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Additional Material of Favositid and Auloporid Tabulate Corals from the Devonian Fukuji Formation, Gifu Prefecture, Japan

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Abstract Nine species of tabulate corals including eight favositids, *Klaamannipora oborensis* Niko and Senzai, 2010, *Pachyfavosites hidensiformis* (Mironova, 1961), *Crenulipora kuwanoi* sp. nov., *Isurugiopora ishiokai* Niko and Senzai, 2010, pachyporid, gen. et sp. indet., *Parastriatopora fukuiensis* Niko and Senzai, 2011, *Parastriatoporella arashimaensis* Niko and Senzai, 2011, *Coenites kameii* Niko and Senzai, 2010, and an auloporid *Syringopora* sp. indet. are described from the Devonian Fukuji Formation, Gifu Prefecture, Central Japan. Stratigraphic distributions of each species are: the Lochkovian to Emsian (early to late Early Devonian) Takaharagawa Member (*P. hidensiformis*, *C. kuwanoi,* pachyporid, gen. et sp. indet., *P. fukuiensis, C. kameii*, and *S.* sp. indet.) and the Emsian to Eifelian? (late Early to early Middle? Devonian) Ozako Member (*K. oborensis, I. ishiokai*, and *P. arashimaensis*). *Crenulipora kuwanoi* is the first undoubted constituent except for the generic type, *C. difformis* Le Maître, 1956, that was described from the Upper Emsian of Morocco. The new material of *P. fukuiensis* reveals external morphology and provides emendations of its specific concept. Except for *C. kuwanoi* and *S.* sp. indet. constituents of the Fukuji tabulate coral fauna are common with those in the Kamianama Formation, Fukui Prefecture. The both formations belong to the Hida Gaien Belt.

Key words: Lochkovian to Eifelian? (Early to Middle? Devonian), tabulate corals, *Crenulipora kuwanoi* sp. nov., Hida Gaien Belt, Fukuji Formation

Introduction

The Devonian Fukuji Formation in the Fukuji area of Okuhidaonsen-gou, Takayama-shi, Gifu Prefecture, Central Japan can be subdivided into the lower Takaharagawa and the upper Ozako Members, whose ages respectively are the Lochkovian to Emsian (early to late Early Devonian) and Emsian to Eifelian? (late Early to early Middle? Devonian). This formation together with the Kamianama Formation in the Kuzuryu Lake-Ise River area, Fukui Prefecture represents the typical Lower Devonian strata of the Hida Gaien Belt. In this paper, the author provides additional tabulate coral species for the Fukuji fauna on the basis of newly collected material that is deposited in National Museum of Nature and Science, Tokyo with abbreviation of NMNS. Detailed geologic setting of this formation and geographic positions of fossil localities are referable in Niko (2001, 2005, 2007).

Systematic Paleontology

Subclass Tabulata Milne-Edwards and Haime, 1850

Order Favositida Wedekind, 1937

Suborder Favositina Wedekind, 1937

Superfamily Favositoidea Dana, 1846

Family Favositidae Dana, 1846

Subfamily Favositinae Dana, 1846

Genus ***Klaamannipora*** Mironova, 1974

Type species: *Favosites coreaniformis* Sokolov, 1952a.

Klaamannipora oborensis
Niko and Senzai, 2010

(Figs. 1-1–7)

Klaamannipora oborensis Niko and Senzai, 2010, p. 37, 39, figs. 4-1–8.

Material examined: Four coralla, NMNS PA17231–17234.

Occurrence: The examined specimens of *Klaamannipora oborensis* were collected from float blocks of gray limestone (bioclastic wackestone) on the northern flank of the Ichinotani Valley near locality FH-10. They are derived from the main part of the Ozako Member in the upper Fukuji Formation.

Discussion: Except for their larger branch diameters rarely attaining 20 mm in the Fukuji specimens, the distinctive features, such as intercorallite wall structure and thickness, corallite diameters and nature of the tabulae, are almost identical with those of the type specimens of *Klaamannipora oborensis*. The type stratum of this species is the Hakubado Member of the upper Kamianama Formation (see Niko and Senzai, 2010, for its geologic setting).

Subfamily Pachyfavositinae Mironova, 1965

Genus ***Pachyfavosites*** Sokolov, 1952b

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

Pachyfavosites hidensiformis (Mironova, 1961)

(Figs. 2-1–4)

Pachyfavosites hidensiformis (Mironova); Niko and Senzai, 2011, p. 29, 31, figs. 1-1–8 [with earlier synonymy].

Material examined: Six coralla, NMNS PA17235–17240.

Occurrence: The examined specimens of *Pachyfavosites hidensiformis* were collected from an outcrop of calcareous shale at locality FH-1 (NMNS PA17235–17237), and float blocks of argillaceous limestone in the Kanashirozako (NMNS PA17238, 17239) and the Ichinotani (NMNS PA17240) Valleys. They occur in the Takaharagawa Member of the lower Fukuji Formation.

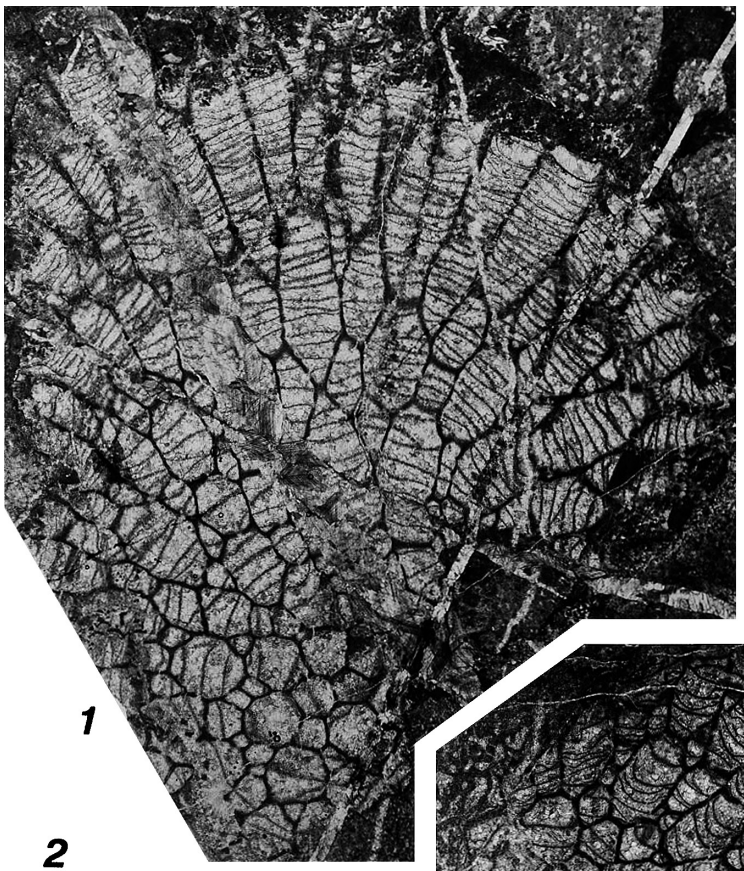
Discussion: *Pachyfavosites hidensiformis* has been known from the Lower Devonian strata in Siberia (Mironova, 1961; Dubatolov *et al.*, 1968; Dubatolov, 1969) and the Kuzuryu Lake-Ise River area (the Oisedani Member of the lower Kamianama Formation; Niko and Senzai, 2011). The diagnostic features of the species are the presence of the columnar projections in growth from and the well-developed septal spines in the peripheral zone of the corallum.

This is only the second species of *Pachyfavosites* described from Japan. It can be easily distinguished from the other species, *P. katoi* Niko (2007, p. 66, 68, figs. 6-1–5; Niko and Senzai, 2010, p. 41, figs. 5-5, 6), from the Ozako and Hakubado Members by having larger corallites, whose approximate diameters are 1.6 mm in *P. hidensiformis*, whereas *P. katoi* has approximately 1.2 mm in corallite diameter.

Subfamily Crenuliporinae Plusquellec, Fernandez-Martinez, Mistiaen and Tourneur, 2004

Genus ***Crenulipora*** Le Maître, 1956

Fig. 1. *Klaamannipora oborensis* Niko and Senzai, 2010, thin sections. **1**, **2**, **5**, **6**, NMNS PA17234. **1**, oblique section of corallum, ×5. **2**, partial enlargement of Fig. 1-1, showing transverse to oblique sections of corallites, ×10. **5**, partial enlargement of Fig. 1-1, showing longitudinal sections of corallites, ×10. **6**, partial enlargement to show intercorallite wall structure and septal spine, transverse section, ×75. **3**, NMNS PA17233, longitudinal section of corallum, ×5. **4**, **7**, NMNS PA17231. **4**, transverse section of corallum, ×5. **7**, partial enlargement to show intercorallite wall structure and tabulae, longitudinal section, ×75.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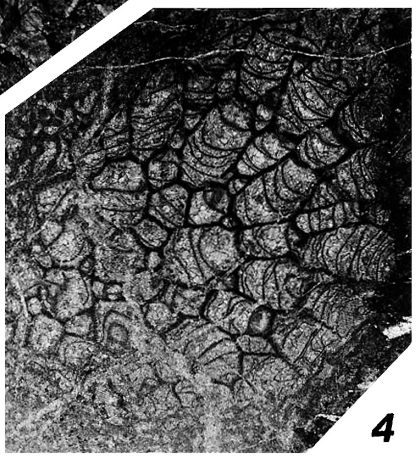
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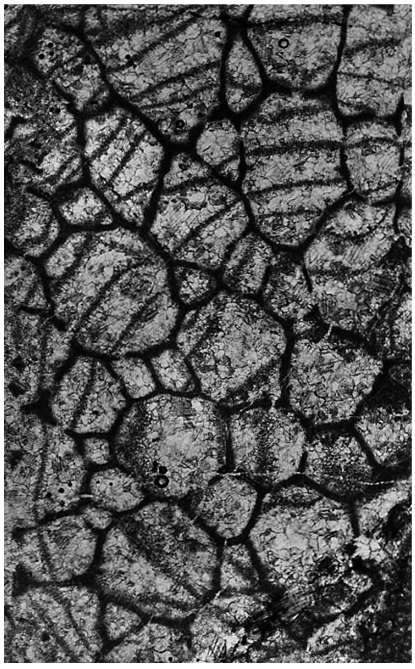
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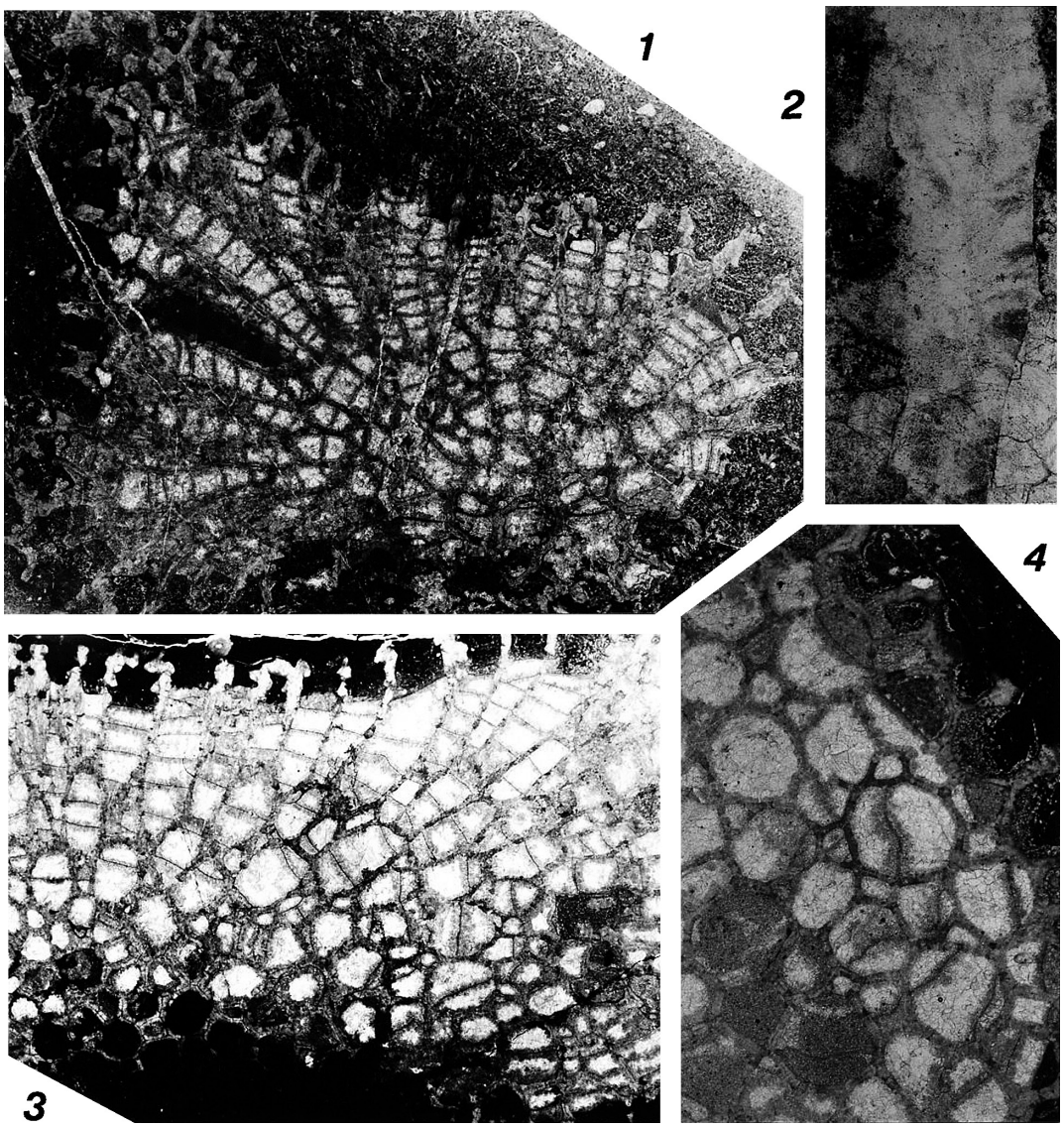


Fig. 2. *Pachyfavosites hidensiformis* (Mironova, 1961), thin sections. **1**, NMNS PA17238, longitudinal section of corallum, ×5. **2**, **3**, NMNS PA17235. **2**, partial enlargement to show intercorallite wall structure and septal spines, longitudinal section, ×50. **3**, oblique section of corallum, ×5. **4**, NMNS PA17237, transverse sections of corallites, ×10.

Type species: *Crenulipora difformis* Le Maître, 1956.

Crenulipora kuwanoi sp. nov.

(Figs. 3-1–5; 4-1–6)

Holotype: NMNS PA17294, from which 17 thin sections were made.

Paratypes: Forty-one thin sections were studied from the nine paratypes, NMNS PA17282, 17284, 17286, 17288, 17290, 17291, 17295–17297.

Other Material examined: Eight specimens, NMNS PA17283, 17285, 17287, 17289, 17292, 17293, 17298, 17299, were assigned to this new species.

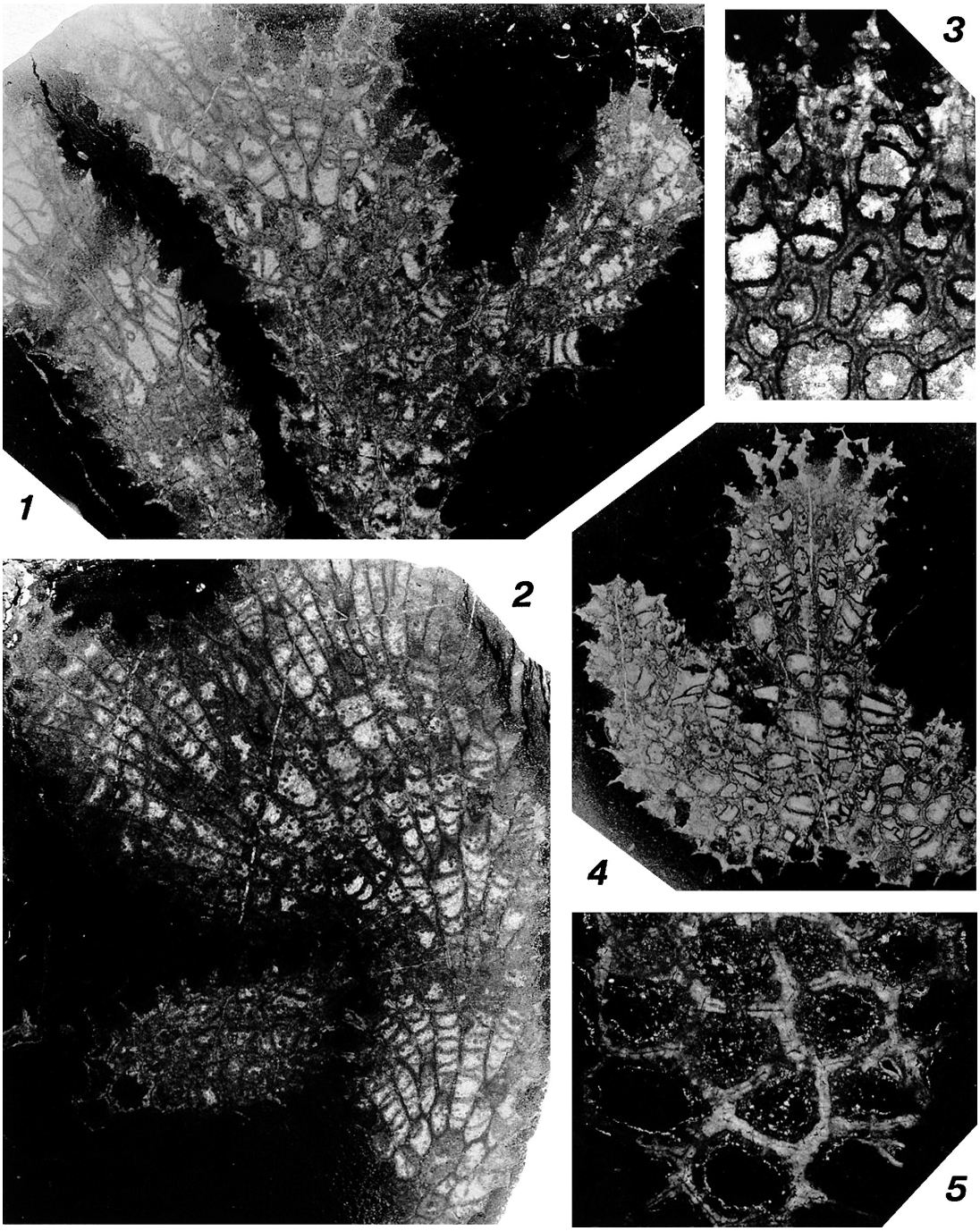
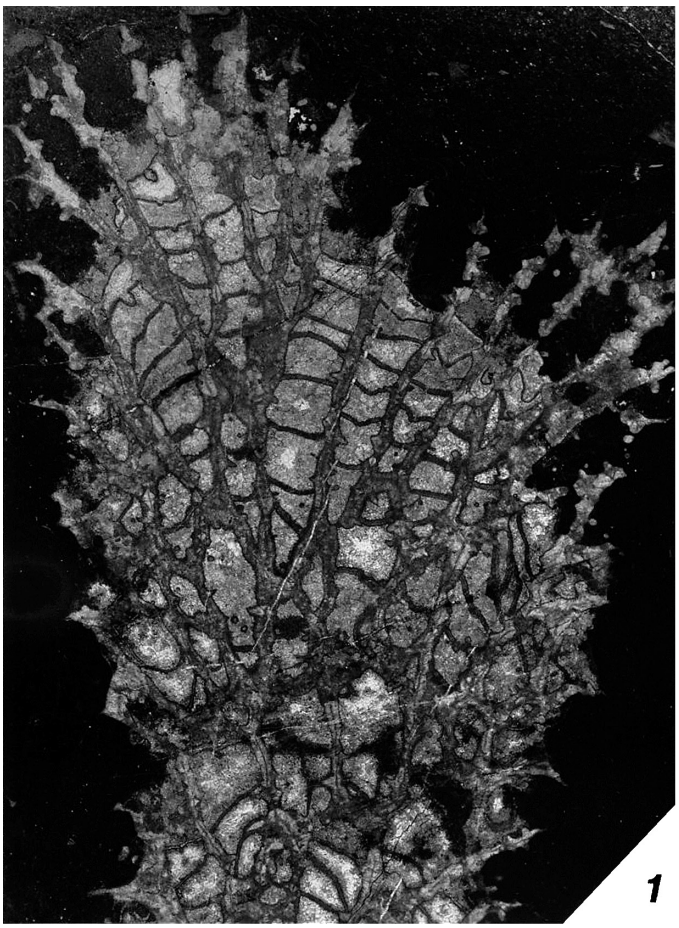


Fig. 3. *Crenulipora kuwanoi* sp. nov., thin sections. **1**, paratype, NMNS PA17291, longitudinal section of corallum, ×5. **2**, paratype, NMNS PA17288, longitudinal sections of branches, ×5. **3**, **4**, holotype, NMNS PA17294. **3**, transverse to longitudinal sections of corallites, showing mural pores, septal spines and tabulae, ×14. **4**, longitudinal to oblique section of corallum, ×5. **5**, paratype, NMNS PA17286, transverse sections of distal corallites, showing mural pores, ×14.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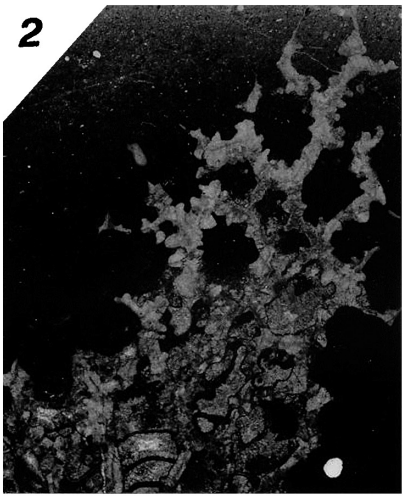
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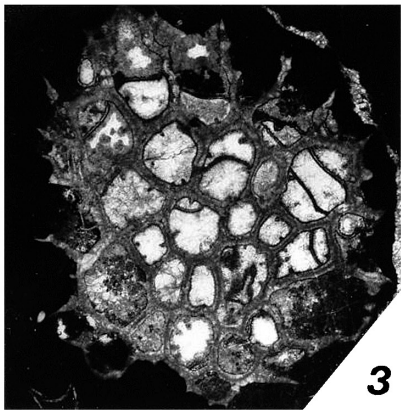
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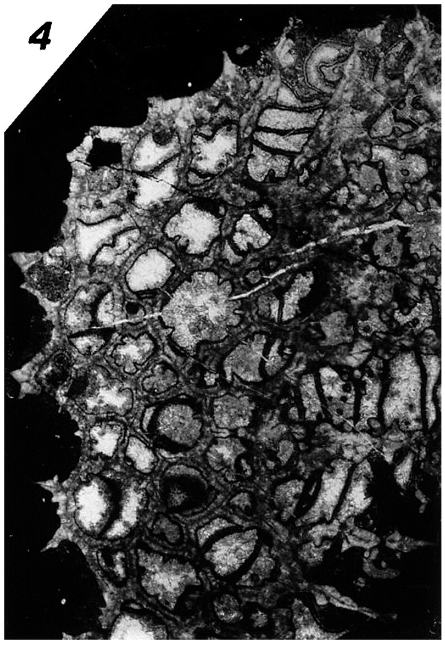
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Diagnosis: Species of *Crenulipora* with slender branches indicating usually 6–8 mm in diameter and small corallite diameter indicating approximately 1.2 mm in adult portions; intercorallite walls thin, up to 0.26 mm; mural pores occur on corallite faces and corners; diameters of mural pores are small, 0.10–0.13 mm; septal spines short, conical to needle-like with approximately 0.12–0.15 mm in length; tabula shape somewhat variable, complete to incomplete; there are 2–9 tabulae in 2.5 mm.

Description: Coralla ramose with slender and subcylindrical, foliose to somewhat irregular shaped branches, cerioid; branching frequent, bifurcate or umbelliferous; largest corallum (paratype, NMNS PA17295) reaches 165 mm in maximum observable diameter and 102 mm in maximum observable height; diameters of usual branches are 6–8 mm. Corallites prismatic to subprismatic, gradually diverge from axial zone of branch to form oblique calices with approximately 36°–60° in angle for branch surface; transverse sections of corallites have 3–6 sides in immature and indistinct 5–10 sides in adult corallites; diameters of corallites are small for the genus, 0.4–1.3 mm, with 1.2 mm mean in adult portions; depressed corallite corner and/or face rarely occur; there are 25–76 corallites in transverse section of branch; calical depth shallow; tabularia (lumina) have subpolygonal transverse sections; increases of new corallites lateral, frequently arise in axial zone. Intercorallite walls thin for the genus, weakly thickened even in axial zone having 0.09–0.19 mm, then their thickness increases up to 0.26 mm in peripheral zone of branch; structure of intercorallite walls are median dark line and stereoplasm of rectradiate fibers; mural pores have circular profiles, occur on corallite faces as mid-wall pores and at corners as angle pores; mode of occurrence of mid-wall pores is uncommon in axial and frequent in peripheral zones and that of angle pores is uncommon throughout; diameters of mural pores are small for genus, 0.10–0.13 mm; septal spines conical to needle-like in relatively rare cases, well-developed in axial zone and proximal portion of peripheral zone, and numerous in distal portion of peripheral zone; length of septal spines short for the genus, approximately 0.12–0.15 mm in protrude portion into tabularium or calical pit; tabula shape somewhat variable; complete tabulae most common, but incomplete ones are not rare; sagging (concave proximally), uparched (concave distally), oblique or weakly sinuate profiles are recognized; distinct axial depressions are rarely developed in complete tabulae; peripheral tabulae may be thickened; there are 2–9 tabulae in 2.5 mm of corallite length.

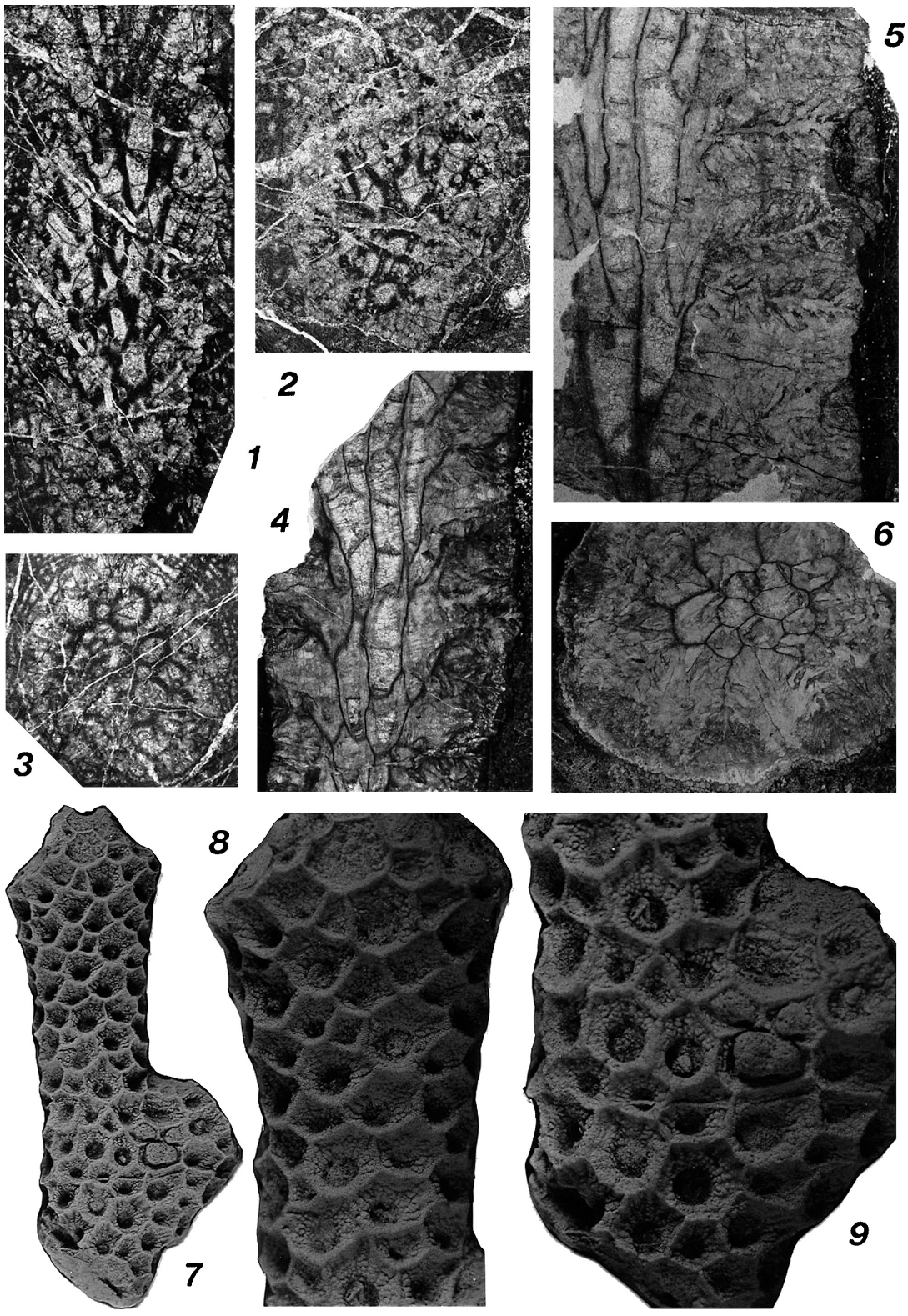
Etymology: The specific name honors the late Dr. Yukio Kuwano, who contributed to the precise age determinations of the Fukuji Formation using conodonts and ostracodes.

Occurrence: *Crenulipora kuwanoi* sp. nov. was collected from an outcrop of calcareous shale at locality FH-1. Stratigarphically, the type stratum belongs to the lower part of the Takaharagawa Member.

Discussion: *Crenulipora kuwanoi* sp. nov. is comparable with the type species of the genus, *C. difformis* Le Maître (1956, p. 1340, 1341, figs. 3, 4), from the Upper Emsian of Morocco. Plusquellec *et al.* (2004) revised this species and its emended diagnostic features of which are almost identical with the Fukuji specimens. Differences between *C. kuwanoi* and *C. difformis* are mainly dimensional. The new species has the much slender branches, smaller diameters of the adult corallites and the mural pores, the thinner intercorallite walls, and the much shorter septal spines.

Although two other species have been

Fig. 4. *Crenulipora kuwanoi* sp. nov., holotype, NMNS PA17294, thin sections. **1**, longitudinal section of branch, ×10. **2**, transverse sections of distal corallites, ×10. **3**, transverse section of branch, ×10. **4**, oblique section of branch, ×10. **5**, partial enlargement to show intercorallite wall structure and septal spines, transverse section, ×75. **6**, partial enlargement to show intercorallite wall structure, septal spines and tabulae, longitudinal section, ×75.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described as *Crenulipora*, namely *C. aculeatissimus* Dubatolov and Spassky, 1964, from the Eifelian of Siberia and *C. qinghegouensis* Li *in* Li and Lin, 1983, from the Lower Devonian (or Upper Silurian?) of Gansu, northwest China. Plusquellec *et al.* (2004) removed them from *Crenulipora* and placed the former species to the genus *Astrocerium* Hall, 1851, and leaved the latter one in open nomenclature. Thus, *Crenulipora kuwanoi* represents the first undoubted constituent except for the generic type. In addition, this discovery from the lower part of the Takaharagawa Member extends stratigraphic range of the genus downwardly to Lochkovian.

Superfamily Pachyporoidea Gerth, 1921

Family Pachyporidae Gerth, 1921

Genus ***Isurugiopora*** Niko, 2005

Type species: *Isurugiopora obesa* Niko, 2005.

Isurugiopora ishiokai Niko and Senzai, 2010

(Figs. 5-1–3)

Isurugiopora ishiokai Niko and Senzai, 2010, p. 47, 49, figs. 9-1–7.

Material examined: Five coralla, NMNS PA17245–17249.

Occurrence: The examined specimens of *Isurugiopora ishiokai* were collected from float brocks of gray limestone (bioclastic wackestone) on the northern flank of the Ichinotani Valley near locality FH-10. They are derived from the main part of the Ozako Member.

Discussion: Because the Fukuji specimens are poorly preserved and present no additional morphologic knowledge, the diagnostic features of *Isurugiopora ishiokai* are omitted here. The types of this species occur in the Hakubado Member.

Pachyporid, gen. et sp. indet.

(Figs. 6-1–7)

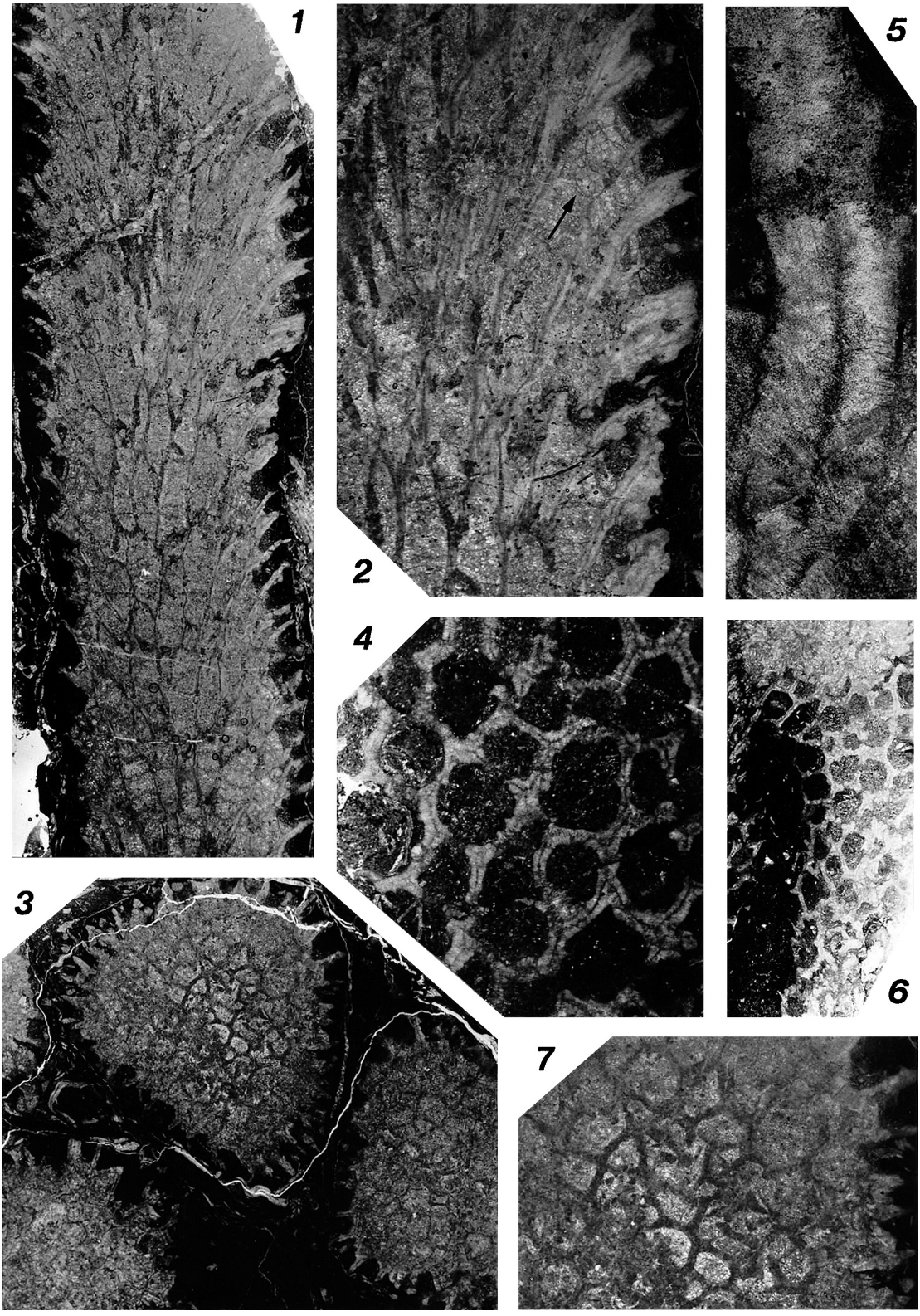
Material examined: A single corallum, NMNS PA17311.

Description: Corallum ramose composed of subcylindrical branches of 8–13 mm in diameter, cerioid; transverse sections of branches subcircular to subtriangular; spacing of branches close, approximately 6–15 mm in distance between axes of adjoining ones. Corallites prismatic to subprismatic having polygonal with 4–6 sides in proximal and rounded subpolygonal with indistinct 6–10 sides in distal portions; each corallite initially runs parallel with branch axis, then gradually diverges to form oblique calice, indicating 50°–75° in approximate angle for branch surface; diameters of corallites approximately 0.5 to 1.5 mm; increases of new corallites lateral and commonly occur near branch axis. Intercorallite walls differentiated into median dark line and stereoplasm, thin in axial and slightly thickened in peripheral zones of branch; mural pores well-developed on corallite faces; septal spines uncommon in axial and numerous in peripheral zones, short conical; tabulae well-developed, mostly complete.

Occurrence: This material occurs in black calcareous shale and was collected by the late Mr. Satoru Yamakoshi in the Fukuji area. Although its accurate locality and mode of occurrence are unknown, the fossil-bearing slab is probably derived from the Takaharagawa Member on the basis of the lithologic character.

Discussion: The closest resemblance of the present Fukuji specimen is to *Cladopora* Hall (1851; type species, *C. seriata* Hall, 1852, p.

Fig. 5. **1**–**3**, *Isurugiopora ishiokai* Niko and Senzai, 2010, NMNS PA17248, thin sections. **1**, longitudinal section of branch, ×5. **2**, oblique (near transverse) section of branch, ×5. **3**, transverse section of branch, ×5. **4**–**9**, *Parastriatopora fukuiensis* Niko and Senzai, 2011. **4**–**6**, NMNS PA17241, thin sections. **4**, longitudinal section of branch, ×10. **5**, longitudinal section of branch, ×14. **6**, transverse section of branch, ×10. **7**–**9**, NMNS PA17244. **7**, external view of branches, ×3. **8**, **9**, partial enlargements of Fig. 5-7, showing details of calices, ×6.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137, 138, pl. 38, figs. 1 a–m). However, the well-developed mural pores, numerous septal spines in the peripheral zone of the branches and well-developed tabulae are beyond the revised generic diagnosis of this genus by Oliver (1963). This material seems to represent a new genus and species, but it is not well-preserved for adequate formal characterization.

Subfamily Parastriatoporidae Chudinova, 1959

Genus ***Parastriatopora*** Sokolov, 1949

Type species: Parastriatopora rhizoides Sokolov, 1949.

Parastriatopora fukuiensis
Niko and Senzai, 2011

(Figs. 5-4–9)

Parastriatopora fukuiensis Niko and Senzai, 2011, p. 34, 36, figs. 3-1–7.

Material examined: Eight coralla, NMNS PA17241–17244, 17307–17310.

Emended diagnosis: Calices composed by platform and pit, the former of which floored by septal ridges and grooves; septal spines usually form 2 rows on each ridge. See Niko and Senzai (2011) for other diagnostic features.

Description: Calices very shallow, composed by funnel shaped platform and pit; calical platforms floored by septal ridges and grooves in interspaces of adjoining ridges; incline of calical platforms is steeper in lower side than upper one; diameters of calical pits are variable, approximately 0.4–1.1 mm; septal ridges bear spines on their upper surface; arrangement of septal spines forms usually 2 rows on each ridge.

Occurrence: The examined specimens of *Parastriatopora fukuiensis* were collected from float blocks of black limestone (bioclastic wackestone (NMNS PA17241, 17242) in the Kanashirozako Valley and an outcrop of argillaceous limestone (NMNS PA17243, 17244, 17307–17310) at locality 6. They are derived from the Takaharagawa Member.

Discussion: Niko and Senzai (2011) established a parastriatoporid species, *Parastriatopora fukuiensis,* on the basis of the types from the Oisedani Member. Its specific concept is herein emended by the six fragmentary branches (NMNS PA17243, 17244, 17307–17310), that reveal the external morphology.

Genus ***Parastriatoporella*** Chudinova, 1959

Type species: *Striatopora immota* Moore and Jeffords, 1945.

Parastriatoporella arashimaensis
Niko and Senzai, 2011

(Figs. 7-1–6)

Parastriatoporella arashimaensis Niko and Senzai, 2011, p. 36, 38, 39, figs. 4-1–8.

Material examined: Thirty-two coralla, NMNS PA17250–17281.

Occurrence: The examined specimens of *Parastriatoporella arashimaensis* were collected from float blocks of buff, gray to light brown limestone (bioclastic wackestone) at locality FH-8 (NMNS PA17251–17254, 17256, 17257, 17259, 17260, 17262, 17264, 17265, 17267–17269, 17271, 17274–17276, 17278, 17279, 17281) and an outcrop of reddish light brown to gray limestone (bioclastic wackestone) at locality FH-9 (NMNS PA17250, 17255, 17258, 17261, 17263, 17266, 17270, 17272, 17273, 17277, 17280). They are derived from the uppermost part of the Ozako Member.

Fig. 6. Pachyporid, gen. et sp. indet., NMNS PA17311, thin sections. **1**, longitudinal section of branch, ×5. **2**, partial enlargement of Fig. 6-1, showing longitudinal to oblique sections of corallites, arrow indicates tabula, ×10. **3**, transverse sections of branches, ×5. **4**, partial enlargement to show details of distal corallites, transverse sections, ×14. **5**, partial enlargement to show intercorallite wall structure, longitudinal section, ×75. **6**, transverse sections of distal corallites, ×5. **7**, partial enlargement of Fig. 6-3, showing transverse sections of proximal corallites, ×10.


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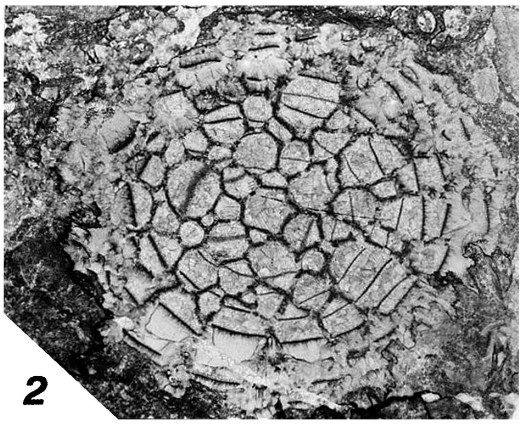
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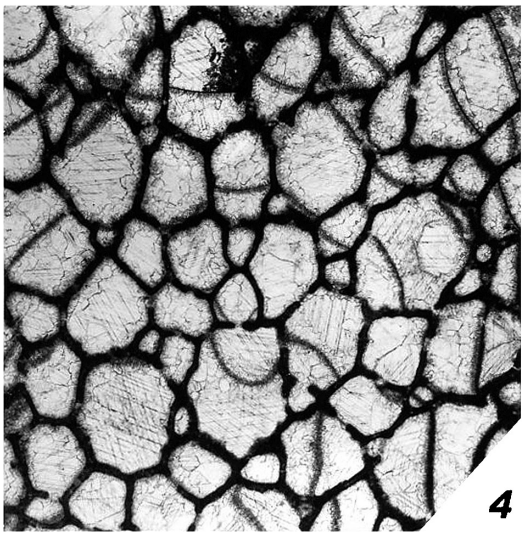
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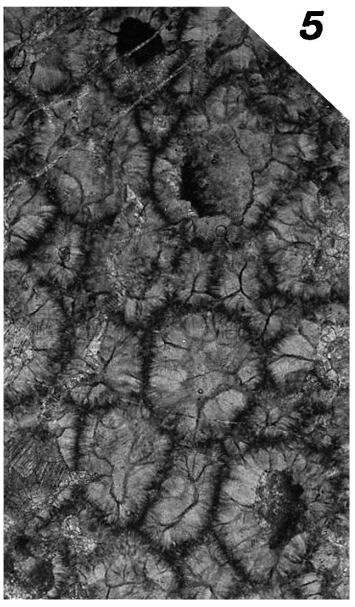
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Discussion: *Parastriatoporella arashimaensis* was described by Niko and Senzai (2011) from the Hakubado Member. Because the Fukuji specimens present no additional morphologic knowledge, see the preceding paper for a description of this species.

Suborder Alveolitina Sokolov, 1950

Family Coenitidae Sardeson, 1896

Genus ***Coenites*** Eichwald, 1829

Type species: *Coenites juniperinus* Eichwald, 1929.

Coenites kameii Niko and Senzai, 2010

(Figs. 8-1, 4, 7)

Coenites kameii Niko and Senzai, 2010, p. 54, 56, 57, figs. 12-1–12 [with earlier synonymy].

Material examined: Seven coralla, NMNS PA17300–17306.

Occurrence: The examined specimens of *Coenites kameii* were collected from an outcrop of calcareous shale at locality FH-1 (NMNS PA17300), and float brocks of black limestone (bioclastic wackestone; NMNS PA17301, 17302, 17305, 17306) and argillaceous limestone (NMNS PA17303, 17304) in the Kanashirozako Valley. They are derived from the Takaharagawa Member.

Discussion: The Fukuji specimens are clearly referable to *Coenites kameii* because they possess identical diameters of the branches and corallites, thickness of the intercorallite walls and similar mode of occurrence of the tabulae with those of the types from the Oisedani Member.

Order Auloporida Sokolov, 1947

Superfamily Syringoporoidea Fromentel, 1861

Family Syringoporidae Fromentel, 1861

Genus ***Syringopora*** Goldfuss, 1826

Type species: *Syringopora ramulosa* Goldfuss, 1826.

Syringopora sp. indet.

(Figs. 8-2, 3, 5, 6)

[?] *Syringopora* sp., Kamei, 1961, p. 4.

Material examined: Six coralla, NMNS PA17225–17230.

Description: Coralla phaceloid, consist of cylindrical corallites with circular to subcircular transverse sections; diameters of corallites relatively large, 2.3–3.8 mm; connecting tubuli probably rare, having 1.2–1.6 mm in diameter and approximately 2.5 mm (only a single instance) in length. Corallite walls 0.38–0.73 mm in thickness; septal spines well-developed, long attaining 0.42 mm; tabulae numerous, infundibuliform and form axial syrinxes in central to subcentral positions of corallites; diameters of axial syrinxes are 0.5–0.9 mm; septal spine like projections are also occur on tabulae.

Occurrence: Specimens of *Syringopora* sp. indet. were collected from float blocks of gray limestone (bioclastic wackestone to grainstone) at locality FH-7. They are derived from the middle part of the Takaharagawa Member.

Discussion: Relatively large diameters of the corallites of these specimens readily distinguish them from *Syringopora* sp. indet. (Senzai and Niko, 2007, p. 132, 133, figs. 2-1–4). The latter Kamianama species indicates approximately 1.0 mm in corallite diameter. The Fukuji specimens probably represent a new species, but their preservation is insufficient to identify with an existing species.

Fig. 7. *Parastriatoporella arashimaensis* Niko and Senzai, 2011, thin sections. **1**, **5**, **6**, NMNS PA17255. **1**, longitudinal section of branch, ×5. **5**, partial enlargement to show transverse sections of distal corallites, ×10. **6**, partial enlargement of Fig. 7-1, showing intercorallite wall structure, ×75. **2**, **3**, NMNS PA17261. **2**, transverse section of branch, ×5. **3**, partial enlargement to show longitudinal sections of distal corallites, ×10. **4**, NMNS PA17266, partial enlargement showing transverse sections of proximal corallites, ×10.

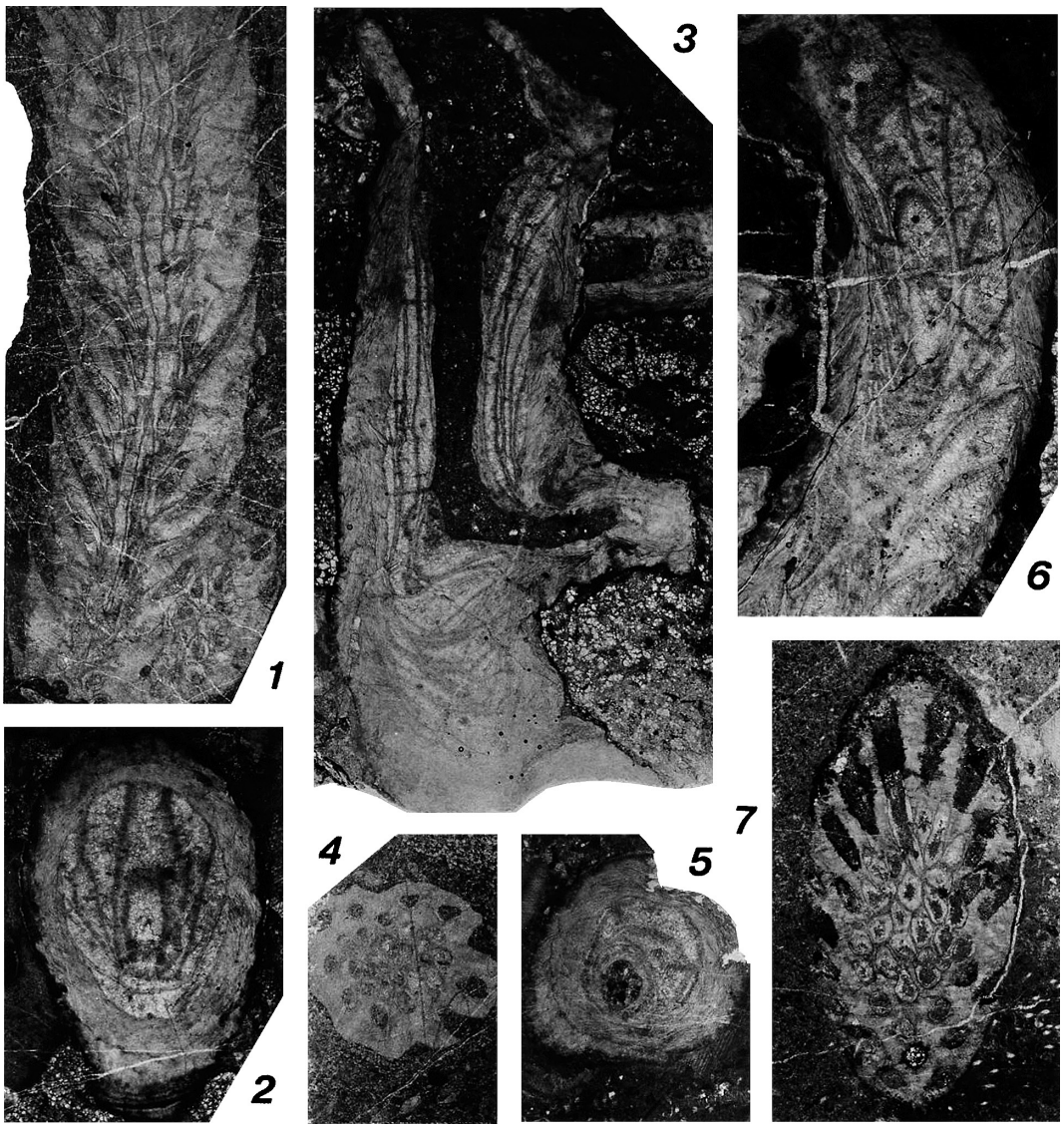

Fig. 8. **1**, **4**, **7**, *Coenites kameii* Niko and Senzai, 2010, thin sections. **1**, **4**, NMNS PA17304. **1**, longitudinal section of branch, ×10. **4**, transverse section of branch, ×10. **7**, NMNS PA17302, oblique section of branch, ×10. **2**, **3**, **5**, **6**, *Syringopora* sp. indet., thin sections. **2**, **3**, **5**, NMNS PA17225. **2**, oblique (near transverse) section of corallite, ×10. **3**, longitudinal section of corallite, ×10. **5**, transverse section of corallite, ×10. **6**, NMNS PA17226, oblique (near longitudinal) section of corallite, ×10.

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