Pombets-Gono-sawa (which may be

called the Takiyoshi-zawa by some people) in the Mikasa [=“Ikushumbets”] area, central Hokkaido, give one of the reference sequences for the Coniacian in Japan. We have obtained there numerous specimens of a bivalve species, which we identify provisionally with *Inoceramus rotundatus* Fiege.

I. rotundatus was described by Fiege (1930), Tröger (1967), Kauffman (*in Herm et al.*, 1979) and Keller (1982) from central Europe. The characters shown by the population of this species at Pombets-Gono-sawa in Hokkaido may not be quite identical with those at the

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type and other localities in central Europe. In this paper we describe the species on the basis of our material.

Our study is based mainly on numerous specimens from a particular member of the Upper Yezo Group exposed along the narrow creek (stream) of the Pombets-Gono-sawa for a restricted extent. This member, about 20 m in thickness, consists of fine-grained sandy siltstone and is situated in the lower part of the whole sequence, about 65 m, of the Coniacian. The localities and the stratigraphic column have been already shown by one of us (Matsumoto, 1984, fig. 4) and are reproduced here with permission (Text-fig. 1). The most prolific outcrop is loc. Ik 2716 and the next is loc. Ik 2710. Fossiliferous nodules from each locality may be indicated as, for instance, Ik 2716 a, b *etc.* There are some other nearby localities.

Some specimens are provisionally kept in the Collections of one of us (M.N.), which are indicated under JG. [Jonan Geological Collection, Oita], and others in the Type Room of Geological Collections, Kyushū University, Fukuoka, indicated under GK. Those which have been transferred from JG. to GK. have double numbers.

Palaeontological description

Family Inoceramidae Zittel, 1881

Genus *Inoceramus* Sowerby, 1814

Type species:—*Inoceramus cuvierii* Sowerby, 1814.

Remarks:—Aside from *Mytiloides* Brongniart, 1822 and *Sphenoceramus* Boehm, 1915, which we regard as independent genera, *Inoceramus* has been subdivided into several subgenera. *I. rotundatus* Fiege, described below, may be referable to a subgenus which is different from *Inoceramus* (*Inoceramus*), but we have not yet arrived at a definite conclusion about its subgeneric assignment. As Kauffman (*in* Herm *et al.*, 1979, p. 68) suggested, we presume that its systematic position may be somewhere between *I. (Inoceramus)* and typical *I. (Cremnoceramus)* Cox, 1969, whose type species is

I. inconstans Woods, 1911. Kauffman (*op. cit.*) described it under *Cremnoceramus* with a query.

Inoceramus rotundatus Fiege, 1930

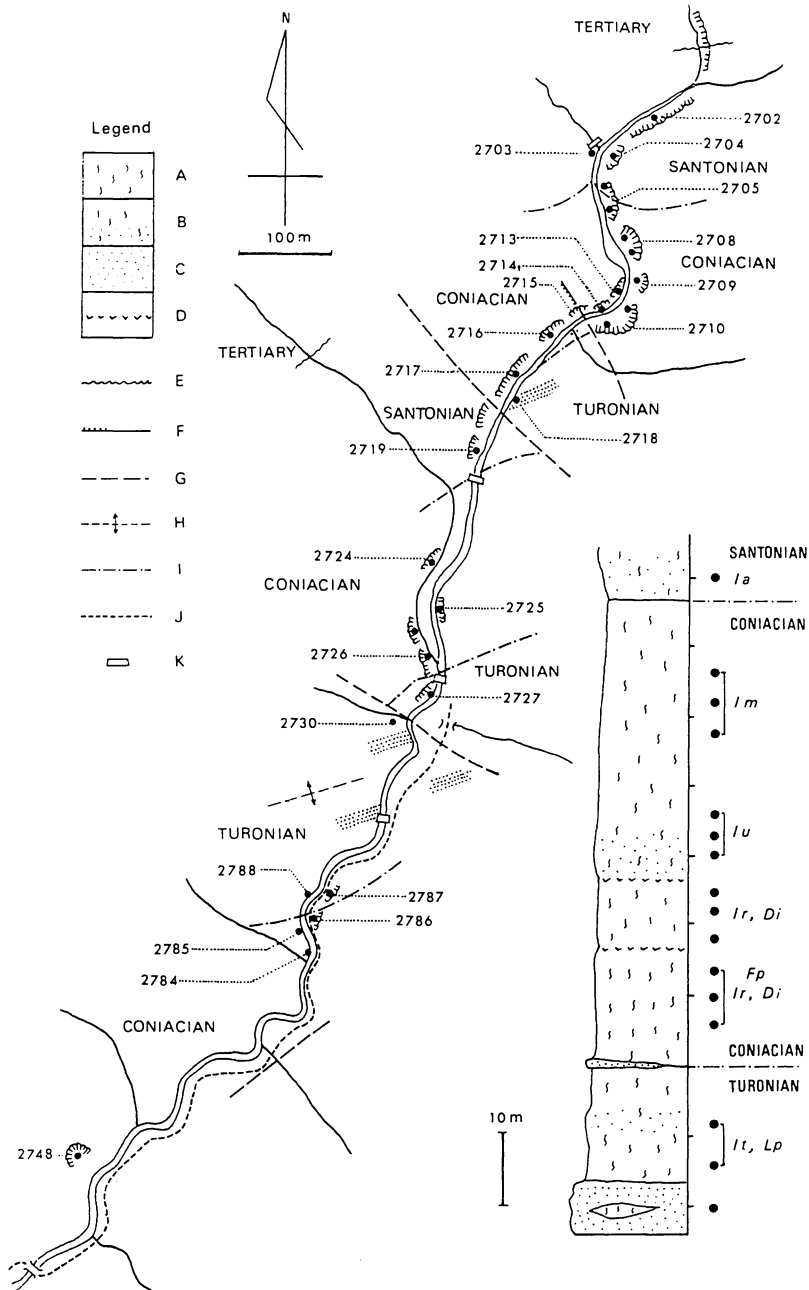
Pl. 41, Figs. 1–4; Pl. 42, Figs. 1a–6b;

Pl. 43, Figs. 1a–11; Pl. 44, Figs. 1–8.

1930. *Inoceramus inconstans rotundatus* Fiege, p. 42, pl. 7, fig. 32; pl. 8, fig. 31; text-fig. 3.
1967. *Inoceramus rotundatus* Fiege; Tröger, p. 110, pl. 12, figs. 5, 6; pl. 13, figs. 10–13.
1979. *Cremnoceramus* ? *rotundatus* (Fiege); Kauffman *in* Herm *et al.*, p. 68, pl. 9, figs. A, C.
1982. *Inoceramus rotundatus* Fiege; Keller, p. 114, pl. 8, fig. 2.

Lectotype:—The specimen illustrated by Fiege, 1930, pl. 7, fig. 32, from Schacht [Shaft] Preussen III, depth 156 m of Rhein-Westfalen coal-field, designated by Bräutigam (1962) (see Keller, 1982).

Material of the description below:—GK. H 10130 from loc. Ik 2786 [=Ik 2118] collected by T. Takahashi; GK. H 10131 [=JG. H 2859] from loc. Ik 2714 c; GK. H 10132 [JG. H 2868] from loc. Ik 2716 h; GK. H 10133–H 10135 [JG. H 2895 A, C, D], GK. H 10136 [JG. H 2861], GK. H 10137–H 10140 [JG. H 2872 A–D], JG. H 2894 and JG. H 2896 from loc. Ik 2716 q; JG. H 2856, JG. H 2867 and JG. H 2870 from loc. Ik 2716 n; JG. H 2869 from loc. Ik 2716 k; GK. H 10141 [JG. H 2900] from loc. Ik 2716 d; JG. H 2874 from loc. Ik 2710k; JG. H 2871A, B, JG. H 2873, and JG. H 2897 A–D from loc. Ik 2716 (undivided); JG. H 2857, JG. H 2860, JG. H 2862, JG. H 2863, JG. H 2864, JG. H 2865 and JG. H 2866 from loc. Ik 2710. There are also many other specimens of imperfect preservation from the same localities as above and also from loc. Ik 2726. Almost all collected by us with the aid of Messrs. T. Takahashi, S. Uchida and K. Muramoto in the Pombets-Gono-sawa [=Takiyoshizawa], Mikasa. A thin, prismatic, inner shell layer is preserved in most of the above speci-



Text-fig. 1. Route map of the Pombets-Gono-sawa, with a stratigraphic profile. Locality numbers should have prefix Ik. Legend — A-D for profile-A: fine-grained sandy siltstone, B: silty fine-grained sandstone, C: thick bedded sandstone, D: tuff, E: unconformity, F: fault (observed), G: fault (inferred), H: anticline, I: stage boundary, J: path (partly damaged), K: small scale dam; Abbreviation of selected species — Ia: *Inoceramus (Platyceramus) amakusensis*, Im: *I. mihoensis*, Ir: *I. rotundatus*, It: *I. tenuistriatus* and *I. teshioensis*, Di: *Didymotis akamatsui*, Fp: *Forresteria (Reesideoceras) petrocoriensis*, Lp: *Lymaniceras planulatum*.

Table 1. Measurements of well preserved specimens of *I. rotundatus* from the Pombets-Gono-sawa (linear dimension in mm).

Specimen	valve	h	l	H	L	b	s	α, β	γ	δ	l/h	b/h	L/H	s/l
JG.H2856	R	25.0	24.3	26.0	25.3	10.8	11.0	128°	115°	73°	0.97	0.43	0.97	0.45
2857	L	51.7	49.8	54.1	52.0	20.2	25.0	105°	134°	62°	0.96	0.41	0.96	0.50
2859a	L	24.3	23.8	26.2	25.0	7.3	15.0	98°	130°	61°	0.98	0.30	0.95	0.63
2859b	R	23.7	22.9	25.3	23.0	8.0	14.1	100°	128°	61°	0.97	0.34	0.91	0.59
2860a	L	62.2	52.0	69.4	60.3	22.8	29.0	108°	126°	66°	0.84	0.37	0.87	0.56
2860b	R	61.2	52.4	66.2	58.4	20.6	—	98°	132°	67°	0.87	0.34	0.88	—
2861c	R	17.1	16.8	17.6	16.0	5.2	10.0	107°	117°	59°	0.98	0.30	0.91	0.60
2862a	L	25.9	25.0	29.4	25.4	9.0	16.1	100°	140°	57°	0.97	0.35	0.86	0.64
2862b	R	27.7	26.4	29.9	26.3	9.1	16.1	93°	135°	52°	0.95	0.33	0.88	0.61
2866	R	23.0	22.4	26.0	23.5	7.5	12.5	105°	133°	63°	0.97	0.33	0.90	0.56
2868	R	37.6	33.7	38.2	35.6	12.0	17.4	107°	130°	62°	0.90	0.32	0.93	0.52
2869	L	40.5	37.4	44.4	40.8	15.2	24.5	103°	—	62°	0.92	0.38	0.92	0.66
2871	R	30.0	28.6	33.7	32.2	11.8	15.0	103°	138°	63°	0.95	0.39	0.96	0.52
2872a	L	20.6	18.2	22.0	19.9	8.2	11.5	102°	135°	66°	0.88	0.40	0.90	0.63
2872b	R	19.5	18.4	20.7	19.3	7.4	11.3	115°	137°	62°	0.94	0.38	0.93	0.61
2873	R	26.8	26.6	29.4	29.0	7.8	16.7	111°	117°	61°	0.99	0.29	0.99	0.63
2874	R	19.8	18.1	20.9	20.2	6.2	10.3	105°	128°	65°	0.91	0.31	0.97	0.57
2894	R	—	—	24.0	24.0	5.4	—	100°	132°	54°	—	—	1.00	—
2895d	L	22.5	21.7	25.9	21.8	9.3	11.7	102°	132°	62°	0.96	0.41	0.84	0.54
2896	R	23.6	23.0	26.0	24.0	9.7	13.6	108°	131°	60°	0.97	0.41	0.92	0.59
2897a	R	21.8	20.4	22.4	20.4	7.6	13.1	104°	—	70°	0.94	0.35	0.91	0.64
2897b	R	25.6	24.2	26.7	24.0	7.1	12.3	108°	136°	66°	0.95	0.28	0.90	0.51
2897c	R	16.6	16.5	16.6	15.9	6.7	10.3	122°	132°	71°	0.99	0.40	0.96	0.62
2897d	L	25.0	24.0	27.8	23.8	9.9	12.9	102°	131°	63°	0.96	0.40	0.86	0.54
2900	R	19.4	19.2	21.4	—	7.7	9.1	112°	—	62°	0.99	0.40	—	0.47+

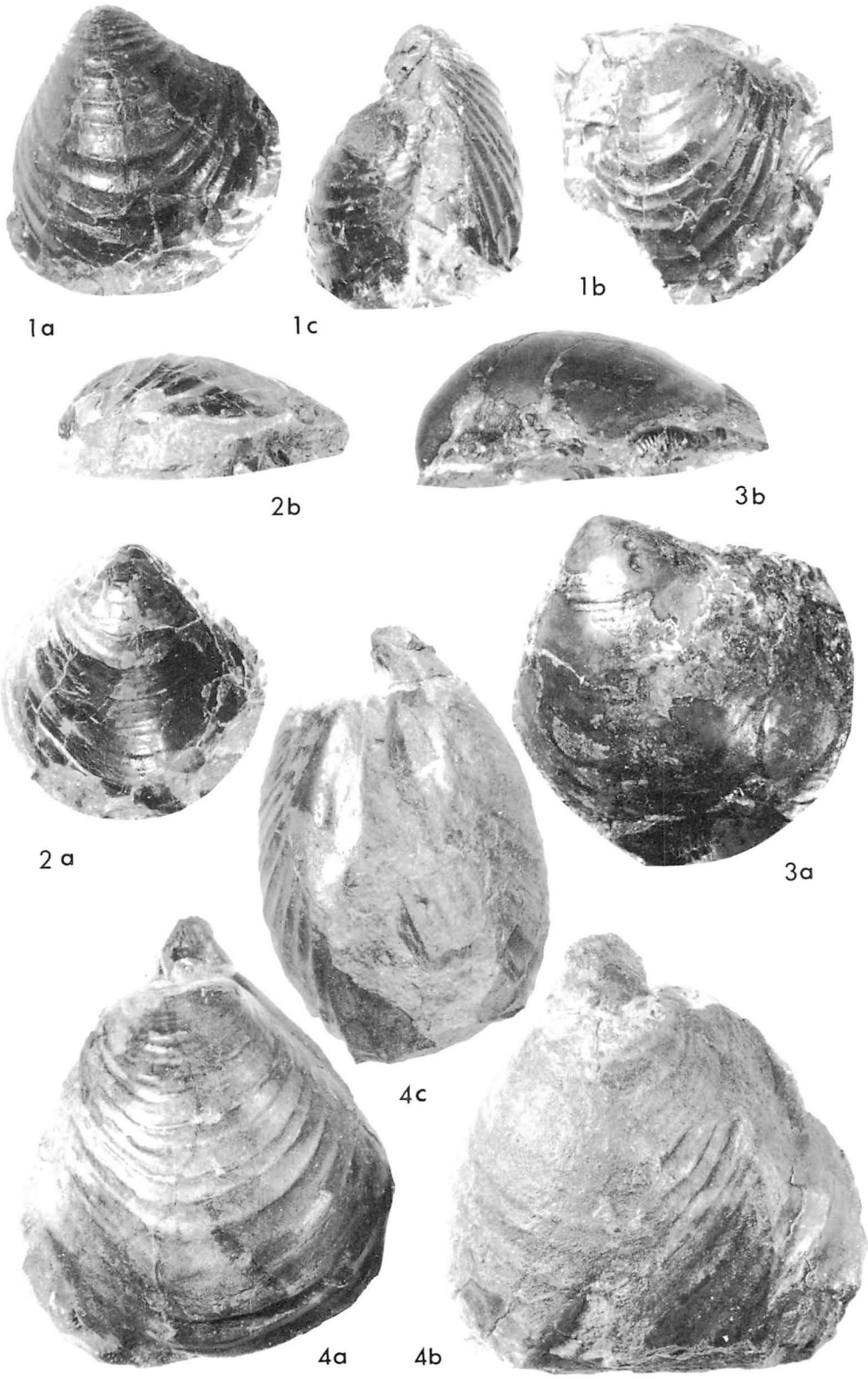
L: left, R: right, h: height, l: length, H: maximum linear dimension from beak to ventral extremity, L: maximum linear dimension perpendicular to H, b: breadth, s: length of hinge-line; α : anterior hinge angle, β : angle of umbonal inflation (nearly equal to or slightly smaller than α in this species), γ : posterior hinge angle, δ : obliquity (angle between hinge-line and H).

Explanation of Plate 41

Figs. 1–4. *Inoceramus rotundatus* Fiege

1. GK. H10131 from loc. Ik 2714c; left (a) and right (b) valves and their anterior view (c), $\times 1.5$.
2. GK. H10132 from loc. Ik 2716h; right valve (a) and its posterior view (b), $\times 1$.
3. JG. H2857 from loc. Ik 2710r; left valve (a) and its anterior view (b), $\times 1$.
4. JG. H2860 from loc. Ik 2710r; right (a) and left (b) valves and their anterior view (c), $\times 1$.

The specimens figured in Plates 41–44 were all collected by the authors with the aid of Messrs. T. Takahashi, S. Uchida and K. Muramoto in the Pombets-Gono-sawa [=Takiyoshi-zawa], Mikasa area. Photos (Pls. 41–44) by M. Noda without whitening.



mens, although it is partly taken away.

Specific characters:—Shell small to moderate in size, nearly equivalve, typically with moderate and rather uniform convexity. Outline sub-rounded to subquadrate, slightly higher than long, with hinge-line somewhat longer than a half of shell length; anterior part inclined steeply, slightly concave near the umbo, showing almost linear margin; ventral margin well rounded, passing gradually to arcuate posterior margin; angle between posterior margin and hinge-line obtuse ($\gamma \leq \text{ca. } 130^\circ$ on the average), showing flattened edge. Beak blunt, anterior and slightly projected above the hinge-line. Axis of growth nearly straight or slightly concave anteriorly,

with average inclination (δ) of about 63° .

Surface ornamented with fine concentric raised lines or rings and concentric ribs of weak to moderate intensity, showing variation with growth and also between individuals.

Biometry:—Measurements on the undeformed specimens ($N=25$) are shown in Table 1. We mentioned below that the small specimens are mostly immature. Some of the biometrical characters show generally allometry in relative growth. The statistics is, therefore, made in two subgroups with the boundary at the growth stage of 25 mm in h, as shown in Tables 2 and 3 respectively. As is clear from Tables 2 and 3, the difference of mean value in each character

Table 2. Biometric characters of the studied sample of *I. rotundatus* ($h < 25$ mm).

Characters	α	β	γ	δ	l/h	b/h	L/H	s/l
<i>N</i>	13	13	11	13	12	12	12	11
<i>m</i>	106.2°	106.2°	130.5°	62.8°	0.957	0.361	0.925	0.588
<i>s</i>	6.78°	6.78°	5.20°	4.49°	0.0337	0.0440	0.0412	0.0336
<i>v</i>	6.38	6.38	3.98	7.15	3.52	12.19	4.45	5.71

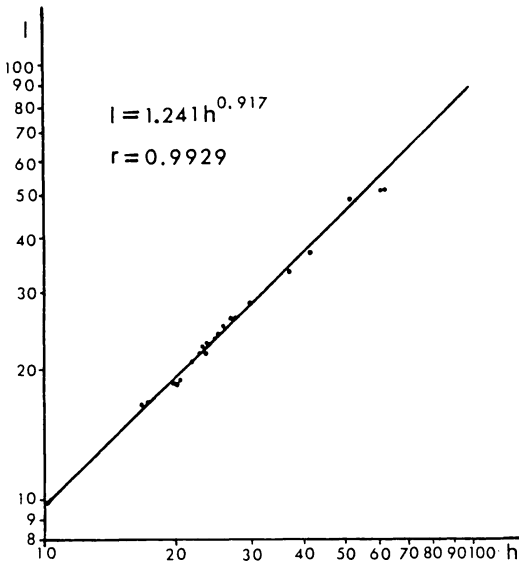
N: sample size, *m*: mean value, *s*: standard deviation, *v*: Pearson's coefficient of variation, other letters as for Table 1.

Table 3. Biometric characters of the studied sample of *I. rotundatus* ($h \geq 25$ mm).

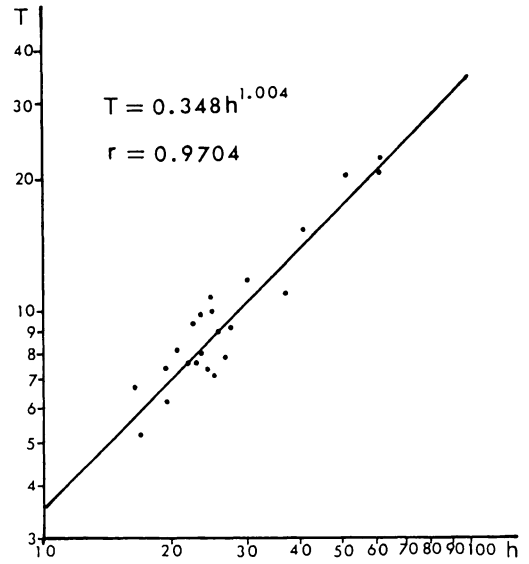
Characters	α	β	γ	δ	l/h	b/h	L/H	s/l
<i>N</i>	12	12	11	12	12	12	12	11
<i>m</i>	105.5°	105.5°	130.4°	62.8°	0.936	0.358	0.915	0.558
<i>s</i>	8.62°	8.62°	8.09°	5.20°	0.0448	0.0473	0.0464	0.0675
<i>v</i>	8.17	8.17	6.20	8.28	4.79	13.21	5.07	12.10

Table 4. Biometric characters of the studied sample of *I. rotundatus*.

Characters	α	β	γ	δ	l/h	$\frac{l/h}{H=20\text{mm}}$	b/h	L/H	s/l
<i>N</i>	25	25	22	25	24	22	24	24	23
<i>m</i>	105.8°	105.8°	130.4°	62.8°	0.946	0.953	0.359	0.920	0.537
<i>s</i>	7.37°	7.37°	6.49°	4.65°	0.0394	0.0307	0.0438	0.0423	0.0574
<i>v</i>	6.96	6.96	4.97	7.40	4.16	3.22	12.19	4.60	10.01



Text-fig. 2. Diagram showing the average relative growth of shell height and shell length in a studied sample of *I. rotundatus*.



Text-fig. 3. Diagram showing the average relative growth of shell height and shell breadth in a studied sample of *I. rotundatus*.

is a little, which is less than the significant limit of Student's t-test. This allows us to summarize totally the measured characters in Table 4, regardless of the difference in growth-stage of the examined specimens.

Both the reduced major axes demonstrated in Text-figs. 2 and 3 show the monophasic allometry. In the relative growth between shell height and breadth, the growth index (α) is a fairly good approximation of 1, which is clearly within the range of isometry, and the growth index (α) of shell height and length shows a slightly negative allometry (Hayami and Matsukuma, 1971, p. 150, 151).

Descriptive remarks:—Many of the examined

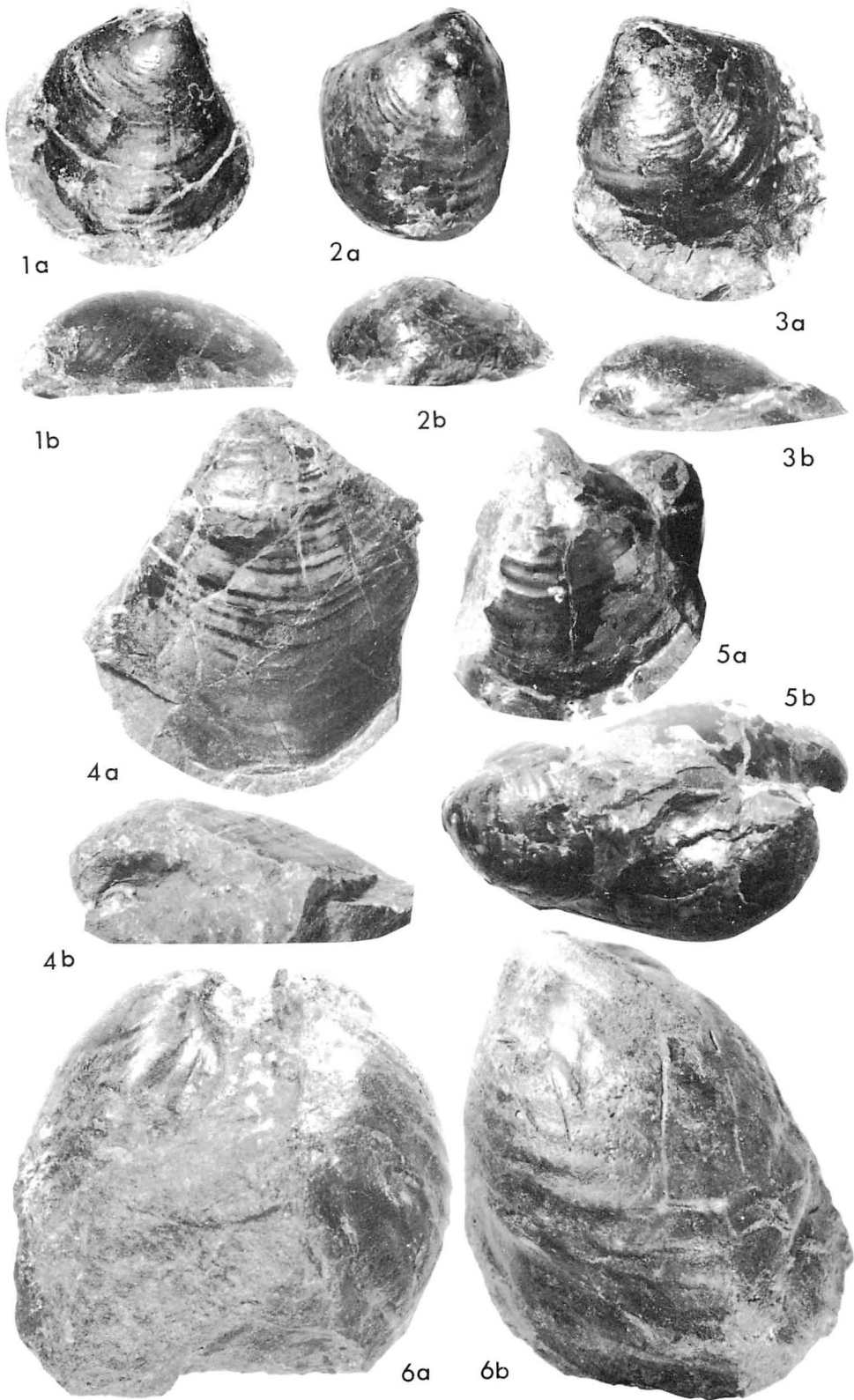
specimens are smaller than the lectotype and certain other illustrated examples from Germany. They show concentric rings fairly well, whereas their concentric ribs are weak or very faint. As will be discussed later, we regard at least some of them as immature.

There are, however, specimens of moderate size. They have ribs of moderate intensity and are close to the lectotype. JG. H 2860 (Pl. 41, Fig. 4) is an example of such a form. Although it is represented by the internal mould for the most part, fine concentric rings are also discernible on the early middle part where the inner shell layer is preserved. On its late part the rings are more distinct and impressed even

Explanation of Plate 42

Figs. 1—6. *Inoceramus rotundatus* Fiege

1. JG. H2766 from loc. Ik 2710r; right valve (a) and its posterior view (b), $\times 1.8$.
2. GK. H10134 from loc. Ik 2716q; right valve (a) and its posterior view (b), $\times 1.8$.
3. JG. H2871B from loc. Ik 2716; left valve (a) and its anterior view, $\times 1$.
4. JG. H2869 from Ik 2716k; left valve (a) and its anterior view (somewhat secondarily compressed) (b), $\times 1$.
5. GK. H10133 from loc. Ik 2716q; left valve (a) and its posterior view (b, above), $\times 1$.
6. JG. H2863 from loc. Ik 2710; anterior view of both valves (a) and left valve (somewhat deformed) (b), $\times 1.5$.



on the internal mould. GK. H 10131 (Pl. 41, Fig. 1) has distinct and regular ribs, although it is not so large as JG. H 2860.

GK. H 10132 (Pl. 41, Fig. 2), JG. H 2857 (Pl. 41, Fig. 3), JG. H 2862 (Pl. 43, Fig. 9), JG. H 2871 A (Pl. 43, Fig. 8) and some others have somewhat weaker concentric ribs than those of the above two, but cannot be separated as a different species for this reason alone. They show a uniform or gradually changing convexity like the more strongly ribbed form, although the ratio of breadth to height (b/h) varies considerably from a specimen to another. Fine concentric rings are also discernible where the shell layer is preserved on these specimens.

The ribs are regular in GK. H 10131, JG. H 2857 and JG. H 2862, slightly irregular in JG. H 2860, and more irregular in distance and strength in GK. H 10132 and JG. H 2871. They are occasionally denser as in JG. H 2869 (Pl. 42, Fig. 4), in which some ribs are stronger than others. Incidentally, this specimen resembles well a figured example from Germany (Tröger, 1967, pl. 2, fig. 6 = Andert, 1934, text-fig. 7 c).

In many of the above-mentioned specimens the major ribs are weak or indistinct or even hardly perceptible on the younger part of the shell and well perceptible ribs begin to appear at dissimilar growth-stages among individuals. JG. H 2863 (Pl. 42, Fig. 6) is an example in which distinct major ribs appear at a later stage than in other specimens, although it is represented by the internal mould for the most part and is secondarily distorted. When the thin shell layer (*i.e.* inner prismatic layer in most cases) is preserved, fine concentric rings or raised lines are more clearly shown than the faint or poorly developed major ribs on the young part in most of the specimens of moderate size (*i.e.* more than 25 mm in height).

In many of the smaller specimens, the concentric rings or raised lines predominate and the major ribs, if present, are weak or hardly perceptible in the umbonal part. This is quite similar to the feature seen on the young part of the specimens of moderate size mentioned above. Therefore, we regard most of the smaller

specimens as immature. They are fairly numerous, but some of them occur together with a presumably adult shell in one and the same nodule (for instance, see Pl. 44, Figs. 7, 8).

In a few specimens there is a sudden change or geniculation in the convexity of the valve at a certain growth-stage. JG. H 2871 B (Pl. 42, Fig. 3) and JG. H 2895 C (Pl. 42, Fig. 2) are examples which show such a feature in the late stage of their small shell. They occur together with the valves of uniform or gradually changing convexity in the same bed (loc. Ik 2716) or even in the same nodule (Ik 2716 q). GK. H 10130 (Pl. 43, Fig. 4) is a small specimen which shows a change of slope in its late part and its ribs become more distinct with growth. The small posterior ear is well preserved in this specimen.

The exceptional specimens mentioned above are similar to, if not identical with, *Inoceramus waltersdorfensis hannovrensis* Heinz, 1932 (Andert, 1934 (part), pl. 4, fig. 2; Tröger, 1967, p. 117, pl. 12, fig. 3; pl. 13, figs. 6–9; Kauffman, 1978a, pl. 5, figs. 3, 15; Kauffman, 1978b, pl. 2, figs. 2, 10; Kauffman *in* Herm *et al.*, 1979, p. 59, pl. 9, figs. D, G; Keller, 1982, p. 112, pl. 8, fig. 3). At least in our case, however, we think it unnatural and unreasonable to separate a small number of these exceptional specimens specifically from the coexisting more numerous, normal specimens of *Inoceramus rotundatus*.

Occurrence:—Localities Ik 2716, Ik 2710, Ik 2714, Ik 2717, Ik 2726 [=2798] b, c and Ik 2786 [=2118], especially abundant at the first two localities where fine-grained sandy siltstone is exposed for about 15 m and 20 m in thickness, respectively. All in the lower part of the Coniacian in the Pombets-Gono-sawa [=Takiyoshi-zawa], Mikasa district, central Hokkaido.

Discussion and conclusion

Taxonomic position:—We regard the described sample from the Pombets-Gono-sawa as representing a single species. The diagnosis has been given on the basis of this sample. It conforms generally with that of *I. rotundatus* Fiege de-

scribed by Tröger (1967) and Keller (1982).

It is, however, troublesome for us to see dissimilar expressions among authors (Fiege, 1930; Tröger, 1967; Kauffman *in Herm et al.*, 1979; Keller, 1982) about the specific characters. For instance, Kauffman recognizes certain differences between left and right valves, but Keller states as equivalve and Tröger nearly equivalve. Our observation on the Japanese forms conform with Tröger's in this respect. The diagram of the cross-section along the axis of growth illustrated by Tröger (1967, fig. 29) shows a low breadth and generally gentle convexity of the valve, but this may be probably due to the secondary compression. Keller writes as "moderately inflated" *mässig gewölbt*). Our observation generally conforms with Keller's, although we recognize a considerable variation in the convexity of valve or b/h. Kauffman takes up a change of slope, or geniculation, of some valves where there is also, according to him, a change of ornamentation. Tröger and Keller recognize only a little or occasional geniculation. We see also the geniculation in a few specimens and generally a uniform or gradually changing convexity predominates in our sample. The observations on the ornamentation are not quite identical among authors either.

The characters shown by the population of Pombets-Gono-sawa described in this paper may not be quite identical with those shown by the populations of the type and other places in Germany. Similarly the populations in

Bohemia, Austria, England and the North American Western Interior Province may be somewhat dissimilar. At least some of the specimens from Hokkaido resemble closely the lectotype, and certain other examples of *I. rotundatus* Fiege from Germany. Therefore, we would be allowed to identify our population with that species. We could, however, expect a minor difference — say on the average weaker, less prominent concentric ribs in our form or generally smaller shell size in our sample than in the lectotype and certain other illustrated specimens from Germany. Whether this is distinctive enough for subspecific separation or not is yet undetermined, unless the populations in Germany are carefully worked out to compare with ours. In fact Keller mentions the variability of the ornamentation and Kauffman (*in Herm et al.*, 1979, p. 70) records the small size of the Gosau specimens.

The relationship of *Inoceramus rotundatus* Fiege with *I. waltersdorfensis hannovrensis* Heinz is a problem. According to Keller (1982, p. 116), the former is more strongly inflated and has higher concentric ribs and a larger angle (α) between the hinge-line and the anterior margin than the latter. There is, however, variation in these characters and Keller himself recognizes the presence of a transitional form between the two species.

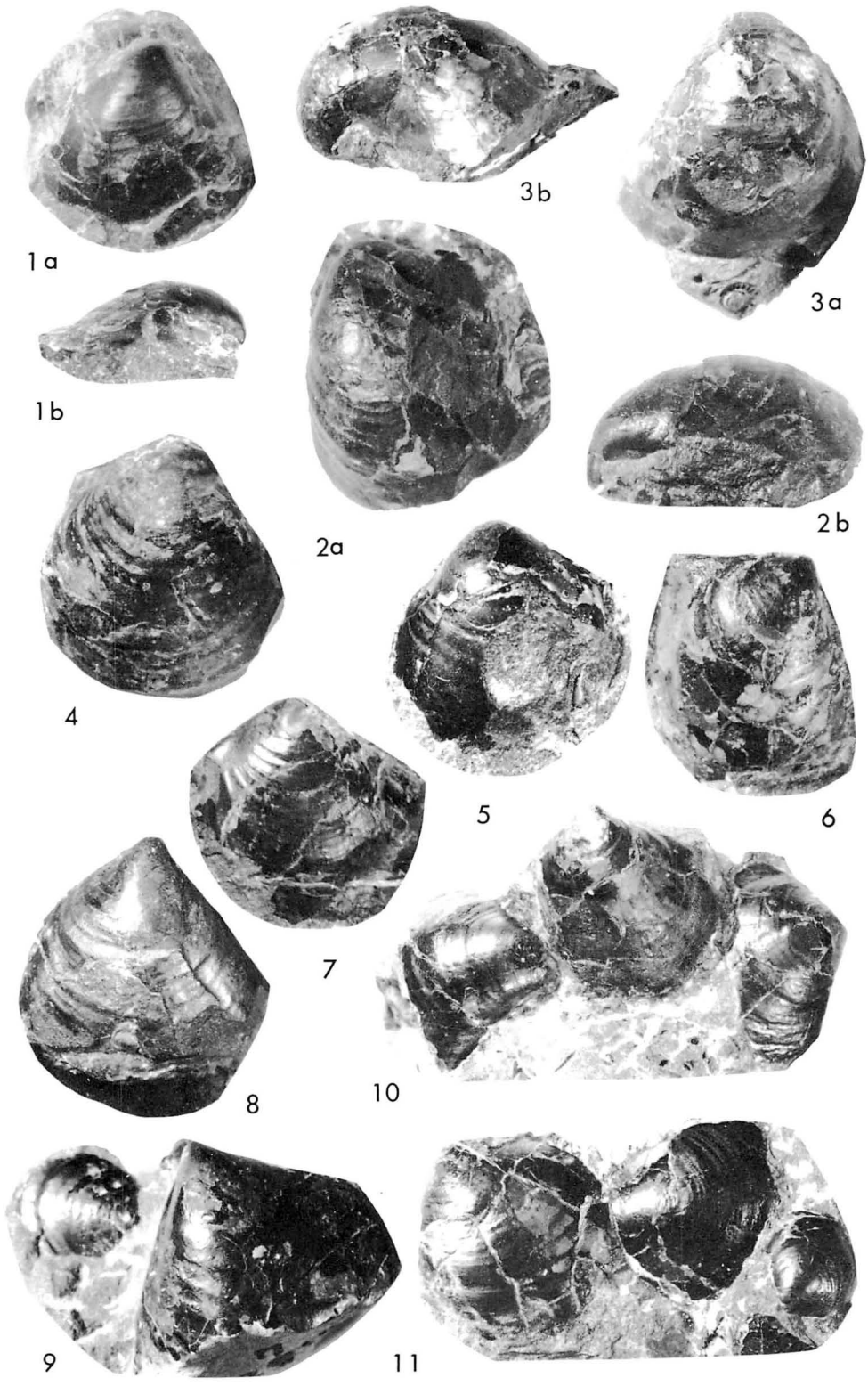
Dr. W. A. Cobban (*in lit.*, April 27, 1984) has kindly shown us an interesting plate on which an intergrading sample ($N \geq 28$) of *I.*

Explanation of Plate 43

Figs. 1—11. *Inoceramus rotundatus* Fiege

(mostly small and presumably immature specimens)

1. GK. H10141 from loc. Ik 2716d; right valve (a) and its anterior view (b), $\times 1.2$.
2. JG. H2867A from loc. Ik 2716n; left valve (a) and its anterior view (b), $\times 1.8$.
3. JG. H2858 from loc. Ik 2716; left valve (a) and its anterior view (b), $\times 1$.
4. GK. H10130 from loc. Ik 2786 [=Ik 2118]; right valve, $\times 1.4$.
5. GK. H10137 from loc. Ik 2716q; left valve, $\times 2$.
6. GK. H10140 from loc. Ik 2716q; right valve, $\times 2$.
7. JG. H2873 from loc. Ik 2716; right valve, $\times 1$.
8. JG. H2871A from loc. Ik 2716; right valve, $\times 1.1$.
9. JG. H2862 from loc. Ik 2710l; left valve (larger one), $\times 1$.
10. JG. H2797 from loc. Ik 2716n; right valves, A, B and C from left to right, $\times 1.1$.
11. GK. H10136 from loc. Ik 2716q; left valve on the left, $\times 1$.



rotundatus and *I. waltersdorfensis* from one locality (USGS Mesozoic locality 21421, Montana, where associated fossils include *Scaphites meriasensis* Cobban and early forms of *S. preventricosus* Cobban) is illustrated.

In the sample of the Pombets-Gono-sawa (Hokkaido), only a few specimens could be identified with *I. waltersdorfensis hannovrensis* but they are not separable from the more numerous normal forms of what we have identified with *I. rotundatus* provisionally. In view of the weaker ribs on the average, our population of *I. rotundatus* could be regarded as showing a somewhat transitional state from *I. w. hannovrensis*. In fact many specimens in our sample resemble a form which Kauffman (1978a, pl. 5, fig. 16) illustrated under "*I. waltersdorfensis* Andert, n. subsp. transitional to *I. rotundatus*", but there are also some specimens which are closer to the lectotype and certain other examples of *I. rotundatus* from Germany. Clearly, no specimen in our sample is identified with *I. waltersdorfensis waltersdorfensis* Andert, 1911 itself (see Andert, 1934, p. 112, pl. 4, figs. 4–6; Tröger, 1967, p. 114, pl. 12, figs. 1, 2; pl. 13, figs. 1–5).

To sum up, we think it better to call the studied sample as *Inoceramus rotundatus* Fiege and at the same time it should be noted that somewhat transitional feature between *I. waltersdorfensis hannovrensis* Heinz and *I. rotundatus* Fiege is shown by some specimens of our sample.

Biostratigraphic position:—There had been discrepancy about the stage boundary and subdivision of Turonian and Coniacian between the scheme by German authors (before Seibertz, 1979) and the international one. Moreover, recent revisions do not seem to be quite identical among authors. We are afraid of this situation and should read carefully the relevant references.

Kauffman (*in Herm et al.*, 1979) states that *I. waltersdorfensis waltersdorfensis* is an excellent biostratigraphic index to the Turonian-Coniacian boundary zone. According to him, its known range in the Western Interior of the United States is uppermost Turonian (top few meters) and lowest Coniacian (basal 1–2 meters).

The age of *I. rotundatus* and *I. waltersdorfensis hannovrensis* was described as early Coniacian by Kauffman (*in Herm et al.*, 1979) but late Turonian to early Coniacian by Keller (1982). Dr. Cobban has shown us another interesting plate on which an assemblage of specimens ($N \geq 18$) ranging in form from *I. waltersdorfensis* through *I. rotundatus* to *I. erectus* Meek is illustrated. They came from one locality (USGS Mesozoic locality D11939, Wyoming), where associated fossils include *Scaphites preventricosus*. This ammonite and *I. erectus* are unmistakable Coniacian species in North America.

We have not yet obtained any example of *I. erectus* and *I. waltersdorfensis waltersdorfensis* from Hokkaido. *I. rotundatus* occurs characteristically in the lower part of the tripartite scheme of Coniacian sequence along the Pombets-Gono-sawa. Its associated fossils include *Forresteria (Reesideoceras) petrocoriensis* (Coquand), *Harleites cf. H. harlei* (Grossouvre), *Didymotis akamatsui* (Yehara) and *Inoceramus uwajimensis* Yehara. The last species is represented by a small number of atypical form in the lower part and its typical form occurs abundantly in the middle part. *I. mihoensis* Matsumoto, *I. (Cordiceramus) n. sp.* and *I. (Platyceramus) yubarensis* Nagao et Matsumoto characterize the upper part. Therefore, we conclude that *I. rotundatus* would be a good subzonal index to the Lower Coniacian in Hokkaido, although the occurrence in other places should be worked out.

Acknowledgments

We are much indebted to Messrs. Takemi Takahashi, Shigehiro Uchida and Kikuwo Muramoto for their kind help in our field work. We are also grateful to Dr. W. A. Cobban and Dr. M. K. Hancock for their kind information on some examples from North America and Europe. Miss Yoshimi Tanigawa assisted us in preparing the typescript.

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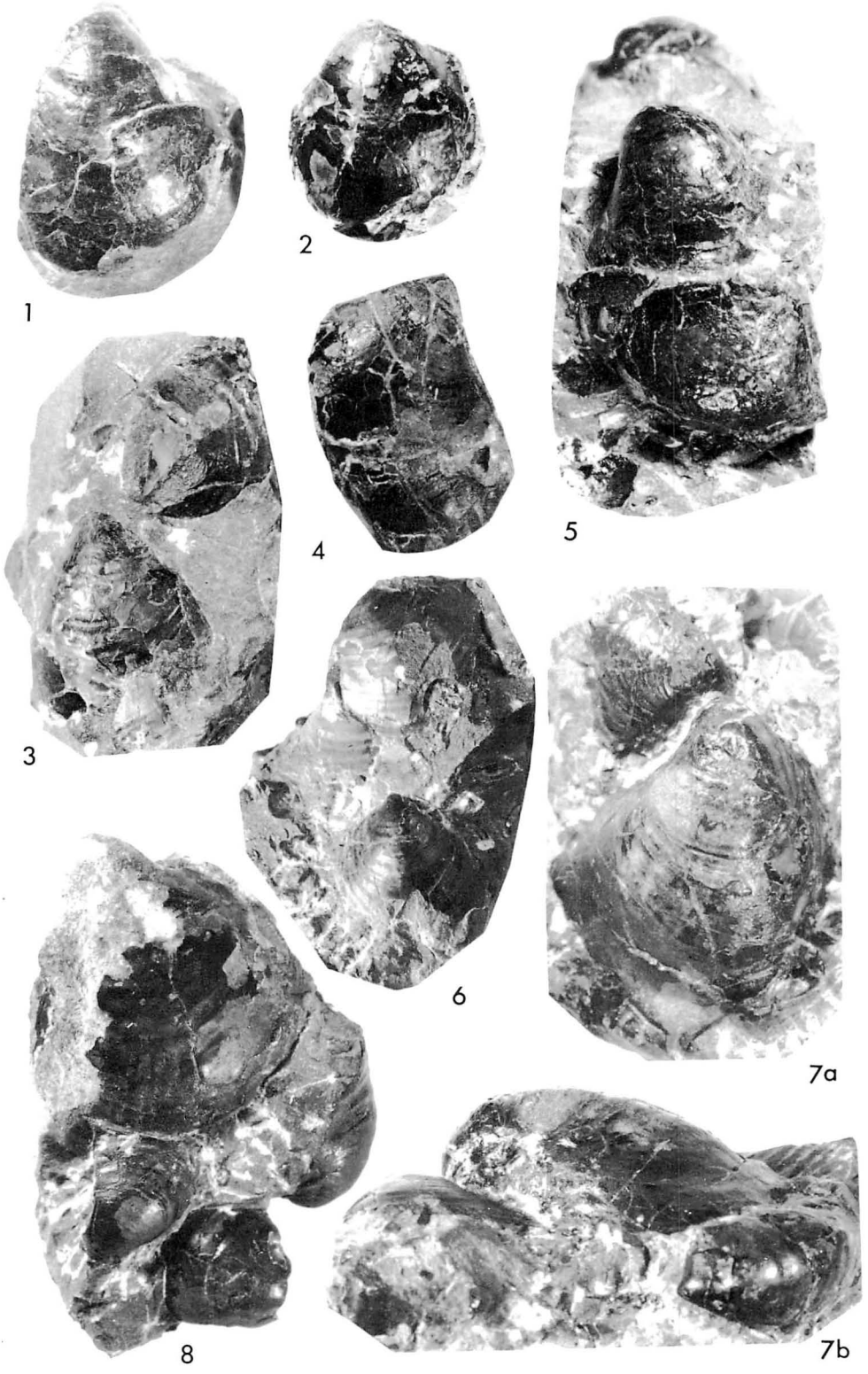
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Explanation of Plate 44

Figs. 1–8. *Inoceramus rotundatus* Fiege

(small, probably immature specimens, sometimes with the adult)

1. JG. H2870 (left valve), × 1; 2. GK. H10141 (left valve), × 1.1; 3. JG. H2867, × 1.2; 1–3 all from loc. Ik 2716n. 4. JG. H2901 from loc. Ik 2716d; right valve, × 1. 5. GK. H10138–10139 from loc. Ik 2716q, × 2. 6. JG. H2874 from loc. Ik 2710k, × 1. 7a, b. JG. H2896 from loc. Ik 2716q; × 1. 8. GK. H10133 from loc. Ik 2716q, × 1 (see also Pl. 42, Figs. 5a, b).



Mikasa 三笠 Pombets-Gono-sawa 奔別五ノ沢 Takiyoshi-zawa 滝吉沢

北海道のコンiacian下部産イノセラムスの1種について：北海道三笠地域の奔別五ノ沢（滝吉沢）に露出する上部白亜系の限定された部分から、従来本邦からは未知のイノセラムス標本を多数採集した。これはドイツその他から産する *Inoceranus rotundatus* Fiege に同定できる。保存のよい25個体については計測し、統計的に性状や変異を調べて記載した。ドイツ産の典型的のものに比較すると肋の弱いものが多いが、後模式標本なみのもある。*I. rotundatus* と *I. waltersdorfensis hannourensis* Heinz との密接な関係は海外でも認められているが、北海道のものはいくらか中間的の性状を示しながらも1つの種を代表し、それは *I. rotundatus* に同定するのが妥当である。本種はこの沢沿いの層序においてコンiacianを3分した下部に特徴的で、伴うアンモナイトも同階下部を示す。三笠地区では1亜帯の示準化石であり、国際対比上も重要な種である。 松本達郎・野田雅之

Postscript. In August 1985, prior to the proof reading, one of us (T.M.) reexamined the outcrop of loc. Ik 2710, with a result that the form of moderate size and distinct ribbing, as represented by JG. H 2860 (Pl. 41, Fig. 4), predominates in the upper part of the exposed sequence.

日本古生物学会特別号の原稿募集

PALAEONTOLOGICAL SOCIETY OF JAPAN, SPECIAL PAPERS, NUMBER 30 を1987年度に刊行したく、その原稿を公募します。適当な原稿をお持ちの方は、次の事項に合わせて申込書を作成し、原稿の写しを添えて、〒812 福岡市東区箱崎 九州大学理学部地質学教室気付、日本古生物学会特別号編集委員会（代表者柳田寿一）宛に申し込んで下さい。

- (1) 古生物に関する論文で、欧文の特別出版にふさわしい内容のもの。同一の大題目の下に数編の論文を集めたもの（例えばシンポジウムの欧文論文集）でもよい。分量は従来発行の特別号に経費上ほぼ匹敵すること。学会以外からも経費が支出される見込のある場合には、その金額に応じて上記よりも分量が多くてよい。
- (2) 内容・文章ともに十分検討済の完成した原稿で、印刷所に依頼して正確な見積りを算出できる状態にあること。申込書とともに必ず原稿の写しを提出して下さい。（用済の上は返却致します）。
- (3) 申込用紙は自由ですが、次の事項を明記して、〔 〕内の注意を守って下さい。
 - (a) 申込者氏名；所属機関または連絡住所・電話番号。〔本会会員であること〕。
 - (b) 著者名；論文題目。〔和訳を付記すること〕。
 - (c) 研究内容の要旨。〔800～1,200字程度、和文で可〕。
 - (d) 内容ならびに欧文が十分検討済であることの証明。〔校閲者の手紙の写しでもよい〕。
 - (e) 本文の頁数（刷上り見込頁数または原稿で欧文タイプ25行詰の場合の枚数一ただし、ハイカーカエリート字体かを添記すること）；また本文中中小活字（8ポ組み）に指定すべき部分があるときは、そのおよその内訳（総頁に対するパーセント）；挿図・表の各々の数と刷上り所要頁数；写真図版の枚数。
 - (f) 他からの印刷経費支出の見込の有無、その予算額、支出源。〔その見込の証明となる書類またはその写しを添えて下さい〕。
 - (g) その他参考事項。
- (4) 申込及び原稿提出締切 1986年4月30日（必着）。採否は編集委員会が必要に応じてレフェリーと相談の上内定し、1987年1月の評議員会で審議決定の上、申込者に回答の予定です。ただしその前または後に、申込者との細部の交渉を、編集委員から求めることがあるかもしれません。
- (5) 上記（f）の他からの印刷経費支出の見込みがない場合は、1987年度の文部省刊行助成金（「研究成果刊行費補助金」）を申請いたしますので、上記（2）の条件が満たされている場合のみ考慮されます。
- (6) 論文が完全な場合には、評議会での決定後できるだけ早く印刷にとりかかる予定です。文部省の刊行助成金の申請は、学会から行ない（例年は12月始めに申請締切）、その採否・金額など決定後印刷にとりかかります。その場合は文部省との約束により、その年の秋（前例では10月20日）までに初校が全部出なければ、補助金の交付が中止されることになっています。
- (7) 特別号の原稿は会誌に準じ、前例を参考として作成して下さい。不明の点は編集委員会に問い合わせして下さい。経費がかかるので、特別な場合を除き、別刷は作成せず、本刷25部を著者に無料進呈します。それ以上は購入（但し著者には割引）ということになります。いくつかの論文を集めて1冊にするときには、世話人の方から指示して、体裁上の不統一のないようにして下さい。印刷上の指示事項が記入できるよう、原稿の左右両側・上下に十分空白をとって、タイプで浄書して下さい。

○文部省出版助成金が得られなかった場合には、出版を繰延べることがあるかもしれません。

○未完成の原稿は募集の対象とはなりません。完全原稿を作成の上申込んで下さい。

行事予定

	開催地	開催日	講演申込締切
1986年 年会・総会	東北大学・他	1986年1月31日～2月2日	1985年11月30日
1986年 135回例会	北九州市自然史博物館 (北九州市中央公民館)	1986年6月14日・15日	1986年 3月31日

講演申込先：〒113 東京都文京区弥生 2-4-16 日本学会事務センター 日本古生物学会 行事係

おわび

- No. 139 の表紙は ISSN 0031-0204 が欠落しています。

Errata for No. 139

- ISSN 0031-0204 were omitted on the cover of No. 139.

お知らせ

- 1986年総会では「古生物の系統分類に関する諸問題」の題でシンポジウムが計画されています(世話人 高柳洋吉他)。
○北九州市での135回例会でもプレプリントを作成する予定です。プレプリントの原稿作成の様式については本誌138号を参照してください。

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