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Stratigraphy of the Devonian Fukuji Formation in Gifu Prefecture and Its Favositid Coral Fauna

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Abstract The Fukuji Formation is subdivided into the lower Takaharagawa Member and the upper Ozako Member (new name). The Takaharagawa Member exceeds 200 m thick and mainly composed of limestones, argillaceous limestones and calcareous shales with subordinate amounts of sandstones and tuffs to tuffaceous sandstones. The Ozako Member is estimated to be 150 m thick and composed of massive limestones. The formation ranges in age from the Lochkovian (early Early Devonian) to possibly the Eifelian (early Middle Devonian). Constituents of the favositid coral fauna of the formation are *Mesofavosites igoi* (Kamei, 1955), *Sapporipora kamitakaraensis* Tsukada, 2005, *Pachyfavosites katoi* sp. nov., *Plicatomurus flexuosus* (Kamei, 1955), *Squameopora takarensis* (Kamei, 1955), *Squameofavosites fukujensis* (Kamei, 1955), *Squameofavosites ichinotanensis* (Kamei, 1955), and *Squameofavosites sugiyamai* (Kamei, 1955). The generic assignment of a species *ichinotanensis* changes from *Favosites*. *Sapporipora karataniorum* Tsukada, 2005 and S*quameopora hidensis* (Kamei, 1955) are synonymized respectively with *Sapporipora kamitakaraensis* and *Squameopora takarensis*. *Pachyfavosites katoi* represents the first record of the genus in Japan.

Key words : Early to Middle Devonian, tabulate corals, Favositidae, *Pachyfavosites katoi* sp. nov., Fukuji Formation, Takaharagawa Member, Ozako Member (new name), Gifu.

Introduction

The Fukuji Formation, named by Kamei (1952), is the richly fossiliferous Devonian sequence that crops out in the Fukuji area of Okuhidaonsen-gou in Takayama-shi, Gifu Prefecture, Central Japan. Although the stratigraphy has been studied minutely as summarized by Igo and Adachi (1981), Harayama (1990) and Niko (2006a), even the most fundamental problem of the sedimentary direction was still an unsettled question. In addition, there was some confusion about its lithostratigraphic subdivisions. The purposes of the present study are to clarify the whole aspects of the Fukuji Formation and to document the favositid coral fauna.

Used abbreviations indicating depositories of coral specimens are as follows: GISUL: Department of Geology, Faculty of Science, Shinshu University, HMM: Hikaru Memorial Museum, NSM: National Science Museum, and UMUT: University Museum of the University of Tokyo.

Stratigraphy

The Fukuji Formation trends east-northeast to northeast and has dips of southwardly steep to nearly vertical gradients (Fig. 1). Diametrically opposite opinions concerning the sedimentary direction were presented, namely Kamei (1952) stated that north-northwest- to northwest-ward the formation becomes older, on the other hand Igo and Adachi (1981) had a reversed view. The former opinion was an established theory and widely accepted (Research Group for the Palaeozoic of Fukuji, 1973; Igo *et al.*, 1975; Ohno, 1977; Niikawa, 1980; Kuwano, 1987 and others). The present observations using geopetal structure consisting of sediment fillings of lime mud and sparry calcite (Fig. 2-3) have resulted in support

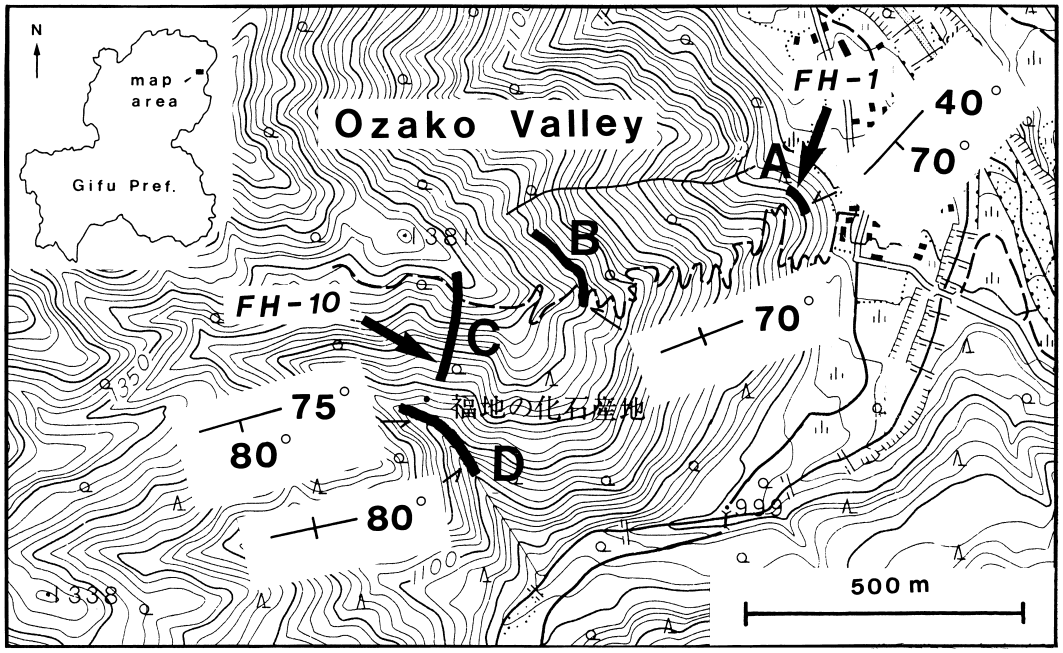


Fig. 1. Index map of the Fukuji area, Gifu Prefecture showing strikes and dips of the Fukuji Formation, and positions of stratigraphic columnar sections (A–D) and coral localities (FH-1, 10). Geographic positions of other localities used in this paper are given in Niko (2005, p. 14, fig. 1). Base map is "Yakedake" (1:25,000 quadrangle) published by Geological Survey Institution.

of the minor opinion, i.e., north-northwest- to northwest-ward the Fukuji Formation becomes younger and it is commonly upturned. A variegated basal conglomerate bed in Igo *et al.* (1980) can be compared with the conglomerates of the Mesozoic Tetori Group.

Lithologically the formation is divided into two units (Fig. 3). It is recommended that the term Takaharagawa should now be restored for the lower unit. The upper unit is newly named the Ozako Member. These members are conformable.

Takaharagawa Member

The exclusion of the Devonian rocks containing a trilobite *Crotalocephalina* from the "Gotlandian" Fukuji Formation was made by Kobayashi and Igo (1956). They called them the Takaharagawa Formation, however subsequent workers revealed that the resting strata are also correlative with the Devonian rather than the "Gotlandian" (see the age mentioned below). Therefore, an important ground separating these formations ceased to exist, and at once time the Takaharagawa Formation was abandoned (Research Group for the Palaeozoic of Fukuji, 1973). Because of the lower portion of the Fukuji Formation in the present two-fold stratigraphic subdivision includes the former Takaharagawa Formation, this portion being here named the Takaharagawa Member with a redefinition.

The Takaharagawa Member is equivalent to the Beds 2 to 6 (the Middle Acid Vitric Tuff Member), the Beds 7 to 11 (the Upper Limestone and Shale Member) and a part of the Bed 1 (the Lower Limestone Member) in Kamei's (1955) lithostratigraphic nomenclature, the Upper Fukuji Formation, the Takaharagawa Formation and a part of the Lower Fukuji Formation in Kobayashi and Igo's (1956) one, the Beds B and C (the Lower Member), the Beds E to I (the Middle Member), the Beds J to N (the Upper Member) and a part of the Bed D (the Lower Member) in Ohno's (1977) one, the D1, D3 and D4 Members

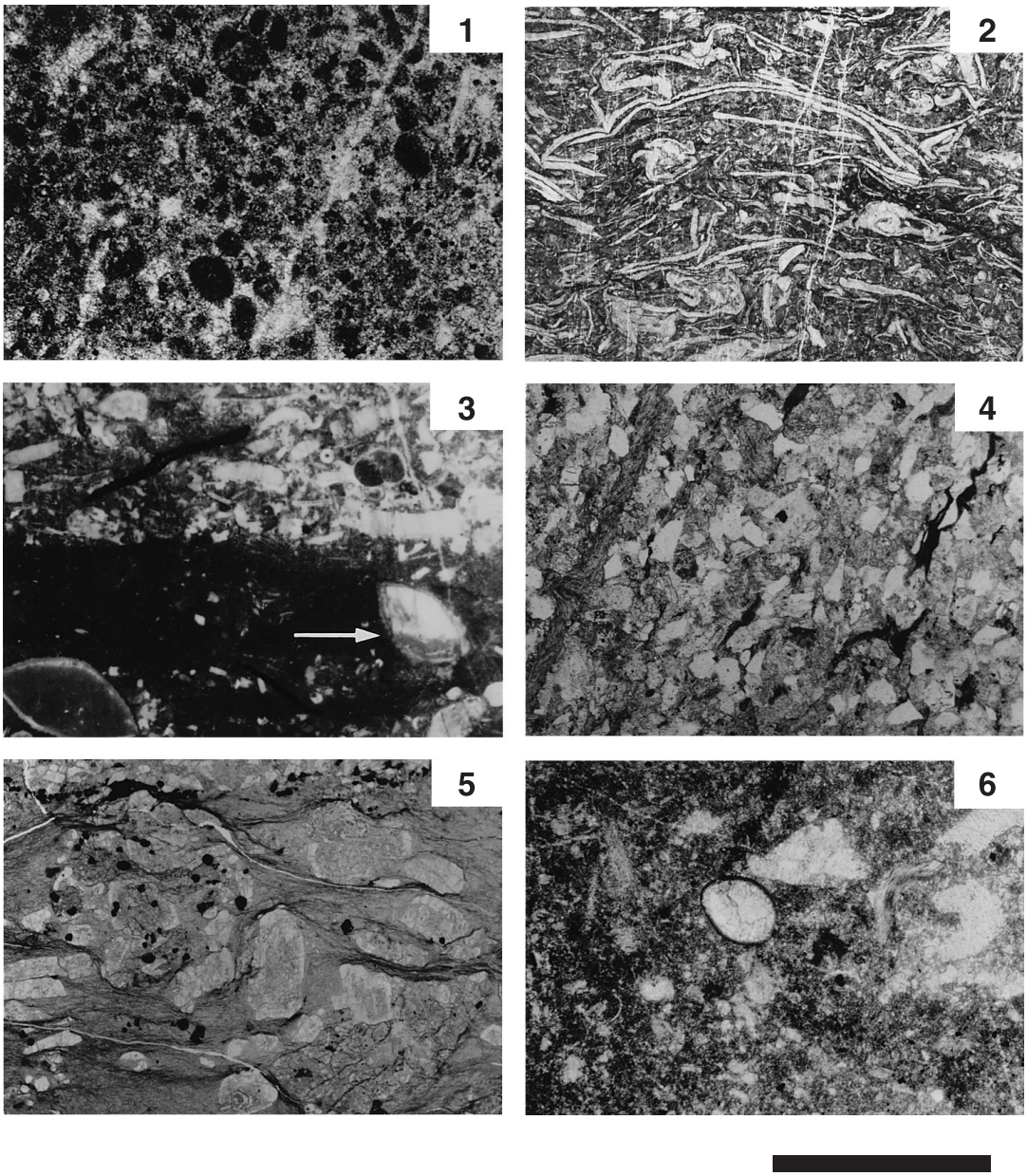


Fig. 2. Lithology of the Fukuji Formation. **1–5**, the Takaharagawa Member. **6**, the Ozako Member. Except for Fig. 2-3 that is polished surface, all figures are hotomicrographs of thin sections. **1**, peloidal wackestone, scale bar equals 1.0 mm for this figure. **2**, bioclastic wackestone, scale bar equals 3.9 mm for this figure. **3**, bioclastic wackestone to wackestone, arrow indicates geopetal structure, this rock specimen was collected near locality FH-7, scale bar equals 14.8 mm for this figure. **4**, sandstone at the base of the member, note containing of brachiopod shell and biotite fragments, scale bar equals 0.8 mm for this figure. **5**, felsic tuff, scale bar equals 2.8 mm for this figure. **6**, bioclastic wackestone, scale bar equals 1.0 mm for this figure.

and a part of the D2 Member in Niikawa's (1980) one, the Lower Shaly Member, the Middle Shaly Member, the Upper Carbonate Member, the Upper Shaly Member and a part of the Lower Carbonate Member in Kuwano's (1987) one. Recently Kurihara (2003) tentatively correlated the calcareous rocks in the Kanashirozako Valley with the Fukuji Formation, whose sequence also can be assignable to the Takaharagawa Member.

Type locality and geographic distribution: The type locality is the lower reaches of the Ichinotani Valley (columnar section D), where it's lowest and upper beds are cut away by the faults. The successions of these missing portions are respectively observable in outcrops at the vicinity of a community of Fukuji (columnar section A) and the eastern slope of Mt. Sora-yama (columnar section B). The Takaharagawa Member also crops out in the southern flank of the Ozako Valley and the northern flank of the Kanashirozako Valley.

Lithology: The Takaharagawa Member is well-bedded, and consists mainly of limestones, argillaceous limestones and calcareous shales. The limestones, typically dark gray- to black-colored, are composed predominately of bioclastic wackestones (Fig. 2-2) and peloidal wackestones (Fig. 2-1) with subordinate amounts of stromatoporoidal and/or coral bafflestones, wackestones and bioclastic packstones, and rarely interbedded with bioclastic grainstones in the middle portion. The base of the member is a gray fossiliferous sandstone (Fig. 2-4) containing a characteristic trilobite *Craspedarges superbus* Kobayashi and Hamada, 1977. The middle portion of the member contains the intercalated thin felsic tuff (Fig. 2-5) to tuffaceous sandstone beds, whose freshly broken surfaces are greenish gray, and weather a light ocherous color. The calcareous sandstone to sandy limestone facies are present in a transitional zone between limestones and tuffaceous intercalations.

Thickness: The thickness exceeds 200 m.

Age: Except for Dr. Tadao Kamei who considered the age of the Takaharagawa Member to be the "Gotlandian" (Kamei, 1952), the Silurian (Kamei, 1955) or the Middle Devonian (Kamei, 1961), roughly the Lochkovian (early Early Devonian) to the Emsian (late Early Devonian) ages are given by trilobites (Kobayashi and Igo, 1956; Kobayashi and Hamada, 1977), corals (Hamada, 1959; Research Group for the Palaeozoic of Fukuji, 1973), brachiopods (Ohno, 1977), conodonts (Igo *et al.*, 1975; Kuwano, 1986, 1987; Igo and Adachi, 1993) and ostracodes (Kuwano, 1987). Unfortunately some fossils were derived from floats thus their exact stratigraphic horizons are not always certain, but the interval of Lochkovian to Emsian probably represents depositional range of the member. The present investigations on the basis of the favositid corals are consistent with this age determination.

Ozako Member (new name)

The member is equivalent to a part of the Bed 1 (the Lower Limestone Member) in Kamei's (1955) lithostratigraphic nomenclature, a part of the Lower Fukuji Formation in Kobayashi and Igo's (1956) one, the Bed A and a part of the Bed D (the Lower Member) in Ohno's (1977) one, the D5 Member and a part of the D2 Member in Niikawa's (1980) one, and a part of the Lower Carbonate Member and an unnamed formation of Kuwano's (1987) one.

Type locality and geographic distribution: The distribution of the Ozako Member is restricted to a small area in the upper reaches of the Ozako Valley to the northern flank of the Ichinotani Valley, which serves as the type locality. The type-section for the member situates near the western margin of the outcrop (columnar section C).

Lithology: The bulk of the member is composed of gray massive limestones. The highest exposed succession is a characteristically fossiliferous limestone, which is lightly stained to buff, brown to reddish brown in color. Wackestone and bioclastic wackestone (Fig. 2-6) are predominant, in addition stromatoporoidal bafflestone is commonly present.

Thickness: The thickness is estimated to be about 150 m.

Age: Detailed correlation of the Ozako

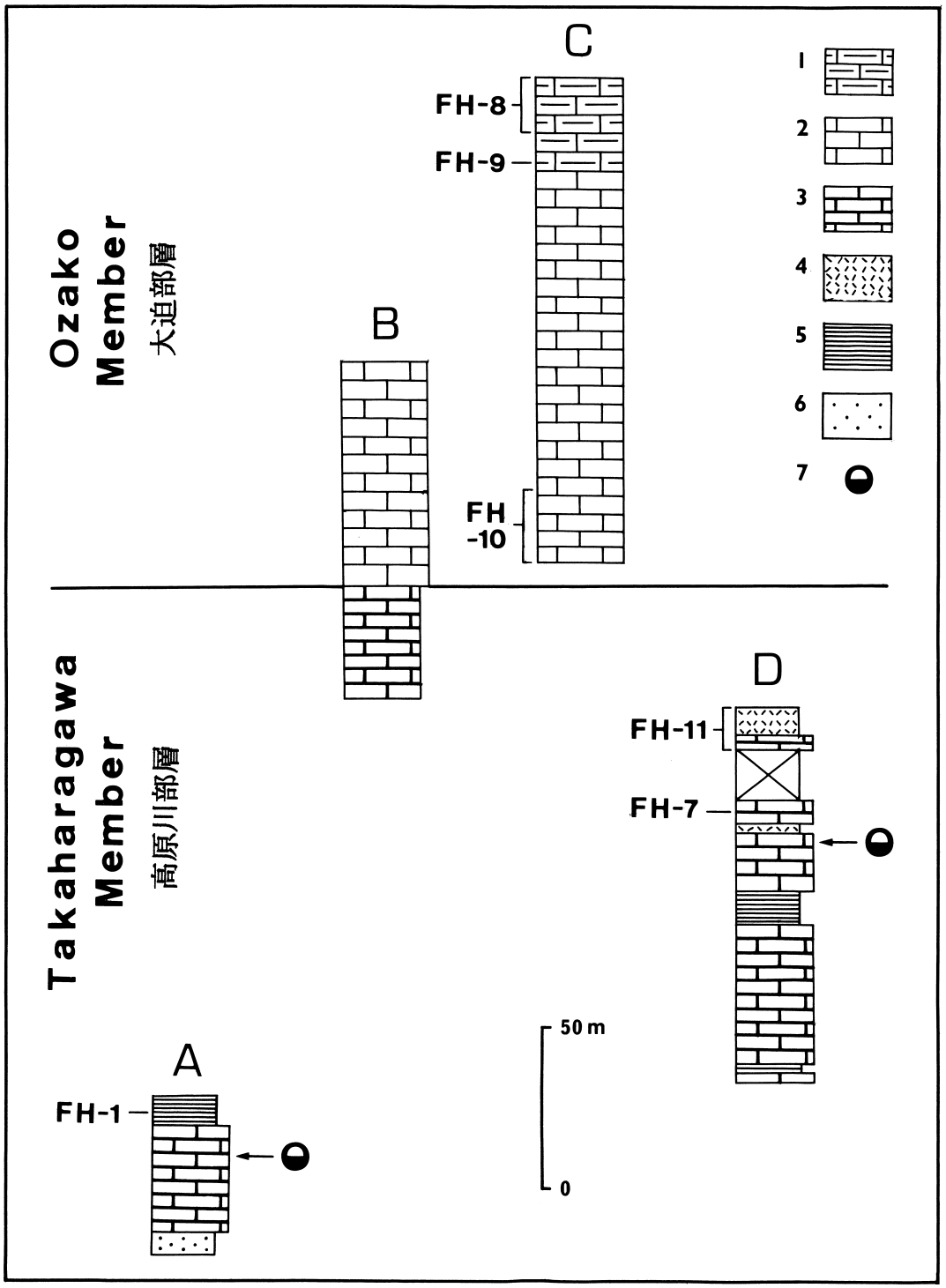


Fig. 3. Stratigraphic columnar sections of the Fukuji Formation. Horizons containing favositid corals (FH-1, 7–9, 11) and geopetal structures are indicated. **1**, massive limestone indicating buff, brown to reddish brown in color. **2**, massive limestone indicating gray in color. **3**, bedded limestone to argillaceous limestone. **4**, tuff to tuffaceous sandstone. **5**, calcareous shale. **6**, sandstone. **7**, geopetal structure.

Member has been disputed because fossils that can indicate a precise age have not been found. Kuwano (1987) identified conodonts from the vicinities of localities FH-8 and FH-9, and stated that "the yield is very low and no diagnostic species have been recovered to fix age as either the Silurian or the Devonian". The present studies on a favositid coral, *Pachyfavosites katoi* sp. nov. yielding near the top of the member and the stratigraphy furnish new clues to this problem. As indicated in the discussion of the species, *P. katoi* shows close affinity with *P. vilvaensis* Sokolov, 1952, whose documented chronological data are Middle Devonian, Eifelian (early Middle Devonian) and Middle (to Early?) Devonian. In consideration of the age of the Takaharagawa Member beneath, the Ozako Member appears to be of Emsian to Eifelian age.

Systematic Paleontology

Order Favositida Wedekind, 1937

Suborder Favositina Wedekind, 1937

Superfamily Favositoidea Dana, 1846

Family Favositidae Dana, 1846

Subfamily Favositinae Dana, 1846

Genus ***Mesofavosites*** Sokolov, 1951

Type species: *Mesofavosites dualis* Sokolov, 1951.

Mesofavosites igoi (Kamei, 1955)

(Figs. 4-1–5)

Mesofavosites igoi (Kamei); Niko, 2006b, p. 14, 16, figs. 1-1–3; 2-1–5 [with earlier synonymy].

Material examined: Twenty-three specimens, HMM 03029, 03135, 03141; NSM PA15804, 15805(?), 15806–15809, 15810(?), 15811, 15812, 16274–16284.

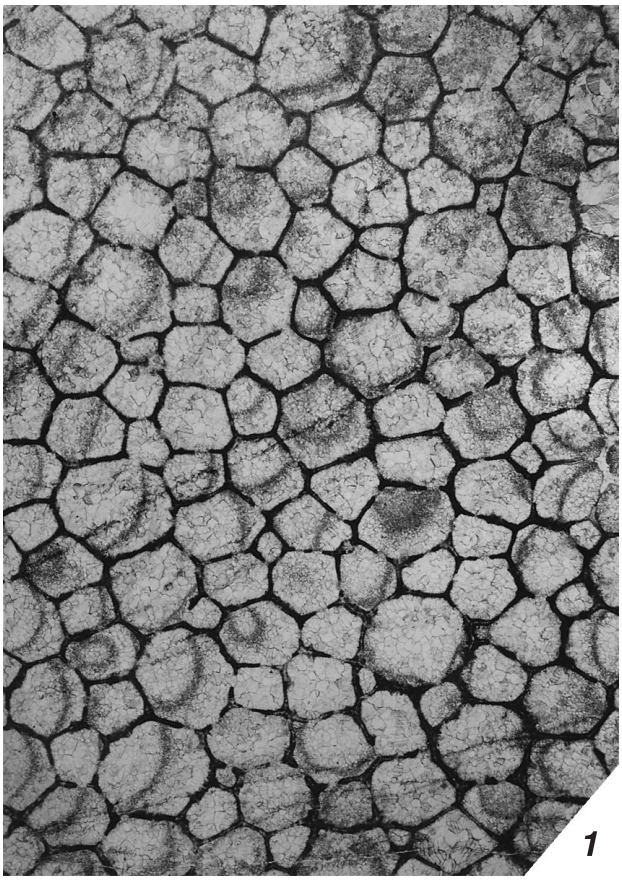
Emended diagnosis: Thickness of intercorallite walls rarely attains 0.15–0.21 mm, 0.04–0.11 mm most common. See Niko (2006b) for other diagnostic features.

Description: Morphologies of coralla, corallites and tabulae and position of mural pores are referable in Niko (2006b). Intercorallite walls differentiated into median dark line and stereoplasm of rect-radiate fibers; thickness of intercorallite walls is mostly 0.04–0.11 mm, and 0.15–0.21 mm in thickened portion as rare cases; diameters of mural pores are 0.15–0.25 mm; septal spines rod-like, whose protruded portions into tabularia attain 0.23 mm in length.

Occurrence: The examined specimens were collected from the float blocks of argillaceous limestone (HMM 03135; NSM PA15805, 15806, 16280) and black limestone of bioclastic wackestone (HMM 03029; NSM PA15807, 15812, 16274–16276) near locality FH-6, an outcrop of black to dark gray limestone of bioclastic wackestone (NSM PA 15804, 16277, 16278), peloidal to bioclastic wackestone (NSM PA16279) and bioclastic packstone (NSM PA16281) at locality FH-7, a float block of gray limestone (stromatoporoidal bafflestone) near locality FH-10 (NSM PA16284), an outcrop of greenish gray tuffaceous sandstone at locality FH-11, (NSM PA15808, 15809), and the float blocks of black limestone of wackestone (NSM PA15810, 15811) and bioclastic wackestone (HMM03141; NSM PA16282, 16283) in the Ichinotani Valley. Except for a specimen (NSM PA16284) that is derived from the Ozako Member, this species commonly occurs in the Takaharagawa Member.

Discussion: The two syntypes of *Favosites uniformis igoi* Kamei, 1955 were re-described by Niko (2006b) as the lectotype (GISUL 30123a) and paralectotype (GISUL 30123b) of *Mesofavosites igoi*. Subsequently, 71 thin sections of newly obtained specimens from the type stratum of this species permit refinement of the specific

Fig. 4. *Mesofavosites igoi* (Kamei, 1955), thin sections. **1**, HMM 03141, transverse sections of corallites, ×10. **2**, **3**, NSM PA15811, transverse sections of corallites, note slightly thickened intercorallite walls at peripheral zone of corallum (Fig. 4-3), ×10. **4**, **5**, NSM PA16279. **4**, longitudinal sections of corallites, ×10. **5**, partial enlargement to show intercorallite wall structure, longitudinal section, ×75.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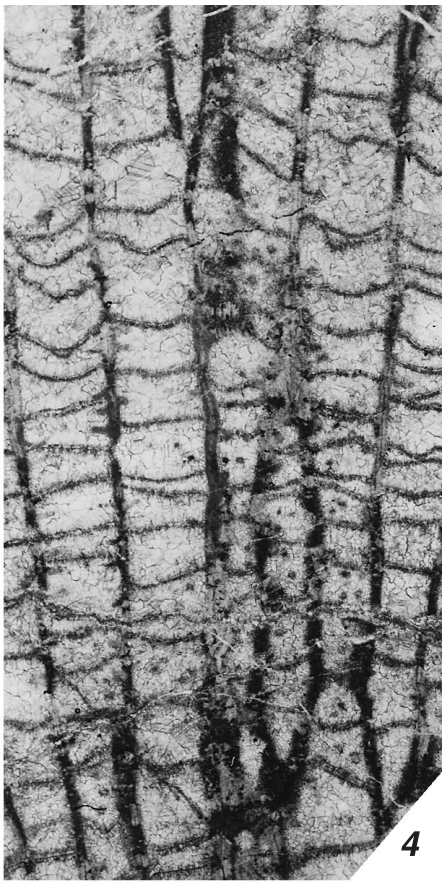
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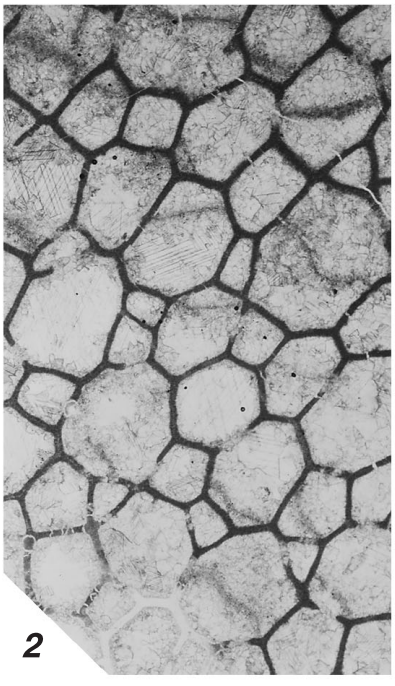
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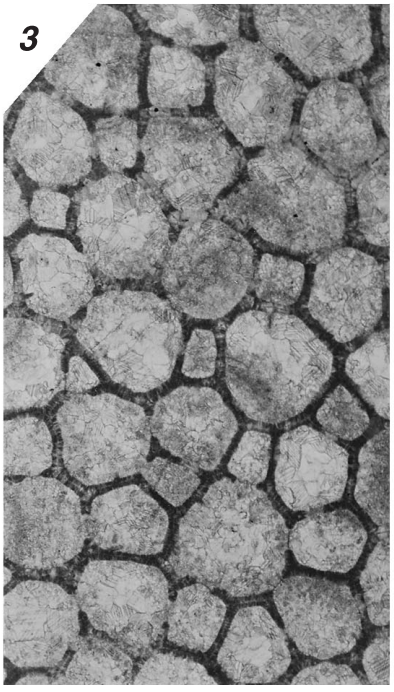
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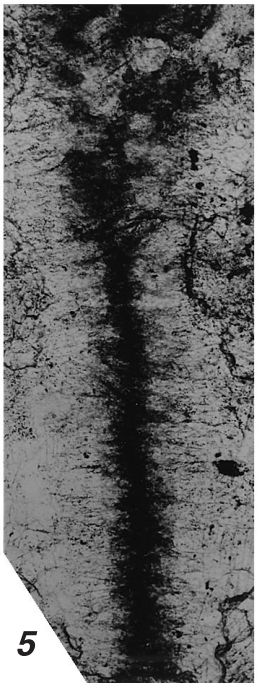
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concept, particularly with respects to intercorallite wall nature. This knowledge is documented herein.

Genus ***Sapporipora*** Ozaki *in* Shimizu, Ozaki and Obata, 1934

Type species: *Sapporipora favositoides* Ozaki *in* Shimizu, Ozaki and Obata, 1934.

Sapporipora kamitakaraensis Tsukada, 2005

(Figs. 5-1–6)

Sapporipora kamitakaraensis Tsukada; Niko, 2006b, p. 16, 18, figs. 2-6–8 [with earlier synonymy].
Sapporipora karataniorum Tsukada, 2005, p. 69, 70, pl. 9, fig. 6, pl. 10, figs. 1–6.

Material examined: Eighteen specimens, HMM 03133, 03338; NSM PA16285–16300.

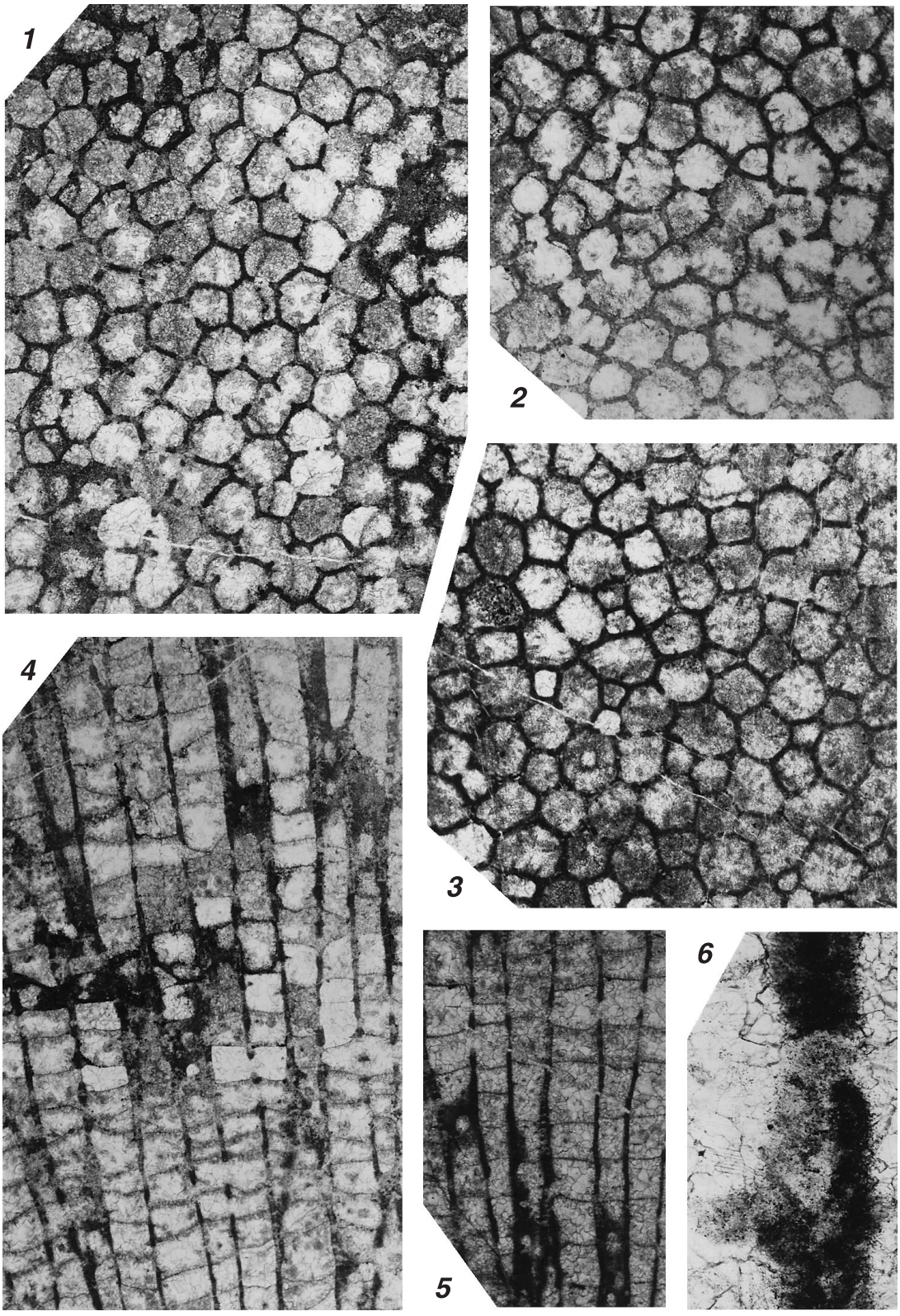
Emended diagnosis: Species of *Sapporipora* with 0.9 mm in approximate corallite diameter, and 0.08–0.12 mm in intercorallite wall thickness; distribution of septal spines ranges from almost absent to numerous as regional differences; fewer tabulae than type species of genus.

Description: Coralla massive indicating domical, subspherical to bulbous growth forms, cerioid; largest specimen (HMM 03338) excesses 127 mm in diameter and 81 mm in height. Corallites prismatic with 3–7 sides, 6 sides most common, to subprismatic; diameters of corallites are rather equal, range from 0.44 to 1.57 mm with 0.9 mm mean; increases of new corallites are lateral, relatively rare; calices may be shallow. Intercorallite walls consists of median dark line and dark stereoplasm composed of very fine fibers that directed perpendicular to upward from median dark line in longitudinal section; thickness of intercorallite walls is fairly uniform, 0.08–0.12 mm; mural pores numerous, occur on corallite faces as mid-wall pores and at corallite corners as angle pores, circular to elliptical profiles; diameters of typical mural pores are 0.21 mm, 0.22×0.29 mm; in peripheral zone of coralla, intercorallite walls slightly wavy in some corallites; distribution of septal spines is variable ranging almost absent to numerous as regional differences; septal spines long and slender, needle-like to rod-like, attaining 0.27 mm in length of their protruded portions into tabularia; tabulae well-developed, but not so abundant in comparison with the type species of the genus, mostly complete, very rarely incomplete; usual profiles of complete tabulae are nearly flat to weakly sagging (concave proximally), but oblique, uparched (concave distally), strongly sagging tabulae also recognized; some tabulae arrange at same level in adjacent corallites; there are 7–13 tabulae in 5 mm of corallite length.

Occurrence: The examined specimens were collected from the float brocks of argillaceous limestone (HMM 03133, 03338; NSM PA16286–16291, 16296) and black limestone of bioclastic wackestone (NSM PA16285, 16292) near locality FH-6, the float blocks of black limestone of bioclastic wackestone on the eastern slope of Mt. Sora-yama (NSM PA16295, 16297), the float brocks of bioclastic wackestone in the Ichinotani Valley (NSM PA16298–16300), and the float blocks of black limestone of bioclastic wackestone (NSM PA16293) and gray limestone of wackestone (NSM PA16294) in the Osobudani Valley. This species occurs in the Takaharagawa Member.

Discussion: Tsukada (2005) proposed a new species, *Sapporipora karataniorum*, for specimens with the slightly wavy intercorallite walls in the peripheral zone of the coralla and the numerous septal spines, but these fall within specific variation of *S. kamitakaraensis*. For this reason they are synonymized herein.

Fig. 5. *Sapporipora kamitakaraensis* Tsukada, 2005, thin sections. **1**, **4–6**, HMM 03338. **1**, transverse sections of corallites, ×10. **4**, **5**, longitudinal sections of corallites, ×10. **6**, partial enlargement to show intercorallite wall structure, longitudinal section, ×75. **2**, **3**, HMM 03133, transverse sections of corallites, note regional differences in spacing of septal spines, ×10.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Subfamily Pachyfavositinae Mironova, 1965

Genus ***Pachyfavosites*** Sokolov, 1952

Type species: *Calamopora polymorpha* var. *tuberosa* Goldfuss, 1826.

Pachyfavosites katoi sp. nov.

(Figs. 6-1–5)

[?] *Caliapora* ? sp., Wakata, 1974, fig. 6 [p. 6].

Holotype: NSM PA16313, from which five thin sections were made.

Other specimens: Nineteen thin sections were studied from the five paratypes, NSM PA16303, 16304, 16308–16310. In addition, seven specimens, NSM PA16301, 16302, 16305–16307, 16311, 16312, were also examined.

Diagnosis: Small species of *Pachyfavosites* with up to 28 mm in corallum diameter of holotype; corallites approximately 1.2 mm in diameter; thickness of intercorallite walls is usually 0.10–0.29 mm, partly thickening to 0.36 mm; mural pores common; typical mural pore has 0.21 mm in diameter; septal spines uncommon, low to high conical; tabulae mostly complete.

Description: Coralla small, subspherical to bulbous, cerioid; holotype has up to 28 mm in diameter and 21 mm in height; maximum observable height of the largest paratype (NSM PA16303) attains 27 mm. Corallites relatively narrow, prismatic, straight, and radiate in arrangement; immature corallites have 3–5 sides, then ontogenetically shift 5–6 sided profiles in adult corallites; corallite diameters range from 0.67 to 1.33 mm, with 1.2 mm mean in adult ones; calices very shallow, perpendicularly oriented to corallum surface; increases of new corallites may be lateral, relatively rare. Intercorallite walls consist of median dark line and stereoplasm, the latter of which microstructure is rect-radiate fibers, and thick in comparing to corallite diameter; thus, tabularia exhibit rounded polygonal to circular profiles; usual thickness of intercorallite walls is 0.10–0.29 mm, slightly thicken to 0.36 mm in peripheral zone of corallum; diameters of tabularia are 0.48–0.90 mm; mural pores common, circular in profile, developed on corallite faces and at near corallite corners; some mural pores closed by pore plate; diameter of typical mural pore is 0.21 mm; septal spines uncommon, low to high conical, ranging 0.08–0.25 mm in length of their protruded portions into tabularia; tabulae mostly complete, weakly sagging to nearly flat, but oblique or uparched complete tabulae are frequently recognized; in addition, incomplete vesicular tabulae are rarely developed; there are 8–15 tabulae in 5 mm of corallite length.

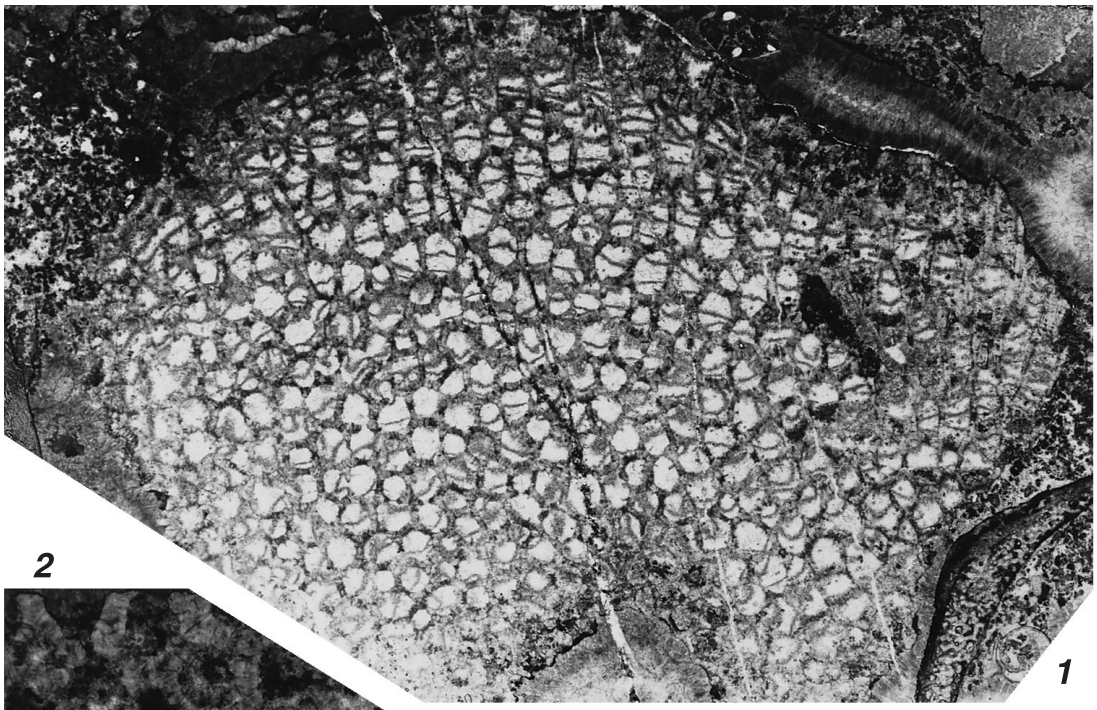
Etymology: The specific name honors Dr. Makoto Kato in recognition of his contributions to the taxonomic study of Paleozoic corals.

Occurrence: *Pachyfavosites katoi* sp. nov. was collected from the float blocks of buff, gray to light brown limestone of bioclastic wackestone at locality FH-8 (NSM PA16301, 16302, 16306–16309, 16311–16313), and an outcrop of reddish light brown limestone of bioclastic wackestone at locality FH-9 (NSM PA16303–16305, 16310). This species occurs in the Ozako Member.

Discussion: The morphological characters of the Fukuji specimens fit well with the diagnosis of *Pachyfavosites* that is known to range from the Upper Silurian to the Upper Devonian. This is the first record of the genus in Japan.

Based on its corallite diameters and intercorallite wall thickness *Pachyfavosites katoi* sp. nov. appears to have close affinities with *P. vilvaensis* Sokolov (1952, p. 48, 49, pl. 11, figs. 1–4) from the Middle Devonian of the Urals, the Eifelian (lower Middle Devonian) of the Kuznetsk Basin, southwestern Siberia (Dubatolov, 1959, p. 59, 60, pl. 16, figs. 3a, b, 4a, b), and the Middle (to Lower?) Devonian of Da Xinggan Ling (Da

Fig. 6. *Pachyfavosites katoi* sp. nov., thin sections. **1–4**, holotype, NSM PA16313. **1**, oblique section of corallum, ×5. **2**, **3**, transverse sections of corallites, note thickened intercorallite walls at peripheral zone of corallum (Fig. 6-2), ×10. **4**, partial enlargement to show intercorallite wall structure, transverse section, ×75. **5**, paratype, NSM PA16303, longitudinal sections of corallites, ×10.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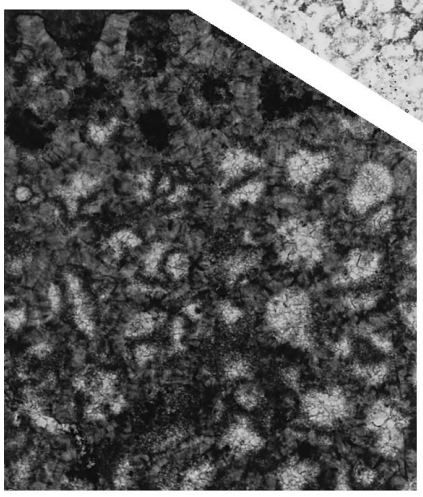
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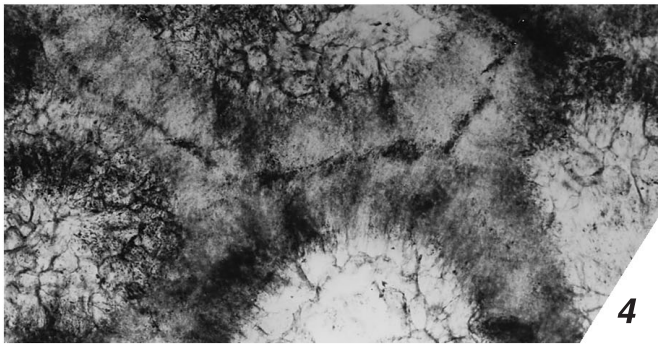
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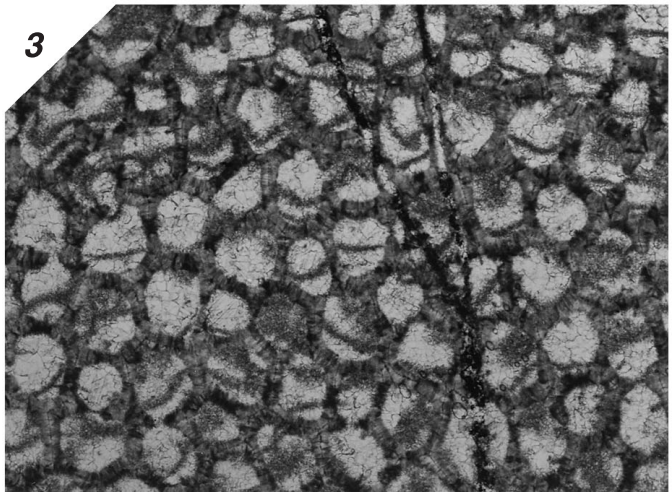
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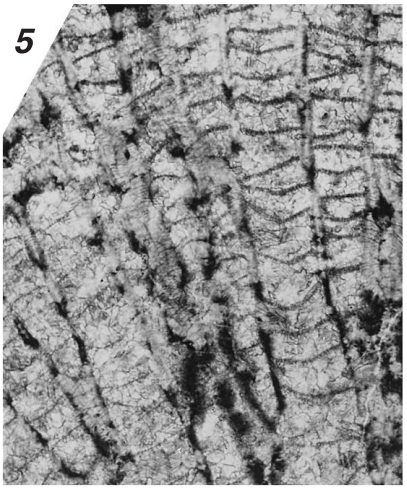
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Hinggan Ling), Northeast China (Tchi, 1982, p. 176, pl. 1, figs. 5a, b). However, *P. katoi* differs from *P. vilvaensis* in having fewer mural pores. *Pachyfavosites katoi* is also similar to *P. bystrowi* Yanet (1959, p. 106, text-figs. 34a, b, pl. 48, figs. 3a, b) from the Eifelian of the Urals and the Lower Devonian of the Kuznetsk Basin (Dubatolov, 1963, p. 23, 24, pl. 9, figs. 1a, b, v, g), but differs in that its corallite diameters are somewhat smaller (approximately 1.2 mm versus 1.25–1.50 mm in *P. bystrowi*) and its septal spines are low to high conical, whereas *P. bystrowi* has the thin and needle-like septal spines. The new species can be differentiated from a somewhat similar species, *P. rariporosus* Dubatolov (1963, p. 24, 25, pl. 10, figs. 1a, b, v, 2, 3), known from the Lower Devonian of the Kuznetsk Basin and the Siegenian (Lower Devonian) of Salair and Altai in southwestern Siberia (Mironova, 1974, p. 63, 64, pl. 31, figs. 1a, b, 2a, b, pl. 32, figs. 1a, b, v, pl. 33, fig. 1, pl. 78, figs. 1a, b), in displaying larger corallite diameters (0.8–1.0 mm in adult corallites of *P. rariporosus*) and intercorallite wall thickness (attaining 0.36 mm in *P. katoi* versus up to 0.25 mm in *P. rariporosus*). Additionally, the coralla of *P. rariporosus* are larger than those of *P. katoi* and attain 100 mm in diameter.

Genus ***Plicatomurus*** Chang, 1959

Type species: *Plicatomurus solidus* Chang, 1959.

Plicatomurus flexuosus (Kamei, 1955)

(Figs. 7-1–3)

Plicatomurus flexuosus (Kamei); Niko, 2006b, p. 18, 20, figs. 3-1–5 [with earlier synonymy].

Material examined: Twenty-one coralla, HMM 03520; NSM PA4219 (same specimen with pl. 21, fig. 3 in Masutomi and Hamada, 1966), 16314–16332.

Occurrence: The examined specimens were collected from an outcrop of calcareous shale at locality FH-1 (NSM PA16314), the float blocks of argillaceous limestone (NSM PA16318) and black limestone of bioclastic wackestone (HMM 03520; NSM PA16315–16317, 16321–16329) near locality FH-6, the float blocks of black limestone of bioclastic wackestone in the Ichinotani Valley (NSM PA16330–16332), and the float blocks of black limestone of bioclastic wackestone in the Osobudani Valley (NSM PA16319, 16320). A specimen (NSM PA4219) was collected by Dr. Tadao Kamei from black limestone (? in the Ichinotani Valley). This species occurs in the Takaharagawa Member.

Remarks: Based on a thin section of the neotype (GISUL 30109), the diagnostic features of *Plicatomurus flexuosus* have been minutely documented by Niko (2006b), thus they are not to redescription.

Genus ***Squameopora*** Preobrazhenskiy, 1967

Type species: *Favosites forbesi takarensis* Kamei, 1955. See the following discussion.

Squameopora takarensis (Kamei, 1955)

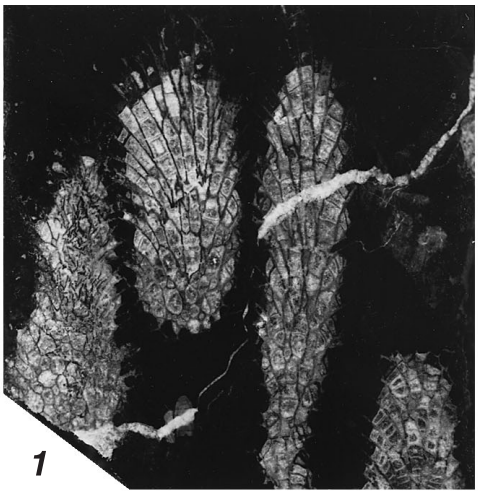
(Figs. 7-4, 5; 8-1–6)

Squameopora takarensis (Kamei); Niko, 2006b, p. 21, 22, figs. 4-7–9; 5-3 [with earlier synonymy].

Squameopora hidensis (Kamei); Niko, 2006b, p. 20, 21, figs. 4-1–6 [with earlier synonymy].

Material examined: Twenty-seven specimens, NSM PA16333–16354; UMUT PC7301 (same specimen with pl. 16, figs. 1a–c in Hamada, 1959), 7302 (same specimen with pl. 16, fig. 2 in ditto), 7303 (same specimen with pl. 16, fig.

Fig. 7. **1–3**, *Plicatomurus flexuosus* (Kamei, 1955). **1**, NSM PA4219, longitudinal polished sections of branches, ×1. **2**, NSM PA16331, transverse thin section of branch, ×5. **3**, NSM PA16323, longitudinal thin sections of corallites at peripheral zone of branch, ×10. **4**, **5**, *Squameopora takarensis* (Kamei, 1955), thin sections. **4**, NSM PA16343, transverse to oblique sections of corallites at axial zone of branch, ×10. **5**, NSM PA16342, longitudinal sections of corallites at peripheral zone of branch, ×10.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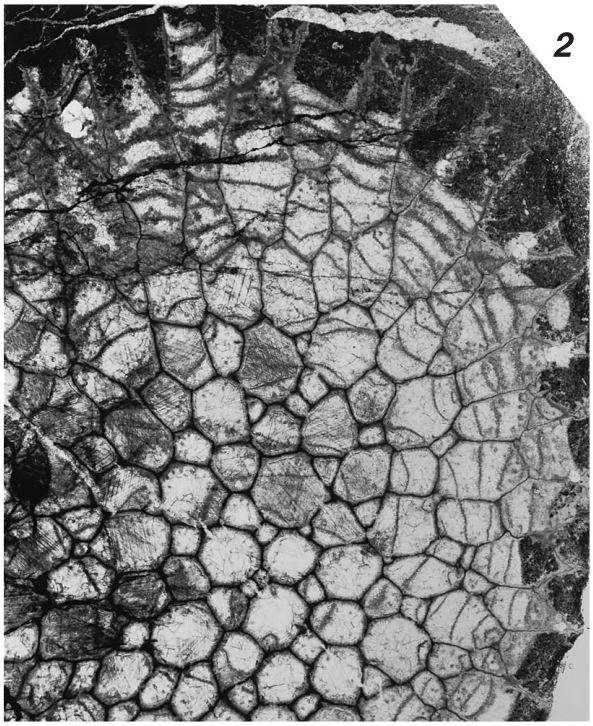
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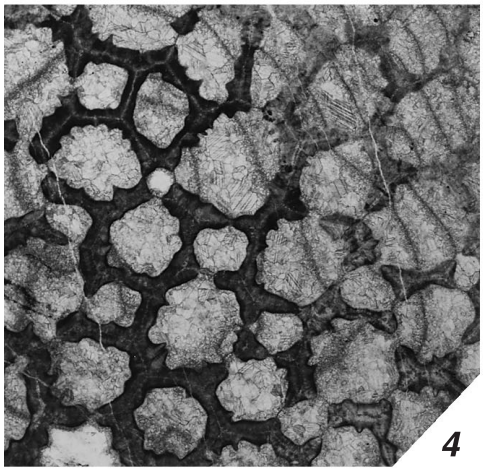
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3 in ditto), 7304 (same specimen with pl. 16, fig. 4 in ditto), 7305 (same specimen with pl. 16, figs. 5, 6 in ditto).

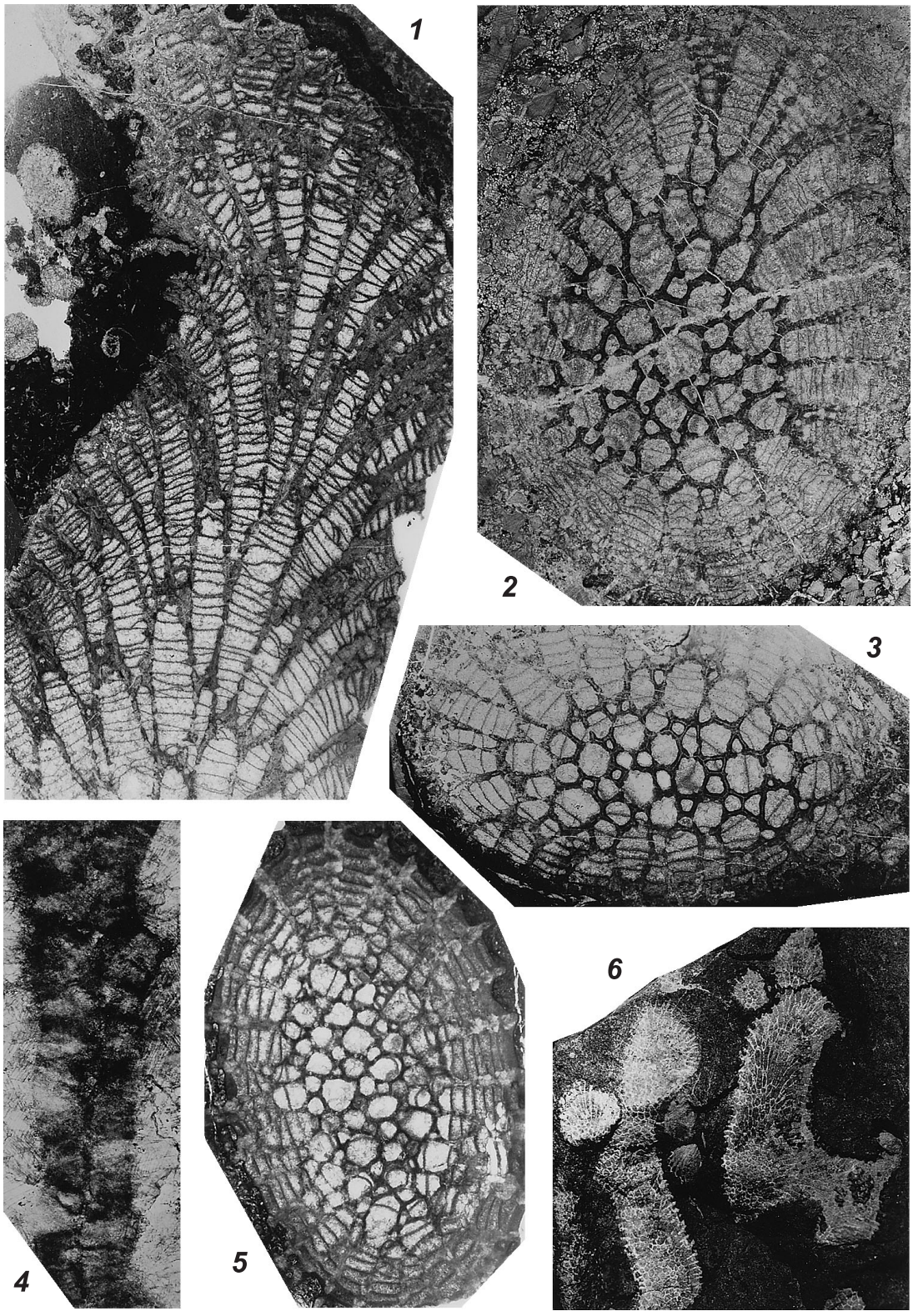
Emended diagnosis: Species of *Squameopora* with most common branch diameters of 10–16 mm, and approximately 1.5 mm in adult corallite diameters; thickness of intercorallite walls attains 0.36 mm in peripheral zone of branch; mid-wall and angle pores developed; septal spines low conical; peripheral tabulae closely spaced.

Description: Coralla ramose with subcylindrical to somewhat irregular shaped branches, cerioid; branching relatively rare, probably bifurcate; anastomoses of adjacent branches are uncommonly developed. Diameters of branches range from 5 to 25 mm, 10–16 mm most common. Corallites prismatic, growing longitudinally and parallel in axial zone of branches, then turning outward to open at acute, approximately 30°, to nearly right angle; transverse sections of corallites are 3–5 sided in immature and 5–8 sided in adult ones, whose diameters ranging 0.33–1.88 mm, with 1.5 mm mean in adult corallites; tabularia have rounded subpolygonal transverse sections; increases of new corallites frequent, lateral; calices very shallow, approximately 0.5–0.7 mm in depth. Usual intercorallite walls consist of median dark line and stereoplasm, but this differentiation becomes obscure in peripheral zone of gerontic branches, where they indicate transparent in appearance; microstructure of stereoplasm is rect-radiate fibers; thickness of intercorallite walls weakly to moderately thickened even in axial zone of branch, 0.09–0.29 mm, furthermore increases attaining 0.36 mm in peripheral zone; peripheral stereozone is indistinct; mural pores occur on corallite faces (mid-wall pores) and at corallite corners (angle pores), have circular to elliptical profiles; diameters of typical mural pores are 0.23 mm, 0.23×0.25 mm; most mural pores closed by pore plate; septal spines sporadic to well-developed in axial zone and well-developed in peripheral zone, short with wide basis, usually low conical having 0.10–0.15 mm in length of protrude portions into tabularia; tabulae usually complete, nearly flat to weakly sagging; spacing of tabulae is close in peripheral zone; in axial zone, there are 6–12 tabulae in 5 mm of corallite length, then this count increases up to 17 in 2.5 mm at peripheral zone; incomplete tabulae indicating strongly oblique, uparched or dissepiment-like profiles are commonly recognized in crowded portions.

Occurrence: The examined specimens were collected from the float blocks of argillaceous limestone (NSM PA16348) and black limestone of bioclastic wackestone to packstone (NSM PA16341) near locality FH-6, an outcrop of gray limestone of bioclastic packstone at locality FH-7 (NSM PA16336), an outcrop of greenish gray tuffaceous sandstone, calcareous sandstone, sandy limestone to limestone of bioclastic grainstone at locality FH-11 (NSM PA16342–16346, 16349–16354), a float block of black limestone of bioclastic wackestone on the eastern slope of Mt. Sora-yama (NSM PA16340), and the float blocks of black limestone of bioclastic wackestone (NSM PA16333–16335, 16337), bioclastic packstone to wackestone (NSM PA16338, 16339), peloidal wackestone (NSM PA16347) in the Ichinotani Valley. The specimens kept in University Museum of the University of Tokyo (UMUT PC7301–7305) were collected by Dr. Takashi Hamada, of which lithofacies are quite identical with those of locality FH-11. This species occurs in the Takaharagawa Member.

Discussion: Kamei (1955) proposed in p. 50 of the literature a new subspecies, *Favosites forbesi takarensis* on the basis of the three syntypes (GISUL 30116a–c) from black limestone,

Fig. 8. *Squameopora takarensis* (Kamei., 1955). **1**, NSM PA16340, longitudinal thin section of branch, ×5. **2**, **4**, NSM PA16342, thin sections. **2**, transverse section of branch, ×5. **4**, partial enlargement to show intercorallite wall structure, longitudinal section, ×75. **3**, NSM PA16343, transverse thin section of branch, ×5. **5**, UMUT PC7301, transverse thin section of branch, ×5. **6**, UMUT PC7305, longitudinal to oblique weathered sections of branches, ×1.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and in p. 53 in ditto a new species, *Favosites hidensis*, on the basis of the holotype (GISUL 30119), paratype (GISUL 30120) and two specimens (GISUL 30121, 30122) from greenish gray tuffaceous sandstone. Results of reexamination of the Kamei's original specimens by Niko (2006b) were as follows; 1) the both forms can be assignable to the genus *Squameopora* and 2) the differences between the forms are minor and only dimensional concerning corallite diameters. The present observations on 123 thin sections of newly collected specimens from the type stratum confirm that *Squameopora takarensis* and *S. hidensis* represent the ecophenotipic variations of a single species. Thus, I place *S. hidensis* in a junior subjective synonym of *S. takarensis* because of the latter species has a priority.

Subfamily Emmonsiinae Lecompte, 1952

Genus ***Squameofavosites*** Chernyshev, 1941

Type species: *Favosites hemisphericus bohemica* Počta, 1902; renamed *Squameofavosites cechicus* Galle, 1978.

Squameofavosites fukujensis (Kamei, 1955)

(Figs. 9-1–5)

Squameofavosites fukujensis (Kamei); Niko, 2006b, p. 22, 24, figs. 5-5–7 [with earlier synonymy].

Squameofavosites fukujiensis [sic] (Kamei); Kato *et al.*, *in* Minato *et al.*, 1979, p. 64, pl. 10, figs. 1, 2.

Material examined: Seven specimens, HMM 03083; NSM PA16355–16360.

Emended diagnosis: Thickness of intercorallite walls 0.06–0.11 mm; squamulae short with 0.21–0.25 mm in length, thin. See Niko (2006b) for other diagnostic features.

Description: Morphologies of coralla, corallites, mural pores, and tabulae are referable in Niko (2006b). Intercorallite walls thin, differentiated into median dark line and stereoplasm of very fine rect-radiate fibers; thickness of intercorallite walls ranges from 0.06 to 0.11 mm; squamulae short and thin, their dimensions are as follows, 0.21–0.25 mm in length, 0.06–0.12 mm in thickness of their bases, and 0.13–0.19 mm width of their bases.

Occurrence: The examined specimens were collected from the float blocks of black limestone of bioclastic wackestone (NSM PA16355, 16358, 16359) and peloidal wackestone (NSM PA16356) near locality FH-6, the float blocks of argillaceous limestone in the Ichinotani Valley (NSM PA16357, 16360), a float block of argillaceous limestone in the Osobudani Valley (HMM 03083). This species occurs in the Takaharagawa Member.

Discussion: The holotype (GISUL 30126) of *Parafavosites fukujensis* Kamei, 1955 was re-described by Niko (2006b) as *Squameofavosites fukujensis*. Subsequently, 58 thin sections of newly obtained specimens from the type stratum of this species permit refinement of the specific concept, concerning respects to intercorallite wall and detailed squamulae natures. These new findings are documented herein.

Separating characters of *Squameofavosites fukujensis* from *S. ichinotanensis* and *S. sugiyamai* are given in the discussions of the latter two species.

Squameofavosites ichinotanensis (Kamei, 1955)

(Figs. 10-1–5)

Favosites ichinotanensis Kamei; Niko, 2006b, p. 14, figs. 1-4–7 [with earlier synonymy].

Material examined: Seven specimens, HMM 03172; NSM PA16361–16366.

Emended diagnosis: Species of *Squameofavosites* with large corallite diameters having approximately 3.0 mm in adult corallites; intercorallite walls 0.09–0.15 mm in thickness; mural pores occur on corallite faces; development of squamulae varies from rare or absent to well-developed; squamulae relatively long with 0.37–0.54 mm in length, thin.

Description: Except for microstructure of stereoplasm and morphology of squamulae, all other features are referable in Niko (2006b). Stereoplasm of intercorallite walls consists of very fine rect-radiate fibers. Development of

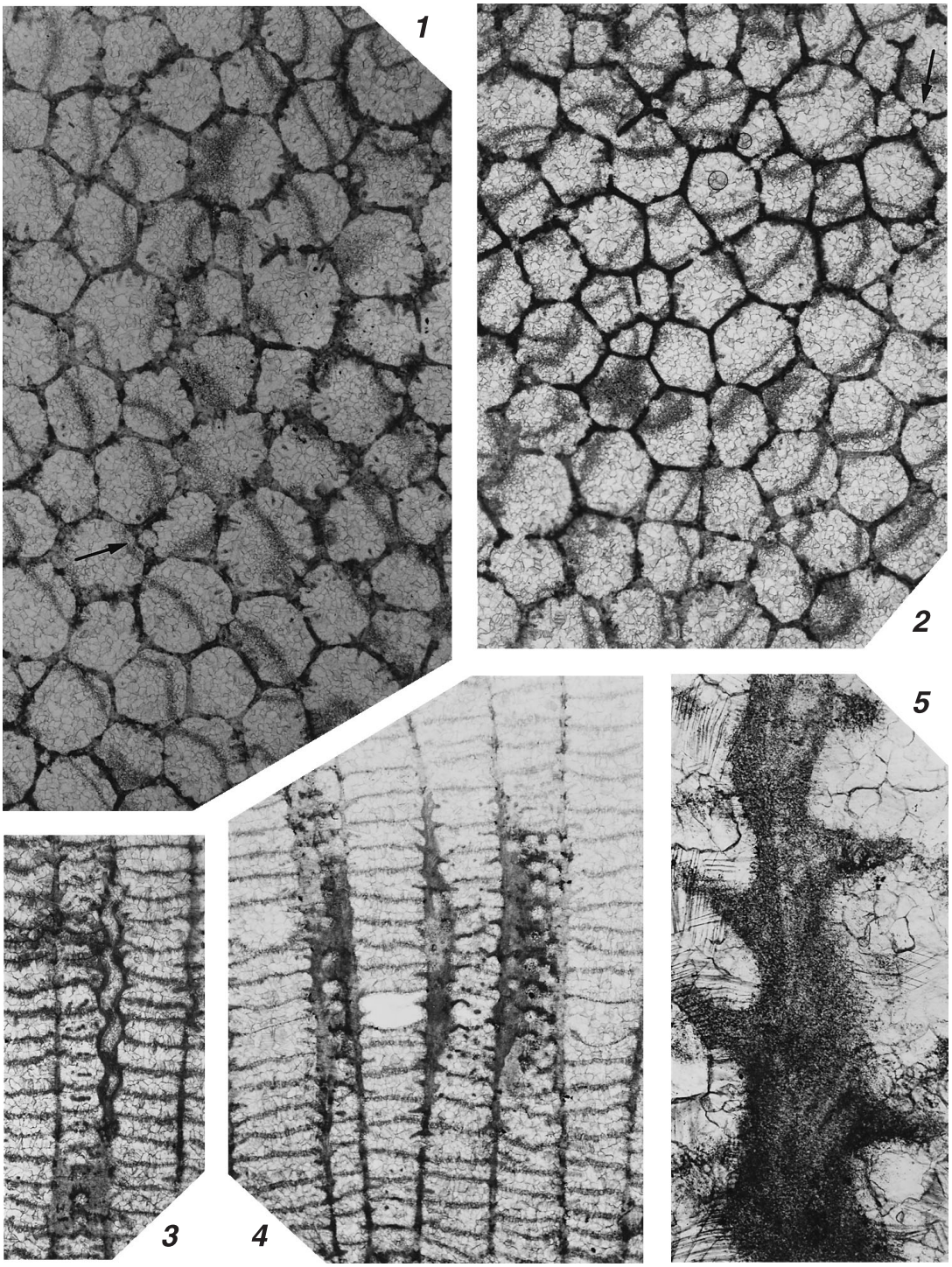


Fig. 9. *Squameofavosites fukujensis* (Kamei, 1955), NSM PA16357, thin sections. **1**, **2**, transverse sections of corallites, arrows indicate commensal worm tubes (*Helicosalpinx*), ×10. **3**, **4**, longitudinal sections of corallites, note commensal worm tube (Fig. 9-3), ×10. **5**, partial enlargement to show intercorallite wall and squamula structure, longitudinal section, ×75.

squamulae varies from rare or absent to well-developed even in a corallum; squamulae relatively long and thin, their dimensions are as follows, 0.37–0.54 mm in length, 0.19–0.23 mm in thickness of their bases, and commonly 0.25–0.31 mm in width of their bases.

Occurrence: The examined specimens were collected from an outcrop of calcareous shale at locality FH-1 (NSM PA16361, 16362), the float blocks of argillaceous limestone (HMM 03172) and black limestone of bioclastic wackestone (NSM PA16365) near locality FH-6, and the float blocks of argillaceous limestone (NSM PA16363) and black limestone of peloidal wackestone (NSM PA16364) and bioclastic wackestone (NSM PA16366) in the Ichinotani Valley. This species occurs in the Takaharagawa Member.

Discussion: This species was originally described as *Favosites ichinotanensis* by Kamei (1955). When the author reexamined the species, the holotype (GISUL 30112) is missing and a single thin section of the paratype (GISUL 30113) is an only available type specimen. Owing to this insufficiency in material, Niko (2006b, p. 14) inadequately wrote that "septal spines irregularly distributed, vary from nearly absent to abundant, thin rod-like, attaining 0.15 mm in length". Twenty-six thin sections of newly collected specimens reveal that apparent septal spine is not recognized in the species and its relatively long and thin squamula indicates "thin rod-like" appearance in section. The generic assignment of the species changes from *Favosites* to *Squameofavosites* herein.

Squameofavosites ichinotanensis is distinguished from *S. fukujensis* by its larger diameter of the adult corallites (approximately 3.0 mm versus approximately 2.1 mm in *S. fukujensis*) and longer squamulae (0.37–0.54 mm versus 0.21–0.25 mm in *S. fukujensis*). In addition, angle pore and tube of commensal worm are not recognized in the present species. Separating characters of *S. ichinotanensis* from *S. sugiyamai* are given in the discussion of the latter species.

Squameofavosites sugiyamai (Kamei, 1955)

(Figs. 11-1–4)

Squameofavosites sugiyamai (Kamei); Niko, 2006b, p. 24, 26, figs. 5-4; 6-1–4 [with earlier synonymy].

Squameofavosites sp. indet; Niko, 2006b, p. 26, 28, figs. 5-1, 2; 6-5, 6 [with earlier synonymy].

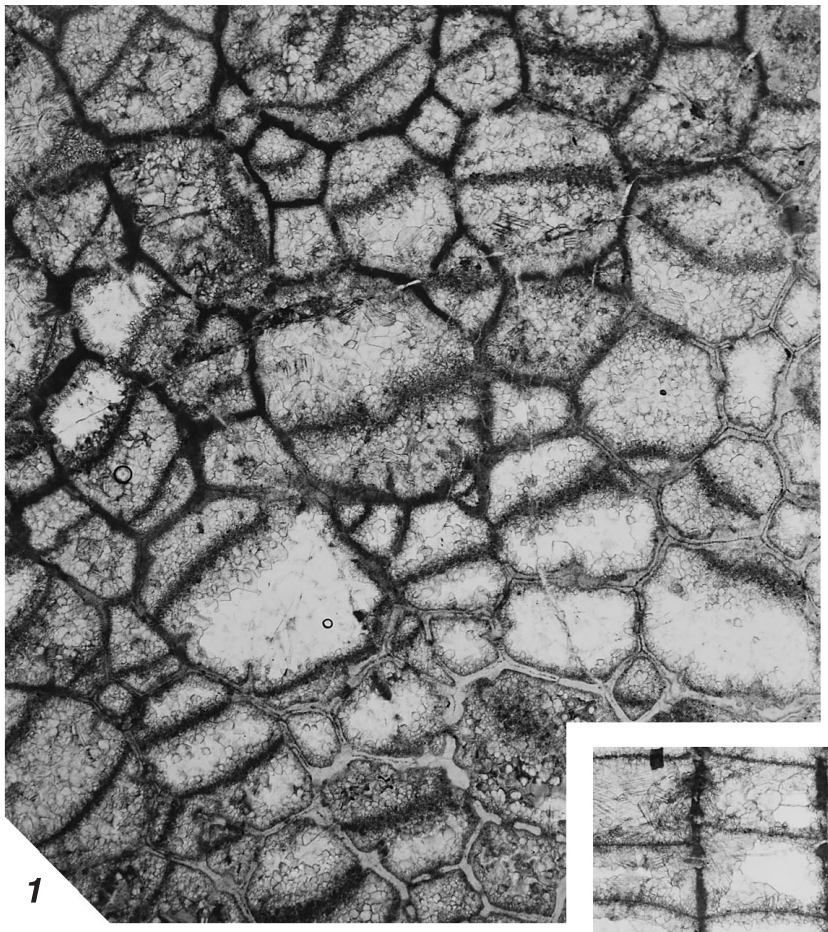
Material examined: Eleven specimens, NSM PA16367–16376; UMUT PC5708 (same specimen with pl. 21, fig. 4 in Masutomi and Hamada, 1966).

Emended diagnosis: Intercorallite walls usually thickened attaining 0.29 mm; squamulae relatively short, 0.25–0.36 mm in length; development of squamulae varies from nearly absent to well-developed. See Niko (2006b) for other diagnostic features.

Description: Morphology of coralla, corallites, mural pores and tabulae are referable in Niko (2006b). Structure of intercorallite walls is median dark line and stereoplasm of very fine rect-radiate fibers; intercorallite walls usually thickened, attaining 0.29 mm, where squamulae well-developed and frequently contiguous, but thin (0.07–0.10 mm) walled portions, almost lacking squamulae, are commonly developed; dimensions of squamulae are as follows, 0.25–0.36 mm in length; 0.15–0.27 mm in thickness of their bases, and 0.21–0.33 mm in width of their bases; adhesion of adjoining 2 or rarely 3 squamulae is commonly developed.

Occurrence: The examined specimens were collected from an outcrop of argillaceous limestone (NSM PA16367, 16369, 16371, 16373, 16374) and dark gray limestone of bioclastic grainstone (NSM PA16370) at locality FH-7, an outcrop of sandy limestone (NSM PA16368) at

Fig. 10. *Squameofavosites ichinotanensis* (Kamei, 1955), NSM PA16363, thin sections. **1**, transverse sections of corallites, ×10. **2**, longitudinal to oblique sections of corallites, ×10. **3**, partial enlargement to show intercorallite wall structure, longitudinal section, ×75. **4**, longitudinal sections of corallites, ×10. **5**, oblique sections of corallites, note well-developed squamulae, ×10.



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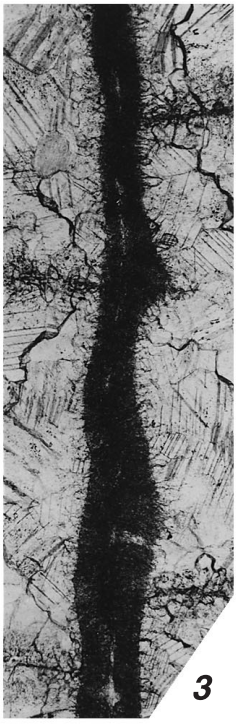

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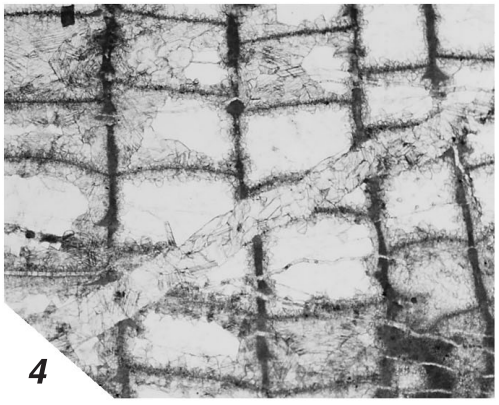

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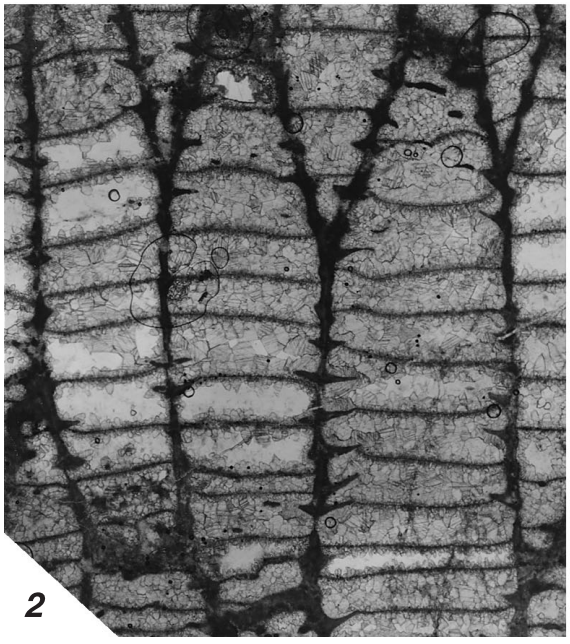

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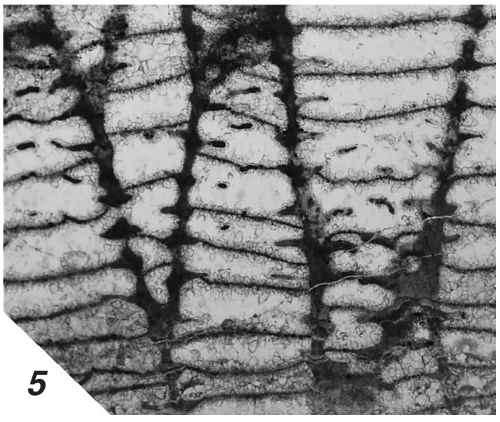

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locality FH-11, and the float blocks of argillaceous limestone (NSM PA16372) and black limestone of bioclastic to peloidal wackestone (NSM PA16375, 16376) at the Ichinotani Valley. A specimen kept in University Museum of the University of Tokyo (UMUT PC5708) was collected by Dr. Takashi Hamada, of which lithofacies are quite identical with those of locality FH-7. This species occurs in the Takaharagawa Member.

Discussion: Examination of 29 thin sections of newly collected specimens confirms the author's prediction that "the examined specimen (=*Squameofavosites* sp. indet.) represents an intraspecific variation of *Squameofavosites sugiyamai*" (Niko, 2006b). This species was originally described as *Favosites forbesi sugiyamai* Kamei, 1955 or incorrectly referred to a Silurian species *Favosites baculoides* Barrande by Kamei (1955).

Squameofavosites sugiyamai is dissimilar to *S. fukujensis* as its thickened intercorallite walls (attaining 0.29 mm versus 0.06–0.11 mm in *S. fukujensis*), and robust and somewhat longer squamulae (0.25–0.36 mm versus 0.21–0.25 mm in *S. fukujensis*). The absence of tube of commensal worm in *S. sugiyamai* may be a diagnostic feature. This species is also unlike *S. ichinotanensis*. *Squameofavosites sugiyamai* has smaller diameter of the adult corallites (approximately 2.3 mm versus approximately 3.0 mm in *S. ichinotanensis*), the thickened intercorallite walls (0.09–0.15 mm in *S. ichinotanensis*), and robust and shorter squamulae (0.37–0.54 mm in *S. ichinotanensis*).

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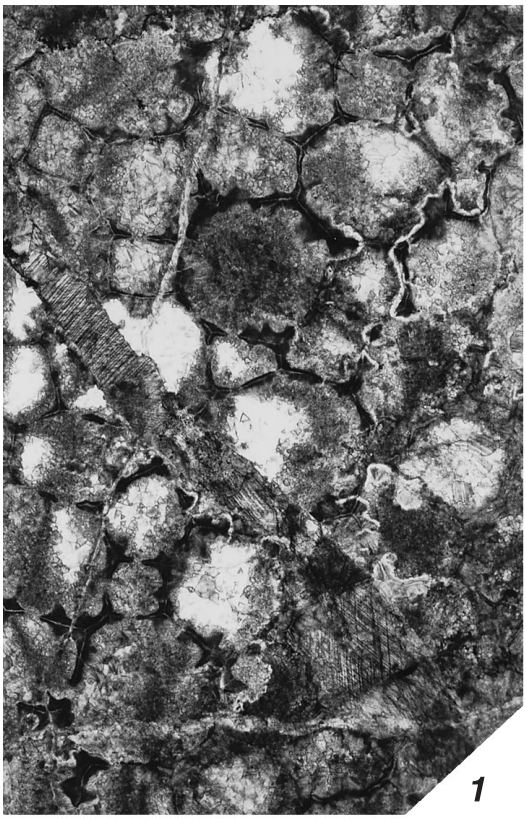
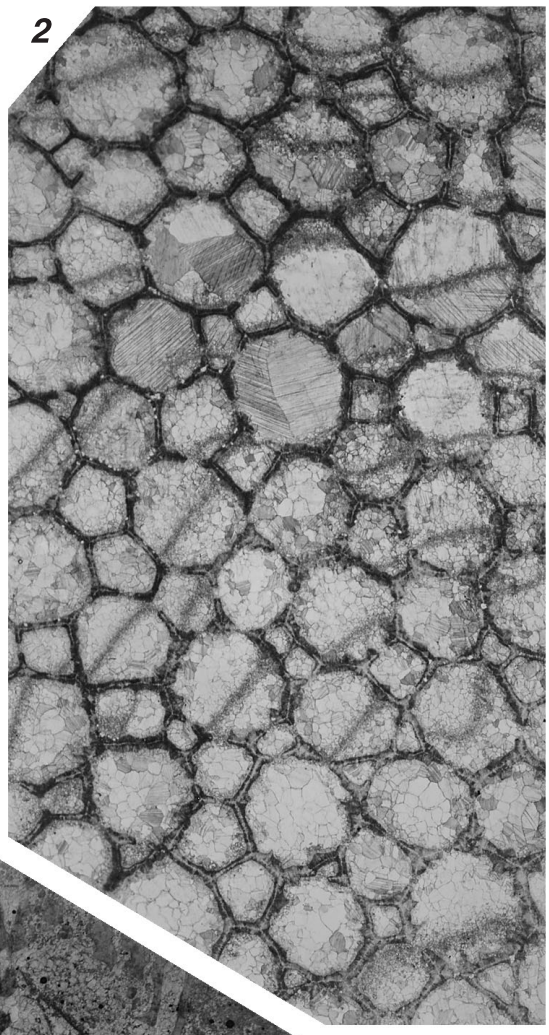
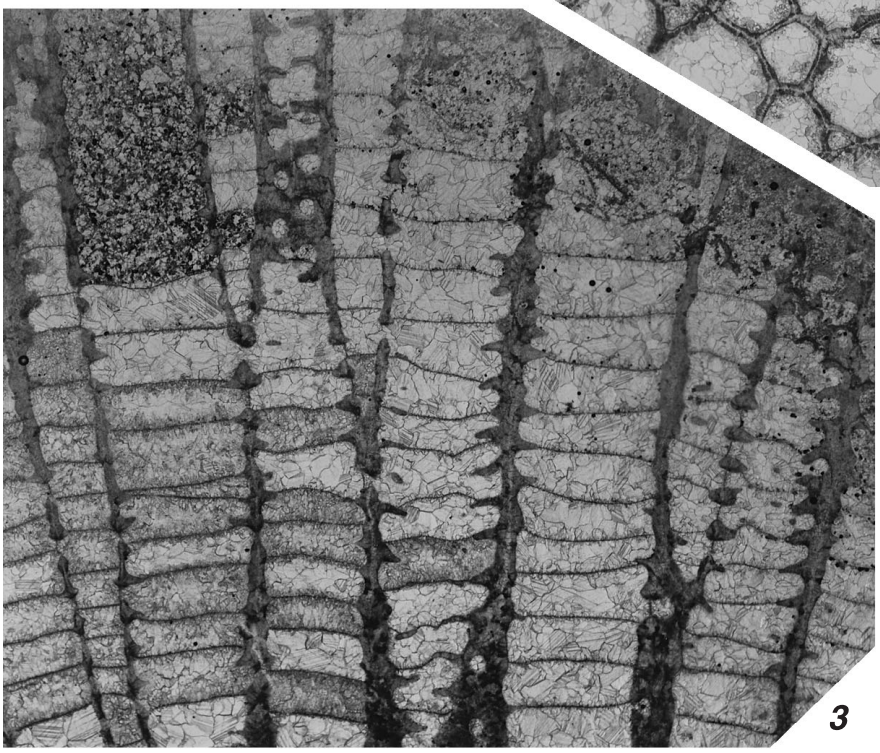
Fig. 11. *Squameofavosites sugiyamai* (Kamei, 1955), thin sections. **1**, NSM PA16374, transverse sections of corallites, note well-developed squamulae, ×10. **2**, NSM PA16371, transverse sections of corallites, ×10. **3**, **4**, NSM PA16367. **3**, longitudinal sections of corallites, ×10. **4**, partial enlargement to show intercorallite wall structure, longitudinal section, ×75.







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