

# Ludlow (Late Silurian) Pachyporid Tabulate Corals from the Suberidani Group, Tokushima Prefecture

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**Abstract** Early Ludlow (Late Silurian) pachyporids of tabulate corals are recognized from limestone of the lowest Suberidani Group in the Katura area, Tokushima Prefecture. This assemblage is composed of five species including two new taxa, namely *Hillaepora gionensis* Niko and Adachi, 1999, *Striatopora* sp. cf. *S. sugiyamai* Niko and Adachi, 1999, *Thamnopora senzaii* sp. nov., *T. suberidaniensis* sp. nov., and pachyporid, gen. et sp. indet. *Thamnopora senzaii* differs from other species of the genus in having the exceptionally slender branches, the numerous mural pores, and very rare occurrence of the tabulae. *Thamnopora suberidaniensis* is distinctive in its thin intercorallite walls for the genus. The Suberidani coral fauna indicates close faunal relationship with that in the G3 Member of the Gionyama Formation, Miyazaki Prefecture. The comparable forms were also reported from the Kawauchi Formation, Iwate Prefecture in Japan, and southern Siberia.

**Key words:** Ludlow (Late Silurian), tabulate corals, Pachyporidae, *Hillaepora*, *Striatopora*, *Thamnopora*, Suberidani Group, Tokushima

## Introduction

This paper concerns five species of pachyporids found in lower Ludlow (Upper Silurian) limestone of the lowest Suberidani Group as the second installment in a series describing the tabulate coral fauna of the group. The fossils studied here were discovered in float blocks from the two localities in the Katura area, Tokushima Prefecture, Southwest Japan (see fig. 1 in Niko, 2001). Detailed geographic settings of these localities are the river bed of the Miyaga-tani Valley (locality KT-8) and vicinity of an abandoned quarry in the Chouzuga-dani Valley (locality KT-9), latter of which is identical with the type locality of an auloporid coral *Aulocystis okitsui* Niko, 2001. The abbreviation NSM for the repository stands for the National Science Museum, Tokyo.

## Systematic Paleontology

Order Favositida Wedekind, 1937

Suborder Favositina Wedekind, 1937

Superfamily Pachyporicae Gerth, 1921

Family Pachyporidae Gerth, 1921

Genus *Hillaepora* Mironova, 1960

*Type species:* *Hillaepora spica* Mironova, 1960.

*Hillaepora gionensis* Niko and Adachi, 1999

(Figs. 1-5, 6)

*Hillaepora gionensis* Niko and Adachi, 1999, p. 112, figs. 1-1-5.

*Material examined:* Fourteen coralla, NSM PA15329–15342.

*Remarks:* See Niko and Adachi (1999) for a full treatment of this species. The type material occurs from the lower Ludlow G3 Member of the Gionyama Formation in Miyazaki Prefecture, southern Japan. The Suberidani coral fauna is most closely related to that of the G3 Member. This species and *Aulocystis okitsui* are only known in these faunas.

*Occurrence:* Dark gray limestone pebbles in limestone conglomerate from locality KT-8:

NSM PA15341, 15342. Brecciated reddish to light gray limestone from locality KT-8(?): NSM PA15337–15340. Brecciated reddish to light gray limestone from locality KT-9: NSM PA15329–15336.

Genus *Striatopora* Hall, 1851

*Type species: Striatopora flexuosa* Hall, 1851.

*Striatopora* sp. cf. *S. sugiyamai* Niko and Adachi, 1999

(Figs. 1-1-4)

*Compare:*

*Striatopora* sp., Adachi and Niko, 1996, p. 70, figs. 4-3, 4. *Striatopora sugiyamai* Niko and Adachi, 1999, p. 114, 116, figs. 2-1-7; 3-1.

*Material examined:* Seven coralla, NSM PA15343–15349.

*Description:* Coralla ramose with cylindrical branches having 1.7–4.0 mm with 2.8 mm mean in diameter, cerioid. Corallites prismatic, range from 0.52 to 0.77 mm in diameter near calical rim; each corallite consists of gradually divergent proximal portion and outwardly curved distal portion; most proximal corallites form stellate structure in axis of branch; calical opening is obliquely upward to nearly perpendicular to surface of branch, with 42°–89° in angle. Abruptly thickening of intercorallite walls in distal portion of corallites to form wide peripheral stereozone; mural pores well-developed, but small in diameter; no apparent septal spine observable; tabulae relatively rare, complete.

*Discussion:* This species compares well with the type material of *Striatopora sugiyamai* from the upper Wenlock (Lower Silurian) G2 to G3 Members of the Gionyama Formation, but has larger branch diameter (approximately 2.8 mm versus usually 1.6–2.3 mm in the Gionyama

specimens), somewhat fewer mural pores, and larger angle of the calical opening (42°–89° versus usually 40°–50° in the Gionyama specimens). These differences are not taken to be sufficient to merit recognition of a new species, because they may be the result of gerontic developments or ecophenotypic variations in *Striatopora sugiyamai*.

*Occurrence:* Brecciated reddish limestone from locality KT-8: NSM PA15346. Brecciated reddish to light gray limestone from locality KT-9: NSM PA15343–15345, 15347, 15348, 15349.

Genus *Thamnopora* Steininger, 1831

*Type species: Thamnopora madreporacea* Steininger, 1831.

*Thamnopora senzaii* sp. nov.

(Figs. 2-1-9; 4-6-8)

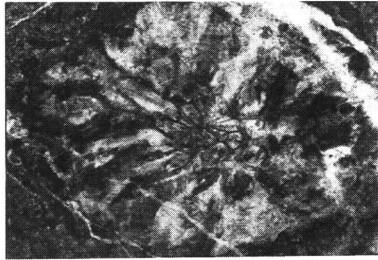
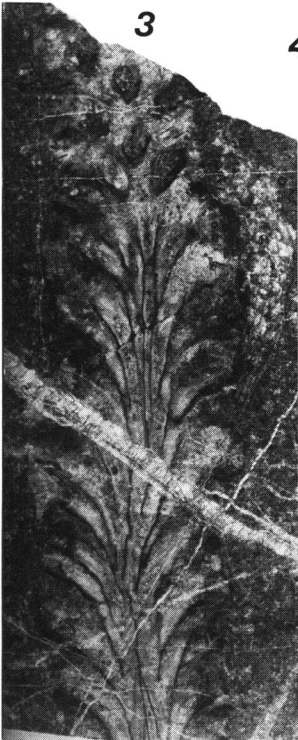
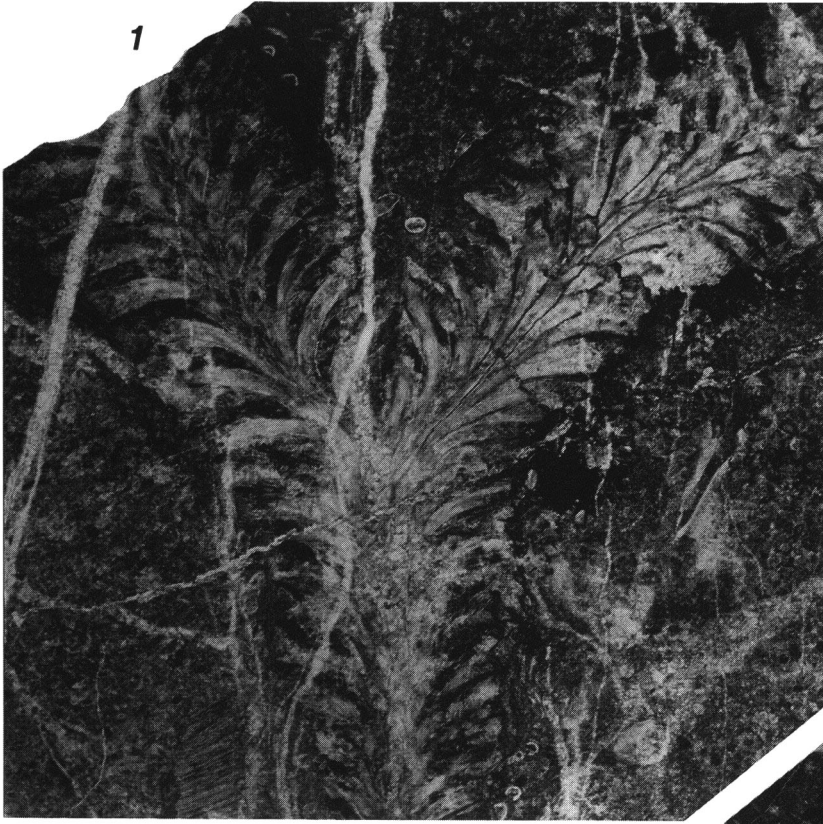
*Holotype:* NSM PA15356, from which 33 thin sections were made.

*Other specimens:* Seven thin sections were studied from the six paratypes, NSM PA15352, 15354, 15355, 15358, 15360, 15363. In addition, eight specimens, NSM PA15350, 15351, 15353, 15357, 15359, 15361, 15362, 15364, were also examined.

*Diagnosis:* Species of *Thamnopora* with exceptionally slender branches, approximately 2.2 mm in diameter and very rare branching; corallite diameters approximately 0.49 mm near calical rim; opening angle of calice usually 50°–70°; intercorallite walls attain 0.21 mm in thickness; transverse sections of calical pits are rounded; mural pores numerous, mostly elliptical; septal spines well-developed, but short; tabulae very rare.

*Description:* Coralla ramose with cylindrical, exceptionally slender branches for genus, diameters of branches range from 1.4 to 3.0 mm

Fig. 1. 1–4, *Striatopora* sp. cf. *S. sugiyamai* Niko and Adachi, thin sections. 1, 3, 4, NSM PA15343. 1, 3, longitudinal sections of branches,  $\times 10$ . 4, transverse section of branch,  $\times 10$ . 2, NSM PA15345, longitudinal section of branch,  $\times 10$ . 5, 6, *Hillaepora gionensis* Niko and Adachi, thin sections. 5, NSM PA15337, oblique sections of branches,  $\times 10$ . 6, NSM PA15332, longitudinal section of branch,  $\times 10$ .



with 2.2 mm mean, cerioid; branching very rare, bifurcate; total corallum diameter and growth form unknown owing to fragile nature. Corallites prismatic with indistinct 4–7 sides (or *Antherolites*-like sub-stellate in rare cases) in transverse section; there are 27–72 corallites in transverse section of branch; corallite diameters range from 0.17 to 0.54 mm with 0.49 mm mean near calical rim; each mature corallite consists of narrowly divergent proximal portion, that forms axial and main zones of branch, and outwardly directed distal portion forming deep calice; calical opening obliquely upward with 41°–80°, usually 50°–70°, in angle to surface of branch; tabularia subcircular to indistinct polygonal in transverse section, then shift rounded calical pits of 0.31–0.38 mm in diameter; increase of new corallites lateral, frequently occurs in axial and main zones of branch. Intercorallite walls thick as compared with corallite diameter, uniformly thickened in each growth stages, range from 0.05 to 0.21 mm in thickness, structurally differentiated into median dark line and stereoplasm; microstructure of stereoplasm not preserved; peripheral stereozone lacking; mural pores numerous, elliptical or sub-circular in rare cases, large as compared with corallite size, approximately 0.10×0.17 mm in diameter in typical one, occur on faces and at edges of corallite prisms; septal spines well-developed, but short, approximately 0.02 mm in length of protruded part into tabularium; tabulae very rare, complete, weakly sagging (concave proximally) in profile.

*Discussion:* The assignment of this Suberidani species to *Thamnopora* is based upon the rounded calical pits and the uniformly thickened intercorallite walls whose respects draw a distinction between the present form and *Cladopora* Hall (1851; type species, *C. seriata* Hall, 1851, p. 400 [nomen nudum], 1852, p. 137, 138, pl. 38,

figs. 1a–m; Oliver, 1963, p. G-6, pl. 5, figs. 1–4) and absence of the frequent joining of the branches to form a reticulate corallum that is a diagnostic feature of *Gracilopora* Chudinova (1964; type species, *G. acuta* Chudinova, 1964, p. 32, 33, pl. 11, figs. 1a, b, v, g). Until now, *Thamnopora* sp. from the Lower Devonian Fukuji Formation, Gifu Prefecture in Obata (ed., Seibido Handy Library. Japanese Fossils, 1993, p. 38) was a solely known record of the genus in Japan.

The exceptionally slender branches and numerous mural pores distinguish *Thamnopora senzaii* sp. nov. from other Silurian species of the genus. An early Early Devonian species *Thamnopora kamysheensis* Mironova (1974, p. 71, pl. 12, fig. 1, pl. 41, figs. 1a, b) from Altai (the basin of the upper stream of the River Ob') in southern Siberia also has the relatively slender branches (approximately 3–5 mm) for the genus and the well-developed mural pores. However, the Siberian species differs from *Thamnopora senzaii* in having more frequent occurrence of the tabulae. The distinctive features between *Thamnopora senzaii* and *T. suberidaniensis* sp. nov. (this report) are given in the discussion of the latter species.

*Etymology:* The specific name honors Mr. Yoshihito Senzai, who discovered the holotype of this coral.

*Occurrence:* Dark gray limestone pebble in limestone conglomerate from locality KT-8: NSM PA15363. Brecciated reddish to light gray limestone from locality KT-9: NSM PA15350–15362, 15364.

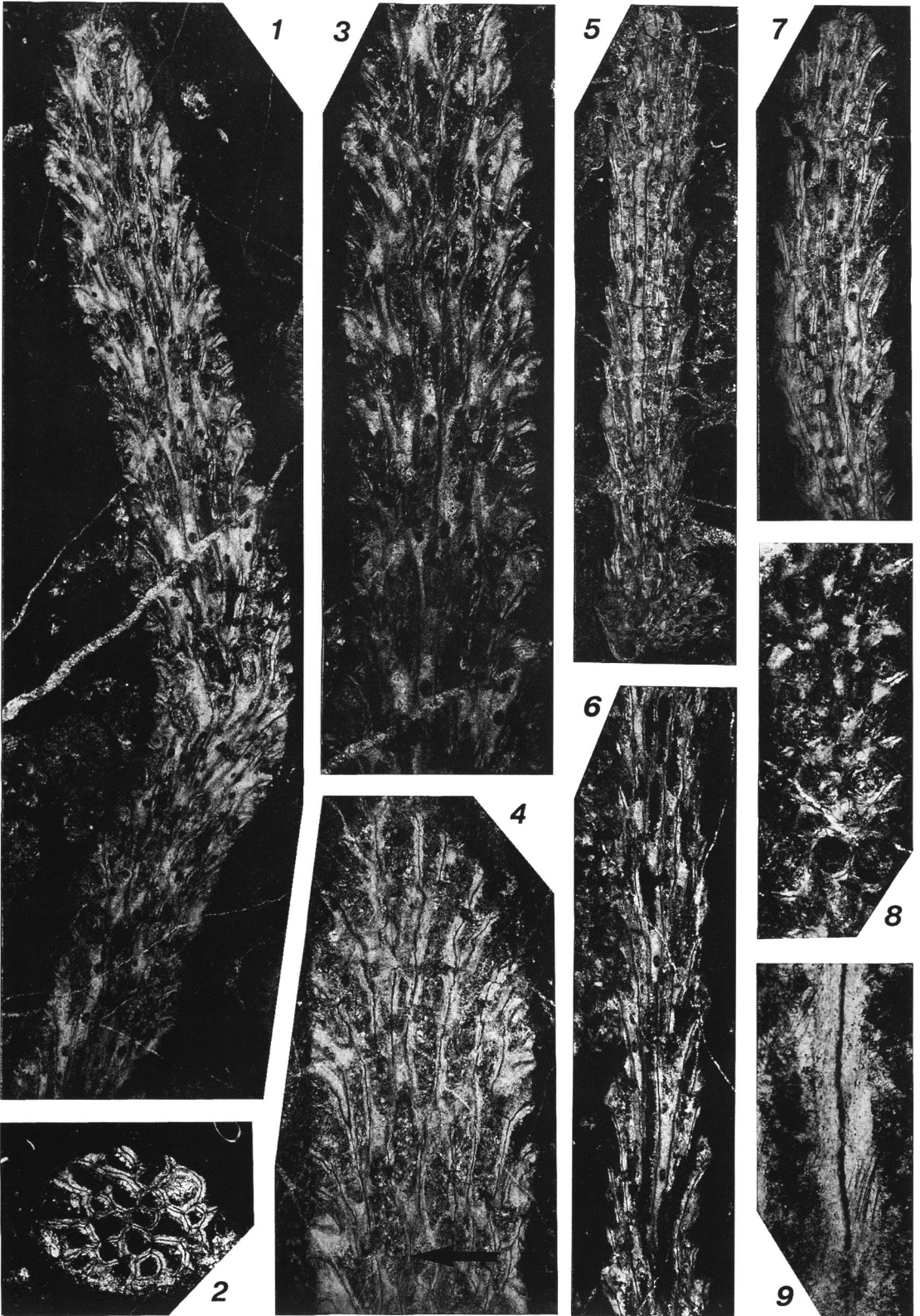
***Thamnopora suberidaniensis* sp. nov.**

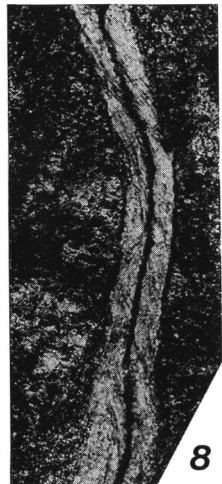
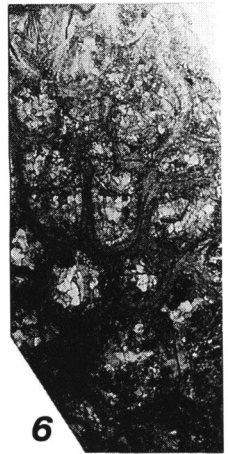
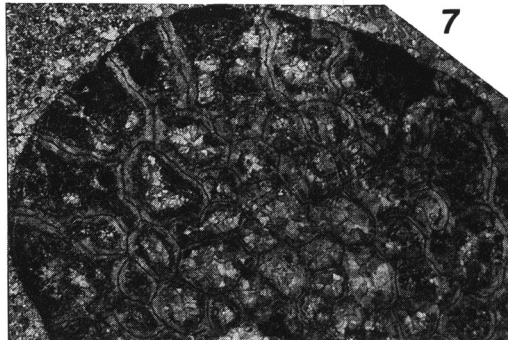
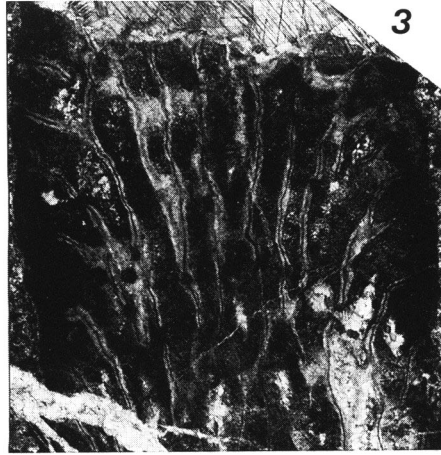
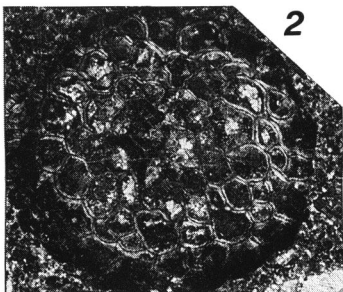
(Figs. 3-1–8)

*Holotype:* NSM PA15368, from which five

Fig. 2. *Thamnopora senzaii* sp. nov., thin sections. 1–4, 7–9, holotype, NSM PA15356. 1, longitudinal section of branch, ×10. 2, transverse section of branch, ×10. 3, partial enlargement of Fig. 2-1, ×14. 4, longitudinal section of branch, arrow indicates tabula, ×14. 7, longitudinal section of branch, ×10. 8, transverse to oblique sections of corallites near calical rim, ×14. 9, partial enlargement to show intercorallite wall structure, ×100. 5, paratype, NSM PA15354, longitudinal section of branch, ×10. 6, paratype, NSM PA15360, longitudinal section of branch, ×10.







thin sections were made.

*Other specimens:* Eleven thin sections were studied from the three paratypes, NSM PA15367, 15369, 15370. In addition, a specimen of questionably assigned to this species, NSM PA15366, was also examined.

*Diagnosis:* Species of *Thamnopora* with relatively slender branches, approximately 4.2 mm in diameter; diameters of corallites attain 1.08 mm; opening angle of calices  $56^{\circ}$ – $75^{\circ}$ ; intercorallite walls thin, 0.13–0.15 mm, thus calical pits are indistinct polygonal in transverse section; mural pores well-developed, subcircular; septal spine may be absent; tabulae common, variable in profile, contain strongly oblique ones.

*Description:* Coralla may be ramose composed of cylindrical, relatively slender branches for genus having 3.5–4.6 mm with 4.2 mm mean in diameter, cerioid; branching point not observable in examined specimens; total corallum diameter and growth form unknown owing to fragile nature. Corallites prismatic with 4–8 sides (or *Antherolites*-like sub-stellate, fan-shaped in rare cases) in transverse section; there are 71–83 corallites in transverse section of branch; corallite diameters variable in size even near calical rim, range from 0.23 to 1.08 mm; each corallite consists of narrowly divergent proximal portion, that forms axial and main zones of branch, and outwardly directed distal portion forming deep calice; calical opening obliquely upward with  $56^{\circ}$ – $75^{\circ}$  in angle to surface of branch; tabularia indistinct polygonal to subcircular, or sub-stellate, fan-shaped in rare cases, in transverse section, then shift indistinct polygonal (usually 6 sided) calical pits of 0.27–0.92 mm in diameter; increase of new corallites lateral, frequently occurs in axial and main zones of branch. Intercorallite walls relatively thin as compared with corallite diameter, structurally differentiated into median dark line and stereoplasm; thickening

gradually toward surface of branch, but apparent peripheral stereozone lacking; thickness of intercorallite walls ranges from 0.13 to 0.15 mm; microstructure of stereozone not preserved; mural pores well-developed, subcircular with approximately 0.13 mm in diameter, occur on faces and at edges of corallite prisms; septal spine may be absent; tabulae common, variable in profile, weakly sagging (concave proximally), nearly flat to strongly oblique to corallites.

*Discussion:* The intercorallite walls do not show sufficiently thickened to assign this new taxon to *Thamnopora*. However, I think that *Thamnopora* is referable to similar genera including *Cladopora*, *Dendrofavosites* (Rukhin, 1937; type species, *Favosites digitatus* Rominger, 1876, p. 39, 40, pl. 15, figs. 1–3; Stumm and Tyler, 1964, p. 26, 27, pl. 1, figs. 4, 5, pl. 3, figs. 3, 4, pl. 4, figs. 4–6, pl. 6, figs. 5, 6), and *Guizhoustriatopora* (Chow in Yang, Kim and Chow, 1978; type species, *G. dushanensis* Chow in Yang, Kim and Chow, 1978, p. 192, pl. 70, figs. 8a–c) as its genus designation. The most characteristic feature of *Cladopora* and *Guizhoustriatopora* is the lozenge-shaped calices which are not developed in the Suberidani species. Form *Dendrofavosites* it can be distinguished in absence of the “squamulae” and/or incomplete tabulae.

With the exception of relatively thin intercorallite walls in compression with corallite size, *Thamnopora suberidaniensis* sp. nov. differs from *T. senzaii* (this report) in having the larger branch diameter (approximately 4.2 mm versus approximately 2.2 mm in *T. senzaii*), the larger corallite diameter near calical rim (attaining 1.08 mm versus approximately 0.49 mm in *T. senzaii*), subcircular mural pores, and commonly developed tabulae. In addition, septal spine may be absent in *Thamnopora suberidaniensis*. “*Coenites*” *triangularis* Sugiyama (1940, p. 133, pl. 21, figs.

Fig. 3. *Thamnopora suberidaniensis* sp. nov., thin sections. 1–3, 8, holotype, NSM PA15368. 1, longitudinal section of branch,  $\times 10$ . 2, transverse section of branch,  $\times 10$ . 3, partial enlargement of Fig. 3-1,  $\times 14$ . 8, partial enlargement to show intercorallite wall structure,  $\times 100$ . 4–6, paratype, NSM PA15367. 4, 5, longitudinal sections of branch,  $\times 14$ . 6, transverse sections of corallites, near calical rim,  $\times 14$ . 7, paratype, NSM PA15370, transverse section of branch,  $\times 14$ .



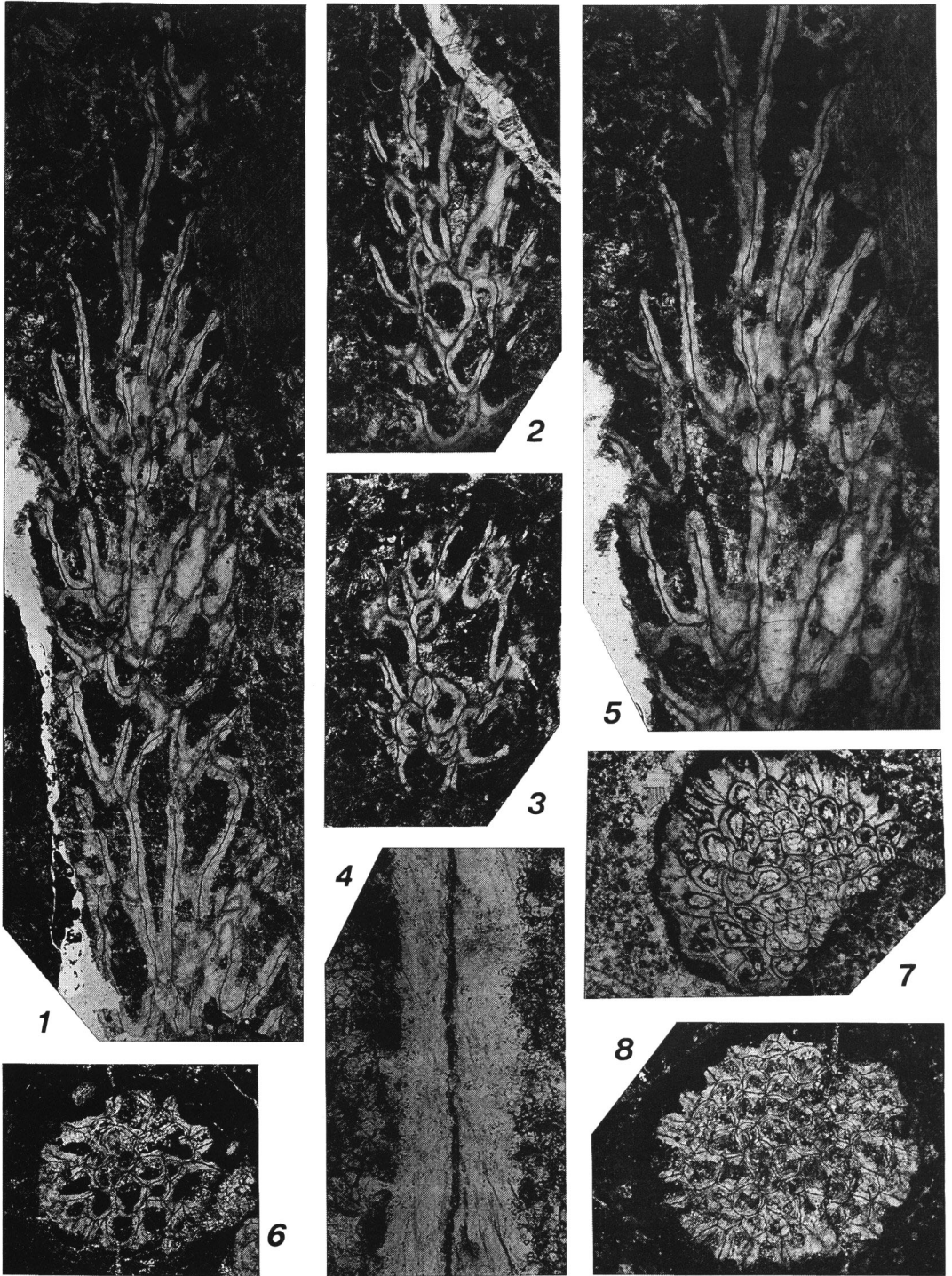


Fig. 4. 1–5, pachyporid, gen. et sp. indet., thin sections, NSM PA15365. 1, longitudinal (but slightly off axis) section of branch,  $\times 10$ . 2, oblique section of branch,  $\times 10$ . 3, oblique (near transverse) section of branch,  $\times 10$ . 4, partial enlargement to show intercorallite wall structure,  $\times 100$ . 5, partial enlargement of Fig. 4-1,  $\times 14$ . 6–8, *Thamnopora senzaii* sp. nov., thin sections. 6, 8, holotype, NSM PA15356, transverse sections of branches,  $\times 14$ . 7, paratype, NSM PA15363, transverse section of branch,  $\times 14$ .

3–5) from the Wenlock to Ludlow *Halysites*-limestone of the Kawauchi Formation, Iwate Prefecture, Northeast Japan is easily separated from *Thamnopora suberidaniensis* in that the former has the V-shaped or somewhat triangular in outline of the calices.

*Etymology*: The specific name is derived from the type stratum named the Suberidani Group.

*Occurrence*: Dark gray limestone pebbles in limestone conglomerate from locality KT-8: NSM PA15367–15370. Brecciated light gray limestone from locality KT-8(?): NSM PA15366.

Pachyporid, gen. et sp. indet.

(Figs. 4-1–5)

*Material examined*: A single corallum, NSM PA15365.

*Description*: Cylindrical branch of 3.2 mm in maximum diameter, cerioid. Corallites prismatic, narrowly divergent through all growth stages, 0.40–0.96 mm in diameter near calical rim; calices to open upwardly with relatively small angle, usually 25°–48°, to surface of branch. Intercorallite walls thick, attaining 0.23 mm in thickness, differentiated into median dark line and stereoplasm; mural pores well-developed on faces (and at edges?) of corallite prisms, elliptical; septal spines short, commonly developed; tabula is not detected.

*Discussion*: The description above is based on the longitudinal (but slightly off axis of branch) and the oblique sections made from a single specimen. Without well-oriented section, adequate discrimination and characterization of this species is impossible.

*Occurrence*: Brecciated reddish limestone from locality KT-9.

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