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Devonian Auloporid Tabulate Corals from the Fukuji Formation, Gifu Prefecture

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Abstract Abundant and well-preserved tabulate corals of Lochkovian to Emsian (Early Devonian) age were recovered from the Fukuji Formation at the Fukuji area, Gifu Prefecture. Among them, six auloporid species are described herein: *Aulopora sorayamaensis* sp. nov., *A.*? sp. indet., *Romingeria cristata* sp. nov., *Kanashiropora kozui* gen. et sp. nov., *Multithecopora*? sp. indet., and *Syringoporella* sp. indet. *Kanashiropora* is proposed for a palaeofavosiporid as the second representative of the family, which was previously restricted in Wenlock (Early Silurian) of Baltica. This new genus and another genus *Palaeofavosipora* are distinguishable in that the septal spine may be absent, tabulae are fewer and the most mural pores situate on mid-faces of the corallites in *Kanashiropora*. Closely related forms with the Fukuji fauna were reported from the Hitoegane Formation, Gifu Prefecture in Japan, and Germany, Baltica and Laurentia.

Key words: Early Devonian, tabulate corals, *Aulopora*, *Romingeria*, *Kanashiropora* gen. nov., *Multithecopora*, *Syringoporella*, Fukuji Formation, Gifu.

Introduction

All auloporid corals described herein came from the Lower Devonian Fukuji Formation (Kamei, 1952), which crops out in the Fukuji area of Gifu Prefecture, Cental Japan as a mixed sequence of carbonate and clastic sediments (see Niikawa, 1980; Harayama, 1990, for geologic setting), and ranges in age from Lochkovian to Emsian (Kuwano, 1987). Since Kouz (1911) found "favosite" coral at this area, a fairly large number of documentation have been made concerning the Fukuji coral fauna. Although its renown for a representative Devonian coral locality resulted from these reports, the majority of the previous works were not accompanied by descriptions and/or adequate illustrations. This makes difficult later taxonomic assignment and paleobiogeographic evaluation of the fauna. The present study will be the first part of a series of publications dealing with abundant and well-preserved tabulate corals of the Fukuji Formation. This account reveals the auloporid fauna that consists of *Aulopora sorayamaensis* sp. nov., *A.*? sp. indet., *Romingeria cristata* sp. nov.,

Kanashiropora kozui gen. et sp. nov., *Multithecopora*? sp. indet., and *Syringoporella* sp. indet.

The detailed fossil localities in the Fukuji area are following: locality FH-1 (latitude 36° 13′ 14″ N, longitude 137° 31′ 53″ E) on the southern flank of the Ozako Valley, locality FH-4 (latitude 36° 13′ 11″ N, longitude 137° 31′ 49″ E) on the eastern slope of Mt. Sora-yama, and locality FH-6 (latitude 36° 12′ 55″ N and longitude 137° 31′ 20″ E) on the northern flank of the Kanashirozako Valley. The talus deposits on the eastern slope of Mt. Sora-yama near locality FH-4, and in the Kanashirozako Valley near locality FH-6 also contain Devonian corals. Specimens collected in the course of this study are deposited in the National Science Museum (prefix NSM), Tokyo with the exception of a specimen of *Aulopora*? sp. indet. and the holotype of *Romingeria cristata*, which have been kept in the Hikaru Memorial Museum (prefix HMM), Takayama.

Systematic Paleontology

Order Auloporida Sokolov, 1947

Superfamily Auloporicae Milne-Edwards and Haime, 1851

Family Auloporidae Milne-Edwards and Haime, 1851

Genus *Aulopora* Goldfuss, 1829

Type species: *Aulopora serpens* Goldfuss, 1829.

Aulopora sorayamaensis sp. nov.

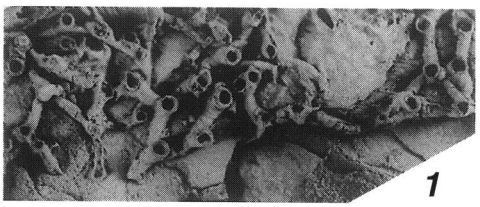
Figs. 1-1–7; 2-1–4

[?]*Aulopora* sp.; Kamei, 1952, p. 63; Kamei, 1955, p. 56; Kamei, 1961, p. 4; Hamada, 1961, p. 26; Kamei, 1962, p. 39.

Holotype: NSM PA14943, from which a thin section was made, and a silicone rubber cast from an external mold was examined.

Other specimens: Six sections and three silicone rubber casts from the three external molds were studied from the five paratypes, NSM PA14944–14947, 14949. In addition, a specimen, NSM PA14948, was also examined.

→ Fig. 1. *Aulopora sorayamaensis* sp. nov. **1**, **4**, **5**, holotype, NSM PA14943, external view of silicon rubber cast. **1**, ×2. **4**, **5**, showing morphological variations, both are ×8. **2**, paratype, NSM PA14945, external view of silicone rubber cast, ×2. **3**, paratype, NSM PA14946, external view of silicone rubber cast, ×8. **6**, **7**, paratype, NSM PA14947, thin sections. **6**, longitudinal thin section of corallite, ×25. **7**, transverse (upper two) and oblique (bottom) sections of corallites, ×25.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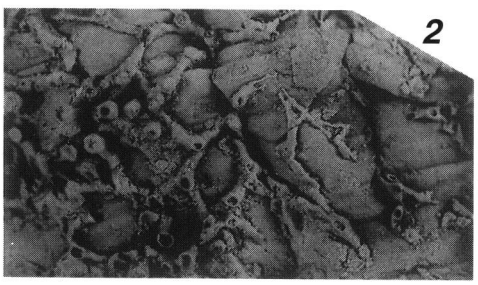
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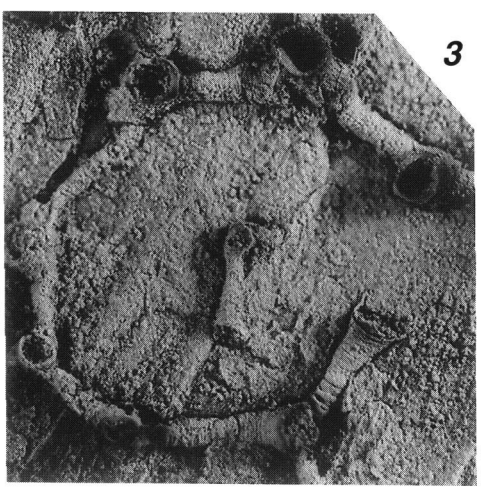
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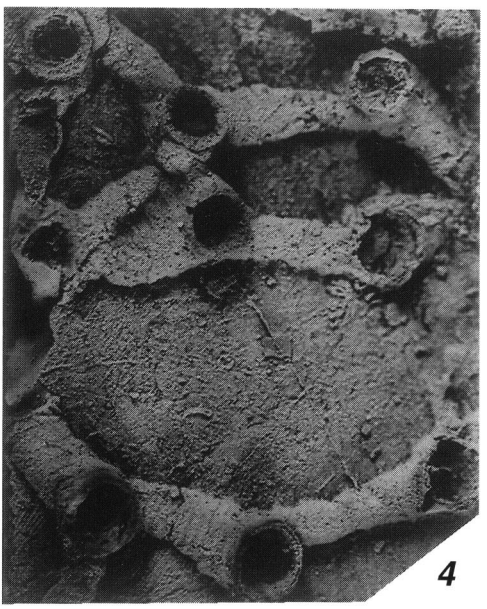
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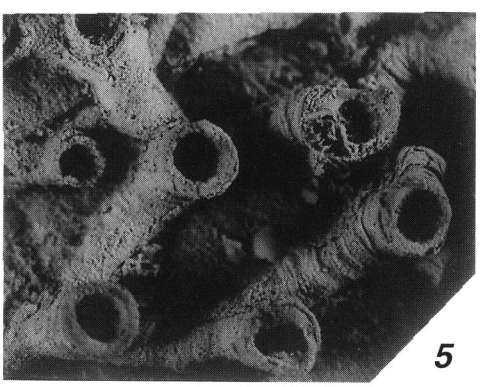
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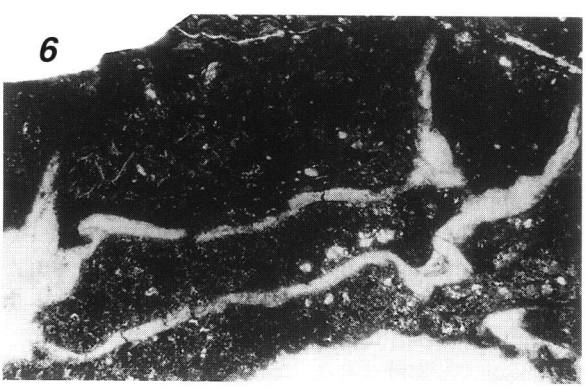
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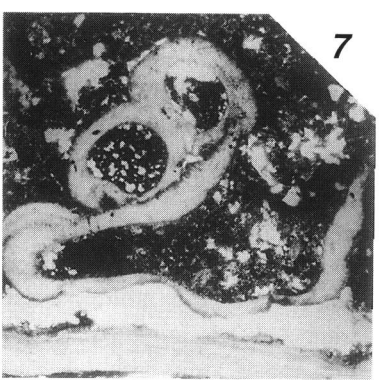
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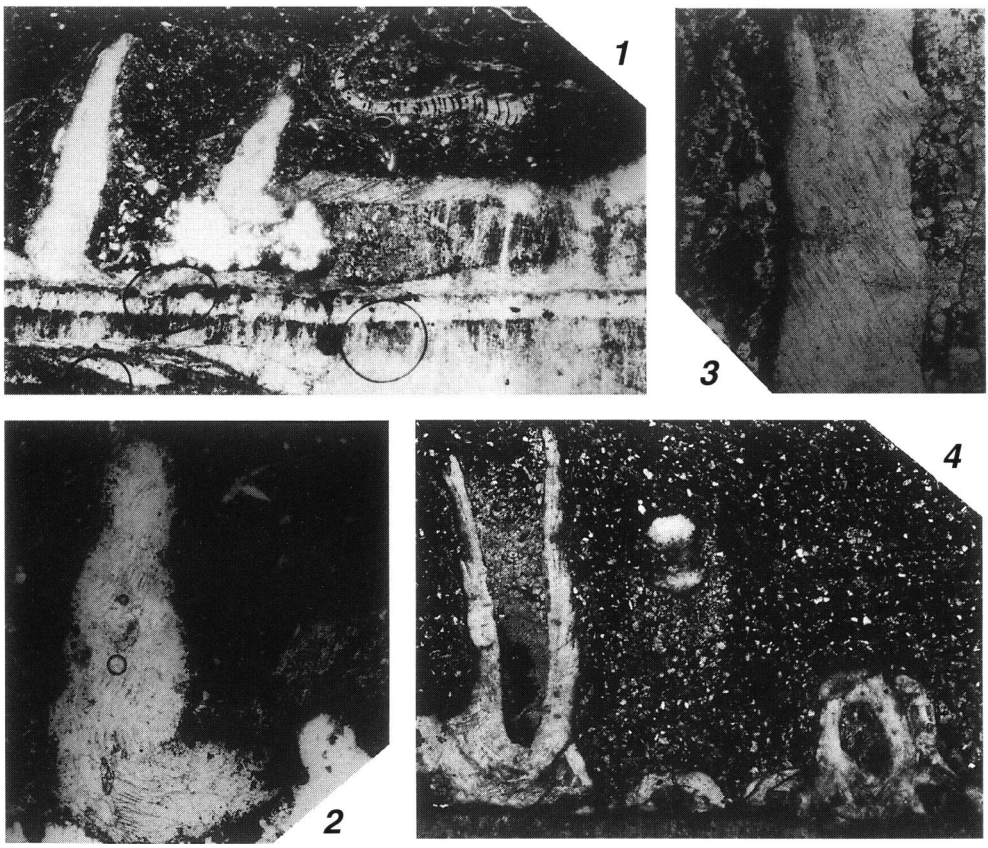


Fig. 2. *Aulopora sorayamaensis* sp. nov., thin sections. **1**, **2**, holotype, NSM PA14943. **1**, longitudinal section of corallite, ×25. **2**, partial enlargement to show corallite wall structure, ×75. **3**, **4**, paratype, NSM PA14944. **3**, partial enlargement to show septal spines, ×75. **4**, longitudinal section of calice (left), transverse section (center) and oblique section (right), ×14.

Diagnosis: Species of *Aulopora* with anastomosed corallites, usually polygonal lacunae and fine septal ridges at calical rim; diameters of calices approximately 1.1 mm; corallite walls attain 0.42 mm in thickness; stereoplasm indicates microlamellar in structure; septal spines rare; tabula absents.

Description: Coralla encrusting mat-like in growth form, adherent; largest corallum (paratype, NSM PA14945) attains approximately 90 mm in diameter. Corallites join in anastomosing assemblage with usually polygonal lacunae that surrounded by 3–7 corallites; sizes and spacing of corallites somewhat variable even in the same corallum; each corallite consists of proximal, reptant portion with strongly elongated trapezoid in longitudinal section and domical, elliptical or sub-triangular in cross section, 0.8–3.3 mm with 2.2 mm mean, in length, and distal, free portion of cylindrical

calice, 1.0–1.7 mm (rarely attains 3.7 mm) with 1.4 mm mean, in length; attachment scars distinct in proximal portion of corallites; calices relatively shallow (or very deep in rare cases) having fine septal ridges at calical rim, where calical diameters range from 0.7 to 1.5 mm with 1.1 mm mean; opening angle of calices indicates 52°–112°, but perpendicular to substrate in common one; cross sections of lumina are usually elliptical in reptant portion and circular in free portion of corallites; increase of new corallites bilateral or rarely unilateral; daughter corallite of offset arises at near basal part of preceding calice. Corallite walls divided into epitheca, that possesses prominent or subdued growth ridges, and stereoplasm with microlamellar structure; each microlamella parallel to epitheca; thickness of corallite walls is 0.02–0.17 mm in prostrate portion and thickened to 0.19–0.42 mm at basal part of calices; septal spines rare, relatively long, but almost enclosed in stereoplasm; only most apical 0.05–0.08 mm of septal spine protrudes into lumen. Tabula absents.

Discussion: *Aulopora sorayamaensis* sp. nov. has a close resemblance to the type species, *A. serpens* (Goldfuss, 1829, pl. 29, 1a–d) from the Middle Devonian in Germany, in the individual corallite shape and size. However, the both species differs in the corallite arrangement. *Aulopora serpens* partly possesses the linear chains with very narrow lacunae, whose arrangement is not recognized in the coralla of *A. sorayamaensis*. Stasinska (1974) believed that *Aulopora serpens* has "fine radial structure" in the corallite walls on the basis of the Couvinan and Givetian (Middle Devonian) material from Poland.

A possibly conspecific form from the Fukuji Formation had been listed since Kamei (1952) as *Aulopora* sp. This species has not been illustrated, but its stratigraphic position (Horizon F1 in Kamei, 1955) is vicinity with the types of *Aulopora sorayamaensis*.

Etymology: The specific name is derived from Mt. Sora-yama. The most prolific locality of the species is situated on the eastern slope of this mountain.

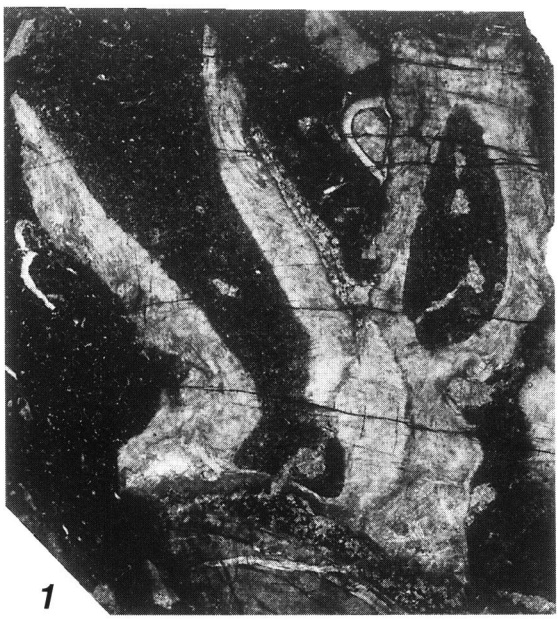
Occurrence: *Aulopora sorayamaensis* sp. nov. was collected from calcareous shale at locality FH-1 (NSM PA14943) and FH-4 (NSM PA14944–14949). Identified substrata of each specimen are as follows: cephalopods (NSM PA14943–14946, 14948), brachiopod (NSM PA14947) and bivalve (NSM PA14949). All specimens occur in the Lochkovian D1 Member of Niikawa's (1980) subdivision.

Aulopora? sp. indet.

Figs. 3-1–7

Material examined: A single corallum HMM 04073.

Description: Corallum encrusting on cephalopod shell, relatively small, adherent; irregularly arranged(?) corallites exhibit bushy growth form; maximum observed diameter of corallum is 24 mm. Each corallite composed of proximal, reptant portion with domed, subtriangular or bulbous cross section, 4.3–4.5 mm in length, and distal,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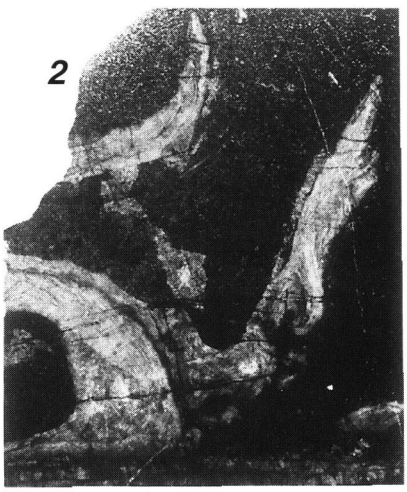
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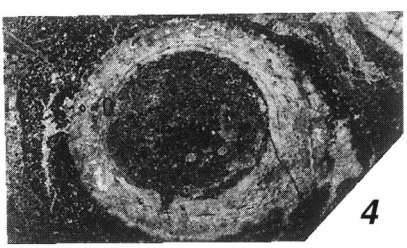
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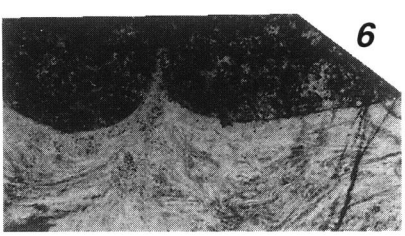
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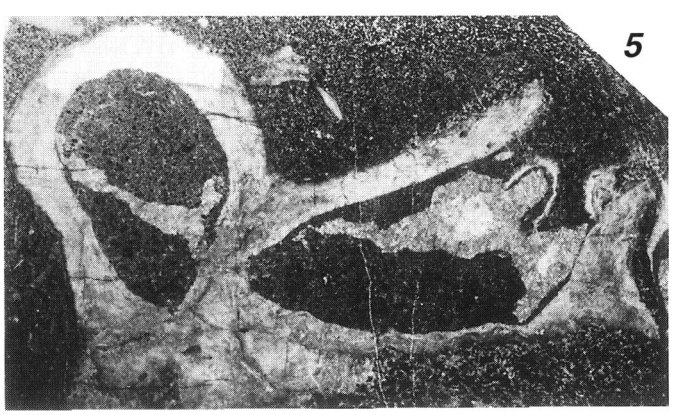
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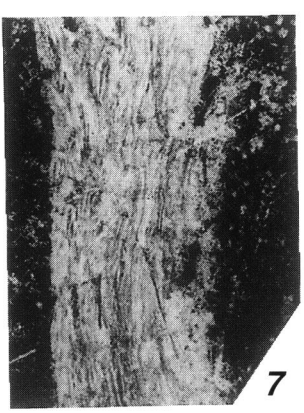
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free portion forming funnel-shaped calice with circular cross section, 2.6–7.0 mm in length; attachment scars distinct in proximal corallite; calices relatively shallow to very deep, oblique with 33°–79° in angle to substrate; diameters of corallites are large for *Aulopora*, range from 2.4 to 3.3 mm in distal one. Corallite walls very thick for family, usually 0.44–0.84 mm in thickness, differentiated into epitheca and stereoplasm that consists of undulated microlamellae; septal spines sporadic, very long, but almost enclosed in stereoplasm; most apical 0.13–0.29 mm of septal spine protrudes into lumen. Tabula absents.

Discussion: The single available specimen probably represents a new species *Aulopora* or externally similar genera including *Cladochonus* (M'Coy, 1847) and *Plexituba* (Stainbrook, 1946), but because the corallite arrangement is not well defined the author will not formalize the species. Comparison with *Aulopora* is most appropriate on the basis of its distinct attachment scars and lacking the tabula in the specimen.

Occurrence: This species was collected from a float pebble of limestone (wackestone; the Emsian? D4 Member) in talus at the Kanashirozako Valley.

Family Romingeriidae Sokolov, 1950

Genus *Romingeria* Nicholson, 1879

Type species: *Aulopora umbellifera* Billings, 1859.

Romingeria cristata sp. nov.

Figs. 4-1–9

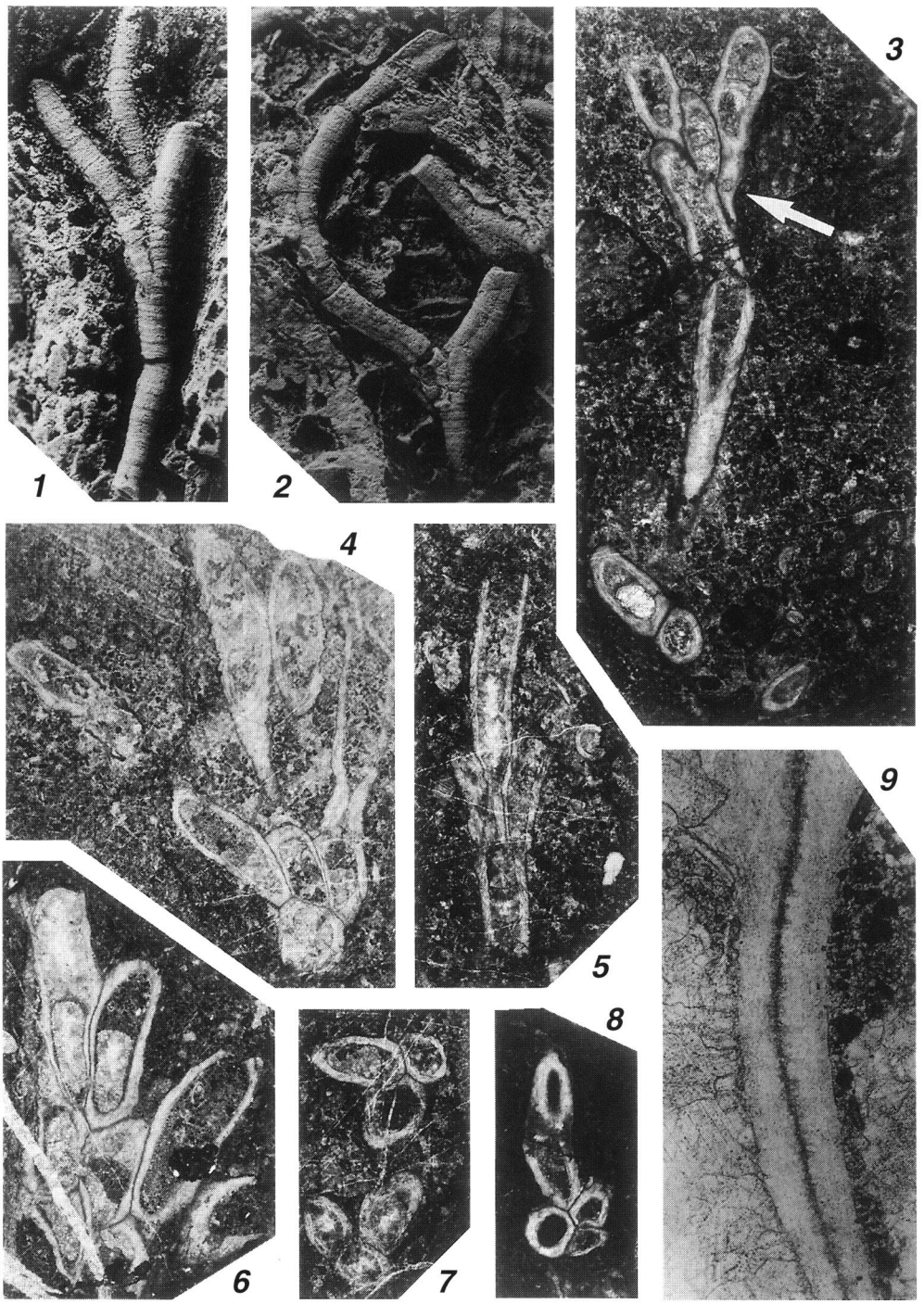
Romingeria sp.; Niko, 2000, p. 16, figs. 1–7.

Holotype: HMM 03505, from which six thin sections were made, and five partially exposed corallum fragments from matrix were examined.

Other specimens: Eight thin sections were studied from the three paratypes, NSM PA14951–14953. In addition, a specimen, NSM PA14950, was also examined.

Diagnosis: Species of *Romingeria* has 3–8+ offsets in each budding point; marginal offsets grow outwardly with usually 30°–36° in angle to preceding and central corallites; diameters of corallites approximately 0.8 mm; corallite walls uniformly

← Fig. 3. *Aulopora*? sp. indet., HMM 04073, thin sections. **1**, longitudinal (left) and oblique (right) sections of corallites, ×10. **2**, longitudinal (top) and transverse (bottom) sections of corallites, ×10. **3**, oblique (left margin) and transverse (center and right) sections of corallites, ×10. **4**, transverse section of free portion of corallite, ×10. **5**, transverse (left) and longitudinal (right) sections of corallites, ×10. **6**, partial enlargement to show septal spine, ×50. **7**, partial enlargement to show corallite wall structure, ×50.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thickened, approximately 0.16 mm; mural pores large, common; septal spine absents; tabulae complete, rare.

Description: Coralla ramose with umbelliferous branches as 3–8+ offsets of new corallites in each budding point, lacking connecting tubule; most proximal portion of umbelliferous branches adheres and cerioid-like; total corallum diameter and growth form unknown owing to fragile nature. Corallites mostly cylindrical with exception of adhered portion, where corallites indicate fan-shaped or indistinct polygonal in cross section; diameters of corallites range from 0.5 to 1.1 mm, with 0.8 mm mean; branching very frequent, thus each corallite short, 5.7–7.0+ mm in length, contains adhered portion of most proximal 1.2–2.1 mm; among umbelliferous branches, a central one grows same direction with preceding corallite; marginal corallites radially arranged with relatively narrow angle, 12°–80°, usually 30°–36° to preceding and central corallites; calices deep, cylindrical, without calical modification; cross sections of tabularia are circular, excepting adhered portion where they usually indicate sub-elliptical. Corallite walls relatively thick, 0.06–0.23 mm with 0.16 mm mean, in thickness, uniformly thickened throughout corallite, composed of epitheca and stereoplasm of microlamellar in structure; epithecae have prominent growth ridges and very weak longitudinal furrows; intercorallite walls in adhered portion consist of median dark line (=fused epitheca) and stereoplasm, range from 0.08 to 0.33 mm in thickness, commonly possess mural pores with circular profiles, large in comparing to corallite size, 0.17–0.25 mm in diameter; septal spine absents; tabulae complete, usually concave distally (uparched), rare; occurrence of tabulae usually concentrates vicinity of budding point; some tabulae may slightly thickened.

Discussion: Based on a specimen that is herein designated as the holotype, Niko (2000) preliminary reported as *Romingeria* sp. This was the first reliable record of the genus in Japan. Newly discovered three paratypes lead a number of dimensional emendations. In addition, "septal spine-like projections very rarely recognized in tabularium" in the previous description should be abandoned. This spinose structure can be regarded as recrystallization of the corallite walls.

Romingeria cristata sp. nov. is very close to *R. jacksoni* Beecher (1903, pl. 5, figs. 10–15) from the Middle Devonian Corniferous Limestone, Laurentia. Particularly, the corallite diameters and character of the tabulae are quite identical. They can be distinguished in number of offsets at a budding point (3–8+ in *Romingeria cristata* versus usually 7 in *R. jacksoni*) and angle of the umbelliferous branches (usually

← Fig. 4. *Romingeria cristata* sp. nov. **1**, **2**, **4**–**7**, **9**, holotype, HMM 03505. **1**, **2**, external view of corallites, note umbelliferous branches, both are ×5. 4, oblique thin section of branch, ×10. **5**, longitudinal thin section of branch, ×10. **6**, oblique thin section of branch, note complete tabulae, ×10. **7**, transverse thin sections of branches, ×10. **9**, partial enlargement to show intercorallite wall structure, ×75. **3**, paratype, NSM PA14952, longitudinal and transverse thin sections of branches, arrow indicates mural pore, ×10. **8**, paratype, NSM PA14953, transverse thin section of branch, ×10.

30°–36° in *R. cristata* versus "turn outward often nearly at right angle" in *R. jacksoni*). In addition, the partial thickening of the corallite walls just before the budding point of *Romingeria jacksoni* is not recognized in *R. cristata*. *Romingeria minor* Beecher (1903, pl. 5, figs. 6–9), also known from the Corniferous Limestone, possesses the smaller diameters of the corallites indicating 0.3–0.4 mm than the usual corallites of *R. cristata* that measure approximately 0.8 mm in diameter.

Etymology: The specific name is derived from the Latin *cristatus* (=having plume) in reference to the external shape of a cluster of the umbelliferous branches.

Occurrence: *Romingeria cristata* sp. nov. was collected from limestone (bioclastic wackestone; the D4 Member) at locality FH-6 (NSM PA14951), the two float pebbles of limestone (bioclastic wackestone; the D4 Member) in talus at the Kanashirozako Valley (NSM PA14950, 14952, HMM 03505), and a float pebble of limestone (bioclastic wackestone; the Siegenian? D2 Member) in talus on the eastern slope of Mt. Sora-yama (NSM PA14953).

Family Palaeofavosiporidae Stasinska, 1976

Genus *Kanashiropora* nov.

Type species: *Kanashiropora kozui* sp. nov., by monotypy.

Diagnosis: Subspherical corallum consists of cerioid proximal portion with prostrate corallites and phacelo-cerioid distal portion with erect corallites that form mostly very deep calices; intercorallite walls usually thick, possess abundant to common mural pores at mid-faces of corallites or near corallite edges in rare cases; stereoplasm consists of microlamellae and rect-radiate fibers; septal spine may absent; tabulae complete, rare.

Etymology: The generic name is derived from the type locality named Kanashirozako Valley.

Kanashiropora kozui sp. nov.

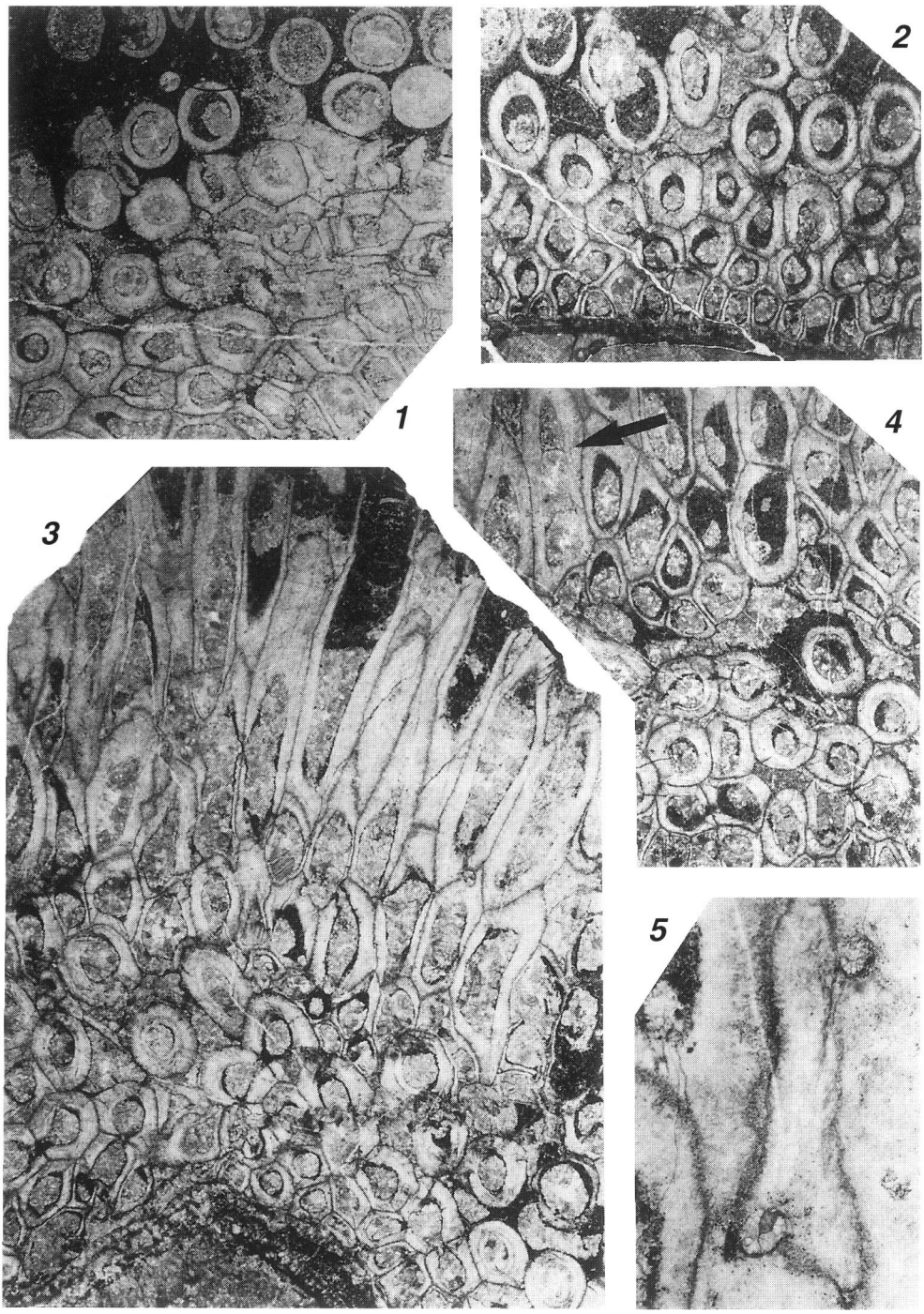
Figs. 5-1–5; 6-5, 6

Holotype: NSM PA14957, from which 14 thin sections were made.

Diagnosis: As for the genus.

Description: Corallum encrusting, 9.5–11.3 mm in thickness, encircles cephalo-

→ Fig. 5. *Kanashiropora kozui* gen. et sp. nov., holotype, NSM PA14957, thin sections. **1**, transverse section of distal corallum, ×10. **2**, longitudinal section of corallum, showing transverse sections of proximal corallites, ×10. **3**, longitudinal section of corallum, including transverse, oblique and longitudinal sections of corallites, note well-developed mural pores in proximal corallites, ×10. **4**, oblique section of corallum, arrow indicates complete tabula, ×10. **5**, partial enlargement to show mural pores and intercorallite wall structure, ×30.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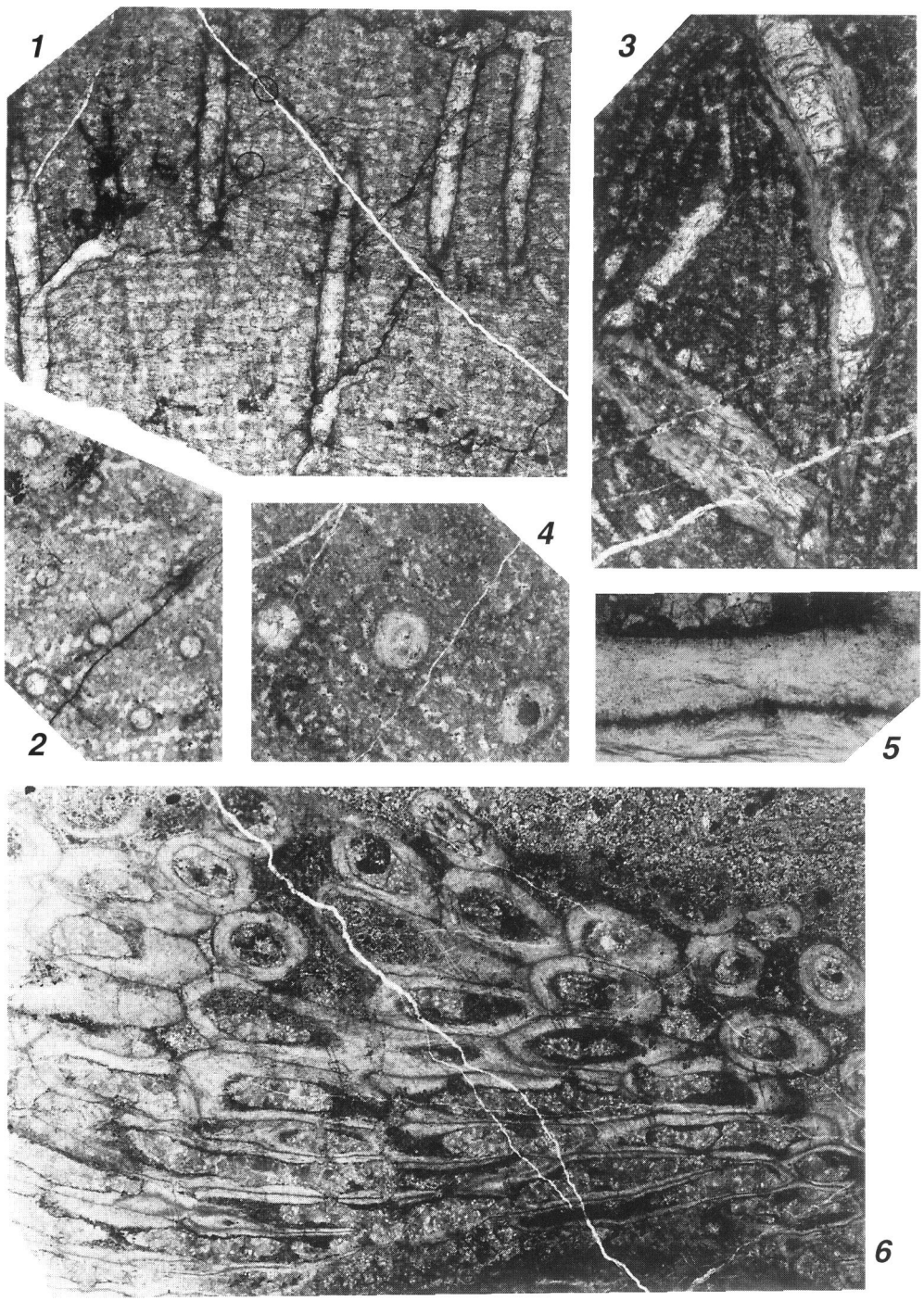
pod shell to form subspherical colony with maximum diameter of 48.5 mm. Proximal corallum cerioid composed of prostrate corallites that have subtrapezoid, polygonal or rarely hemicircular in cross section; in distal, erect stages, corallites frequently losing contact, where corallum indicates phacelo-cerioid and forms irregular shaped longitudinal lacunae; closely spaced adjacent corallites mostly less than 1.6 mm apart in center-to-center distance even in phaceloid portion; cross sections of distal corallites are prismatic with 4–8 sides or fan-shaped to bulbous in margin of adhered cluster in cerioid portion, or circular in phaceloid portion; diameters of usual corallites range from 0.3 to 1.1 mm, with 0.9 mm mean; connecting tubule absents; calices open perpendicular to corallum surface, mostly very deep, but shallow to very shallow calices rarely recognized; no calical modification detected; tabularia usually subcircular to indistinct polygonal in cross section, narrowed by intercorallite (corallite) wall thickening; offset not observed in examined thin sections. Intercorallite walls variable in thickness, but usually thick excepting most proximal corallites, range from 0.06 to 0.56 mm, usually 0.21–0.46 mm, in thickness, composed of median dark line (=fused epitheca) and stereoplasm; microstructure of stereoplasm differentiated into inner (underlying) microlamellar layer and outer (overlying) layer of rect-radiate fibers; each microlamella parallel to median dark line; corallite walls in phaceloid portion are 0.04–0.27 mm in thickness; mural pores abundant in proximal corallites and common in cerioid portion of distal corallites, subcircular in cross section, form a single row in mid-face of each corallite or near corallite edges in rare cases; diameters of mural pores are relatively large in comparing to corallite size, 0.15–0.19 mm; phaceloid portion lacks mural pore; septal spine may absent; tabulae complete, rare, weakly concave distally (uparched) and roughly rectangular to corallite.

Discussion: In respects of its phacelo-cerioid distal corallum, prostrate proximal corallites and the usually thick intercorallite walls with the rect-radiate fibers in the stereoplasm, *Kanashiropora* gen. nov. is closely similar to *Palaeofavosipora* that was proposed by Stasinska (1976, pl. 29, figs. 1–6, pl. 30, figs. 1–4) on the basis of a Wenlock (Early Silurian) species *Fletcheria clausa* Lindström (1866, pl. 31, fig. 14; 1896, pl. 1, figs. 9–12, pl. 2, figs. 13–17a, b, 18) from Gotland, Baltica. It is apparent that the both genera belong the same family. However, the monotypic species *Palaeofavosipora clausa* is diagnosed by the numerous septal spines attaining the center of the tabularia and the well-developed tabulae with the concentric structure. In addition, the mural pores of the *Palaeofavosipora clausa* always situate at the corallite edges.

→ Fig. 6. **1**, **2**, *Syringoporella* sp. indet., NSM PA14954, thin sections. **1**, longitudinal section, ×10. **2**, transverse section, ×10. **3**, **4**, *Multithecopora*? sp. indet., NSM PA14956, thin sections. **3**, near longitudinal section, ×10. **4**, transverse section, ×10. **5**, **6**, *Kanashiropora kozui* gen. et sp. nov., holotype, NSM PA14957, thin sections. **5**, partial enlargement to show intercorallite wall structure, ×75. **6**, longitudinal section of proximal corallum, ×10.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Previously *Palaeofavosipora* was the sole included genus of the Palaeofavosiporidae. This discovery of *Kanashiropora kozui* sp. nov. from the Fukuji Formation represents the first palaeofavosiporid found outside Baltica, and upwards extends the stratigraphic range of the family to Early Devonian.

Etymology: The specific name honors the late Dr. Shukusuke Kozu. As noted in the commencement of this report, he was a forerunner of the study of the Devonian corals in the Fukuji Formation.

Occurrence: *Kanashiropora kozui* gen. et sp. nov. was collected from a float pebble of limestone (bioclastic wackestone; the D4 Member) in talus at the Kanashirozako Valley.

Superfamily Syringoporicae Fromentel, 1861

Family Multithecoporidae Sokolov, 1950

Genus *Multithecopora* Yoh, 1927

Type species: *Multithecopora penchiensis* Yoh, 1927.

***Multithecopora*? sp. indet.**

Figs. 6-3, 4

Material examined: Two coralla, NSM PA14955, 14956.

Description: Coralla may dendritic to phaceloid, always occur inside stromatoporoids. Corallites cylindrical with approximately 0.9 mm in diameter; distances (center-to-center) between corallites are usually 1.8–2.8 mm; no connecting tubule detected in examined thin sections. Corallite walls variable in thickness and usually thick, attain 0.40 mm, differentiated into epitheca and stereoplasm; partial tabularia become narrow by corallite wall thickening; septal spines long, but irregular in distribution. Tabulae complete or incomplete, abundant, roughly rectangular to corallite.

Discussion: Although unsuccessful attempts to make the well-oriented longitudinal section preclude a strict determination in the generic level, this species tentatively refers to *Multithecopora* rather than *Syringoporella* in possession of the narrow tabularia by the corallite wall thickening and the incomplete tabulae.

Occurrence: This species was collected from a float boulder of limestone (bioclastic wackestone; the D4 Member) in talus at the Kanashirozako Valley (NSM PA14955) and a float boulder of argillaceous limestone (the D2 Member) in talus at the eastern slope of Mt. Sora-yama (NSM PA14956).

Genus *Syringoporella* Kettner, 1934

Type species: *Syringopora moravica* Roemer, 1883.

Syringoporella sp. indet.

Figs. 6-1, 2

Material examined: A single corallum, NSM PA14954.

Description: Corallum phaceloid, occurs inside stromatoporoid. Corallites cylindrical, very narrow with approximately 0.4 mm in diameter; distances (center-to-center) between corallites are usually 0.8–2.5 mm; lateral increase of new corallites frequently occurs; reliable connecting tubule not detected in examined thin sections. Corallite walls thin for genus, approximately 0.04 mm in thickness, may differentiated into epitheca and stereoplasm; septal spine probably absents; tabulae complete, well-developed, roughly rectangular to corallite.

Discussion: This species resembles a Late Silurian species, *Syringoporella yamakoshii* Niko (2001, figs. 4-1–4) from the Hitoegane Formation, Gifu Prefecture, in very narrow corallite diameters with the thin corallite walls. Its specific determination should await information about the connecting tubule.

Occurrence: From the same stromatoporoid colony as a specimen (NSM PA14955) of *Multithecopora*? sp. indet. (this report).

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