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The fossil on the cover is an adult example (T. TAKAHASHI coll.) of *Mikasaites orbicularis* MATSUMOTO (subfamily Marshallitinae, family Kossmaticeratidae) from the Lower Cenomanian (Cretaceous) of the Mikasa area, central Hokkaido. (photo by M. NODA, natural size)

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743. MIOSPORES FROM THE EOCENE NANGGULAN FORMATION IN THE YOGYAKARTA REGION, CENTRAL JAVA*

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Abstract. The author has discriminated and descrided 48 palynomorph types which consist of 4 spores and 44 pollen grains from the Eocene Nanggulan Formation in the Yogyakarta region, central Java. 17 species of 48 palynomorph types are new: *Laevigatosporites javanicus* n. sp., *Smilacipites spinulifer* n. sp., *Magnoliaepollenites ellipticus* n. sp., *Quercoidites ellipsodeus* n. sp., *Tricolpopollenites elongatus* n. sp., *Brevitricolpites circularis* n. sp., *Tricolporopollenites javanensis* n. sp., *T. marginatus* n. sp., *T. rasus* n. sp., *Retitricolporites protensus* n. sp., *Striatricolporites striolatus* n. sp., *Polygalacidites speciosus* n. sp., *Graminidites punctulosus* n. sp., *Proteacidites matsuokae* n. sp., *Subtriporopollenites minutulus* n. sp., *Subtriporopollis specialis* n. sp. and *Tiliaepollenites tropicus* n. sp.

The Nanggulan palyno-assemblage is characterized by main pollen grains of *Dicolpopollis malesianus*, *Polygalacidites speciosus*, *Striatricolporites* spp., *Proteacidites* spp., *Graminidites punctulosus* etc. and a comparative study with some Eocene palyno-assemblages in other areas is made.

Introduction

This paper is a report on spores and pollen grains from a lignite seam of the Eocene Nanggulan Formation in the Yogyakarta region, central Java.

The lignite material was provided by K. Matsuoka, member of the Overseas Field Research (grant no. 504308; project leader T. Saito), who has collected it near Kalisongo, west of Nanggulan in the Yogyakarta region, central Java.

The author has distinguished 17 new species and described 48 palynomorph types which consist of 4 spores and 44 pollen grains. This palyno-assemblage is characterized by main pollen grains of *Dicolpopollis malesianus, Polygalacidites speciosus, Striatricolporites* spp., *Proteacidites* spp., *Graminidites punctulosus* etc., which occur relatively abundantly or show morphologically characteristic features, is conspicuously different from the Eocene palynofloras of Japan and some other areas.

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The author thanks Dr. K. Matsuoka, Associate Professor of Department of Geology, Nagasaki University, for his kind offering of the lignite material of the Nanggulan Formation.

Thanks are also due to Professor Dr. T. Saito, Department of Earth Sciences, Faculty of Science, Yamagata University, who is a project leader of the Overseas Field Research entitled "Micropaleontology, Paleomagnetology and lithostratigraphy of Tertiary rocks, central Java", for his permission to publish this paper.

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Miss Akiko Nishi has assisted in preparing the text-figure.

Material and method

The examined lignite material was collected by K. Matsuoka from the lowest part of the Nanggulan Formation in the Kali Puru section near Kalisongo, west of Nanggulan, central Java.

The material was processed by mechanical and chemical methods (maceration by $KClO_3$ and conc. HNO_3, treatment by 15% KOH and then by acetolysis method, centrifuging and washing in pure water after each step). The residues were mounted in glycerine jelly. All slides were sealed with a manicure.

All specimens illustrated in this paper and the material from which they were obtained are in the palynological collection of the Department of Geology, Faculty of Liberal Arts, Nagasaki University.

Paleontological notes and palynological assemblage

According to Kadar's report (1981), the Nanggulan Formation, which is subdivided into two members, namely the lower Kalisongo and the upper Kaliseputih Members, consists of four biostratigraphic units of foraminifera and *Axinea*. The lignite seam belongs to the lowest *Axinea* zone of the Kalisongo Member, which consists mostly of shallow-marine sedi mentary rocks. Based on a recent study of planktonic foraminifera, the Nanggulan Formation ranges from Middle Eocene to Oligocene.

Okada (1981) found well-preserved nannofossils in the middle and upper parts of the Nanggulan Formation and confirmed correlation with the Middle Eocene *Nannotetrina quadrata* Zone (CP 13) and *Reticulofenestra umbilica* Zone (CP 14).

Matsuoka (1981) made a list of dinoflagellate cysts and *Pediastrum* from the Nanggulan Formation and stated that this cyst assemblage is characterized by a lack of Wetzeliaceae and Deflandreaceae.

The miospores recovered from the examined lignite material indicate 48 palynomorph types which appear to be important for characterizing the Nanggulan palynoassemblage.

The fossil genera and species found are as follows.

Trilete spores:
- *Leiotriletes maxoides* Krutzsch *minoris* Krutzsch
- *Alsophilidites kerguelensis* Cookson

Monolete spores:
- *Laevigatosporites javanicus* n. sp.
- ?*Laevigatosporites* sp.

Pollen grains:

Inaperturate:
- *Smilacipites spinulifer* n. sp.
- *Smilacipites echinatus* Wodehouse
- *Classites capucinii* González Guzmán

Monocolpate:
- *Clavapalmaedites* sp.
- *Magnoliaepollenites ellipticus* n. sp.

Dicolpate:
- *Dicolpopollis malesianus* Muller

Tricolpate:
- *Quercoidites umiensis* (Takahashi) Takahashi
- *Quercoidites ellipsodeus* n. sp.
- *Tricolpopollenites elongatus* n. sp.
- *Cupuliferoidaepollenites fallax* (Potonié) Potonié
- *Tricolpites minutireticulosus* Takahashi

Tricolpate—Tetracolpate:
- *Brevitricolpites circularis* n. sp.

Tricolporate:
- *Cupuliferoipollenites* sp.
- *Tricolporopollenites javanensis* n. sp.
- *Tricolporopollenites marginatus* n. sp.
- *Tricolporopollenites rasus* n. sp.
- *Tricolporopollenites consularis* Takahashi *consularis*
- *Tricolporopollenites ovatorotundus* Takahashi

Tricolporopollenites sp. a
Tricolporopollenites sp. b
Tricolporopollenites sp. c
Tricolporopollenites sp. d
Cyrillaceaepollenites minor (Takahashi) Takahashi
Retitricolporites protensus n. sp.
Ilexpollenites tertiarius (Takahashi) Takahashi
Striatricolporites striolatus n. sp.
Striatricolporites agustinus González Guzmán
Striatricolporites sp.
Euphorbiacites sp.

Tetracolporate:
Tetracolporopollenites obscurus Pflug & Thomson

Stephanocolporate:
Polygalacidites speciosus n. sp.

Monoporate:
Graminidites punctulosus n. sp.

Triporate:
Proteacidites mollis Samoilovitch
Proteacidites cf. *annularis* Cookson
Proteacidites similis Harris
Proteacidites matsuokae n. sp.
Subtriporopollenites minutulus n. sp.
Subtriporopollenites sp.
Subtriporopollis specialis n. sp.
Triporopollenites sp. a
Triporopollenites sp. b
Tiliaepollenites tropicus n. sp.
Tiliaepollenites cf. *punctulosus* Takahashi
?*Tiliaepollenites* sp.

There are only a few papers on Tertiary palynology of Southeast Asia. Of 48 palyhomorph types, 6 species are assigned to the miospores previously described from Paleocene-Eocene sediments of Southeast Asia and the Southern Hemisphere.

Alsophilidites kerguelensis Cookson was, hitherto, described and illustrated from the Tertiary brown coal of the Kerguelen Island and from the bright coal seam of the Eocene Yaw Series of Kalewa in Burma.

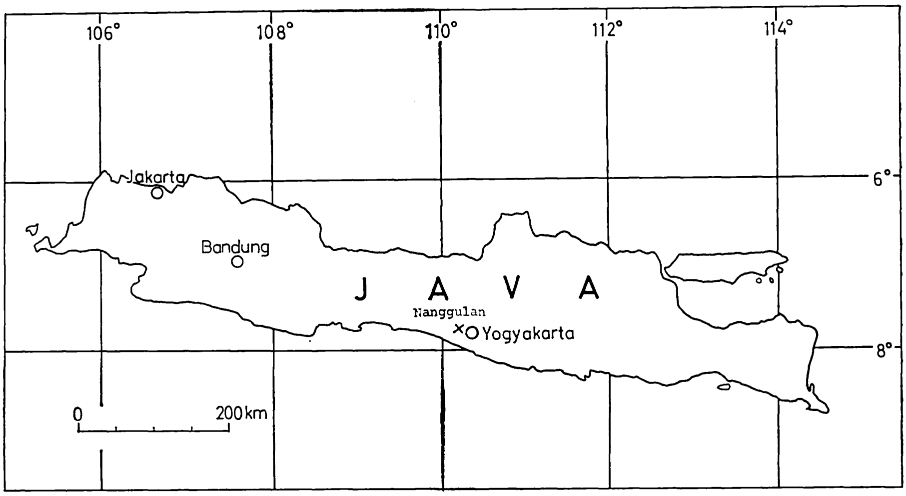
Classites capucinii González Guzmán and *Striatricolporites agustinus* González Guzmán are known from the Eocene Mirador Formation of the Tibu area in Colombia, South America. Botanical affinity of the former is unknown, but it may be a coniferous pollen type, judging from its morphological characteristics. The latter somewhat resembles the Anacardiaceae type, according to González Guzmán's opinion. The author is, however, of opinion that the latter rather resembles the Cucurbitaceae (*Gymnostemma* or *Actinostemma*) type.

Muller (1968) described and illustrated *Dicolpopollis malesianus* Muller and *Dicolpopollis elegans* Muller from the *Proxapertites* Zone (Paleocene?) to *Retitriporites variabilis* Zone (Eocene) of the Plateau Sandstone Formation of Sarawak, Malaysia.

The *Dicolpopollis* specimens of the Nanggulan Formation of Java can be assigned to the species *D. malesianus* of Sarawak. This species is one of representatives of the Nanggulan palyno-assemblage.

Proteacidites annularis Cookson is known from the Paleocene-Miocene formations of Australia and from the Paleocene-Oligocene formations of New Zealand. *Proteacidites similis* Harris was first described from the Middle Paleocene Pebble Point Formation, Dilwyn Bay, Victoria, Australia. Both species occur very rarely in the lignite seam of the Nanggulan Formation.

Some tricolpate, tricolporate and triporate pollen grains occur in common with the Paleogene and Miocene of Japan and the Miocene of Korea: *Quercoidites umiensis* (Takahashi) Takahashi, *Cupuliferoidaepollenites fallax* (Potonié) Potonié, *Tricolpites minutireticulosus* Takahashi, *Tricolporopollenites consularis* Takahashi *consularis*, *Tricolporopollenites ovatorotundus* Takahashi, *Cyrillaceaepollenites minor* (Takahashi) Takahashi, *Ilexpollenites tertiarius* (Takahashi) Takahashi



Text-fig. 1. Map showing the locality of the lignite seam of the Nanggulan Formation (×).

and *Tiliaepollenites* cf. *punctulosus* Takahashi.

Smilacipites echinatus Wodehouse which belongs doubtfully to the genus *Smilax*, is an American species from the Eocene Green River Formation, Colorado, U. S. A.

Leiotriletes maxoides Krutzsch *minoris* Krutzsch, *Cupuliferoidaepollenites fallax* (Potonié) Potonié, and *Tetracolporopollenites obscurus* Pflug & Thomson are Tertiary European species.

Proteacidites mollis Samoilovitch is one of the Maestrichtian-Danian Siberian species.

The genus *Polygalacidites* was established by Sah and Dutta (1966) as a monotypic genus with type species *Polygalacidites clarus* Sah & Dutta from the Umsawmat bed of the Cherra Formation (Eocene or? Paleocene) in Assam, India. The new species *Polygalacidites speciosus* is one of the most remarkable species of the Nanggulan assemblage. This species shows strong resemblance to pollen grains of *Polygala* (Family Polygalaceae) which is herbs.

The Nanggulan palyno-assemblage is relatively similar to the Kalewa palyno-assemblage from the Eocene coal in Burma, in spite of the different species constituting the assemblage. The Kalewa assemblage with *Dicolpopollis kalewensis* as a main constituent and consisting of tricolpate, tricolporate, triporate and *Tetracolporopollenites* possesses some common characteristics with the Nanggulan assemblage.

Germeraad, Hopping and Muller (1968) reported on the palynological zonation of Tertiary sediments from tropical areas, namely Colombia, Venezuela, Trinidad, Nigeria and Borneo. However, there is no common species between the Nanggulan assemblage and the Tertiary assemblages of the tropical areas above mentioned, excepting *Dicolpopollis malesianus* Muller (1968) from the *Proxapertites* Zone (Paleocene?) to the *Retitriporites variabilis* Zone (Eocene) of the Plateau Sandstone Formation in Sarawak, Malaysia.

Descriptive palynology

Anteturma Sporites Potonié 1893

Turma Triletes Reinsch 1881 emend. Potonié & Kremp 1954

Subturma Azonotriletes Luber 1935

Infraturma Laevigati Bennie & Kidston 1886 emend. Potonié 1956

Genus *Leiotriletes* Naumova 1939 emend. Potonié & Kremp 1954

Type species: *Leiotriletes sphaerotriangulus* (Loose 1932) Potonié & Kremp 1954.

Leiotriletes maxoides Krutzsch *minoris* Krutzsch

Pl. 49, Fig. 1.

1962. *Leiotriletes maxoides* Krutzsch *minoris* Krutzsch, Atlas, Lief. I, 16, Taf. 1, Fig. 2-8.

Dimensions: Grain size 50 μm in diameter; amb broadly rounded triangular with convex sides; exine 1.5 μm thick, laevigate; trilete mark not extending to the equator.
Occurrence: Rare.
Comparison: The present grain seems to belong to *Leiotriletes maxoides* Krutzsch *minoris* Krutzsch from the Miocene and Oligocene of Germany.
Botanical affinity: Unknown.

Genus *Alsophilidites* Cookson 1947 ex Potonié 1956

Type species: *Alsophilidites kerguensis* Cookson 1947.

Alsophilidites kerguelensis Cookson

Pl. 49, Figs. 2-3.

1947. *Trilites* (*Alsophilidites*) *kerguelensis* Cookson, B.A.N.Z. Ant. Res. Exped. 1929-1931, Rpts-ser. A, 2, pt. 8, 136, pl. 16, fig. 69.
1956. *Alsophilidites kerguelensis* Cookson, Potonié, *Beih. Geol. Jb.*, 23, 14, Taf. 1, Fig. 3.
1960a. *Alsophilidites kerguelensis* Cookson, Potonié, *Senck. leth.*, 41, 1/6, 459-460, Taf. 1, Fig. 20.

Dimensions: Grain size 45-61 μm in equatorial diameter; exine 1-1.5 μm thick, laevigate; trilete mark straight or slightly undulate, reaching almost to the equator.
Occurrence: Few.
Comparison: These grains belong to *Alsophilidites kerguelensis* Cookson from the Tertiary brown coal of the Kerguelen Island and from the bright coal belonging to the Eocene Yaw Series of Kalewa in Burma.
Botanical affinity: Unknown.

Turma Monoletes Ibrahim 1933

Subturma Azonomonoletes Luber 1935

Infraturma Laevigatomonoleti Dybova & Jachowicz 1957

Genus *Laevigatosporites* Ibrahim 1933

Type species: *Laevigatosporites vulgaris* (Ibrahim 1932) Ibrahim 1933.

Laevigatosporites javanicus n. sp.

Pl. 49, Figs. 5-6.

Description: Monolete spore; reniform or elliptical in lateral view. Exine smooth, 0.6-1 μm thick. Dehiscence moderately long, straight or slightly arc. Grain size 49-51 μm $\times$ 32.5-42 μm.
Holotype: Pl. 49, Fig. 5; grain size 49 $\times$ 34 μm; exine 1 μm thick, laevigate; slide GN 4654.
Occurrence: Rare.
Comparison: The present species is

morphologically similar to the European species *Laevigatosporites nutidus* (Mamczar) Krutzsch *nutidus* (Krutzsch, 1967, 149-150, Taf. 53, Fig. 4-12), but the former can be distinguished from the latter by the much thinner exine.

Botanical affinity: Polypodiaceae.

?*Leavigatosporites* sp.

Pl. 49, Fig. 4.

Description: Monolete spore; reniform or bean-shape in lateral view. Dehiscence long, arc. Exine 1 μm thick, 1.5 μm thick in dehiscence side, laevigate except finely punctate sculpture in dehiscence area. Grain size 55.3×29.5 μm.

Occurrence: Very rare.

Remark: This specimen with the finely punctate sculpture only in the dehiscence area was very rarely found. This species belongs doubtfully to the genus *Laevigatosporites*.

Botanical affinity: Polypodiaceae.

Anteturma Pollenites Potonié 1931

Turma Aletes Ibrahim 1933

Subturma Azonaletes Luber 1935 emend. Potonié & Kremp 1954

Infraturma Subpilonapiti Erdtman 1947 emend. Vimal 1952

Genus *Smilacipites* Wodehouse 1933

Type species: *Smilacipites echinatus* Wodehouse 1933.

Smilacipites spinulifer n. sp.

Pl. 49, Figs. 7, 8a-b.

Description: Inaperturate pollen grains; ellipsoidal or originally spherical in form. Exine thin, 0.5 μm± thick, provided with finely granulate or punctate sculptures and sharp conical spines somewhat densely or sparsely arranged, 0.5-1.5 μm in length, apparently folded and deformed by pressure. Grain size 30-33 μm×25-26 μm in diameter.

Holotype: Pl. 49, Fig. 7; grain size 33×25.5 μm in diameter; exine thin, finely punctate and sparsely echinate, 0.5-1 μm in length; slide GN 4654.

Occurrence: Rare.

Comparison: Wodehouse (1933) established the genera *Smilacipites* and *Peltandripites* with large or small spines and/or granules. The genus *Smilacipites* is much smaller in size than the *Peltandripites*. The present specimens belong apparently to the genus *Smilacipites* and are similar to *Smilacipites molloides* Wodehouse (1933, p. 500, fig. 25) from the Eocene Parachute Creek Member of the Green River Formation, Colorado, U.S.A., however this new species is much smaller than *S. molloides*.

Botanical affinity: *Smilax*.

Smilacipites echinatus Wodehouse

Pl. 49, Figs. 10-12.

1933. *Smilacipites echinatus* Wodehouse, *Bull. Torr. Bot. Club*, 60, 500, fig. 27.

Dimensions: Grain size 22.5-27 μm×16.6-21.5 μm in diameter; exine thin, smooth, provided with sharp spines irregularly arranged, varying from 1.7 μm to 3.5 μm in length, from 1 μm to 2.5 μm in width at base.

Occurrence: Few.

Remarks: The present specimens seem to belong to *Smilacipites echinatus* Wodehouse from the Eocene Parachute Creek Member, Green River Formation, Colorado, U.S.A. The grain of the Figure 10 possesses more numerous spines than other grains. Wodehouse found two specimens of *Smilacipites echinatus* and described that one of these shows the granular character rather distinctly while in the other it is absent. The present specimens show no granular character.

Botanical affinity: Belonging to the genus *Smilax* is doubtful.

Infraturma Circumpollini (Pflug 1953) Klaus 1960

Genus *Classites* González Guzmán 1967

Type species: *Classites capucinii* González Guzmán 1967.

Classites capucinii González Guzmán

Pl. 50, Figs. 1-3.

1967. *Classites capucinii* González Guzmán, E. J. Brill, 62, pl. 30, figs. 2-2a.

Dimensions: Grain size 24.4-30 μm × 24-27 μm in diameter; size of ring 20(?)-28 μm × 20(?)-23 μm in diameter; exine 0.5-0.8 μm thick; psilate; exine of ring 1 μm thick (ektexine : endexine=1 : 1); a reduced scar not visible on the proximal side.

Occurrence: Few.

Remarks: The grains seem to belong to *Classites capucinii* González Guzmán from the Eocene Mirador Formation (pollen zone IIIa) of the Tibu area, Colombia, South America. A ring on one hemisphere of the grain exist distinctly, but a reduced scar on one hemisphere is not visible. The Figure 3 belongs very doubtfully to *Classites capucinii*.

Botanical affinity: Unknown.

Turma Plicates Naumova 1937 emend. Potonié 1960

Subturma Monocolpates Iversen & Troels-Smith 1950

Genus *Clavapalmaedites* Rao & Ramanujam 1978

Type species: *Clavapalmaedites hammenii* Rao & Ramanujam 1978.

Clavapalmaedites sp.

Pl. 49, Fig. 9.

Description: Monosulcate pollen grain; oval in distal polar view. Sulcus long, narrow, extending all along long axis of grain. Exine 1 μm thick; baculate and clavate, 1.3 μm in length. Grain size 25.5 × 22 μm in diameter.

Occurrence: Very rare.

Comparison: This grain is comparable with that of *Clavapalmaedites hammenii* Rao & Ramanujam (1978, p. 414) from the Miocene strata of India. However, the former differs from the latter in having baculate and clavate sculptures.

Botanical affinity: ?Palmae.

Genus *Magnoliaepollenites* Nagy 1969

Type species: *Magnoliaepollenites simplex* Nagy 1969.

Magnoliaepollenites ellipticus n. sp.

Pl. 49, Figs. 13-15.

Description: Heteropolar, monocolpate pollen grains; ellipsoidal to elongate oval in distal polar view. Colpus long, strong, straight or somewhat arc. Exine 2-2.5 μm thick; ektexine : endexine=1 : 1; ektexine finely intrabaculate or intrarugulate, endexine chagrenate. On the surface of exine very small pores relatively sparsely visible. Grain size 46.5-55 μm in length; 25-32.5 μm in width.

Holotype: Pl. 49, Figs. 15a-b; grain size 50 × 32.5 μm; exine 2.5 μm thick (ektexine : endexine=1 : 1); ektexine intrabaculate, endexine chagrenate; very small pores visible on the surface of ektexine; slide GN 4656.

Occurrence: Few.

Comparison: Nagy (1969) first established the new genus *Magnoliaepollenites* and in the next year Krutzsch (1970) proposed the genus *Magnolipollis.* However, the author recognizes that the latter is a junior synonym of the former.

This new species differs from *Magnoliaepollenites simplex* Nagy (1969, p. 399, pl. 41, figs. 1, 4) in form and structure of exine. *Magnoliaepollenites* (*al. Magnolipollis*) *magnolioides* Krutzsch n. comb., *Magnoliaepollenites* (*al. Magnolipollis*) *micropunctatus* Krutzsch n. comb., and *Magnoliaepollenites* (*al. Magnolipollis*) *neogenicus* Krutzsch n. comb. *neogenicus* differ in much thinner exine and structure of exine.

Botanical affinity: ?Magnoliaceae.

Subturma Dicolpates Erdtman 1947

Genus *Dicolpopollis* Pflanzl 1956 emend. Potonié 1966

Type species: *Dicolpopollis kockelii* Pflanzl 1956.

Dicolpopollis malesianus Muller

Pl. 50, Figs. 4-10.

1968. *Dicolpopollis malesianus* Muller, *Micropaleontology*, 14, 1, p. 13, pl. 5, fig. 5.

Dimensions: Grain size 29-36 μm in width, 20.5-27.5 μm in height; exine up to 1.5 μm thick; columellae small, arranged in a reticulate pattern, forming baculate to clavate muri; lumina variable in size and shape, generally larger in central zone, up to 1.5 μm.

Occurrence: Abundant.

Comments: Potonié (1960a) described *Disulcites kalewensis* Potonié (464-466, Taf. 2, Fig. 27-43; Abb. 3-4) from the Eocene coal of Kalewa in Burma and he (1966) considered the genus *Disulcites* as a junior synonym of the genus *Dicolpopollis* and gave the emended diagnosis. *Dicolpopollis malesianus* Muller is closely similar to *Dicolpopollis kalewensis*(Potonié) Potonié, but differs apparently in more remarkable sculpture.

Muller (1968) found that *Dicolpopollis malesianus* and *Dicolpopollis elegans* occur from the *Proxapertites* Zone (Paleocene?) to the *Retitriporites variabilis* Zone (Eocene) of the Plateau Sandstone Formation in Sarawak, Malaysia.

Botanical affinity: Palmae—*Calamus.*

Subturma Triptyches Naumova 1939

Genus *Quercoidites* Potonié, Thomson & Thiergart 1950 ex Potonié 1960

Type species: *Quercoidites henrici* (Potonié 1931) Potonié 1960.

Quercoidites umiensis (Takahashi) Takahashi

Pl. 50, Figs. 11-13, 30.

1957. *Tricolpopollenites umiensis* Takahashi, *Mem. Fac. Sci., Kyushu Univ.*, Ser. D, Geol., 5, 4, 217, Taf. 38, Fig. 37-39; Taf. 39, Fig. 31-32.

1979. *Quercoidites umiensis* (Takahashi) Takahashi, Takahashi & Kim, *Palaeontographica*, B, 170, 38, pl. 9, figs. 3-5, 24.

Dimensions: Grain size 27-34.2 μm $\times$ 19-19.5 μm; exine 1-1.5 μm thick, intrabaculate; breadth/length ratio 0.56-0.72.

Occurrence: Rare.

Remarks: Morphologically the present specimens appear to be closely comparable to those of *Quercoidites umiensis* (Takahashi) Takahashi from the Paleogene and

Miocene formations of Japan and from the Miocene formations of Korea.

Potonié (1960a) bescribed *Quercoidites* sp. (grain size 20-30 μm), which is comparable with the present species, from the Eocene coal of Kalewa in Burma.

Botanical affinity: Cupuliferae.

Quercoidites ellipsodeus n. sp.

Pl. 50, Figs. 16-17.

Description: Tricolpate pollen grains; elliptical to oval in equatorial view. Outline weakly crenate or finely wavy. Extremities of grain rounded or somewhat broadly rounded. Three colpi slender, more or less parallel, almost reaching poles. Exine 1-2 μm thick, somewhat thicker in the pole area, intrabaculate; ektexine: endexine=2 : 1. Grain size 30-36 μm$\times$22-24 μm. Breadth/length ratio 0.67-0.74.

Holotype: Pl. 50, Fig. 16; grain size 35.5$\times$24 μm; exine 2 μm thick, intrabaculate; ektexine: endexine=2 : 1; surface of exine uneven; breadth/length ratio 0.68; slide GN 4656.

Occurrence: Few.

Comparison: This new species can be distinguished from *Quercoidites henrici* (Potonié) Potonié, Thomson & Thiergart (Potonié, 1931, p. 329, pl. 2, fig. 19; Potonié, Thomson & Thiergart, 1950, p. 54, pl. B, figs. 22-23) in having slender colpus and rough ornamentation of exine surface and from *Quercoidites microhenrici* (Potonié) Potonié, Thomson & Thiergart (Potonié, 1931, p. 26, pl. 1, fig. V 19c; Potonié, Thomson & Thiergart, 1950, p. 55, pl. B, figs. 24-25) in general form, size and ornamentation.

Quercoidites fusus Sah (1967, p. 51-52, pl. 5, figs. 2-3) from the Upper Neogene strata in Rusizi valley, Burundi, Africa, differs from the present species in general form, size, and ornamentation of exine.

Botanical affinity: Cupuliferae.

Genus *Cupuliferoidaepollenites* Potonié, Thomson & Thiergart 1950 ex Potonié 1960

Type species: *Cupuliferoidaepollenites liblarensis* (Thomson in Potonié, Thomson & Thiergart 1950) Potonié 1960.

Cupuliferoidaepollenites fallax (Potonié) Potonié

Pl. 50, Figs. 19-24.

1934. *Pollenites fallax* Potonié, *Arb. Inst. Palaeobot. Petrogr. Brennst.*, 4, p. 70, fig. 10.

1953. *Tricolpopollenites liblarensis* (Thomson) Thomson & Pflug *fallax* (Potonié) Thomson & Pflug, *Palaeontographica*, B, 94, S. 97, Taf. 11, Fig. 133-151.

1960a. *Cupuliferoidaepollenites fallax* (Potonié) Potonié, *Senck. leth.*, 41, 1/6, S. 468, Taf. 2, Fig. 64-65; Abb. 6.

Dimensions: Grain size 15-17.5 μm$\times$8.5-10.5 μm; exine thin, 0.4-0.8 μm thick, laevigate or faintly chagrenate; Fig. 22—exine 0.8 μm thick.

Occurrence: Common.

Remarks: These specimens belong clearly to *Cupuliferoidaepollenites fallax* (Potonié) Potonié.

Botanical affinity: Cupuliferae.

Genus *Tricolpopollenites* Pflug & Thomson 1953

Type species: *Tricolpopollenites parmularis* (Potonié 1934) Thomson & Pflug 1953.

Tricolpopollenites elongatus n. sp.

Pl. 50, Figs. 14-15.

Description: Tricolpate pollen grains; prolate or perprolate shape in equatorial view. Meridional furrows (colpi) extending from pole to pole. Extremities of grain sharply rounded. Exine 1-1.5 μm thick, chagrenate or/and punctate. Grain size 38-43 μm $\times$ 16-21 μm. Breadth/length ratio 0.38-0.55.

Holotype: Pl. 50, Fig. 14; grain size 38.5 $\times$ 21 μm; exine 1 μm thick, chagrenate to punctate; breadth/length ratio 0.54; slide GN 4657.

Occurrence: Few.

Comparison: The present species is apparently similar to *Quercoidites ellipsodeus* Takahashi n. sp., but differs from the latter in having larger size, more elongate shape, and different structure of exine.

Botanical affinity: Unknown.

Genus *Tricolpites* Cookson 1947 ex Couper 1953 emend. Belsky, Boltenhagen & Potonié 1965

Type species: *Tricolpites reticulatus* Cookson 1947 ex Couper 1953.

Tricolpites minutireticulosus Takahashi

Pl. 50, Figs. 18, 25-27.

1979. *Tricolpites minutireticulosus* Takahashi, Takahashi & Kim, *Palaeontographica*, B, 170, p. 40, pl. 10, figs. 5-8.

Dimensions: Grain size 15-21 μm $\times$ 12.5-17.5 μm (Fig. 18—22.5 μm in diameter); exine 0.5-0.9 μm thick (fig. 18-1 μm thick), intrabaculate; surface of exine very finely reticulate (lumen less than 1 μm in diameter); breadth/length ratio 0.73-0.83.

Occurrence: Few.

Comparison: Morphologically the present specimens appear to be closely comparable to those of *Tricolpites minutireticulosus* Takahashi from the Miocene Changgi and Yonil Groups in the Yeoungill Bay district, Korea.

Botanical affinity: Salicaceae or Cruciferae.

Genus *Brevitricolpites* González Guzmán 1967

Type species: *Brevitricolpites variabilis* González Guzmán 1967.

Brevitricolpites circularis n. sp.

Pl. 50, Figs. 28-29.

Description: Tricolpate or tetracolpate pollen grains; spherical or spheroidal in polar view. Three or four colpi very short but distinct, 2-3 μm deep in polar view, extending one third (or less) the radius. Exine thin, 1 μm or less thick, somewhat coarsely punctate. Grain size 15-17 μm $\times$ 14-16 μm in diameter.

Holotype: Pl. 50, Fig. 28; grain size 16.8 $\times$ 14.5 μm in diameter; colpi three, very short; exine 1 μm thick, somewhat coarsely punctate; slide GN 4653.

Occurrence: Few.

Comparison: This new species can be distinguished from *Brevitricolpites variabilis* González Guzmán with tricolpate to tricolporate feature (1967, p. 35, pl. 12, figs. 6-6b) from the pollen zones I-IV of the Eocene Upper Los Cuervos and Mirador Formations, Colombia, in ornamentation of exine.

Tricolpites pachyexinus Couper with three or four colpi (1953, p. 62, pl. 8, figs. 120-121) from the Upper Cretaceous Lower Ohai Group, New Zealand, differs from the present species in having longer colpi and smooth exine.

Tricolpites sp. A (Drugg, 1967, p. 49, pl. 7, fig. 37) from the Maestrichtian Marca shale and the Danian Lower Dos Palos shale at Escarpado Canyon in California is similar to this new species, but the former differs from the latter in having larger size and smooth exine.

Botanical affinity: Unknown.

Subturma Ptychotriporines Naumova 1939

Genus *Tricolporopollenites* Pflug & Thomson 1953

Type species: *Tricolporopollenites dolium* (Potonié 1931) Thomson & Pflug 1953.

Tricolporopollenites javanensis n. sp.

Pl. 51, Figs. 1-5.

Description: Tricolporate pollen grains; prolate to subprolate in equatorial view. Three colpi extending from pole to pole. Caverna relatively deep. Equatorial pores round, large, on a certain occasion with short rugae. Exine smooth or weakly chagrenate, 0.5-2 μm thick. Grain size 30-42 μm$\times$21-29 μm. Breadth/length ratio 0.55-0.78.

Holotype: Pl. 51, Fig. 1; grain size 40.5 $\times$22.5 μm; exine 1 μm thick, weakly chagrenate; pores round, large; breadth/length ratio 0.56; slide GN 4656.

Occurrence: Common.

Comparison: The present species is similar to *Tricolporopollenites* (*al. Cupuliferoipollenites*) *prolongatus* (Takahashi) n. comb. from the Miocene Cheonbug Conglomerate of the Yonil Group, Korea, but differs from the latter in size and pore shape.

Botanical affinity: Unknown.

Tricolporopollenites consularis Takahashi subsp. *consularis*

Pl. 51, Figs. 7-9.

1961. *Tricolporopollenites consularis* Takahashi, *Mem. Fac. Sci., Kyushu Univ.*, Ser. D, Geol., 11, 3, p. 323, pl. 24, figs. 55-56 (pro parte).

1979. *Tricolpolporopollenites consularis* Takahashi subsp. *consularis*, Takahashi & Kim, *Palaeontographica*, B, 170, p. 41, pl. 10, figs. 9-27; pl. 11, fig. 2.

Dimensions: Grain size 30-37 μm$\times$20-23 μm; exine intrabaculate or intrarugulate, 1-1.2 μm thick; breadth/length ratio 0.56-0.66.

Occurrence: Few.

Comparison: These grains seem to belong to those of *Tricolporopollenites consularis* Takahashi *consularis* from the Paleogene and Miocene formations of West Japan and from the Miocene Changgi and Yonil Groups of Korea.

Botanical affinity: ?Cupuliferae.

Tricolporopollenites marginatus n. sp.

Pl. 51, figs. 10-14.

Description: Tricolporate pollen grains; oval to subcircular in equatorial view; circular to oval in polar view. Polar axis longer than equatorial axis. Three colpi parallel or converging to the poles, almost reaching the poles; each with a somewhat large and round pore. Exine punctate or intrabaculate, 1-1.5 μm thick. Grain size 23-27 μm$\times$19-26 μm. Breadth/length ratio 0.83-0.96.

Holotype: Pl. 51, Fig. 11; grain size 24 $\times$21.5 μm; exine 1 μm thick, intrabaculate; pore large, round; breadth/length ratio 0.895; slide GN 4655.

Occurrence: Common.

Comparison: *Tricolporopollenites marginatus* is similar to *Tricolporopollenites emarginalis* Takahashi (Takahashi & Kim, 1979, p. 41, pl. 11, figs. 11-22) from the

Miocene Changgi and Yonil Groups of Korea, but can be distinguished from the latter in its comparatively larger pores and more spherical form.

Botanical affinity: Unknown.

Tricolporopollenites rasus n. sp.

Pl. 51, Figs. 18-20.

Description: Tricolporate pollen grains; prolate to subprolate in equatorial view. Three colpi narrow, converging to the poles, extending from pole to pole, with meridionally elongated pores. Exine laevigate to faintly chagrenate, 0.5 μm thick. Grain size 15-19 μm $\times$ 11-14 μm. Breadth/length ratio 0.71-0.77.

Holotype: Pl. 51, Fig. 19; grain size 19 $\times$ 13.5 μm; exine 0.5 μm thick, laevigate; pores meridionally elongated; breadth/length ratio 0.71; slide GN 4656.

Occurrence: Few.

Comparison: This new species is closely related to *Tricolporopollenites* (*al. Cupuliferoipollenites*) *pseudopusillus* (Takahashi) Takahashi n. comb. (1979, p. 45, pl. 13, figs. 6-7) from the Middle Miocene Pohang Formation of the Yonil Group, Korea, but the exine in the latter is thicker and its shape is much slender.

Botanical affinity: Unknown.

Tricolporopollenites ovatorotundus Takahashi

Pl. 51, Fig. 24.

1979. *Tricolporopollenites ovatorotundus* Takahashi, Takahashi & Kim, *Palaeontographica*, B, 170, p. 42, pl. 12, fig. 28-32.

Dimensions: Grain size 22 μm in diameter; exine 1.5 μm thick, intrabaculate; equatorial pores small, round.

Occurrence: Very rare.

Comparison: Only one specimen was found. This specimen is comparable with the grain of *Tricolporopollenites ovatorotundus* Takahashi from the lower coal bearing formation of the Changgi Group, Korea.

Botanical affinity: Unknown.

Tricolporopollenites sp. a

Pl. 51, Figs. 15a-b.

Description: Tricolporate pollen grains; subprolate in equatorial view. Three colpi comparatively narrow, extending from pole to pole, with short rugae. Caverna not so deep. Exine intrabaculate, 1.5 μm thick in the pole area, 0.8 μm thick in equatorial area; ektexine : endexine= 2 : 1. Grain size 22.5 $\times$ 17.5 μm Breadth/length ratio 0.78.

Occurrence: Very rare.

Remarks: Only one specimen was found.

Botanical affinity: Unknown.

Tricolporopollenites sp. b

Pl. 51, Fig. 17.

Description: Tricolporate pollen grain; prolate in equatorial view. Three colpi parallel, almost reaching the poles. Exine chagrenate, 2 μm thick, with somewhat meridionally elongated pores; Grain size 24 $\times$ 16 μm. Breadth/length ratio 0.67.

Occurrence: Very rare.

Comparison: The present specimen is similar to *Tricolporopollenites* (*al. Cupuliferoipollenites*) *ovuliformis* (Takahashi) n. comb. (Takahashi & Kim, 1979, p. 44, pl. 12, figs. 8-24) from the Miocene Changgi and Yonil Groups of Korea, but the former differs from the latter in having thicker exine and small rugae. However, the author can not determine its species name.

Botanical affinity: Unknown.

Tricolporopollenites sp. c

Pl. 51, Fig. 28.

Description: Tricolporate pollen grain; spheroidal in equatorial view. Three colpi parallel, not so long; caverna comparatively deep. Equatorial pores meridionally elongated. Exine 1 μm thick, intrabaculate. Grain size 24×21.5 μm. Breadth/length ratio 0.895.

Occurrence: Very rare.

Remarks: Only one specimen was found.

Botaeical affinity: Unknown.

Tricolporopollenites sp. d

Pl. 51, Fig. 16.

Description: Tricolporate pollen grain; prolate in equatorial view. Three colpi parallel, comparatively short, with large and equatorially somewhat elongated pores (equatorial diameter 4 μm, meridional diameter 3 μm). Exine 1 μm thick, finely intrabaculate. Grain size 28×20 μm. Breadth/length ratio 0.71.

Occurrence: Very rare.

Remarks: Only one specimen was found.

Botanical affinity: ?Leguminosae.

Genus *Cupuliferoipollenites* Potonié 1951 ex Potonié 1960

Type species: *Cupuliferoipollenites pusillus* (Potonié 1934) Potonié 1960.

Cupuliferoipollenites sp.

Pl. 51, Fig. 6.

Description: Tricolporate pollen grain; subprolate in equatorial view. Three colpi relatively narrow, almost reaching the poles. Caverna not deep. Equatorial pores large, equatorially elongated (rugae). Exine 1.3 μm thick, smooth. Grain size 35.5×29 μm. Breadth/length ratio 0.82.

Occurrence: Very rare.

Remarks: This specimen possesses three large rugae and smooth exine. Accordingly, this belongs undoubtedly to the genus *Cupuliferoipollenites*.

Botanical affinity: Unknown.

Genus *Cyrillaceaepollenites* Mürriger & Pflug 1951 ex Potonié 1960

Type species: *Cyrillaceaepollenites megaexactus* (Potonié 1931) Potonié 1960.

Cyrillaceaepollenites minor (Takahashi) Takahashi

Pl. 51, Fig. 29.

1961. *Tricolporopollenites minor* Takahashi, *Mem. Fac. Sci., Kyushu Univ.*, Ser. D, Geol., 11, 3, p. 320-321, pl. 24, figs. 18-31.

1979. *Cyrillaceaepollenites minor* (Takahashi) Takahashi, Takahashi & Kim, *Palaeontographica*, B, 170, p. 46, pl. 13, figs. 32-36.

Dimensions: Grain size 13.5×12.5 μm; exine 0.5 μm thick, laevigate; rugae small; breadth/length ratio 0.93.

Occurrence: Very rare.

Comparison: Only one specimen was found. The present specimen is apparently identified with *Cyrillaceaepollenites minor* (Takahashi) Takahashi from the Paleogene and Miocene formations of West Japan and from the Miocene Yonil Group of Korea.

Botanical affinity: Cyrillaceae.

Genus *Euphorbiacites* Sung & Lee 1976

Type species: *Euphorbiacites wallensenensis* (Pflug 1953) Sung & Lee 1976.

Euphorbiacites sp.

Pl. 50, Fig. 31.

Description: Tricolporate pollen grain; prolate in equatorial view. Three colpi more or less parallel, converging to the poles, almost extending from pole to pole. Caverna very deep. Pores large, elongating somewhat equatorially. Exine is relatively firm with sculpture which consists of closely spaced bacula of 2 μm high in the polar area and 1.5 μm high in the equatorial area. Grain size 41× 30 μm. Breadth/length ratio 0.73.

Occurrence: Very rare.

Comparison: Only one specimen was found. The present specimen is similar to *Euphorbiacites* sp. (Li, Sung & Li, 1978, p. 34, pl. 10, fig. 32) from the Eocene and Oligocene formations of the Yangtze-Han River plain, China, but the former differs from the latter in having smaller size, thinner exine, and somewhat equatorially elongated pores (rugae).

Botanical affinity: Euphorbiaceae.

Genus *Retitricolporites* v. d. Hammen 1956 ex v. d. Hammen & Wijmstra 1964

Type species: *Retitricolporites guianensis* v. d. Hammen & Wijmstra 1964.

Retitricolporites protensus n. sp.

Pl. 51, Figs. 21-23.

Description: Tricolporate pollen grains; prolate in equatorial view. Three colpi narrow, slender, converging to the poles, extending from pole to pole with meridionally somewhat elongated pores. Exine very finely reticulate. Lumen of reticulum less than 1 μm in diameter. Muri baculate to clavate, 0.5-0.7 μm high. Grain size 16-17 μm×9-12 μm. Breadth/length ratio 0.56-0.71.

Holotype: Pl. 51, Fig. 22; grain size 16 ×10.5 μm; muri baculate to clavate, 0.5-0.7 μm high. Breadth/length ratio 0.66; slide GN 4653.

Occurrence: Few.

Comparisom: *Retitricolporites protensus* is similar to the elongate form of *Retitricolporites* (*al. Tricolporopollenites*) *microreticulatus* (Pflug & Thomson) n. comb., but differs from the latter in having baculate and clavate muri.

Amongst the pollen of recent plants a close similarity is seen with the pollen of *Hydrangea* and it is quite likely that the present pollen grains are related to the family Saxifragaceae.

Botanical affinity: Saxifragaceae.

Genus *Ilexpollenites* Thiergart 1937 ex Potonié 1960

Type species: *Ilexpollenites iliacus* (Potonié 1931) Potonié 1960.

Ilexpollenites tertiarius (Takahashi) Takahashi

Pl. 51, Figs. 25-27.

1961. *Tricolporopollenites tertiarius* Takahashi, *Mem. Fac. Sci., Kyushu Univ.*, Ser. D, Geol., 11, 3, p. 332, pl. 26, figs. 29-33.

1963. *Ilexpollenites tertiarius* (Takahashi) Takahashi, *Mem. Fac. Sci., Kyushu Univ.*, Ser. D, Geol., 14, 2, p. 150, pl. 21, fig. 18.

Dimension: Grain size 18.5-27 μm× 15.5-19.5 μm; clavae 1.5-2 μm high, 1 μm ± in diameter; breadth/length ratio 0.57-0.92.

Occurrence: Few.

Comparison: The present specimens

belong to *Ilexpollenites tertiarius* (Takahashi) Takahashi from the Paleogene and Miocene formations of West Japan and from the Miocene Changgi and Yonil Groups of Korea. The Figures 26 and 27 with densely spaced clavae are closely comparable with the grain of *Ilexpollenites tertiarius* from the Hioki Group of Waku, Yamaguchi Prefecture (Takahashi, 1963, pl. 21, fig. 18).

Botanical affinity: *Ilex.*

Genus *Striatricolporites* v.d. Hammen 1956 ex Leidelmeyer 1966

Type species: *Striatricolporites pimulis* Leidelmeyer 1966.

Striatricolporites striolatus n. sp.

Pl. 51, Figs. 30-32.

Description: Tricolporate pollen grains; prolate in equatorial view. Three colpi narrow, converging to the poles, extending from pole to pole, with meridionally more or less elongated pores. Exine finely striate; muri 0.9-1.5 μm high. Striae running parallel or more or less obliquely to the colpus. Grain size 21-24 μm × 13-16 μm. Breadth/length ratio 0.57-0.72.

Holotype: Pl. 51, Fig. 32; grain size 23 × 13.2 μm; exine finely striate; muri 0.9 μm high; breadth/length ratio 0.57; slide GN 4653.

Occurrence: Common.

Comparison: This new species is closely similar to *Striatricolporites augustinus* González Guzmán (1967, p. 39, pl. 12, figs. 1-1f) from the Middle Eocene Mirador Formation (pollen zones III-IV) of the Tibu area, Colombia, but the former differs from the latter in possessing equatorially elongated pores (rugae), judging from the Guzman's photographs.

The morphological characters of *Striatricolporites striolatus* seem to be much similar to that of the *Gymnostemma*-type, and it is quite likely that they might represent that genus.

Botanical affinity: Cucurbitaceae—*Gymnostemma.*

Striatricolporites agustinus González Guzmán

Pl. 51, Figs. 33-34.

1967. *Striatricolporites agustinus* González Guzmán, E. J. Brill, p. 39, pl. 12, figs. 1-1f.

Dimensions Grain size 21 μm × 16-17.5 μm; exine finely striate; muri 1 μm ± high; breadth/length ratio 0.67-0.83.

Occurrence: Few.

Remarks: *Striatricolporites agustinus* is somewhat broader than *Striatricolporites striolatus* and possesses the equatorially elongated pores.

Botanical affinity: Cucurbitaceae—*Gymnostemma* or *Actinostemma.*

Striatricolporites sp.

Pl. 51, Fig. 35.

Description: Tricolporate pollen grain; prolate in equatorial view. Three colpi long, relatively narrow, longitudinal, converging to the poles, reaching to the poles, with equatorial rugae. Exine finely striate; muri 1 μm high. Grain size 32.5 × 17 μm. Breadth/length ratio 0.52.

Occurrence: Very rare.

Botanical affinity: Unknown.

Subturma Ptychopolyporines Naumova 1937 emend. Potonié 1960

Genus *Tetracolporopollenites* Pflug & Thomson 1953

Type species: *Tetracolporopollenites sapotoides* Pflug & Thomson 1953.

Tetracolporopollenites obscurus Pflug & Thomson

Pl. 52, Figs. 1-3.

1953. *Tetracolporopollenites obscurus* Pflug & Thomson, *Palaeontographica*, B, 94, S. 108, Taf. 14, Fig. 86-99, 102-108.

Dimensions: Grain size 33-34 μm×25-27 μm; exine 1-1.5 μm thick, finely intrabaculate or faintly intrarugulate; pores large, round or equatorially elongate.

Occurrence: Few.

Comparison: The grains seem to belong to those of *Tetracolporopollenites obscurus* Pflug· & Thomson from the Lower and Middle Tertiary of West Germany.

Botanical affinity: Sapotaceae.

Genus *Polygalacidites* Sah & Dutta 1966

Type species: *Polygalacidites clarus* Sah & Dutta 1966.

Polygalacidites speciosus n. sp.

Pl. 52, figs. 4-14.

Description: Stephanocolporate pollen grains; suboblate to spheroidal with swelling in the equatorial area in equatorial view; amb circular to subcircular in polar view. Colpi numerous, generally six to eight in number, comparatively not so long, running more or less parallel meridionally, not reaching to the poles. Ora (pores) transversally parallel, connected transversally as ring or belt (synorate). Exine 0.5-1.5 μm thick, chagrenate. Grain size 17-26 μm×20-27 μm. Breadth/length ratio 0.94-1.14.

Holotype: Pl. 52, Figs. 5a-b; grain size 25×24 μm; six colpi; synorate; exine 1 μm thick, chagrenate; breadth/length ratio 0.96; slide GN 4655.

Occurrence: Abundant.

Comparison: Hitherto, *Polygalacidites clarus* Sah & Dutta (1966) has been described by Sah & Dutta (1966, 1968) from the Eocene (?Paleocene) Jaintia Series of Assam. *Polygalacidites speciosus* differs from the Indian species *Polygalacidites clarus* Sah & Dutta in number of colpus and development of synora.

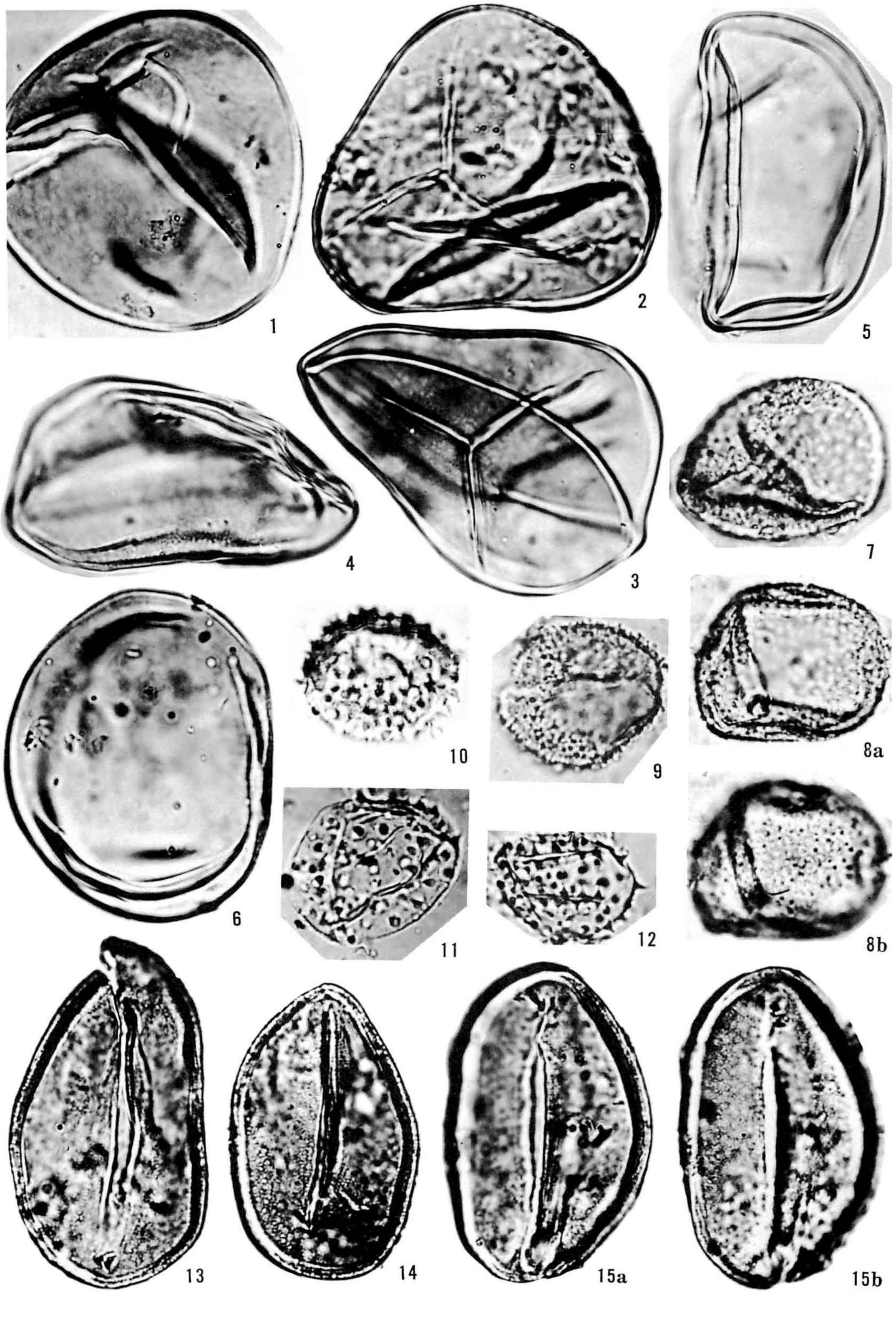
Botanical affinity: Polygalaceae—*Polygala*.

Turuma Poroses Naumova 1937 emend. Potonié 1960

Explanation of Plate 49

(All figures ×1000)

Fig. 1. *Leiotriletes maxoides* Krutzsch subsp. *minoris* Krutzsch Slide GN 4655.
Figs. 2-3. *Alsophilidites kerguelensis* Cookson
Fig. 2: slide GN 4654; Fig. 3: slide GN 4655.
Fig. 4. ?*Laevigatosporites* sp. Slide GN 4653.
Figs. 5-6. *Laevigatosporites javanicus* n. sp.
Fig. 5: holotype, slide GN 4654; Fig. 6: slide GN 4657.
Figs. 7-8. *Smilacipites spinulifer* n. sp. Slide GN 4654; Fig. 7: holotype.
Fig. 9. *Clavapalmaedites* sp. Slide GN 4654.
Figs. 10-12. *Smilacipites echinatus* Wodehouse
Fig. 10: slide GN 4655; Fig. 11: slide GN 4657; Fig. 12: slide GN 4653.
Figs. 13-15. *Magnoliaepollenites ellipticus* n. sp.
Figs. 13-14: slide GN 4657; Figs. 15a-b: holotype, slide GN 4656.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8b
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15b

Subturma Monoporines Naumova 1937 emend. Potonié 1960

Genus *Graminidites* Cookson 1947

Type species: *Graminidites media* Cookson 1947.

Graminidites punctulosus n. sp.

Pl. 52, Figs. 15-19.

Description: Monoporate pollen grains. Figura circular to subcircular in outline. Pore single, 3-4.7 μm in diameter, surrounded by large annulus of 3-4.5 μm in width. Exine finely punctate, 0.5-1 μm thick, with secondary folds. Grain size 28-41 μm in diameter.

Holotype: Pl. 52, Fig. 19; grain size 38 μm in diameter; pore single, 4.7 μm in diameter, surrounded by the annulus of 4 μm in width; exine 1 μm thick, very finely punctate or intrapunctate; slide GN 4656.

Occurrence: Common.

Comparison: This new species is closely comparable with *Graminidites pseudogramineus* Krutzsch (1970, S. 52, Taf. 1, Fig. 6-11) from the Pliocene or Plio-Pleistocene sediments of Germany, but the former differs from the latter in possessing much broader or stronger annulus surrounding the pore.

Graminidites sp. from the Pohang Formation of the Yonil Group (Takahashi & Kim, 1979, p. 61, pl. 24, fig. 7) has only a very weak annulus surrounding the pore.

Botanical affinity: Gramineae.

Subturma Triporines Naumova 1939 emend. Potonié 1960

Genus *Proteacidites* Cookson 1950 ex Couper 1953

Type species: *Proteacidites adenanthoides* Cookson 1950.

Proteacidites mollis Samoilovitch

Pl. 52, Figs. 20a-b; pl. 53, Figs. 1-2.

1961. *Proteacidites mollis* Samoilovitch, Samoilovitch et al., *Trudy VNIGRI*, no. 117, p. 185, pl. 54, fig. 14; pl. 59, figs. la-d; pl. 61, fig. 9.

Dimensions: Grain size 29-33 μm in diameter; triangular with convex sides in polar view; exine punctate, 1.5-2 μm thick.

Occurrence: Few.

Comparison: In general morphological characters the present specimens are considered to belong to *Proteacidites mollis* Samoilovitch from the Maestrichtian-Danian Upper Symsk Subseries, western Siberian Lowland, USSR.

Botanical affinity: Proteaceae.

Proteacidites matsuokae n. sp.

Pl. 53, Fig. 3-7.

Description: Triporate pollen grains; isopolar; amb triangular with somewhat concave sides in polar view. Exine finely punctate, 1.3-2.5 μm thick; ektexine : endexine=1 : 2. Apertures 3-9 μm in diameter. Grain size 29-35 μm in equatorial diameter.

Holotype: Pl. 53, Figs. 5a-b; grain size 29 μm in equatorial diameter; exine finely punctate, 1.5 μm thick; ektexine : endexine =1 : 2; slide GN 4653.

Occurrence: Few.

Comparison: *Proteacidites matsuokae* can be distinguished from *Proteacidites scaboratus* Couper (1960, p. 52, pl. 5, figs. 22-23) from the Upper Senonian or Maestrichtian to Danian strata of New Zealand in ornamentation and structure of exine.

The present species resembles *Proteaci-*

dites incurvatus Cookson forma *minor* Samoliovitch (Samoilovitch et al., 1961, p. 188, pl. 60, figs. 3a-b; pl. 61, fig. 8) from the Maestrichtian-Danian Upper Symsk Subseries, western Siberian Lowland, USSR, but the former differs from the latter in having smaller grain size and aperture.

Botanical affinity: Proteaceae.

Proteacidites cf. *annularis* Cookson

Pl. 53, Fig. 8.

1950. *Proteacidites annularis* Cookson, *Australian Jour. Sci., Res.*, Ser. B, Biol. Sci., 3. 2, p. 170, pl. 1, fig. 15.

Dimensions: Grain size 27 μm in equatorial diameter; exine 2 μm thick (Ektexine: endexine=1 : 2), punctate; apertures 4-5 μm.

Occurrence: Very rare.

Comparison: Except for the comparatively thinner exine, the present specimen appears to be almost identical with the grain of *Proteacidites annularis* Cookson from the Oligocene-Miocene(?) brown coal, South Australia.

Range: Paleocene (Wangerip Group in the Princetown area, South Australia); Oligocene-Miocene (?) (brown coal, Moorlands, South Australia); Paleocene-Eocene (*Lygistepollenites balmei—Nothofagidites asperus* Zone, Latrobe Group, Gippsland, Australia); Paleocene (Waipawan)-Upper Eocene (Runangan) (Dannevirke Series-Arnold Series, New Zealand); Middle Oligocene (Waitakian, Landon Series, New Zealand).

Botanical affinity: Proteaceae.

Proteacidites similis Harris

Pl. 53, Figs. 9a-b.

1965. *Proteacidites similis* Harris, *Palaeontographica*, B, 115, p. 94, pl. 29, figs. 11-12.

Dimensions: Grain size 31.5 μm in equatorial diameter; ora circular 2 μm in diameter; exine 2.3 μm thick, scabrate appearing minutely reticulate.

Occurrence: Very rare.

Comparison: The present specimen is very closely similar to *Proteacidites similis* Harris from the Middle Paleocene Pebble

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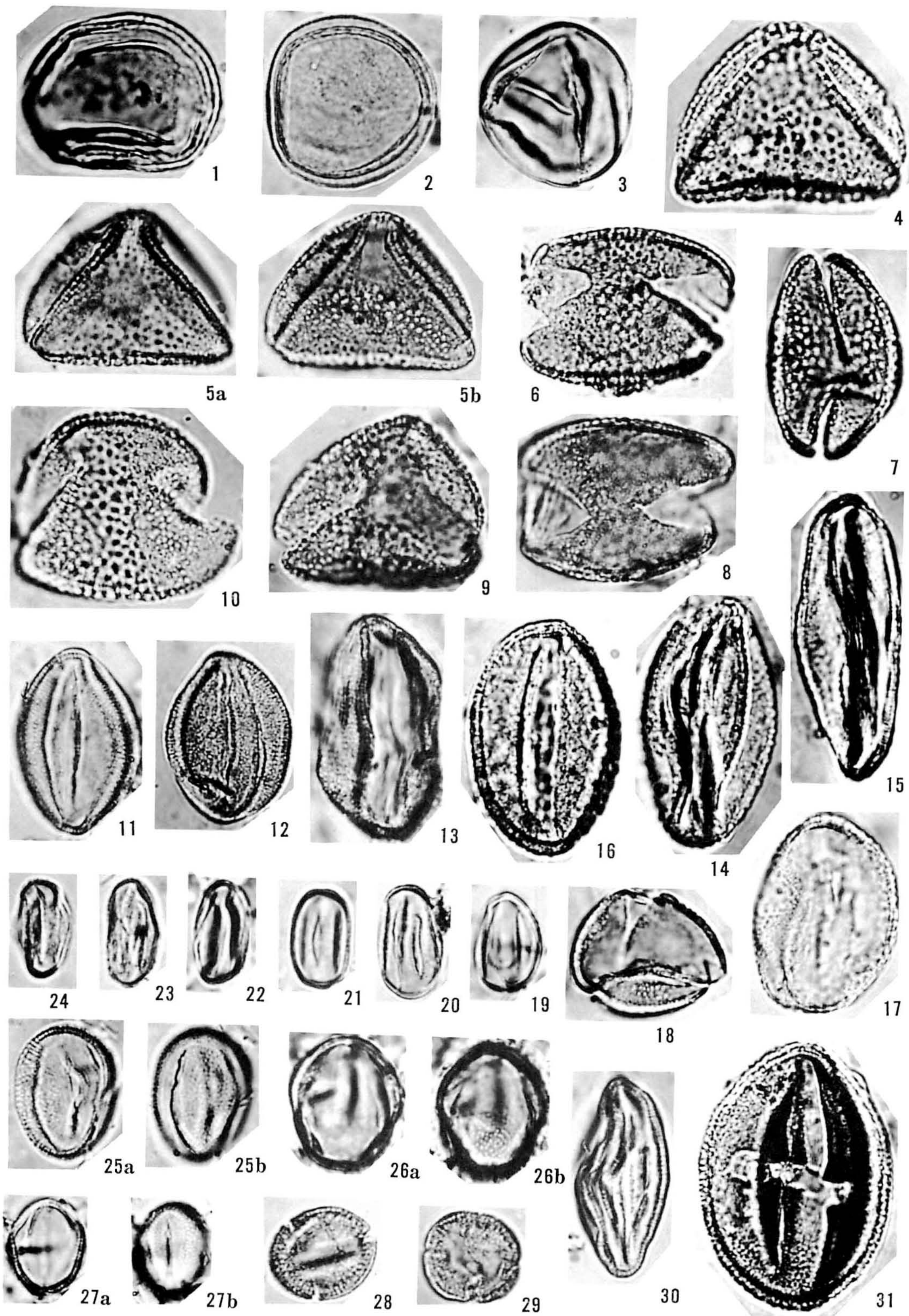
Explanation of Plate 50

(All figures ×1000)

Figs. 1-3. *Classites capucinii* González Guzmán
Fig. 1: slide GN 4656; Fig. : slide GN 4653; Fig. 3: slide GN 4655.
Figs. 4-10. *Dicolpopollis malesianus* Muller
Figs. 4, 6, 10: slide GN 4654; Figs. 5a-b, 8, 9: slide GN 4653; Fig. 7: slide GN 4656.
Figs. 11-13, 30. *Quercoidites umiensis* (Takahashi) Takahashi
Fig. 11: slide GN 4654; Fig. 12: slide GN 4655; Figs. 13, 37: slide GN 4653.
Figs. 14-15. *Tricolpopollenites elongatus* n. sp. Slide GN 4657; Fig. 14: holotype.
Figs. 16-17. *Quercoidites ellipsodeus* n. sp.
Fig. 16: holotype, slide GN 4656; Fig. 17: slide GN 4654.
Figs. 18, 25-27. *Tricolpites minutireticulosus* Takahashi
Figs. 18, 27a-b: slide GN 4655; Figs. 25a-b: slide GN 4657; Figs. 26a-b: slide GN 4653.
Figs. 19-24. *Cupuliferoidaepollenites fallax* (Potonié) Potonié
Figs. 19, 20: slide GN 4655; Fig. 21: slide GN 4654; Figs. 22-23: slide GN 4653.
Figs. 28-29. *Brevitricolpites circularis* n. sp. Slide GN 4653; Fig. 28: holotype.
Fig. 31. *Euphorbiacites* sp. Slide GN 4656.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Point Formation, Dilwyn Bay, Victoria, Australia.

Botanical affinity: Proteaceae.

Genus *Subtriporopollenites* Pflug & Thomson 1953

Type species: *Subtriporopollenites anulatus* Pflug & Thomson 1953 subsp. *anulatus*

Subtriporopollenites minutulus n. sp.

Pl. 53, Figs. 10-12, 13 (?), 18-19.

Description: Triporate pollen grains. Equatorial outline circular to subcircular or oval. Pores relatively large, circular, 2-2.5 μm in diameter; two or three pores subequatorial. Exine 0.6-1.5 μm thick, finely punctate, with a weak annulus of 1 μm$\pm$ in width around the pore. Grain size 18-22 μm$\times$16-22 μm in equatorial diameter.

Holotype: Pl. 53, Fig. 10; grain size 20 $\times$19.5 μm in equatorial diameter; exine 1 μm thick, punctate; pores relatively large, 2.5 μm in diameter; slide GN 4654.

Occurrence: Common.

Comparison: The present specimens are comparable to *Subtriporopollenites anulatus* Pflug & Thomson subsp. *nanus* Pflug & Thomson (1953, S. 86, Taf. 9, Fig. 54-55) and *Subtriporopollenites firmus* Pflug (1953, S. 86, Taf. 9, Fig. 62-63) from the Tertiary deposits of Germany, but *S. anulatus nanus* has intrabaculate to laevigate exine and *S. firmus* has fossulate sculpture of exine.

Botanical affinity: ?Juglandaceae.

Subtriporopollenites sp.

Pl. 53, Fig. 15.

Description: Triporate pollen grain. Subcircular or oval in equatorial outline. Pores very small; two pores subequatorial and one pore equatorial. Exine 1 μm thick, chagrenate, without atrium, labrum and annulus around the pore. Grain size 23.5 μm in equatorial diameter.

Occurrence: Very rare.

Botanical affinity: Unknown.

Genus *Triporopollenites* Pflug & Thomson 1953 emend. Potonié 1960

Type species: *Triporopollenites coryloides* Pflug 1953.

Triporopollenites sp. a

Pl. 53, Fig. 16.

Description: Triporate pollen grain. Triangular in equatorial outline. Three pores very small, planaperturate; two pores equatorial. Exine 1 μm thick, finely punctate, with annulus around the pore. Grain size 15 μm in equatorial diameter.

Occurrence: Very rare.

Remarks: This grain has three apertures (pores) and each is situated at the midpoints of the sides of the triangular amb.

Botanical affinity: Unknown.

Triporopollenites sp. b

Pl. 53, Fig. 17.

Description: Triporate pollen grain. Triangular with convex sides in equatorial outline. Three pores round, equatorial. Exine 2.5 μm thick, intrarugulate or finely punctate, without labrum and annulus; ektexine: endexine=1 : 3. Grain size 32 μm in equatorial diameter.

Occurrence: Very rare.

Botanical affinity: Unknown.

Genus *Subtriporopollis* Sah 1967

Type species: *Subtriporopollis tenuis* Sah 1967.

Subtriporopollis specialis n. sp.

Pl. 53, Figs. 20-21.

Description: Triporate pollen grains. Amb rounded triangular or circular in polar view. Pores circular, slightly protruded; two pores subequatorial. Exine finely reticulate; lumina very small; muri baculate, 0.5-0.7 μm high; annulus drop-shaped. Grain size 19-22 μm $\times$ 17.5-18 μm in equatorial diameter.

Holotype: Pl. 53, Fig. 20; grain size 19 $\times$ 17.5 μm in equatorial diameter; exine reticulate; muri baculate, 0.7 μm high; slide GN 4656.

Occurrence: Few.

Comparison: Sah (1967) established the genus *Subtriporopollis* by the triporate pollen grains with reticulum yielded from the Neogene strata, Rusizi valley, Burundi. The present species differs from *Subtriporopollis tenuis* Sah (1967, p. 119-120, pl. 10, fig. 16) and *Subtriporopollis rotundis* Sah (1967, p. 120-121, pl. 10, figs. 17-19) in grain zize and pore size.

Botanical affinity: Rubiaceae.

Genus *Tiliaepollenites* Potonié 1931

Type species: *Tiliaepollenites indubitabilis* Potonié 1931.

Tiliaepollenites tropicus n. sp.

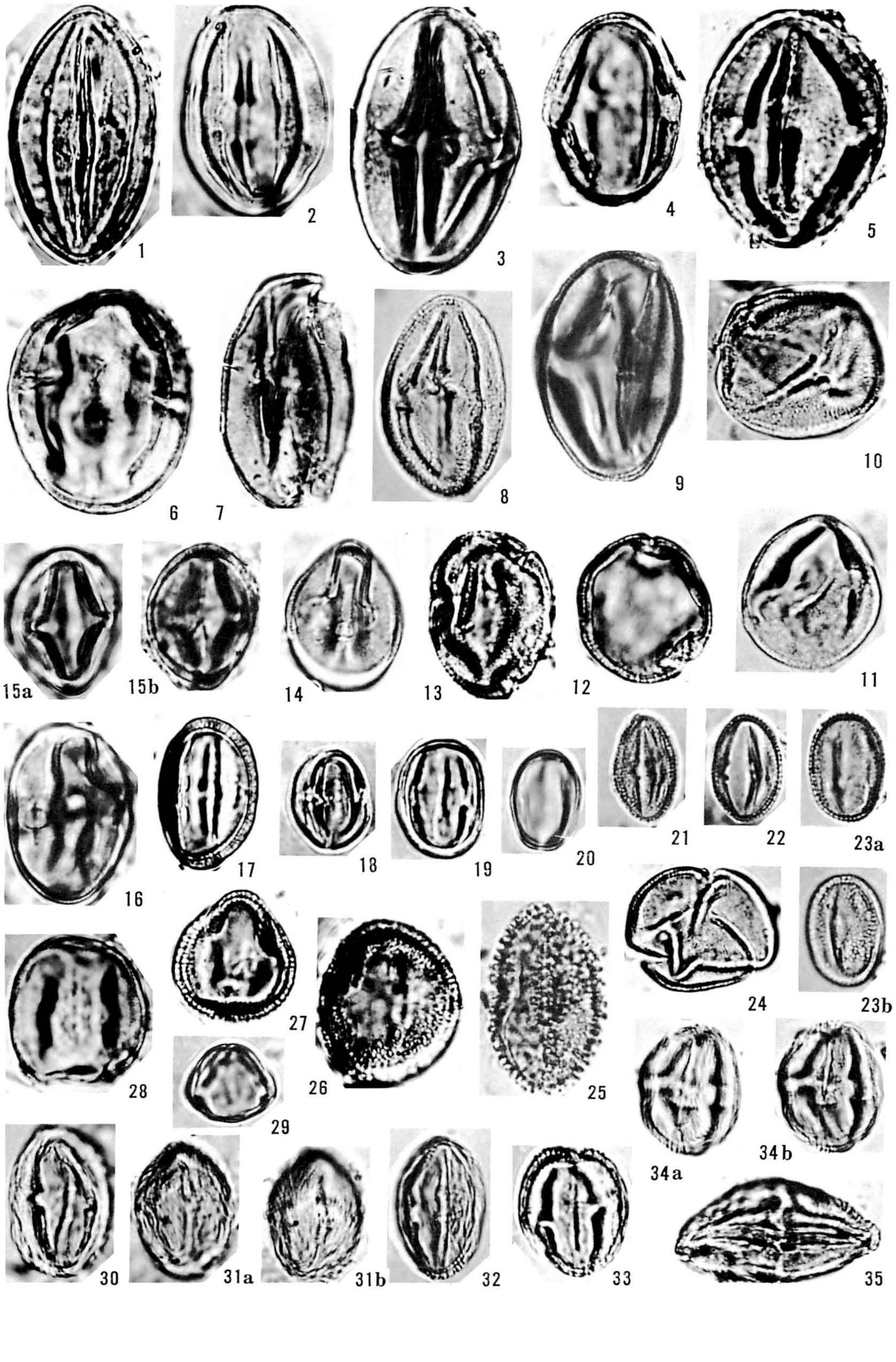
Pl. 53, Figs. 23-24.

Description: Triporate pollen grains. Amb circular in polar view. Three germinals circular, relatively large, more or less protruded, with postvestibulum. Exine

Explanation of Plate 51

(All figures $\times$1000)

Figs. 1-5. *Tricolporopollenites javanensis* n. sp.
Fig. 1: holotype, slide GN 4656; Fig. 2: slide GN 4653; Figs. 3-5: slide GN 4655.
Fig. 6. *Cupuliferoipollenites* sp. Slide GN 4655.
Figs. 7-9. *Tricolporopollenites consularis* Takahashi subsp. *consularis* Slide GN 4654.
Figs. 10-14. *Tricolporopollenites marginatus* n. sp.
Figs. 10, 13: slide GN 4657; Figs. 11, 12: slide GN 4655; Fig. 11: holotype; Fig. 14: slide GN 4654.
Figs. 15a-b. *Tricolporopollenites* sp. a Slide GN 4653.
Fig. 16. *Tricolporopollenites* sp. d Slide GN 4654.
Fig. 17. *Tricolporopollenites* sp. b Slide GN 4657.
Figs. 18-20. *Tricolporopollenites rasus* n. sp.
Figs. 18, 19: slide GN 4656; Fig. 19: holotype; Fig. 20: slide GN 4653.
Figs. 21-23. *Retitricolporites protensus* n. sp. Slide GN 4653; Fig. 22: holotype.
Fig. 24. *Tricolporopollenites ovatorotundus* Takahashi Slide GN 4656.
Figs. 25-27. *Ilexpollenites tertiarius* (Takahashi) Takahashi
Fig. 25: slide GN 4654; Fig. 26: slide GN 4657; Fig. 27: slide GN 4656.
Fig. 28. *Tricolporopollenites* sp. c Slide GN 4656.
Fig. 29. *Cyrillaceaepollenites minor* (Takahashi) Takahashi Slide GN 4653.
Figs. 30-32. *Striatricolporites striolatus* n. sp. Slide GN 4653; Fig. 32: holotype.
Figs. 33-34. *Striatricolporites agustinus* González Guzmán
Fig. 33: slide GN 4657; Figs. 34a-b: slide GN 4655.
Fig. 35. *Striatricolporites* sp. Slide GN 4654.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finely reticulate, 1 μm thick; lumina less than 1 μm. Grain size 28-31 μm $\times$ 27.5-30 μm in equatorial diameter.

Holotype: Pl. 53, Figs. 24a-b; grain size 28 $\times$ 27.5 μm in equatorial diameter; exine finely reticulate, 1 μm thick, with postvestibulum around the pore; slide GN 4657.

Occurrence: Rare.

Comparison: *Tiliaepollenites tropicus* is comparable with *Tiliaepollenites paucus* Sah (1967, p. 116-117, pl. 10, fig. 15) from the Neogene sediments of Rusizi valley, Burundi, but the former differs from the latter in having much smaller grain.

The general form, pore character and exine ornamentation of the grains strongly suggest affinity with Tiliaceae.

Botanical affinity: Tiliaceae.

Tiliaepollenites cf. *punctulosus* Takahashi

Pl. 53, Figs. 14a-b.

1979. *Tiliaepollenites punctulosus* Takahashi, Takahashi & Kim, *Palaeontographica*, B, 170, p. 56, pl. 20, figs. 10-16.

Dimensions: Grain size 27 μm in eqatorial diameter; exine finely punctate, 1 μm thick, with postvestibulum around the pore; germinals somewhat protruded, equatorial.

Occurrence: Very rare.

Comparison: The present specimen is closely similar to the grain of *Tiliaepollenites punctulosus* Takahashi from the Miocene Changgi and Yonil Groups of Korea, with exception of its smaller size.

Botanical affinity: Tiliaceae.

?*Tiliaepollenites* sp.

Pl. 53, Fig. 22.

Description: Tetraporate pollen grain. Equatorial contour circular. Pore circular, relatively small, somewhat protruded; three pores subequatorial and one pore equatorial, with postvestibulum(?). Exine laevigate, 0.5 μm thick. Breadth of pore rim about 3 μm. Grain size 28 μm in equatorial diameter.

Occurrence: Very rare.

Remarks: Only one specimen was found. This tetraporate grain belongs doubtfully to the genus *Tiliaepollenites*.

Botanical affinity: ?Tiliaceae.

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Explanation of Plate 52

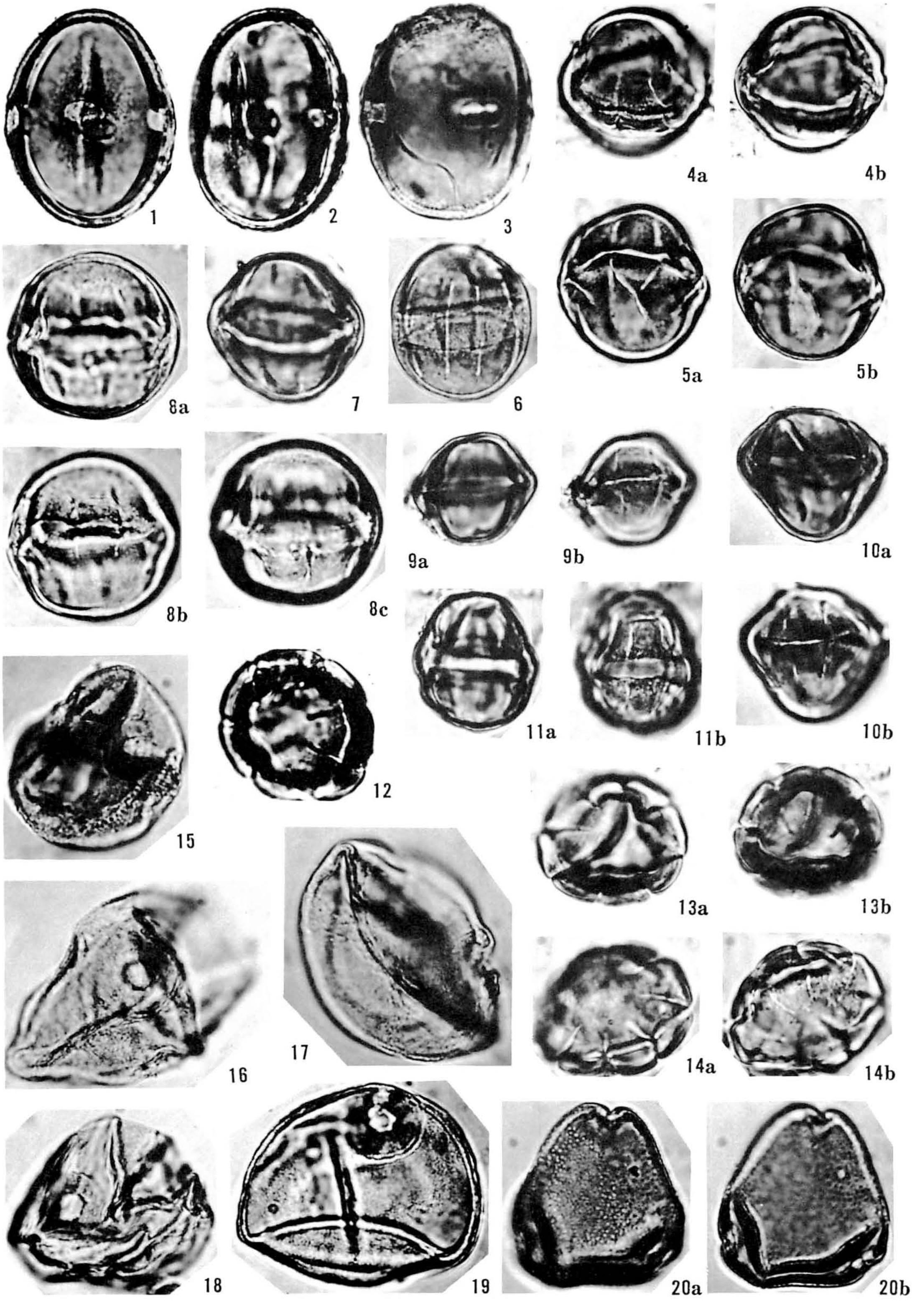
(All figures ×1000)

Figs. 1-3. *Tetracolporopollenites obscurus* Pflug & Thomson
Fig. 1: slide GN 4655; Fig. 2: slide GN 4657; Fig. 3: slide GN 4654.

Figs. 4-14. *Polygalacidites speciosus* n. sp.
Figs. 4-5: slide GN 4655; Figs. 5a-b: holotype; Figs. 6-9, 13-14: slide GN 4654; Figs. 10-11: slide GN 4653; Fig. 12: slide GN 4656.

Figs. 15-19. *Graminidites punctulosus* n. sp.
Figs. 15-18; slide GN 4654; Fig. 19: holotype, slide GN 4656

Figs. 20a-b. *Proteacidites mollis* Samoilovitch Slide GN 4653.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中部ジャワ，ジョクジャカルタ地方の始新世ナングラン層産胞子・花粉：筆者は，中部ジャワ，ジョクジャカルタ地方の始新世ナングラン層の亜炭から，胞子4種と花粉44種，合計48種を識別し，記載した。48種中17種が新種である：*Laevigatosporites javanicus* n. sp., *Smilacipites spinulifer* n. sp., *Magnoliaepollenites ellipticus* n. sp., *Quercoidites ellipsodeus* n. sp., *Tricolpopollenites elongatus* n. sp., *Brevitricolpites circularis* n. sp., *Tricolporopollenites javanensis* n. sp., *T. marginatus* n. sp., *T. rasus* n. sp., *Retitricolporites protensus* n. sp., *Striatricolporites triolatus* n. sp., *Polygalacidites speciosus* n. sp., *Graminidites punctulosus* n. sp., *Proteacidites matsuokae* n. sp., *Subtriporopollenites minutulus* n. sp., *Subtriporopollis specialis* n. sp., *Tiliaepollenites tropicus* n. sp.

ナングラン花粉群集は *Dicolpopollis malesianus, Polygalacidites speciosus, Striatricolporites* spp., *Proteacidites* spp., *Graminidites punctulosus* 等の主要花粉によって特徴付けられており，他の地域の若干の始新世花粉群集との比較研究がなされた。 高橋 清

Explanation of Plate 53

(All figures ×1000)

Figs. 1-2. *Proteacidites mollis* Samoilovitch
Fig. 1: slide GN 4655; Fig. 2: slide GN 4654.

Figs. 3-7. *Proteacidites matsuokae* n. sp.
Fig. 3: slide GN 4654; Fig. 4: slide GN 4657; Figs. 5a-b: holotype, slide GN 4653; Figs. 6-7: slide GN 4655.

Fig. 8. *Proteacidites* cf. *annularis* Cookson Slide GN 4655.

Figs. 9a-b. *Proteacidites similis* Harris Slide GN 4655.

Figs. 10-13(?), 18-19. *Subtriporopollenites minutulus* n. sp.
Figs. 10, 13: slide GN 4654; Fig. 10: holotype; Figs. 11, 18: slide GN 4653; Fig. 12: slide GN 4657; Fig. 19: slide GN 4656.

Figs. 14a-b. *Tiliaepollenites* cf. *punctulosus* Takahashi Slide GN 4654.

Fig. 15. *Subtriporopollenites* sp. Slide GN 4653.

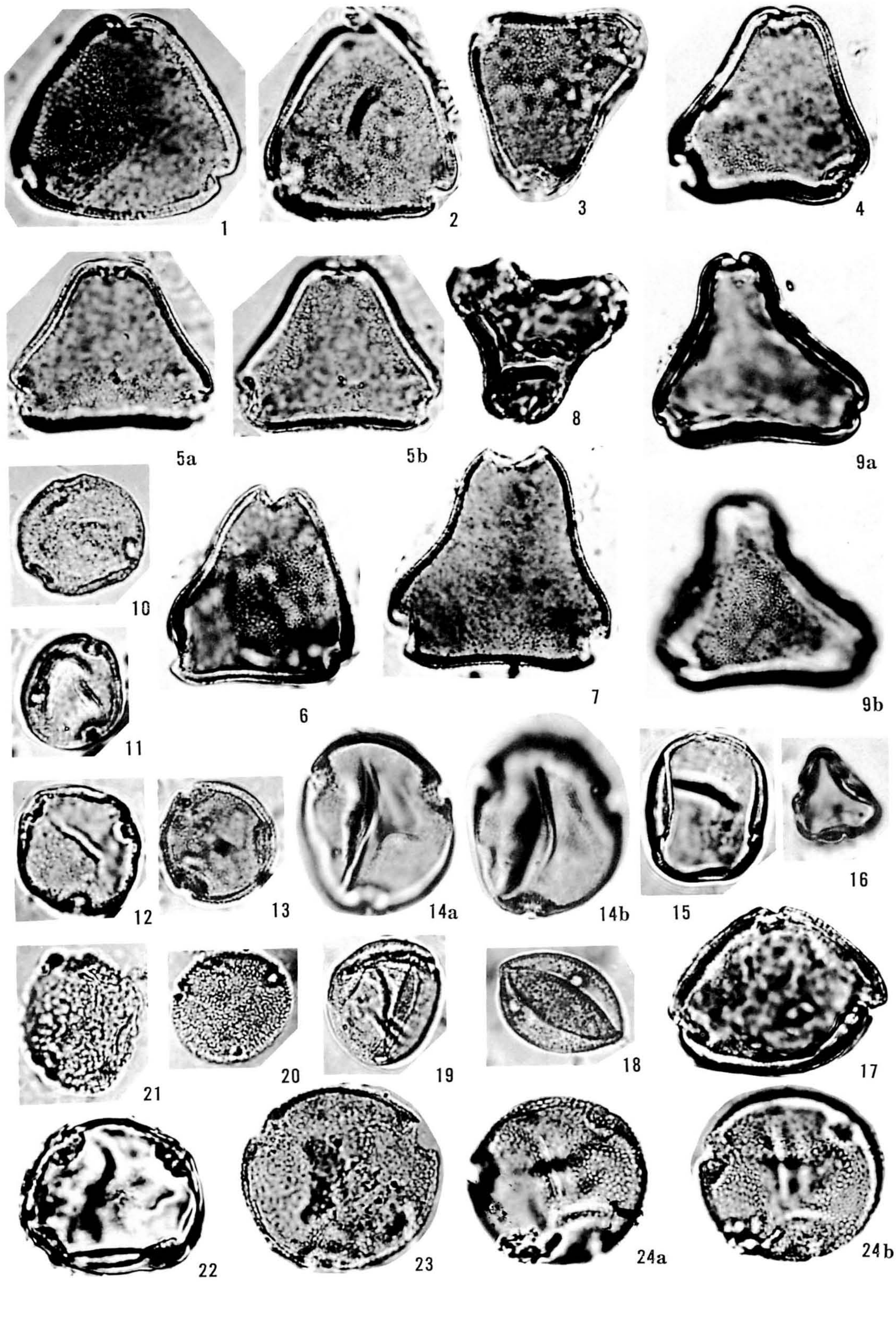
Fig. 16. *Triporopollenites* sp. a Slide GN 4653.

Fig. 17. *Triporopollenites* sp. b Slide GN 4656.

Figs. 20-21. *Subtriporopollis specialis* n. sp.
Fig. 20: holotype, slide GN 4656; Fig. 21: slide GN 4654.

Fig. 22. ?*Tiliaepollenites* sp. Slide GN 4657.

Figs. 23-24. *Tiliaepollenites tropicus* n. sp.
Fig. 23: slide GN 4654; Figs. 24a-b: holotype, slide GN 4657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Trans. Proc. Palaeont. Soc. Japan, N.S., No. 126, pp. 327-333, June 30, 1982

744. URANIUM-SERIES AGE OF THE "KAMETSU FORMATION", RIUKIU LIMESTONE ON THE TOKUNO-SHIMA, RYUKYU ISLANDS*

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Abstract. Uranium-series dating of some hermatypic corals (*Acropora* sp.) reveals that the uppermost part of the Pleistocene series occurred on Tokuno-shima (Central Ryukyus) is likely to be Middle Pleistocene in age, at least older than 300,000 years. Although the coral ages obtained are almost near or beyond the limitation of the $^{230}Th/^{234}U$ method of dating, the upper limit of the age is estimated from the mean $^{234}U/^{238}U$ activity ratio to be approximately 700,000 years. This result is suggestive that reefy sediments formed during the last interglacial stage, 120,000 eyars ago when sea level stood about 6 m higher than the present, is exposed nowhere on the island. In addition, the absence of the Holocene Raised Coral Reef Limestone (Hanzawa, 1935) on the island may also imply that the vicinity of Tokuno-shima has been locally subsided since the last 120,000 years.

The present paper deals with radiometric ages estimated by the $^{230}Th/^{234}U$ and $^{234}U/^{238}U$ methods for hermatypic corals from the uppermost part of the Pleistocene series on Tokuno-shima, Central Ryukyu Islands. These are the first uranium-series dates from this island, which allow us to correlate the dated stratigraphic unit with those on the other islands in Ryukyus and to relate it to various Pleistocene events in other areas.

Most of all islands in Central and Southern Ryukyus are capped or rimmed with Quaternary reefy limestone which was divided into two stratigraphic units, Pleistocene Riukiu Limestone and Holocene Raised Coral Reef Limestone by Hanazawa (1935). Subsequently, the Riukiu Limestone has been subdivided into a few unit on some islands. For an example, Nakagawa (1967) redefined the Pleistocene series on Tokuno-shima as the Ryukyu Group and stratigraphically subdivided into three, Kametsu, Kinoko and Itokina Formations, in descending order, each of which was morphostratigraphically correlated among subdivisions on the neighboring islands, Okierabu-jima, Yoron-jima and Kikai-jima (Nakagawa, 1969). It presents, however, practical difficulty to determine the age of each unit by means of a radiometric dating such as $^{230}Th/^{234}U$ method, because organic remains of calcium carbonate are diagenetically altered in most cases to stable phase (low Mg calcite) in phreatic and/or vadose environments. Moreover, morphostratigraphic technique also can be hardly employed to correlate among subdivisions on respective islands, because of the local variation in the rate of vertical displacement (Konishi *et al.*,

* Received July 21, 1981; read Jan 24, 1981 at Sendai.

1974). Those reasons have made it hard to assign chronologically the formation of Pleistocene series in Ryukyus, even though it was geologically investigated in detail and stratigraphically subdivided into some units.

The coral samples analyzed here are only a genus *Acropora* collected at Isen-zaki (27°39.4′ N Lat., 128°56.3′ E Long.), the southernmost end of Tokuno-shima (Fig. 1), where a narrow (ca. 100 m in width) but cospicuous marine terrace is developed over a distance of several kilometers along the coast. The top of the terrace is approximately 9 m in altitude. As illustrated in Fig. 2, the limestone unit which overlies a basal conglomerate is about 7 m in the maximum thickness. The uppermost part of the limestone unit is abundant in coral heads (mostly of *Acropora* sp.), over 100 cm in diameter in growth position. During five days for an on-the-spot investigation, fourty-eight coral heads were carefully examined for their mineralogical nature by the staining method using Feigl's solution in an area of about 20,000 m^2 on the surface of the terrace, and fifteen samples were chosen for their appearance of aragonitic nature and took back to the laboratory.

The terrace sediments shown in Fig. 2

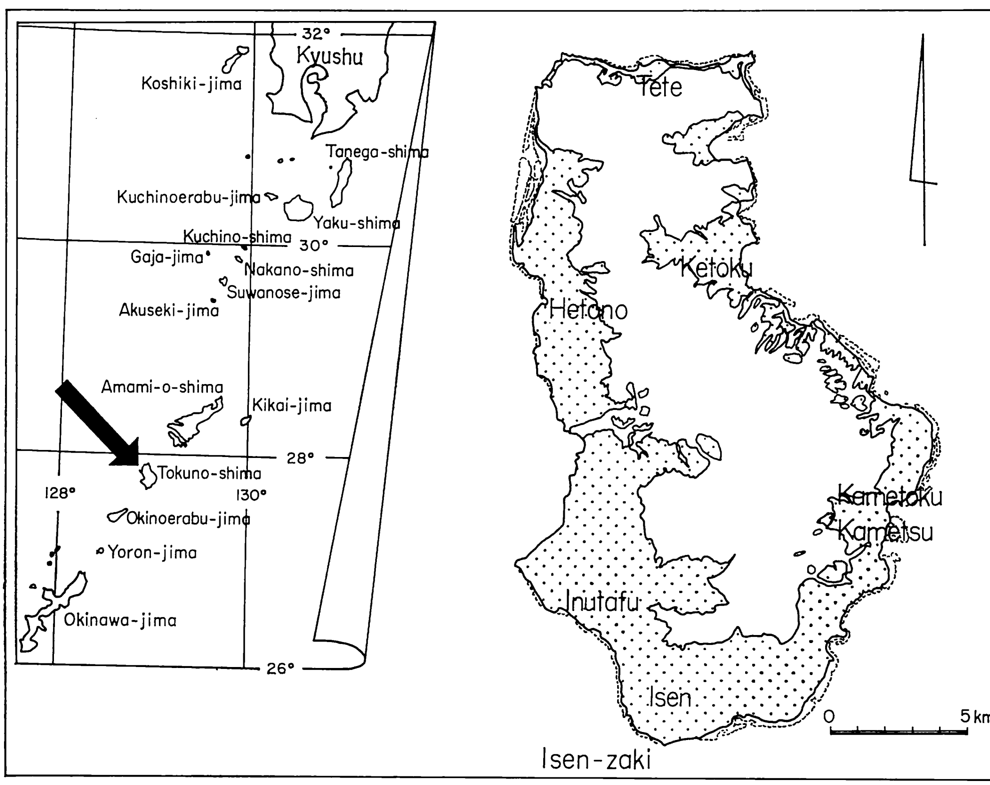

Fig. 1. Index map showing the locality where the fossil coral samples were collected. (Dotted part is the distributing area of Pleistocene series on Tokuno-shima; after Nakagawa, 1967).

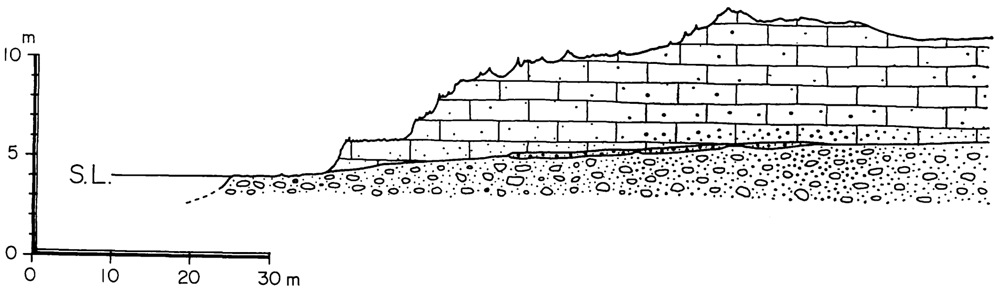

Fig. 2. Simplified sketch of the terrace sediments at Isen-zaki, the southernmost end of Tokuno-shima.

come under a part of the Kametsu Formation of Nakagawa (1967) and are regarded as the uppermost part of the Pleistocene series on Tokuno-shima. The ^{14}C dates of 5,800±230 (Machida *et al.*, 1976) through $43{,}700^{+7{,}000}_{-5{,}800}$ years B. P. (seen in the table compiled by Pirazzoli, 1978) have been reported for some corals which were collected at the same locality as the sampling site in this study. The Research Group for Active Faults (1980) seems to consider that the limestone units formed during two stages (120,000 and less than 100,000 years ago, respectively) are occurred along Isen-zaki.

Results of analyses are summarized in Table 1.

X-ray powder diffraction patterns revealed that low Mg calcite appeared owing to the recrystallization of skeletal aragonite was detectable in most samples. It was only one sample numbered as 80-2-9-5 that was free of the secondary calcite. In the present study, the analyses were repeated for this and the other two samples (Nos. 75-11-10-1 and 75-11-10-2) in which only a few percent or less in weight of calcite was detected. Two sorts of ^{232}U-^{228}Th spikes, namely "Harwell" spike allotted by the Uranium-Series Intercomparison Project (Harmon *et al.*, 1979) and "KU (Kanazawa Univ.)" spike prepared by the author, were used as yield tracers in the repeated analyses, separately. Consequently, the high reproducibility of the results attests to the reliability of each value listed in Table 1. ^{230}Th/^{234}U ages were calculated by the equation;

$$^{230}\mathrm{Th} = {}^{238}\mathrm{U}[1-\exp(-\lambda_0 t)] + ({}^{234}\mathrm{U} - {}^{238}\mathrm{U})[\lambda_0/(\lambda_0-\lambda_4)] \cdot [1-\exp(\lambda_4 t - \lambda_0 t)]$$

where λ_0 and λ_4 are decay constants of ^{230}Th and ^{234}U, respectively. The quoted errors are based on the counting statistics.

The samples containing five percent or more of calcite cannot be anticipated showing the reliable uranium-series dates, because a closed system respect to uranium and thorium isotopes has not been retained throughout their diagenetic history. The upper six ^{230}Th/^{234}U ages for three samples in Table 1, however, are reliable enough to use in the discussion below for the following evidences; (1) The specimens are entirely or almost free of recrystallization, as shown by the absence or an extremely small quantity of the secondary calcite. (2) The assumption of negligible initial ^{230}Th is supported by the observation that two samples seem to be free of ^{232}Th and that ^{230}Th/^{232}Th ratios in the other one

Table 1. Isotopic composition and estimated ages of fossil corals from the Kametsu Formation.

Sample No.	Calcite (wt %)	Isotope Concentraion				Activity Ratio			Estimated ^{230}Th Age (ka)
		^{238}U (ppm)	^{234}U (dpm/g)	^{232}Th (ppm)	^{230}Th (dpm/g)	^{234}U/^{238}U	^{230}Th/^{232}Th	^{230}Th/^{234}U	
80-2-9-5	0	3.07±0.05	2.30±0.04	< 0.02	2.32±0.04	1.01±0.02		1.01±0.02	> 468
		3.02±0.05	2.33±0.04	< 0.02	2.29±0.04	1.03±0.01		0.983±0.021	$423^{+\infty}_{-78}$
75-11-10-1	< 1	3.52±0.08	2.70±0.06	< 0.02	2.70±0.06	1.03±0.02		1.00±0.03	$486^{+\infty}_{-134}$
		3.41±0.09	2.60±0.07	< 0.02	2.60±0.06	1.02±0.02		1.00±0.03	$529^{+\infty}_{-169}$
75-11-10-2	3	3.34±0.04	2.58±0.03	0.0464±0.0085	2.63±0.06	1.04±0.01	236 ± 43	1.02±0.03	> 407
		3.42±0.05	2.55±0.04	0.0257±0.0034	2.46±0.03	1.02±0.01	392 ± 52	0.943±0.018	301^{+35}_{-27}
80-2-8-3	5	3.22±0.04	2.41±0.03	< 0.02	2.50±0.04	1.00±0.01		1.04±0.02	∞
80-2-9-2	5	3.26±0.04	2.45±0.03	0.0441±0.0077	2.07±0.04	1.01±0.01	196 ± 34	0.845±0.018	201^{+13}_{-12}
80-2-9-4	9	2.88±0.04	2.14±0.03	< 0.02	1.69±0.06	1.00±0.01		0.790±0.028	169^{+16}_{-13}
75-11-10-4	21	2.83±0.07	2.11±0.05	< 0.02	2.00±0.08	1.00±0.02		0.948±0.045	320^{+220}_{-70}
75-11-10-5	43	2.59±0.06	1.93±0.04	0.114±0.016	2.25±0.06	1.00±0.02	82.3±11.8	1.17±0.04	∞

(For the upper three samples, the results in the upper and lower rows were obtained by use of "Harwell" and "KU" spikes as a yield tracer, respectively.)

(75-11-10-2) are very much higher than those in natural waters, which are commonly 1 to 3.

The ^{230}Th/^{234}U ratios for the upper three samples in Table 1 range from 0.943±0.018 to 1.02±0.03. These values are suggestive that ^{230}Th has been nearly attained equilibrium with its parent ^{234}U. For this reason, the limestone unit from which the samples examined were derived appears to be too old for the ^{230}Th/^{234}U method of dating to be applicable, although the ages can be numerically calculated by using the above equation, as shown in the table. In other words, the Kametsu Formation of Nakagawa (1967) is regarded as being more than 300,000 years old.

Nakagawa (1969) attempted once to correlate morphostratigraphically the Kametsu Formation with his Wan Formation on Kikai-jima. On the other hand, the Pleistocene series on Kikai-jima was subdivided into four units, Araki Limestone, and Younger, Middle and Older Limestone Members of Riukiu Limestone, in descending order by Konishi *et al.* (1974), which have been dated by the ^{230}Th/^{234}U and ^{231}Pa/^{235}U methods to be 35,000-45,000, 55,000-65,000, 80,000-100,000 and 120,000-130,000 years, respectively. The Wan Formation of Nakagawa (1969) seems to be matchable a suit from the Araki Limestone through the Middle Limestone Member of Riukiu Limestone of Konishi *et al.* (1974). In this viewpoint, it may be said for the above-mentioned date of the Kametsu Formation to be too old contrary to the expectations. However, the reliability of an age of more than 300,000 years is supported by the average value of ^{234}U/^{238}U ratios in Table 1.

The $^{234}U/^{238}U$ activity ratio can be used to estimate the age of biogenic carbonates by the following equation, provided that the initial activity ratio (Ro) is known and the sample has remained closed to uranium and the daughters between ^{238}U and ^{234}U in the uranium decay series:

$$^{234}U/^{238}U=1+(Ro-1)e^{-\lambda_{234}t}$$

Because three values for Ro have been reported up to present, the equation is plotted in Fig. 3 to show the decrease of $^{234}U/^{238}U$ ratio as a function of time for the cases, each of which Ro is 1.15 (Thurber, 1962), 1.14 (Ku *et al.*, 1977) and 1.12 (Nikolayev *et al.*, 1979), respectively.

The $^{234}U/^{238}U$ ratios for the three samples are characterized by limited ranges of 1.01±0.02 to 1.04±0.01, and the mean is calculated to be 1.03±0.01. From this mean $^{234}U/^{238}U$ ratio, the age of the Kametsu Formation is estimated to be 387,000 through 709,000 years. Finally, it may be given as a conclusion here that the uppermost part of the Pleistocene series on Tokuno-shima is 300,000 years of age or more, the upper limit of which is estimated as being approximately 700,000 years.

It follows justly from a conclusion stated above that a question arises as to the reefy sediments which must have been formed around Tokuno-shima during high stand of the sea 120,000 years ago. Shoreline features standing about 6 m above the present sea level have been found in many places in the world, and they are thought to represent a eustatic high sea stand that occurred 120,000

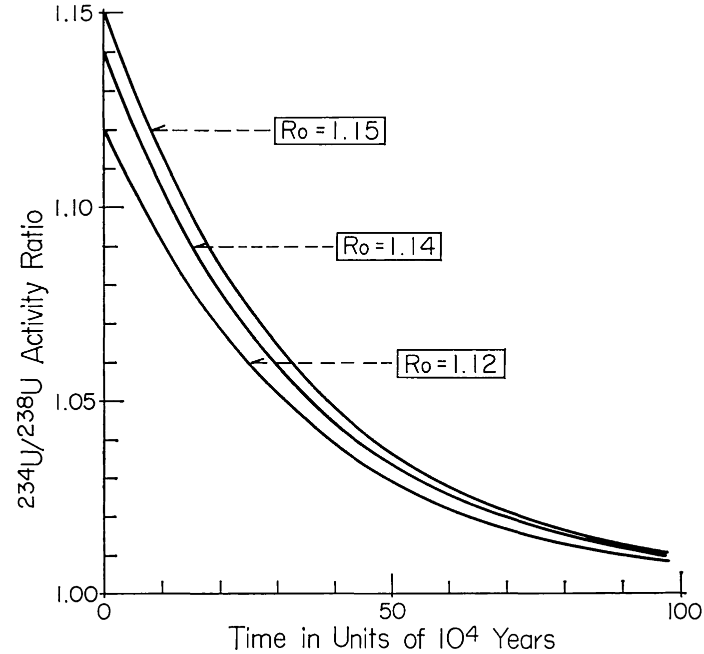

Fig. 3. Decay curves of the excess ^{234}U toward the secular equilibrium with ^{238}U for the initial $^{234}U/^{238}U$ activity ratios of 1.15 (Thurber, 1962), 1.14 (Ku *et al.*, 1977) and 1.12 (Nikolayev *et al.*, 1979).

years B. P. (Bloom *et al.*, 1974 ; and others). The then reefy limestone have been reported on Kikai-jima, which is located approximately 120 km NE of Tokuno-shima and is the outermost island in the central segment of the Ryukyu island arc, by Konishi *et al.* (1970, 1974). They argued from the present elevation of such a limestone unit and the other units formed during the subsequent interstadial phases that Kikai-jima has been rising at a rate of 1-2 m per 1,000 years since the last 120,000 years due to the neotectonic interplay as plate convergence of the active island arc and trench system. If Tokuno-shima has not been moved vertically during the past 120,000 years, the island should be surrounded by the coraliferous limestone unit which reaches the maximum elevation of about 6 m and is dated as being 120,000 years. As concluded above, even the uppermost part of the Pleistocene series is thought to be Middle Pleistocene in age and no Late Pleistocene reefy limestone is found on Tokuno-shima. Consequently, no occurrence of the reefy limestone formed in the last interglacial stage may be suggestive that Tokuno-shima locating more backward than Kikai-jima in the Ryukyu island arc, appears to have been subsided during the past 120,000 years. In addition, the absence of the Holocene Raised Coral Reef Limestone (Hanzawa, 1935) on Tokuno-shima may support that the vicinity of Tokuno-shima has been locally subsided since the last 120,000 years.

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徳之島"亀津層"(琉球石灰岩)の放射年代:南西諸島徳之島に分布する更新統最上部とされている亀津層(中川, 1967)から採集したサンゴ(*Acropora* sp.)化石について, ^{230}Th 年代を求めた。その結果, $^{230}Th/^{234}U$ 放射年代測定法の適用限界か, あるいはそれを越える値(30万年以上)が得られた。また $^{234}U/^{238}U$ 放射能比に基づく ^{234}U 年代は 387,000〜709,000年と推定された。すなわち, 亀津層の年代値は30万年以上, そしてその上限は約70万年と結論される。結局, 徳之島には喜界島などで見られる最終間氷期およびその後の数回の亜間氷期に形成された礁性堆積物(Konishi *et al.*, 1974)や完新世の"隆起サンゴ礁石灰岩"(Hanzawa, 1935, の Raised Coral Reef Limestone)が現在陸上に露出していなく, このことは, 少なくとも過去12万年間は, 徳之島付近が沈降傾向にあることを示唆している。 大村明雄

Trans. Proc. Palaeont. Soc. Japan, N.S., No. 126, pp. 334-340, pl. 54, June 30, 1982

745. A NEW NAUTILOID SPECIES FROM THE UPPER CRETACEOUS IZUMI GROUP OF SHIKOKU*

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Abstract. A specimen from the Upper Cretaceous Izumi Group of the Sanuki Mountains, Shikoku, is described as representing a new species of *Eutrephoceras*. This is clearly different from *E. dekay* (Morton), the type-species from the North American Atlantic Coast. But in the sutural pattern and shell form it possibly resembles *E. neubergicum* (Redtenbacher) from the Upper Cretaceous of Europe and is somewhat similar to *E. cookanum* (Whitfield) from the Lower Tertiary of North America. It is suggested that some characters of *Nautilus*, e. g. the less inflation of flanks and the slightly sinuous suture, are foreshadowed in this species.

Introduction

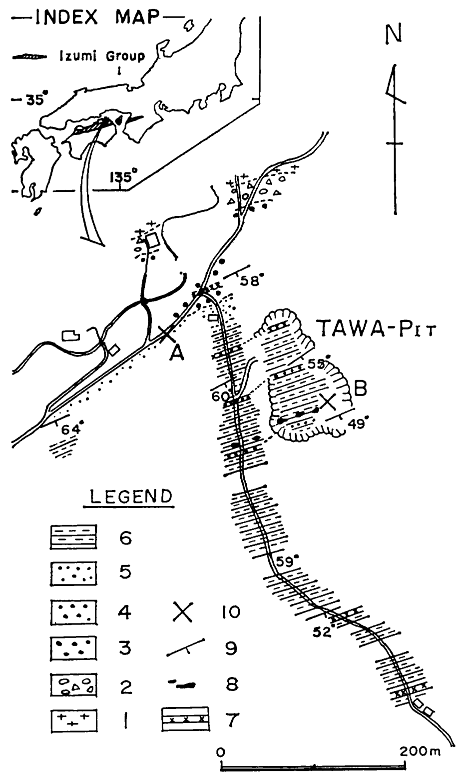
This paper is to report a new species of *Eutrephoceras* which was obtained from the Upper Cretaceous Izumi Group of the Sanuki Mountains of Shikoku and to consider its implications.

Geological Setting

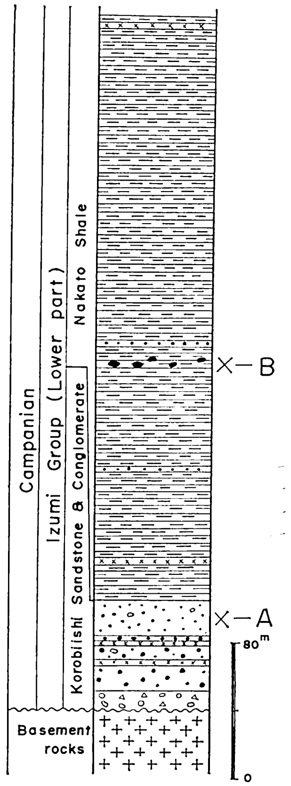
The locality where the natutiloid specimen was found is the Tawa pit (long. 134°12′07″E, Lat. 34°10′44″N; Text-fig. 1) at Tawa, Nagao-cho, Ookawa-gun, Kagawa Prefecture. In this pit, the strata of about 90 meters in thickness crop out. They belong to the Nakato Shale, which is a member in the lower part of the Izumi Group, and overlies conformably the basal member called the Korobiishi Sandstone and Conglomerate (Nakano, 1953; Nakagawa, 1961).

The nautiloid fossil was collected from a nodule of the hard calcareous mudstone in the massive black shale, about 150 meters above the base of the Izumi Group. The location is shown in Text-fig. 1, and the horizon is indicated as B in Text-fig. 2. From the same horizon-B I have collected *Baculites subanceps pacificus* Matsumoto et Obata, *Gaudryceras* sp., *Didymoceras* sp., Acteocinidae ? gen. et sp. indet., Aporrhaidae ? gen. et sp. indet., *Gyrodes* ? sp., Naticidae ? gen. et sp. indet., *Acila* (*Truncacila*) *hokkaidoensis* (Nagao), *Anomia* sp., *Glycymeris* sp., *Inoceramus* (*Endocostea*) *balticus toyajoanus* Nagao et Matsumoto, *I.* sp., *Nanonavis elongatus* (Nagao et Otatume), *Parvamussium* cf. *awajiense* (Ichikawa et Maeda), *P. yubarense* (Yabe et Nagao), *Portlandia cuneistriata* Ichikawa et Maeda, *Linthia* sp., shark teeth, fish scale and *Populus* sp., and from the horizon-A, about 150 meters lower than B (see Text-fig. 2), *Loxo japonica* (Amano). Among these fossils, ammonoids have been identified by Dr. T. Matsumoto,

* Received July 22, 1981; read July 29, 1980, at Kochi.



Text-fig. 1. Geological route map at and around the Tawa-pit. 1: granite, 2: conglomerate, 3: coarse-grained sandstone, 4: medium-grained sandstone, 5: fine-grained sandstone, 6: mudstone, 7: tuff, 8: nodule, 9: dip & strike, 10: locality of fossils, A & B: fossiliferous horizon; 1: basement rocks, 2-8: Izumi Group



Text-fig. 2. Geologic columnar section at and around the Tawa-pit (Legend: same as in Text-fig. 1)

gastropods by Mr. T. Kase, bivalves by Drs. M. Tashiro and M. Noda, plant by Dr. K. Matsuo, all of whom I owe much.

Now the horizon-B is characterized by the common occurrence of *Baculites*. This *Baculites* bed is traced to the west, and it seems to be stratigraphically higher than the *Metaplacenticeras subtilistriatum* (Jimbo) bed (Matsumoto *et al.*, 1980) which is exposed in the west of the area of Text-fig. 1. Consequently the bed which yielded the present specimen is regarded as Upper Campanian, because *M. subtilistriatum* and *B. subanceps pacificus* are the indices of the Upper Campanian (Matsumoto, 1977).

Palaeontological Description

Family Nautilidae de Blainville, 1825

Genus *Eutrephoceras* Hyatt, 1894

Type-species: *Nautilus dekay* Morton, 1834

Remarks: *Cimomia* and *Eutrephoceras* are rather similar with respect to shell form and sutures, but in the typical representatives of them there is some difference in the sutural pattern. According to Kummel (1956), in *Eutrephoceras* the suture is essentially straight or only slightly sinuous, but in some species of *Cimomia* it is so sinuous that it could lead to the *Hercoglossa* type suture. In some other species of *Cimomia,* it is transitional to the *Eutrephoceras* type.

Eutrephoceras is most intimately related to *Nautilus* (s. s.). I expect that the ancestor of living *Nautilus* could be found in some Late Cretaceous species of *Eutrephoceras* by way of the Tertiary ones.

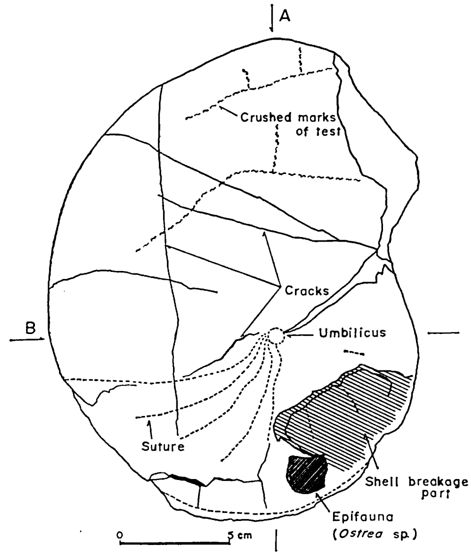
Occurrence: Upper Jurassic to Neogene. World wide.

Eutrephoceras tawaense sp. nov.

Pl. 54, Figs. 1-4; Text-figs. 1-4

Holotype: K-4-50 (in my collection number), to be kept in the Kagawa Natural Science Museum of Kagawa Prefecture. It consists of a completely preserved phragmocone (internal mould) and the body chamber of one-third volution. The shell is partly crushed, as illustrated in Text-fig. 3 and Pl. 54, Fig. 1. The surface of the whorl has partly test and some epifauna. On the body chamber weak breakage and cracks are recognized and the conch is slightly deformed, as illustrated in Text-figs. 3, 4-A and B and Pl. 54, Fig. 2.

Diagnosis: Shell nautiliconic, subglobular and involute. Umbilicus rather small with rounded umbilical shoulder,



Text-fig. 3. Lateral view of the holotype of *E. tawaense* sp. nov. A & B: Position of conch section shown in Text-fig. 4 and the measured points

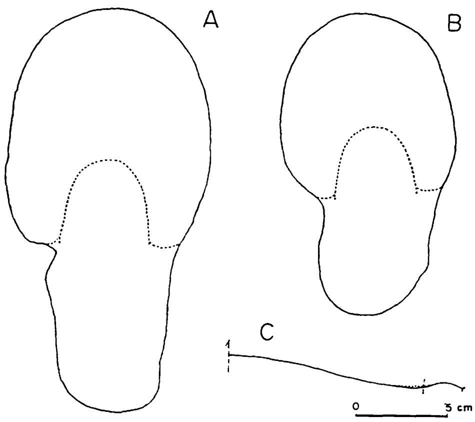
and funnel like wall. Whorl nearly as high as broad or slightly higher than broad, with moderately convex flanks and moderately rounded venter. Suture forms very widely arcuate ventral saddle, very shallow lateral lobe and a small and indistinct saddle on the umbilical wall. Position of siphuncle unknown.

Remarks: Cross section of the whorl is illustrated in Text-fig. 4-A and B. If the undeformed shell is measured, the ratio of the height to the breadth of the whorl may be approximately 0.96. The tangent line on the whorl side is almost

Measurments (in mm.) of *Eutrephoceras tawaense* sp. nov.

	Diameter	Umbilicus	Height	Breadth	B./H.
(A) Preserved last part	213.3 (100)	7.7 (4)	126.5 (59)	107.9 (51)	0.85
(B) Near the last septum	164.4 (100)	— (5)	100.5 (61)	96.3 (59)	0.96

(A & B: shown in Text-fig. 3)



Text-fig. 4. Conch section and suture of the holotype of *E. tawaense* sp. nov. A & B: shown in Text-fig. 3

parallel or slightly convergent. Venter and ventral shoulders are moderately rounded. There are about 5 camerae in an adoral quarter-volution. Umbilicus is measured about 7.7 mm. Shell surface of the preserved test as well as the internal mould is almost smooth without rursiradiate ribs of *Cymatoceras* type. The lateral lobe of the last suture is more concave than the others, but it may have been secondarily modified as suggested by a crack. The restored original lateral lobe is as shallow as the line shown in Text-fig. 4-C. Eight septa are exposed on a part of the outer volution. The septal distances on the mid-lateral of the exposed part are measured in mm. in aboral order as follows:

13.3, 14.4, 15.5, 14.1, 21.7*, 18.2*, 17.5
(*: on the crushed air-chamber)

Comparison: Judging from the character of the suture, shell form and the smooth surface, the present species is assigned to *Eutrephoceras*. It is clearly distinguished from *Eutrephoceras dekay* (Morton) (Morton, 1834; see Miller and Garner, 1962), the type-species, from the Upper Cretaceous of the Atlantic Coast of North America, in its narrower whorl section and its suture without ventral lobe.

With respect to the suture, the present species is similar to the following species:

Eutrephoceras kobayashii Matsumoto, 1962, Japan
E. kummeli Wiedmann, 1960, India, Madagascar and South Africa
E. meritenii Wiedmann, 1960, India, and Spain
E. montomollini (Pictet et Campiche), 1859, England, France and Switzerland
E. neubergicum (Redtenbacher), 1873, Austria and Germany
E. sp. Morozumi, 1979, Japan

E. kobayashii from the Upper Cretaceous of Hokkaido has a somewhat broader whorl section, larger umbilicus and more inflated flanks; *E. kummeli* (Wiedmann, 1960, p. 166-167, pl. 20, figs. B-D, pl. 25, figs. 3, 6-7) has a more globular conch; *E. montomollini* (see Wiedmann, 1960, p. 164, pl. 19, fig. G, pl. 23, fig. H) has a subtriangular whorl section and more globular conch and *E. meriteni* (Wiedmann, 1960, p. 164-165, pl. 25, figs. 4-5, pl. 26, figs. 5-6, text-fig. 7) an ovoidal whorl section and more involute conch than the present species.

E. neubergicum seems to be very similar to the present species in its restored shell form and pattern and density of septa. The illustrated specimens from the Alps (Hauer, 1858, p. 14, pl. 1, figs. 1-2; Redtenbacher, 1873, p. 97-98, pl. 22, fig. 4) and Germany (Schlüter, 1876, p. 174-175, pl. 48, figs. 3-5) are smaller and somewhat deformed and the precise comparison with ours is difficult.

Meanwhile, Wiedmann (1960) regarded "*Nautilus*" *neubergicus* from the Alps as an example of *Angulithes fleuriausianus* (d' Orbigny) (Wiedmann, 1960, p. 183-185, pl. 19, fig. A, pl. 20, figs. N, O, pl. 21, figs. I, L, M, pl. 23, fig. O, pl. 26, figs. 1-3, text-figs. 14-15) and transferred *N. neubergicus* from Germany to *Eutrephoceras darupense* (Schlüter) (Wiedmann, 1960, p. 157-158, pl. 21, figs. C (upper), D, pl. 23, figs. F, P, text-fig. 2). As is shown by Hauer's illustration (1858, pl. 1, figs. 1-2), the Alpine specimen indeed suggests a similarity to *A. fleuriausianus*, but there still remain unsettled points. It is doubtful whether the open umbilicus is readily closed by the depression or not. The illustrated syntypes of *E. darupense* (Schlüter, 1876, p. 176, pl. 49, figs. 4-5) have clearly broader septal interspaces than *E. neubergicum* and a closed umbilicus. One of the illustrated specimens of *N. neubergicus* by Schlüter (1876, pl. 48, fig. 5) shows a ventrally situated siphuncle like that of *E. darupense*, but the siphuncle position of other specimens (Schlüter, 1876, pl. 48, figs. 3-4) is not known, as in the Alpine specimens. From these points it is still premature to erase the name *E. neubergicum*. Whether the subtrigonal whorl section in the illustrated type of "*Nautilus*" *neubergicus* Redtenbacher (Hauer, 1858, pl. 1, figs. 1-2) is as a product of secondary deformation or the *Angulithes* type primary character is uncertain. The suture of *Angulithes* is, as a rule, considerably sinuous. For the time being, I follow Kummel (1956, p. 382), who has assigned this species to *Eutrephoceras*. (Prof. Matsumoto made an inquiry about this point to Dr. Summersberger, but has not yet received an answer.)

E. sp., which was described by Morozumi (1979) from the Upper Cretaceous Izumi Group of the Izumi Mountains, seems to resemble the present species, but the specimen is too incompletely preserved for the precise comparison.

In addition to these species, *E. alsecence* Reeside (Reeside, 1927, p. 7, pl. 1-2, pl. 3, figs. 1-5, pl. 5, figs. 1-2), from the Upper Cretaceous of the Western Interior of North America, should be taken into comparison. I have excluded it from a group of the above mentioned species for the reason of its having a shallow ventral lobe. Otherwise, this specise is especially similar to the present species in the shell form, septal distance and size.

With respect to the sutural pattern, the present species may be compared also with the following Tertiary species of *Eutrephoceras*:

Eutrephoceras bryani (Gabb), 1877, U. S. A.
E. cookanum (Whitfield), 1892, U. S. A.
E. japonicum (Shimizu), 1926, Japan
E. oregonense Miller, 1947, U. S. A.

Except for *E. japonicum*, the above species have less inflated flanks, as in the present species. *E. bryani* (Miller, 1947, p. 28-29, pl. 8, figs. 1-4, pl. 93, figs. 1-2), however, is clearly distinguished by its much broader umbilicus, broader spacing of suture and more compressed whorl section at the adult stage.

It should, however, be taken into consideration that the septal distance may change with growth. The measurements shown in the preceding page suggest that the septa may be somewhat more widely spaced in immature stages than in the adult stage of the present species. Be that as it may, the present species can be distinguished from *E. bryani* in other points.

E. cookanum (Whitfield) (1892, p. 285-286, text-fig. 2, pl. 48, fig. 1, pl. 49, figs. 4-5; Miller, 1947, p. 30-31, pl. 10, figs. 1-2, pl. 11, figs. 1-3, pl. 12, fig. 1) has a more rounded whorl section and somewhat larger umbilicus than the present species. It has about 4 or 5 camerae in a quarter volution, and is rather similar to the present species as compared with the others.

E. oregonense (Miller, 1947, p. 34, pl. 21, figs. 1-2) has a more or less subdiscoidal conch and there are about 7 camerae in the adoral quarter volution.

E. japonicum (Shimizu, 1958, p. 25-27, pl. 8, figs. 1-6; Kobayashi and Kamada, 1959, p. 109-110, text-figs. 2-3, pl. 9, figs. 1-2) is more globular in shell form with the maximum breadth in the lower part of whorl section and there are only 3.5 camerae in a quarter volution, although its sutural pattern closely resembles that of the present species.

Concluding Remarks

To sum up, the present new species resembles certain Cretaceous and Early Tertiary species of *Eutrephoceras* in shell form and suture. Especially it closely resembles *E. neubergicum* from the Upper Cretaceous of Europe and somewhat similar to *E. cookanum* from the Lower Tertiary of North America. It is also suggested that it may foreshadow some characters of *Nautilus*, such as the less inflation of flanks and the slightly sinuous suture.

Acknowledgements

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Hokkaido: 北海道 Izumi: 和泉 Kagawa: 香川 Korobiishi: 転石 Nagao-cho: 長尾町 Nakato: 中通 Ookawa-gun: 大川郡 Sanuki: 讃岐 Shikoku: 四国 Tawa: 多和 Yezo: 蝦夷

四国の上部白亜系和泉層群から産出したオウムガイ類化石（新種）：香川県に分布する上部白亜系和泉層群の中通頁岩層からオウムガイ類化石が産出した。これを *Eutrophoceras* の新種として記載した。貝殻は密巻きでへそが小さく亜球状である。縫合線はゆるい曲線で腹部に広い鞍部と側面に浅くて広い総部，へそ壁にあまり目立たない小さな鞍部をもっている。

類似の縫合線を持つ種として，白亜紀後期の *E. kobayashii*, *E. kummeli*, *E. meriteni*, *E. montomollini*, *E. neubergicum* と和泉山脈から報告された *E.* sp., 第三紀初期の *E. bryani*, *E. cookanum*, *E. japonicum*, *E. oregonense* がある。これらのうち白亜紀後期の *E. neubergicum*（これ自身に少し問題あり）と第三紀初期の *E. cookanum* が隔壁の形状においてよく類似している。

なお螺環があまり膨れておらず縫合線が軽微ながら波曲することは *Nautilus* の性状への前兆を暗示しているように思う。

産出層の地質時代は *Baculites subanceps pacificus* を伴うこととそれが本地域の西方で *Metaplacenticeras subtilistriatum* の産出層準の上位より産出することから上部カンパニアンに対比される。

古市光信

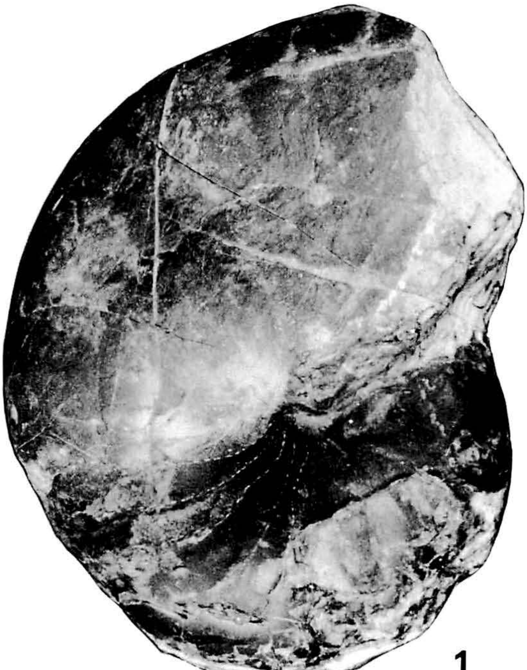
Explanation of Plate 54

Figs. 1-4. *Eutrephoceras tawaense* sp. nov.

1 & 3. Lateral views .... ×2/5 (holotype, K-4-50)

2. Apartural view .... ×2/5 (ditto)

4. Ventral view .... ×2/5 (ditto)



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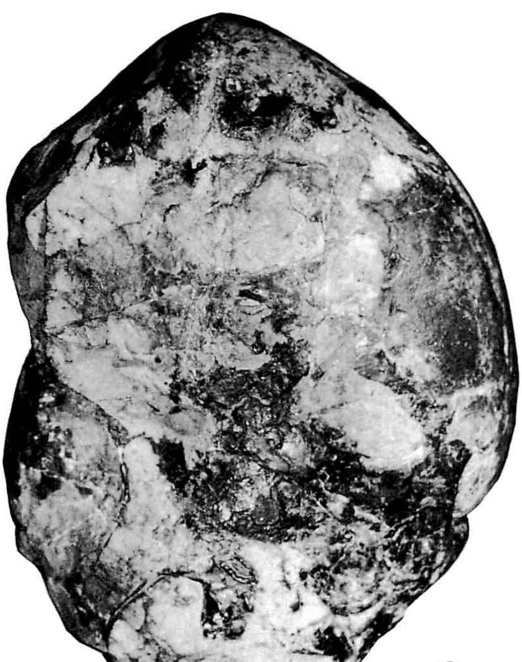

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Trans. Proc. Palaeont. Soc. Japan, N.S., No. 126, pp. 341-355, pls. 55, 56, June 30, 1982

746. SOME CRETACEOUS ECHINOIDS FROM THE MONOBE AREA, CENTRAL SHIKOKU*

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Abstract. This paper contains the systematic descriptions of some spatangoid echinoids from the Monobe area, Kochi Prefecture. The echinoids from the Barremian Monobe-Yunoki Formation are assigned to *Heteraster* (3 species) and a new genus (1 species), and a species from the Santonian part within the Kajisako Formation to *Epiaster*. The Barremian species are common to those from other areas in the Outer Zone of Southwest Japan. A new genus is established for a species characterized by having a single peripetalous fasciole. As an appendix an Albian species belonging to this genus from another area in Japan is redescribed.

Introduction

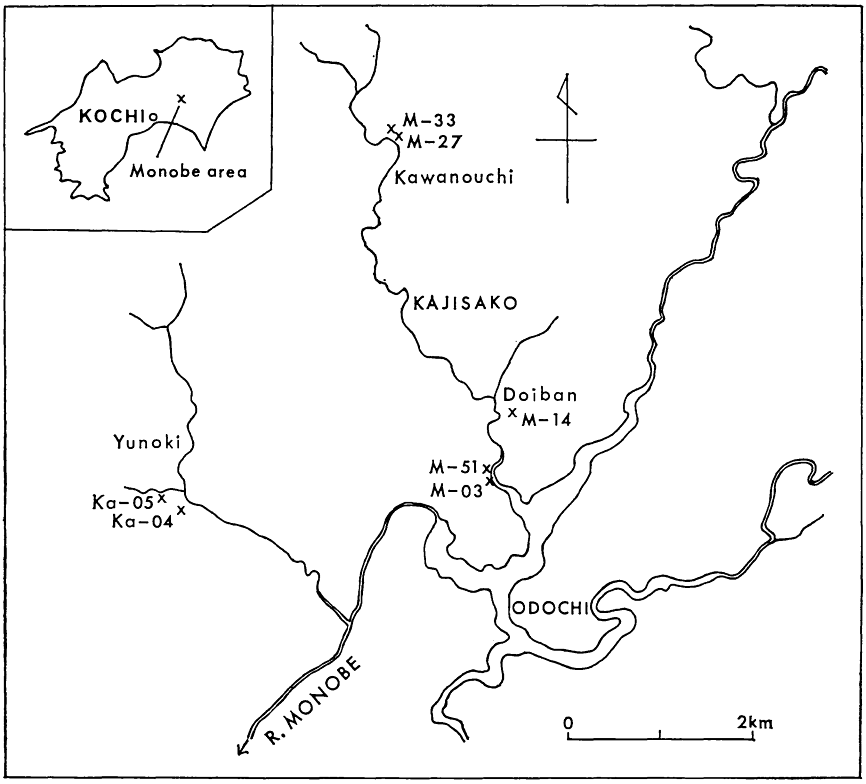
The Monobe area, Kochi Prefecture (Text-fig. 1) is known as one of the classical and typical outcrop areas of the Lower Cretaceous in Southwest Japan. Recently a large number of molluscan fossils were discovered at various horizons within the Cretaceous strata of this area. These fossils have been intensively studied by specialists of respective fields. Consequently, our knowledge about the Cretaceous stratigraphy of the present area have much increased. The up-to-date stratigraphic context of the Monobe Cretaceous has been described elsewhere (Tashiro, Kozai, Okamura and Katto, 1980; Tashiro, Kozai and Katto, 1980).

Echinoid fossils occur at several horizons associated with abundant marine molluscan fossils, though in small numbers. All the echinoid specimens for the present study were collected by the junior author (Kozai), and then their specific identification was carried out by the senior author (Tanaka). Thus, this paper is to present the result of our study on these echinoids. Furthermore, appended to this paper by the senior author in connexion with the establishment of a new genus is the descriptive remarks on a hitherto described species concerned.

The repositories of the specimens described here are as follows: OES= Odochi Elementary School, Kochi; GSJ= Geological Survey of Japan, Tsukuba.

Before going further, we wish to express our sincere gratitude to Professor Emeritus Tatsuro Matsumoto of Kyushu University for his valuable suggestions and kindness in critical reading of the

* Received August 3, 1981.



Text-fig. 1. Localities of echinoid specimens in the Monobe area.

draft. We are also indebted to Dr. Masayuki Tashiro of Kochi University and Dr. Ikuwo Obata of the National Science Museum, Tokyo for their helpful advice, to Professor Keiji Nakazawa of the Department of Geology and Mineralogy, Kyoto University for permission to examine the collection, and to Mr. Yoshio Masai of the Geological Survey of Japan for photographing the specimens.

Localities of Echinoid Specimens

The details of the biostratigraphy of the Cretaceous strata in the Monobe area have been published elsewhere (Tashiro, Kozai, Okamura and Katto, 1980; Tashiro, Kozai and Katto, 1980). The Lower Cretaceous of this area is divided in ascending order into the Monobe Formation (Lower Barremian), the Yunoki Formation (Upper Barremian) and the Hibihara Formation (Aptian-Albian), which are about 400 m, 750 m and 800 m thick respectively. Each formation consists of sandstone, partly conglomeratic, in the lower part and mudstone in the upper part. The Lower Cretaceous echinoid examined came from locs. M-27 and M-33 of the Monobe Formation and from locs. Ka-04 and Ka-05 of the Yunoki Formation (Text-fig. 1). All these localities are occupied by siltstone or fine sandy siltstone. Loc. Ka-04, among others, yields a number of echinoids. The Upper Cretaceous strata, about 250 m thick, comprise the Nagase Formation (Cenomanian) below and the Kajisako Formation (Turonian-Lower Campanian) above. The Nagase Formation is dominated by sandstone, and the Kajisako Formation by mudstone. Only one Upper Cretaceous specimen available for this study was obtained from loc. M-14 of the Upper Santonian part within the Kajisako Formation (Text-fig. 1).

Locs. Ka-04 and Ka-05 are situated at Kahoku-cho, Kami-gun, Kochi Prefecture, and locs. M-27, M-33 and M-14 at Monobe-mura, Kami-gun.

Systematic Descriptions

Subclass Euechinoidea Bronn, 1860

Superorder Atelostomata Zittel, 1879

Order Spatangoida Claus, 1876

Suborder Toxasterina Fischer, 1966

Family Toxasteridae Lambert, 1920

Genus *Epiaster* d'Orbigny, 1853

Remarks:—The genus *Epiaster* has been regarded as a synonym of the genus *Heteraster* by Fischer (in Moore, ed., 1966). But, following Mortensen's (1950) classification of the Echinoidea, we separate *Epiaster* from *Heteraster* as a distinct genus. Actually, *Epiaster* is characterized by, among other features, the frontal ambulacrum having rounded or comma-shaped pore pairs separated by a granule and by the paired ambulacra which are petaloid, generally depressed, and more or less closed distally, with nearly equal poriferous zones. On the other hand, in *Heteraster* the frontal ambulacrum has regularly or irregularly alternating larger and smaller pores and the anterior paired ambulacra are composed of unequal poriferous zones. Thus, the two genera are clearly distinguishable from each other.

Epiaster sp. aff. *E. nobilis* Stoliczka

Pl. 55, Fig. 1

Compare:

1873. *Epiaster nobilis* Stoliczka, *Mem. Geol. Surv. India, Palaeont. Indica*, ser. 8, vol. 4, pt. 3, p. 20, pl. 3, figs. 7-8.

Material:—OES. 14007A, B (A, internal mould; B, imperfect external mould of aboral surface), from loc. M-14.

Description:—This is secondarily deformed. The test is medium-sized, and seems to have a rather roundly subovate outline which is somewhat longer than wide. The frontal sinus is rather shallow, becoming much shallower near the ambitus; thus the anterior notch, if any, is probably indistinct. The apical system is subcentral, and its structure is uncertain because of the poor preservation.

The frontal ambulacrum is rather shallowly sunken and subpetaloid; at the middle of the petaliferous part the poriferous zones are somewhat narrower than the interporiferous ones. Its pore pairs are small, comma-shaped, circumflexed, and are separated by a granule. The paired ambulacra are wider than the frontal ambulacrum, nearly straight, shallowly sunken, petaloid, and more or less closed distally. The anterior paired petals are slightly longer, slightly wider and much more divergent than the posterior, extending about two-thirds the way to the margin. The pores of the anterior petals are transversely elongated, and are somewhat longer in the posterior poriferous zones than in the somewhat narrower anterior; the pores of each pair are opposite and not conjugate. The posterior petals extend about two-thirds the way to the ambitus, and have poriferous zones of nearly equal width, with similar elongate pore pairs.

The peristome is anterior and transversely oval. The plastron is amphisternous, probably protamphisternous. Periproct is not observable. The aboral surface is covered with numerous minute granules and fine tubercles. Peripetalous or lateroanal fasciole is not present.

Remarks:—Whether a subanal fasciole is present or lacking in the specimen available can not be ascertained owing to the poor preservation. Nevertheless, the present form is safely referable to *Epiaster* on the basis of the general features of the test. This species closely resembles *Epiaster nobilis* Stoliczka, from the Senonian (Arrialoor Group) of India, in many respects. However, it differs from that species in that its paired petals are more closed distally than in the Indian species. It is also to some extent similar to an undescribed species of *Epiaster* obtained by the senior author from the Aptian Hinagu Formation of Kyushu. The Hinagu specimens, however, are considered as representing a distinct species separated from the present species by their paired ambulacra that are narrower, more flexuous, less petaloid and more open distally. Moreover, the present form is easily distinguished from *Epiaster nutrix* Lambert (1903, p. 86, pl. 3, figs. 3-5), from the Senonian of Madagascar, by having nearly equal paired petals that are longer, wider, less sunken and less closed distally.

Occurrence:—A block at loc. M-14, middle part of the Kajisako Formation, siltstone interlaminated with fine sandstone, Upper Santonian because of the associated occurrence of *Inoceramus japonicus* Nagao et Matsumoto.

Genus *Heteraster* d'Orbigny, 1853

Remarks:—The genus *Paraheteraster* Nisiyama, 1968 (type-species: *Washitaster* (?) *macroholcus* Nisiyama, 1950, from the Barremian of Japan), is regarded as a synonym of *Heteraster*. This is to be discussed in the later part of this paper.

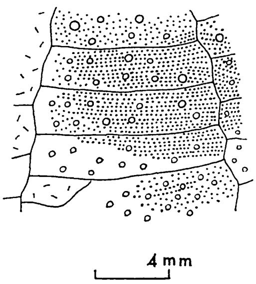
Heteraster macroholcus (Nisiyama)

Pl. 55, Fig. 2

1950. *Washitaster* (?) *macroholcus* Nisiyama, *Inst. Geol. Palaeont. Tohoku Univ., Short Papers*, no. 1, p. 44, text-figs. 4-6.
1954. *Washitaster macroholcus*, Tanaka and Okubo, *Jour. Geol. Soc. Japan*, vol. 60, p. 221, pl. 7, figs. 1-2, text-figs. 5, 7.
1954. *Washitaster barremicus*, Tanaka and Okubo, *Ibid.*, vol. 60, p. 220, pl. 7, fig. 3, text-fig. 7.
1965. *Heteraster macroholcus*, Tanaka, *Trans. Proc. Palaeont. Soc. Japan*, N. S., no. 59, p. 133, pl. 16, figs. 3-4, text-fig. 4.
1968. *Paraheteraster macroholcus*, Nisiyama, *Palaeont. Soc. Japan, Special Papers*, no. 13, p. 190, pl. 21, fig. 3; *Ibid.*, no. 11 (1966), pl. 18, figs. 3, 12-13.
1968. *Paraheteraster barremicus*, Nisiyama, *Ibid.*, no. 13, p. 191.

Material:—OES. 04153, 04177 and 04179, from loc. Ka-04, and probably also OES. 27006, from loc. M-27.

Descriptive remarks:—In the present species the frontal sinus is deep and very long, with a distinct anterior notch, the frontal ambulacrum shows an irregular alternation of several longer pores and one shorter pore in the outer row and somewhat inward disposition of pores (slightly smaller than the normal round to oval pores), opposite to shorter outer pores, in the inner row, the paired ambulacra are flush, and the peristome is deeply sunken. Furthermore, a broad, diffuse granular band or pseudo-fasciole which is covered with streaks of granules very slightly smaller than those covering the rest of the aboral surface and decorated with tubercles, as figured by Devriès (1960, pl. 16, figs. 5-6), surrounds the petals (Text-



Text-fig. 2. Diagrammatic sketch of granular band in *Heteraster macroholcus* (Nisiyama). GSJ. 6016, from the Arida Formation (Lower Barremian), northeast of Yuasa, Wakayama Prefecture.

fig. 2). It is about 6 mm wide in an about 70 mm long test. The largest (OES. 04153) of the specimens available probably attains about 70 mm in length.

Occurrence:—Loc. Ka-04, Yunoki Formation, fine sandy siltstone, Upper Barremian (OES. 04153, 04177, 04179). Moreover, one specimen (OES. 27006) probably identical with this species is found in sandy siltstone of the Monobe Formation (Lower Barremian) at loc. M-27.

Heteraster nexilis Nisiyama

pl. 55, Fig. 3

1950. *Heteraster nexilis* Nisiyama, *Inst. Geol. Palaeont. Tohoku Univ., Short Papers*, no. 1, p. 42, text-figs. 1-3.
1968. *Heteraster nexilis*, Nisiyama, *Palaeont. Soc. Japan, Special Papers*, no. 13, p. 186.

Material:—OES. 27001, 27002-1 and 27002-2, from loc. M-27, and probably also OES. 33012, from loc. M-33.

Descriptive remarks:—This species is characterized by, among other features, the moderately deep frontal sinus, distinct anterior notch, alternations of two to three larger pores and one smaller pore at the middle of the frontal ambulacrum, and by the superficial paired ambulacra. One (OES. 27001) of the specimens, though longitudinally compressed secondarily, is probably at least 27 mm long.

Occurrence:—Loc. M-27, Monobe Formation, siltstone, Lower Barremian (OES. 27001, 27002-1, 27002-2). Moreover, a specimen (OES. 33012) probably identical with this species is found in fine sandy siltstone of the Monobe Formation (Lower Barremian) at loc. M-33.

Heteraster sp.

Pl. 55, Fig. 4

Material:—Two specimens, OES. 04154 and 04167, from loc. Ka-04, and another OES. 05057b, from loc. Ka-05.

Description:—The specimens available are poorly preserved and somewhat deformed by the subsequent disfigurement. The frontal sinus is rather shallow, becoming much shallower towards the ambitus, thus the anterior notch, if any, is probably indistinct. The frontal ambulacrum is rather shallowly sunken and subpetaloid. Its poriferous zones show regular alternations of a pair of slit-shaped pores widely spaced and a pair of elongate oval pores close together, the pore pairs lining up in four files. However, in each specimen only a double pair of longer pores is placed opposite to each other at the middle of the two poriferous zones. The paired ambulacra are somewhat flexuous, slightly sunken and subpetaloid. The anterior paired ambulacra consist of anterior poriferous zones with elongate oval pores close together and much wider posterior poriferous zones with slit-shaped pores widely set. The poriferous zones of the posterior paired ambulacra have slit-shaped pore pairs. The peristome is transversely oval and shallowly sunken.

The plastron is mesamphisternous. The periproct is longitudinal oval.

Remarks:—The present form is closely similar in many respects to *Heteraster yuasensis* (Tanaka et Okubo) (1954, p. 223, pl. 7, fig. 6, text-fig. 7; redescribed by Tanaka, 1965, p. 136. pl. 16, figs. 6-7, text-fig. 6), from the Barremian of various areas in the Outer Zone of Southwest Japan. But the presence of double pairs of longer pores in the frontal ambulacrum is not known in any specimens hitherto referred to *Heteraster yuasensis* (instead, a double pair of smaller pores is exceptionally observed in either of the both poriferous zones in some specimens), even when the test is of normal size. Since the present specimens are very small (probably about 12 mm long) and have no more than twenty pore pairs in the petaliferous part of the frontal ambulacrum, they are considered as representing young individuals. Therefore, it is suggested that the presence of a double pair of longer pores in the frontal ambulacrum is not due to intraspecific variation in a given species such as *Heteraster yuasensis*. Double pairs of longer pores, if present, may occur more commonly in the expected larger (adult) forms than in the smaller (young) forms of the species described here. This, together with the slightly depressed paired ambulacra, may remind us of some similarity of the present form to a *Heteraster* species, from the Barremian Arida Formation of the Yuasa area, Wakayama Prefecture (Tanaka and Okubo, 1954, p. 224, pl. 7, fig. 7, text-fig. 7), which has been compared with *Heteraster böhmi* (Loriol) (synonymous with *H. bravoensis* (Böse) according to Cooke, 1955) with some doubts. Anyhow, we refrain from further taxonomic discussion of the present form, because of the very small size and poor preservation of the material available.

Occurrence:—Loc. Ka-04, Yunoki Formation, siltstone, Upper Barremian (OES. 04154, 04167); loc. Ka-05, Yunoki Formation, siltstone, Upper Barremian (OES. 05057b).

Suborder Hemiasterina Fischer, 1966

Family Hemiasteridae Clark, 1917

Genus *Pseudowashitaster* Tanaka nov.

Type-species: — *Pseudowashitaster mysticus* Tanaka, sp. nov. (described below)

Generic diagnosis:—Test large or rather large, oval in outline, with a very long, deep frontal sinus; anterior notch distinct. Apical system far posterior, ethmophract, with four gonopores. Frontal ambulacrum very long, deeply sunken; prre pairs generally similar, not separated by a granule. Paired ambulacra flexuous, very unequal in length and width; poriferous zones unequal; anterior zones with minute, round pores; much wider posterior zones with elongated pores. Anterior paired ambulacra considerably narrow almost throughout the way, much longer, much narrower, much less divergent than the posterior, very slightly sunken; posterior paired ambulacra flush. Peristome far anterior; periproct high up on the posterior truncated surface. Peripetalous fasciole single, distinct; no other fascioles.

Occurrence:—So far as the material available is concerned, this new genus contains two species to be described below, from the Barremian and the Albian of Japan respectively. Moreover, an undescribed species probably referable to this genus is found in the Aptian of Japan.

Remarks:—This new genus is similar to *Washitaster* in the general features of the test. But the former differs from the latter in that the peripetalous fasciole is not multiple but single and the pore pairs of the frontal ambulacrum are not separated by a granule. Moreover, the new genus has a much larger test than does *Washitaster*. On the other hand, *Pseudowashitaster* resembles *Heteraster* in many respects, but is clearly separated from that genus by the presence of a well-defined, narrow, continuous peripetalous fasciole crowded by granules much smaller than those covering the rest of the aboral surface, and by the rather uniform pore pairs of the frontal ambulacram. *Heteraster* has no more than a broad, diffuse granular band or pseudo-fasciole decorated with tubercles as figured by Devriès (1960, pl. 12, fig. 11; pl. 16, figs. 5-6). Regularly or irregularly alternating larger and smaller pores in the frontal ambulacrum is usual in *Heteraster*, whereas in *Pseudowashitaster* somewhat inward placed outer pores (see Text-fig. 4), if present, are not common, their inconstant numbers and positions being merely a matter of intraspecific variability. Furthermore, the considerable narrowness of the anterior paired ambulacra also is one of the most prominent characters of the new genus. This feature, however, is not known in any *Heteraster* species. To sum up, *Pseudowashitaster* is clearly distinguishable either from *Washitaster* or from *Heteraster*.

The presence of a peripetalous fasciole alone suggests a close affinity of the new genus to the hemiasterid echinoids. In some of the specimens referable to the present new genus, however, the peripetalous fasciole is more or less poorly demarcated including very few granules or small tubercles in such a manner as illustrated by Devriès (1960, pl. 16, figs. 7-8), in very limited portions of the way. Nevertheless, the peripetalous fasciole of the present new genus is far narrower and far better defined than a broad, diffuse granular band or pseudo-fasciole as figured by Devriès (1960, pl. 16, figs. 5-6), approaching to the genuine peripetalous fasciole as figured by him (1960, pl. 16, fig. 9) on the whole and is moreover well traceable throughout the course. On the other hand, so far as the general features of the frontal ambulacrum and paired ambulacra are concerned, it is evident that *Pseudowashitaster* is more closely allied to *Heteraster* than to peripetalous fasciole-bearing hemiasterid echinoids. Anyhow, attaching importance to the presence of a peripetalous fasciole alone, one is strongly inclined to the conclusion that the present new genus is provisionally placed in the family Hemiasteridae. On the other hand, a possibility can not be denied that the new genus could be a specialized offshoot of the Toxasteridae. Its exact taxonomic position at family level will be reserved for further study. Furthermore, it should be noticed that *Washitaster longisulcus* (Adkins et Winton) (1920, p. 55, pl. 9, figs. 4, 8-10), from the Albian of Texas, which appears similar to *Pseudowashitaster* species, has considerably narrow anterior paired ambulacra. This may not bear a genetic relation to *Pseudowashitaster* but may indicate a parallelism development in different provinces.

Washitaster japonicus (Tanaka et Okubo) which is now assigned to *Pseudowashitaster* was placed by Nisiyama (1968) in the genus *Paraheteraster* established by himself. But, according to Tanaka (1965), *Washitaster* (?) *macroholcus* Nisiyama, 1950, the type-species of *Paraheteraster*, is characterized by, among other features, the pore arrangement of *Heteraster* (s. s.) type (Devriès, 1960) in the frontal ambulacrum and the lacking of genuine fasciole (instead, a broad, diffuse granular band or pseudo-fasciole decorated with tubercles surrounds the petals; see Text-fig. 2), thus being referable to *Heteraster*. The contrasting difference in width of the anterior paired ambulacra also makes it impossible to place both *Washitaster* (?) *macroholcus* and *Washitaster japonicus* in one and the same genus. To sum up, it is reasonable to regard *Paraheteraster* as a synonym of *Heteraster*.

Pseudowashitaster mysticus Tanaka, sp. nov.

Pl. 55, Figs. 5-7; Pl. 56, Figs. 1-2; Text-figs. 3-4

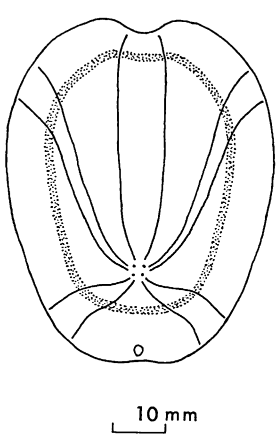
1965. *Washitaster* (?) sp., Tanaka, *Trans. Proc. Palaeont. Soc. Japan*, N. S., no. 59, p. 138, pl. 16, figs. 8-9, text-fig. 7.

Type-specimens:—Holotype, GSJ. 6017, represented by an internal mould, from loc. Ka-04, about 700 m south of Yunoki, Kahoku-cho, Kami-gun, Kochi Prefecture, Yunoki Formation, Upper Barremian; paratypes, GSJ. 6018 A, B (A, internal mould; B, external mould) and GSJ. 6019 (external mould), from the same locality.

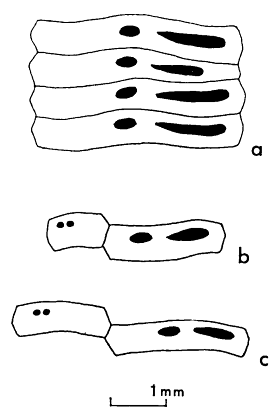
Diagnosis:—Test large, oval, with the widest point anterior to the midpoint, not greatly constricted behind. Aboral surface gently arched, highest near the apical system. Frontal sinus very long, deep, somewhat constricted and shallower immediately behind the frontal margin, nearly parallel-sided in the main part of the way, extending to the peristome; anterior notch deep. Apical system very eccentric behind, ethmophract, with four gonopores.

Frontal ambulacrum very long, deeply sunken; poriferous zones broader than half the width of the interporiferous zones. Inner pores oval; outer pores elongated silt-shape, accuminated inwards, scarcely or occasionally set more or less inwards; pores of each pair opposite, rather close together, not separated by a granule. Paired ambulacra very unequal, flexuous, subpetaloid, open distally.

Anterior paired ambulacra very long, considerably narrow almost throughout the way, somewhat narrower than half the width of the frontal ambulacrum when



Text-fig. 3. Suggested figure of *Pseudowashitaster mysticus* Tanaka, sp. nov. Aboral view. Restored from the holotype and paratypes.



Text-fig. 4. *Pseudowashitaster mysticus* Tanaka, sp. nov., from loc. Ka-04, Yunoki Formation, Upper Barremian. a, Frontal ambulacrum (Holotype, GSJ. 6017). b, Right anterior paired ambulacra (Paratype, GSJ. 6019). c, Right posterior paired ambulacra (Paratype, GSJ. 6019).

compared with each other near the midway between the apical system and the ambitus, but rapidly widening near the ambitus, very slightly sunken in the petaliferous part extending about two-thirds the way to the ambitus, diverging at a smaller angle than do the posterior paired ambulacra then turn forwards and laterally, becoming almost straight, and then diverge laterally and cross the ambitus far anteriorly. Anterior poriferous zones very narrow; pores minute, round, near together. Posterior poriferous zones much wider than the anterior; pores oval in the inner row, elongate in the outer row; pores of each pair opposite, rather close together. Interporiferous zones wider than the anterior poriferous zones, narrower than the posterior poriferous zones.

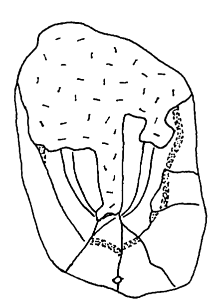
Posterior paired ambulacra shortest, wide, flush, diverging at a very large angle and then converge laterally; petaliferous part extending about one-third the way to the margin. Anterior poriferous zones much narrower than the posterior, composed of minute, round pores closely spaced. Posterior poriferous zones consisting of oval inner pores and elongate outer pores; pores of each pair opposite, rather near together. Interporiferous zones more or less wider than the posterior poriferous zones.

Peristome far anterior, rather transversely oval. Periproct oval, vertically elongate, high up on the posterior truncated surface. Tubercles on the aboral surface small, of varying sizes, perforate, crenulate, scrobiculate; the largest scattered in the anterior interambulacral areas, becoming smaller and closer along the frontal sinus and near the ambitus; numerous granules between tubercles. Peripetalous fasciole crowded by much smaller granules single, distinct, well defined, narrow, continuous, running nearly in a straight line between the anterior and posterior paired ambulacra, crossing the anterior paired ambulacra at about one-fourth the way from the ambitus; no other fascioles.

Measurements:—The holotype, though incompletely preserved, probably attains 70 mm or more in length. The peripetalous fasciole is a little more than 1 mm wide in the paratypes.

Remarks:—The three specimens available from the present area are incomplete and secondarily depressed. Accordingly, the specific diagnosis given here is based on observations on several specimens (e. g. GSJ. 6116, 6117) from the Upper Neocomian (Barremian) Ishido Formation of the western Sanchu Graben, Nagano Prefecture and one specimen from the Barremian Arida Formation of the Yuasa area, Wakayama Prefecture (Text-fig. 5) in addition to those from the Monobe area. The Ishido specimens were described previously as a species provisionally referred to *Washitaster* (Tanaka, 1965).

In the present study, the holotype is not sufficiently well preserved and the paratypes are also fragmentary and deformed by the subsequent disfigurement.



Text-fig. 5. *Pseudowashitaster* sp. cf. *P. mysticus* Tanaka, sp. nov. Diagrammatic sketch of a specimen of the Kyoto Univ. Coll., from the Arida Formation (Lower Barremian), northeast of Yuasa, Wakayama Prefecture. Aboral view. ×ca. 0.7.

Nevertheless, a suggested figure of the test of the present new species, restored from the holotype and paratypes, is shown in Text-fig. 3. Of course, a modification of the horizontal outline of the test and the position of the apical system, if required, should be made, though probably slightly, when more specimens of good preservation are obtained. Moreover, we have insufficient information about the side outline of the test, which is not figured here. In a comparatively weakly depressed specimen, registered GSJ. 6117, from the Ishido Formation, the test measures at least 13 mm high against the presumed 30 mm length between the apical system and the anterior margin. It follows from this that the test is rather low. A peripetalous fasciole, one of the most striking features of *Pseudowashitaster,* is not preserved in the holotype because of the internal mould. It is, however, observable in the paratypes GSJ. 6018 B (Pl. 56, Fig. 2) and GSJ. 6019 (Pl. 56, Fig. 1) and also in an Ishido specimen (GSJ. 6117; Pl. 56, Fig. 3) and an Arida specimen (Text-fig. 5).

The outer pores in the frontal ambulacrum show intraspecific variation in arrangement. In some specimens (e.g. holotype GSJ. 6017 and GSJ. 6117 from the Ishido Formation), one shorter pore is set more or less inwards every five to seven longer pores near the middle part of the poriferous zones and every two to four longer pores near the distal part. On the other hand, in a specimen (GSJ. 6116 from the Ishido Formation) only one or two shorter pores are placed somewhat inwards within a series of about 40 pores in the middle part of the poriferous zones.

This new species closely resembles *Pseudowashitaster japonicus* (Tanaka et Okubo) (1954, p. 220, pl. 7, fig. 4, text-fig. 7) to be redescribed below, from the Albian Yatsushiro Formation of Kyushu, in the general features of the test. But the peripetalous fasciole crosses the anterior paired ambulacra much less distally in the former species than in the latter. Moreover, the outer pores in the frontal ambulacrum are elongated slit-shape and accuminated inwards in *Pseudowashitaster mysticus* sp. nov., whereas in *P. japonicus* they are shorter and elongate oval.

In connexion with the occurrence of *Pseudowashitaster* in the Barremian and Albian in Japan, it should be noticed that a specimen (GSJ. 6055) provisionally referable to this genus was obtained by the senior author from the Aptain Hinagu Formation of Kyushu. This specimen (Pl. 55, Fig. 8) also is characterized by the long, distinct frontal sinus, the frontal ambulacrum composed of similar, elongate pore pairs, and by the considerably narrow anterior paired ambulacra, although a peripetalous fasciole is not discernible because of the internal mould. Furthermore, in the frontal ambulacrum three to four shorter pores set somewhat inwards are observed within a series of about 30 outer pores in the middle part.

The present species and *Pseudowashitaster japonicus* (Tanaka et Okubo) appear similar to *Washitaster longisulcus* (Adkins et Winton) (1920, p. 55, pl. 9, figs. 4, 8-10) from the Albian of Texas, in many respects. However, the formers have a single peripetalous fasciole as against multiple in the latter. In the above Texas species the pore pairs of the frontal ambulacrum are separated by a granule, but such is not the case with the Japanese two species. Furthermore, a minor but distinct difference is that the frontal sinus is nearly parallel-sided in the main part of the way in the Japanese two species, whereas in *Washitaster longisulcus* it is biconvex-sided. It is also added here that the test is larger in the formers than in the latter.

Occurrence:—Loc. Ka-04, Yunoki Formation, siltstone, Upper Barremian (GSJ. 6017, 6018A, B and 6019).

Concluding Remarks

Summarizing the systematic descriptions, the following five species belonging to three genera are identified on the material from the Monobe area:

Epiaster sp. aff. *E. nobilis* Stoliczka
Heteraster macroholcus (Nisiyama)
Heteraster nexilis Nisiyama
Heteraster sp.
Pseudowashitaster mysticus Tanaka, sp. nov.

Epiaster and *Heteraster* belong to the Toxasteridae. *Pseudowashitaster* is a new genus, assigned to the Hemiasteridae, which is characterized by, among other features, a single peripetalous fasciole and considerably narrow anterior paired ambulacra.

Epiaster sp. aff. *E. nobilis* was obtained from the middle part (Upper Santonian) of the Kajisako Formation. *Heteraster* cf. *macroholcus* and *Heteraster nexilis* came from the Monobe Formation (Lower Barremian), and *Heteraster macroholcus, Heteraster* sp. and *Pseudowashitaster mysticus* from the Yunoki Formation (Upper Barremian). In addition to the species mentioned above, a regular echinoid whose ambulacra are composed of trigeminate compound plates and a spatangoid echinoid were obtained from locs. M-51 and M- 03 (Text-fig.1) respectively of the Nagase Formation, but their generic determination is impossible because of the poor preservation. Furthermore, an echinoid fragment of unknown taxonomic position is also found in the Hibihara Formation.

Among the Lower Cretaceous echinoids, the two hitherto described species of *Heteraster* are known to occur in the Barremian of other areas in the Outer Zones of Southwest Japan (Nisiyama, 1950; Tanaka and Okubo, 1954; Tanaka, 1965; Nisiyama, 1968). As mentioned before, such is the case with *Pseudowashitaster mysticus* Tanaka, sp. nov. (e.g. Tanaka, 1965). From the above facts it is concluded that the correlation of the Monobe-Yunoki Formation based on the molluscan fanules (Tashiro, Kozai, Okamura and Katto, 1980) and on the echinoid fanules respectively are in harmony with each other. However, *Aphelaster serotinus* Tanaka et Shibata and *Heteraster yuasensis* (Tanaka et Okubo) which are known from the Barremian of various areas in the Outer Zone of Southwest Japan (Tanaka and Okubo, 1954; Tanaka and Shibata, 1961; Tanaka, 1965; Obata *et al.*, 1979; Hayashi *et el.*, 1981), have not yet been discovered in the Monobe area. The only identified Upper Cretaceous echinoid is closely allied to *Epiaster nobilis* Stoliczka from the Senonian (Arrialoor Group) of India. This is the first report of an *Epiaster* species from Japan.

APPENDIX

Notes on *Pseudowashitaster japonicus* (Tanaka et Okubo)

by Keisaku Tanaka

This species originally referred co *Washitaster* is represented by a single specimen, from the Albian Yatsushiro Formation of the Yatsushiro district, Kyushu (Tanaka and Okubo, 1954, *Jour. Geol. Soc. Japan*, vol. 60, p. 220, pl. 7, fig. 4, text-fig. 7), which is the holotype by monotype. The original specific diagnosis is mostly available, but it is too brief. Accordingly, in connexion with the establishment of the new genus *Pseudowashitaster* and the description of its type-species, the diagnosis of the present species is improved in the lines to follow, on the basis of the writer's subsequent observations (Pl. 56, Figs. 4-5; Text-fig. 6).

Material:—Holotype, GSJ. 6020, represented by an internal mould (A) and also imperfect external moulds of the aboral (B) and oral surfaces (C). It was obtained from the siltstone of the middle part (Lower Albian) of the Yatsushiro Formation.

Description:—The holotype is deformed by the subsequent disfigurement, and the original size of the test is difficult to estimate. The test probably attains about 65 mm in length. Presumably, it had originally an oval or elliptical outline. The aboral surface is highest near the apical system.

The frontal sinus is very long, deep, somewhat constricted immediately behind the frontal margin, and nearly parallel-sided in the main part of the way, forming a conspicuous notch in the anterior edge of the test then extends to the peristome. The apical system is far backwards and ethmophract, with four gonopores, and the madreporite extends as far back as to separate the posterior genital plates, touching the posterior occular plates.

The frontal ambulacrum is very long and deeply sunken, having poriferous

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Explanation of Plate 55

Fig. 1. *Epiaster* sp. aff. *E. nobilis* Stoliczka
1a, Aboral view, ×1. 1b, Oral view, ×1. OES. 14007A, from loc. M-14, middle part of Kajisako Formation, Upper Santonian.

Fig. 2. *Heteraster macroholcus* (Nisiyama)
Aboral view, ×1. OES. 04153, external mould, from loc. Ka-04, Yunoki Formation, Upper Barremian.

Fig. 3. *Heteraster nexilis* Nisiyama
3a, Aboral view, ×1.2. 3b, Oral view, ×1.2. OES. 27001, from loc. M-27, Monobe Formation, Lower Barremian.

Fig. 4. *Heteraster* sp.
4a, Aboral view, ×2. 4b, Oral view, ×2. OES. 04154, from loc. Ka-04, Yunoki Formation, Upper Barremian.

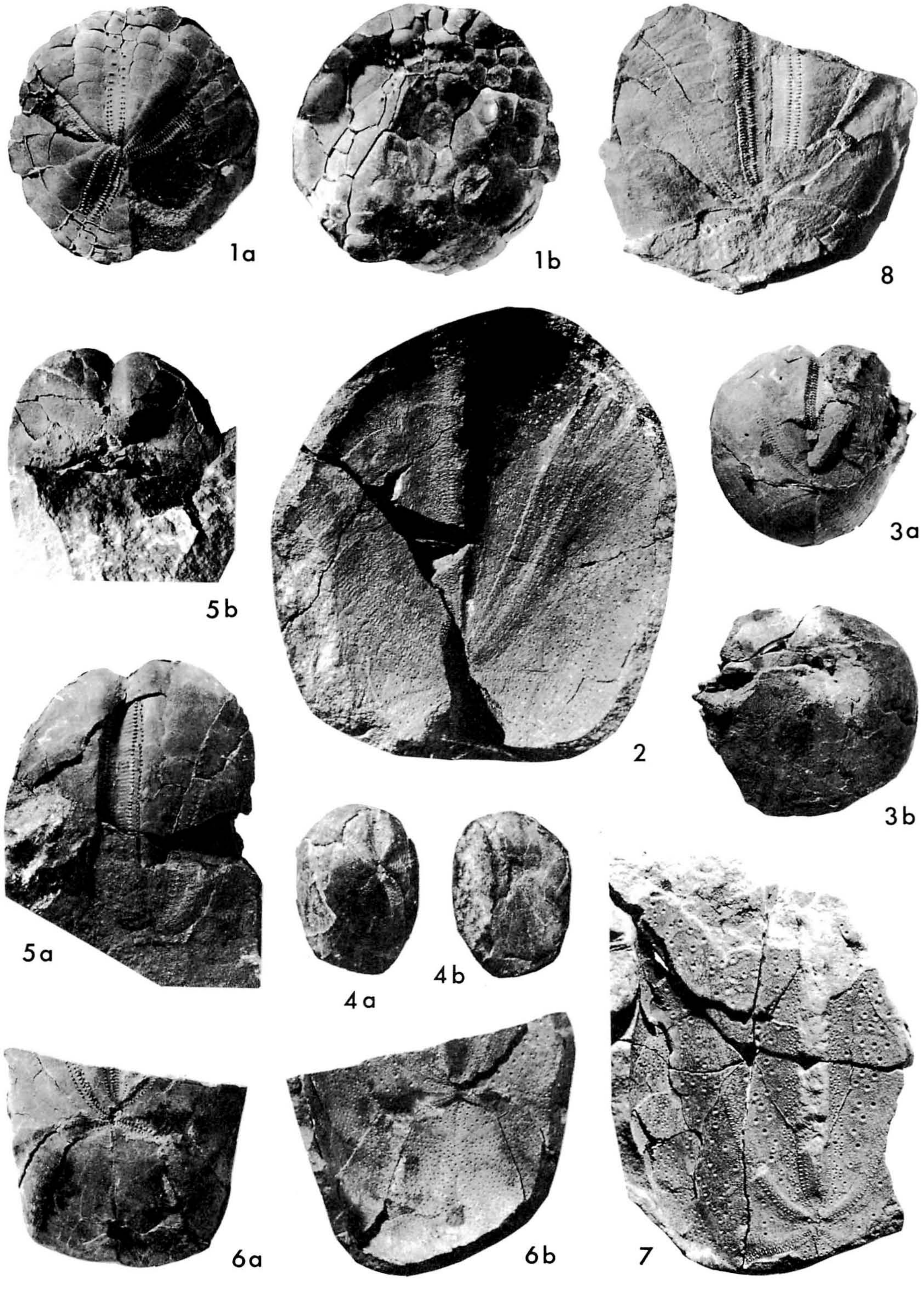
Fig. 5. *Pseudowashitaster mysticus* Tanaka, sp. nov.
5a, Aboral view, ×1. 5b, Oral view, ×1. Holotype, GSJ. 6017, from loc. Ka-04, Yunoki Formation, Upper Barremian.

Fig. 6. *Pseudowashitaster mysticus* Tanaka, sp. nov.
6a, Aboral view, ×1. 6b, Aboral view, ×1, external mould. Paratype, GSJ. 6018A, B, from loc. Ka-04, Yunoki Formation, Upper Barremian.

Fig. 7. *Pseudowashitaster mysticus* Tanaka, sp. nov.
Aboral view, ×1. Paratype, GSJ. 6019, external mould, from loc. Ka-04, Yunoki Formation, Upper Barremian.

Fig. 8. *Pseudowashitaster*(?) sp.
Aboral view, ×1.5. GSJ. 6055, from Yatsushiro district, Kumamoto Prefecture, upper part of Hinagu Formation, Aptian.

All specimens illustrated here are internal moulds, unless otherwise stated.
Photos by Y. Masai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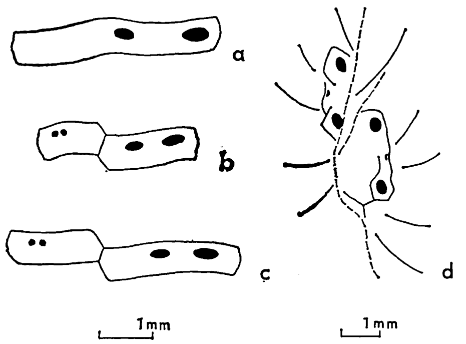

Text-fig. 6. *Pseudowashitaster japonicus* (Tanaka et Okubo), from the middle part (Lower Albian) of the Yatsushiro Formation, Yatsushiro district, Kumamoto Prefecture (Holotype, GSJ. 6020). a, Frontal ambulacrum. b, Right anterior paired ambulacra. c, Right posterior paired ambulacra.

zones which are of about half the width of the interporiferous zones. The poriferous zones are composed of oval inner and elongate oval outer pores, and the pores of each pair are widely spaced without a granule in between. In the left poriferous zone, five of the series of 75 outer pores are placed somewhat inwards with an irregular interval. The paired ambulacra are very unequal in length and width, flexuous, subpetaloid and open distally. The anterior paired ambulacra are very long and very slightly sunken in their petaliferous part, diverging at a rather small angle. They are considerably narrow almost throughout the way and are much narrower than half the width of the frontal ambulacrum when compared with each other near the midway between the apical system and the ambitus. The posterior paired ambulacra are very short and flush, diverging at a very large angle. In the both paired ambulacra, the anterior poriferous zones are much narrower than the posterior, the former consisting of minute, round pores close together and the latter of oval inner and elongate oval outer pores each pore pair of which is rather widely set.

The peristome is very eccentric in front and poorly preserved. The plastron is amphisternous. The periproct is oval and vertically elongate. The tubercles are of varying sizes, perforate, crenulate and scrobiculate. They are rather widely dotted on the aboral surface, becoming smaller and closer along the frontal sinus and towards the ambitus. The oral surface is covered with rather closely spaced tubercles which are somewhat smaller than on the aboral surface. The peripetalous fasciole crowded by granules much smaller than those covering the rest of the aboral surface is preserved in the anterior part of the test, and is single, well defined and narrow (about 1 mm wide), crossing the anterior paired ambulacra rather near the ambitus.

Remarks:—Whether peripetalous fasciole is single or multiple (as in *Washitaster*) in the holotype can not be ascertained because of the poor preservation. Nevertheless, this species is safely referable to *Pseudowashitaster* on the basis of the general features of the test.

The present species differs from *Pseudowashitaster mysticus* Tanaka, sp. nov. especially in course of the peripetalous fasciole and features of the pore pairs in the frontal ambulacrum, as has been described in the preceding main article.

Occurrence:—North of Tuzura, Sakamoto-mura, Yatsushiro-gun, Kumamoto Prefecture, middle part of Yatsushiro Formation, Lower Albian, siltstone (Coll. T. Matsumoto and K. Kanmera).

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Explanation of Plate 56

Fig. 1. *Pseudowashitaster mysticus* Tanaka, sp. nov.
Aboral view, ×3. Paratype, GSJ. 6019, external mould, from loc. Ka-04, Yunoki Formation, Upper Barremian. A peripetalous fasciole is seen between two arrows.

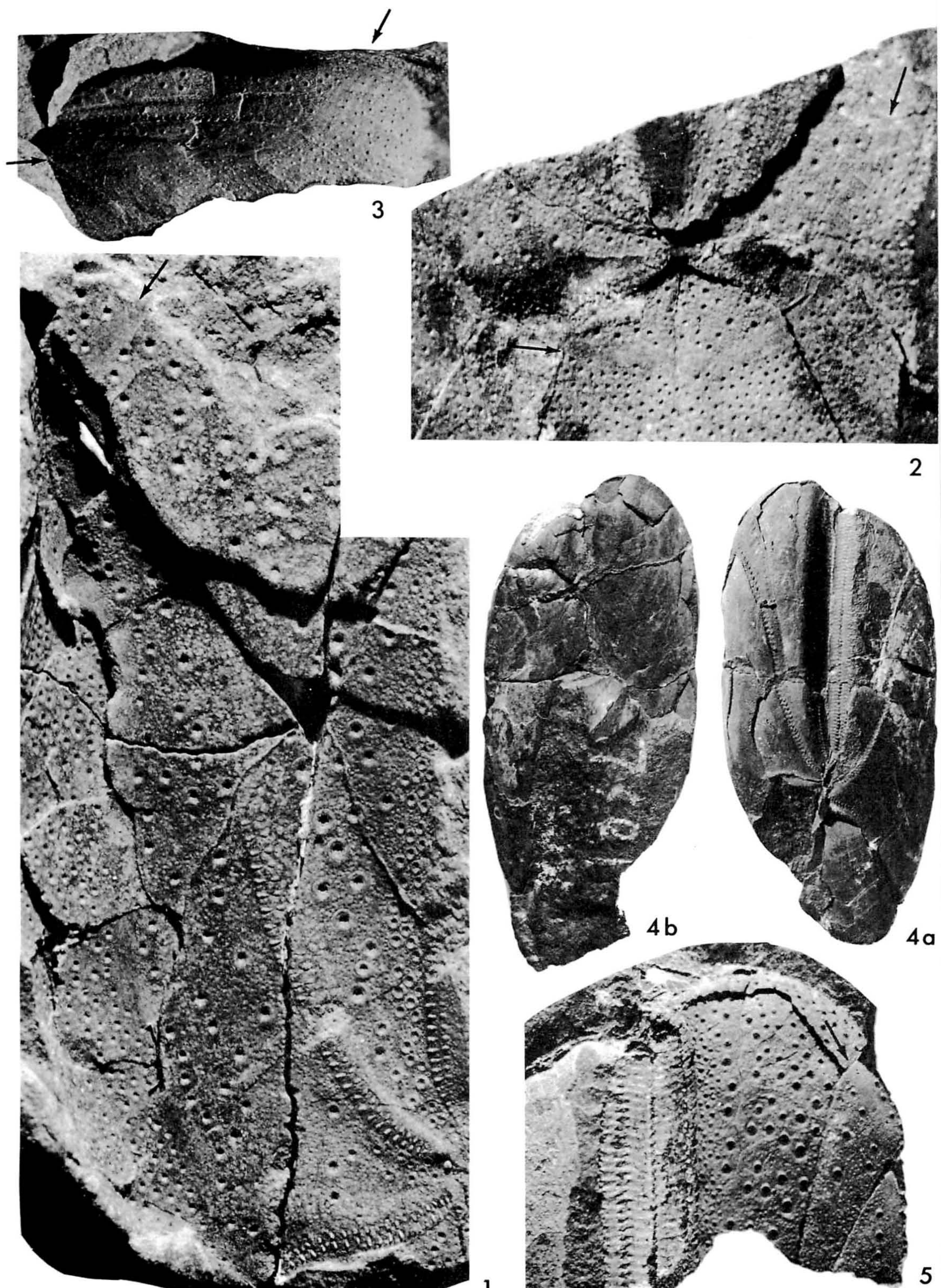
Fig. 2. *Pseudowashitaster mysticus* Tanaka, sp. nov.
Aboral view, ×3. Paratype, GSJ. 6018B, external mould, from loc. Ka-04, Yunoki Formation, Upper Barremian. A peripetalous fasciole is seen between two arrows.

Fig. 3. *Pseudowashitaster mysticus* Tanaka, sp. nov.
Aboral view, ×2. GSJ. 6117, external mould, from Ishido, Saku-cho, Minamisaku-gun, Nagano Prefecture, Ishido Formation, Barremian. A peripetalous fasciole is seen between two arrows. Front to the right.

Fig. 4. *Pseudowashitaster japonicus* (Tanaka et Okubo)
4a, Aboral view, ×1. 4b, Oral view, ×1. Holotype, GSJ. 6020 A, internal mould, from Yatsushiro district, Kumamoto Prefecture, Yatsushiro Formation, Lower Albian.

Fig. 5. *Pseudowashitaster japonicus* (Tanaka et Okubo)
Aboral view, ×3. Holotype, GSJ. 6020B, external mould, from Yatsushiro district, Kumamoto Prefecture, Yatsushiro Formation, Lower Albian. A peripetalous fasciole is seen between two arrows.

Photos by Y. Masai


3
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5

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Arida 有田, Doiban 土居番, Hinagu 日奈久, Ishido 石堂, Kahoku-cho 香北町, Kajisako 梶佐古, Kami-gun 香美郡, Kawanouchi 川ノ内, Monobe 物部, Odochi 大栃, Sanchu 山中, Yatsushiro 八代, Yuasa 湯浅, Yunoki 柚ノ木

四国物部地域産の白亜紀ウニ化石：高知県東部，物部地域の下部白亜系物部—柚ノ木層（バレミアン）産のウニ化石について *Heteraster* 3種，新属1新種を，上部白亜系梶佐古層中部（サントニアン）産のものについて *Epiaster* 1種を識別し，古生物学的記載を行った。新種は柚ノ木層（バレミアン上部）から産し，これに対して新属を提唱し，*Pseudowashitaster mysticus* と命名した。このものは，関東山地山中地溝帯の石堂層や和歌山県湯浅地方の有田層（いずれもバレミアン）からも産する。新属は，特に単一の周花帯線の発達，かなり幅狭い前対歩帯，前歩帯における対孔の性質によって外見上類似する *Washitaster* や *Heteraster* とは区別され，Hemiasteridae 科に属する。現在までの所，この新属は模式種と後記の1種からなり，さらに本属におそらく同定される1種が熊本県八代地方の日奈久層（アプチアン）からもみいだされる。 田中啓策・香西 武

付録として，八代地方の八代層中部（アルビアン下部）から産した *Washitaster japonicus* (Tanaka et Okubo) を上記新属名のもとに記載した。 田中啓策

日本古生物学会会則　(1978, 1, 20 改訂)

第 1 条　本会は日本古生物学会という。
第 2 条　本会は古生物学およびこれに関係ある諸学科の進歩および普及を計るのを目的とする。
第 3 条　本会は第2条の目的を達するため次の事業を行なう。
1. 会誌そのほかの出版物の発行。2. 学術講演会の開催。3. 普及のための採集会・講演会そのほかの開催。4. 研究の援助・奨励および研究業績ならびに会務に対する功労の表彰その他第2条の目的達成に資すること。
第 4 条　本会の目的を達するため総会の議を経て本会に各種の研究委員会を置くことができる。
第 5 条　本会は古生物学およびこれに関係ある諸学科に興味を持つ会員で組織する。
第 6 条　会員を分けて普通会員・特別会員・賛助会員および名誉会員とする。
第 7 条　普通会員は所定の入会申込書を提出した者につき評議員会の議によって定める。
第 8 条　特別会員は本会に10年以上会員であり古生物学について業績のあるもので，特別会員5名の推薦のあったものにつき評議員会の議によって定める。
第 9 条　賛助会員は第2条の目的を賛助する法人で評議員会の推薦による。
第10条　名誉会員は古生物学について顕著な功績のある者につき評議員会が推薦し，総会の決議によって定める。
第11条　会員は第12条に定められた会費を納めなければならない。会員は会誌の配布を受け第3条に規定した事業に参加することができる。
第12条　会費の金額は総会に計って定める。会費は普通会員年4,500円，特別会員年6,000円，賛助会員年1口10,000円以上とする。名誉会員は会費納入の義務がない。在外の会員は年6,000円(または等価のU.S.ドル）とする。
第13条　本会の経費は会費・寄付金・補助金などによる。
第14条　会費を1ヶ年以上滞納した者および本会の名誉を汚す行為のあった者は，評議員会の議を経て除名することができる。
第15条　本会の役員は会長1名，評議員15名，および常務委員若干名とする。任期は総て2年とし再選を妨げない。
会長の委嘱により本会に幹事および書記若干名を置くことができる。
常務委員会は評議員会において互選された者で構成される。但し会務上必要とする場合は，特別会員の中から常務委員若干名を評議員会の議を経て加えることができる。
第16条　会長は特別会員の中から評議員会において選出され，本会を代表し会務を管理する。
会長に事故ある場合は会長が臨時代理を委嘱する。
第17条　本会には名誉会長を置くことができる。名誉会長は評議員会が推薦し総会の決議によって定める。名誉会長は評議員会に参加することができる。
第18条　本会は毎年1回定例総会を開く。その議長には会長が当たり本会運営の基本方針を決定する。
総会の議案は評議員が決定する。
会長は必要があると認める時は臨時総会を召集する。総会は会員の十分の一以上の出席をもって成立する。会長は会員の三分の一以上の者から会議の目的たる事項および召集の理由を記載した書面をもって総会召集の請求を受けた場合は臨時総会を召集する。
第19条　総会に出席しない会員は他の出席会員にその議決権の行使を委任することができる。但し，欠席会員の議決権の代行は1人1名に限る。
第20条　総会の議決は多数決により，可否同数の時は議長がこれを決める。
第21条　会長および評議員は評議員会を組織し，総会の決議による基本方針に従い運営要項を審議決定する。
第22条　常務委員は常務委員会を組織し評議員会の決議に基づいて会務を執行する。
第23条　会計監査1名をおく。監査は評議員会において評議員および幹事をのぞく特別会員の中から選出される。任期は2年とし再選を妨げない。
第24条　本会の会計年度は毎年1月1日に始まり12月31日に終る。
第25条　本会会則を変更するには総会に付議し，その出席会員の三分の二以上の同意を得なければならない。
付　則　1）評議員会の議決は無記名投票による。

行事予定

	開催地	開催日	講演申込締切
第130回 例会	三重大学	1982年10月17日	1982年8月17日
1983年年会・総会	東京大学	1983年1月22・23日	1982年11月22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

お知らせ

○日本古生物学会では過去5年間経費の節減をはかりながら皆様の会費を据置いてきましたが，昨今の諸物価の高騰により次第に財政が苦しくなって参りました。現在の規模の活動を続けていくには来年度は会費の値上げをお願いしなければならなくなる見通しですので，お含みいただくと共に会費の完納に御協力下さるようお願いいたします。

○日本古生物学会では年会・例会をより魅力あるものにするため，シンポジウムをはじめ各種の新しい形の会合（例えば，テクニックの会合，ポスターセッション，ワークショップ，夜間小集会など）の提案を歓迎します。よい企画がありましたら早目に常務委員会あてお申出下さるようお願いします。

○日本古生物学会刊行の和文誌「化石」を次のように充実させる方向で検討しています。1）Ｂ５版の定期的（年２回発行）の刊行物とする［昭和57年度より実施］。2）現在の予約購読制を改め，誌代を会費に含め全会員に配布する。３）原著論文を掲載し，内容を一層充実させる。これらの実施につきましては，印刷実費に相当する会費の値上げが伴ないますので，御意見などがありましたら，化石編集部または常務委員会まで早目にお申出下さい。 常務委員会

○化石31号（Ｂ５版52ページ，1982年６月21日発行，1,500円）が刊行されました。「化石」は今回から本誌と同じＢ５版となり内容の刷新がはかられています。主な内容は次の通りです。

論説（本邦白亜系における海成・非海成層の対比，カキの古生態学），評論（寒武系の基底について），学会通信（進化古生物学研究所設立趣旨ならびに構想），化石通信（斎藤報恩会自然史博物館），ニュース，新刊紹介など。

「化石」は本学会の和文定期刊行物として1983年度から会費に含めて全会員に配布する方向で検討しておりますが，本号および今年度内に出版予定の32号は従来通りの方法（予約購読およびバラ売）で販売いたします。お申込は東北大学理学部地質学古生物学教室内化石編集部（送金先：振替 仙台17141）にお願いします。

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