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730. NEOGENE MICROFOSSILS OF CHLOROPHYCEAE, PRASINOPHYCEAE AND ACRITARCHS FROM NIIGATA, CENTRAL JAPAN*

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Abstract. This is a report on the microplankton of the Chlorophyceae, Prasinophyceae and acritarchs from the Neogene sediments in the Niigata district, central Japan. Two species and two subspecies of the Chlorophyceae, one of the Parsinophyceae and eight of the acritarchs belonging to eight form genera are described and illustrated: *Tytthodiscus densiporosus* n. sp. subsp. *densiporosus* n. subsp., *T. densiporosus* n. sp. subsp. *minus* n. subsp., *Palambages* sp., *Pterospermella pterina* n. sp., *Leiosphaeridia* cf. *fastigatirugosa* (STAPLIN) DOWNIE & SARJEANT, *L. grandiformis* n. sp., *L. minuscula* n. sp., *Lancettopsis* sp., *Micrhystridium ariakense* TAKAHASHI, *Baltisphaeridium sphaeroides* n. sp., *B. nakajoense* n. sp. and *Cymatiosphaera pulchella* n. sp. Morphological characteristics of the genera *Tytthodiscus, Crassosphaera, Pleurozonaria, Tasmanites* and *Leiosphaeridia* are discussed. According to PARKE et al. (1978), the fossil genus *Pterospermella* is a synonym of the recent genus *Pterosperma*, but the authors are inclined to accept the genus *Pterospermella*.

These phytomicroplankton described in this paper are important for a basic knowledge of their stratigraphic and geographic distribution in the Neogene formations around the Sea of Japan.

Introduction

The junior author, K. MATSUOKA, engaged in research on dinoflagellates from the Neogene and Quaternary sediments in the Niigata district, central Japan. At that time, he made many slides and found many dinoflagellates and other phytomicroplankton.

The senior, K. TAKAHASHI, has examined these slides and recognized many specimens of the Chlorophyceae, Prasinophyceae and acritarchs. These phytomicroplankton are described and illustrated in detail.

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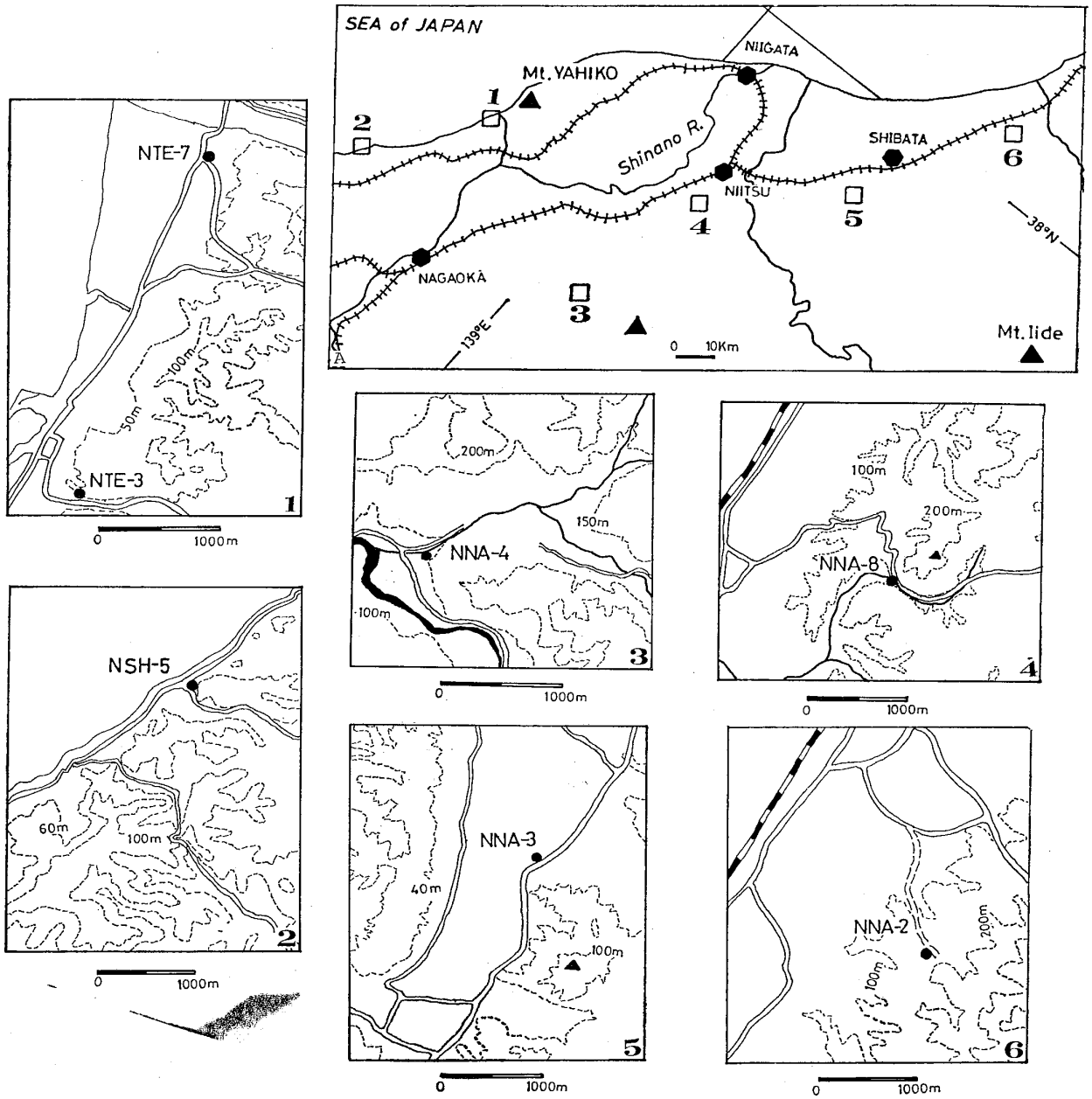
This is the first report on the phytomicroplankton of the Chlorophyceae (*Tytthodiscus* and *Palambages*), Prasinophyceae (*Pterospermella*) and acritarchs recovered from the Neogene sediments in the Niigata district. Morphological characteristics of the genera *Tytthodiscus, Crassosphaera, Pleurozonaria, Tasmanites* and *Leiosphaeridia*, which have morphologically similar feature, are discussed.

According to PARKE et al. (1978), the genus *Pterospermella* EISENACK 1972 is a synonym of the recent genus *Pterosperma*, but the authors are inclined to use the genus *Pterospermella* as a form or organ genus in the family Pterospermataceae of the class Prasinophyceae.



Text-fig. 1. Sample location map. A: Index map; 1: Teradomari area, 2: Ishiji area, 3: Imogawa area, 4: Tedoriga-fuchi area, 5: Shibata area, 6: Nakajo area

The phytomicroplankton examined in this paper should offer the first basic data for research of the biostratigraphical and geographical distribution in the Neogene sediments around the Sea of Japan.

Geological setting and sample locations

The Neogene and Quaternary marine sediments are widely distributed in the Niigata sedimentary basin, central Honshu. They are divided into following six forma-

Table 1. Location and lithology of the Neogene Formations in the Niigata district.

Sample	Formation	Lithology	Location
NNA-2	Nanatani Formation	dark grey hard mudstone	2 km SSE of Sekizawa, Nakajo-cho, Kita-Kanbara-gun, Niigata Pref.
NNA-3	Nanatani Formation	dark grey hard mudstone	1 km west of Matsuoka, Shibata City, Niigata Pref.
NNA-4	Nanatani Formation	dark grey hard mudstone	Minami-Imogawa, Shitada-mura, Minami-Kanbara-gun, Niigata Pref.
NNA-8	Nanatani Formation	dark grey hard mudstone	Tetoriga-fuchi, Tagami-cho, Minami-Kanbara-gun, Niigata Pref.
NTE-3	Teradomari Formation	dark grey laminated siltstone	Teradomari, Teradomari-cho, Santo-gun, Niigata Pref.
NTE-7	Teradomari Formation	black hard laminated siltstone	Shiraiwa, Teradomari-cho, Santo-gun, Niigata Pref.
NSH-5	Shiiya Formation	dark grey hard mudstone	Ishiji, Nishiyama-cho, Kariwa-gun, Niigata Pref.

tions; the Nanatani, Teradomari, Shiiya, Nishiyama, Haizume and Oguni Formations in ascending order. There have been many geological and palaeontological studies for the purpose of petroleum exploration. Recently biostratigraphical investigations in this district have been much promoted by several micropalaeontologists, MAIYA (1978) on planktonic foraminifera, NAKASEKO & SUGANO (1973) on radiolaria, NISHIDA (1976) and SATO & TOMIZAWA (1979) on calcareous nannoplankton, KOIZUMI (1977) on diatom and YAMANOI (1978) on pollen grains. According to these results, the geological ages of these formations are as follows.

Nanatani Formation……Early to Middle Miocene

Teradomari Formation……Middle to Late Miocene

Shiiya Formation……Late Miocene to Early Pliocene

Nishiyama Formation……Late Pliocene to Early Pleistocene

Haizume Formation (including Wanatsu and Tsukayama Formations)……Early to Middle Pleistocene

Oguni Formation……Middle Pleistocene

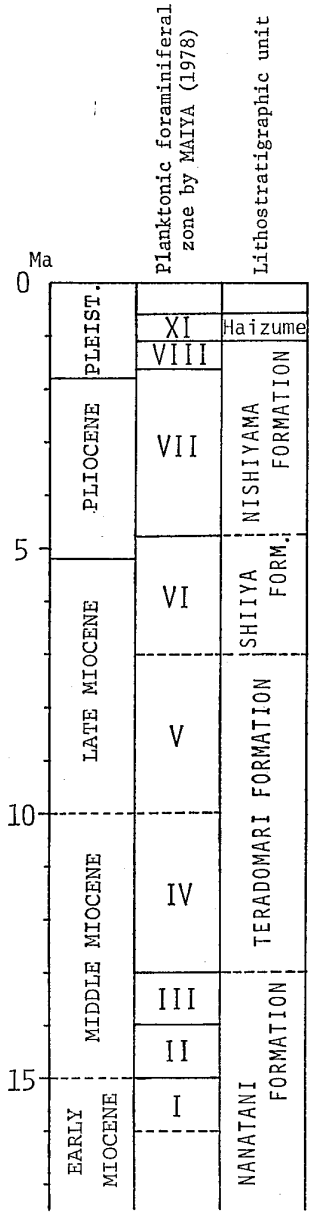
Location and lithology of the samples examined are listed in Table 1.

Preparation method

Preparation for palynological analysis was carried out by mechanical and chemical methods [treatment by 10% KOH, maceration by mixed acid solution of HCl, HNO_3 and H_2O (1 : 1 : 1), and then by 30 % HF, centrifuging and washing in pure water after each step].

The residual material contains pollen grains, spores, dinoflagellate cysts, algae, acritarchs etc. These phytomicrofossils were mounted in glycerine jelly on slides. Cover-slips on the slides were sealed with nail enamel.

All slides are kept in the palynological collection of the Department of Geology, Nagasaki University.



Text-fig. 2. Stratigraphy and geologic ages of the Neogene formations in the Niigata district.

Tytthodiscus, *Crassosphaera*, *Pleurozonaria*, *Tasmanites* and *Leiosphaeridia*

The genus *Tytthodiscus* was first described by NOREM (1955) from Tertiary marine sediments in the San Joaquin Valley of California. According to him, this genus is disk-shaped organisms, whose wall is thick and consists of elongated hexagonal segments which are solid or provided with small central tubule which may extend all or part-way through the wall. Wall surface is smooth or uniformly granular. Size ranges from 25 to 200 microns in diameter. However, his description is not enough to distinguish the genus *Tytthodiscus* from the genera *Pleurozonaria* O. WETZEL 1933 and *Crassosphaera* COOKSON & MANUM 1960. Accordingly, MÄDLER (1963) emended the NOREM's description and defined as follows; the genus *Tytthodiscus* is spherical and often disk-shaped organisms whose wall is composed of a relatively thick, very resistant, radially arranged, fibrous to prismatic crystallite, whose inner side consists of a poroid layer and outer surface is membranous. Canal pores are completely penetrated from the inner side to outer surface.

Our present specimens which have a poroid layer with a honeycomb-like or reticulate pattern on the inner side of the wall belong surely to the genus *Tytthodiscus*. Especially, the specimens with eroded wall show clearly the honeycomb-like or reticulate pattern. The larger form, *Tytthodiscus densiporosus* n. sp. subsp. *densiporosus* n. subsp., and the smaller form, *T. densiporosus* n. sp. subsp. *minus* n. subsp., are described in this paper.

Already described species of *Tytthodiscus*.

Tytthodiscus californiensis NOREM 1955 (Pliocene to Eocene in the Wasco oil field, California; 80–200 μm)

T. mecsekensis NAGY 1965 (Neogene—Middle Miocene, Mecsek Mountains, Hungary; 63 μm)

T. schandelahensis (THIERGART 1944) MÄDLER 1963 (Lower Jurassic, Posidonian shales, Germany; 90–180 μm)

T. vanderhammeni SOLE DE PORTA 1959 (Upper Oligocene, North Colombia)

COOKSON and MANUM (1960) described and illustrated the new genus *Crassosphaera* with originally spherical body, of which wall is ornamented with prominences or projections which may or may not form a regular pattern and is perforated by minute radial tubules which are composed of a tubule to each prominence.

They stated that the main differences between *Crassosphaera* and *Tytthodiscus* are the shape of the body and the construction of the wall, and that a more important difference is the segmented wall of *Tytthodiscus* as against the unsegmented wall of *Crassosphaera*.

According to them, the genus *Crassosphaera* differs from the other genera *Tytthodiscus* and *Tasmanites* in having the wall ornamented with prominences or projections, of which center is perforated by radial branched or unbranched canal pores.

Previously described species of *Crassosphaera*.

Crassosphaera concinna COOKSON and MANUM 1960 (Neocomian, Komewu, Papua, New Guinea; Lower Tertiary, Forlandsundet, Vestspitsbergen; Komewu specimen 65–85 μm, Spitsbergen specimen 106 μm)

C. cooksoni KRIVÁN-HUTTER 1963 (Palaeogene, Dorog Basin, Hungary)

C. digitata COOKSON and MANUM 1960 (Neocomian, Komewu Papua; 65 μm)

C. hexagonalis WALL 1965 (Lower Jurassic, Jet Rock, Yorkshire; 60–150 μm)

C. manumi KRIVÁN-HUTTER 1963 (Palaeogene, Dorog Basin, Hungary)

C. minor KRIVÁN-HUTTER 1963 (Palaeogene, Dorog Basin, Hungary)

C. stellulata COOKSON and MANUM 1960 (Eocene, Rottnest Island, Western Australia; 67–99 μm)

C. stellulata COOKSON and MANUM var. *minor* KEDVES 1962 (Sparnacian, Eocene, Dudar, Hungary)

According to O. WETZEL (1933, p. 29) and MÄDLER (1963, p. 331–332), the genus *Pleurozonaria* is spherical and disk-shaped organisms, whose wall consists of a relatively thick and very resistant organic material, yellow to brown in colour, columnar or hexagonal elements (poroids) which are visible to be a honeycomb-like pattern and penetrated by many canal pores which may pass completely through the wall. The canal pores are branched or unbranched. A pylome may be presented, but not yet be firmly proved.

MÄDLER (1963) accepted *Crassosphaera* as a junior synonym of *Pleurozonaria*. However, MURI and SARJEANT (1971) preferred to maintain as separate entities, pending reconsideration of the taxonomy of the whole group.

Pleurozonaria chondrota (NOREM 1955) MÄDLER 1963 (Miocene, Freeman-Jewett and Vedder members, Temblor Formation, California; 25–140 μm)

P. distans MÄDLER 1963 (Lower Jurassic, Goslar; 80–84 μm)

P. diversipora MÄDLER 1963 (Lower Jurassic, Goslar; 130–132 μm)

P. globulus WETZEL 1933 (Cretaceous, Krywonogi, Poland; 40–48 μm)

P. macropora (EISENACK 1967) MÄDLER 1963 (Lower Jurassic, Goslar; 75–105 μm)

P. media MÄDLER 1963 (Lower Jurassic, Posidonian shales; 100–130 μm)

P. polyporosa MÄDLER 1963 (Lower Jurassic, Goslar and Doernten; 120–170 μm)

P. spongiosa MÄDLER 1963 (Lower Jurassic, boringhole Lingen 330; 90–100 μm)

P. suevica (EISENACK 1957) MÄDLER 1963 (Lower Jurassic, Fukoiden-Kalk, Balingen; Posidonian shales; 70–102 μm)

P. wetzeli MÄDLER 1963 (Lower Jurassic, Goslar; 110–120 μm)

According to EISENACK (1958, p. 2), the genus *Tasmanites* NEWTON 1875 is sphe-

rical and disk-shaped organisms, whose wall consists of a relatively thick and very resistant organic material, yellow to dark red-brown in colour and penetrated by pores which may pass completely or partially through it. A large circular opening, the pylome, may be rarely present in some specimens. Younger specimens possess always a thin wall and no pore. Accordingly, these younger specimens are not distinguishable from the genus *Leiosphaeridia*.

Sporangites huronensis (= *Tasmanites huronensis*) was first described by DAWSON as a sporangium from the Devonian black shales at Kettle Point, Lake Huron (EISENACK 1958, 1963; WALL 1962). NEWTON (1875) newly described such forms as *Tasmanites punctatus* from Australia and Tasmania. EISENACK (1938) established the genus *Leiosphaera* for similar spherical cysts from the Baltic and other European Silurian and named them *Leiosphaera solida* (=*Bion solidum* EISENACK 1931). KRÄUSEL immediately informed him that DAWSON already described such forms as *Sporangites huronensis* and later KRÄUSEL corrected many mistaken interpretation described by DAWSON and renamed *Sporangites huronensis* as *Leiosphaera huronensis*. SCHOPF et al. (1944) criticized the ambiguous term *Sporangites* and proposed that the genus *Tasmanites* is valid. With references of the description of DAWSON, NEWTON, KRÄUSEL and SCHOPF et al. and by a microscopic examination of the DAWSON's preparates, which were sent by KRÄUSEL, EISENACK (1958) recognized that the spherical organisms described as *Leiosphaera solida* (=*L. huronensis*) identify with the DAWSON's forms and they accord with *Tasmanites punctatus* described by NEWTON (1875). Further, he stated that the genus *Leiosphaera* must be replaced by the genus *Tasmanites* for the organisms suitable to the NEWTON's definition and he proposed the new genus *Leiosphaeridia* for *Leiosphaera* which was given for the organisms unsuited to the DAWSON's and NEWTON's description.

According to the WALL's account (1962), OSTENFELD described two spherical green algae, *Pachysphaera pelagica* n. gen. et sp. and *Halosphaera minor* n. sp., which were collected at the time of Greenlandic and Icelandic sailing by WANDEL, KUNDSEN and OSTENFELD. They appear to be comparable with leiospheres. Prior to this, OSTENFELD determined that *Pachysphaera* possesses a thick wall penetrated by pores with a separation of about 3 μm and *Halosphaera minor* OSTENFELD differs from *Pachysphaera* in having thin wall and no pore.

Pachysphaera pelagica is closely similar to several species of *Tasmanites* in size, shape and wall thickness. The wall structure is generally identical with that of *Tasmanites* and the cell wall often possesses a straight or weakly arched suture. No pylome of *Pachysphaera* was observed.

WALL (1962) concluded that the genus *Tasmanites* is to be regarded as a fossil green alga with biological affinities to the present marine organism *Pachysphaera pelagica* OSTENFELD and other species of *Pachysphaera*, and *Pachysphaera* is regarded as a living representative of the fossil genus *Tasmanites*.

Previously described species of *Tasmanites*.

Tasmanites alaskansis (WHITE 1929) WINSLOW 1962 (Lower Cretaceous, Northern Alaska; Upper Devonian — Lower Mississippian, Ohio)

T. asperum BONEHAM 1967 (Devonian, Michigan, Ohio, Ontario)

T. avelinoi SOMMER 1953 emend. SOMMER and VAN BOEKEL 1966 (Devonian, Para, Brazil)

T. balteus FELIX 1965 (Neogene—Upper Miocene, Louisiana)

T. balticus EISENACK 1963 (Ordovician, Baltic

region)

T. bobroeskae WAZYNSKA 1967 (Sinian and Cambrian, boreholes, Bialowieza, Poland)

T. chicagoensis (REINSCH 1884) SCHOPF, WILSON and BENTALL 1944 (Devonian, Kettle Point, Ontario; Chicago Boulder Clay; Permian, Tasmania)

T. corrugatus FELIX 1965 (Neogene—Upper Miocene, Louisiana)

T. decorus BONEHAM 1967 (Devonian, Michigan, Ohio, Ontario)

T. derbyi SOMMER 1953 emend. SOMMER and VAN BOEKEL 1966 (Devonian, Para, Brazil)

T. distinctus BONEHAM 1967 (Devonian, Michigan, Ohio, Ontario)

T. eisenacki UTECH 1962 (Middle Buntsandstein, Lower Triassic, Hildesheim Forest, Germany)

T. erichsenii SOMMER and VAN BOEKEL 1963 (Devonian, Para, Brazil)

T. erraticus EISENACK 1963 (Gotlandian, Wenlockian—Lower Ludlow, North Germany)

T. euzebioi SOMMER 1953 emend. SOMMER and VAN BOEKEL 1966 (Devonian, Para, Brazil)

T. ferruginus BONEHAM 1967 (Devonian, Michigan, Ohio, Ontario)

T. fissura FELIX 1965 (Neogene—Upper Miocene, Louisiana)

T. fulgidus FELIX 1965 (Neogene—Upper Miocene, Louisiana)

T. globulus (O. WETZEL 1933) MORGENROTH 1966 (Cretaceous, Krywonogi, Poland; Lower Eocene, North Germany)

T. hartti SOMMER 1953 emend. SOMMER and VAN BOEKEL 1966 (Devonian, Para, Brazil)

T. huronensis (DAWSON 1871) SCHOPF, WILSON and BENTALL 1944 emend. WINSLOW 1962 (Devonian, Kettle Point, Lake Huron, Canada; Upper Devonian—Lower Mississippian, Ohio)

T. kaljoi TIMOFEYEV 1966 (Late Precambrian, Cambrian, Ordovician, Silurian, Poland; USSR)

T. lamegoi SOMMER 1956 (Devonian, Para, Brazil)

T. mangaseus TIMOFEYEV 1966 (Late Precambrian, Cambrian, Ordovician, Silurian, Poland; USSR)

T. martinssoni EISENACK 1958 (Ordovician, Baltic region)

T. medius (EISENACK 1931) EISENACK 1958 (Silurian, Baltic region)

T. minutus EISENACK 1965 (Ordovician, Baltic region)

T. mourai SOMMER 1953 emend. SOMMER and VAN BOEKEL 1966 (Devonian, Para, Brazil)

T. newtoni WALL 1962 (Liassic, Lower Jurassic, Great Britain)

T. normi EISENACK 1962 (Lower Carboniferous, Woodford Formation, Oklahoma)

T. plicatilis BONEHAM 1967 (Devonian, Michigan, Ohio, Ontario)

T. porosus FELIX 1956 (Neogene—Upper Miocene, Louisiana)

T. primigenus (NAUMOVA 1950) DOWNIE and SARJEANT 1964 (Upper Devonian, Russian platform)

T. punctatus NEWTON 1875 (Permian, La Trobe, Tasmania)

T. roxoi SOMMER 1953 emend. SOMMER and VAN BOEKEL 1966 (Devonian, Para, Brazil)

T. salustianoi SOMMER 1953 emend. SOMMER and VAN BOEKEL 1966 (Devonian, Para, Brazil)

T. sinuosus WINSLOW 1962 (Upper Devonian—Lower Mississippian, Ohio)

T. sommeri WINSLOW 1962 (Upper Devonian—Lower Mississippian, Ohio)

T. tanbaensis TAKAHASHI and YAO 1969 (Permian, Tanba Belt, Japan)

T. tapajonensis SOMMER 1953 emend. SOMMER and VAN BOEKEL 1966 (Devonian, Para, Brazil)

T. tardus EISENACK 1958 (Liassic, Lower Jurassic, Germany)

T. tenellus VOLKOVA 1968* (Lower Palaeozoic, USSR)

T. trematus EISENACK 1962 (*Expansns* Limestone, Ordovician, Öland, Baltic region)

T. usitatus FELIX 1965 (Neogene—Upper Miocene, Louisiana)

T. validus FELIX 1965 (Neogene—Upper Miocene, Louisiana)

T. vanboekeli MUIR and SARJEANT 1971 (Devonian, Para, Brazil)

T. variabilis VOLKOVA 1968* (Lower Palaeozoic, USSR)

* See MUIR and SARJEANT (1971).

T. verrucosus EISENACK 1962 (Ostsee Limestone, South Finland)
T. winslowae BONEHAM 1967 (Devonian, Michigan, Ohio, Ontario)

EISENACK (1958) established the fossil genus *Leiosphaeridia* with thin wall and no wall pore. WALL (1962) stated that the thin-walled organism *Halosphaera minor* OSTENFELD can be compared with members of the fossil genus *Leiosphaeridia* EISENACK 1958. Further, he concluded: "a similar relationship is envisaged between members of the genus *Leiosphaeridia* EISENACK 1958 and the recent green alga *Halosphaera minor* OSTENFELD 1899 and other green algae with a thicker but almost entirely non-punctate wall and the genus *Leiosphaeridia* probably includes forms which are unrelated to the Chlorophyceae as well. The evidence connecting *Pachysphaera* with *Tasmanites* (and *Halosphaera minor* with *Leiosphaeridia*) is sufficient to justify classification of the fossil genera in the Chlorophyceae."

Taxonomy of *Pterosperma* and *Pterospermella*

EISENACK (1972) established a new genus *Pterospermella* with the type species *P. aureolata* (COOKSON and EISENACK 1958) EISENACK 1972 for species of *Pterospermopsis* W. WETZEL 1952, because of insufficient description of its type species *Pterospermopsis danica* W. WETZEL and vagueness of its systematic position. Upon this reason, he (1972) transferred all species of *Pterospermopsis* except *P. danica* W. WETZEL to the genus *Pterospermella*. Further, he emphasized that the genus *Pterospermella* is closely similar to the recent genus *Pterosperma* POUCHET and provided a new family Pterospermellaceae including the genera *Pterospermella* EISENACK (type genus), *Cymatiosphaera* O. WETZEL 1933 emend. DEFLANDRE 1954, *Dictyotidium* EISENACK 1955 emend. STAPLIN 1961, *Pterosphaeridia* MÄDLER 1963, *Cymatiosphaeropsis* MÄDLER 1963, *Duvernaysphaera* STAPLIN 1961 and *Enigmasphaera* COOKSON and EISENACK 1971. However, he stated that transference of these genera to the family Pterospermataceae which includes the recent genera *Pachysphaera* OSTENFELD and *Pterosperma* POUCHET depends on result of the future investigation on the mode of the opening and the construction of the wall.

PARKE et al. (1978) reported in detail on the life-history of the recent genus *Pterosperma* POUCHET with the two phases, motile and non-motile. Information concerning the non-motile phycoma phase of members of the Pterospermataceae is very important for the fossil genus *Pterospermella*. By PARKE et al. the phycomata of seven species of *Pterosperma* have been produced and grown in culture from the motile cells liberated from phycomata obtained from the sea. They proposed *Pterosperma rotundum* POUCHET as the type species of the genus *Pterosperma* POUCHET 1893 and indicated the genera *Pterosphaera, Cysta, Trochiscia, Pterocystis, Pterococcus, Cymatiosphaera, Pterospermopsis* and *Pterospermella* as the synonymy of the genus *Pterosperma* in the phycoma phase.

According to their opinion, the fossil genus *Pterospermella* is the synonym of the recent genus *Pterosperma*. However, the authors are of opinion that the fossil genus *Pterospermella* EISENACK 1972 should be placed independently in the family Pterospermataceae, because this genus always indicates its phycoma phase and never its motile phase.

Descriptive palynology

Class Chlorophyceae KÜTZING 1843

Order Tasmanales MÄDLER 1963

Family Tasmanaceae SOMMER 1956 emend. MÄDLER 1963

Genus *Tytthodiscus* NOREM 1955 emend. MÄDLER 1963

Type species: *Tytthodiscus californiensis* NOREM 1955.

Tytthodiscus densiporosus n. sp.

Pl. 12, Figs. 1-15; Pl. 13, Figs. 1-2

Description: Body spherical to ellipsoidal, 54-174 μm in diameter. Wall 1.5-9 μm thick, penetrated by distinct canal-pores; canal-pores always appear to pass from inner wall side with a poroid layer of a honeycomb-like or network pattern to the outer surface. The canal-pores are uniformly and densely distributed 1-3 μm apart, 1 μm± wide on the inner wall surface, with appreciable taper. The specimen with eroded wall shows clearly the honeycomb-like pattern on the inner wall side (see Pl. 12, Fig. 3). Body surface smooth, characterized by very small pores visible at high magnification, with occational minor folding; surface often has weathered or corroded appearence and sometimes rounded pyrites (?) originated from the organic body of the specimens (see Pl. 12, Figs. 5 and 6). Colour yellow to orange in transmitted light.

Remarks: The genus *Tytthodiscus* is similar to the genera *Crassosphaera*, *Pleurozonaria* and *Tasmanites*, but differs from three latters in having the poroid layer with the honeycomb-like or network pattern on the inner wall side.

Tytthodiscus densiporosus n. sp. subsp. *densiporosus* n. subsp.

Pl. 12, Figs. 1-9

Description: Body spherical to ellipsoidal, 96-174 μm×84-147 μm in diameter. Wall 2.5-9 μm thick, penetrated by distinct canal-pores; canal-pores always appear to pass from the inner wall surface to the outer surface. The canal-pores are uniformly and densely distributed 2-3 μm apart, 1 μm± wide on the inner wall surface, with appreciable taper. The inner wall side is composed of a poroid layer ornamented with a honeycomb-like or fine network pattern. Body surface laevigate, characterized by very small pores visible at high magnification, with occasional minor folding; surface often has weathered or corroded appearence and sometimes rounded pyrites (?) originated from the organic body of the specimens (see Pl. 12, Figs. 5 and 6). The corroded specimens show clearly the honeycomb-like or network pattern on the inner wall side (see Pl. 12, Fig. 3). Some specimens show a single straight(?) suture on the wall. Colour yellow to orange in transmitted light.

Holotype: Pl. 12, Fig. 2; 126×120 μm in diameter; wall 4.5 μm thick; canal-pores are uniformly distributed 2.3-3 μm apart, 1 μm± in diameter, with appreciable taper; slide NNA-2-3; Nanatani Formation (Early-Middle Miocene), 2 km SSE of Sekizawa, Nakajo-cho, Kita-Kanbara-gun, Niigata Prefecture.

Occurrence and range: Abundant; Nanatani, Teradomari and Shiiya Formations, Niigata Prefecture.

Comparison: This new subspecies is easily distinguished from the other Neogene and pre-Neogene specimens by its size, wall thickness and densely arranged wall canal-pores. This is closely similar to *Tytthodiscus schandelahensis* (THIERGART 1944) MÄDLER 1963 from the Lower Jurassic Posidonian shales, Germany and *Tytthodiscus mecsekensis* NAGY 1965 from the Middle Miocene grey clayey marl,

Mecsek Mountains, Hungary, but the former differs from *T. schandelahensis* in having much thinner wall and *T. mecsekensis* in having much larger size.

Tytthodiscus densiporosus n. sp. subsp. *minus* n. subsp.

Pl. 12, Figs. 10-15; Pl. 13, Figs. 1-2

Description: Body spherical to ellipsoidal or oval, 54-85.5 μm×43.5-81 μm in diameter. Wall 1.5-5.4 μm thick, penetrated by canal-pores, which always appear to pass from the inner wall surface, but only partly reach the outer wall surface. The pores are densely distributed 1-2 μm apart, less than 1 μm in width on the inner wall surface. The inner wall side consists of the poroid layer ornamented with the weak network pattern, sometimes this network pattern is not visible. Body surface smooth, characterized by very small penetrated pores only partly visible at high magnification through a microscope, with occasional minor folding; surface sometimes is cleft. Colour yellow to orange in transmitted light.

Holotype: Pl. 12, Fig. 15; 75×73.5 μm in diameter; wall 4.2 μm thick; pores are uniformly distributed 2 μm± apart, less than 1 μm in diameter; slide NNA-4-5; Nanatani Formation (Early-Middle Miocene), Minami-Imogawa, Shitada-mura, Minami-Kanbara-gun, Niigata Prefecture.

Occurrence: Few from the locality Nakajo and abundant from the locality Minami-Imogawa; Nanatani Formation (Early-Middle Miocene).

Remarks: The present subspecies is the smallest *Tytthodiscus*. This is much smaller than *T. densiporosus densiporosus*.

Order Chlorococcales MARCHAND orth. mut. et emend. OASCHER 1915

Family Hydrodictyaceae (GRAY) DUMORTIER orth. mut. COHN 1880

Genus *Palambages* O. WETZEL 1961

Type species: *Palambages morulosa* O. WETZEL 1961.

Palambages sp.

Pl. 14, Fig. 15

Description: The colony is spherical to subspherical. The individual cells 14-19 μm×12-13 μm in diameter. The wall in profile smooth, thin, 0.8 μm thick. The number of cells per colony is about 20 in optical section (on one surface). Colony size 45.9×42 μm in diameter.

Occurrence: Very rare; Nanatani Formation (Early-Middle Miocene), Chujo-cho, Kita-Kanbara-gun, Niigata Prefecture.

Comparison: Only one specimen was found. This is superficially similar to *Palambages morulosa* O. WETZEL from the Baltic Senonian and Danian chalk and flint and *Palambages* sp. (TAKAKASHI and SHIMONO, 1980) from the Pleistocene Minoshirotori lake deposits, Gifu Prefecture, but differs from *Palambages morulosa* and *Palambages* sp. in having much smaller colony and single cells.

Class Prasinophyceae CHRISTENSEN 1962

Order Pterospermatales

Family Pterospermataceae OSTENFELD 1902

Genus *Pterospermella* EISENACK 1972

Type species: *Pterospermella aureolata* (COOKSON & EISENACK 1958) EISENACK 1972.

Pterospermella pterina n. sp.

Pl. 14, Figs. 1-5.

Description: Central body circular to oval in polar view, provided with a relatively large undulating and radially folded equatorial wing. The radial folds of wing somewhat spine-like, about 13-16 in number. The equatorial wing is diaphanous. Contour of wing circular to elliptical. Surface of shell smooth. Overall diameter 150-228 μm × 135-207 μm. Diameter of central body 72-126 μm × 60-114 μm. Thickness of central body wall 3 μm or less. Breadth of wing 25-66 μm.

Holotype: Pl. 14, fig. 3; overall diameter 228×168 μm; diameter of central body 126×102 μm; breadth of wing 30-54 μm; radial folds 14 in number; slide NNA-2-3; Nanatani Formation (Early-Middle Miocene), 2 km SSE of Sekizawa, Nakajocho, Kita-Kanbara-gun, Niigata Prefecture.

Occurrence: Few, Nanatani Formation, Nakajo-cho; rare, Teradomari Formation, Teradomari-cho, Santo-gun, Niigata Prefecture.

Comparison: *Pterospermella australiensis* (DEFLANDRE & COOKSON, 1955) EISENACK from the Lower Cretaceous, Onepah Station, New South Wales, is much smaller than the present specimens. *P. pterina* is closely similar to *P. barbarae* (GORKA 1963) EISENACK from the Upper Cretaceous (Campanian) strata, Magnuszew, Poland and from the Eocene and Oligocene strata, Meckelfeld near Hamburg, Germany, but the former is different from the latter in having smooth surface of the central body and equatorial wing (ala). *P. helientoides* (DE CONINCK 1968) EISENACK from the Ypresian, Sondage de Kallo near Antwerpen, Belgium, possesses much thicker wall of the central body.

Incertae sedis

Group Acritarcha EVITT 1963

Subgroup Sphaeromorphitae DOWNIE, EVITT & SARJEANT 1963

Genus *Leiosphaeridia* EISENACK 1958 emend. DOWNIE & SARJEANT 1963

Type species: *Leiosphaeridia baltica* EISENACK 1958.

Leiosphaeridia cf. *fastigatirugosa* (STAPLIN) DOWNIE & SARJEANT

Pl. 13, Figs. 3-6

1961. *Leiosphaeridium fastigatirugosum* STAPLIN, Palaeontology, vol. 4, pt. 3, p. 408, pl. 50, fig. 9.
1963. *Leiosphaeridia fastigatirugosa* (STAPLIN) DOWNIE & SARJEANT, Palaeontology, vol. 6. pt. 1, p. 95.

Description: Body originally spherical to ellipsoidal, 102-180 μm×78-105 μm in diameter. Wall smooth (laevigate), very thin. Canals or pores not present on cell wall and no evidence of pylome. Body outline irregular, always conspicuously crumpled and plicated with the numerous folds being characteristic of the species.

Occurrence: Few, Nanatani Formation (Early-Middle Miocene); rare, Shiiya Formation (Late Miocene to Early Pliocene).

Remarks: The present specimens are very closely similar to *Leiosphaeridia fastigatirugosa* (STAPLIN) DOWNIE & SARJEANT from the Upper Devonian of Alberta, Canada and possess both spherical and ellipsoidal forms, although the latter has only spherical form. Accordingly, the authors describe them as *L.* cf. *fastigatirugosa* (STAPLIN) DOWNIE & SARJEANT.

Comparison: This species is very closely similar to *Leiosphaeridia* sp. (PICHLER, 1971, p. 325-326, pl. 3, figs. 42, 46) from the Devonian Upper Junkerberg Formation of the Eifel Synclinorium, W-

Germany and the authors accept that the latter may be the same species as *L. fastigatirugosa*.

Leiosphaeridia grandiformis n. sp.

Pl. 13, Figs. 7-10

Description: Body originally spherical to ellipsoidal, 121-165 μm×109.5-156 μm in diameter. Wall finely rugulate to verrucate or rarely smooth, 5.4-7.5 μm thick (sometimes 2 μm±). Canals or pores not present on cell wall and no evidence of pylome. Body surface irregular, always conspicuously folded.

Holotype: Pl. 13, Fig. 9; 141×120 μm in diameter; wall finely rugulate, 7.5 μm thick; more or less folded; slide NNA-2-2; Nanatani Formation (Early-Middle Miocene), 2 km SSE of Sekizawa, Nakajo-cho, Kita-Kanbara-gun, Niigata Prefecture.

Occurrence: Common, Nanatani Formation, Nakajo-cho.

Comparison: This new species is apparently different from *Leiosphaeridia* cf. *fastigatirugosa* (STAPLIN) DOWNIE & SARJEANT in having much thicker wall and finely rugulate to verrucate ornamentation on wall surface and from *Leiosphaeridia minuscula* n. sp. in having larger size, thicker wall and finely rugulate to verrucate ornamentation.

Leiosphaeridia minuscula n. sp.

Pl. 13, Figs. 12-13

Description: Body originally spherical to ellipsoidal, 52-93 μm×50-75 μm in diameter. Wall somewhat laevigate to chagrenate, 3.5-4.5 μm thick. Canals or pore not present on cell wall and no evidence of pylome. Body surface somewhat irregular, always crumpled with some folds.

Holotype: Pl. 13, Fig. 12; 93×72 μm in diameter; wall somewhat laevigate, 4.5 μm thick, with some folds; slide NNA-2-2; Nanatani Formation (Early-Middle Miocene), 2 km SSE of Sekizawa, Nakajo-cho, Kita-Kanbara-gun, Niigata Prefecture.

Occurrence: Few, Nanatani Formation, Nakajo-cho, Niigata Prefecture.

Comparison: The present specimens are superficially similar to *Leiosphaeridia* (*al. Protoleiosphaeridium*) *orbiculata* (STAPLIN) DOWNIE & SARJEANT (STAPLIN, 1961, p. 405, pl. 48, fig. 12; DOWNIE & SARJEANT, 1963, p. 95; HEMER & NYGREEN, 1967, p. 187, pl. 3, figs. 5-6), but the former differs from the latter in having larger size. They are similar to *L. pusila* MÄDLER (1963, p. 348, pl. 25, figs. 10-13) from the Posidonian shales, borehole Etzel 24, Glockenberg near Doernten, brickyard Osterfeld near Goslar, W. Germany, but the former is different from the latter in having thicker wall.

Genus *Lancettopsis* MÄDLER 1963

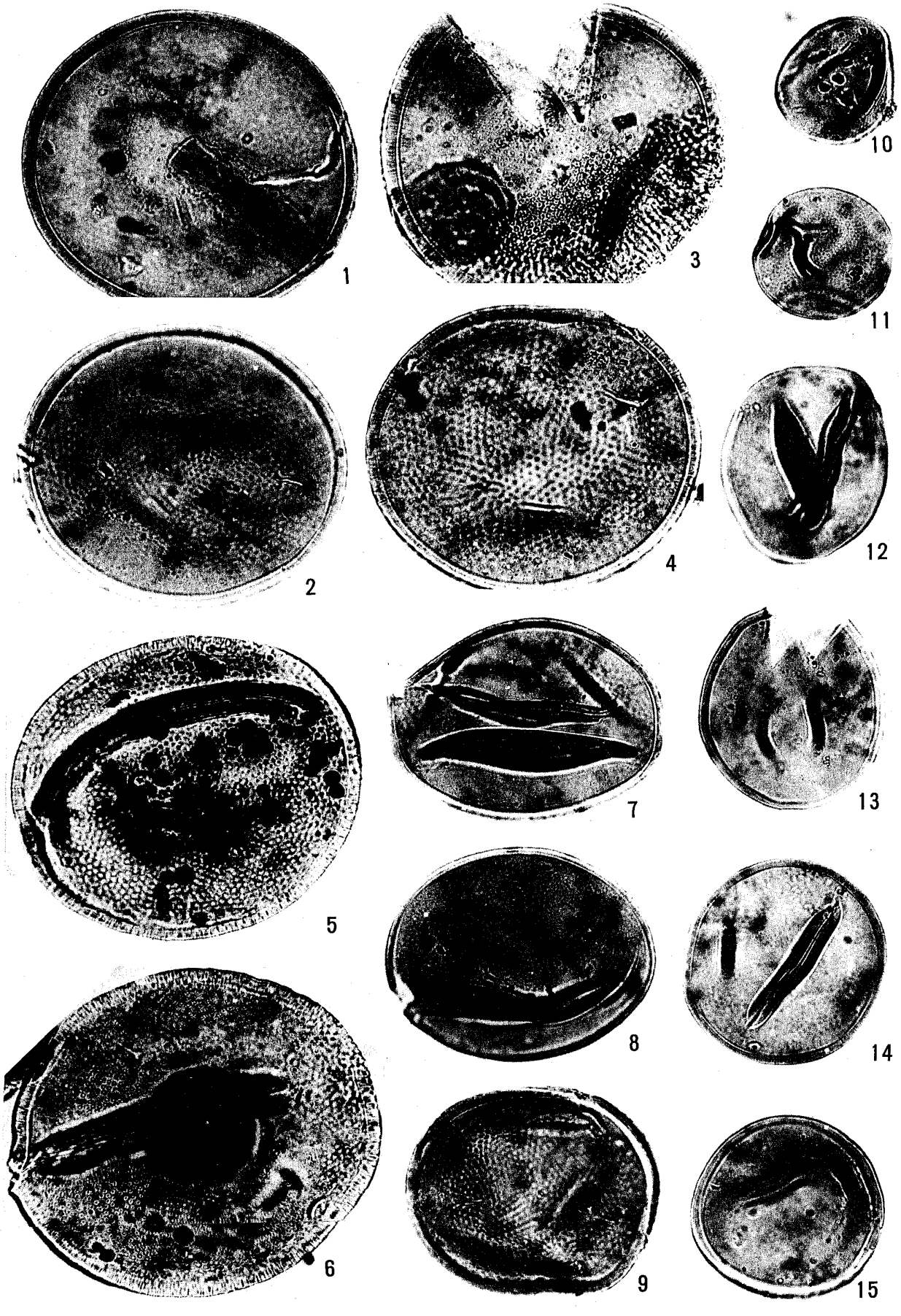
Type species: *Lancettopsis lanceolata* MÄDLER 1963.

Explanation of Plate 12

(All figures magnified ×400)

Figs. 1-9. *Tytthodiscus densiporosus* n. sp. subsp. *densiporosus* n. subsp.
Figs. 1, 8: slide NNA-2-2; figs. 2, 7, 9: slide NNA-2-3; fig. 3: slide NNA-3-4; fig. 4: slide NNA-2-5; fig. 5: slide NTE-3-1; fig. 6: slide NTE-3-2; fig. 2: holotype.

Figs. 10-15. *Tytthodiscus densiporosus* n. sp. subsp. *minus* n. subsp.
Fig. 10: slide NNA-2-2; figs. 11, 15: slide NNA-4-5; fig. 12: slide NNA-4-1; figs. 13, 14: slide NNA-4-2; fig. 15: holotype.



Lancettopsis sp.

Pl. 13, Fig. 11

Description: Body lanceolate, 124.2 μm long, 35.4 μm wide. Wall smooth (laevigate), very thin. Canals or pores not present on cell wall and no evidence of pylome. Body outline irregular, always conspicuously crumpled and plicated with the numerous folds.

Occurrence: Very rare, Nanatani Formation (Early-Middle Miocene), Nakajo-cho, Niigata Prefecture.

Remarks: The genus *Lancettopsis* was established by MÄDLER (1963, p. 351-353). He (1963) distinguished the genera *Lancettopsis* and *Campenia* from the genus *Leiosphaeridia*. *Lancettopsis lanceolata* MÄDLER (1963, p. 353, pl. 28, figs. 4-8; pl. 29, figs. 1-3), which is the type species of the genus *Lancettopsis*, is only one species of this genus and possesses much larger shell than the present specimen.

Subgroup Acanthomorphitae DOWNIE, EVITT & SARJEANT 1963

Genus *Micrhystridium* DEFLANDRE 1937 emend. DOWNIE & SARJEANT 1963

Type species: *Micrhystridium inconspicuum* (DEFLANDRE 1935) DEFLANDRE 1937.

Micrhystridium ariakense TAKAHASHI

Pl. 14, Figs. 6a-b, 7

1971. *Micrhystridium ariakense* TAKAHASHI, Trans. Proc. Palaeont. Soc. Japan, N. S. No. 81, p. 19-20, pl. 4, figs. 1-10

Dimensions: Test diameter 18×16.5 μm (Figs. 6a-b) to 19×14 μm (Fig. 7); test wall thin; length of spines less than 1 μm.

Occurrence: Rare, Nanatani Formation (Early-Middle Miocene), Nakajo-cho and Minami-Imogawa, Shitada-mura, Niigata Prefecture.

Remarks: Hitherto, one of the authors, TAKAHASHI, described this species from the Pleistocene lower formation of the Ariake Sea area, west Kyushu (TAKAHASHI, 1971) and from the Miocene formations in the Yeoungill Bay district, Korea (TAKAHASHI and KIM, 1979).

Genus *Baltisphaeridium* EISENACK 1958 emend. DOWNIE & SARJEANT 1963

Type species: *Baltisphaeridium longispinosum* (EISENACK 1931) EISENACK 1958.

Baltisphaeridium sphaeroides n. sp.

Pl. 14, Figs. 8-9

Description: Test spherical to ellipsoidal, 45-50 μm×42-43.5 μm in diameter. Wall smooth, 1.8-2 μm thick, spines very fine, straight, 1-1.5 μm long; number of spines numerous. Wall surface always more or less folded.

Holotype: Pl. 14, Fig. 9; 45×42 μm in diameter; wall smooth, 1.8 μm thick; spines very fine, straight, numerous, 1-1.2 μm long; slide NNA-2-3; Nanatani Formation (Early-Middle Miocene), 2 km SSE of Sekizawa, Nakajo-cho, Kita-Kanbara-gun, Niigata Prefecture.

Occurrence: Rare, Nakajo-cho, Nanatani Formation.

Comparison: This new species differs apparently from *Micrhystridium koraiense* TAKAHASHI (TAKAHASHI and KIM, 1979, p. 65, pl. 25, figs. 10-11, 14-15) and *Baltisphaeridium kimurae* TAKAHASHI (TAKAHASHI and KIM, 1979, p. 65-66, pl. 25, figs. 35-36) from the Yonil Group, Korea in having much larger size and very fine spines.

Baltisphaeridium nakajoense n. sp.

Pl. 14, Figs. 10-12

Description: Test originally spherical, 28.5-41.8 μm×24-35 μm in diameter. Wall relatively thin, 1-1.6 μm thick; spines small, echinate or conical sometimes with truncated or rounded tips, 0.8-1.5 μm high; number of spines numerous. Wall surface always conspicuously folded.

Holotype: Pl. 14, Figs. 11a-; b30.4×27.3 μm in diameter; wall 1.6 μm thick, spines numerous, straight, echinate or conical, with truncated or rounded tips; slide NNA-2-3; Nakajo-cho, Kita-Kanbara-gun, Niigata Prefecture.

Occurrence: Few, Nakajo-cho, Nanatani Formation.

Comparison: The present specimens are superficially similar to *Baltisphaeridium aquaticum* TAKAHASHI and SHIMONO (1980, p. 10-11, pl. 1, figs. 1-9; pl. 2, figs. 1-6) from the Pleistocene Minoshirotori lake deposits, Gifu Prefecture, Japan, but the former differs from the latter in having much smaller size, thinner wall and much shorter spines.

Subgroup Herkomorphitae DOWNIE, EVITT & SARJEANT 1963

Genus *Cymatiosphaera* O. WETZEL 1933 emend. DEFLANDRE 1954

Type species: *Cymatiosphaera radiata* O. WETZEL 1933.

Cymatiosphaera pulchella n. sp.

Pl. 14, Figs. 13-14

Description: Shell spherical with 15-16 polygonal fields, 67.5 μm×60-63 μm in diameter. Wall relatively thin, less than 2.5 μm thick. The width of the polygonal fields varies from 21 to 27 μm. The spines, muri of the networks, are relatively slender and shorter, 1.8-2.7 μm high. The networks connect with the straight line.

Holotype: Pl. 14, Figs. 14a-b; sheil size 67.5×63 μm in diameter; width of the networks 21-27 μm; muri 1.8-2.7 μm high; slide NNA-2-5; Nanatani Formation (Early-Middle Miocene), 2 km SSE of Sekizawa, Nakajo-cho, Kita-Kanbara-gun, Niigata Prefecture.

Occurrence: Few, Nanatani Formation, Nakajo-cho.

Comparison: This new species is comparable with *Cymatiosphaera globulosa* TAKAHASHI (1964, 1971) from the Oligocene Asagai Formation in the Joban coalfield and from the Pleistocene upper for-

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Explanation of Plate 13

(All figures magnified ×400)

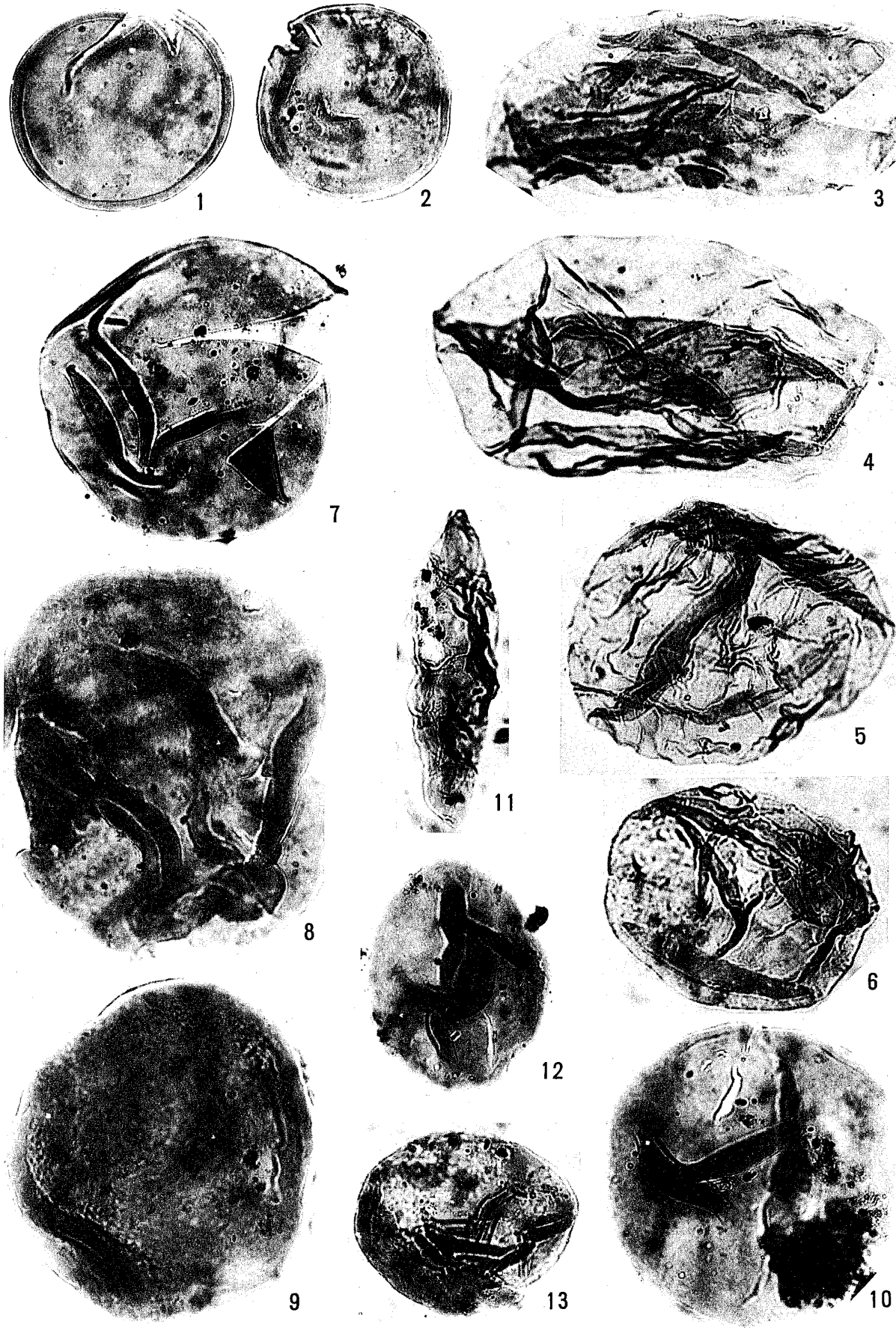
Figs. 1-2. *Tytthodiscus densiporosus* n. sp. subsp. *minus* n. subsp.
Fig. 1: slide NNA-4-2; fig. 2: slide NNA-4-5.

Figs. 3-6. *Leiosphaeridia* cf. *fastigatirugosa* (STAPLIN) DOWNIE & SARJEANT.
Fig. 3: slide NNA-4-2; fig. 4: slide NNA-4-1; fig. 5: slide NNA-4-5; fig. 6: slide NSH-5-5.

Figs. 7-10. *Leiosphaeridia grandiformis* n. sp.
Figs. 7, 8, 10: slide NNA-2-3; fig. 9: holotype, slide NNA-2-2.

Fig. 11. *Lancettopsis* sp.
Slide NNA-2-2.

Figs. 12-13. *Leiosphaeridia minuscula* n. sp.
Slide NNA-2-2; fig. 12: holotype.



mation of the Ariake Sea bottom, off the coast of Kojiro, Shimabara Peninsula, but the former differs from the latter in its much larger size and much wider networks.

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Explanation of Plate 14

Figs. 1-5. *Pterospermella pterina* n. sp.
Fig. 1 : slide NNA-2-1, ×200 ; fig. 2 : slide NTE-7-10, ×280 ; fig. 3 : slide NNA-2-3, holotype, ×200 ; figs. 4, 5 : slide NNA-2-2, ×400.

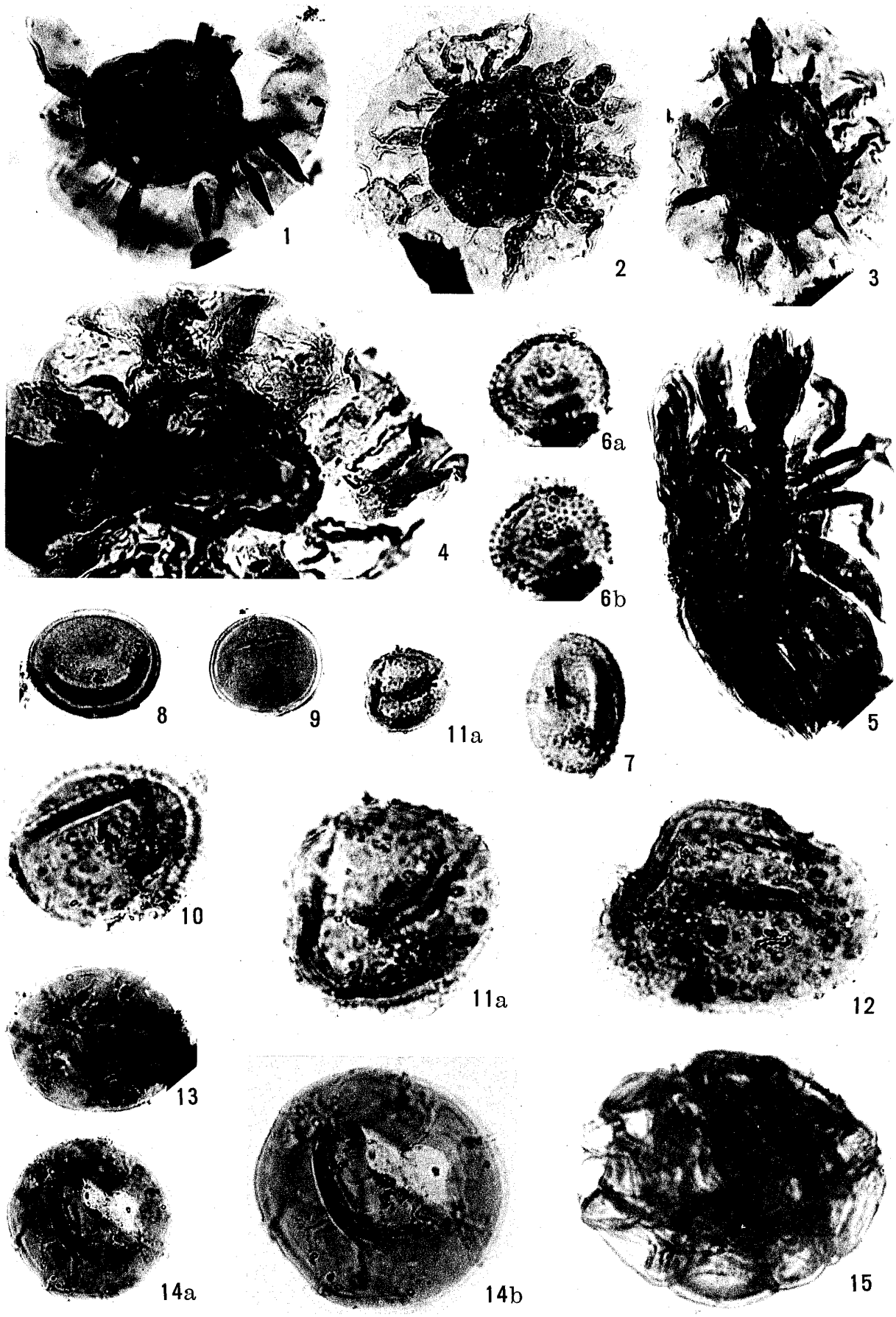
Figs. 6-7. *Micrhystridium ariakense* TAKAHASHI ×1000
Figs. 6a-b : slide NNA-2-3 ; fig. 7 : slide NNA-4-2.

Figs. 8-9. *Baltisphaeridium sphaeroides* n. sp. ×400
Fig. 8 : slide NNA-2-2 ; fig. 9 : slide NNA-2-3, holotype.

Figs. 10-12. *Baltisphaeridium nakajoense* n. sp.
Figs. 10, 11a-b : slide NNA-2-3 ; fig. 10, 11b : ×1000 ; fig. 11a : ×400 ; figs. 11a-b : holotype ; fig. 12 : slide NNA-2-5, ×1000.

Figs. 13-14. *Cymatiosphaera pulchella* n. sp.
Fig. 13 : slide NNA-2-1, ×400 ; figs. 14a-b : slide NNA-2-5, holotype ; fig. 14a : ×400 ; fig. 14b : ×600.

Fig. 15. *Palambages* sp.
Slide NNA-2-5, ×1000.



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中部日本新潟産緑藻綱，プラシノ藻綱，アクリターチの新第三紀微化石：新潟地方の新第三紀層産緑藻綱，プラシノ藻綱およびアクリターチの微小プランクトンに関する報告である。8つの形態属に属する緑藻綱の2種と2亜種，プラシノ藻綱の1種およびアクリターチの8種が記載・図示された。それらは *Tytthodiscus densiporosus* n. sp. subsp. *densiporosus* n. subsp., *T. densiporosus* n. sp. subsp. *minus* n. subsp., *Palambages* sp., *Pterospermella pterina* n. sp., *Leiosphaeridia* cf. *fastigatirugosa* (STAPLIN) DOWNIE & SARJEANT, *L. grandiformis* n. sp., *L. minuscula* n. sp., *Lancettopsis* sp., *Micrhystridium ariakense* TAKAHASHI, *Baltisphaeridium sphaeroides* n. sp., *B. nakajoense* n. sp. および *Cymatiosphaera pulchella* n. sp. である。

Tytthodiscus 属，*Crassosphaera* 属，*Pleurozonaria* 属，*Tasmanites* 属および *Leiosphaeridia* 属の形態的特徴について述べた。パーク他 (1978) によれば，化石属 *Pterospermella* は現生属 *Pterosperma* と同義であるが，筆者等は *Pterospermella* を受入れる考えである。

この論文に記載された，これらの植物性微小プランクトンは日本海周辺の新第三紀層における層位学的および地理学的分布の基礎知識に重要である。 高橋 清・松岡数充
