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Devonian Auloporid Tabulate Corals from the Kamianama Formation, Fukui Prefecture

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Abstract Although the Early Devonian Kamianama Formation in the Kuzuryu Lake — Ise River area of Fukui Prefecture has long been known for its diverse and abundant corals, besides rare exceptions preceding studies were not referring to taxonomic positions of these coral species. As the first account in a series documenting the Kamianama tabulate coral fauna, this study focuses on auloporids. Two previously described species, *Aulopora sorayamaensis* Niko, 2001b and *Romingeria cristata* Niko, 2001b, are considered, and two new species of syringoporoids, *Multithecopora kamianamaensis* and *Syringoporella fujiwarai*, are found in the fauna. They have corresponding species in the Fukuji Formation, Gifu Prefecture.

Key words : Early Devonian, tabulate corals, *Aulopora*, *Romingeria*, *Multithecopora*, *Syringoporella*, Kamianama Formation, Fukui.

Introduction

The Kamianama Formation is the Devonian shallow marine deposits in the Kuzuryu Lake — Ise River area of Ono-shi, Fukui Prefecture, Central Japan (see inset of Fig. 1). The first appearance of this formation name in the valid articles was probably Fujimoto (1953), who used the "Kamianama Group" for the "Gotlandian" rocks taking the form of introduction of Hayasaka, Ozaki, Kamei, Matsuo, Kubota and Kato's unpublished works. A substantial and original definition of the formation was given by Kawai (1956). Subsequently, Kurihara (2003) provided the most thorough study of the Middle Palaeozoic rocks in this area. He divided clastic facies of these rocks into the Lower Silurian Kagero and Upper Silurian to Lower Devonian Shibasudani Formations, and redefined resting carbonate facies as the Kamianama Formation. According to this recent definition, black to dark gray limestone, being composed mainly of wackestone and packstone, is predominant in the formation and in which thin beds of calcareous shale, felsic tuff and sandstone are occasionally intercalated. Because of the Kamianama fauna bears a close resemblance to that of the Fukuji Formation, Gifu Prefecture (Okazaki *et al.*, 1974; Kobayashi and Hamada, 1977; Kamiya and Niko, 1997), its age denotes the Lochkovian (to Emsian?) in Early Devonian time.

Since the first discovery of favositids and heliolitid by Ishioka and Kamei (1950), the Kamianama Formation has long been known for its richly diverse and abundant corals that are documented in Kamei (1955, 1962), Ozaki (1955a, 1955b, 1956a, 1956b, 1956c, 1957), Kawai (1956), Kawai *et al.* (1957), Maeda (1958), Hamada (1959, 1961), Masutomi and Hamada (1966), Yamada (1966, 1967), Ono Earth Science Research Society (1977), Kato (1978), Kato *et al.* (1980), Metal Mining Agency of Japan (1980), Oyagi (2003), Kurihara (2003) and Hirata (2006). Except for Ozaki (1957) concerning

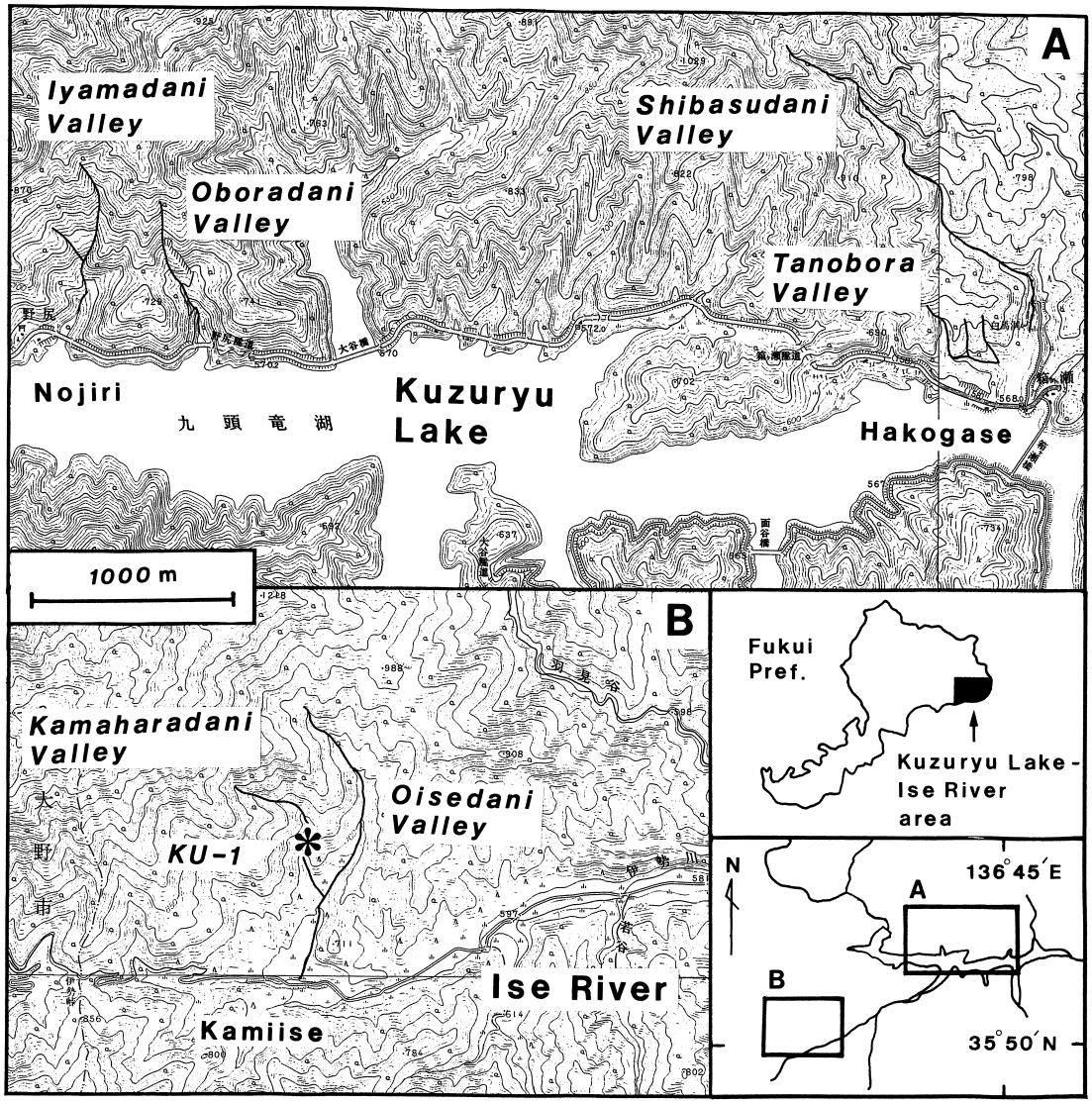


Fig. 1. Index map showing coral localities in the Kuzuryu Lake area (A) and the upper Ise River area (B). Used base maps are "Echizenasahi", "Shiratori" and "Heikedake" of 1:25,000 quadrangles published by Geographical Survey Institution.

"*Oborophyllum oboroensis*" and Hamada (1959) concerning *Squameopora hidensis*, however, they have no profound consideration for taxonomic position of each specimen. Thus, comprehensive faunal treatment is not still available. This descriptive study represents the first part of a research program whose objective is to reveal the whole aspect of the Kamianama tabulate coral fauna. All coral specimens dealt with in this study are kept in the National Science Museum (abbreviation NSM). Geographic positions of localities are given in Fig. 1.

Systematic Paleontology

Order Auloporida Sokolov, 1974

Superfamily Auloporoidea Milne-Edwards and Haime, 1851

Family Auloporidae Milne-Edwards and Haime, 1851

Genus ***Aulopora*** Goldfuss, 1829

Type species: *Aulopora serpens* Goldfuss, 1829.

Aulopora sorayamaensis Niko, 2001b
(Figs. 2-1–3)

Aulopora sorayamaensis Niko, 2001b, p. 74, 76, 77, figs. 1-1–7; 2-1–4 [with earlier synonymy]; Hirata, 2006, p. 28, pl. 8, fig. 28.

Material examined: Two coralla, NSM PA15780, 15781.

Occurrence: Float block of argillaceous limestone at the Kamaharadani Valley (NSM PA15780). Calcareous shale at locality KU-1 (NSM PA15781). Substrata of each specimen are as follows: unidentified lamellar organism (NSM PA15780) and cephalopod (NSM PA15781).

Remarks: *Aulopora sorayamaensis* is an encrusting coral with the anastomosed corallites, and is known from the Lochkovian calcareous shale of the Fukuji Formation. Although the external morphology of the present material is not observable, the Kamianama specimens agree well with the types in their internal structure and dimensions. The diagnostic features of this characteristic species have been minutely documented by Niko (2001b), and need not be discussed again.

Family Romingeriidae Sokolov, 1950

Genus ***Romingeria*** Nicholson, 1879

Type species: *Aulopora umbellifera* Billings, 1859.

Romingeria cristata Niko, 2001b
(Figs. 2-4–6)

Romingeria cristata Niko, 2001b, p. 79, 81, 82, figs. 4-1–9 [with earlier synonymy]; Hirata, 2006, p. 30, pl. 9, fig. 30.

Material examined: Four coralla, NSM PA15782–315785.

Occurrence: Float blocks of black limestone (bioclastic to peloidal wackestone) at the Kamaharadani Valley (NSM PA15782–15784) and argillaceous limestone at the Oboradani Valley (NSM PA15785).

Emended diagnosis: This species has 3–13 offsets in each budding point. See Niko (2001b, p. 79, 81) for other diagnostic features.

Discussion: *Romingeria cristata* was first described from the Early Devonian (Siegenian to Emsian?) limestone of the Fukuji Formation. This species is the most abundant auloporid coral in the Kamianama Formation. The plentiful material provides confirmation of offset number at the budding points, whose pervious numeral volume indicate "3–8+". As shown in Fig. 2-4, a branch of a well-preserved specimen (NSM PA15783) has the 13 offsets. This number probably denotes the upper limit of the offsets, and is added in the specific diagnosis.

Superfamily Syringoporoidea Fromentel, 1861

Family Multithecoporidae Sokolov, 1950

Genus ***Multithecopora*** Yoh, 1927

Type species: *Multithecopora penchiensis* Yoh, 1927.

Multithecopora kamianamaensis sp. nov.
(Figs. 2-9; 3-1–6)

Multithecopora? sp. A, Hirata, 2006, p. 30, pl. 9, fig. 30.

Holotype: NSM PA15788, from which 18 thin sections were made.

Other specimens: Fifteen thin sections were studied from the five paratypes, NSM PA15786, 15787, 15790, 15792, 15794. In addition, five specimens, NSM PA15789, 15791, 15793, 15795, 15796, were also examined.

Diagnosis: Species of *Multithecopora* having up to 110 mm in corallum diameter; corallite diameters small, approximately 1.0 mm in adult ones; connecting tubuli long attaining 2.18 mm and relatively thick attaining 0.69 mm, mostly oblique and weakly sinuate; corallite walls 0.21–0.46 mm in usual thickness; septal spines sporadic; tabulae very rare, complete.

Description: Coralla moderate in size, low domical to somewhat irregular shaped, mostly phaceloid, but partial adhesion of corallites very rarely presents; largest corallum (holotype) has approximately 110 mm in diameter and 45 mm in height; this species always occurs inside stromatoporoids. Corallites prostrate with semicircular transverse sections in basal portion of corallum, then they turn upward in growth direction and cylindrical with mostly circular transverse sections; adherent corallites have contact depression(s); arrangement of adult corallites is roughly narrow radial to nearly parallel; corallite diameters are small, 0.61–1.36 mm, with 1.0 mm mean in adult ones; spacing of corallites looks wide owing to its small corallite diameters, usually 1.8–3.8 mm in center to center distance between adjoining corallites; increases of new corallites lateral, bifurcate, occur in basal portion of corallum; calical rims faintly inflate with deep calical pits; connecting tubuli rare, long, 0.73–2.18 mm in length, and relatively thick, 0.42–0.69 mm in diameter, mostly oblique to orientation of corallites, and weakly sinuate; there is a tendency that connecting tubuli occur at same levels. Corallite walls composed of thin epitheca and thickened stereoplasm, variable in thickness ranging 0.04–0.59 mm, usually 0.21–0.46 mm; microstructure of stereoplasm is lamellar; transverse sections of tabularia are subcircular to circular, strongly narrowed in some corallites by stereoplasmic wall thickening; approximate ratios of tabularium diameter per corallite diameter are 0.1–0.7; septal spines sporadic, completely or mostly enclosed in stereoplasm; tabulae vary rare, complete; those profiles are weakly sagging (concave proximally) to nearly flat in usual tabulae, weakly uparched (concave distally) in rare cases, or very rarely oblique.

Etymology: The specific name is derived from the type stratum named the Kamianama Formation.

Occurrence: Float blocks of black to gray limestone (peloidal to bioclastic wackestone, NSM PA15786–15788, 15792, 15795; stromatoporoidal packstone NSM PA15789–15791, 15793, 15796; peloidal to bioclastic packstone to grainstone, NSM PA15794). Localities of each specimen are as follows: the Kamaharadani Valley (NSM PA15786–15788), the Oboradani Valley (NSM PA15789–15793), the Tanobora Valley (NSM PA15794), the Iyamadani Valley (NSM PA15795), and the Shibasudani Valley (NSM PA15796).

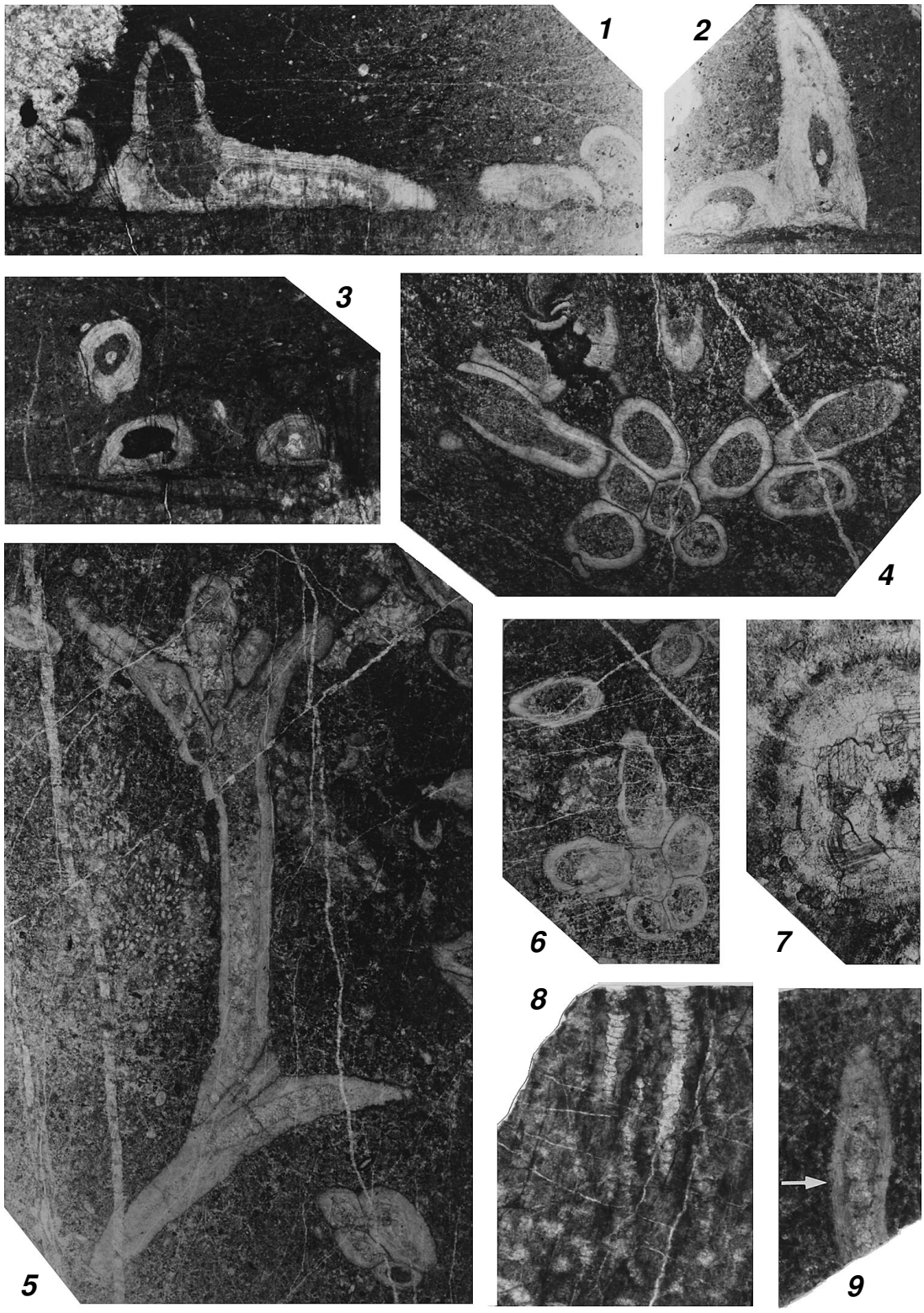
Discussion: Middle Palaeozoic records of *Multithecopora* are limited. The only species, *M*.? sp. indet. in Niko (2001b, p. 86, figs. 6–3, 4) from the Early Devonian (Siegenian to Emsian?) limestone of the Fukuji Formation, is comparable with *M. kamianamaensis* sp. nov. Both of these species have similarities in spacing of the corallites, corallite diameters and thickness of the corallite walls. The main difference exists in mode of occurrence of the tabulae, namely those of the new species are much fewer than the Fukuji specimens. A specimen assigned to *M*.? sp. A from the Kamianama Formation in Hirata (2006) is probably conspecific with the new species.

Genus ***Syringoporella*** Kettner, 1934

Type species: *Syrongopora moravica* Roemer, 1883.

Syringoporella fujiwarai sp. nov.
(Figs. 2-7, 8; 4-1–6)

Fig. 2. **1**–**3**, *Aulopora sorayamaensis* Niko, 2001b, NSM PA15780, thin sections. **1**, longitudinal, transverse and oblique sections of corallites, ×10. **2**, transverse and oblique sections of corallites, ×10. **3**, transverse sections of corallites, ×10. **4**–**6**, *Romingeria cristata* Niko, 2001b, thin sections. **4**, NSM PA15783, transverse section of branch, ×10. **5**, **6**, NSM PA15782, longitudinal and transverse sections of branches, ×10. **7**, **8**, *Syringoporella fujiwarai* sp. nov., thin sections. **7**, paratype, NSM PA15800, partial enlargement of transverse section of corallite to show corallite wall structure, ×75. **8**, holotype, NSM PA15798, longitudinal sections of corallites, note crowded septal spines, ×14. **9**, *Multithecopora kamianamaensis* sp. nov., holotype, NSM PA15788, thin longitudinal to slightly oblique section of corallite, arrow indicates tabula, ×10.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Holotype: NSM PA15798, from which 12 thin sections were made.

Other specimens: Forty-eight thin sections were studied from the five paratypes, NSM PA15797, 15799–15802.

Diagnosis: Species of *Syringoporella* with very narrow corallites of approximately 0.58 mm in diameter of adult ones; spacing of corallites mostly wide; increases of new corallites from stolons commonly occur; probable connecting processes vary rarely recognized; corallite walls attain 0.23 mm in thickness; septal spines mostly absent, but crowded in part; tabulae complete, well developed.

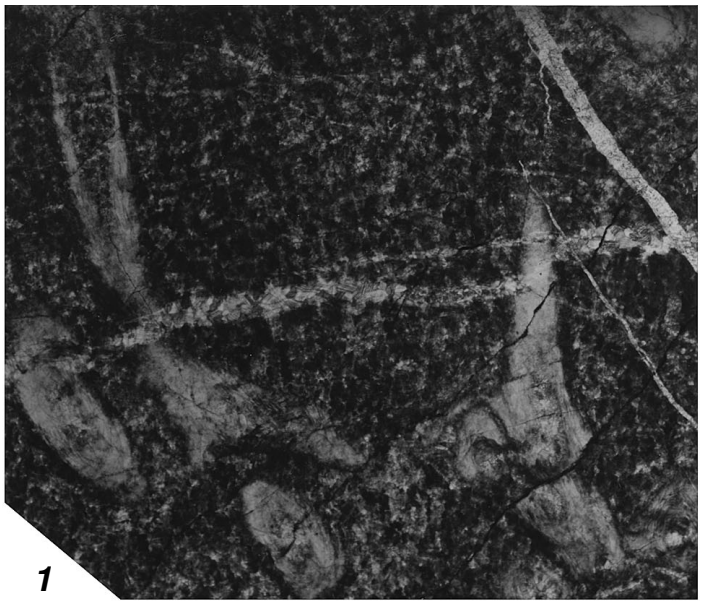
Description: Coralla thick tabular, phaceloid; largest corallum (paratype, NSM PA15802) attains approximately 150 mm in diameter and 31 mm in height; this species always occurs inside stromatoporoids. Corallites very narrow cylindrical with circular transverse sections, parallel in arrangement; corallite diameters range from 0.27 to 0.67 mm, with 0.58 mm mean in adult ones; spacing of corallites is mostly wide with 1.6–2.4 mm in center to center distance between adjoining corallites, but closely adjoining corallites with 0.8 mm in ditto distance rarely developed; calical rims weakly inflated, with usually shallow calical pits; tabularia circular in transverse section, partly narrowed by corallite wall thickening; increases of new corallites lateral; branching common; each offset consists of proximal portion indicating upward coverture with sudden inflation, and elect cylindrical portion; increases from stolons also common; diameters of stolon are 0.19–0.33 mm; at least two offsets arise from a single stolon; no well-oriented connecting tubuli detected; an only instance of probable connecting process (but not through its central axis) of approximately 0.15 mm in length occurs between closely adjoining two corallites. Corallite walls consist of relatively thick epitheca and stereoplasm, the latter of which commonly thickened, ranging 0.05–0.23 mm in corallite wall thickness; microstructure of stereoplasm not well preserved; development of septal spines variable even in the same corallum; they are mostly absent, but crowded in part, where septal spines attain 0.07 mm in length of protruded portion into tabularium and corallite wall thickness has approximately 0.19 mm; there is no apparent difference in corallite diameters between septate and non-septate portions; tabulae complete, well developed for the genus, indicate variable spacing; most usual tabulae weakly sagging, but nearly flat, weakly uparched, and oblique ones commonly developed; there are 0–11 tabulae in 1 mm of corallite length.

Etymology: The specific name honors Mr. Kozo Fujiwara, who was the first to collect this species.

Occurrence: Float blocks of black to dark gray limestone (peloidal to bioclastic wackestone) at the Kamaharadani Valley (NSM PA15797, 15799), at the Oisedani Valley (NSM PA15798, 15800), and at the Oboradani Valley (NSM PA15801, 15802).

Discussion: The septal spines of *Syringoporella fujiwarai* sp. nov. are not omnipresent. Its main corallites lacking the septal spines resemble *S. paramoravica* Yang *in* Yang *et al.*, (1978, p. 217, pl. 81, figs. 1a, b) and partial corallites bearing the crowded septal spines are comparable with *S. spinosa* Yang *in* Yang *et al.*, (1978, p. 217, pl. 81, figs. 2a, b). The both Chinese species are known from the same locality and stratigraphic horizon in the Middle Devonian of Guizhou. Besides their synonymy, the distinctive respects are as follows: in the former portions, *S. fujiwarai* differs by its thicker corallite walls (attaining 0.23 mm verses 0.04–0.11 mm in *S. paramoravica*), and in the latter portions, the new species differs by its somewhat smaller corallite diameters (approximately 0.58 mm versus usually 0.6–0.75 mm in *S. spinosa*).

Fig. 3. *Multithecopora kamianamaensis* sp. nov., thin sections. **1**–**3**, **5**, **6**, holotype, NSM PA15788. **1**, **2**, longitudinal and oblique sections of corallites, ×10. **3**, **5**, oblique and transverse sections of corallites, note connecting tubuli, ×14. **6**, partial enlargement of longitudinal section of corallite to show corallite wall structure, ×75. **4**, paratype, NSM PA15787, transverse sections of corallites, ×10.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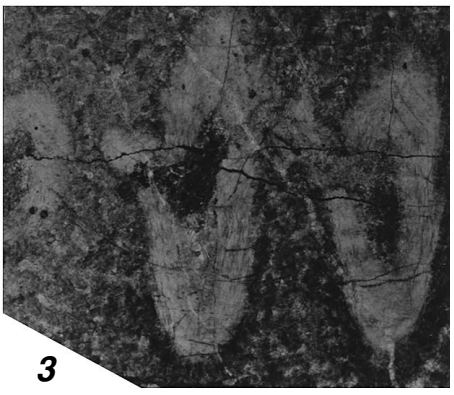
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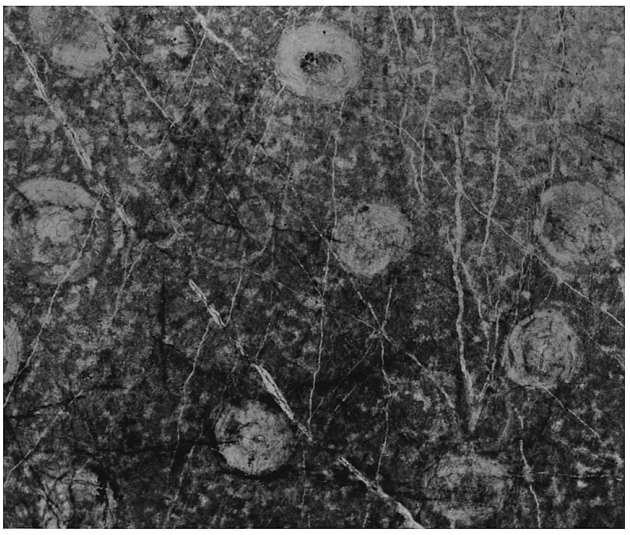
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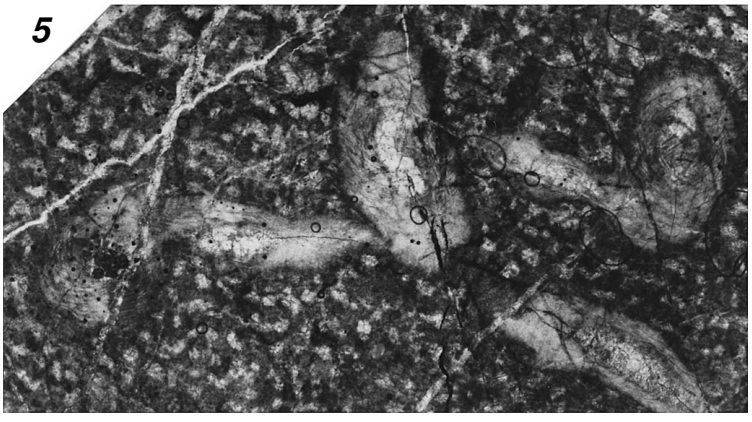
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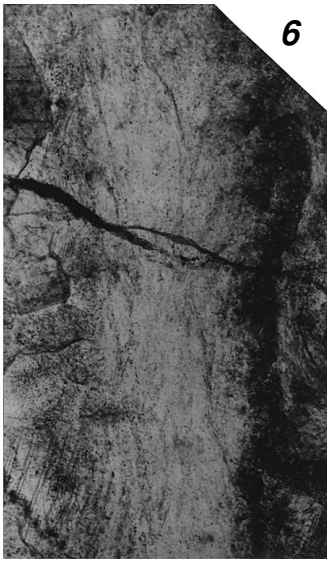
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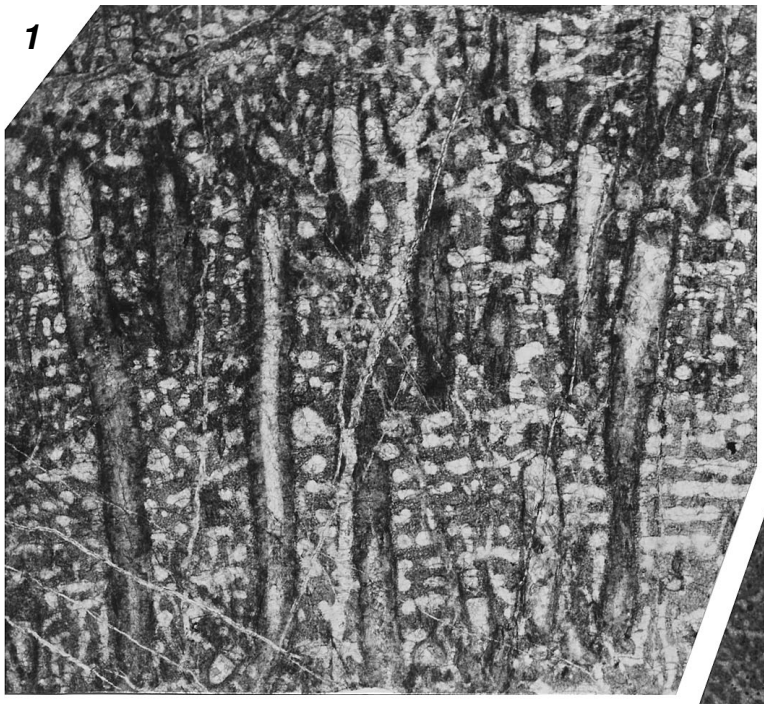
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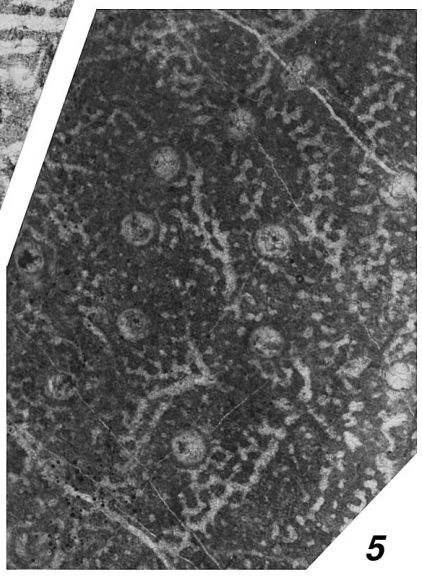
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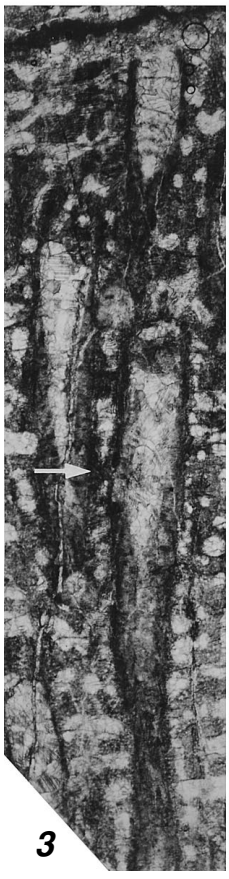
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Syringoporella yamakoshii Niko (2001a, p. 68, 70, figs. 1-1–4) from the Upper Silurian Hitoegane Formation, Gifu Prefecture and an Early Devonian (Emsian?) species *S.* sp. indet. (Niko, 2001b, p. 87, figs. 6–1, 2) from the Fukuji Formation indicate much thinner corallite walls (0.04–0.08 mm in *S. yamakoshii*; approximately 0.04 mm in *S.* sp. indet.) than those of *S. fujiwarai*.

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Fig. 4. *Syringoporella fujiwarai* sp. nov., thin sections. **1**–**4**, **6**, holotype, NSM PA15798. **1**, longitudinal and oblique sections of corallites, ×10. **2**, longitudinal and oblique sections of offsets, and longitudinal section of stolon, ×14. **3**, partial enlargement of longitudinal sections of corallites, arrow indicates probable connecting process, ×14. **4**, partial enlargement of longitudinal sections of corallites to show branching and calical pit, ×14. **6**, partial enlargement of longitudinal section of corallite to show corallite wall structure, ×75. **5**, paratype, NSM PA15800, transverse sections of corallites, ×10.

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