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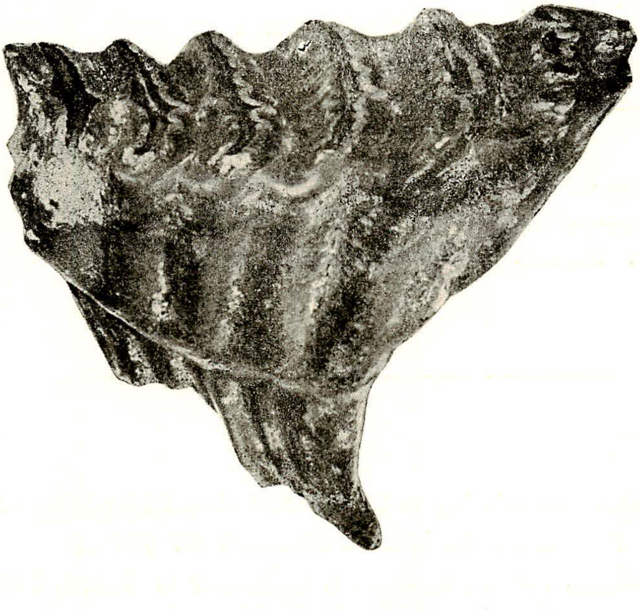

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# 578. ONTOGENIES OF TWO UPPER CAMBRIAN TRILOBITES FROM NORTHERN BLACK HILLS, SOUTH DAKOTA*

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南ダコタ Black Hills 北部産のカンブリア紀後期三葉虫 2 種の個体発生： *Aphelaspis walcotti* RESSER および *Glaphyraspis parva* (WALCOTT) の発生過程を研究した結果，*Aphelaspis walcotti* の幼虫は *A. subditus, Parabolinoides contractus, P. moustonus, Dunderburgia ? anyta* および *Olenus gibbosus* の幼虫と類似し，また *Glaphyraspis parva* については *Welleraspis lata, W. swartzi, W. lochmanae* および *Pemphigaspis bullata* の幼虫に類似することが判った。このことは上記二組の三葉虫がそれぞれ独立した科を構成するものであることを暗示している。 胡 忠 恒・陳 莉 玲

## Introduction

In the summer of 1962 the senior author, Dr. Christina LOCHMAN-BALK, and a few students of the Department of Geology, New Mexico Institute of Mining and Technology, had a Summer Field Camp around the Black Hills, South Dakota, to study the Cambrian stratigraphy and paleontology. Among the various collections, a small sample was obtained from about half way to the top of the Moll section, Bear Butte, southeastern Deadwood City, northern Black Hills. The material weighs approximately 5 kgs., and is of light gray color. It is a fine to medium crystalline limestone, filling with a few small intraformational pebbles and abundant of disarticulated trilobite fragments. It is very fossiliferous and contains *Aphelaspis walcotti* RESSER, *Glaphyraspis parva* (WALCOTT), *Cheilocephalus* sp., and inarticulate brachiopods specimens.

Preparation of the collection by the senior author yielded over 266 cranidia, 70 pygidia, 97 librigenae, 6 hypostomata, and 201 immature forms of *Aphelaspis walcotti;* 76 cranidia, 41 pygidia, 32 librigenae, 6 hypostomata, and 49 immature forms of *Glaphyraspis parva* (WALCOTT); 6 rather poorly preserved fragments of *Cheilocephalus* sp., and a larger numbers of inarticulate brachiopods. Because the material was collected from the same limited position and horizon, it is believed that each of the genera is represented by a single species within which intraspecific variation may be observed.

Two trilobites are described here: *Aphelaspis walcotti* and *Glaphyraspis parva*. They are interpreted as the same ecological habitants, and the morphologic variations within a single population are possibly sexual as in so many recent arthropods; there are distinctive differences between the male and the female forms. The male individuals are more

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abundant than the female and often possess a small body size. The ontogenetic separation and the sexual recognition are based on the schemes in the senior author works (HU, 1968a, b).

The senior author wishes to express his thanks to Dr. K. E. CASTER, University of Cincinnati, Ohio for his supervision. Thanks also go to Drs. Christina LOCHMAN-BALK, New Mexico Institute of Mining and Technology, New Mexico for her field guidance, and D. S. JOHNSON, University of Singapore, for kindly reading over the present manuscript.

All of the figured specimens are stored in the Geology Museum of Cincinnati, Ohio (U. C. M.).

## Systematic Paleontology

### Family Pterocephaliidae KOBAYASHI, 1935

### Genus *Aphelaspis* RESSER, 1936

### *Aphelaspis walcotti* RESSER

Pl. 8, figs. 1-36; Pl. 9, figs. 34-36; text-figs. 1A-N

*Aphelaspis walcotti* RESSER, 1938, p. 59, pl. 13, 14; PALMER, 1954, p. 746, pl. 86, figs. 2, 4-8; SHAW, 1956, p. 51, pl. 3, figs. 1-6; PALMER, 1962, p. 33, pl. 4, figs. 24, 28, 33; RASETTI, 1965, p. 76, pl. 18, figs. 10-20.

*Aphelaspis simulans* RESSER, 1938, p. 59, pl. 13, figs. 19-21.

*Aphelaspis minor* RASETTI, 1962, p. 89, pl. 19, figs. 18-25.

*Aphelaspis transversa* RASETTI, 1962, p. 88, pl. 16, figs. 21-27.

*Remarks:* The present species is represented by a few hundreds of both mature and immature specimens which permitted a detailed study of individual variation and of morphogenesis during their ontogenetic developmental stages. According to the cranidia and pygidia, the adult forms can be segregated into two clear different groups which separate from each other in a single distinct feature. One group is characterized by a less relieved cranidium, shallow axial and frontal furrows, weakly convex glabella, preglabellar field moderately sloping downward and somewhat convex, anterior border flat, librigena with ocular platform broad and of low convexity, and the short genal spine rather rapidly tapered; pygidium ovate-transverse and with the posterior margin bending slightly inward. The other group is characterized by a highly relieved cranidium, deeper axial and frontal furrows, strongly convex glabella, preglabellar field and anterior border more convex, fixigena convex and directed upward, librigena convex and directed upward, librigena with ocular platform narrow and of high convexity, and the long genal spine gently tapered; pygidium semicircular-transverse and without posterior marginal border notch.

It is postulated that these slight but consistent differences in the adult exoskeletons are the expressions of sexual dimorphism. The first group is tentatively regarded as the female form and the second as the male form. The sexual ratio of the present species is about 182. The largest female cranidium is about 1.2 cm in length (sag.), that of the male is 1.0 cm (sag.) only.

Careful examination of both female and male groups indicates that the length of the male glabella is statistically shorter than that of female and tapers shortly, however these features are by no means constant (compare pl. 8, figs. 30, 33 to 32, 36) and some males may show both longer and nearly subquadrate glabella resembling those of the female. The distinct character between the female and the male forms is that the male cranidium always possesses deeper dorsal furrows (compare pl. 9, figs. 35 to 34, 36) than the female, and that of female is shallower.

The species *Aphelaspis transversa*, *Aphelaspis minor* reported by RASETTI (1965) from Tennessee, and *Aphelaspis walcotti* illustrated by SHAW (1956) from Wyoming, possessing the deeper dorsal furrows and shorter glabella are synonymized as the male form of the present species. *Aphelaspis buttsi* (KOBAYASHI) and *Aphelaspis lata* RASETTI reported by RASETTI from Tennessee present similar structure as those found in *Aphelaspis walcotti* and presumably belong to a single species, the morphological differences being sexual.

The ontogenetic development of the present species is similar to that of *Aphelaspis subditus* PALMER (HU, 1969) and *Aphelaspis* sp. (PALMER, 1962), except that the present species shows the anaprotaspid shield consisting of four axial segments; this is the earliest larva known. The metaprotaspid shield shows faintly impressed cephalic segmental furrows on the fixigenal area; both of these features are well conformed with many other species as reported by the author (HU, 1968a, b) and STØRMER (1942).

### *Aphelaspis walcotti* RESSER, ontogeny

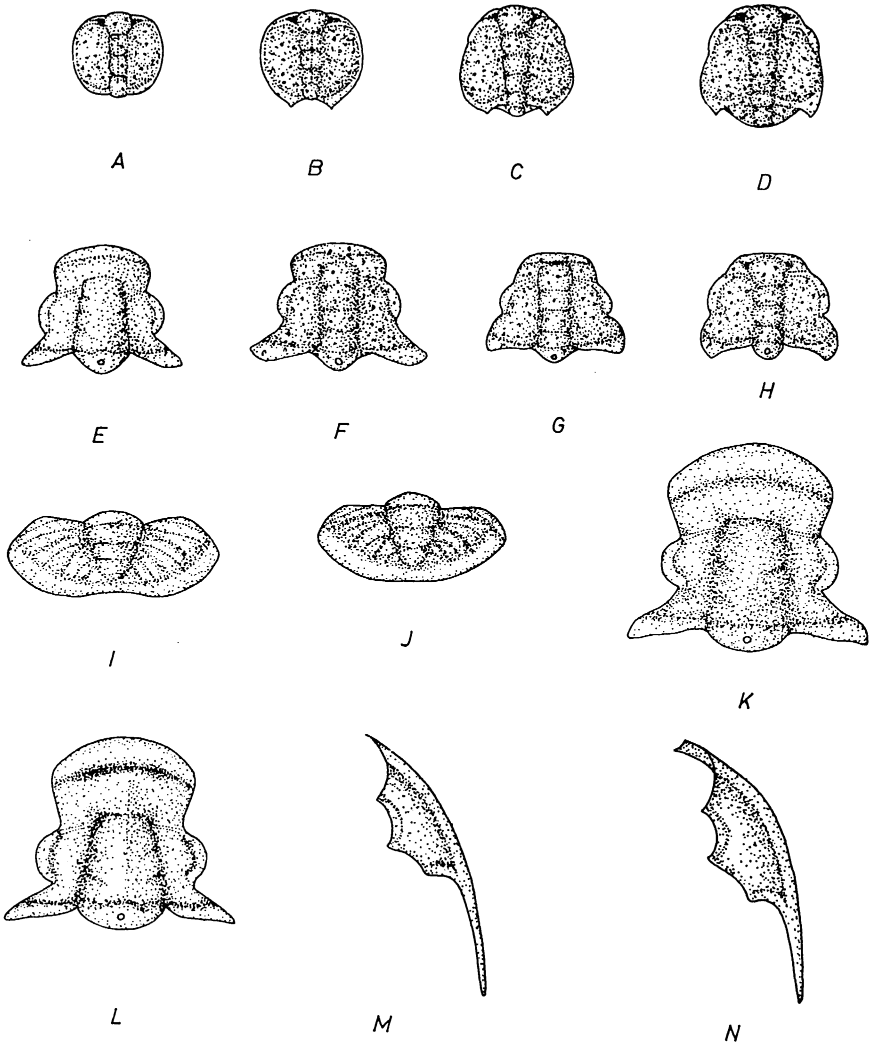
**Anaprotaspid stage** (Pl. 8, fig. 1, and text-fig. 1A). The shield is round, convex, about 0.25-0.28 mm in length (sag.). The axial lobe is well defined by dorsal furrows, narrowly cylindrical, and divided into four indistinct rings; the anterior lobe or the first axial ring is broad and expanding forward, and the following three are narrower and of uniform width. The pleural lobe is convex and about twice as wide as the axis (tr.). The distinctly impressed anterior pits are situated on the sides of the frontal lobe. Short paired supercilioid ridges extend postero-laterally from the sides of the frontal lobe. The surface is covered with fine granules. A narrow but well defined border surrounds the shield margin, and a longitudinal fissure is faintly impressed along the central axis.

The present stage is represented by only one specimen which is low convex, and in which the axial lobe and rings are indistinctly marked compared with those of the later stages. This phenomenon may indicate that the skeleton is thin and has low hardness at this stage, and so is deformed due to the compaction of the sediments.

**Metaprotaspid stage** (Pl. 8, figs. 2, 3 and text-fig. 1B). The shield is round in outline, convex, about 0.29-0.32 mm long (sag.). The axial lobe is slenderly cylindrical and divided into five axial rings by well defined dorsal and ring furrows; the first ring or the frontal lobe is round and convex, and a pair of short supercilioid ridges extending laterally from the sides; the second to fourth axial rings are of about the same size, convex, and marks with faint fissure along the central axis; the last or the occipital ring is smaller than the previous one, which is round and located on the posterior margin of the shield. The pleural lobe is convex, about twice as wide as the axis (tr.). The surface of the shield is covered by medium sized granules. A pair of deeply marked pits is situated on the sides of the frontal lobe, and the pleural lobe is faintly impressed by two or three pairs of postero-laterally directed furrows.

The present stage differs from the previous one is that the axial lobe has five axial rings.

**Paraprotaspid stage** (Pl. 8, figs. 4-8 and



Text-figure 1. A growth sequence of *Aphelaspis walcotti* RESSER. A, Anaprotaspis, ×45; B, Metaprotaspis, ×45; C, D, Paraprotaspides, ×50; H, G, Early meraspides, ×40, ×35; F, E, Late meraspides, ×30, ×20; I, A "male" pygidium, ×4; J, A "female" pygidium, ×4; L, M, A "male" cranidium and a librigena, ×4, ×3; K, N, A "female" cranidium and a librigena, ×4, ×5. (all drawings were made from photographs.)

text-figs. 1C, D). The shield is rounded or subcircular in outline, convex, about 0.32-0.40 mm in length (sag.). The glabella is divided by rather deeply impressed ring furrows into a large frontal lobe, three uniform glabellar segments, and a small occipital ring. The frontal pits are distinct and triangular. The palpebral lobe is narrow, well delimited by a furrow, and continuous with the palpebral ridge towards the posterior lateral margin of the frontal lobe. The fixigena is about one and a half as wide as the glabella, convex, and with the narrow posterior border well delimited by a border furrow. The posterior border curves slightly postero-laterally and continues into a short and broad fixigenal spine directed backward. The protopygidium is lenti-form, convex, sloping downward steeply behind of the cranidial shield. One or two segments are visible. The axial ring is oval-transverse and convex above the pleural lobe. The pleural lobe is low and has single interpleural groove. The surface is covered by medium sized granules.

The main characters of the present stage are that the protopygidium appears, the fixigena becomes narrower, and the central axial fissure is absent.

**Early meraspid stage** (Pl. 8, figs. 9-13 and text-figs. 1H, G). The cranidium is regularly trapezoidal in outline, convex and about 0.45 to 0.60 mm in length (sag.). The glabella is nearly cylindrical but expanding slightly forward. It is divided into four convex segments; the first glabellar segment is the largest, convex, and marked with a pair of lateral pits at the margin; the second to fourth are equal in size. The occipital ring is narrower than those of the glabellar segments, convex, and with a minute median nodule. There is a narrow, forwardly arched anterior border appears in front of the glabella. The convex fixigena is about the same width as the glabella (mid-line, tr.), with the narrow and well elevated palpebral lobe situated in front of the mid-length of the glabella. The palpebral ridge is elevated, curving continuously from the palpebral lobe and directed to the sides of the first glabellar segment. The posterior fixigenal furrow is distinctly impressed, horizontal and curving forward before ending at the extreme lateral border. The anterior facial suture is short and convergent-convex, and the posterior one is broadly divergent-convex. The surface is covered by medium sized granules.

The distinct characters of the present stage are that the cranidium is trapezoidal in outline, the glabella and the fixigena are about the same width (tr.), and the anterior border has appeared.

**Late meraspid stage** (Pl. 8, figs. 14-18, 20 and text-figs. 1E, F). The cranidium is trapezoidal, convex, about 0.80-1.6 mm in length (sag.). The glabella is cylindrical or slightly tapering forward, convex, divided into four segments by incomplete or complete glabellar furrows. The occipital ring is crescentic, convex both vertically and posteriorly, and bearing a tiny median tubercle. A narrow preglabellar field appears in between the glabella and the anterior border, and is flat to slightly convex. The anterior border is convex, arches slightly forward and is well delimited by a frontal furrow. The fixigena is narrower than the glabella, horizontally convex or slightly sloping upward. The palpebral lobe is sickle-shaped, convex, well demarked by a palpebral furrow, and its anterior end is continued by the narrow and well elevated palpebral ridge. The anterior facial suture is slightly divergent-convex, whereas the posterior facial suture is divergent and straight. The surface of the exoskeleton is faintly granulated.

The present stage is distinguished from the previous one in having the glabella parallel sided or slightly tapering forward; the glabellar furrow complete; fixigena narrower than the glabella; the palpebral lobe sickle-shaped and situated on the mid-line of the glabella (tr.), and the posterior fixigena is greatly reduced in width (sag.).

*Remarks:* The morphologic changes of the present species during its ontogenetic development very closely resemble those of *Aphelaspis* sp. (PALMER, 1962), *Aphelaspis subditus* PALMER (HU, 1969), *Dunderburgia? anyta* (HALL & WHITEFIELD) (HU, 1968a). *Parabolinoides contractus* FREDERICKSON (HU, 1969), and *Parabolinoides moustonus* HU (HU, 1970). The similarities suggest that these genera form an allied group perhaps are family level?

*Figured specimens:* Anaprotaspis, U. C. M. 40309; Metaprotaspides, U. C. M. 40309a-b; Paraprotaspides, U. C. M. 40309c-g; Early meraspides, U. C. M. 40309h-l; Late meraspides, U. C. M. 40309m-q, s; Immature pygidium, U.C.M. 40309u; Hypostoma, U. C. M. 40309t.

Female form: Cranidia, U.C.M. 40309d', h', i'; Pygidia, U. C. M. 40309v, y, a'; Librigena, U. C. M. 40309g'.

Male form: Cranidia, U. C. M. 40309r, z, b', c', e', j', k'; Pygidia, U. C. M. 40309w, x; Librigena, U. C. M. 40309f'.

## Family Lochocephalidae HUPÉ, 1953

## Genus *Glaphyraspis* RESSER, 1937

## *Glaphyraspis parva* (WALCOTT)

Pl. 9, figs. 1-33 and text-figs. 2A-O

*Liostracus parva* WALCOTT, 1899, p. 463, pl. 65, fig. 6.

*Glaphyraspis parva* (WALCOTT), RESSER, 1937, p. 12; LOCHMAN & HU, 1962, p. 438, pl. 68, figs. 7-52; RASETTI, 1965, p. 40, pl. 10, figs. 9-17.

*Raaschella ornata* LOCHMAN, 1938, p. 82, pl. 18, figs. 6-10; PALMER, 1954, p. 767, pl. 98, figs. 7-9.

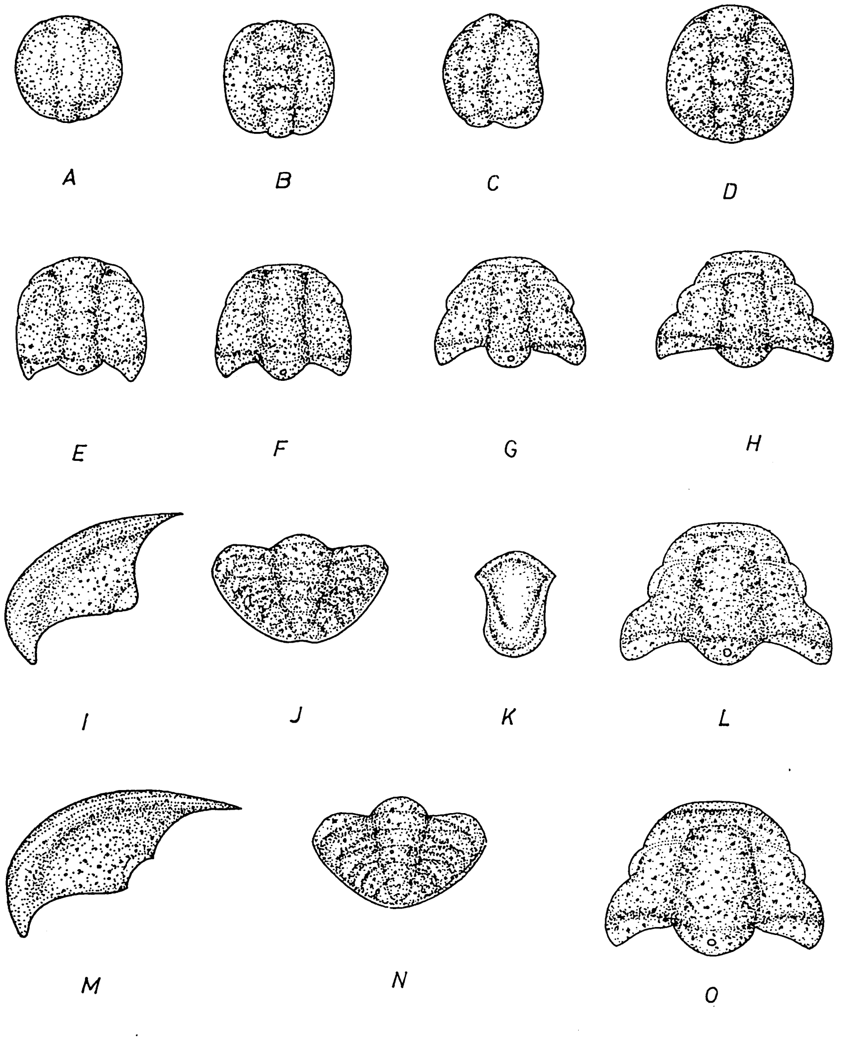
*Raaschella occidentalis* LOCHMAN, in LOCHMAN & DUNCAN, 1944, p. 43-44, pl. 4, figs. 1-5.

*Glaphyraspis ornata* (LOCHMAN), RASETTI, 1961, p. 112; PALMER, 1962, p. 93, pl. 19, figs. 15-19, 26, 27 and text-fig. 2C, and 1965, p. 51, pl. 7, figs. 15-17, 20-22; RASETTI, 1965, p. 41, pl. 10, fig. 8, and pl. 11, figs. 13, 14.

*Glaphyraspis oderi* RASETTI, 1965, p. 41, pl. 10, figs. 18-22.

*Remarks:* The material from the Moll section consists of about 250 mature and immature specimens. The specimens are interpreted as representing the disarticulated moults of a single population of *Glaphyraspis parva* which were normally the habitants of the area during the early *Aphelaspis* zone period. The smallest immature is about 0.22 mm and the largest adult 1.8 mm in length (sag.), and the series forms a very continuous growth sequence between these limits.

A detailed comparison of the specimens of this population reveals that two kinds of intraspecific variant can be recognized in the cranidia, librigenae, and pygidia. One group is characterized by a shorter nearly subtrapezoidal glabella, broader ocular platform, and having the rounded pygidium well marked by larger pleural nodes; the other group by a slightly rectangular-oblongus glabella, narrow ocular platform, and having the pygidial margin without distinct node. These morphologic variations again possibly represent the sexual differences within the same species popula-



Text-figure 2. A growth series of *Glaphyraspis parva* (WALCOTT). A, Anaprotaspis, ×60; B, C, Dorsal and lateral views of a metaprotaspis, ×60; D, E, Two paraprotaspides, ×60, ×55; F, An early meraspis, ×35; G, H, Two late meraspides, ×25, ×20; I, M, A male and a female librigenae, ×20; J, N, A male and a female pygidia, ×14, ×20; K, Hypostoma, ×14; L, O, A female and a male cranidia, ×12, ×11. (all drawings were prepared by tracing the outline from photographs.)

tion, as seen in *Aphelaspis walcotti*. The first group is tentatively designated as the male form and the second as the female. The sex ratio is 123.

It seems that the ornamentations of fine to coarse granules, and the occipital median tubercle, present on the dorsal surface of the exoskeleton may have no actual specific significance since within the same population these features may or may not preserved and are very variable. They thus appear to be individual variations.

The species *Glaphyraspis oderi* reported by RASETTI (1965) from Tennessee, *G. ornata* by PALMER (1965, pl. 7, figs. 16, 17 only) from Nevada and *G. occidentalis* by LOCHMAN & DUNCAN (1944) from Montana all possessing elongate glabella are possibly the female form of *G. parva*, whereas those of *G. parva* by WALCOTT (1899) from Yellowstone Park, *G. ornata* by RASETTI (1965) from Tennessee, by LOCHMAN (1938) from Texas, and PALMER (1965, pl. 7, figs. 15, 20-22) from Nevada all having the shorter trapezoidal glabella are presumably the male form. Those cranidia illustrated by SHAW (1956), RASETTI (1965, pl. 10, figs. 9-16 & 1961, pl. 22, figs. 14-17), and LOCHMAN & HU (1960, pl. 97, figs. 1-8) with nearly parallel sided glabella do not belong to this species.

## *Glaphyraspis parva* (WALCOTT), ontogeny

**Anaprotaspid stage** (Pl. 9, fig. 1 and text-fig. 2A).—The shield is about 0.20-0.22 mm in length (sag.), moderately convex, and with no clear dorsal furrows. The axial lobe is slightly elevated and with a round node at both the anterior and posterior ends.

In the present stage the specimens surface shows no any distinct characters, except for a pair of elevated nodes at the anterior and posterior margins, which suggest the orientation of the shield. The specimen is presumably as early larva of this species before the metaprotaspid stage, and the distinctive characters arise later in ontogeny. It is the earliest and the smallest specimen which has been recovered from the material, the specimen been also slightly deformed and possibly indicates that the skeleton was thin and not well hardened in this stage.

**Metaprotaspid stage** (Pl. 9, figs. 2, 3 and text-figs. 2B, C).—The shield is subcircular, convex, with well differentiated axial and pleural lobes, and about 0.23 to 0.28 mm in length (sag.). The axial lobe extends the full length of the shield, expands slightly anterioly, and is indistinctly divided into five convex segments. The pleural lobes are convex, swelling laterally along the margin, and of about the same width as the axial lobe. The anterior pits are indistinctly impressed, a pair of superciliary eye brow ridges extends posterolaterally from the sides of the first axial segment —the frontal lobe.

The present stage differs from the previous one in having the axis and the pleural lobes well differentiated, and the axis divided into five convex segments. The stage can presumably be correlated to the stage assigned by PALMER (1962, p. 93) to the anaprotaspid stage.

**Paraprotaspid stage** (Pl. 9, figs. 4-8 and text-figs. 2D, E).—The shield is convex, about 0.30-0.35 mm long, subcircular and divided into cephalic and protopygidial shields by a distinct suture. The cephalic shield is trapezoidal in outline, convex, and well differentiated into axial and pleural lobes by distinct dorsal furrows. The axial lobe is expanded forward from the small occipital ring, divided into four unequal segments; the anterior segment being the largest. The fixigena is about the same width as the axis and convex along the lateral margin. A pair of indistinct anterior pits is impressed on the sides of the first glabellar segment. The narrow supercilioid ridges run postero-laterally from the sides of the frontal lobe along the anterior fixigenal border. The posterior fixigenal border is deeply separated by a border furrow; it is narrow and curves posteriorly at the extreme lateral end. The protopygidium slopes steeply downward from the posterior cephalic margin. It is presumably lenti-form and consists of one or two segments.

The present stage is equivalent to PALMER's (1962) metaprotaspid and early meraspid stages, and it is mainly characterized by the presence of the protopygidium and broadened posterior fixigenal border, but no anterior border has yet appeared.

**Early meraspid stage** (Pl. 9, figs. 9-12, 20 and text-fig. 2F).—The cranidium is trapezoidal in outline, convex, about 0.40 mm in length (sag.). The glabella is regularly oblong with parallel sides, convex, and divided into four transverse segments. The glabellar furrows are all shallow across the central axis and deepen laterally. A pair of faint pits impressed on the sides of the first glabellar segment. The occipital ring is deeply separated by an occipital furrow, is convex posteriorly, and bears a minute median node. The anterior border is narrow, distinctly marked by a frontal furrow, and arched forward. The fixigena is about the same width as the glabella on the mid-line (tr.), convex. The narrow palpebral lobe located laterally, and the palpebral ridge is elevated, running continuously from the anterior end of the palpebral lobe direct to the sides of the first glabellar segment. The posterior fixigenal furrow is broad and deep, with the elevated marginal border slightly wider than the occipital ring. The anterior facial suture is very short and convex, and the posterior one is broadly divergent-convex.

The pygidium is semicircular in outline, convex, transverse, and consists of 4 or 5 disankylosed segments. The axis is conical, tapers slightly posteriorly and is marked with distinctly convex axial rings. The pleural lobe is flat or slightly convex along the inner marginal border and is wider than the axis. The pleural bands end with a pair of short broad spines. The skeletal surface is covered by dense granules, and a pair of large nodes is on the lateral ends of each pygidial segment.

The present stage is characterized by the oblong glabella, narrow anterior border, and the disankylosed pygidial segments.

**Late meraspid stage** (Pl. 9, figs. 13, 17, 21, 27, 28 and text-figs. 2G, H).—The cranidium is rectangular in outline, convex, about 0.50 to 0.70 mm in length (sag.). The glabella is cylindrical but tapering forward, and with a rounded anterior margin. The glabellar furrows are complete but the anterior one is shallower than the next. The occipital ring is crescentic convex, and well delimited by the occipital furrow, and marked with a minute median granule. A narrow preglabellar field appears in front of the glabella; it is flat or slightly depressed. The anterior border is narrower than the preglabellar field, gently convex, arching slightly forward, and with the median notch directed to the glabella. The fixigena is narrower than the width of the glabella between the palpebral lobes (tr.), convex, and the narrow small palpebral lobe is located in front of the mid-line of the glabella (tr.); its end is continuous with the well-elevated palpebral ridge forward to the anterior glabella. The posterior fixigena is rather broadly convex, and has the posterior border about the same length as the occipital ring (tr.).

The librigena has generally the same form as that of the adult but slightly narrower and the free margin curves gently. The pygidium is subtriangular in outline, and has no marginal spine. All of the exoskeleton is covered by fine or medium-sized granules, and parallel ridges are marked along the anterior cephalic border.

The present stage is differentiated from the preceding one in having the glabella conical; a preglabellar field; fixigena narrower; and subtriangular pygidium. It is differentiated from the holaspis by the slender glabella; by the frontal furrow absence of the median notch; and the transverse-triangular pygidium.

*Remarks:* PALMER (1962) reported a growth series of *Glaphyraspis "ornata"* from Nevada. The skeletons are beautifully preserved and silicified, showing

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## Explanation of Plate 8

*Aphelaspis walcotti* RESSER

Fig. 1. Anaprotaspid shield, showing four axial segments, x45, U.C.M. 40309.

Figs. 2, 3. Two metaprotaspides, showing five axial segments and a longitudinal fissure along the central axis, x45, U.C.M. 40309a; x45, U.C.M. 40309b.

Figs. 4–8. Five paraprotaspid shields, showing the appearence of the protopygidia, 4, x50, U.C.M. 40309c; 5, x50, U.C.M. 40309d; 6, x50, U.C.M. 40309e; 7, x50, U.C.M. 40309f; 8, x45, U.C.M. 40309g.

Figs. 9–13. Five early meraspid cranidia, showing the presence of the anterior border, 9, x35, U.C.M. 40309h; 10, x30, U.C.M. 40309i; 11, x40, U.C.M. 40309j; 12, x25, U.C.M. 40309k; 13, x30, U.C.M. 40309l.

Figs. 14–18, 20. Six late meraspid cranidia, showing the presence of the preglabellar field, 14, x30, U.C.M. 40309m; 15, x25, U.C.M. 40309n; 16, x20, 40309o; 17, x17, U.C.M. 40309p; 18, x14, U.C.M. 40309g; 20, x10, U.C.M. 40309s.

Figs. 19, 29, 30, 33. Top views of a few male cranidia, 19, x4.5, U.C.M. 40309r; 29, x3.3, U.C.M. 40309b'; 30, x3.5, U.C.M. 40309c'; 33, x4, U.C.M. 40309e'.

Fig. 21. A complete hypostoma, x8, U.C.M. 40309t.

Fig. 22. An immature pygidium, showing the disankylosed thoracic segments, x20, U.C.M. 40309u.

Figs. 23, 26, 28. Three female pygidia, showing the rounded posterior marginal border, x23, x6, U.C.M. 40309v; 26, x3, U.C.M. 40309y; 28, x4, U.C.M. 40309a'.

Figs. 24, 25. Two male pygidia, x7, U.C.M. 40309w; x4, U.C.M. 40309x.

Fig. 27. Front view of a male cranidium, showing the deep dorsal furrow, x4, U.C.M. 40309z.

Figs. 31, 32. Front and top views of a nearly complete female cranidium, showing the shallow dorsal furrow, x3, U.C.M. 40309d'.

Fig. 34. A male librigena, showing the narrow ocular platform, x3, U.C.M. 40309f'.

Fig. 35. A female librigena, x5, U.C.M. 40309g'.

Fig. 36. A nearly complete female cranidium, showing the subquadrate glabella, x3, U.C.M. 40309h'.


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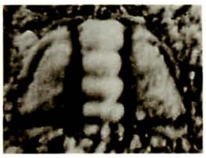
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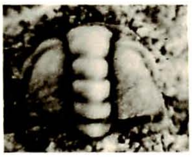
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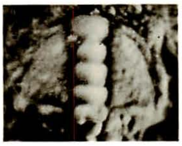
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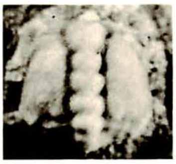
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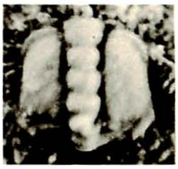
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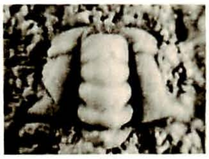
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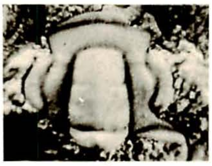
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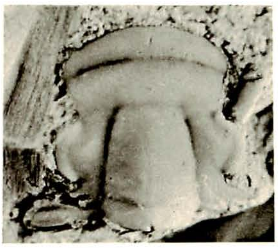
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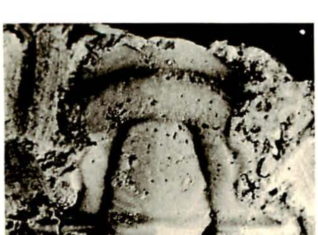
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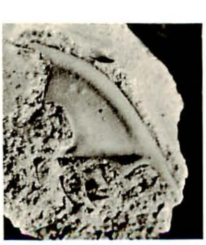
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both ventral and dorsal well. The smallest shield "anaprotaspis" bears a pair of posterior fixigenal spines, and demonstrates the common structure held by most of the trilobite larvae. It is unfortunate that PALMER gives only a few figures; more photographs would possibly show the complete growth sequence and the adult variations.

The ontogenetic development of the present species is most closely similar to that of the *Welleraspis lata* HOWELL (HU, 1964), *Welleraspis swartzi* (TASCH), *Welleraspis lochmanae* HU, (HU, 1969), and *Pemphigaspis bullata* HULL (HU, 1968b), indicating that these species are phylogenetically closely related. Here RASETTI's (1959) taxonomic assignment (Family Lonchocephalidae) and PALMER's (1962, p. 95) interpretation are strongly supported.

*Figured specimens:* Anaprotaspis, U. C. M. 40310; Metaprotaspides, U. C. M. 40310a-b; Paraprotaspis, U. C. M. 40310c-g; Early meraspides, U. C. M. 40310h-k; Late meraspis, U. C. M. 40310l; Immature librigena, U. C. M. 40310t; Hypostoma, U. C. M. 40310w.

Female form: Cranidia, U. C. M. 40310m, n, q, b', f'; Pygidia, U. C. M. 40310c', d'; Librigena, U. C. M. 40310r.

Male form: Cranidia, U. C. M. 40310o, u, x, e'; Pygidia, U. C. M. 40310s, y, z, a'; Librigena, U. C. M. 40310v.

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## Explanation of Plate 9

*Glaphyraspis parva* (WALCOTT)

Fig. 1. A slightly deformed anaprotaspid shield, showing no distinct axial segments, ×60, U.C.M. 40310.

Figs. 2, 3. Two metaprotaspid shields, showing the well differentiated dorsal furrows and axial rings, ×60, U.C.M. 40310a; ×60, U.C.M. 40310b.

Figs. 4-8. Five paraprotaspid shields, showing the appearence of protopygidium, 4, ×60, U.C.M. 40310c; 5, ×50, U.C.M. 40310d; 6, ×55, U.C.M. 40310e; 7, ×40, U.C.M. 40310g.

Figs. 9-12. Four early meraspid cranidia, notice the presence of the anterior border, 9, ×35, U.C.M. 40310h; 10, ×35, U.C.M. 40310i; 11, ×35, U.C.M. 40310j; 12, ×30, U.C.M. 40310k.

Fig. 13. A late meraspid cranidium, showing the appearence of the preglabellar field, ×25, U.C.M. 40310l.

Figs. 14, 15, 18, 29, 33. A few female cranidia, showing the rectangular-oblongus glabella, 14, ×20, U.C.M. 40310m; 15, ×22, U.C.M. 40310n; 18, ×24, U.C.M. 40310q; 29, ×15, U.C.M. 40410b'; 33, ×12, U.C.M. 40310f'.

Figs. 16, 22, 25, 32. Four male cranidia, showing the trapezoidal glabella, 16, ×22, U.C.M. 40310o; 22, ×15, U.C.M. 40310u; 25, ×20, U.C.M. 40310x; 32, ×11, U.C.M. 40310e'.

Figs. 17, 21. Two immature librigenae, ×20, U.C.M. 40310p; ×26, U.C.M. 40310t.

Fig. 19. A female librigena, ×20, U.C.M. 40310n.

Figs. 20, 26-28. Four male pygidia, 20, ×30, U.C.M. 40310s; 26, ×14, U.C.M. 40310y; 27, ×11, U.C.M. 40310z; 28, ×30, U.C.M. 40310a'.

Fig. 23. A male librigena, ×20, U.C.M. 40310v.

Fig. 24. A hypostoma, ×14, U.C.M. 40310w.

Figs. 30, 31. Two female pygidia, showing the smaller pleural granules, ×17, U.C.M. 40310c'; ×20, U.C.M. 40310d'.

*Aphelaspis walcotti* RESSER

Figs. 34, 36. Two male cranidia, showing the deeper dorsal furrows and longer glabellae, ×6, U.C.M. 40309j'; ×4, U.C.M. 40309k'.

Fig. 35. A female cranidium, showing the shallow dorsal furrows, ×3.6, U.C.M. 40309i'.


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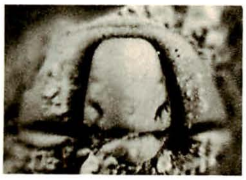
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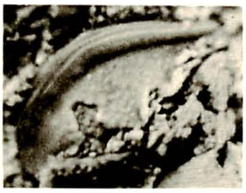
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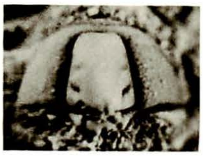
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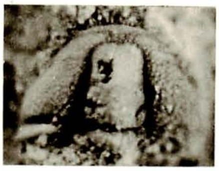
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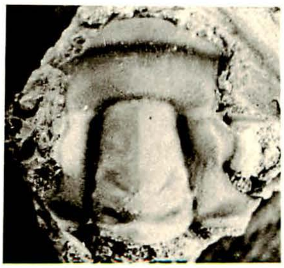
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Trans. Proc. Palaeont. Soc. Japan, N.S., No. 82, pp. 73-92, pls. 10-12, June 30, 1971

# 579. SOME NEOGENE CHEILOSTOMATA (BRYOZOA) FROM OKINAWA-JIMA*

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沖縄島からの新第三紀唇口類（こけ虫）： 沖縄島のこけ虫化石は未だ報告されていないが，今回試料を得たのでここに報告する。20属33種を同定記載し，古環境など明らかにした。

速　水　倶　子

## Introduction and Acknowledgments

The fossil bryozoans described in the present article form the first record of the phylum from Okinawa-jima. The specimens were collected by Dr. Hiroshi NODA of the Institute of Geology and Paleontology, Tohoku University, during his field work and fossil collecting in several parts of Okinawa-jima in the winter of 1969. The bryozoans are all from the single newly discovered locality in the lower part of a cliff newly cut for the purpose of building a fertillizer mixing tank, and situated near to the Yagena Harbor, Yonagusuku-son in the south-central part of the Island.

The purpose of this article is to describe the bryozoan fauna and thus contribute to the geological distribution of the phylum in the Cenozoic rocks of Japan and to aid in the establishment of a bryozoan chronological scale for Japan.

Here the writer expresses her thanks to Professor Kotora HATAI of the Institute of Geology and Paleontology, Tohoku University, for his kindness and guidance throughout the course of the present work. Thanks are due to Dr. Hiroshi NODA of the same Institute for his kind offer of the specimens and valuable information on the stratigraphic position of the fossils. Appreciation is due to Messrs. Kimiji KUMAGAI and Shohei OTOMO of the same Institute for their photographic work.

## Notes on the Stratigraphy of the Fossil Bryozoan Sandstone Beds

The fossil bryozoans described in the present article were collected with other fossil invertebrates by Hiroshi NODA from a newly cut cliff not far from the Yagena Harbor, Yonagusuku-son in the south-central part of Okinawa-jima (Text-fig. 1). This cliff measures about 20 meters in width and more than 10 meters in height, and in it is exposed the following sequence. In the lower part of the cliff is developed the Yonabaru Clay of a little more than 8 meters in thickness and its base is not exposed. Superposed on the Yonabaru is a laminated sandstone of about 50-60 cm in thickness,

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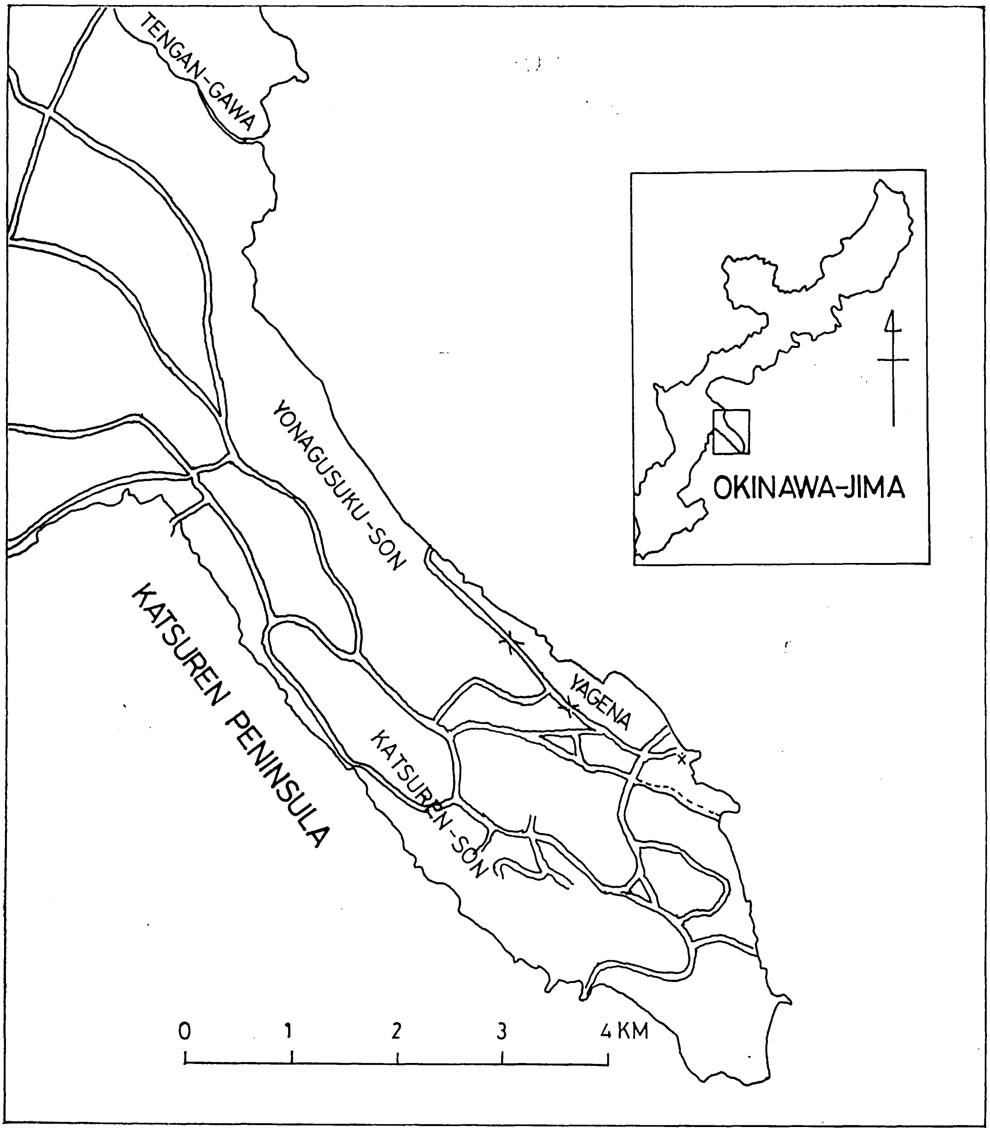
* Received July 15, 1970; read June 27, 1970 at the Ibaraki University, Mito.



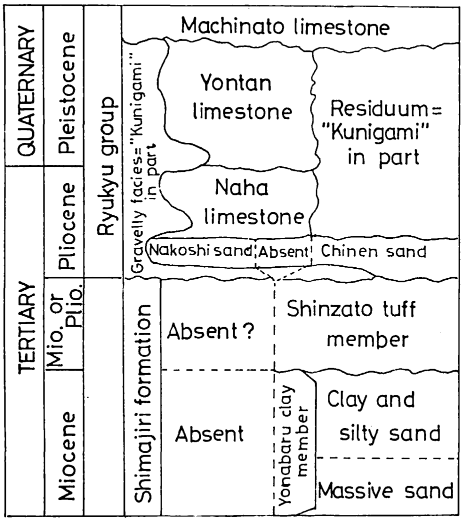
Text-fig. 1. Map showing the position of the fossil localities.

succeeded upward with about 3 m thick fossiliferous sandstone (bryozoans and molluscs), and a 5 m thick white tuff intercalated with siltstone at the top. The sandstone situated above the Yonabaru Clay is correlated by NODA with the lowest part of the Shinzato Tuff of MACNEIL (1960). The mentioned sequence was not exposed at the time of MACNEIL's survey.

The stratigraphic position of the Shinzato Tuff according to the classification by MACNEIL (1960) is as shown in Table 1.

The stratigraphic sequence observed in the newly cut cliff is remarkably similar to that of the type locality (MAC-

Table 1. Stratigraphic classification of the younger Neogene rocks in Okinawa-jima, according to MACNEIL (1960).



NEIL, 1960).

The fossil bryozoans are from the fossiliferous sandstone mentioned above, and in association there were found abundant, well preserved specimens of gastropods, bivalves and solitary corals. The gastropods and bivalves are now being studied by NODA.

The geological age of the Shinzato Tuff was stated to be Miocene or Pliocene by MACNEIL, but NODA is in the opinion that the basal part of the formation which is represented by the fossiliferous sandstone mentioned above may be Early Pliocene in age (oral communication).

## The Fossil Bryozoa

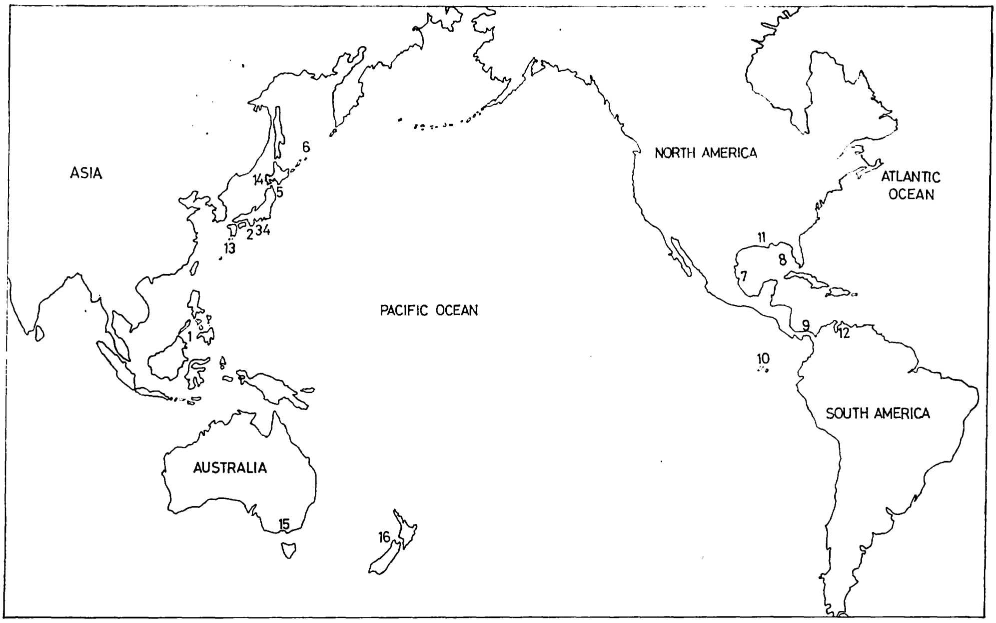
The fossil bryozoans washed out of the fossiliferous sandstone are represented by 33 species distributed among 20 genera (Table 2). These bryozoans are rather well preserved as shown in the annexed plates and represent the first record of the phylum from the Island. From the occurrence of the bryozoans some interesting features can be recognized concerning their geographic distribution (Text-fig. 2). Among the 33 species distinguished in the fauna, only 13 are in common with the fauna of the so-called "Ryukyu Limestone" (KATAOKA, 1960). The Ryukyu Limestone is superposed with unconformity upon the Shinzato Tuff in Okinawa-jima and thus one would expect a larger number of species mutual between the two formations. Probably bottom control and local ecological factors played an important role in establishing the dissimilar bryozoan fauna of the Ryukyu Limestone and Shinzato Tuff. Only two species (*Steganoporella magnilabris* (BUSK) and *Parasmittina trispinosa* (JOHNSTON)) seem to be cosmopolitan in distribution, being recorded from the Philippine Region, Kii Peninsula, Sagami Bay and its vicinity, Tsugaru Strait and Mutsu Bay, Off Florida and Tortugas Islands, Galapagos Islands, Panama Canal Zone, the Cenozoic of Venezuela, Pleistocene of Kikai-jima and the Quaternary of Louisiana. The remaining species are all of Indo-Pacific distribution, Recent and fossil. Since none of the 33 species are known from the waters around the Kuril Islands and Hokkaido, it is evident that the fauna is a typical Indo-Pacific one. The two species (*Caberea hataii* OKADA and *Parasmittina trispinosa* (JOHNSTON)) that have been recorded from Mutsu Bay in northern Northeast Honshu seem to be, at a glance, species having relation with cool water temperature. However, it is known that the bay is influenced by the warm water Tsushima Current; the same two species are also known from off Florida and Tortugas Island. Thirteen of the 33 species are known from the Philippine Islands and neighboring seas. Three spe-

Table 2. Distribution of the Bryozoa; numbers refer to Text-fig. 2.

| Distribution<br>Genus and species | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Antropora tincta* (HASTINGS) | | | | | | | | | + | | | | | | | |
| *Cranosina coronata* (HINCKS) | + | | | | | | | | | | | | + | | | |
| *Copidozoum planum* (HINCKS) | | + | | | | | | | + | | | | | | | |
| *Steganoporella magnilabris* (BUSK) | + | + | + | + | | | | + | | | | + | + | | | |
| *Thalamoporella novae-hollandiae* (HASWELL) | + | | | | | | | | | | | | + | | | |
| *Cellaria punctata* (BUSK) | | + | + | + | | | | | | | | | + | | | |
| *Caberea hataii* OKADA | | + | | | + | | | | | | | | | | | |
| *Schizomavella ovoidea* CANU & BASSLER | + | | | | | | | | | | | | + | | | |
| *S.* sp. | | | | | | | | | | | | | | | | |
| *Cleidochasma biavicularia* (CANU & BASSLER) | + | | | | | | | | | | | | + | | | |
| *C. bassleri* (CALVET) | | | | + | | | | | | | | | | | | |
| *C. granifera* (CANU & BASSLER) | + | | | | | | | | | | | | | | | |
| *C.* aff. *fallax* (CANU & BASSLER) | | | | | | | | | | | | | + | | | |
| *Hippoporella spinigera* (PHILIPPS) | + | | | | | | | | | | | | | | | |
| *Cigclisula occlusa* (BUSK) | + | | | | | | | | | | | | | | | |
| *Mucronella* sp. | | | | | | | | | | | | | | | | |
| *Parasmittina aviculoumbonata* KATAOKA | | | | | | | | | | | | | + | | | |
| *P. spathulata* (SMITT) | | | | | | | + | | | | + | | + | | | |
| *P. peristoaviculata* KATAOKA | | | | | | | | | | | | | + | | | |
| *P. trispinosa* (JOHNSTON) | | + | | + | + | | | + | + | + | | | + | | | |
| *Smittina* sp. | | | | | | | | | | | | | | | | |
| *Smittoidea acaroensis* (LEVINSEN) | | | | | | | | | | | | | | | | + |
| *Rhynchozoon* aff. *grandicella* CANU & BASSLER | | | | | | | | | | | | | | | | |
| *R.* sp. | | | | | | | | | | | | | | | | |
| *R.* (?) sp. | | | | | | | | | | | | | | | | |
| *Adeonellopsis arculifera* (CANU & BASSLER) | + | | | | | | | | | | | | | | | |
| *A. subteres* (ROEMER) | | | | | | | | | | | | | | | | |
| *A. yarraensis* (WATERS) | + | | | + | | | | | | | | | + | | + | |
| *Holoporella palmata* (MICHELIN) | | | | | | | | | | | | | | | | |
| *H.* sp. | | | | | | | | | | | | | | | | |
| *Costazia radiata* (ORTMANN) | + | + | + | + | | | | | | | | | + | | | |
| *Conescharellina concava* CANU & BASSLER | + | | | | | | | | | | | | | | | |
| *C.* cf. *breviconica* CANU & BASSLER | + | | | | | | | | | | | | | | | |

cies (*Steganoporella magnilabris* (BUSK), *Cellaria punctata* (BUSK) and *Costazia radiata* (ORTMANN)) extend their range northward to the Izu Peninsula, Shizuoka Prefecture and six are known from the Kii Peninsula, Wakayama Prefecture.

Thus as mentioned above, the bryozoan fauna is typically Indo-Pacific in geographical distribution. However, explanation for the difference in the bryozoan biota between the Shinzato Tuff and superjacent "Ryukyu Limestone"



Text-fig. 2. Index map of localities showing geographical distributions.
1. Philippine Region. 2. Kii Peninsula. 3. Izu Peninsula. 4. Sagami Bay and its vicinity. 5. Tsugaru Strait and Mutsu Bay. 6. Kuril Islands and neighbouring district. 7. Gulf of Mexico. 8. Off Florida and Tortugas Islands. 9. Panama Canal Zone. 10. Galapagos Islands. 11. Quaternary of Louisiana. 12. Cenozoic of Venezuela. 13. Pleistocene of Kikai-jima. 14. Miocene of Hokkaido. 15. Tertiary of Southwest Victoria. 16. Tertiary of New Zealand.

must be reserved until the bryozoans from more localities of the two formations have been studied.

The environment of the bryozoan fauna, so far as the present locality is concerned, is judged to have been a warm water inner neritic zone area probably not influenced directly by the open sea although free connection therewith is evident from the assemblage of the bryozoans, gastropods and bivalves.

## **Descriptions and Remarks on the Bryozoa**

### Order Cheilostomata BUSK, 1852

### Suborder Anasca LEVINSEN, 1909

### Family Hincksinidae CANU & BASSLER, 1927

### Genus *Antropora* NORMAN, 1903

### *Antropora tincta* (HASTINGS, 1930)

Pl. 10, fig. 1.

1930. *Crassimarginatella tincta* HASTINGS, p. 708, pl. 5, figs. 16–19; pl. 17, fig. 120.
1950. *Antropora tincta* (HASTINGS); OSBURN, p. 54, pl. 4, fig. 7; pl. 29, figs. 7, 8.
1965. *Antropora tincta* (HASTINGS); MAWATARI, p. 600.

*Description:* Zoarium encrusts shell fragment. Zooecium oval, distal part narrower than proximal. Gymnocyst vestigial or wanting. Mural rim smooth and not bearing spines, cryptocyst narrow. Vestigial avicularia triangular and small at proximal end of each zooecium. One septule located on distal wall. No dietellae. Ovicell not found.

*Measurements* (*in mm*):
Zoaria: Lz=0.60-0.64, Wz=0.44-0.48;
Opecia: lop=0.40-0.42, wop=0.32-0.36.

*Distribution*: Recent: Galapagos Islands, Panama Canal Zone (HASTINGS, 1930), Point Conception, California to Peru and Galapagos Islands [4-143 m] (OSBURN, 1950).

*Depository*: IGPS coll. cat. no. 91480.

### Genus *Cranosina* CANU & BASSLER, 1933

### *Cranosina coronata* (HINCKS, 1881)

Pl. 10, fig. 4.

1881. *Membranipora coronata* HINCKS, p. 147, pl. 10, fig. 1.
1882. *Membranipora coronata* HINCKS; HINCKS, p. 118.
1920. *Ellisina coronata* (HINCKS); CANU & BASSLER, p. 126.
1926. *Setosellina coronata* (HINCKS); HARMER, p. 265, pl. 16, figs. 2-4.
1929. *Ellisina coronata* (HINCKS); CANU & BASSLER, p. 104, pl. 7, figs. 9, 10.
1953. *Cranosina coronata* (HINCKS); BASSLER, p. 160, fig. 122, 6.
1960a. *Cranosina coronata* (HINCKS); KATAOKA, p. 227, pl. 25, fig. 7.

*Description*: Zoarium encrusting. Zooecia large, without gymnocyst, aperture occupying the entire front; spines wanting. Cryptocyst narrow but deep, strongly tuberculate, particularly at the sides of opecia. Avicularium at distal end of each zooecium placed transversely. Porechambers and ovicells not found.

*Measurements* (*in mm*):
Zooecia: Lz=0.80-1.04, Wz=0.56-0.60;
Opecia: lop=0.48-0.56, wop=0.20-0.24.

*Distribution*: Recent: Philippine, Ceylon (HINCKS, 1881 and 1882), Celebes, New Guinea [18-32 m] (HARMER, 1926), Philippine Region [53-104 m] (CANU & BASSLER, 1929). Pleistocene: Kikai-jima (KATAOKA, 1960a).

*Depository*: IGPS coll. cat. no. 91481.

## Family Calloporidae NORMAN, 1903

### Genus *Copidozoum* HARMER, 1926

### *Copidozoum planum* (HINCKS, 1880)

Pl. 10, fig. 2.

1880. *Membranipora plana* HINCKS, p. 81, pl. 11, fig. 2.
1923. *Membranipora vibraculoides* OKADA, p. 223, fig. 25.
1930. *Copidozoum planum* (HINCKS); HASTINGS, p. 713.
1950. *Copidozoum planum* (HINCKS); OSBURN, p. 73.
1965. *Copidozoum planum* (HINCKS); MAWATARI, p. 601, fig. 54b.

*Description*: Zoarium encrusting. Zooecia moderate size, distinct, oval. Gymnocyst slightly developed, and cryptocyst narrow, descending to center, crenated. Mural rim smooth, without spines. Interzooecial avicularia placed scattering. Ovicell globose, perforated with small pores. Dietellae and septules not found.

*Measurements* (*in mm*):
Zooecia: Lz=0.60-0.72, Wz=0.32-0.44;
Opecia: lop=0.48-0.60, wop=0.24-0.32;
Interzooecial avicularia:
lav=0.48, wav=0.20;
Diameter of ovicell=0.32.

*Distribution*: Recent: Panama Region [18-55 m] and Galapagos Islands [9-11 m] (HASTINGS, 1930), Straits of Korea [218 m] (OKADA, 1923).

*Depository*: IGPS coll. cat. no. 91482.

## Family Steganoporellidae HINCKS, 1884

### Genus *Steganoporella* SMITT, 1873

### *Steganoporella magnilabris* (BUSK, 1854)

Pl. 10, figs. 3, 11.

1884. *Steganoporella magnilabris* (BUSK); BUSK, p. 75, pl. 23, fig. 2.
1890. *Steganoporella magnilabris* (BUSK); ORTMANN, p. 30, pl. 2, fig. 7.
1923. *Steganoporella magnilabris* (BUSK); OKADA, p. 224.
1923. *Steganoporella magnilabris* (BUSK); CANU & BASSLER, p. 63, pl. 14, figs. 12, 13.
1926. *Steganoporella magnilabris* (BUSK); HARMER, p. 277, pl. 167, figs. 1-3, 7, 9, 12, text-fig. 10.
1928. *Steganoporella magnilabris* (BUSK); CANU & BASSLER, p. 64, pl. 7, figs. 8-12; pl. 32, fig. 6.
1929. *Steganoporella magnilabris* (BUSK); CANU & BASSLER, p. 144, pl. 15, figs. 1, 2.
1935. *Steganoporella magnilabris* (BUSK); OKADA & MAWATARI, p. 130.
1941. *Steganoporella magnilabris* (BUSK); SILÉN, p. 62.
1952. *Steganoporella magnilabris* (BUSK); MAWATARI, p. 263.
1953. *Steginoporella magnilabris* (BUSK); BASSLER, p. 172, figs. 132, 1a, 1b.
1960a. *Steginoporella magnilabris* (BUSK); KATAOKA, p. 236, pl. 28, fig. 9.
1965. *Steginoporella magnilabris* (BUSK); MAWATARI, p. 604, figs. 63a-d.
1967. *Steginoporella magnilabris* (BUSK); WEISBORD, p. 35, pl. 2, figs. 1-3; pl. 6, fig. 1.
1967. *Steganoporella magnilabris* (BUSK); RUCKER, p. 824, fig. 13, i.

*Description:* Zoarium encrusts pelecypod-shell, uni- or bilamellar. Zooecia distinct, large, separated by a shallow furrow. Mural rim thin, salient. Frontal cryptocyst finely porous. Opecia irregular or semilunar, a little elongate.

*Measurements (in mm):*
A-Zooecia: Lz=0.80-1.20, Wz=0.60-0.72;
B-Zooecia: Lz=1.00-1.40, Wz=0.80-0.88.

*Distribution:* Recent: Sagami Bay [0-366 m] (ORTMANN, 1890), Straits of Korea [93-110 m] (OKADA, 1923), Philippine, Celebes Region [0-350 m] (HARMER, 1926), Gulf of Mexico Region [44-333 m] (CANU & BASSLER, 1928), Philippine Region [37-421 m] (CANU & BASSLER, 1929), Izu (Japan) (OKADA & MAWATARI, 1935), Japan [0-600 m] (SILÉN, 1941), Venezuela (WEISBORD, 1967). Lower Pliocene: Venezuela (WEISBORD, 1967). Pliocene and Miocene: Florida (CANU & BASSLER, 1923).

*Depository:* IGPS coll. cat. no. 91483.

## Family Thalamoporellidae
## LEVINSEN, 1902

### Genus *Thalamoporella* HINCKS, 1887

### *Thalamoporella novae-hollandiae* (HASWELL, 1880)

Pl. 10, fig. 8.

1926. *Thalamoporella novae-hollandiae* (HASWELL); HARMER, p. 295, pl. 19, figs. 14-16, 18, 19, text-fig. 11.
1960a. *Thalamoporella novae-hollandiae* (HASWELL); KATAOKA, p. 238, pl. 27, fig. 12.

*Description:* Zoarium free, cylindrical, stem quadrangular. Zooecia large, elongate, separated by a thin thread. Frontal porous cryptocyst. Aperture almost round, with proximal round wide sinus. Two large opeciules asymmetrical, pierced, porous cryptocyst. Avicularium interzooecial larger than zooecia, rounded distally.

*Measurements (in mm):*
Zooecia: Lz=0.92-1.00, Wz=0.40-0.44;
Interzooecial avicularia:
lav=1.08, wav=0.42.

*Distribution:* Recent: Jedan, Aru Island [13 m] (HARMER, 1926), Pleistocene: Kikai-jima (KATAOKA, 1960a).

*Depository:* IGPS coll. cat. no. 91484.

### Family Cellariidae HINCKS, 1880

### Genus *Cellaria* ELLIS & SOLANDER, 1786

### *Cellaria punctata* (BUSK, 1852)

Pl. 12, fig. 7.

1890. *Cellaria triangularis* ORTMANN, p. 32, pl. 2, fig. 13.
1921. *Cellaria triangularis* BUSK; OKADA, p. 30, text-fig. 7.
1926. *Cellaria punctata* (BUSK); HARMER, p. 337, pl. 21, figs. 14-16, text-fig. 13, a.
1929. *Cellaria japonica* CANU & BASSLER, p. 171, pl. 20, fig. 8.
1935a. *Cellaria triangularis* ORTMANN; SAKAKURA, p. 15.
1935b. *Cellaria triangularis* ORTMANN; SAKAKURA, p. 108.
1935. *Cellaria triangularis* ORTMANN; OKADA & MAWATARI, p. 132.
1941. *Cellaria punctata* (BUSK); SILÉN, p. 70, figs. 85, 86.
1952. *Cellaria punctata* (BUSK); MAWATARI, p. 275, pl. 12, fig. 6, text-fig. 10.
1957. *Cellaria punctata* (BUSK); KATAOKA, p. 145.
1960a. *Cellaria punctata* (BUSK); KATAOKA, p. 240, pl. 27, fig. 13.
1965. *Cellaria punctata* (BUSK); MAWATARI, p. 605, text-figs. 68a-d.

*Description:* Zoarium free, articulated; segments cylindrical, formed of 8 rows of zooecia. Zooecia distinct, separated by a slight furrow, hexagonal, arranged in transverse rows. Mural rim thick, smooth; cryptocyst deep, lozenge-shaped, smooth. Aperture semilunar, transverse, bordered by a thick salient peristome; proximal border straight sometimes mounted, with two lateral denticles. Avicularia interzooecial, as large as, or sometimes larger than zooecia.

*Measurements (in mm):*
Zooecia: Lz=0.40-0.42, Wz=0.30-0.32;
Avicularia: lav=0.40-0.44, wav=0.36;
Diameter of zoarium=1.00.

*Distribution:* Recent: Japan [64-275 m] (ORTMANN, 1890), Japan [18-128 m] (OKADA, 1921), Philippine Region [0-113 m] (HARMER, 1926), Japan Sea (CANU & BASSLER, 1929), Japan and Straits of Korea (OKADA & MAWATARI, 1935), Bonin Islands [100-120 m] (SILÉN, 1941). Pleistocene: Boso (Japan) (SAKAKURA, 1935a), Kikai-jima (KATAOKA, 1960a). Pliocene: Aomori (Japan) (KATAOKA, 1957).

*Depository:* IGPS coll. cat. no. 91485.

### Family Scrupocellariidae LEVINSEN, 1909

### Genus *Caberea* LAMOUROUX, 1816

### *Caberea hataii* OKADA, 1929

Pl. 12, fig. 12.

1929. *Caberea hataii* OKADA, p. 13, pl. 1, fig. 2; pl. 4, fig. 2, text-fig. 2.
1935b. *Caberea hataii* OKADA; SAKAKURA, p. 109.
1937. *Caberea hataii* OKADA; OKADA & MAWATARI, p. 437.
1941. *Caberea hataii* OKADA; SILÉN, p. 82, figs. 96, 97; pl. 5, fig. 19; pl. 6, fig. 22.
1965. *Caberea hataii* OKADA; MAWATARI, p. 610, figs. 88d-f.

*Description:* Zoarium free, tuft irregular flabellate. Zooecia arranged in transverse rows of four serial, somewhat elongate, nearly uniformly wide throughout length. Scutum may not entirely fill opecia. Two spines present at distal part of mural rim. Avicularia located at proximal part of zooecium, single or paired.

*Measurements (in mm):*
Zooecia: Lz=0.48, Wz=0.28.

*Distribution:* Recent: Goto Islands (Japan) [200-300 m] and Sagami Bay (Japan) [50-600 m] (SILÉN, 1941), Tsugaru Strait (Japan) (OKADA, 1929).

*Depository:* IGPS coll. cat. no. 91486.

## Family Schizoporellidae JULLIEN, 1903

### Genus *Schizomavella* CANU & BASSLER, 1917

### *Schizomavella ovoidea* CANU & BASSLER, 1929

Pl. 10, fig. 12.

1929. *Schizomavella ovoidea* CANU & BASSLER, p. 305, pl. 33, figs. 6-8.
1960a. *Schizomavella ovoidea* CANU & BASSLER; KATAOKA, pl. 33, fig. 13.

*Description:* Zoarium multilamellar, encrusts shell fragment. Zooecia distinct, separated by a thin thread. Frontal granular, bordered by a row of thread like areolar pores. Aperture pyriform, with two small cardelles. No lyrula. Avicularia small, located before aperture, median rounded. Peristome thin.

*Measurements (in mm):*
Zooecia: Lz=0.44-0.52, Wz=0.40-0.48.

*Distribution:* Recent: Philippine Region [35-48 m] (CANU & BASSLER, 1929). Pleistocene: Kikai-jima (KATAOKA, 1960a).

*Depository:* IGPS coll. cat. no. 91487.

### *Schizomavella* sp.

Pl. 11, fig. 5.

*Description:* Zoarium encrusting, zooecia of moderate size. Frontal porous cryptocyst. Aperture almost round and proximally wide a round sinus. Two lateral cardelles. Suboral avicularium small, triangular, transverse. Ovicell not found.

*Measurements (in mm):*
Zooecia: Lz=0.76, Wz=0.44-0.48.

*Remarks:* The present specimens resemble *Schizomavella cincta* (HINCKS), but differ from it in having no prominent umbo.

*Depository:* IGPS coll. cat. no. 91488.

## Family Cleidochasmatidae CHEETHAM & SANDBERG, 1964

### Genus *Cleidochasma* HARMER, 1957

### *Cleidochasma biavicularia* (CANU & BASSLER, 1929)

Pl. 10, fig. 9.

1929. *Gemellipora biavicularia* CANU & BASSLER, p. 312, pl. 34, fig. 7.
1960a. *Gemelliporella biavicularia* (CANU & BASSLER); KATAOKA, p. 252, pl. 29, fig. 3.

*Description:* Zoarium free, bilamellar. Zooecia distinct, undulated, convex, separated by a deep furrow. Frontal reticulate, pores sporadic, or marginal areolae present. Aperture keyhole-shaped. Frontal avicularia, transverse and suboral avicularia present. Ovicell not found.

*Measurements (in mm):*
Zooecia: Lz=0.48-0.68, Wz=0.40-0.48.

*Remarks:* According to the original description by CANU & BASSLER (1929), this species is an encrusting type, but KATAOKA (1960a) stated "the zoarial features have two types, one is the same as the original description; encrusting form, and the other is the bifurcating narrow cylindrical tube type." The present writer found only the narrow cylindrical type in the present collection. The zooecia are arranged back to back.

*Distribution:* Recent: Philippine Region [39-104 m] (CANU & BASSLER, 1929). Pleistocene: Kikai-jima (KATAOKA, 1960a).

*Depository:* IGPS coll. cat. no. 91489.

### *Cleidochasma bassleri* (CALVET, 1931)

Pl. 10, fig. 13.

1890. *Schizoporella cleidostoma* ORTMANN, p. 49, pl. 3, fig. 37.
1890. ?*Schizoporella cleidostoma* var. *inermis* ORTMANN, p. 50.
1890. ?*Schizoporella cleidostoma* var. *japonica* ORTMANN, p. 50.
1929. ?*Hippoporina planulata* CANU & BASSLER, p. 321, pl. 37, fig. 6, text-figs. 132J, 133C.
1929. *Hippoporina fallax* (pars) CANU & BASSLER, p. 320, text-figs. 132 I, 133 B.
1957. *Cleidochasma bassleri* (CALVET); HARMER, p. 1042, pl. 71, figs. 5, 16.
1965. *Cleidochasma bassleri* (CALVET); MAWATARI, p. 616, figs. 114a, b.

*Description:* Zoarium encrusts on shell fragment, bilamellar. Zooecia subhexagonal, obscure. Frontal smooth, flat, marginal with several pores. Aperture keyhole-shape with two cardelles, avicularia small, triangular, aperture unilateral or bilateral, sometimes wanting, typically directed outwards and distally. Ovicells small, smooth, immersed distal zooecium. No spines.

*Measurements (in mm):*
Zooecia: Lz=0.60-0.62, Wz=0.48-0.50;
Aperture: lap=0.28, wap=0.14.

*Distribution:* Recent: Sagami Bay (Japan) [183 m] (ORTMANN, 1890), Philippine Region [35-422 m] (CANU & BASSLER, 1929), Sulu Archipelago [16-23 m], Sumbawa [69 m], and Badjo Bay [0-40 m] (HARMER, 1957).

*Depository:* IGPS coll. cat. no. 91490.

### *Cleidochasma granifera* (CANU & BASSLER, 1929)

Pl. 10, fig. 7.

1929. *Hippoporina granifera* CANU & BASSLER, p. 319, pl. 35, fig. 10.

*Description:* Zoarium encrusts on shell fragment. Zooecia distinct, separated by a little elongated furrow, deformed by avicularium. Frontal very convex, ornamented with large granulations. Aperture keyhole-shaped, avicularia lateral and under aperture, forming small umbo. Ovicell hyperstomial, globose, numerous granular, not closed by operculum.

*Measurements (in mm):*
Zooecia: Lz=0.36-0.48, Wz=0.24-0.40;
Ovicell: lov=0.24, wov=0.24.

*Distribution:* Recent: Philippine Region [421 m, 11.6°C] (CANU & BASSLER, 1929).

*Depository:* IGPS coll. cat. no. 91491.

### *Cleidochasma* aff. *fallax* (CANU & BASSLER, 1929)

Pl. 11, fig. 9.

Aff.:
1929. *Hippoporina fallax* CANU & BASSLER, p. 320, pl. 37, figs. 4, 5.
1929. *Gemelliporella obesa* CANU & BASSLER, p. 313, pl. 35, figs. 3, 4.
1957. *Cleidochasma fallax* (CANU & BASSLER); HARMER, p. 1043, pl. 71, figs. 6-8.
1960a. *Gemelliporella* cf. *fallax* (CANU & BASSLER); KATAOKA, p. 252, pl. 37, fig. 5.

*Description:* Zoarium encrusts on shell fragment. Zooecia distinct, frontal garnished, reticulate, marginal pores rare.

Aperture keyhole-shaped: peristome not salient. Avicularia frontal with pivot, its direction inconstant and sometimes form umbo. Ovicell hyperstomial, reticulate, no pores.

*Measurements (in mm):*
Zooecia: Lz=0.44-0.52, Wz=0.36-0.48;
Aperture: lap=0.20-0.22, wap=0.12;
Ovicell: lov=0.25, wov=0.20.

*Distribution:* Recent: Philippine Region [35-439 m] (CANU & BASSLER, 1929), New Guinea and Timor [0-118 m] (HARMER, 1957). Pleistocene: Kikai-jima (KATAOKA, 1960a).

*Remarks:* The present specimen resembles this species by the characters of the frontal, aperture, and other features, but differs from it in the character of the avicularia. It may be a new species.

*Depository:* IGPS coll. cat. no. 91492.

## Family Hippoporinidae BASSLER, 1935

### Genus *Hippoporella* CANU, 1917

### *Hippoporella spinigera* (PHILIPPS, 1899)

Pl. 10, fig. 10.

1929. *Hippoporina squamosa* CANU & BASSLER, p. 322, pl. 37, figs. 8, 9.
1957. *Hippoporella spinigera* (PHILIPPS); HARMER, p. 1100, pl. 73, fig. 13.

*Description:* Zoarium encrusts on shell fragments. Zooecia small, smooth, outline slightly indistinct. Aperture subcircular, transverse; suboral lip distally with a straight, denticulate edge overhanging orifice; rising gradually on one side, descending on other, where a minute sinus exists. Suboral avicularia acute, present on both sides of aperture, frontal avicularia larger than suboral one, their orientation inconstant. Spines 6 to 8.

*Measurements (in mm):*
Zooecia: Lz=0.28-0.32, Wz=0.28-0.36.

*Distribution:* Recent: Philippine Islands (CANU & BASSLER, 1929), Sumbawa [69 m] (HARMER, 1957).

*Depository:* IGPS coll. cat. no. 91493.

## Suborder Ascophora LEVINSEN, 1909

## Family Stomachetosellidae CANU & BASSLER, 1917

### Genus *Cigclisula* CANU & BASSLER, 1927

### *Cigclisula occlusa* (BUSK, 1884)

Pl. 10, fig. 5.

1884. *Escharoides occlusa* BUSK, p. 150, pl. 21, figs. 8-8b.
1927. *Cigclisula (Escharoides) occlusa* (BUSK); CANU & BASSLER, p. 7.
1929. *Cigclisula occlusa* (BUSK); CANU & BASSLER, p. 291. pl. 31, figs. 3-10.
1953. *Cigclisula occlusa* (BUSK); BASSLER, p. 200, fig. 150, 2.
1957. *Cigclisula occlusa* (BUSK); HARMER, p. 1057, pl. 69, figs. 16-18.

*Description:* Zoarium free, ramose. Zooecia large, separated by a thread, back to back. Frontal very porous pleurocyst, marginal pores large. Aperture large, with small lateral cardelles. Suboral avicularium located laterally under aperture, form small umbo. Ovicell hyperstomial with marginal grilled pores. Frontal avicularia small, 1-6, interzooecial avicularium large, spatulate.

*Measurements (in mm):*
Zooecia: Lz=0.96-1.20, Wz=0.52-0.92;
Avicularia: lav=0.80, wav=0.60.

*Distribution:* Recent: Indian Ocean [384 m] (BUSK, 1884), Philippine Region [37-104 m] (CANU & BASSLER, 1929), Timor [0-40 m] (HARMER, 1957).

*Depository:* IGPS coll. cat. no. 91494.

## Family Smittinidae LEVINSEN, 1909

### Genus *Mucronella* HINCKS, 1880

### *Mucronella* sp.

Pl. 11, fig. 1.

*Description:* Zoarium encrusts, bilamellar. Zooecia of moderate size, distinct, separated by a salient thread. Frontal small granular, with a row of marginal areolae. Aperture rather round, with a broad lyrula at proximal portion. No avicularia, or cardelles. Ovicell not found.

*Remarks:* The present specimen resembles *M. major* (HINCKS), but differs from it by lacking of the oral spine and smaller measurements.

*Depository:* IGPS coll. cat. no. 91495.

### Genus *Parasmittina* OSBURN, 1952

### *Parasmittina aviculoumbonata* KATAOKA, 1960

Pl. 11, fig. 6.

1960a. *Parasmittina aviculoumbonata* KATAOKA, p. 256, pl. 36, fig. 8.

*Description:* Zoarium encrusts, bilamellar. Zooecia distinct, separated by a salient thread, rectangular, arranged in linear series. Frontal granular, bordered by a row of areolar pores. Aperture subcircular, with broad lyrula and no cardelles. Small avicularia on both sides of aperture, frontal avicularia one or two, sometimes wanting, small, spatulate. Ovicell hyperstomial, large globose with perforated area bordered by raised thin ridge on the frontal.

*Measurements* (*in mm*):
Zooecia: Lz=0.80, Wz=0.40-0.48;
Ovicell: lov=0.36, wov=0.52.

*Distribution:* Pleistocene: Kikai-jima (KATAOKA, 1960a).

*Depository:* IGPS coll. cat. no. 91496.

### *Parasmittina spathulata* (SMITT, 1873)

Pl. 11, fig. 2.

1928. *Smittina trispinosa spathulata* SMITT; CANU & BASSLER, p. 114, pl. 15, figs. 9-13, text-fig. 21.
1929. *Smittina trispinosa* var. *spathulata* SMITT; CANU & BASSLER, p. 349.
1952. *Parasmittina spathulata* (SMITT); OSBURN, p. 415, pl. 49, figs. 12-14.
1960a. *Parasmittina spathulata* (SMITT); KATAOKA, p. 258, pl. 35, fig. 4.
1964. *Parasmittina spathulata* (SMITT); CHEETHAM & SANDBERG, p. 1037, text-figs. 44-47.

*Description:* Zoarium encrusts on shell fragments. Zooecia large, distinct, separated by a salient thread. Frontal granulated, polished, bordered by a row of areolar pores, sometimes additional pores present, especially at proximal part. Aperture rounded, with large lyrula. Peristome thin not raised, not bearing spines. Frontal avicularia of three types; one very large and spatulate, other small, oval and very long.

*Measurements* (*in mm*):
Zooecia: Lz=0.60-0.92, Wz=0.32-0.60.

*Distribution:* Recent: Gulf of Mexico Region (CANU & BASSLER, 1928), Florida [24-81 m] (CANU & BASSLER, 1929), Galapagos Islands [46-183 m] (OSBURN, 1952). Quaternary: Louisiana (CHEETHAM & SANDBERG, 1964). Pleistocene: Kikai-jima (KATAOKA, 1960a).

*Depository:* IGPS coll. cat. no. 91497.

### *Parasmittina peristoaviculata* KATAOKA, 1960

Pl. 11, fig. 7.

1960a. *Parasmittina peristoaviculata* KATAOKA, p. 256, pl. 34, fig. 4.

*Description:* Zoarium encrusting, bilamellar. Zooecia very large, exceeding 1.00 mm in length, distinct, separated by a thread. Frontal granulated, bordered by large areolar pores, slightly costate. Aperture somewhat elliptical, with broad lyrula in proximal part. Peristomie entire, thick, salient especially at distal part. Avicularium occurs along peristomie in peristomice. Ovicell not found.

*Measurements (in mm):*
Zooecia: Lz=1.00-1.52, Wz=0.48-0.60.

*Distribution:* Pleistocene: Kikai-jima (KATAOKA, 1960a).

*Depository:* IGPS coll. cat. no. 91498.

### *Parasmittina trispinosa* (JOHNSTON, 1838)

Pl. 11, fig. 3.

1890. *Smittina trispinosa* JOHNSTON; ORTMANN, p. 45, pl. 3, fig. 26.
1923. *Smittina trispinosa* JOHNSTON; CANU & BASSLER, p. 143, pl. 22, figs. 7-14.
1929. *Smittina trispinosa* JOHNSTON; CANU & BASSLER, p. 340, pl. 41, figs. 1-3.
1930. *Smittina trispinosa* JOHNSTON; CANU & BASSLER, p. 27, pl. 4, figs. 1-5.
1953. *Parasmittina trispinosa* (JOHNSTON); OSBURN, p. 412, pl. 49, figs. 7, 8.
1960a. *Parasmittina trispinosa* (JOHNSTON); KATAOKA, p. 258, pl. 35, fig. 3.
1960b. *Parasmittina trispinosa* (JOHNSTON); KATAOKA, p. 397.
1965. *Parasmittina trispinosa* (JOHNSTON); MAWATARI, p. 619, fig. 125c.

*Description:* Zoarium short cylindrical, multilamellar (?). Zooecia distinct, separated by a salient thread, forms and direction and regular. Frontal granular, bordered by a row of small, rounded areolar pores. Peristome thin, sometimes rises on side. Aperture rough, circular, with narrow lyrula. Two frontal avicularia small, short spatulate or oval. Ovicells not found.

*Measurements (in mm):*
Zooecia: Lz=0.56-0.68, Wz=0.40-0.44.

*Distribution:* Recent: Cosmopolitan down to a depth of 160 m (CANU & BASSLER, 1923), Philippine Region [42 m] and China Sea [198 m] (CANU & BASSLER, 1929), Galapagos Islands [62-73 m] (CANU & BASSLER, 1930), from Oregon to the Galapagos Islands (OSBURN, 1952). Pleistocene: South Carolina (CANU & BASSLER, 1923), Kikai-jima (KATAOKA, 1960a). Pliocene: Florida (CANU & BASSLER, 1923). Miocene: North Carolina (CANU & BASSLER, 1923).

*Depository:* IGPS coll. cat. no. 91499.

## Genus *Smittina* NORMAN, 1903

### *Smittina* sp.

Pl. 11, fig. 8.

*Description:* Zoarium encrusting, multilamellar. Zooecia distinct, pores large. Aperture rather round with large lyrula bearing avicularium. Every zooecium with avicularium cradled in depressed incomplete part of peristome. Oral spines and ovicell not found.

*Measurements (in mm):*
Zooecia: Lz=0.52-0.72, Wz=0.40-0.44.

*Remarks:* The present specimen resembles *S. canui* ROGICK, 1956, but differs from it in the smaller measurements, shape of lyrula, and because the ovicells were not found, specific determination is reserved.

*Depository:* IGPS coll. cat. no. 91500.

## Genus *Smittoidea* OSBURN, 1952

### *Smittoidea acaroensis* (LEVINSEN, 1909)

Pl. 10, fig. 6.

1952. *Smittina acaroensis* LEVINSEN; BROWN, p. 329, fig. 253.

*Description:* Zoarium encrusting, unilamellar. Zooecia vary in size, distinct, a thin thread on surface. Frontal granulate, bordered by a row of areolar pores. Aperture round when non-ovicelled and somewhat rectangular when ovicelled, with lyrula. Median avicularium small and oval, placed always in same location, within peristome border, proximal and just external to lyrula. Ovicell hyperstomial, not globose, front face punctured by a number of small irregular pores. Two small cardelles present.

*Measurements (in mm):*
Zooecia: Lz=0.56-1.04, Wz=0.28-0.40;
Ovicell: lov=0.32.

*Distribution:* Recent: New Zealand, Curtis Island, Bass Strait, Great Barrier Reef (BROWN, 1952). Upper Pliocene: Castlecliff (BROWN, 1952).

*Depository:* IGPS coll. cat. no. 91501.

## Family Reteporidae SMITT, 1867

### Genus *Rhynchozoon* HINCKS, 1895

### *Rhynchozoon* aff. *grandicella* CANU & BASSLER, 1923

Pl. 12, fig. 3.

Aff.:
1923. *Rhynchozoon grandicella* CANU & BASSLER, p. 156, pl. 47, figs. 7, 8.
1956. *Rhynchozoon grandicella* CANU & BASSLER; OSBURN, p. 459, pl. 54, figs. 7, 8, 11.

*Description:* Zoarium encrusts on shell fragment. Zooecia distinct, separated by a furrow, elongated. Frontal smooth, with few areolar pores in marginal part. Aperture rounded, proximal somewhat sinuate. Avicularia usually placed lateral of aperture, forming large umbonate process. Frontal avicularia elongate, sometimes oblique. Spines and ovicell not found.

*Measurements (in mm):*
Zooecia: Lz=0.52-0.96, Wz=0.56-0.64;
Frontal avicularia: lav=0.32, wav=0.08.

*Distribution:* Recent: OSBURN (1952) stated " The known range is from about 34° to 28°N Lat. and the bathymetric range from 33 m to 121 m." Pleistocene: Southern California (CANU & BASSLER, 1923).

*Affinities:* The present specimen agrees with the original description of CANU & BASSLER, except for the presence of frontal avicularium. And this also resembles OSBURN's description. But because the ovicell was not found specific determination is withheld until more specimens are found.

*Depository:* IGPS coll. cat. no. 91502.

### *Rhynchozoon* sp.

Pl. 12, fig. 2.

*Description:* Zoarium encrusting, bilamellar. Zooecia distinct, quincunx, separated by a thin thread. Frontal reticulate, with marginal spotted areolar pores. Aperture rounded, with asymmetrical narrow sinus. Suboral avicularium chamber forming small umbonate process, and located somewhat peristomie. No frontal avicularia.

*Measurements (in mm):*
Zooecia: Lz=0.64-0.88, Wz=0.40-0.44.

*Remarks:* This specimen belongs to the genus *Rhynchozoon* and may represent a new species.

*Depository:* IGPS coll. cat. no. 91503.

### *Rhynchozoon* (?) sp.

Pl. 11, fig. 10.

*Description:* Zoarium erect, free, forming semicyclic column, multilamellar.

Zooecia distinct, rather inflated frontal, bordered by a row of round areolar pores. Frontal smooth or sometimes reticulate, umbo places at middle or lateral of aperture; aperture semicircular, with more or less straight proximal border. Avicularia of moderate size and located that tip of umbo. No spines.

*Measurements (in mm):*
Zooecia: Lz=0.52-0.60, Wz=0.32-0.44.

*Remarks:* The present specimen resembles *Holoporella*, but differs from it in wanting the interzooecial avicularium. Whether this specimen belongs to this genus or some other one must be determined after more and better preserved specimens are found.

*Depository:* IGPS coll. cat. no. 91504.

## Family Adeonidae JULLIEN, 1903

## Genus *Adeonellopsis* MACGILLIVRAY, 1886

### *Adeonellopsis arculifera* (CANU & BASSLER, 1929)

Pl. 11, fig. 12.

1929. *Adeona arculifera* CANU & BASSLER, p. 377, pl. 52, figs. 1, 2.
1957. *Adeonellopsis arculifera* (CANU & BASSLER); HARMER, p. 800, pl. 53, figs. 13, 14, text-figs. 82C, 84A.

*Description:* Zoarium free, bilamellar. Zooecia distinct, separated by a furrow with a marginal row of sporadic pores. Aperture semicircular, transverse; peristome somewhat salient proximally. Ascopore small. Between aperture and ascopore, a triangular avicularium with acute tip proximally or sometimes transverse. Interzooecial avicularia almost as large as suboral one, and directed distally or transverse.

*Measurements (in mm):*
Zooecia: Lz=0.60, Wz=0.36-0.40;
Peristome: lper=0.08-0.10,
wper=0.12-0.20.

*Distribution:* Recent: Philippine Islands [39-53 m] (CANU & BASSLER, 1929), Paternoster Island (North of Sumbawa) [0-36 m] (HARMER, 1957).

*Depository:* IGPS coll. cat. no. 91505.

### *Adeonellopsis subteres* (ROEMER, 1863)

Pl. 11, fig. 4.

1968. *Adeonellopsis subteres* (ROEMER); DAVID & POUYET, p. 89, pl. 13, figs. 7, 8.

*Description:* Zoarium free, bilamellar; frond flat, rarely convex. Zooecia distinct, separated by a shallow furrow and surrounded by a row of slit-like pores. Aperture semicircular and transverse. Peristome salient in proximal part. Ascopore small, 4-8 stellate pores present. Between aperture and ascopore, one triangular avicularia present, tip directed obliquely distally and outward from median line of zooecium.

*Measurements (in mm):*
Zooecia: Lz=0.52-0.60, Wz=0.32;
Peristome: lper=0.10-0.12,
wper=0.14-0.16.

*Distribution:* Chattien: Kassel (Germany) (DAVID & POUYET, 1968).

*Depository:* IGPS coll. cat. no. 91506.

### *Adeonellopsis yarraensis* (WATERS, 1881)

Pl. 11, fig. 11.

1881. *Microporella yarraensis* WATERS, p. 331, pl. 15, figs. 27, 28.
1881. ? *Microporella clavata* WATERS, p. 332, pl. 18, fig. 84.
1884. *Adeonella tuberculata* BUSK, p. 180.
1890. *Adeonella tuberculata* BUSK; ORTMANN, p. 53, pl. 4, figs. 9a, b.
1929. *Adeonellopsis pentapora* CANU & BASSLER, p. 382, pl. 53, figs. 1-5.

1957. *Adeonellopsis yarraensis* (WATERS); BROWN, p. 79.
1957. *Adeonellopsis yarraensis* (WATERS); HARMER, p. 799, pl. 53, figs. 18, 19.
1960a. *Adeonellopsis pentapora* CANU & BASSLER; KATAOKA, p. 264, pl. 32, fig. 10.

*Description:* Zoarium free, bilamellar; frond flat or somewhat inflated. Zooecia rather distinct, separated by a shallow furrow and surrounded by a row of pores. Aperture somewhat embedded, semicircular, transverse. Cribriform area small, perforated by stellate pores. Between aperture and cribriform area, two avicularia, sometimes only one. Salient avicularium on front, at base of each zooecium but sometimes wanting.

*Measurements (in mm):*
Zooecia: Lz=0.48-0.52, Wz=0.32.

*Distribution:* Recent: Maizuru [64-73 m] and Sagami Bay [183 m] in Japan (ORTMANN, 1890), Philippine Region [37-970 m] (CANU & BASSLER, 1929). Pleistocene: Kikai-jima (KATAOKA, 1960a). Miocene (?): Victoria (Australia) (WATERS, 1881).

*Depository:* IGPS coll. cat. no. 91507.

## Family Celleporidae BUSK, 1852

### Genus *Holoporella* WATERS, 1909

### *Holoporella palmata* (MICHELIN, 1847)

Pl. 12, fig. 1.

1930. *Holoporella palmata* (MICHELIN); CANU & LECOINTRE, p. 111, pl. 23, figs. 1-11.

*Description:* Zoarium free, ramose, zooecium of moderate size, distinct, narrow, with shallow groove, frontal smooth but sometimes reticulate with a row of marginal areolae pores. Aperture rather round with very narrow lyrule and cardelles. Two different avicularia present; one at tip of umbo lateral of aperture, and another interzooecial and as large as or larger than suboral avicularia. Both with pivot. No spines, ovicell not found.

*Measurements (in mm):*
Zooecia: Lz=0.56-0.72, Wz=0.48;
Aperture: lap=0.20.

*Distribution:* Miocene: Touraine (France) (CANU & LECOINTRE, 1930).

*Depository:* IGPS coll. cat. no. 91508.

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## Explanation of Plate 10

Fig. 1. *Antropora tincta* (HASTINGS), x20.
Fig. 2. *Copidozoum planum* (HINCKS), x20.
Figs. 3, 11. *Steganoporella magnilabris* (BUSK), x30.
3. Basal view of zoarium.
11. Frontal view of another zoarium.
Fig. 4. *Cranosina coronata* (HINCKS), x30.
Fig. 5. *Cigclisula occlusa* (BUSK), x20.
Fig. 6. *Smittoidea acaroensis* (LEVINSEN), x30.
Fig. 7. *Cleidochasma granifera* (CANU & BASSLER), x20.
Fig. 8. *Thalamoporella novae-hollandiae* (HASWELL), x20.
Fig. 9. *Cleidochasma biavicularia* (CANU & BASSLER), x20.
Fig. 10. *Hippoporella spinigera* (PHILIPPS), x30.
Fig. 12. *Schizomavella ovoidea* CANU & BASSLER, x20.
Fig. 13. *Cleidochasma bassleri* (CALVET), x20.


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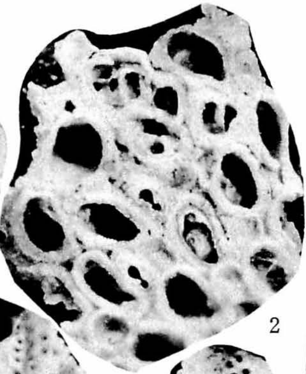
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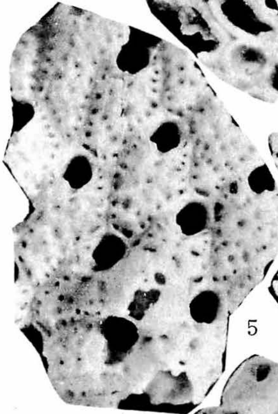
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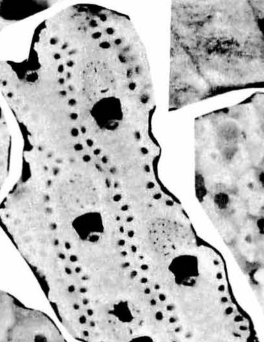
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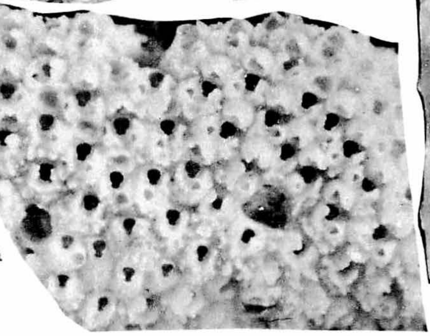
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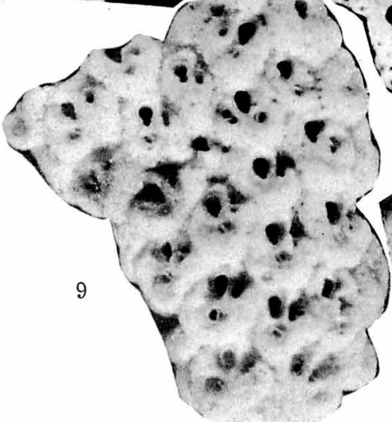
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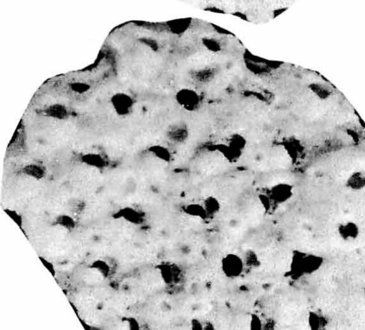
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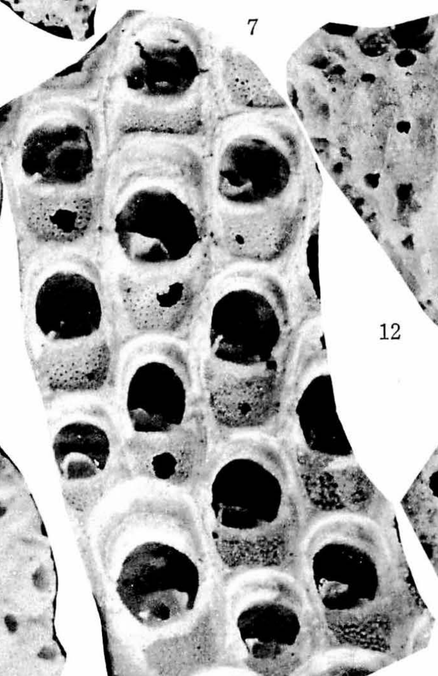
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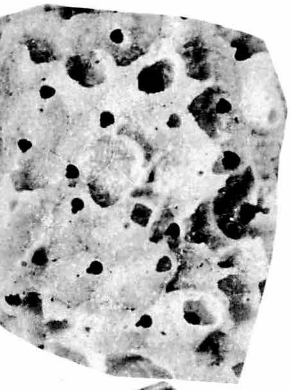
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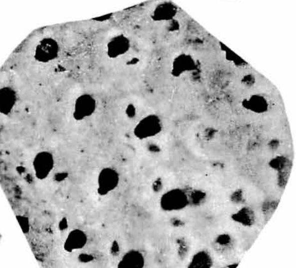
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### *Holoporella* (?) sp.

Pl. 12, fig. 6.

*Description:* Zoarium encrusting, unilamellar. Zooecia somewhat indistinct, convex, with many irregularly directed avicularia; elongated triangular, or short triangular, sometimes ovate in shape. Knob-like salient at proximal and lateral of aperture. Proximal one with elongated triangular avicularium. Areolar pores sometimes at marginal portion.

*Measurements (in mm):*

Zooecia: Lz=0.60, Wz=0.52.

*Remarks:* The present specimen resembles *Holoporella* and *Hippoporella* (especially *Hippoporella gorgonensis* HASTINGS), but differs from them by lacking spines.

*Depository:* IGPS coll. cat. no. 91509.

## Genus *Costazia* NEVIANI, 1895

### *Costazia radiata* (ORTMANN, 1890)

Pl. 12, figs. 4, 5.

1890. *Cellepora radiata* ORTMANN, p. 56, pl. 1, fig. 14.
1929. *Costazia radiata* (ORTMANN); CANU & BASSLER, p. 432, pl. 63, figs. 8, 9.
1935. *Cellepora radiata* ORTMANN; OKADA & MAWATARI, p. 141.
1960a. *Costazia radiata* (ORTMANN); KATAOKA, p. 267, pl. 33, fig. 3.

*Description:* Zoarium encrusting, unilamellar. Zooecia distinct, short cylindrical, salient, nearly smooth. Basal border of zooecia with areolar pores. Peristome salient, tubular with a pair of avicularia on each side of peristome, but sometimes wanting. Avicularia with pivot. Aperture semicircular with wide triangular sinus in proximal part. Ovicell not found.

*Measurements (in mm):*

Zooecia: Lz=0.52, Wz=0.44-0.48;
Aperture: lap=0.18, wap=0.14;
Peristome: lper=0.28-0.48,
wper=0.22-0.44;
Avicularia: lav=0.16, wav=0.10.

*Distribution:* Recent: Sagami Bay (Japan) [61-73 m] (ORTMANN, 1890), Japan Sea and Philippine Region [42-53 m] (CANU & BASSLER, 1929). Pleistocene: Kikai-jima (KATAOKA, 1960a).

*Depository:* IGPS coll. cat. no. 91510.

## Family Conescharellinidae LEVINSEN, 1909

## Genus *Conescharellina* D'ORBIGNY, 1852

### *Conescharellina concava* CANU & BASSLER, 1929

Pl. 12, figs. 8, 9.

1929. *Conescharellina concava* CANU & BASSLER, p. 488, pl. 66, figs. 8, 9.

*Description:* Zoarium free, large cone-shaped, transverse. Zooecia arranged in radial rows, with apertures very close together. Apertures elliptical with a wide semielliptical sinus. Radial rows separated by shallow furrows containing a row of small poriform avicularia close together. Base concave, perforated by large scattered pores.

*Measurements (in mm):*

Zoaria: height of zoaria=3.80,
diameter of zoaria=2.50-4.00.

*Distribution:* Recent: China Sea [161 m] (CANU & BASSLER, 1929).

*Depository:* IGPS coll. cat. no. 91511.

### *Conescharellina* cf. *breviconica* CANU & BASSLER, 1929

Pl. 12, figs. 10, 11.

Cf.:
1929. *Conescharellina breviconica* Canu & Bassler, p. 491, pl. 69, figs. 10–17.

*Description:* Zoarium free, short conical, less than 2.0 mm high. Zooecia large, numerous arranged in quincunx. Aperture long elliptical, with wide sinus. Interzooecial avicularium large, elliptical. Base flat, exhibits zooecial ribs arranged around a more or less large cancellated center.

*Measurements (in mm):*
Zoaria: height of zoaria=1.83,
diameter of zoaria=1.80.

*Remarks:* The present specimens resemble *C. breviconica*, but differ from it in the measurements which are higher than wide, and sometimes as wide as high.

*Distribution:* Recent: Philippine Region [145-214 m] (Canu & Bassler, 1929).

*Depository:* IGPS coll. cat. no. 91512.

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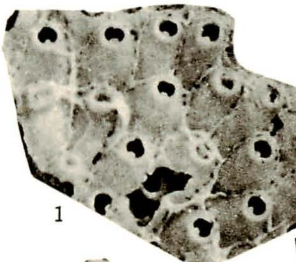
## Explanation of Plate 11

Fig. 1. *Mucronella* sp., x20.
Fig. 2. *Parasmittina spathulata* (Smitt), x30.
Fig. 3. *Parasmittina trispinosa* (Johnston), x20.
Fig. 4. *Adeonellopsis subteres* (Roemer), x30.
Fig. 5. *Schizomavella* sp., x30.
Fig. 6. *Parasmittina aviculoumbonata* Kataoka, x20.
Fig. 7. *Parasmittina peristoaviculata* Kataoka, x30.
Fig. 8. *Smittina* sp., x30.
Fig. 9. *Cleidochasma* aff. *fallax* (Canu & Bassler), x20.
Fig. 10. *Rhynchozoon* (?) sp., x20.
Fig. 11. *Adeonellopsis yarraensis* (Waters), x30.
Fig. 12. *Adeonellopsis arculifera* (Canu & Bassler), x20.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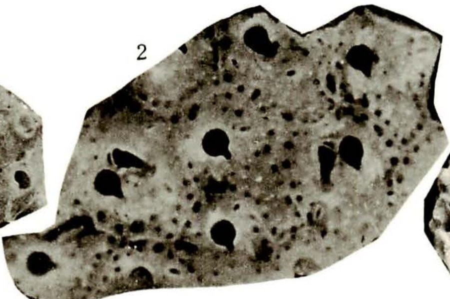
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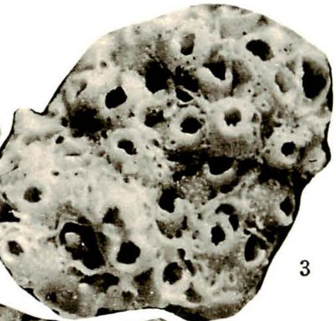
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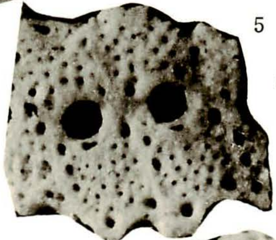
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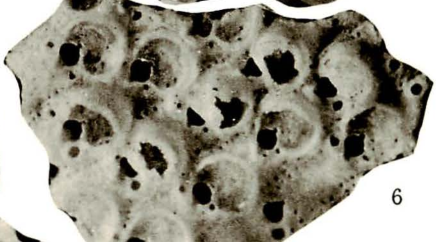
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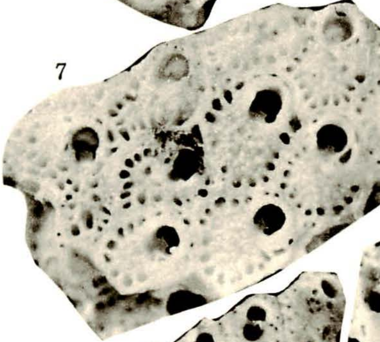
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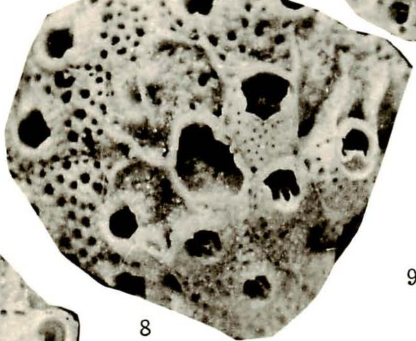
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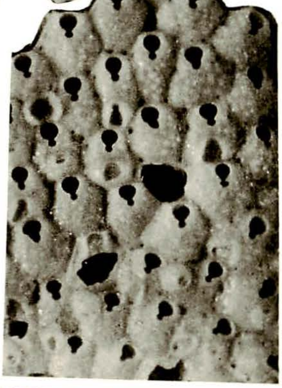
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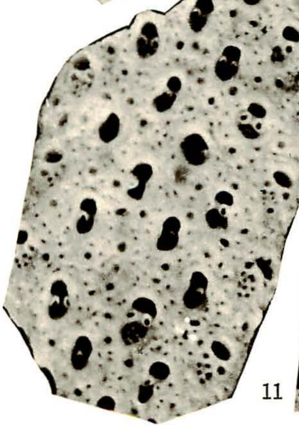
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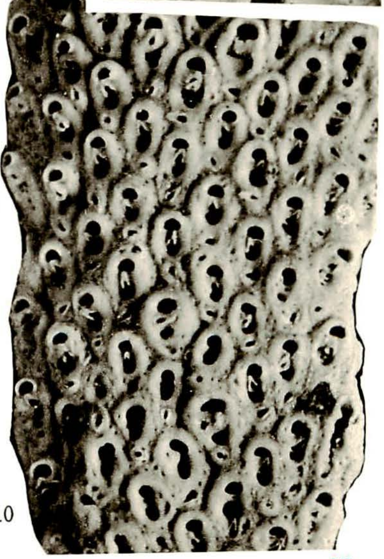
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|  |  |  |  |
|---|---|---|---|
| Chinen | 知　念 | Katsuren-son | 勝連村 |
| Kunigami | 国　頭 | Machinato (Minato) | 牧　港 |
| Naha | 那　覇 | Nakoshi (Nakaoshi) | 仲尾次 |
| Ryukyu | 琉　球 | Shimajiri | 島　尻 |
| Tengan-gawa | 天願川 | Yagena | 屋慶名 |
| Yonabaru | 与那原 | Yonagusuku-son | 与那城村 |
| Yontan (Yomitan) | 読　谷 |  |  |

## Explanation of Plate 12

Fig. 1. *Holoporella palmata* (MICHELIN), ×20.
Fig. 2. *Rhynchozoon* sp., ×20.
Fig. 3. *Rhynchozoon* aff. *grandicella* CANU & BASSLER, ×20.
Figs. 4, 5. *Costazia radiata* (ORTMANN), ×30.
  4. A pair of avicularia of peristome.
  5. Another zoarium; cylindrical zooecia, avicularia obscured.
Fig. 6. *Holoporella* (?) sp., ×30.
Fig. 7. *Cellaria punctata* (BUSK), ×30.
Figs. 8, 9. *Conescharellina concava* CANU & BASSLER,
  8. Basal view of large conical zoarium, ×20.
  9. Lateral view of the same zoarium, ×30.
Figs. 10, 11. *Conescharellina* cf. *breviconica* CANU & BASSLER.
  10. Lateral view of conical zoarium, ×30.
  11. Basal view of the same zoarium, ×30.
Fig. 12. *Caberea hataii* OKADA, ×30.


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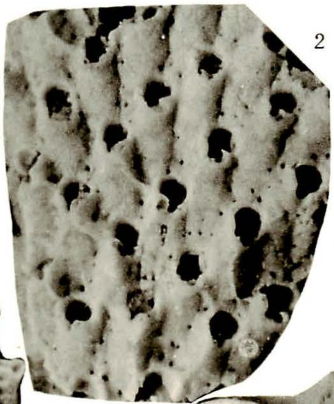
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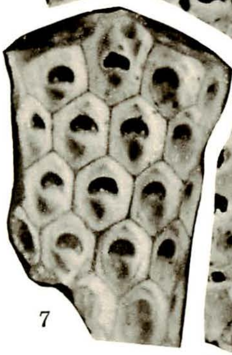
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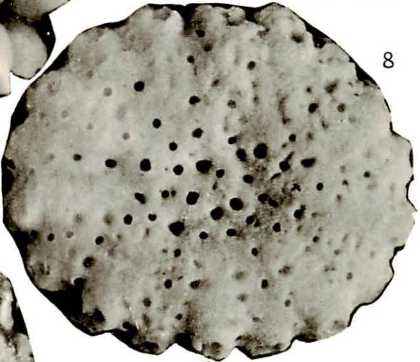
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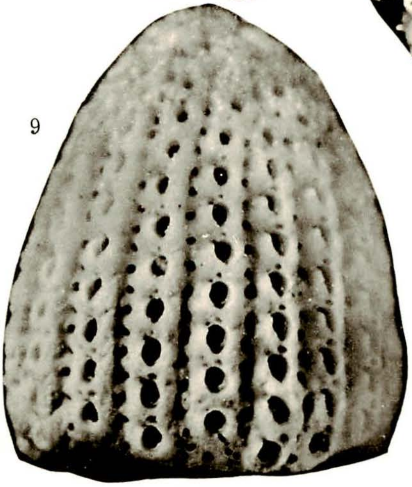
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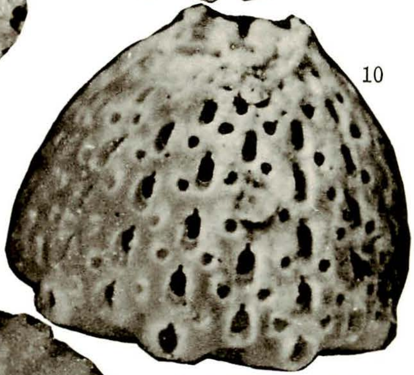
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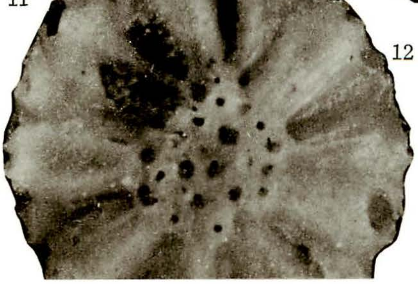
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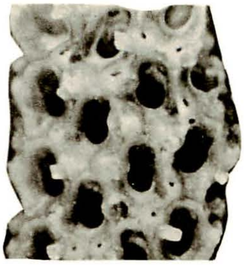
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Trans. Proc. Palaeont. Soc. Japan, N.S., No. 82, pp. 93-116, pls. 13, 14, June 30, 1971

# 580. FUSULINID BIOSTRATIGRAPHY AND MOLLUSCAN FAUNA FROM THE UPPERMOST PART OF THE SAKAMOTOZAWA FORMATION, AND THE PRE-KANOKURA UNCONFORMITY, IN THE SOUTHERN PART OF THE KITAKAMI MASSIF, NORTHEAST JAPAN

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南部北上山地坂本沢層最上部の化石層序と軟体動物化石群，並びに“先叶倉統不整合”について：南部北上山地に発達するペルム系坂本沢層の最上部元岩沢砂岩部層の岩相・化石層序学的検討の結果，白鳥沢石灰岩部層上部と同時異相の関係にあることを指摘した。また世田米地区の元岩沢砂岩部層より産出した軟体動物化石群より１属１種の頭足類，３属３種の腹足類，１新属を含む４属５種の斧足類を記載した。これらは，すべて上位の叶倉層および天神ノ木層の動物群と共通または近縁種で，両者の間に著しい時間間げきは存在しない。したがって，叶倉層の基底礫岩の分布を考慮しても“先叶倉統不整合”は地域的なものと推論する。

村　田　正　文

## Introduction and Acknowledgement

The Permian System in the southern part of the Kitakami Massif has been accepted as one of the standard type sections in Japan. Among the problems still remaining on the geology, that on the "pre-Kanokura unconformity" is important for the Permian stratigraphy and tectonics in the Kitakami Massif. There are two views on the post-Sakamotozawa pre-Kanokura break, one emphasizes a significant tectonic movement (MINATO, 1966) and the other denies such tectonism; (ONUKI, 1956, 1969; SAITO, 1966, 1968). From a bio-stratigraphical study of the Sakamotozawa Formation based on the fusulinids, and a paleontological study of the molluscs from the uppermost part of the Sakamotozawa Formation in the type and the Setamai areas, it was found that the fusulinid fauna of the uppermost part of the Sakamotozawa Formation is characterized by *Pseudofusulina ambigua* (DEPRAT), *Misellina* sp. and *Monodiexodina matsubaishi* (FUJIMOTO), and that the Motoiwazawa Sandstone Member of ONUKI (1956) in the Setamai District is contemporaneous with the uppermost part of the thick limestone (Shiratorizawa Limestone Member) cropping out in the lower course of the Kanokurazawa Valley. The Motoiwazawa Sandstone Member yielded many brachiopods and molluscs, comprising among the latter, three species of gastropods distributed among three genera, five species of bivalves belonging to four genera and one species of cephalopod. Among these nine species, two of bivalves and one cephalopod were

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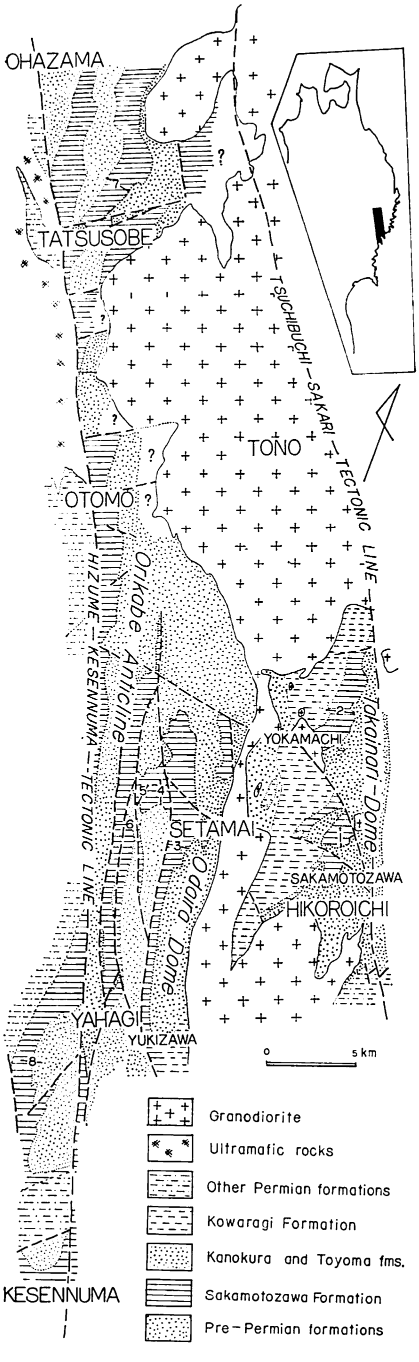
described by HAYASAKA (1925, 1962), HAYAMI (1960) and NAKAZAWA and NEWELL (1968) from the Kanokura Formation. The gastropods described in this work as new to science are from the Tenjinnoki Formation in the Maiya District. In general, the molluscan fauna of the uppermost part of the Sakamotozawa Formation extends upward to the superjacent Kanokura Formation.

The writer here offers his cordial thanks to Professor Kotora HATAI of the Institute of Geology and Paleontology, Tohoku University, for his help and advice during the course of this study. Acknowledgments are due to Professor Yoshio ONUKI of the Department of Geology, Miyagi College of Education, Professor Keiji NAKAZAWA of the Department of Geology and Mineralogy, Faculty of Science, Kyoto University, and Dr. Yasuji SAITO of the Department of Geology, National Science Museum for their suggestions and discussions.

## Note on the Stratigraphy of the Sakamotozawa Formation

In general, the pre-Permian formations in the southern part of the Kitakami Massif comprise six major anticlinal structures, each plunging southwards, with the axes trending in N-S to NNE-SSW directions. They are named the Tsuchikura Anticline, Takainari Dome, Odaira Dome, Orikabe Anticline, Senmaya Dome and Tobigamori Dome, in the order from east to west. The Permian System in the south Kitakami Massif rests on the Early and Middle Carboniferous formations with distinct unconformity, and is distributed around the anticlinal structures and in the synclinal parts between them. Early to Middle Permian rocks in the southern part of the Kitakami Massif differ considerably with area, due to the different movement of the basement complex (MURATA, 1964b, 1969; SAITO, 1968). The Sakamotozawa and its synonymous formations are developed in two belt areas each with N-S trend, and separated by a formation contemporaneous in age but of different litho-facies. The eastern belt area is named to the Hikoroichi District and extends along the western limb of the Takainari Dome from the northeast of Yokamachi, Sumita-cho, Kesen-gun, Iwate Prefecture, to the south of Hikoroichi, Ofunato City, Iwate Prefecture, via the type area of the Sakamotozawa Formation. The formation in the western belt covers the wide area between the western limbs of the Odaira Dome and the Orikabe Anticline, and extends from the east of Ohazama, Hienuki-gun, Iwate Prefecture, to the vicinity of Kesennuma City, Miyagi Prefecture and includes the Tatsusobe, Otomo, Setamai, and Yahagi areas (Text-fig. 1).

The Early Permian Sakamotozawa Formation was named by ONUKI (1937, 1938) the Sakamotozawa "Stage" (formation in the present sense) of his Yukizawa "Series" (group in the present sence) for the sequence of basal conglomerate, sandstone, slate and thick limestone, exposed in the Sakamotozawa Valley west of Sakamotozawa, Hikoroichi-machi, Ofunato City, Iwate Prefecture, in his study on the Palaeozoic stratigraphy of the southern part of the Kitakami Massif. MINATO *et al.* (1954) studied the stratigraphy of the Permian System in the Setamai District and proposed a time-stratigraphic subdivision, and distinguished three litho-stratigraphic units in the Sakamotozawa Series, e. g. Group VII, Group IX and Group X in ascending order. The Group VIII begins with remarkable basal conglomerate and con-

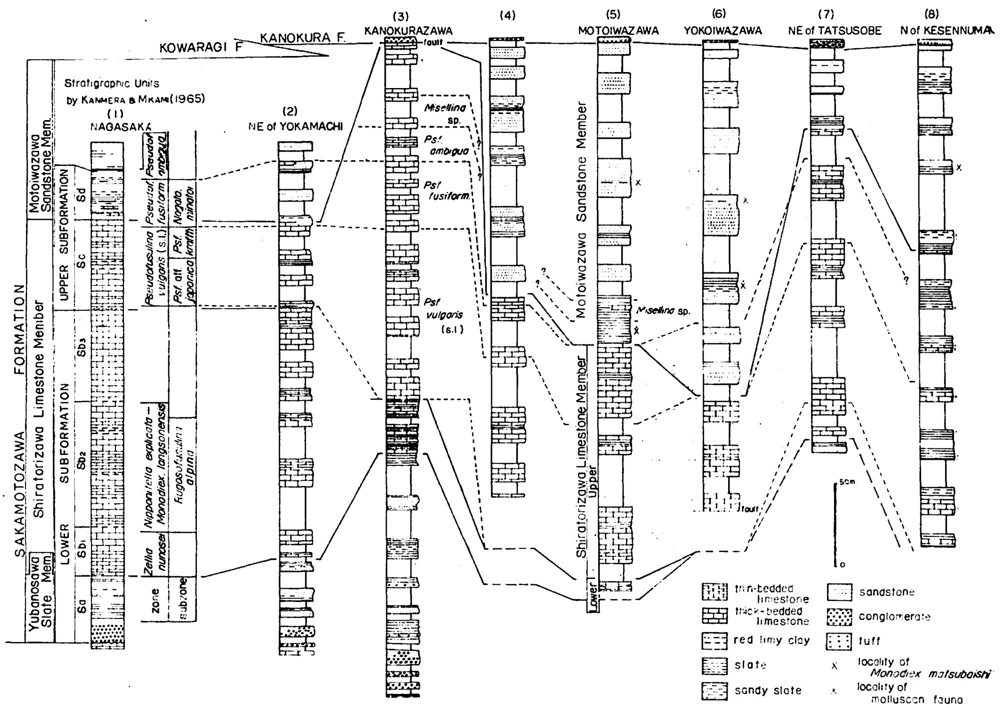


Text-fig. 1. Distribution of the Sakamotozawa Formation. Large Capitals—area mentioned in text.

sists mainly of sandstone and slate layers. The Group IX is a thick limestone formation. And the Group X is mainly of sandstone facies. Subsequently, ONUKI (1956) summarized the geology of the Kitakami Massif and established a standard succession of the Paleozoic and Mesozoic rocks distributed in the southern part of the massif. ONUKI accepted the three litho-stratigraphic units of the Sakamotozawa Formation in the Setamai District of MINATO *et al.* (1950) and proposed for them the names of Yubanosawa Slate, Shiratorizawa Limestone and Motoiwazawa Sandstone members in upward sequence.

Hikoroichi District

The Sakamotozawa Formation in the Hikoroichi District, includes the type area, lies upon the Middle Carboniferous Nagaiwa Formation (ranging from the late *Millerella* Zone to the *Profusulinella* Zone) with a distinct unconformity. The formation begins with notable basal conglomerate, sandstone and slate facies, and is succeeded upwards with conformity by a thick limestone intercalated with sandstone and slate lenses. ONUKI (1956) classified the Sakamotozawa Formation in the type section into two parts, the Yubanosawa Slate Member and the thick limestone facies as the Shiratorizawa Limestone Member, and supposed the Motoiwazawa Sandstone Member in the Setamai District to be missing in the type area. Recently, MIKAMI (1965, 1969) and KANMERA and MIKAMI (1965a, b) studied the succession, sedimentological features and fusulinid fauna of the type Sakamotozawa Formation shown in Text-fig. 2. They subdivided this formation into two subformations by a disconformity. The Lower Subformation was classified into the basal part (Sa) and the main part of three members ($Sb_{1-3}$), and the



Text-fig. 2. Columnar sections of the Sakamotozawa Formation.

Upper Subformation into the main (Member Sc) and uppermost (Member Sd) parts. The Sa of the Lower Subformation corresponds to the Yubanosawa Slate Member of ONUKI (1956) and the $Sb_{1-3}$ and the Upper Subformation to his Shiratorizawa Limestone Member.

The disconformity between the Lower and Upper subformations is an uneven surface and the basal limestone-conglomerate or conglomerate at the basal part of the Upper Subformation, is distributed northward from Sakamotozawa to the northeast of Yokamachi. However, no evidence of this disconformity has been found in the other districts in the southern part of the Kitakami Massif. The disconformity may be a local phenomenon of an uplifted belt. The Member Sc of the Upper Subformation is about 60 meters in thickness, and consists mainly of bedded limestone of three cycles of sedimentation, except at the basal part. Member Sd, nearly 30-50 meters in thickness, is composed of an alternation of sandstone and slate of various thickness, intercalated with limestone lenses. The lateral changes in lithofacies and thickness are striking in this part of the formation in north to south direction. The sandstone facies is well developed in the northern part of this district, in contrast to the slate and limestone facies which thicken towards the south.

The upper part of the Upper Subformation in the type section of the Sakamotozawa Formation is missing by erosions. However, elsewhere the Member Sd of the Upper Subformation is overlain with conformity by an alternation of coarse to medium grained sandstone and black slate about 50 meters in thickness, and is succeeded upwards by a thick bed of the so-called Usuginu Conglomerate. They had been referred to the Kanokura Formation by ONUKI (1956), YAMADA (1959), MIKAMI (1965, 1969), KANMERA and MIKAMI (1968a, b) and SAITO (1968). The alternation facies yielded no fossil to date, but the writer considers that, the alternation should better be refered to the Motoiwazawa Sandstone Member of ONUKI (1956) than to the Kanokura Formation, because the fusulinid fauna from the upper part of the Member Sd indicates an age slightly older than the top of the Sakamotozawa Formation in the Setamai Area.

In the west of Yokamachi, a thick limestone is exposed along the eastern limb of the Odaira Dome with N-S trend at Okunigiri, Mt. Horo-oroshi and Mt. Azumane. It was considered to be Permian in age and was referred to the Sakamotozawa Formation by ONUKI (1956) and SAITO (1966, 1968). Thus, the Sakamotozawa Formation was thought to be continuous from the Hikoroichi District to the Setamai area. However, this limestone yielded Middle Carboniferous corals as *Siphonodendron pseudomartini* (YABE and HAYASAKA), *Dibunophyllum* sp., *Syringopora* sp., *Kueichoupora setamaiensis* MINATO, etc. The Permian System in the belt area between the Hikoroichi District and the eastern limb of the Odaira Dome begins with poorly developed basal conglomerate or conglomeratic coarse sandstone, and is succeeded upwards by coarse to medium grained sandstone, thick black slate intercalated with sandstone and thin limestone layers, and has at the upper part thick black slate with lenticular limestone and the so-called Usuginu Conglomerate. The lithofacies of the lower part of this Permian System changes eastward laterally to grade into the type Sakamotozawa Formation. And the upper part of the System succeeds conformably the just mentioned, "Kanokura Formation" in the Hikoroichi District. Lithologically, the Permian sequence in the belt area between the Hikoroichi District and the Odaira Dome differs distinctly from the Sakamotozawa and the Kanokura formations by the poor development of basal conglomerate, limestone in the lower part and sandstone in the upper part, and by the lack of the basal conglomerate of Kanokura Formation. This formation should be referred to the Kowaragi Formation of ONUKI (1956, 1969) in the Karakuwa Peninsula.

### Ohazama-Kesennuma District

The Permian System in this wide belt area is distributed along the western limb of the Orikabe Anticline and in the synclinorium between the Orikabe Anticline and the Odaira Dome. The Permian formations in the Tatsusobe area, the northern end of the Orikabe Anticline, was named by HIROKAWA and YOSHIDA (1956) as the Tatsusobe Formation in the lower and the Kumonoue-yama Formation in the upper. In this paper the Tatsusobe Formation is considered to be a synonym of the Sakamotozawa Formation, because of their mutual lithofacies and stratigraphic position. The Kumonoue-yama Formation is a synonym of the Kanokura Formation for the same reasons.

In general, the lithofacies and stratigraphic successions of the three lithostratigraphic units of the Sakamotozawa Formation, defined by MINATO *et al.* (1954) and named by ONUKI (1956), extend over the district. The lateral change in lithofacies is rather distinct in east to west direction due to the different movement of the basement of and around the

Odaira Dome and the Orikabe Anticline. The Sakamotozawa Formation of the western slope of the Orikabe Anticline covers the Middle Carboniferous limestones as in the Hikoroichi District, and also the Lower Carboniferous formations with distinct clino-unconformity. The basal conglomerate of the Sakamotozawa Formation is well developed near both anticlinal structures. The sandstone and slate facies of the Yubanosawa Slate Member which intercalate dacitic tuff in the Ohazama-Kesennuma District are thicker and richer in coarse materials than at the type area, amounting to about 50 to 200 meters in thickness. The sandstone facies just mentioned becomes thinner in north to south direction along the Orikabe Anticline.

The Shiratorizawa Limestone Member consists of a thin alternation of black slate and muddy limestone, and thick bedded gray limestone in ascending order. The alternation facies of the lower part is developed only along the western slope of the Odaira Dome. Consequently, the thick bedded gray limestone covers the Yubanosawa Slate Member directly in the Orikabe Anticline area. According to the biostratigraphical evidence, as mentioned in the next paragraph, the lowermost part of the thick bedded gray limestone in the western part of this belt area corresponds to the top of the lower part (less than 30 meters in thickness) of the limestone member in the eastern part. The total thickness of the member attains nearly 250 meters in the western limbs of the Odaira Dome and the Orikabe Anticline, but decreases westward to 110 meters in the eastern limb of the Orikabe Anticline. No evidences for the unconformity, found by MIKAMI (1965) between the Upper and Lower subformations of the type Sakamotozawa Formation, have been found in the Ohazama-Kesennuma District.

The type section of the Motoiwazawa Sandstone Member is along the lower course of the Motoiwazawa Valley southwest of Kawaguchi in the Setamai area, where the axial part of the synclinorium between the Odaira Dome and the Orikabe Anticline is developed. In the type section, this member lies on the thick bedded gray limestone of the Shiratorizawa Limestone Member with conformity, and consists of calcareous slate of about 30 meters in thickness and small limestone lenses in the lower part, and medium grained massive sandstone of nearly 150 meters in thickness in the upper part. The sandstone facies changes laterally eastward to calcareous slate. The thickness of the Motoiwazawa Sandstone Member changes from 0 to 300 meters, reversally to the development of the Shiratorizawa Limestone Member. The Motoiwazawa Sandstone Member is not developed in the eastern margin of this district, but it thickens towards the Orikabe Anticline.

The Sakamotozawa Formation in the Ohazama-Kesennuma District is overlain by the Kanokura Formation. In general, the Kanokura Formation begins with basal conglomerate, and is succeeded upwards by thick sandstone facies of the Kattisawa Sandstone Member, and calcareous rocks of the Iwahata Limestone Member of ONUKI (1956). The type locality of the Kanokura Formation is along the middle course of the Kanokurazawa Valley, west of Kachizawa in the eastern marginal part of the Setamai area. In this area, the thick gray limestone of the Shiratorizawa Limestone Member is in fault contact with the basal granule to pebble conglomerate (about 7 meters in thickness) of the Kanokura Formation. A hornblende porphyrite dyke intrudes along the fault. The Motoiwazawa Sandstone Member is overlain by the basal conglomerate of the Kanokura Formation in the larger part of the Ohazama-Kesennuma District. The basal conglomerate of the Kanokura Formation is not distributed throughout the district. In the Tatsusobe area, the basal conglomerate is of pebble to cobble size distributed throughout, the size and thickness of the gravels decreases in south or southeast direction, and becomes a conglomerate with sporadic distribution of its granules in the Yahagi and the Kesennuma area.

The lithofacies of the Sakamotozawa Formation in the Ohazama-Kesennuma District changes laterally into the pyroclastic Ubaishi Formation and into the lower part of the slaty Ochiai Formation at the west.

## Fusulinid Biostratigraphy of the Sakamotozawa Formation

The Shiratorizawa Limestone Member of the Sakamotozawa Formation has yielded a rich fauna of fusulinids from many horizons of the limestone. MINATO *et al.* (1954) subdivided the Sakamotozawa Series in the Setamai area into the Kawaguti and the Kabayama stages on the basis of the fusulinids. Subsequently MINATO, KATO and HASEGAWA (1964) referred the Kawaguti stage to the *Pseudoschwagerina* zone and the Kabayama stage to the *Pseudofusulina* zone. According to those authors the *Pseudoschwagerina* zone in the Kitakami Massif is characterized by *Pseudoschwagerina* (*Robustoschwagerina*) *schellwieni* HANZAWA, and the *Pseudofusulina* zone by the *Pseudofusulina vulgaris* and *Pseudof. kraffti* faunas.

KANMERA and MIKAMI (1965a, b) published the results of their biostratigraphical and paleontological studies on the Sakamotozawa Formation in the type area. They recognized five fusulinid zones in the Sakamotozawa Formation, two of which were referred to the Lower Subformation, and these to the Upper, as follows:

In general, the Early Permian formations in the southern part of the Kitakami Massif yield the same kind of fusulinid fauna as the Sakamotozawa Formation in its type area. However, the vertical ranges, abundancy and distribution of the fusulinids differ with area even within the Sakamotozawa Formation.

| Subformation | Member | zone | subzone |
|---|---|---|---|
| Upper Subformation | Sd | *Pseudofusulina ambigua* | |
| | | *Pseudof. fusiformis* | *Nagatoella minatoi* |
| | | | *Pseudof. kraffti* |
| | | *Pseudof. vulgaris* (s.l.) | |
| | Sc | | *Pseudof.* aff. *japonica* |
| | $Sb_3$ | | |
| Lower Subformation | $Sb_2$ | *Monodiexodina langsonensis–Nipponitella explicata* | *Rugosofusulina alpina* |
| | $Sb_1$ | *Zellia nunosei* | |

The faunal assemblage and stratigraphical distribution of the fusulinid fossils of the Sakamotozawa Formation in the type area as described by KANMERA and MIKAMI (1965a, b), are shown in Text-fig. 2. In the Hikoroichi district, *Quasifusulina tenuissima* (SCHELLWIEN), *Rugosofusulina alpina* (SCHELLWIEN), *Monodiexodina langsonensis* (SAURIN) and *Nipponitella explicata* HANZAWA are abundant in many horizons of the main part of the Lower Subformation. *Zellia nunosei* HANZAWA is also abundant, but is limited to Member $Sb_1$ of the Lower Subformation in the Hikoroichi District. Member Sc of the Upper Subformation is characterized by abundant *Pseudofusulina* aff. *japonica* (GÜMBEL), *Pseudof. vulgaris vulgaris* (SCHELLWIEN and DYRENFURTH), *Pseudof. vulgaris globosa* (SCHELLWIEN and DYRENFURTH), *Pseudof. kraffti kraffti* (SCHELLWIEN and DYRENFURTH) and *Schwagerina* aff. *compacta* (WHITE). Among the listed species, *Pseudof. vulgaris vulgaris* decreases in abundancy upward from the base of Member Sc, and *Pseudof. kraffti kraffti* is limited nearly to the upper part of Member Sc. The stratigraphical range of *Pseudoschwagerina* (*Robustoschwagerina*) *shellwieni* HANZAWA, an important Early Permian species in the Kitakami Massif, extends from Member $Sb_2$ up to the upper part of Member Sc. The horizon of maximum abundancy of *Pseudoschwagerina* (*Robustoschwagerina*) *schellwieni* in this district is apparently in the lower part of the Member Sc. The larger part of Member Sd is characterized by *Pseudofusulina fusiformis* (SCHELLWIEN and DYRENFURTH) and *Nagatoella minatoi* KANMERA and MIKAMI. The uppermost part of Member Sd yielded *Pseudofusulina ambigua* (DEPRAT).

The lower part of the Shiratorizawa Limestone Member in the eastern half of the Ohazama-Kesennuma District, consists of a thin alternation of black slate and muddy limestone. In the eastern part of the Setamai area, *Quasifusulina tenuissima* (SCHELLWIEN), *Rugosofusulina alpina* (SCHELLWIEN), *R.* cf. *rossica* (SCHELLWIEN), and *Paraschwagerina* (*Acervoschwagerina*) sp. in association with a few *Monodiexodina langsonensis* (SAURIN) and *Nipponitella* sp. have been found. *Zellia nunosei* HANZAWA is found rarely in the lower part of the Shiratorizawa Limestone Member. Near the top of the lower part of the Shiratorizawa Limestone Member 8 meters below the base of its upper part, abundant *Pseudoschwagerina* (*Robustoschwagerina*) *schellwieni* HANZAWA were found in association with some *Zellia nunosei* HANZAWA, *Rugosofusulina* cf. *rossica* (SCHELLWIEN) and *Paraschwagerina* (*Acervoschwagerina*) sp. This horizon is the lowest of the abundant occurrence of *Pseudoschwagerina* (*Robustoschwagerina*) *schellwieni* HANZAWA in this district, and it probably corresponds with the Horizon $I_2$ of MINATO *et al.* (1954).

Three fusulinid zones and subzones of the Upper Subformation in the Sakamotozawa Formation, defined by KANMERA and MIKAMI (1965a, b) are recognized in the Ohazama-Kesennuma District in the upper part of the Shiratorizawa Limestone Member. The fusulinid fauna in the lower and middle parts of the mentioned limestone, except the lowermost part in the Orikabe Anticline area, belongs to the *Pseudofusulina vulgaris* (s. l.) and *Pseudof. fusiformis* zones. The lowermost part of the gray limestone in the Orikabe Anticline area, less than 20 meters thick, where the upper part of the limestone member contacts with the Yubanosawa Slate Member directly, yielded abundant, *Pseudoschwa-*

*gerina* (*Robustoschwagerina*) *schellwieni* HANZAWA, in association with *Zellia nunosei* HANZAWA, *Quasifusulina* cf. *tenuissima* (SCHELLWIEN), *Rugosofusulina* cf. *rossica* (SCHELLWIEN) and *Paraschwagerina* (*Acervoschwagerina*) sp. These fusulinids are succeeded upwards by the fauna of the *Pseudofusulina vulgaris* (s.l.) zone. The just cited faunal assemblage is of the same composition as the fauna from the uppermost part of the lower part of the Shiratorizawa Limestone Member in the Odaira Dome area. The *Pseudofusulina vulgaris* (s. l.) zone in the Ohazama-Kesennuma District contains rarely *Paraschwagerina* (*Acervoschwagerina*) sp. in the lower horizon, and the faunal difference between the subzones of *Pseudofusulina* aff. *japonica* and *Pseudofusulina kraffti* is not clear. The stratigraphical range of *Pseudofusulina kraffti kraffti* (SCHELLWIEN and DYRENFURTH) extends from the middle level of the *Pseudofusulina vulgaris* (s. l.) zone up to the *Pseudofusulina fusiformis* zone in this district, although there is a decrease in abundancy upwards. The *Pseudofusulina fusiformis* zone can be recognized by the common occurrence of *Nagatoella minatoi* KANMERA and MIKAMI, *Eoverbeekina* cf. *cheni* THOMPSON and FOSTER and *Sphaerulina crassispira* (LEE). The range of *Pseudofusulina fusiformis* (SCHELLWIEN and DYRENFURTH) overlaps that of *Pseudofusulina ambigua* (DEPRAT) at the highest level of the *Pseudof. fusiformis* zone. *Toriyamaia laxiseptata* KANMERA is rare in the *Pseudofusulina vulgaris* (s. l.) and the *Pseudofusulina fusiformis* zones. The *Pseudofusulina ambigua* zone in this district is characterized by abundant *Pseudofusulina ambigua* (DEPRAT) and *Pseudofusulina* sp. as in the type area of the Sakamotozawa Formation. The zone is recognized in the upper part of the gray limestone along the eastern margin of the Setamai area, and in the uppermost part on the western slope of the Orikabe Anticline. In the lower course of the Kanokura Valley, the highest level of the *Pseudofusulina fusiformis* zone is about 100 meters above the base of the upper part of the Shiratorizawa Limestone Member. The thickness of the *Pseudofusulina ambigua* zone is nearly 20 meters. The *Misellina* sp. zone about 20 meters in thickness, occurs above the *Pseudofusulina ambigua* zone and is characterized by *Misellina* sp., *Pseudofusulina ambigua* (DEPRAT) and *Pseudof.* spp. The uppermost part of the Shiratorizawa Limestone Member, about 30 meters in thickness in the Kanokurazawa Valley in the eastern margin of the Setamai area yielded ill-preserved *Pseudofusulina* sp. The limestone member is in contact with the Kanokura Formation by a fault. At some horizons in the upper part of the Shiratorizawa Limestone Member abundant well-preserved "*Mizzia*" spp. and *Michelinia* (*Michelinopora*) *multitabulata* YABE and HAYASAKA have been found.

The stratigraphically and paleontologically highest parts of the Shiratorizawa Limestone Member differ with area. Measured from the bottom, the highest part of the member is higher than the *Misellina* sp. zone in the eastern margin of the Setamai area. The limestone member is distributed in the Tatsusobe, the Otomo and the Kesennuma areas in the Hikoroichi District and the western limb of the Orikabe Anticline where it restricted to the top of the *Pseudofusulina ambigua* zone. In the Motoiwazawa Sandstone Member the limestone member is named the *Pseudofusulina fusiformis* zone. In the eastern slope of the Orikabe Anticline, the limestone member is distributed in the eastern part of the

Tatsusobe area, the Yokoiwazawa Valley and in the Yahagi area, where it does not extend up to the top of the *Pseudofusulina vulgaris* (s. l.) zone. MINATO, KATO and HASEGAWA (1964) and MINATO and KATO (1965) reported on the occurrence of *Misellina claudiae* (DEPRAT), *Pseudofusulina kraffti* (SCHELLWIEN), "*Parafusulina*" sp., *Michelinia* (*Michelinopora*) *multitaburata* YABE and HAYASAKA, *Yatsengia kabayamensis* MINATO and *Wentzelophyllum* sp. from the top of the Shiratorizawa Limestone Member, and designated the fossil horizon as Horizon $J_1$. However, there still remains doubt as to whether the horizons of their different localities are the same.

The fusulinid fauna of the Motoiwazawa Sandstone Member was not known before the discovery by the writer of *Misellina* sp., *Pseudofusulina ambigua* (DEPRAT), *Pseudof.* sp. and *Monodiexodina matsubaishi* (FUJIMOTO) from four localities in this district, one of which includes the type locality of the sandstone member. In the type section, the lower part of the member, which consists of calcareous slate with small limestone lenses, yielded poorly preserved *Monodiexodina matsubaishi* (FUJIMOTO) admixed with a rich molluscan fauna in the slate facies and abundant *Misellina* sp. *Pseudofusulina ambigua* (DEPRAT) and *Pseudof.* sp. from the limestone lenses. This fossiliferous horizon corresponds to the *Misellina* sp. zone in the Kanokurazawa Valley. At about 80 meters below the base of the Kanokura Formation in the Motoiwazawa Valley, *Monodiexodina matsubaishi* (FUJIMOTO) was found. The same species is abundant in the lower part of the Kanokura Formation where it forms a fossil layer several centimeters thick. *Monodiexodina matsubaishi* (FUJIMOTO) was also collected from the middle and upper parts of this sandstone member in the Yokoiwazawa Valley, east of Orikabe, and at Yahagi in the Kesennuma Area.

## Molluscan Fauna from the Upper Part of Sakamotozawa Formation

The Motoiwazawa Sandstone Member of the upper part of the Sakamotozawa Formation is short of macro-fossil records in general, however, some brachiopods and a coral were reported; MOTEGI (1956, MS.) collected *Buxtonioides* sp. from the upper part of the Sakamotozawa Formation in the Kesennuma area. *Phricodothyris* sp., *Avonia echidniformis* GRABAU em. CHAO, *Juresania juresanensis* (TSCHERNYSCHEW), *Mesolobus mesolobus* (NORWOOD and PRATTEN) and *Productus yohi* CHAO were described by NAKAMURA (1959), from his lower part of the Sakamotozawa Series, which however, was revised by MINATO and KATO (1965) to the Upper Sakamotozawa Series. This fossiliferous part was designated by MINATO and KATO (1965) as Horizon $J_2$. TAKEDA (1963, MS) collected a poorly preserved *Michelinia* (*Michelinopora*) sp. from a sandstone of the upper part of the Sakamotozawa Formation in the Tatsusobe area.

Recently, a rich molluscan fauna was found from the lower part of the Motoiwazawa Sandstone Member at its type section and in the Yokoiwazawa Valley. The fauna included *Avonia echidniformis* and *Mesolobus mesolobus* and fragments of other brachiopods. From the fauna the writer distinguished one species of nautiloid, three species of gastropods distributed among three genera and five species of bivalves belonging to four genera include one new genus, as follows:—

Nautiloidea
  *Tainoceras kitakamiense* HAYASAKA
Gastropoda
  *Bellerophon* (*Bellerophon*) *kitakamiensis* MURATA, n. sp.
  *Knightites* (*Retispira* ?) *hanzawai* MURATA, n. sp.
  " *Murchisonia* " n. sp.
Bivalvia
  *Towapteria nipponica* NAKAZAWA and NEWELL
  *Waagenoperna* (*Permoperna*) *hayamii* NAKAZAWA and NEWELL
  *Aviculopecten* sp.
  *Aviculopecten* ? sp.
  *Pseudoactinodontophora yabei* MURATA, n. gen. and n. sp.

Among the listed species *Tainoceras kitakamiense, Towapteria nipponica,* and *Waagenoperna* (*Permoperna*) *hayamii* were described by HAYASAKA (1925, 1962), HAYAMI (1960), NAKAZAWA and NEWELL (1968) from the lower part of the Kanokura Formation in the Kesennuma area and from the Tenjinnoki Formation in the Maiya District which is an equivalent of the lower part of the Kanokura. Although *Actinodontophora katsurensis* ICHIKAWA differs from *Pseudoactinodontophora yabei* generically, the former is seemingly the most closely related species to the latter. *A. katsurensis* was also recorded by NAKAZAWA and NEWELL (1968) from the Kanokura Formation in the Kesennuma area. The proposed new gastropod species also occurred from the Tenjinnoki Formation in the Maiya District.

As a result of this work, it may be concluded that the molluscan fauna from the Motoiwazawa Sandstone Member of the Sakamotozawa Formation like *Monodiexodina matsubaishi* (FUJIMOTO) extends upwards to the Kanokura Formation. The continuous vertical distribution of the fossils is interesting from the view of the pre-Kanokura unconformity and suggests that there was no significant time gap between the two formations. Also it may be added that the said break is one of the unsettled problems on the Permian stratigraphy in the Japanese Islands.

## On the Pre-Kanokura Unconformity

The stratigraphical and geo-tectonical significance of the basal conglomerate of the Kanokura Formation has been a subject of disputation by many authors. The pre-Kanokura unconformity was stated to be significant by MINATO *et al.* (1954), and to indicate the Abean Movement (MINATO, 1960, 1966, 1968). MINATO (loc. cit.), from reading of the geological map of the Setamai area concluded that the unconformity between the Sakamotozawa and the Kanokura formations showed a structural difference and that the upper part of the Sakamotozawa Formation was eroded away before deposition of the Kanokura Formation. The pre-Kanokura disturbance was stated by MINATO (1966) to indicate a slight positive diastrophic movement, less positive than the pre-Sakamotozawa movement, and was correlated with the " Saalisch " phase of the Variscan Orogeny. However, ONUKI (1956, 1969) doubted the importance of the pre-Kanokura unconformity. SAITO (1968) admitted the presence of an unconformity, and without giving any evidence denied a tectonic movement between the two formations. Meanwhile, some authors (KANO and SEKI, 1954; KANO, 1955; YAMASHITA, 1957) gave weight to the pre-Kanokura Unconformity pertaining to the granitic plutonism. In the Kitakami and Abukuma massifs, the so-called " Usuginu Conglomerate " which commonly contains pebbles of granitic rocks is intercalated in different horizons of the Permian System. The conglomerate occurs in the upper part of the Kanokura Formation in the areas of distribution of the Sakamotozawa Formation. The basal conglomerate of the Kanokura and Sakamotozawa formations contain only few pebbles of granitic rocks. The Hikami Granite a possible origin of the pebbles of granite, which is exposed in the south of Hikoroichi, was K-A dated to be $>222\times10^6$ y. B. P., according to KAWANO and UEDA (1964).

MINATO (1966) and his co-workers (1964, 1965) figured a generalized stratigraphical section of the Carboniferous and Permian formations in the southern part of the Kitakami Massif, when they proposed the pre-Kanokura disturbance. The contact of the basal conglomerate of the Kanokura Formation with the Shiratorizawa Limestone Member in the Kanokurazawa and the Kachizawa valleys was explained by them as the result of folding and erosion before the deposition of the Kanokura Formation. Their figure showed that, the Shiratorizawa Limestone Member was originally covered uniformly with the Motoiwazawa Sandstone Member, and after the folding due to the pre-Kanokura disturbance the upper part of the Sakamotozawa Formation over the Horizon $J_0$ was eroded away at the crest of an anticline before the deposition of the Kanokura Formation. However, recent stratigraphical and biostratigraphical evidences show that, the Shiratorizawa Limestone Member along the eastern margin of the Setamai area (including the Kanokurazawa, Kachizawa and Kamiyashiki valleys) is developed to its highest horizon, and is in contact with the basal csnglomerate of the Kanokura Formation with a fault and the Motoiwazawa Sandstone Member was probably not deposited there. The stratigraphically highest part of the limestone member differs in the other areas. The highest part just mentioned belongs to the *Pseudofusulina ambigua* zone in the Hikoroichi District and in the western limb of the Orikabe Anticline, to the *Pseudofusulina fusiformis* zone in the type area of the Motoiwazawa Sandstone Member and to the *Pseudofusulina vulgaris* (s. l.) zone in the Yokoiwazawa Valley, east of Orikabe. In the areas just mentioned the Motoiwazawa Sandstone Member is developed between the Shiratorizawa Limestone Member and the Kanokura Formation. The *Misellina* sp. zone stretches over both the upper part of the limestone member in the eastern margin of the Setamai area and the Motoiwazawa Sandstone Member in its type area. The faunal assemblages of the topment level of the limestone member and of the Motoiwazawa Sandstone Member are not known however, the biostratigraphical evidences may support the change in lithofacies from the upper part of the Shiratorizawa Limestone Member laterally to the Motoiwazawa Sandstone Member.

The basal conglomerate of the Kanokura Formation is an extraneous conglomerate with the " Usuginu Conglomerate". It is succeeded upwards by a thick sandstone formation, and is developed in nearly all areas of distributions of the Kanokura Formation. But, the canglomerate is missing in some areas in the southern and south-eastern parts of the Ohazama-Kesennuma District, because of the lateral change in grain size and thickness of the conglomerate decreasing south- and east-wards, simultaneously with the increase in thickness of the overlying sandstone facies. The Tenjinnoki Formation in the Nagasaka-Maiya District in the southwestern part of the Kitakami Massif, which is an equivalent of the Kanokura Formation, has basal conglomerate like that of the Kanokura Formation. But, there are many broad areas in the southern part of the Kitakami Massif where neither the basal conglomerate nor the thick sandstone formation is developed, except in the Ohazama-Kesennuma and the Nagasaka-Maiya districts. Further, the stratigraphical ranges of *Monodiexodina matsubaishi* (FUJIMOTO) and the molluscan fauna of the Motoiwazawa Sandstone Member both extend up to the Kanokura Formation and cross the pre-Kanokura unconformity. From these reasons, the writer considers that the pre-Kanokura unconformity may be a local one due to the different movements of the sedimentary basin.

The pre-Kanokura unconformity is thought to have no relation with the granitic plutonism, even though pebbles of granitic rocks are found in the so-called "Usuginu Conglomerate". Because the deposition of the "Usuginu conglomerate commenced during deposition of the *Pseudofusulina ambigua* zone in the southwestern part of the Kitakami Massif, as pointed out by MURATA and MAIYA (1964), SAITO (1966, 1968), ONUKI (1959) and MURATA (1969). Some pebbles of the granitic rocks are also found in the tuffaceous sandstone of the Yubanosawa Slate Member of the Sakamotozawa Formation, at Kashiwari, in the Setamai area. Further, the absolute age of a granite pebble from the so-called "Usuginu Conglomerate" at Kogaizawa, Sumita-cho, Kesen-gun, Iwate Prefecture, which belongs to the Ochiai Formation, is determined recently to be $420\text{-}425\times10^6$ y. B. P. by the K-A method (UEDA, MS). Therefore the pebbles of granitic in the so-called Usuginu Conglomerate are of a different origin.

## Systematic Description of Molluscan Fauna

Class Gastropoda CUVIER, 1797

Order Archaeogastropoda THIELE, 1825

Suborder Bellerophontina ULRICH and SCOFIELD, 1897

Superfamily Bellerophontacea M'COY, 1851

Family Bellerophontidae M'COY, 1851

Subfamily Bellerophontinae M'COY, 1851

Genus *Bellerophon* MONTFORT, 1808

Subgenus *Bellerophon* (*Bellerophon*) MONTFORT, 1808

*Bellerophon* (*Bellerophon*) *kitakamiensis* MURATA, n. sp.

Pl. 13, figs. 1-3.

*Description*:—Somewhat elongate, rather large bellerophontid gastropods with selenizone on a raised median crest, apertural opening elongate cardiform; earliest growth stage unknown; early growth stages coiled uniformly to three-fourths of body-whorl, but loosely in mature stage, whorl profile varying from slightly compressed to elongate subcardiform; upper surface well arched in early stages with a high, distinct median crest, but decreasing in curvature in mature stage; lateral surfaces slightly flattened, though not set off from upper surface by angulation; selenizone convex on median crest; slit depth unknown, but probably less than 10 per cent of body-whorl circumference; lateral lips curving back from anterior lips, their junction with body-whorl simple in early growth stages, becoming slightly reflex-

Table 1. Measurements (in mm.) of *Bellerophon* (*Bellerophon*) *kitakamiensis* MURATA, n. sp.

| Specimen | | Length | Width | Thickness |
|---|---|---|---|---|
| 91389 | Holotype | 33.7 | 20.5 | 19.5+ |
| 91390A | Paratype | 34.0+ | 23.0+ | —— |
| 91390B | 〃 | 19.0+ | 15.0+ | 13.0+ |
| 91390C | 〃 | 22.2+ | 18.0+ | 13.5+ |
| 91390D | 〃 | 24.0+ | 19.6+ | —— |
| 91390E | 〃 | 16.2+ | 15.5+ | —— |

ed with maturity and a little thickened; interior of lateral lips curved, but not excavated; spiral ornament lacking; mature stage characterized by increasing rugosities of growth lines.

The measurements of *Bellerophon* (*Bellerophon*) *kitakamiensis* MURATA, n. sp. are given in Table 1.

*Remarks:*—This species is based on six specimens, including a nearly perfect mold specimen. Although this new species is similar to many described Upper Palaeozoic species, the ontogenic changes of shell form serve to distinguish it from any of them. *Bellerophon* (s. str.) *timorensis* WANNER, 1922, *B.* (s. str.) *timorensis gibber* WANNER, 1922, and *B.* (s. str.) *triangularis* WAAGEN, 1881, seem to be closely related to this new species, but they have a more elongate shell and a more distinct median crest.

*Repository:*

Holotype—IGPS* coll. cat. no. 91389.

Paratypes—IGPS coll. cat. nos. 91390A-E.

*Occurrence:*—Common in the lower part of the Motoiwazawa Sandstone Member of the Sakamotozawa Formation in the Motoiwazawa Valley, southwest of Kawaguchi, Sumita-cho, Kesen-gun, Iwate Prefecture. Several specimens of this species were also collected from the lower part of the Kanokura Formation in Kesennuma City, Miyagi Prefecture, and from the Tenjinnoki Formation in the Teranosawa, Valley, Towa-cho, Tome-gun, Miyagi Prefecture.

### Subfamily Knightitinae KNIGHT, 1956

### Genus *Knightites* MOORE, 1941

### Subgenus *Retispira* KNIGHT, 1945

### *Knightites* (*Retispira* ?) *hanzawai* MURATA, n. sp.

Pl. 13, figs. 4-6.

*Description:*—Rather elongate bellerophontid gastropods with collabral undulation and a distinct selenizone on low median crest; shell medium in size, coiled uniformly in early growth stages, loosening to nearly straight in mature stage without aperture flare; upper surface arched moderately in early stages, flattened in mature stage, with a low distinct median crest; lateral slopes well rounded in early stages, becoming flat with maturity, so whorl profile in mature stage more angular; selenizone concave on low median crest, bordered by lirae; slit deep, approximately 25 per cent of body-whorl circumference; aperture not flaring; narrowly phaneromphalous, details of umbilicus unknown; ornamented by numerous spiral lirae in two sets, two to four finer lirae inter-

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* Abbreviation for the Institute of Geology and Paleontology, Tohoku University, Sendai, Japan.

Table 2. Measurements (in mm.) of *Knightites* (*Retispira* ?) *hanzawai* MURATA, n. sp.

| Specimen | | Length | Width | Thickness |
|---|---|---|---|---|
| 91391 | Holotype | 23.0 | 13.2 | 10.5+ |
| 91392A | Paratype | 23.8+ | 14.0+ | —— |
| 91392B | " | 18.5+ | 13.2+ | 10.0+ |
| 91392C | " | 22.4+ | 14.4+ | —— |
| 91392D | " | 17.2+ | —— | 15.6+ |
| 91392E | " | 16.7 | 11.4+ | —— |

calated between two coarser lirae, ornamented also by faint growth lines; shell modified by transverse undulations on upper surface and upper part of lateral surfaces, strengthened at shoulder.

The measurements of *Knightites* (*Retispira* ?) *hanzawai* MURATA, n. sp. are given in Table 2.

*Remarks*:—This new species is based on five molds of more or less deformed specimens. The selenizone on the low but distinct median crest of this species resemble *Bellerophon* (*Pharkidonotus*) of GIRTY (1912) rather than *Knightites* (*Retispira*) of KNIGHT (1845). But its narrowly phaneromphalous umbilici, deeper slit and surface ornamentations have close affinity to *Knightites* (*Retispira*). Therefore, this species is referred to *Knightites* (*Retispira*) MOORE (Op. cit.) with question. This new species is not identifiable with any known species of *Bellerophon* (*Pharkinodotus*) nor *Knightites*.

*Repository*:

Holotype—IGPS coll. cat. no. 91391.

Paratypes—IGPS coll. cat. nos. 91392A-E.

*Occurrence*:—Rather common in the lower part of the Motoiwazawa Sandstone Member of the Sakamotozawa Formation in the Motoiwazawa Valley.

## Order ? Archaeogastropoda THIELE, 1925

## Suborder Murchisoniina COX & KNIGHT, 1960

## Superfamily Murchisoniacea KOKEN, 1896

## Family Murchisoniidae KOKEN, 1896

## Genus *Murchisonia* D'ARCHIAC & DE VERNEUIL, 1841

### "*Murchisonia*" n. sp.

Pl. 13, figs. 7-10.

*Description*:—Shell high-spired turbinate with ten or more whorls, spire slightly convex conical whorl with an angular spiral ridge bearing selenizone on mid-whorl periphery; protoconch unknown; selenizone flat to concave; suture indistinct; surface with narrow spiral threads and collabral nodes, about five spiral threads distributed on lower two-thirds of upper whorl surface, two or three more distinct spiral threads on lower whorl between sutures, collabral nodes developed regularly on upper whorl face only.

The measurements of "*Murchisonia*" n. sp. are given in Table 3.

*Remarks*:—Four fragmental external molds of high-spired gastropods are in the present collection. All of them are elongated or compressed by deformation, but the surface sculpture is well preserved. (Pl. 13, fig. 7).

The present material, although not abundant, serves to show that they represent an undescribed species. Among the known species of Murchisoniidae, the

Table 3. Measurements (in mm.) of "*Murchisonia*" n. sp.

| Specimen | Number of whorl | Height | Width | Whorl height | Apical angle (degrees) |
|---|---|---|---|---|---|
| 91393A | 10 | 38.2 | 6.8+ | 6.2+ | 12 |
| 91393B | 11 | 30.5 ? | 8.5 | 5.8+ | 17 |
| 91393C | 7+ | 20.0+ | 4.8+ | 5.0+ | 13 |
| 91393D | 7+ | 14.2+ | 11.1 ? | 4.3 | 41 ? |

general shape and surface ornamentations of this species suggest affinity with "*Murchisonia*" *yabei* HAYASAKA (1943, p. 32, pl. 2, figs. 2, 3; pl. 4, figs. 1, 2; pl. 5; text-fig. 2) from the Middle Permian Akasaka Limestone in Japan. But the collabral nodes of "*Murchisonia*" *yabei* are developed on the upper and the lower whorl faces and separated with double-crested selenizone. The characters of the surface ornamentation and selenizone of these species suggest two different genera, one resembles *Helicospira* of GIRTY (1915) and the other is similar to *Micrentoma* of DONALD (1898) rather than *Murchisonia* of D'ARCHIAC and DE VERNEUIL (1841). Two of the present specimens, show a large, ovoidal apertural opening with a siphonal canal. From such characters the present species should be referred to some order other than the present one.

*Repository*:—IGPS coll. cat. nos. 91393 A-E.

*Occurrence*:—Rather common in the lower part of the Motoiwazawa Sandstone Member of the Sakamotozawa Formation in the Motoiwazawa Valley, southwest of Kawaguchi, Sumita-cho, Kesen-gun, Iwate Prefecture.

## Class Cephalopoda CUVIER, 1797

## Subclass Nautiloidea AGASSIZ, 1847

## Order Nautilida AGASSIZ, 1847

## Superfamily Tainoceratacea HYATT, 1883

## • Family Tainoceratidae HYATT, 1883

## Genus *Tainoceras* HYATT, 1882

### *Tainoceras kitakamiense* HAYASAKA, 1962

Pl. 14, fig. 13.

1962. *Tainoceras kitakamiense* HAYASAKA, *Bull. Natl. Sci. Mus., v. 6, n. 2,* p. 140, Text-fig. 2, pl. 12, figs. 1, 2.

*Remarks*:—A single incomplete steinkern of a heavily compressed specimen is at hand. It appears to be a part of the living chamber and eight chambers of the phragmocone. Although smaller in size (about two-thirds), this form may be identical with *Tainoceras kitakamiense* HAYASAKA, 1962, from the Kanokura Formation at Imo, Yahagi-cho, Rikuzen-Takada City, Iwate Prefecture, by the characteristic features of its row of large, prominent nodes on the ventrolateral border. The slightly concaved broad median depression is bordered with by pair of rows of less prominent nodes. The sutures are moderately closely set (*ca.* 6 mm on venter).

*Repository*:—IGPS coll. cat. no. 91394.

*Occurrence*:—Rare in the lower part of the Motoiwazawa Sandstone Member of the Sakamotozawa Formation in the Motoiwazawa Valley, southwest of Kawaguchi, Sumita-cho, Kesen-gun, Iwate Prefecture.

### Class Bivalvia LINNÉ, 1758

### Subclass Pteriomorphia BEURLEN, 1944

### Order Pterioida NEWELL, 1965

### Suborder Pteriina NEWELL, 1965

### Superfamily Pteriacea GRAY, 1845

### Family Bakevelliidae KING, 1850

### Genus *Towapteria* NAKAZAWA and NEWELL, 1968

### *Towapteria nipponica* NAKAZAWA and NEWELL, 1968

Pl. 14, figs. 5-8.

1959. *Pteria* sp., NAKAZAWA, *Mem. Coll. Sci., Univ. Kyoto, Ser. B, v. 27, no. 2,* p. 196, Text-fig. 1.

1968. *Towapteria nipponica* NAKAZAWA and NEWELL, *Mem. Fac. Sci., Kyoto Univ., Ser. Geol. & Min., v. 35, n. 1,* p. 59, pl. 3, figs. 5-8.

*Remarks:*—There are four left and one right valves at hand. They are all external and internal molds, and more or less deformed obliquely by compression. Taking the deformation into account, the present form is quite identical with *Towapteria nipponica* NAKAZAWA and NEWELL, 1968, from the Tenjinnoki Formation at Tenjinnoki, Maiya, Towa-cho, Tome-gun, Miyagi Prefecture. NAKAZAWA and NEWELL (1968) also recorded this species from the same formation at Teranosawa, Maiya, Towa-cho, the Kanokura Formation at Kamiyasse, Kesennuma City, Miyagi Prefecture, and the Gujo Formation at Gujo, Oe-cho, Kyoto Prefecture.

The measurements of the present specimens of *Towapteria nipponica* NAKAZAWA and NEWELL are given in Table 4.

*Repository:*—IGPS coll. cat. nos. 91395 A-E.

*Occurrence:*—Common in the lower part of the Motoiwazawa Sandstone Member of the Sakamotozawa Formation in the Motoiwazawa Valley, southwest of Kawaguchi, Sumita-cho, Kesen-gun, Iwate Prefecture.

### Family Isognomonidae WOODRING, 1925

### Genus *Waagenoperna* TOKUYAMA, 1959

### Subgenus *Permoperna* NAKAZAWA and NEWELL, 1968

### *Waagenoperna* (*Permoperna*) *hayamii* NAKAZAWA and NEWELL, 1968

Pl. 14, figs. 9, 11.

1925. *Liecea sinensis* NEWELL, FRECH, HAYASAKA (non FRECH, 1911), *Sci. Rep., Tohoku Imp. Univ., 2nd Ser. v. 8, n. 2,* p. 14, pl. 8, figs. 11, 12, 13 ?

1960. "*Isognomon*" n. sp., HAYAMI, *Jour. Fac. Sci., Univ. Tokyo, Sec. 2, v. 12, pt. 2,* p. 327, Text-fig. 6.

Table 4. Measurements (in mm.) of *Towapteria nipponica* NAKAZAWA and NEWELL.

| Specimen | Length | Height | Hinge length |
|---|---|---|---|
| 91395A LV | 15.2 | 9.8 ? | 13.9 |
| 91395B 〃 | 11.5 | 7.5 | 10.2 |
| 91395C 〃 | 10.2+ | 6.5+ | 10.0 |
| 91395D 〃 | 9.8 | 7.1 | 7.0+ |
| 91395E RV | 11.4 | 7.2 | 9.6 |

LV: Left valve. RV: Right valve.

1968. *Waagenoperna* (*Permoperna*) *hayamii* NAKAZAWA and NEWELL, *Mem. Fac. Sci., Kyoto Univ., Ser. Geol. & Min.*, *v. 35*, *n. 1*, p. 62, pl. 3, figs. 9-11.

*Remarks:*—Two specimens, one larger and the other smaller are in the collection. The smaller one is represented by a rather severely deformed internal mold of a right valve but most features except the anterior ear and surface ornamentations are preserved. The ligament area is provided with four ligament pits. Near the last ligament pit a weak posterior lateral tooth extends posteroventrally. The other one is represented by an external mold of a nearly perfect left valve except the posteroventral margin. The anterior ear is small, subtriangular and clearly demarcated from the body of the shell by a furrow. Apical angle about 55 degrees. The smaller specimen is quite identical with *Waagenoperna* (*Permoperna*) *hayamii* NAKAZAWA and NEWELL from the Tenjinnoki Formation in the Maiya District. The other specimen is larger than the type specimens of *Waagenoperna* (*Permoperna*) *hayamii* NAKAZAWA and NEWELL, and as large as the specimens of HAYASAKA (1925) from the Kanokura Formation in the Yahagi area, and of HAYAMI (1960) from the same formation in the Kesennuma area.

The measurements of the present specimens of *Waagenoperna* (*Permoperna*) *hayamii* NAKAZAWA and NEWELL are in Table 5.

*Repository:*—IGPS coll. cat. nos. 91397, 91398.

*Occurrence:*—Rather rare from the lower and middle parts of the Motoiwazawa Sandstone Member of the Sakamotozawa Formation in the Motoiwazawa and the Yokoiwazawa valleys, Sumita-cho, Kesen-gun, Iwate Prefecture.

## Superfamily Pectinacea RAFINESQUE, 1815

## Family Aviculopectinidae MEEK and HAYDEN, 1864

## Subfamily Aviculopectininae MEEK and HAYDEN, 1864

## Genus *Aviculopecten* M'COY, 1851, em. NEWELL, 1938

### *Aviculopecten* sp.

Pl. 14, figs. 12a, b.

*Remarks:*—A single fragmental compressed external mold of right valve is at hand. The radial costae of different strength may be classified into three orders. First order costae 8 or 9 in number. Between two of them a costa of the second order is intercalated irregularly and attains a size of first one in the early growth stage. Third order costae are more delicate and placed irregularly. The ornamentation is somewhat similar to that of *Aviculopecten hataii* MURATA, (1964b), and *A.* cf. *hataii* by NAKAZAWA and NEWELL (1968).

*Repository:*—IGPS coll. cat. no. 91396.

Table 5. Measurements (in mm.) of *Waagenoperna* (*Permoperna*) *hayamii* NAKAZAWA and NEWELL.

| Specimen | Length | Height | Hinge length |
|---|---|---|---|
| 91397 RV | 14.5+ | 25.4 ? | 11.2 |
| 91398 LV | 35.4 | 42.2 | 22.8 |

*Occurrence:*—Rare; the lower part of the Motoiwazawa Sandstone Member of the Sakamotozawa Formation in the Motoiwazawa Valley, southwest of Kawaguchi, Sumita-cho, Kesen-gun, Iwate Prefecture.

### *Aviculopecten* ? sp.

Pl. 14, fig. 10.

*Remarks:*—A small external mold of a left valve of *Aviculopecten*-like shell, the ligamental area is not preserved. The surface of the shell is ornamented with several weak radial costae.

*Repository:*—IGPS coll. cat. no. 86884.

*Occurrence:*—Rare, the middle part of the Motoiwazawa Sandstone Member of the Sakamotozawa Formation in the Yokoiwazawa Valley, near Orikabe, Sumita-cho, Kesen-gun, Iwate Prefecture.

## Subclass Palaeoheterodonta NEWELL, 1965

## Order Unionoida STOLICZKA, 1871

## Superfamily Unionacea FLEMING, 1828

## ? Family Actinodontophoridae NEWELL, 1969

### Genus *Pseudoactinodontophora* MURATA, new genus

Type species: *Pseudoactinodontophora yabei*, new species, Sakamotozawa Formation, northeast Japan; Early Permian.

*Diagnosis:*—Shell medium in size, equivalve, elongate elliptical; umbo prosogyre, located at least at one-fourth of shell length from anterior margin, only slightly salient above hinge margin; dorsal margin nearly straight, ventral margin broadly convex, anterior margin short and well rounded, posterior margin probably subrounded and truncate obliquely; escutcheon distinct, deeply incised, bounded by a sharp ridge extending to near posterior end of hinge; lunule unknown; ligament opisthodetic, nymphs well defined; anterior muscle scar subcircular, deeply impressed close to anterodorsal margin with buttress, posterior scar large, obscure; surface with growth lines. Hinge-plate with a series of radiating cardinal and subcardinal teeth located below beak, and an obscure lateral tooth and socket in each valve; four strong cardinal teeth, ornamented with rather coarse striations on each side three of which run anteroventrally, posterior most cardinal tooth vertical or directed slightly posteroventrally; seven to nine subcardinal teeth, directed posteroventrally, and becoming short and thin posteriorly.

*Remarks:*—The external and internal characters of the proposed genus are similar to the Permian *Actinodontophora* ICHIKAWA (1951, p. 327, type: *A. katsurensis* ICHIKAWA), but the details of the dentition are different. *Actinodontophora katsurensis* ICHIKAWA, which is the only known species of the genus, posseses "two (in one case, three ?) cardinals and five to seven subcardinals" and thus differs from *Pseudoactinodontophora. Actinodontophora* is known from the Middle or Upper Permian formation at Katsura in Shikoku, and from the Middle Permian Kanokura Formation in the Kesennuma area. *Pseudoactinodontophora* is from the Lower Permian Sakamotozawa Formation in the Setamai area. Although the present new genus differs from *Actinodontophora*, the latter seems to be the most closely related genus to the present one. Possibly, *Actinodontophora* may be a descendant of *Pseudoactinodontophora*. The Upper Triassic *Palaeopharus*

Table 6. Measurements (in mm.) of *Pseudoactinodontophora yabei* MURATA. n. gen. n. sp.

| Specimen | | | Length | Height |
|---|---|---|---|---|
| 86885 | Holotype | RV<br>LV | 76.5 | 19.0 |
| 86886A | Paratype | LV | 45.8+ | 22.2 |
| 86886B | 〃 | LV | 44.0+ | 19.4 |
| 86886C | 〃 | RV | ca 27.0 | 12.5 |
| 86886D | 〃 | RV | 43.5+ | 14.2 |
| 86886E | 〃 | RV | ca 56 | 13.0 |

KITTL (1907, p. 34, type: *P. schell* DIENER) is another genus similar to the newly proposed one but it can be distinguished from the new genus in the dentition and ornamentation of the shell surface.

### *Pseudoactinodontophora yabei* MURATA, n. gen. and n. sp.

Pl. 14, figs. 1-4.

*Description:*—Shell medium in size, equivalve, inequilateral, strongly elongated posteriorly; umbo subdued located at one-fourth to one-ninth of shell length from anterior margin. Dorsal margin nearly straight or gently convex, ventral margin broadly convex, anterior margin short and well rounded, posterior margin probably subrounded and truncate obliquely; escutcheon long and deep, bounded by sharp ridge extending to near posterior end of hinge; ligament opisthodetic, nymphs well defined; dentition of four cardinal teeth, anterior three strong, thick, and becoming short posteriorly, but posterior most cardinal tooth longer than others and bisected in right valve, seven to nine subcardinal teeth thin and somewhat geniculate.

The measurements of *Pseudoactinodontophora yabei* MURATA, n. sp. are given in Table 6.

*Remarks:*—This new species is based on about ten specimens, all of which are internal and external molds of incomplete valves. Their preservations are not so good, but the characters of their dentition are well observed in some specimens. As mentioned above, the present form seems to be closely related to *Actinodontophora katsurensis* ICHIKAWA, but the dentition is different. This species is named in honor of the late Dr. Hisakatsu YABE, who died on June 23, 1969.

*Repository:*—

Holotype—IGPS coll. cat. no. 86885.

Paratype—IGPS coll. cat. nos. 86886A-I.

*Occurrence:*—Abundant in the lower part of the Motoiwazawa Sandstone Member of the Sakamotozawa Formation in the Motoiwazawa Valley, southwest Kawaguchi, Sumita-cho, Kesen-gun, Iwate Prefecture.

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## Explanation of Plate 13

Figs. 1-3. *Bellerophon (Bellerophon) kitakamiensis* MURATA, n. sp.

1a, b. Right side and apertural views of a gum-type of the holotype; IGPS coll. cat. no. 91389, ×1.

1c, 3. Enlarged view of the gum-type of the holotype and a paratype to show details of the umbilicus and surface ornamentation; IGPS coll. cat. no. 31389, 91390A, ×2.

2a-c. Adapertural, left side and posterior views of the gum-type of a paratype; IGPS coll. cat. no. 91390B, ×2.

Horizon and Locality: Lower part of the Motoiwazawa Sandstone Member of the Sakamotozawa Formation (Early Permian) in the Motoiwazawa Valley, Sumita-cho, Kesen-gun, Iwate Prefecture.

Figs. 4-6. *Knightites (Reptispira ?) hanzawai* MURATA, n. sp.

4a-d. Adapertural, oblique adapertural, right side and posterior views of the gum-type of the holotype; IGPS coll. cat. no. 91391, ×2.

4e. Enlarged view of gum-type of the holotype to show the details of surface ornamentation, ×3.

5a, b. Left side and adapertural views of internal mold of paratype; IGPS coll. cat. no. 91392A, ×2.

6. Adapertural view of the gum-type of a paratype; IGPS coll. cat. no. 91392B, ×2.

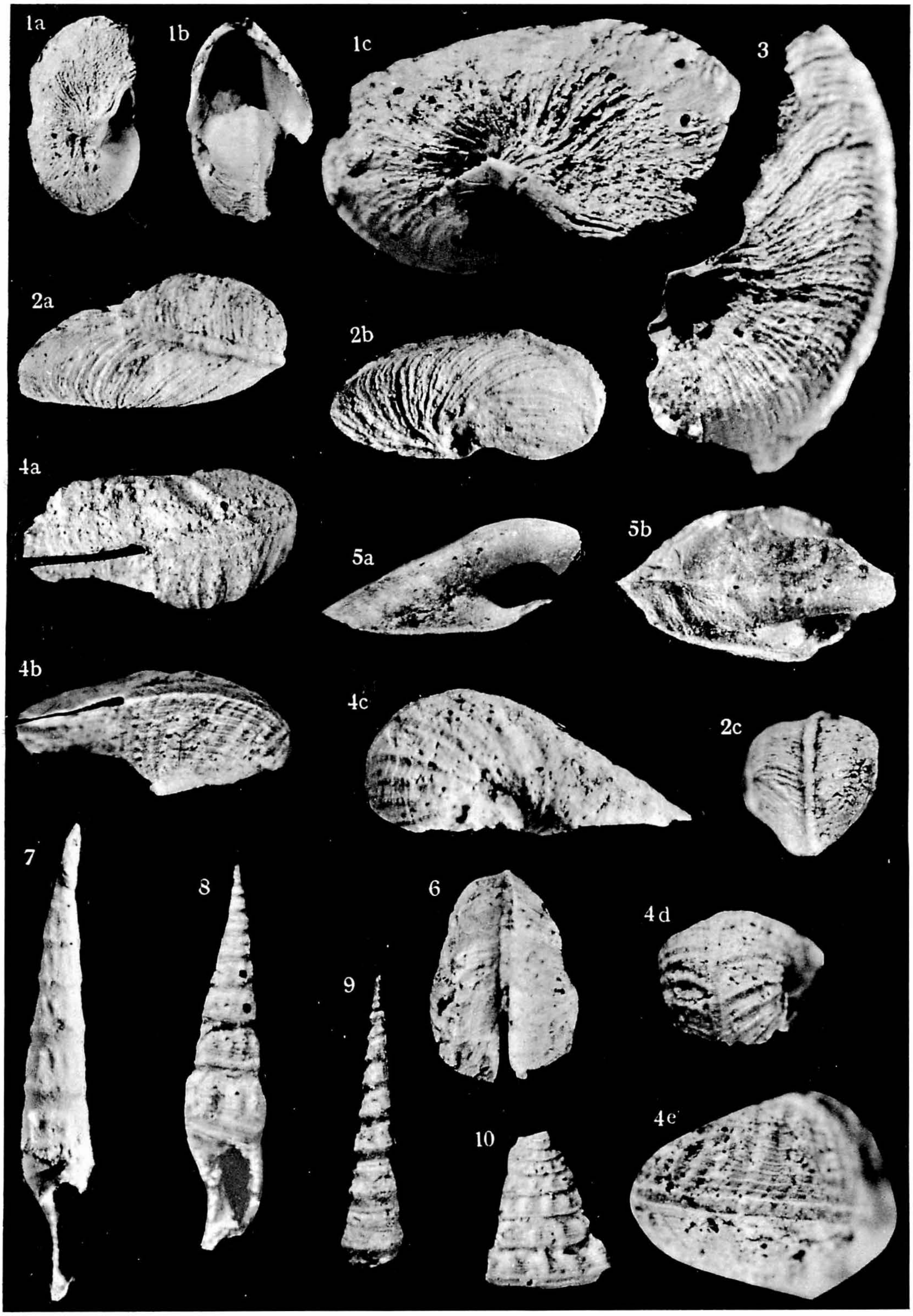
Horizon and Locality: Same as figs. 1-3.

Figs. 7-10. "*Murchisonia*" n. sp.

7, 8. Apertural view of gum-types; IGPS coll. cat. nos. 91393A, B, ×2.

9, 10. Lateral view of gum-types; IGPS coll. cat. nos. 91393C, D, ×2.

Horizon and Locality: Same as figs. 1-3.



K. KUMAGAI & S. OHTOMO photo.

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|---|---|
| Azumane | 東峰 |
| Gujo | 公庄 |
| Hikami | 氷上 |
| Hikoroichi | 日頃市 |
| Horooroshi | 母衣下 |
| Kachizawa | 合地沢 |
| Kanokurazawa | 叶倉沢 |
| Karakuwa Peninsula | 唐桑半島 |
| Kawaguchi | 川口 |
| Kesennuma | 気仙沼 |
| Kogaizawa | 子飼沢 |
| Kowaragi | 小原木 |
| Maiya | 米谷 |
| Motoiwazawa | 元岩沢 |
| Nagaiwa | 長岩 |
| Nagasaka | 長坂 |
| Odaira | 大平 |
| Ohazama | 大迫 |
| Okunigiri | 奥新切 |
| Orikabe | 折壁 |
| Otomo | 小友 |
| Sakamotozawa | 坂本沢 |
| Setamai | 世田米 |
| Sumita-cho | 住田町 |
| Takainari | 高稲荷 |
| Tatsusobe | 達曽部 |
| Yahagi | 矢作 |
| Yokamachi | 八日町 |
| Yokoiwazawa | 横岩沢 |
| Yukizawa | 雪沢 |

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## Explanation of Plate 14

Figs. 1–4. *Pseudoactinodontophora yabei* MURATA, n. gen. n. sp.
1a, b, 4. Gum-type of left and right valves of the same individual, holotype ; IGPS coll. cat. no. 86885, ×1.
2. Gum-type of left valve, posterior part of hinge-plate shifted slightly, paratype; IGPS coll. cat. no. 86886A, ×1.
3a, b. External mold and gum-type of left valve, paratype; IGPS coll. cat. no. 86886B, 3a. ×1, 3b. ×2.
Horizon and Locality: Lower part of the Motoiwazawa Sandstone Member of the Sakamotozawa Formation (Early Permian) in the Motoiwazawa Valley, Sumita-cho, Kesen-gun, Iwate Prefecture.

Figs. 5–8. *Towapteria nipponica* NAKAZAWA and NEWELL.
5a–c. External and internal molds and gum-type of left valve; IGPS coll. cat. no. 91395A, ×2.
6a, b, 8a, b. External mold and gum-types of left valves; IGPS coll. cat. nos. 91395B, D, ×2.
7. Gum-type of left valve; IGPS coll. cat. no. 91395C, ×2.
Horizon and Locality: Same as figs. 1–4.

Figs. 9, 11. *Waagenoperna (Permoperna) hayamii* NAKAZAWA and NEWELL.
9. Internal mold of right valve; IGPS coll. cat. no. 91397, ×2.
Horizon and Locality: Same as figs. 1–4.
11a, b. External mold and gum-type of left valve; IGPS coll. cat. no. 91398, ×1.
Horizon and Locality: Middle part of the Motoiwazawa Sandstone Member of the Sakamotozawa Formation (Early Permian) in the Yokoiwazawa Valley, southeast of Orikabe, Sumita-cho, Kesen-gun, Iwate Prefecture.

Fig. 10. *Aviculopecten* ? sp.
External mold of left valve; IGPS coll. cat. no. 86884, ×1.
Horizon and Locality: Same as fig. 11.

Fig. 12. *Aviculopecten* sp.
a, b. External mold and gum-type of right valve; IGPS coll. cat. no. 91396, ×2.
Horizon and Locality: Same as figs. 1–4.

Fig. 13. *Tainoceras kitakamiense* HAYASAKA.
Ventral view of steinkern; coll. cat. no. 91394, ×1.
Horizon and Locality: Same as figs. 1–4.

1a

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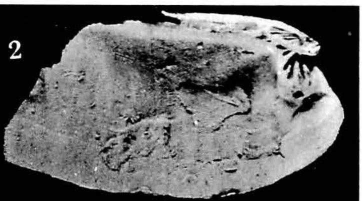

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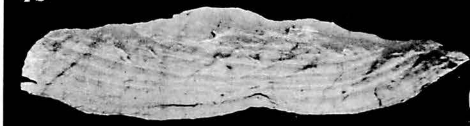

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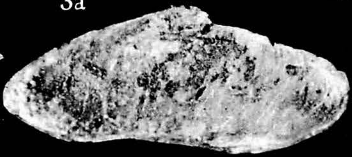

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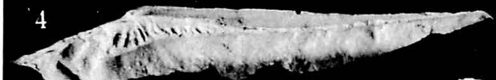

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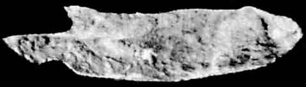

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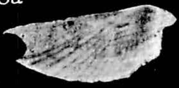

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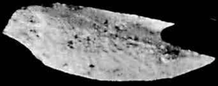

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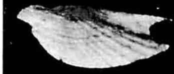

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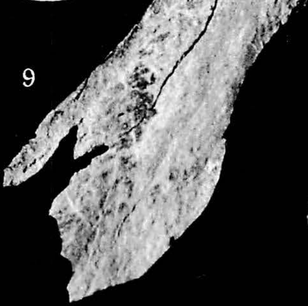

11a

12a

12b

13

10

11b

K. KUMAGAI & S. OHTOMO photo.

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# 581. CORRELATION OF LATE CENOZOIC MARINE SECTIONS IN JAPAN AND THE EQUATORIAL PACIFIC

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日本列島ならびに赤道太平洋域の後期新生代海成層の対比： 中上部中新世から現世にわたる浮遊性珪藻の層位的分布を赤道太平洋域の海底柱状底質について確かめ，それを同一底質中の他の微化石層序と古地磁気層序と比較した。この層序はヨーロッパの標準層序とも比較された。赤道太平洋域のいくつかの特徴種は日本列島の層序にも出現し，両地域の対比を可能にしている。この対比により，これまで考えられてきた男鹿半島の地層の時代を次のように訂正するのが妥当であるとの結論に達した。1）船川層上部と北浦層は上部鮮新統に対比され，2）中新一鮮新統の境界はおそらく船川層下部に位置し，3）女川層上部は上部中新世を含む可能性がある。

この対比によると男鹿半島の層序の一部（例えば女川層上部と船川層下部）は不整合による削剝かあるいは堆積速度の急激な減少を示しているように見える。その理由は，1）*Rhizosolenia praebergonii* の進化による最初の出現は赤道域では上部鮮新世下部（Gauss 正磁極期中部）に，男鹿半島では船川層中部に認められる。この種は赤道域で進化したので，それの日本列島における最初の出現は低緯度と同時かあるいは後になるはずである。2）*Thalassiosira nativa* 等の種は，赤道域と男鹿半島で同じ分布を示す。3）赤道域で後期中新世初期に絶滅する *Coscinodiscus yabei* が女川層で同様に絶滅していることは，女川層の上部も後期中新世に属することを示す。　Lloyd H. BURCKLE

## Introductory note

For the past year I have been studying Late Cenozoic diatoms in deep-sea sediment cores recovered from the eastern Equatorial Pacific. This work has been carried out in conjunction with similar studies on the Radiolaria, Foraminifera and paleomagnetic stratigraphy in the same cores (see for example; HAYS *et al.*, 1969; SAITO *et al.*, in prep.). In the course of this study it soon became apparent that some of the more stratigraphically useful diatom species are also present in the Miocene and Pliocene sections of Japan (KANAYA, 1959; KOIZUMI, 1966, 1968). These include such forms as: *Actinocyclus ellipticus* GRUN. var. *javanicus* REINHOLD, *Coscinodiscus endoi* KANAYA, *C. vetustissimus* PANTOCSEK, *C. yabei* KANAYA, *Denticula hustedtii* SIMONSEN and KANAYA, *Rouxia californica* PERAGALLO, *Rhizosolenia praebergonii* MUCHINA and *Thalassiosira nativa* SHESHUK. The purpose of this paper is to report on the geologic ranges of these species in the Equatorial Pacific and their possible correlation to sections in Japan. During the course of my discussion some questions must be raised regarding the age of certain formations on Japan.

Since 1962, ships of the Lamont-Doherty Geological Observatory have recovered

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Table 1.

| Core No. | Position | | Water Depth (M) | Length (cm) |
|---|---|---|---|---|
| | Latitude | Longitude | | |
| RC12-63 | 05°58′N | 142°39′W | 4949±10 | 1558 |
| RC12-65 | 04°39′N | 144°58′W | 4868 | 2426 |
| RC12-66 | 02°36.6′N | 148°12.8′W | 4755 | 2800 |

more than 200 deep-sea sediment cores from the eastern Equatorial Pacific. These cores range in age from Eocene to Pleistocene and in length from less than a few centimeters to over 28 meters. The Eocene cores are generally Radiolarian oozes with few diatoms, while Oligocene and Early Miocene sediments tend to be richly calcareous, containing mostly coccoliths although some diatoms and Radiolaria are also present. The Middle Miocene to Pleistocene cores, on the other hand, contain mostly diatoms and Radiolaria with few calcareous nannofossils and even fewer Foraminifera.

Since 1966, all cores taken by Lamont-Doherty ships have been oriented for paleomagnetic measurements. This technique is especially useful to the marine micropaleontologists because it permits him to compare ranges of microfossil species against actual time-lines (OPDYKE *et al.*, 1966; HAYS and OPDYKE, 1967; HAYS *et al.*, 1969). Of the cores recovered from the Equatorial Pacific since 1966, three are of special interest to this study (Table 1). They all penetrate into the Miocene and, on the basis of magnetic stratigraphy, have essentially complete Pliocene and Pleistocene sections. One core (RC12-65) penetrates the Late Miocene and bottoms in the uppermost part of the Middle Miocene (Text-fig. 1). The diatom stratigraphy and the paleomagnetic stratigraphy of these three cores will provide the basis for the discussion to follow.

## Acknowledgements

I wish to thank Drs. T. SAITO and N. D. OPDYKE for critically reviewing the manuscript and making numerous helpful suggestions. I am especially grateful to Dr. OPDYKE for generously supplying the author with records of the paleomagnetic stratigraphy for the cores used in this study and to Dr. SAITO for advice and help in searching through Japanese literature. Thank are also extended to Linda MURPHY for typing and proofreading the manuscript and to D. JOHNSON for drafting. The cores used in this study were curated under the direction of Mr. Roy CAPO.

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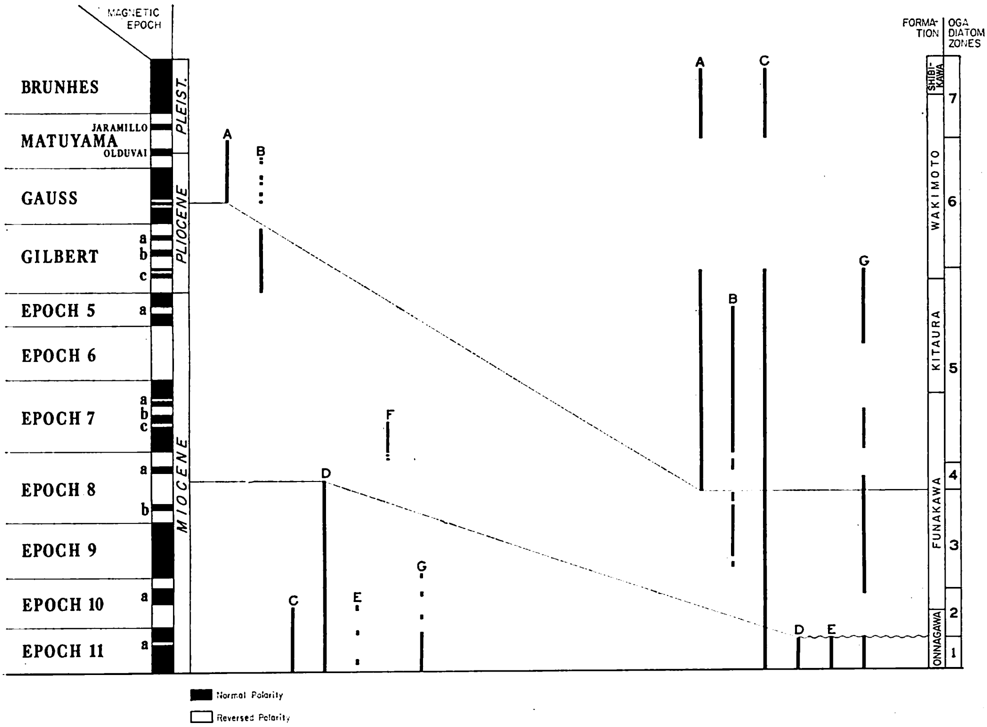
## Previous work

Modern work on Equatorial Pacific fossil diatoms began in 1954 when KOLBE published a study of diatoms in cores from this area taken by the Swedish Deep-Sea Expedition. Besides making a taxonomic study, he listed those forms which were restricted to the pre-Pleistocene and made an attempt to define the Pliocene/Pleistocene boundary in one of the cores (SW76). KANAYA (1969) subsequently presented evidence that the boundary defined by KOLBE was really an erosional unconformity.

MUCHINA (1963) discussed geologic ranges of selected diatom species from a single core from the Equatorial Pacific and included in her discussion two stratigraphically important species: *Rhizosolenia praebergonii* and *Thalassiosira convexa* (MUCHINA, 1965). In subsequent papers (MUCHINA, 1966, 1969) these species were used as early Pleistocene guide fossils with the first appearance of *Th. convexa* being used to define the Pliocene/Pleistocene boundary and the range of *R. praebergonii* being used to define the upper part of the lower Pleistocene. MUCHINA (1969) further reported on the occurrence of *Coscinodiscus yabei* KANAYA in Equatorial Pacific sediments and defined it as a largely Miocene species.

More recently HAYS *et al.* (1969) published a combined biostratigraphic (Foraminifera, Radiolaria, diatoms and discoasters) and paleomagnetic study of selected Pliocene-Pleistocene cores from the Equatorial Pacific while BURCKLE (1969) related a Late Miocene to Pleistocene diatom zonation for this region to zonations based upon other microfossil groups as well as to the record of paleomagnetic reversals. These last two papers will be discussed more fully



Text-fig. 1. Proposed correlation between the Equatorial Pacific and the Oga Peninsula section, Japan. Letter designations indicate the following species: A. *Rhizosolenia praebergonii* MUCH.; B. *Thalassiosira nativa* SHESHUK.; C. *Denticula hustedtii* SIMONSEN and KANAYA; D. *Coscinodiscus yabei* KANAYA; E. *Coscinodiscus endoi* KANAYA; F. *Rouxia californica* PERAGALLO; G. *Coscinodiscus vetustissimus* PANTOCSEK. Japanese diatom zones are after KOIZUMI, 1968.

later on.

Modern work on Japanese fossil diatoms began in 1950 with publication by ICHIKAWA on a comparison of marine Miocene diatoms between the Noto Peninsula and the environs of Kanazawa City. KANAYA (1959) defined several diatom zones in the middle Miocene Onnagawa Formation of the Oga Peninsula and demonstrated that these zones were recognizable over a considerable area. This observation was amply borne out by subsequent work on the Miocene of Hokkaido (SAWAMURA and YAMAGUCHI, 1961, 1963) and of Honshu (SAWAMURA, 1963). Eventually it came to be recognized that there were significant time-parallel, sequential changes in diatom species combinations that could be recognized in widely different localities (SAWAMURA, 1963). In 1966 KOIZUMI discussed the late Tertiary diatoms of the Ajigasawa district and in 1968 established a diatom zonation for the middle Miocene to Pliocene of the Oga Peninsula.

## Stratigraphy

*Paleomagnetic Stratigraphy*—HARRISON and FUNNELL (1964) and FULLER *et al.* (1966) were the first to record polarity reversals in deep-sea sediment cores while OPDYKE *et al.* (1966) were the first to show that the direction of remanent magnetism can be correlated from core to core. These same authors also related paleomagnetic correlations to correlations based upon microfossils. Where the paleomagnetic stratigraphy is known, the ranges of microfossil species can be matched with it. Thus, for the last four million years, an absolute or near absolute time value can be placed upon the first and last appearance of species.

Subsequent work on deep-sea cores has served to strengthen the interdependence of paleomagnetic stratigraphy and biostratigraphy (see for example; HAYS and OPDYKE, 1967; BERGGREN *et al.*, 1967; HAYS *et al.*, 1969). Additional work has also pushed our knowledge of geomagnetic reversals back into the Tertiary. Recently, FOSTER and OPDYKE (1970) reported on the paleomagnetic stratigraphy on a long core (RC12-65) recovered from the eastern Equatorial Pacific. The core extends into the uppermost part of the Middle Miocene, is essentially continuous and contains eleven magnetic Epochs (Text-fig. 1). As mentioned previously, this core along with several others from the Equatorial Pacific forms the basis of my discussion (Table 1).

Cores used in this study were internally oriented by cutting a groove down its length as it is extruded on board ship. Into this groove a string is laid which serves to retain the orientation of the core during shipment. In the laboratory, the core is split along this string making possible the detection of reversals as 180° shifts in magnetic declination. Specimens were removed from the split cores at intervals of from 10 to 20 cm and measured on a 5 cps spinner magnetometer (FOSTER, 1966) after partial demagnetization by alternating fields.

*Middle/Upper Miocene Boundary*—The Tortonian stage was originally proposed by MAYER EYMAR in 1857. More recently, GIANOTTI (1953) proposed a type section in the valley of the Rio Mazzapiedi—Rio De Castellania, east of Tortona. In a discussion of this stage, CITA and BLOW (1970) present evidence that the base of the Tortonian is referable to a horizon in the upper part of Zone N15 (BLOW, 1969). This is the *Globorotalia* (*T.*) *continuosa* Zone of BLOW (1969) and the *Globorotalia menardii* Zone of BOLLI (1957).

Because there are few foraminifera in our Equatorial Pacific cores it was not possible to use these criteria for defining the base of the Tortonian. However, WILCOXON and BRAMLETTE (1967), studying Middle Tertiary samples from the Cipero section of Trinidad have related nannoplankton zones to the foraminiferal zones of BOLLI. The most important of the nannoplankton within the *G. menardii* Zone is *Discoaster hamatus* MARTINI and BRAMLETTE which appears to be exclusive to this zone. In one of our Equatorial Pacific cores (RC12-65) *D. hamatus* is present in two samples near the bottom of the core within Geomagnetic Epoch 11. Ruling out any significant hiatuses in the lower part of the core I suggest that the very bottom of core RC12-65 penetrates into the uppermost part of the Middle Miocene and the Middle/Upper Miocene boundary falls somewhere within Geomagnetic Epoch 11.

*Miocene/Pliocene Boundary*—Using planktonic Foraminifera it has, so far, proved difficult to relate the Miocene/Pliocene boundary in Italy with sections elsewhere in the world. The main reason for this is that the type Lower Pliocene (Tabianian of MAYER EYMAR, 1868) contains a planktonic foraminiferal fauna indigenous to the intra-Mediterranean region. To circumvent this problem some authors (for example, BLOW, 1969; PARKER, 1967) have studied the more richly fossiliferous "trubi beds" (type section of the Zanclian of SEGUENZA, 1868) of Sicily, a unit which is believed to be correlative with the Tabianian of northern Italy. Recently, however, BLOW (1969) and CITA and BLOW (1970) have pointed out that the base of the Zanclian is younger than the base of the Tabianian and, therefore, not strictly correlative. BLOW (1969) indicates that the Miocene/Pliocene boundary, if based on the beginning of the Zanclian, falls within his Zone N18, whereas, if it is based upon the beginning of the Tabianian the epochal boundary will fall near the Zone N17/N18 boundary.

Because of the presence of the easily recognizable and widespread *Sphaeroidinella dehiscens* datum some 12 to 15 meters above the base of the "trubi beds" CITA and BLOW (1970) argue that the Zanclian be utilized as the base of the Pliocene in preference to the Tabianian. This criterion was applied to a long core (RC12-66) from the Equatorial Pacific by SAITO *et al.* (in prep.) and found to fall below the "c" event of the Gilbert Reversed Magnetic Epoch (Text-fig. 1). If this criterion is to be used, therefore, the Miocene/Pliocene boundary would occur near the boundary of the Gilbert Reversed Epoch and Magnetic Epoch 5. If the beginning of the Tabianian is used as the base of the Pliocene than the Miocene/Pliocene boundary, based upon faunal criteria developed by SAITO *et al.* (in prep.) should fall between the end of Magnetic Epoch 6 and the beginning of the Gilbert Reversed Magnetic Epoch. Since the Tabianian has priority as the type section for the Lower Pliocene I choose to follow the suggestion of SAITO *et al.* (in prep.) in the placement of this boundary with respect to the magnetic stratigraphy.

The placement of the Miocene/Pliocene boundary in Japan has been a matter of some concern owing to the paucity in this part of the section of fossils which can be used to correlate with the standard sections of Europe. In the Oga Peninsula section the boundary is normally placed at the contact between the Kitaura Formation and the Wakimoto Formation (see for example, SAITO, 1963). TAKAYANAGI and OBA (1966) reported that the highest occurrence of *Sphaeroi-*

*dinellopsis seminulina* (SCHWAG.) within the Kitaura Formation and placed the Miocene/Pliocene boundary at the top of this unit. KOIZUMI (1968) followed the "general practice" but points out that the exact positioning of the boundary is open to question.

*Pliocene/Pleistocene Boundary*—During the latter half of the 19th century and early part of the 20th century, the stratigraphy of the continental and marine Pleistocene was roughed out in Europe. An important contribution was made by DE STEFANI (1876) who introduced the following chronological succession in Italy: Pliocene, Lower Post Pliocene and Upper Post Pliocene. The base of the Lower Post Pliocene was marked by the immigration of cold water species into the Mediterranean. GIGNOUX (1910, 1913) introduced the term Calabrian, and designated the type section for the Calabrian at Santa Maria de Catanzaro in southern Italy. He differed with DE STEFANI's chronology in placing the Calabrian in the uppermost part of the Pliocene. This designation was never universally accepted and RUGGIERI and SELLI (1950) redesignated it as the lowest Pleistocene stage. The. 18th International Geological Congress (London, 1948) made a recommendation that the lower Pleistocene should include as its basal member in the type-area the Calabrian formation and invited the Italian Geological Society to select a type area for the Pliocene/Pleistocene boundary.

In 1961, EMILIANI *et al.* proposed that the type Plio-Pleistocene boundary be recognized at Le Castella (Calabria). Their reasons for proposing this section were that it was close to the classic Calabrian section at Catanzaro, was thicker, and less tectonically disturbed than the section in Catanzaro.

A proposal was made and accepted at the 7th INQUA Congress in Denver, Colorado, USA (1965) that the type section of the Plio-Pleistocene be established at Le Castella (Calabria), Italy. However, as RICHMOND (1967) has pointed out, this proposal has no legal force since it must be passed on by the International Geological Congress. Most workers, however, accept the Le Castella section as the type section for the Plio-Pleistocene boundary.

The Pliocene/Pleistocene boundary in deep-sea sediments was first defined by ARRHENIUS (1952) on the basis of carbonate content. KOLBE (1954) utilized paleontologic criteria in placing the boundary in core 76 of the Swedish Deep-Sea Expedition—a boundary which KANAYA (1969) has since shown to be an unconformity. RIEDEL (1957) suggested that the last appearance of *Pterocanium prismatium* RIEDEL and *Eucyrtidium elongatum peregrinum* RIEDEL in tropical Pacific cores be used to make the base of the Pleistocene. ERICSON *et al.* (1963) reported on a significant floral and faunal change in eleven deep-sea cores which they suggested be used to define the beginning of the Pleistocene. This boundary was approximately correlative with the last appearance of *Pterocanium prismatium* (RIEDEL *et al.*, 1963) in the Equatorial Pacific.

Although TAKAYANAGI and SAITO (1962) first suggested that their new species *Globorotalia tosaensis* may be ancestral to *G. truncatulinoides* (D'ORBIGNY) it was BANNER and BLOW (1965) who applied this criterion to the Pliocene/Pleistocene section at Le Castella. Near the base of the Calabrian they noted the first evolutionary appearance of *G. truncatulinoides* from *G. tosaensis*. The utility of this zonation was demonstrated by PARKER (1967) in deep-sea cores from the tropical Indo-Pacific. BERGGREN *et al.* (1967), in a combined paleomagnetic and paleontologic study of a deep-sea core from the North Atlantic, discovered that this evolutionary transition occurred in the Olduvai Event of the Matuyama Reversed Magnetic Epoch at about 1.71–1.86 m. y. (FOSTER and OPDYKE, 1970). This finding was later corroborated by GLASS *et al.* (1967). Subsequent papers have developed criteria from other microfossil groups for defining this boundary. HAYS (*in* HAYS *et al.*, 1969), for example, found that *Pterocanium prismatium* disappeared just after the Olduvai Event in the Equatorial Pacific, while BURCKLE (*in* HAYS *et al.*, 1969), working on the same core, found that *Rhizosolenia praebergonii* also disappeared just after the Olduvai. Subsequently, BURCKLE (1969) pointed out that the first appearance of *Pseudoeunotia doliolus* (WALL.) GRUN. occurs in the Olduvai Event and may be used to define the base of the Pleistocene.

In the Japanese section the transition from *G. tosaensis* to *G. truncatulinoides* has been recorded by TAKAYAMA (*in* IKEBE, 1969) in the Umegase Formation of the Boso Peninsula, central Japan just below the U6 tephra. Concommitant with this, NAKAGAWA *et al.* (1969) have shown that the U6 horizon corresponds to a magnetic polarity event which is correlated with the Olduvai.

## Discussion of floras

Having defined the Late Cenozoic epoch boundaries with respect to the various biostratigraphic and paleomagnetic criteria we now have the basis by which we can relate the Late Cenozoic diatom zones in the Equatorial Pacific to those on the Japanese Island. Of the several Miocene-Pliocene diatom species which occur in both the Equatorial Pacific and Japan, two are considered most significant: *Rhizosolenia praebergonii* and *Coscinodiscus yabei* (Plate I). As can be seen in Text-fig. 1, *R. praebergonii* first appears in the middle of the Gauss Normal Magnetic Epoch, a time-interval which we identify with the lower part of the Upper Pliocene (HAYS *et al.*, 1969). Since this species bears a fairly close resemblance to *R. bergonii* PERAG., I suggest that this species is its most immediate ancestor. In fact, within a 10 cm interval below the first appearance of *R. praebergonii* a few forms are present which are morphologically intermediate between *R. bergonii* and *R. praebergonii*, indicating that its first appearance in the Equatorial Pacific is evolutionary rather than ecological.

Except for its occurrence in the Oga Peninsula section of Japan (KOIZUMI, 1968) *R. praebergonii* appears to have been restricted to the low latitudes. It has not been found in the North or South Pacific (DONAHUE, Personal Communication) nor has it been reported in any of the higher latitude land sections in the circum-Pacific area. Its presence in Japan, however, may be attributed to the northward flowing warm water Tsushima Current (ASANO, 1957).

KOIZUMI (1968) reports the first appearance of *R. praebergonii* in the middle of the Miocene Funakawa Formation of the Oga Peninsula (Base of Diatom Zone 4). The fact that this species appears to have originated in lower latitudes suggests that a Miocene designation for the Funakawa is, in part at least, incorrect. If a direct correlation is drawn between the first appearance of *R. praebergonii* in the Equatorial Pacific and that in the Oga Peninsula section, the middle part of the Funakawa Formation should be early Late Pliocene in age, or younger. This means that the overlying Kitaura Formation, a unit which is normally placed within the Miocene, should also be moved up into the Pliocene. Should the range of *R. praebergonii* in the Oga Peninsula section approximate that of the Equatorial Pacific, the Pliocene/Pleistocene boundary should fall within the upper part of the Kitaura Formation or the Shibikawa Formation.

That this correlation is reasonable seems to be borne out by examination of ranges of other species which are common to both Japan and the Equatorial Pacific. *Thalassiosira nativa*, for example, first appears in Epoch 5 (latest Miocene) in Equatorial Pacific cores and, although its occurrence is sporadic, ranges concurrently with *R. praebergonii*. In the Japanese section, *Th. nativa* appears in the lower part of the Funakawa Formation (Oga Diatom Zone 3) and ranges concurrently with *R. praebergonii* to the upper part of Diatom Zone 5 (KOIZUMI, 1968). The species *Coscinodiscus vetustissimus* also has similar ranges in the Equatorial Pacific and Japan.

A noticeable departure from this pattern is *Denticula hustedtii*. In the Equatorial Pacific, this form disappears in the lower part of the upper Miocene. This observation is borne out by MUCHINA (1969) who places the range of *D. hustedtii* in her upper Miocene and lower Pliocene. In the Japanese section, on the other hand, KOIZUMI (1968) records this species well into the upper Pliocene. Such an observation appears to be consistant with my results for higher latitudes where I see this form ranging up through much of the Pliocene.

Still another important form found in both the Equatorial Pacific and Japan is *Rouxia californica*. Although described by PERAGALLO, it was HANNA (1930) who first emphasized the stratigraphic value of this species. He pointed out that it occurs abundantly in a narrow zone some 500 feet below the top of the Monterey shale and its stratigraphic equivalents. KANAYA (1959) reported it from the Matazawa Formation of Japan but not from any of its stratigraphic equivalents. KOIZUMI (1968), on the other hand, does not report its occurrence from the Oga Peninsula section. In Equatorial Pacific cores this form occurs rarely in the middle part of the upper Miocene (*i. e.* approximately in the uppermost part of Geomagnetic Epoch 8 and the lower half of Geomagnetic Epoch 7). Since this species is rare in the Equatorial Pacific we cannot draw an exact correlation between high and low latitudes. However, the range of this species in higher latitudes must encompass the middle part of the upper Miocene.

A final species of importance to both the Japanese and Equatorial Pacific section is *Coscinodiscus yabei*. KANAYA (1959) described and named this species and pointed out its importance as a middle Miocene marker fossil. The value of this form in correlation has been demonstrated by a number of Japanese diatomists (see for example; SAWAMURA, 1963; ONO, 1968; KOIZUMI, 1968). In the Equatorial Pacific, BURCKLE (1969) notes that this species ranges up into the lower part of the upper Miocene, while MUCHINA (1969) records a sharp drop in abundance for the species across her Miocene/Pliocene boundary and then notes its sporadic occurrence throughout the Pliocene. In Text-fig. 1, I present evidence that this species disappears well below the Miocene/Pliocene boundary. It would appear then that KANAYA'S (1959) conclusion that the last appearance of this species defines the top of the Middle Miocene is essentially correct although my data places its last appearance somewhat later in the early Late

Miocene.

If we accept the last appearance of *C. yabei* and the first appearance of *R. praebergonii* as valid datum points which can be correlated with the Equatorial Pacific section then it follows that the Miocene/Pliocene boundary in the Oga Peninsula section must fall in the upper part of the Onnagawa Formation or the lower half of the Funakawa Formation. Such a correlation also implies that this part of the section between the upper part of the Onnagawa Formation and the lower part of the Funakawa Formation (KOIZUMI's Diatom Zones 2 and 3) has been greatly shortened. Forms such as *R. californica* which occur between the upper limit of *C. yabei* and the lower limit of *R. praebergonii* in the Equatorial Pacific have not been reported from a similar stratigraphic position in the Oga Peninsula section (KOIZUMI, 1968).

## Summary and conclusions

In this report I have tried to point out the utility of diatoms in correlaitng between Late Cenozoic sediments in the Equatorial Pacific and the Japanese Islands. In this case, their value is further enhanced because the diatom zones in the Equatorial Pacific have been related to zonations based upon other microfossil groups as well as the paleomagnetic stratigraphy. Such an interdisciplinary approach permits us to develop fossil diatom criteria with which to define epoch boundaries.

When such criteria are applied to the Oga Peninsula section it becomes apparent that some adjustment in the age designations of these units are in order. These adjustments may be summarized as follows:

1. The upper part of the Funakawa Formation and the overlying Kitaura Formation, units which have been placed in the Miocene, should be assigned to the upper part of the Pliocene.
2. The Miocene/Pliocene boundary, if it is present in the Oga Peninsula sections, probably falls within the lower part of the Funakawa Formation.
3. The upper part of the Onnagawa Formation probably extends into the Late Miocene.
4. Since some parts of the Oga Peninsula section appear to be greatly shortened or truncated (*eg.* lower part of the Funakawa and upper part of the Onnagawa Formations) it is possible that unconformities or at least intervals of reduced sedimentation rates are present.

The basis upon which the above conclusions are drawn may be summarized as follows:

1. The first evolutionary appearance of *R. praebergonii* in the Equatorial Pacific occurs in the middle part of the Gauss Normal Magnetic Epoch (early Late Pliocene). In the Oga Peninsula section it first appears in the middle of the Funakawa Formation (Base of Diatom Zone 4). Available evidence indicates that this form was largely restricted to tropical and subtropical water and its first appearance in higher latitude sediments must either be correlative with or post-date its first appearance in lower latitude sediments.
2. The first appearance of *Th. nativa* in the Equatorial Pacific occurs in Geomagnetic Epoch 5 near the Miocene/Pliocene transition and ranges concurrently, though sporadically, with *R. praebergonii*. In the Oga Peninsula section, *Th. nativa* first appears in the lower part of the Funakawa Formation

(Diatom Zone 3) where I suggest the Miocene/Pliocene boundary might be placed.

3. In the Equatorial Pacific, *Coscinodiscus yabei* extends into the lower part of the Upper Miocene while in the Oga Peninsula section it last occurs in the upper part of the Onnagawa Formation (Diatom Zone 1). KANAYA (1959) and, later, KOIZUMI (1968) used the last appearance of this species to define the middle Miocene. Although it would be premature to say that the last appearance of this species in Japan and in the Equatorial Pacific is time-correlative, I would sugggest that part of the Upper Miocene may be also included in the Onnagawa Formation.

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PALAEONTOLOGICAL SOCIETY OF JAPAN, SPECIAL PAPERS NUMBER 17 を 1972 年度に刊行したく，その原稿を公募します。適当な原稿をお持ちの方は，次の事項に合わせて申込書を作成し，〒812 福岡市箱崎町 九州大学理学部地質学教室気付，日本古生物学会特別号編集委員会（代表者 松本達郎）宛に申し込んで下さい。

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**訂正：** 本誌前号（No. 81）でお知らせした，日本古生物学会特別号 15 号（浜田隆士著：小興安嶺の下部デボン紀腕足類［英文］）の会員頒布価格が誤って居りましたので，改めてお知らせします。本会会員 2,000 円（郵送料を含む）尚 非会員価格は従前通り 2,500 円（郵送料 200 円）です。

申込は 〒812 福岡市箱崎町・九州大学理学部地質学教室内
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# 日本古生物学会報告紀事出版規定

(1970年1月19日改正)

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## 例会通知

| | 開催地 | 開催日 | 講演申込締切日 |
|---|---|---|---|
| 108回例会 | 九州大学 | 1971年10月22-24日 | 1971年6月10日 |
| 1972年総会·年会 | 千葉大学 | 1972年1月下旬 | 1971年12月10日 |

◎ 108回例会（九州大学）は日本地質学会ほか3学会と共催。本会に関連あるシンポジウムとしては，「九州周辺海域の地質学的諸問題」（世話人・奈須紀幸，鹿間時夫，星野通平，水野篤行，鎌田泰彦，加賀美英雄，小西健二，高橋良平，首藤次男）が予定されている。

◎ 108回例会に参加される方々は，地質学雑誌（46年3月号）を参照の上，早目に宿舎等の申込みを済ませて下さい。

## お知らせ

本学会内の「化石硬組織同位体」研究グループの第3回研究発表会が11月5日（金）と6日（土）の両日，東京都中野区南台1-15-1・東大・海洋研究所で開催されます。講演希望者は，〒920 石川県金沢市丸ノ内1・金沢大学理学部地学教室 小西健二 気付「化石硬組織同位体」研究グループ宛，演題と講演時間を記入して申込んで下さい。なお講演要旨プレプリントの原稿締切は9月30日です。

◎ 本会誌の出版費の一部は文部省研究成果刊行費による。

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