Bull. Natl. Mus. Nat. Sci., Ser. C, **35**, pp. 39–51, December 22, 2009

Middle Permian Tabulate Corals from the Akasaka Limestone, Gifu Prefecture

Shuji Niko

Department of Environmental Studies, Faculty of Integrated Arts and Sciences, Hiroshima University,
1–7–1 Kagamiyama, Higashihiroshima, Hiroshima 739–8521, Japan
E-mail: niko@hiroshima-u.ac.jp

Abstract Three species of the Capitanian (late Middle Permian) tabulate corals of the order Auloporida are described from the Akasaka Limestone, Gifu Prefecture, Central Japan. They include the aulocystid auloporoids *Pseudoromingeria kotoi* (Yabe and Hayasaka, 1915b) and *P. ignicula* sp. nov., and a roemeriid syringoporoid *Akasakapora masutomii* gen. et sp. nov. *Pseudoromingeria* Yabe and Sugiyama, 1941 and *Sinopora* Sokolov, 1955 are synonymized. Because of *Sinopora* is the type genus of the family Sinoporidae Sokolov, 1955, this family in consequence becomes a junior subjective synonym of the preoccupied family Aulocystidae Sokolov, 1950. *Akasakapora* is the youngest representative of roemeriid that is characterized by having ramose corallum, frequently anastomosed branches, partially separated corallites, infundibuliform tabulae, axial or eccentric syrinxes and lamellar microstructure in stereoplasm, and lacking of distinct peripheral stereozone. Among the known genera of roemeriids, the new genus has close relationship with an Early Permian genus *Bayhaium* Langenheim and McCutcheon, 1959 from the accreted terrane in California. They may be the relics of the family survived in a tropical marine condition of the Panthalassa Ocean.

Key words: Capitanian (late Middle Permian), tabulate corals, *Akasakapora* gen. nov., *Pseudoromingeria*, *Sinopora*, Akasaka Limestone, Gifu.

Introduction

Tabulate coral specimens described in this paper were derived from the Middle to Upper Permian Akasaka Limestone (Koto, 1898) in Akasaka-cho of Ogaki, Gifu Prefecture, Central Japan. The limestone is an allochthonous block in the Jurassic accretionary complex of the Mino Terrane and estimated to be 250 m thick. Four lithostratigraphic units, namely the Lower, Middle, Upper, and Uppermost Members, were established by Wakimizu (1902), Akasaka Research Group (1956), Sakagami (1980), Ishii *et al.* (1981). Among them, the Upper Member consists mainly of well-stratified black limestones (bioclastic wackestone) that yield a rich and diverse marine biota with the present corals. According to biostratigraphic researches by Ozawa (1927) and more recently by Ozawa and Nishiwaki (1992), the member ascribes to the *Yabeina globosa* fusulinacean zone of a Capitanian (late Middle Permian) age.

Based on paleomagnetic inclinations, Hattori and Hirooka (1979) revealed that the limestone-greenstone complexes of the Mino Terrane including the Akasaka Limestone formed in an equatorial region. This paleogeographic reconstruction has been supported by the paleontologic analyses of foraminifers (Ishii *et al.*, 1985; Ozawa, 1987; Kobayashi, 1997) and brachiopods (Tazawa, 1997). The present tabulate coral assemblage consists of *Pseudoromingeria kotoi* (Yabe and Hayasaka, 1915b), *P. ignicula* sp. nov., and *Akasakapora masutomii* gen. et sp. nov. They probably represent a tropical tabulate coral fauna of the western Panthalassan province (Ross and Ross, 1990; Zaw Win, 2000) in late Middle Permian.

The following institutional abbreviations are used: IGPS, Institute of Geology and Paleontology, Tohoku University, Sendai; KFM, Kinshozan Fossil Museum (Kaseki-kan), Ogaki; NSM, National Science Museum, Tokyo.

Systematic Paleontology

Order Auloporida Sokolov, 1947

Superfamily Auloporoidea Milne-Edwards and Haime, 1851

Family Aulocystidae Sokolov, 1950

[including Family Sinoporidae Sokolov, 1955]

Discussion: Because sparsity of the tabulae in *Sinopora* Sokolov, 1955 considered as one of the important criteria for higher level taxonomic classification, Sokolov (1955) proposed Sinoporidae as a new auloporid family based on the genus. As discussed below, the morphologic characters including tabula nature of *Sinopora* fall within those of an aulocystid genus *Pseudoromingeria* Yabe and Sugiyama, 1941. Sinoporidae is thus best maintained as a junior subjective synonym of the preoccupied family Aulocystidae.

Genus ***Pseudoromingeria*** Yabe and Sugiyama, 1941

Pseudoromingeria Yabe and Sugiyama, 1941, p. 379–382; Hill, 1981, p. F642, 643; Lin *et al*., 1988, p. 286; Niko, 2001, p. 16, 17.

Sinopora Sokolov, 1955, p. 226; Hill, 1981, p. F644; Lin *et al*., 1988, p. 288.

Type species: *Romingeria*? *kotoi* Yabe and Hayasaka, 1915b.

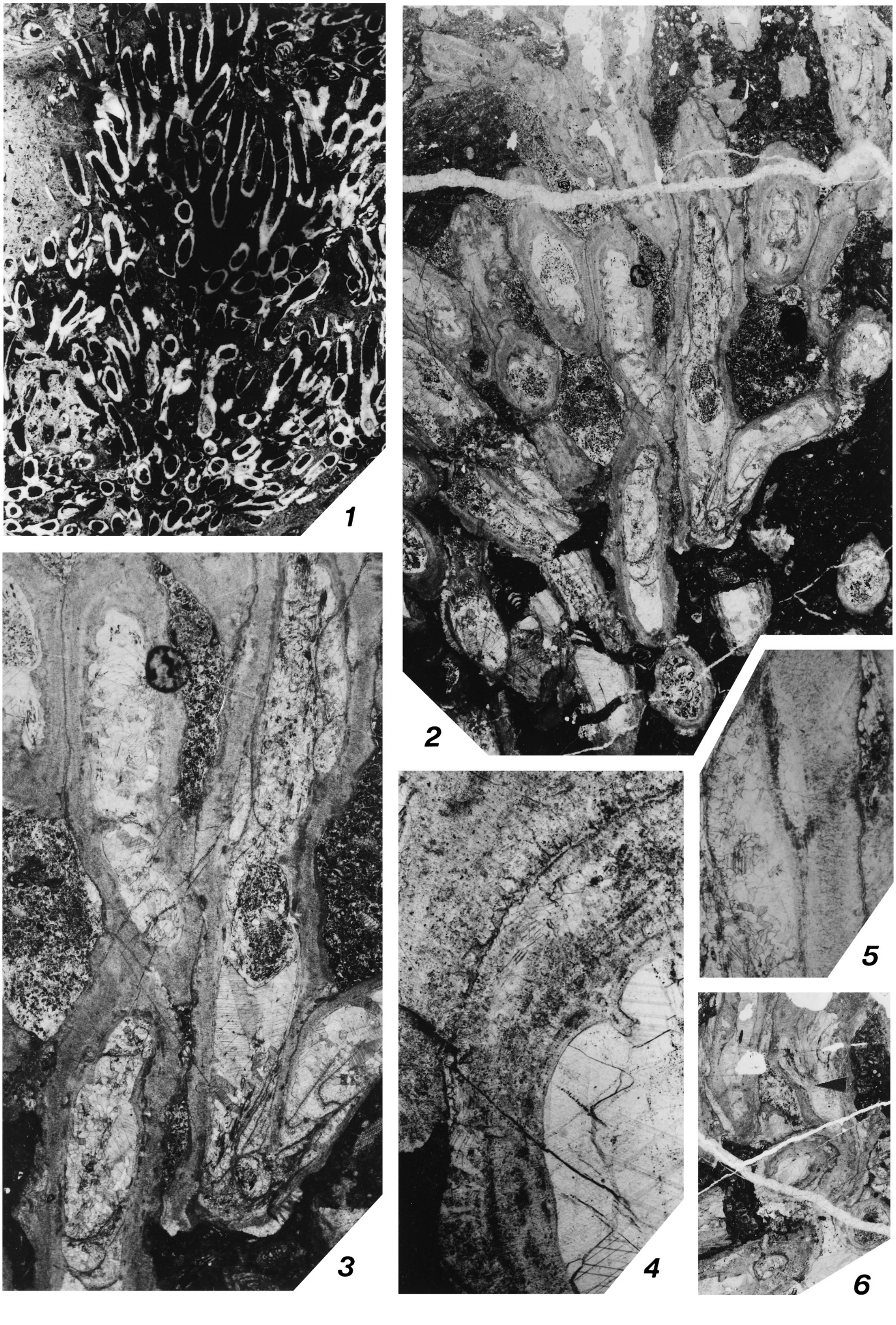
Emended diagnosis: Coralla phaceloid with partial subcerioid portions including lacunae to phacelo-cerioid; lax mass with adhered corallites forms indistinct branches, thus some specialized species indicate subramose appearance; prostrate in early stages; increase lateral; without connecting tubule. Corallites moderate to relatively slender for Aulocystidae; corallite (intercorallite) walls thick to exceptionally thick; mural pores rarely developed in cerioid portion; septal spines common to numerous; spacing of tabulae variable ranging almost absent to crowded; both complete and incomplete tabulae occur; the latter ones indicate infundibuliform, oblique, dissepiment-like or concave; infundibuliform tabulae partly form indistinct axial syrinx.

Discussion: Reexamination of the holotype (IGPS 8232) of the generic type species confirms that *Pseudoromingeria kotoi* has the two different morphologic features in an identical corallum. They are type-1: phaceloid with cylindrical corallites where tabulae are absent to sparse, and type-2: subcerioid with partially adhered corallites including relatively wide lacunae. The usual tabulae in the latter feature are crowded and infundibuliform. Although the morphologic type-2 was previously emphasized in *Pseudoromingeria*, the subcerioid portions are not principal. If the material is not sufficient, investigators may perhaps overlook the feature. The diagnosis of *Sinopora* Sokolov, 1955, based on *Monilopora dendroidea* Yoh *in* Yoh and Huang (1932, p. 10–12, pl. 2, figs. 3, 4) from the Lower Permian Chihsia Limestone in southeastern Anhui, South China, indicates a close affinity with that of the morphologic type-1. There is a high possibility that the generic concept of *Sinopora* forms a part of the generic diagnosis of *Pseudoromingeria* indicating wide variation. The both genera, therefore, are synonymized herein.

Pseudoromingeria kotoi (Yabe and Hayasaka, 1915b)

(Figs. 1-1–6; 2-1–5)

Fig. 1. *Pseudoromingeria kotoi* (Yabe and Hayasaka), holotype, IGPS 8232. **1**, longitudinal polished section of corallum, ×5. **2**, longitudinal to transverse thin sections of corallites, ×5. **3**, partial enlargement of Fig. 1-2, note adhered corallites and crowded tabulae, ×10. **4**, partial enlargement of transverse thin section of corallite to show corallite wall structure and septal spine, ×25. **5**, partial enlargement of Fig. 1-2 to show corallite wall structure and dissepiment-like tabulae, ×25. **6**, longitudinal to transverse sections of corallites, arrow indicates increase of new offset, ×5.


1
2
3
4
5
6

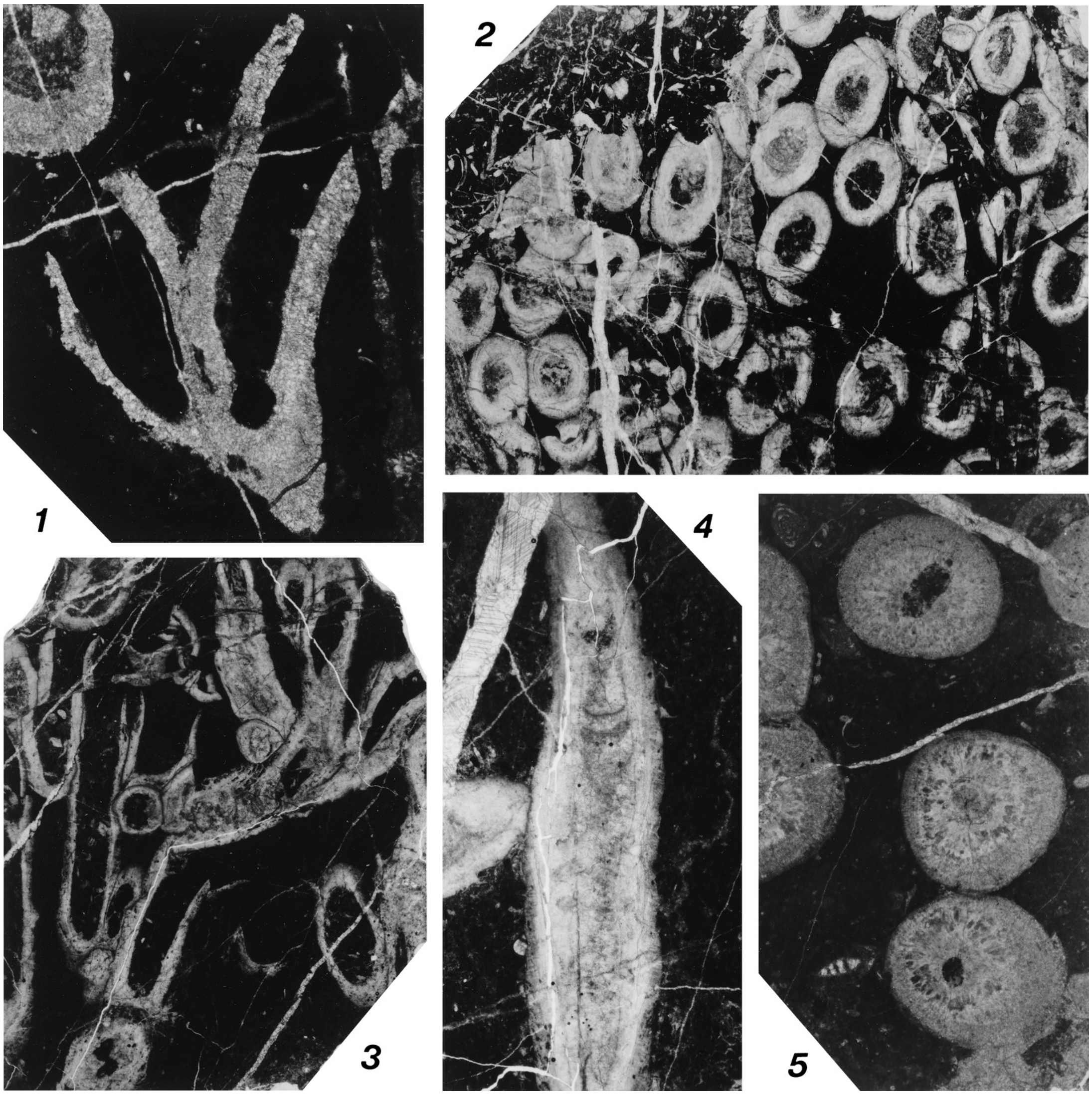


Fig. 2. *Pseudoromingeria kotoi* (Yabe and Hayasaka), thin sections. **1**, NSM PA16698, longitudinal and transverse sections of corallites, ×10. **2**–**4**, NSM PA16701. **2**, transverse section of corallum, ×5. **3**, longitudinal section of corallum, ×5. **4**, longitudinal section of corallite, note complete tabulae, ×10. **5**, NSM PA16699, transverse sections of corallites, note thickened corallite walls, ×10.

[?] *Syringopora*? sp., Yabe, 1904, p. 17.
Romingeria? *kotoi* Yabe and Hayasaka, 1915b, p. 85, 86.
Pseudoromingeria kotoi (Yabe and Hayasaka); Yabe and Sugiyama, 1941, p. 379–382, figs. 1–3; Hashimoto, 1981, figs. 4-3, 4; Hill, 1981, figs. 439-2a, b; Lin *et al*., 1988, figs. 334-a–c; Makiguchi, 1995, p. 66, pl. 7, fig. 2.
[non] Cf. *Pseudoromingeria kotoi*; Yabe and Sugiyama, 1941, p. 382, fig. 4 [see Niko, 1999, p. 38].
[partium] *Pseudoromingeria kotoi*; Minato, 1955, p. 186, pl. 43, figs. 1, 4 [non pl. 17, fig. 3, see Niko, 1999, p. 38].
Syringopora? sp., Obata (ed.), 1994, p. 108.
Sinopora sp., Kamiya and Niko, 1995, p. 23, figs. 1–4.

Material examined: IGPS 8232 (holotype); NSM PA16698–16701.

Emended diagnosis: Coralla phaceloid with subcerioid portions that composed of lax mass of adhered corallites; corallite diameters approximately 2.1 mm; corallite walls have 0.23–1.17 mm in thickness; septal spines common; dissepiment-like tabulae well developed; infundibuliform, oblique and concave ones also occur.

Description: Coralla domical attaining 190 mm in diameter and 85 mm in height in the largest specimen (NSM PA16701), composed of phaceloid portion with cylindrical corallites and less frequent subcerioid one that consists lax mass of partially adhered corallites including relatively wide lacunae; connecting tubule absent; early growth stages are prostrate and *Cladochonus*-like. Diameters of cylindrical corallites range from 0.7 to 2.8 mm, usually 1.5–2.4 mm with 2.1 mm mean; spacing of phaceloid corallites is relatively close for the genus, usually 2.5–4.5 mm in center-to-center distance; transverse sections of corallites are circular to subcircular in phaceloid portion and subcircular to rarely subpolygonal in subcerioid one; calices deep, lacking calical modification or indicating weak inflation; increase of new corallites lateral with a single to multiple offset(s), common to frequent. Corallite walls very thick to exceptionally thick, usually range from 0.23 to 0.61 mm, rarely thickened to 1.17 mm; intercorallite wall thickness between adhered corallites attains 1.67 mm; constituents of corallite walls are epitheca and stereoplasm, the latter of which indicates lamellar structure, but rect-radiate fibers of primarily microstructure are rarely preserved; septal spines common, needle-like, rod-like to high-conical with 0.19–0.38 mm in length of protruded portion; tabularia (lumina) are narrowed by corallite (or intercorallite) wall thickening; ratios of tabularium diameter per corallite diameter usually 0.48–0.70, this ratio decreases to approximately 0.1 in rare cases; shape and spacing of tabulae are variable; they are usually absent or very rare, but crowded tabulae are recognized in part, complete with sagging profiles or incomplete; crowded tabulae apt to develop in subcerioid portion; dissepiment-like tabulae most common, in addition infundibuliform, oblique and concave ones are also developed; there are 0–6 tabulae in 5 mm of corallite length; crowded infundibuliform tabulae form indistinct axial syrinx.

Detailed fossil locality: Ohkubo on the southern foot of Mt. Kinsho-zan (NSM PA16698, 16699); unknown (IGPS 8232; NSM PA16700, 16701).

Discussion: In the specific level, *Pseudoromingeria kotoi* is easily distinguished from *P. dendroidea*, and two previously known species of the genus in Japan, namely *P. ryozensanensis* (Niko, 2001, p. 20, 22, figs. 3-5; 4-1–6) from the Lower Permian Ryozensan Limestone, Shiga Prefecture, and a Middle Permian specimen figured by Konishi (1960, p. 325, 327, text-figs. 1, 2) as *Sinopora dendroidea* from the *Yabeina* zone of the Zenbutujidani Formation in the Taishaku Limestone Group, Hiroshima Prefecture, by its larger corallite diameters (approximately 2.1 mm versus "average diameter of corallites about 1.5 mm" in *P. dendroidea*, 1.3–1.7 mm in *P. ryozensanensis*, and average of 1.66 mm in the Taishaku specimen).

Pseudoromingeria ignicula sp. nov.

(Figs. 3-1–6)

[partium] *Pseudofavosites* sp., Tokai Fossil Society, 1974, pl. 7 figs. 2–4 [non pl. 7, fig. 1]

Holotype: NSM PA16702, from which three thin sections were made.

Other specimens: Ten thin sections were studied from the five paratypes, NSM PA16703–16705, 16707, 16708. In addition, a poorly preserved specimen, NSM PA16706, was also examined.

Diagnosis: Coralla subramose, phacelo-cerioid with approximately 7 to 16 mm in branch diameter; distal ends of most corallites became free, forming relatively narrow phaceloid portion; corallite diameters approximately 1.9 mm; intercorallite walls 0.23–0.79 mm in thickness; septal spines well-developed; usual tabulae complete and sagging; incomplete tabulae rare, concave or dissepiment-like.

Description: Coralla subramose with indistinct and somewhat irregularly shaped to nearly cylindrical branches, phacelo-cerioid; total corallum shape and size are unknown; largest specimen (paratype, NSM PA16704) is 60 mm in diameter and 65 mm in height; bifurcation of branches common; branch diameters are variable ranging from approximately 7 to 16 mm; narrow lacunae commonly developed in cerioid portions; connecting tubule absent. Distal ends of most corallites became free and cylindrical that form relatively narrow phaceloid portion; in cerioid portions, profiles of corallites are subpolygonal, semicircular to fan-shaped profiles; corallite diameters are 0.8–2.4 mm with 1.9 mm mean; calices deep, indicating weak inflation and open obliquely upward with 25º–40° in usual angle to branch axis; increase of new corallites lateral, common. Intercorallite walls mostly very thick, range from 0.23 to 0.79 mm, consist of median dark line (fused epitheca) and stereoplasm; corallite walls in phaceloid portions are 0.27–0.38 mm in thickness; stereoplasm has lamellar structure, but rect-radiate fibers are partly preserved as primarily microstructure; mural pores very rarely developed, approximately 0.25 mm in diameter; septal spines well-developed, low to high conical to rod-like with 0.21–0.29 mm in length of protruded portion; tabularia (lumina) are narrowed by intercorallite (or corallite) wall thickening; ratios of tabularium (lumen) diameter per corallite diameter are 0.30–0.57; spacing of tabulae are variable; they are usually absent or very rare, but crowded tabulae are recognized in part; usual tabulae are complete with sagging profiles; incomplete tabulae rarely developed, those profiles are concave or dissepiment-like; there are 0–4 tabulae in 2.5 mm of corallite length.

Etymology: The specific name is derived from the Latin *igniculus*, meaning little flame, in reference to its branch shape.

Detailed fossil locality: Futatsuberi on the southern foot of Mt. Kinsho-zan (NSM PA16703); unknown (NSM PA16704–16708).

Discussion: In its subramose corallum with relatively narrow phaceloid portions, numerous septal spines and measurements of the intercorallite wall thickness, *Pseudoromingeria ignicula* sp. nov. appears most similar to an Early Permian species *P. onishii* Niko (2001, p. 17, 18, 20, figs. 2-1–4; 3-1–4), found in the Ryozensan Limestone. The younger Ryozensan species, however, differs from *P. ignicula* in having the well-developed infundibuliform tabulae and smaller corallite diameters (usually 1.1–1.6 mm) than those of the new species.

Superfamily Syringoporoidea Fromentel, 1861
Family Roemeriidae Počta, 1904

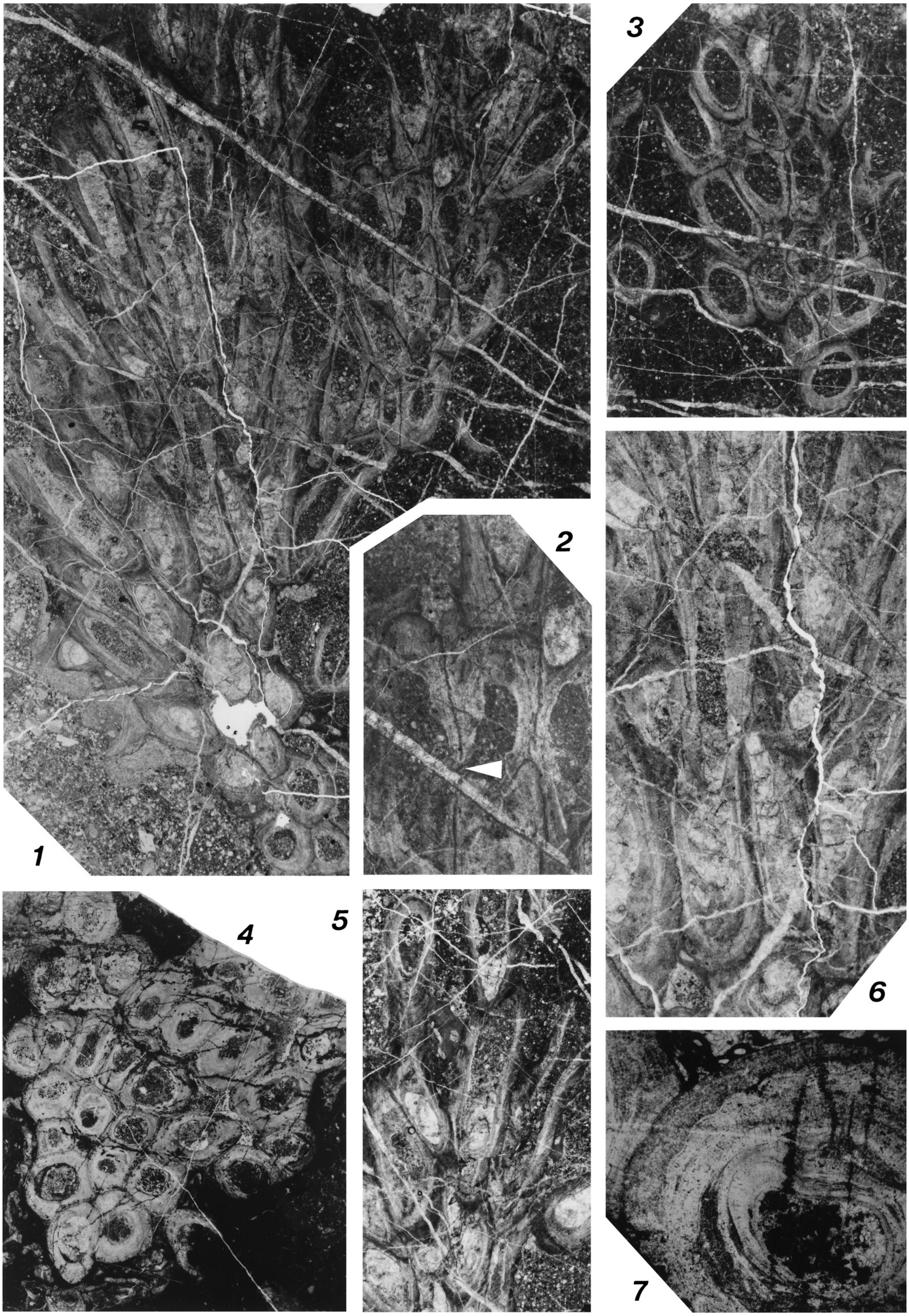
Remarks: The family Roemeriidae has been ascribed to the order Favositida or the order Auloporida. An assessment of higher taxonomic relationships of the family is beyond the scope of this paper. Following a reasonable Hill and Jell's (1970) conclusion that *Roemeria*, *Roemeripora* (and its possible synonym *Vaughanites*), *Roemerolites*, *Armalites*, *Pseudoroemeripora,* and *Bayhaium* are considered to have syringoporoid affinities, I tentatively treat the family as a member of the Auloporida.

Genus ***Akasakapora*** gen. nov.

Type species: *Akasakapora masutomii* sp. nov. by monotypy.

Diagnosis: Corallum ramose and partially reticulate; branches subcylindrical, composed of gently diverged corallites, whose most portions

Fig. 3. *Pseudoromingeria ignicula* sp. nov., thin sections. **1**–**3**, **5**, **6**, holotype, NSM PA16702. **1**, longitudinal to oblique sections of branches, ×5. **2**, partial enlargement of Fig. 3-1 to show mural pore (arrow), ×10; **3**, transverse section of branch, ×5. **5**, longitudinal section of branch, ×5. **6**, partial enlargement of Fig. 3-1, note incomplete and complete tabulae, ×10. **4**, **7**, paratype, NSM PA16704. **4**, transverse section of branch, ×5. **7**, partial enlargement of transverse section of corallite to show corallite wall structure, ×25.


1
2
3
4
5
6
7

are contiguous and prismatic; some distal ends of corallites, however, indicate partial separation; calices deep, oblique; intercorallite walls slightly thicken in peripheral zone, but distinct stereozone is not developed; mural pores rare; septal spines well-developed; most dominant tabulae are infundibuliform that form axial or eccentric syrinx.

Etymology: The generic name is derived from the Akasaka Limestone.

Akasakapora masutomii sp. nov.

(Figs. 4-1–5; 5-1–8)

[?] *Favosites* sp., Gottsche, 1884, p. 653; Yabe and Hayasaka, 1915a, p. 60.

"*Pseudofavosites*" sp., Masutomi and Hamada, 1966, p. 68, pl. 33, fig. 3.

[partium] *Pseudofavosites* sp., Tokai Fossil Society, 1974, pl. 7 fig. 1 [non pl. 7, figs. 2–4].

Pseudofavosites sp., Hashimoto, 1981, fig. 5-3; Makiguchi, 1995, p. 66, pl. L, fig. 2, pl. 7, fig. 1.

Holotype: KFM 00429, from which 31 thin sections were made.

Diagnosis: As for the genus.

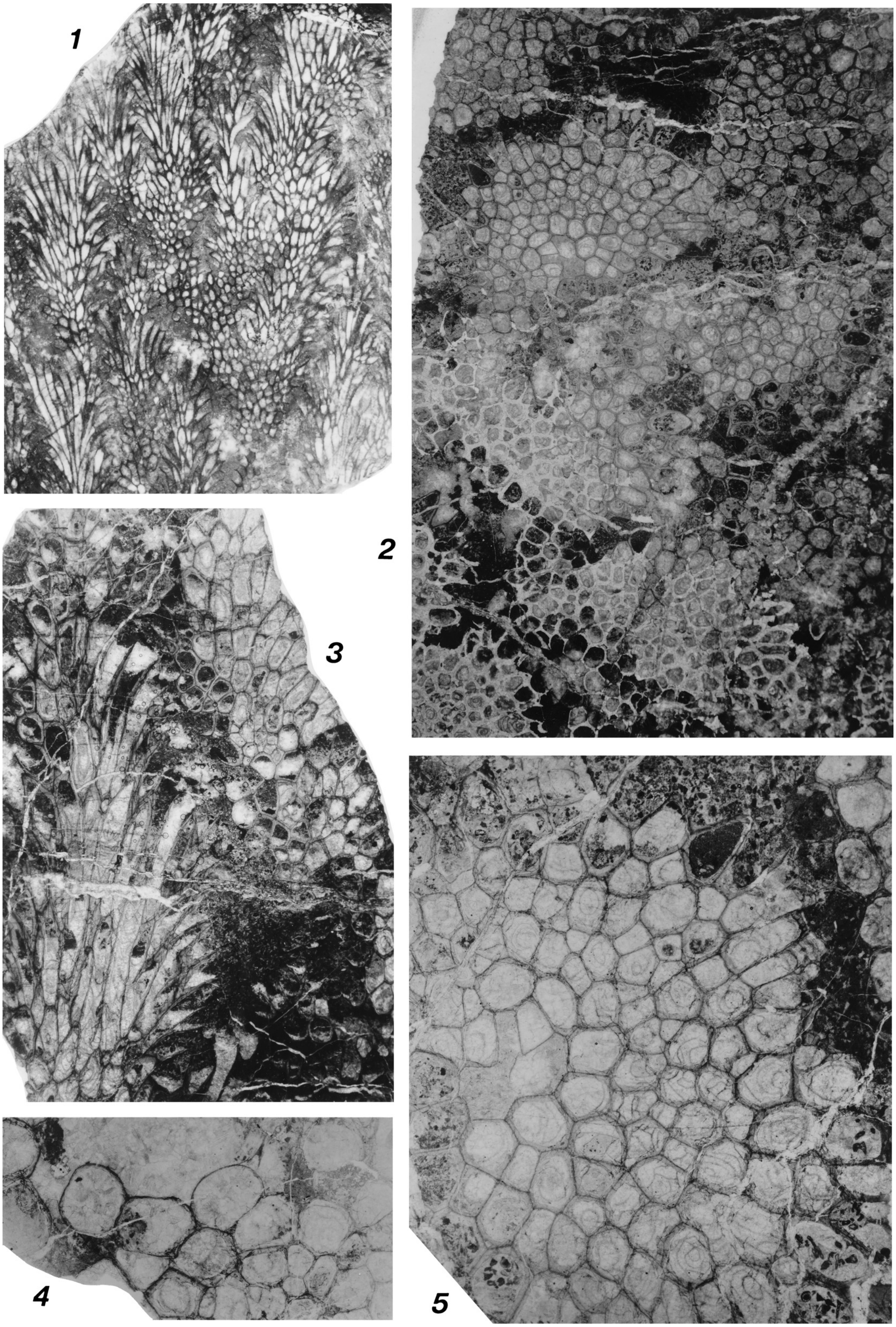
Description: Corallum ramose, large, more than 190 mm in width and 130 mm in height, mostly cerioid; branches subcylindrical with 12–19 mm in usual diameter, and frequently anastomosed to form reticulated framework in part. Corallites mostly contiguous and prismatic, but distal ends of which indicate partial separation, accordingly they are subcylindrical with fan-shaped transverse sections; in prismatic corallites, transverse sections have 3–5 sides in proximal portions, then 5–8 sides in distal ones; each corallite exhibits gentle divergence forming deep calice that opens obliquely upward with 35º–60º in angle to branch axis; except for the proximal portions that exhibit rapid increases of corallite diameter, inflation of corallite is week; diameters of corallites range from 0.6 to 2.6 mm; average of adult corallite diameters is 2.1 mm; lateral increase of new corallite commonly occurs in axial zone of branch. Intercorallite walls consist of median dark line and stereoplasm, the latter of which differentiated into inner layer of rect-radiate fibers and outer lamellar layer; intercorallite wall thickness is moderate for the family, usually 0.15–0.42 mm, slightly thicken to 0.71 mm in peripheral zone of branch, but distinct peripheral stereozone is not developed; mural pores rare, relatively large, 0.75 mm in diameter; septal spines well-developed needle-like to high conical having 0.20–0.51 mm in length of protruded portion; tabulae numerous, usually incomplete, uncommonly complete; among incomplete tabulae, infundibuliform tabulae are most dominant, but uparched, sagging or dissepiment-like ones frequently occur; in complete tabulae, weakly sagging form is most common; crowded infundibuliform tabulae form axial or rarely eccentric syrinx that has sporadic domical tabellae; diameters of syrinxes are approximately 0.4–0.6 mm; there are 2–17 tabulae (and tabellae) in 5 mm of corallite length.

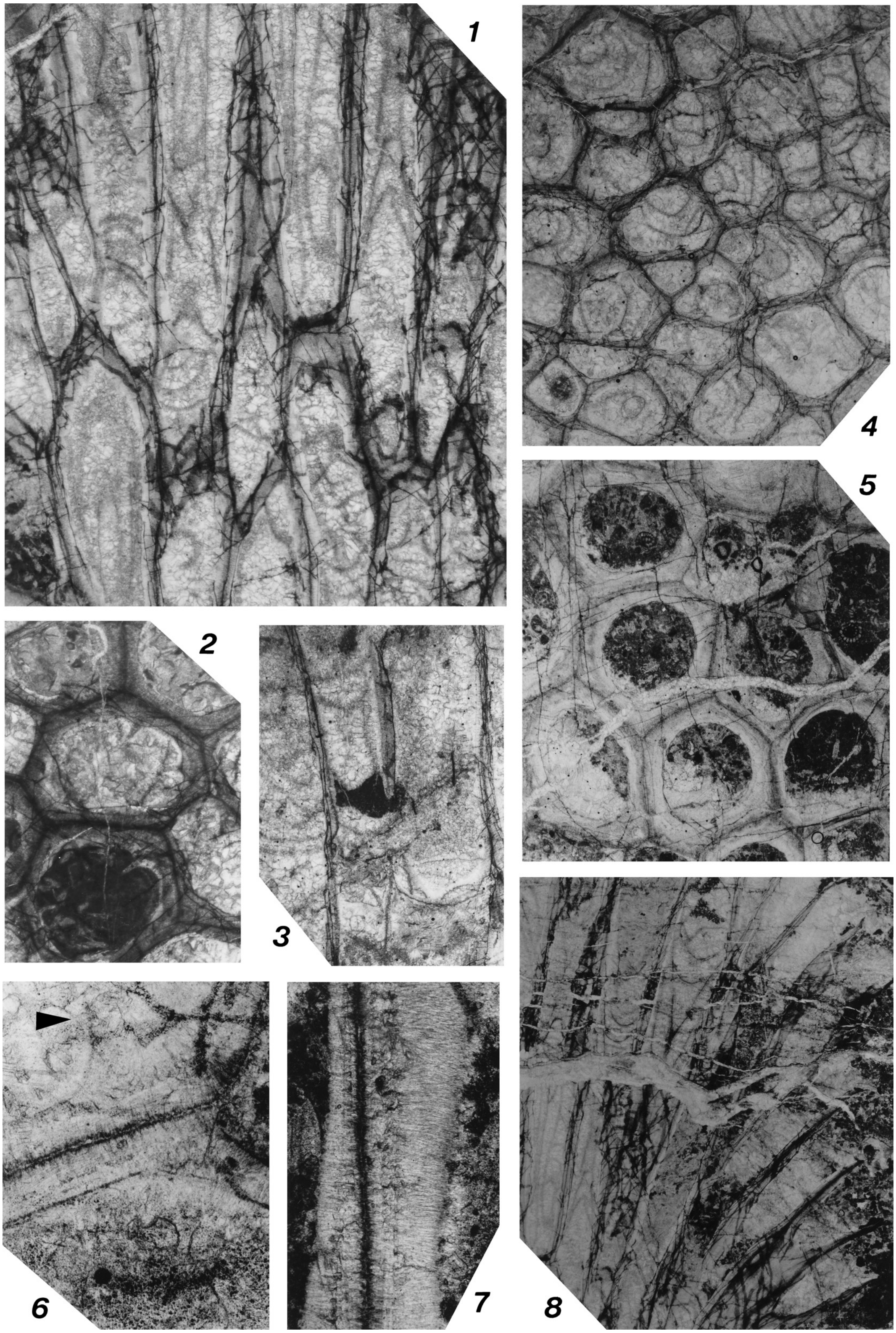
Etymology: The specific honors the late Dr. Kazunosuke Masutomi, who first illustrated the coral in Masutomi and Hamada (1966).

Detailed fossil locality: Futatsuberi on the southern foot of Mt. Kinsho-zan.

Discussion: Since Masutomi and Hamada's (1966) tentative assignment, the present tabulate coral had been regarded as a pseudofavositid favositid. Niko (1999) claimed, however, that the ramose corallum of the Akasaka specimen is unusual for *Pseudofavosites* and it may be a different genus. In fact, the following features in the coral seem to be diagnostic of the Roemeriidae rather than the Pseudofavositidae: partial separations of peripheral corallites, infundibuliform tabulae forming syrinx, and lamellar microstruc-

Fig. 4. *Akasakapora masutomii* gen. et sp. nov., holotype, KFM 00429. **1**, longitudinal polished section of corallum, ×0.7. **2**, transverse thin sections of branches, ×2.5. **3**, longitudinal and oblique thin sections of branches, ×2.5. **4**, transverse thin section of branch, note partial separations of corallites, ×5. **5**, transverse thin section of branch, ×5.


1
2
3
4
5


1
2
3
4
5
6
7
8

ture in stereoplasm. The specimen is the youngest and first Middle Permian records of the Roemeriidae. In addition, it represents the first occurrence of the family in Japan.

Among the known genera of the family, *Akasakapora masutomii* gen. et sp. nov. is closely related with a Wolfcampian (early Early Permian) genus *Bayhaium* Langenheim and McCutcheon (1959; type and sole included species, *B. merriamorum* Langenheim and McCutcheon, 1959, p. 100, 101, pl. 19, figs. 1–6), from the McCloud Limestone, California, by being the ramose corallum. Discriminative feature occurs in the intercorallite walls, *Bayhaium* has a distinct peripheral stereozone with the tunnel-like intercorallite connections, whereas the peripheral intercorallite walls of *Akasakapora* are also slightly thickened, but those morphologic respects are not developed. Furthermore, reticulation of the corallum is not documented in *Bayhaium.* The McCloud Limestone belongs the Eastern Heyfork Terrane that possesses oceanic origin and accreted to North American cratonic basement during Middle Jurassic time (e.g., Coney *et al*., 1980; Irwin and Wooden, 1999). There is a possibility that the *Bayhaium–Akasakapora* lineage was a Permian relict of roemeriids in a tropical marine condition of the Panthalassa Ocean.

The ramose corallum with the frequently anastomosed branches of *Akasakapora* indicates evident distinction from the Devonian (to Early Carboniferous?) genera *Roemeria* Milne-Edwards and Haime (1851; type species, *Calamopora infundibulifera* Goldfuss, 1829, p. 78; Jell and Hill, 1970, p. 160–162, pl. 1, figs. 1a–h), and *Roemeripora* Kraicz (1934; type species, *Roemeria bohemica* Barrande *in* Počta, 1902, p. 262, pl. 102, figs. 9, 10, pl. 111, figs. 21–25, pl. 116, figs. 11, 12; Kraicz, 1934, pl. 3, figs. 1–7; Hill, 1981, fig. 455, 1a, b), whose coralla are discoid, massive, bulbous to simple columnar.

Acknowledgements

Loan of the *Akasakapora masutomii* specimen for the present study from KFM was kindly arranged by Messrs. Hideo Hashimoto and Teruo Ono. My appreciation is extended to Dr. Masayuki Ehiro for loan of the holotype of *Pseudoromingeria kotoi* from IPGS. Mr. Toshiaki Kamiya accompanied the author with the field works during which some additional specimens of *P. kotoi* were acquired. I also thank Messrs. Yoshihito Senzai, Manao Mastuo and Masakazu Hori for donating the tabulate coral specimens to NSM. Dr. Hisayoshi Igo kindly reviewed the manuscript and provides helpful comments for its improvement.

References

Akasaka Research Group, 1956. Geological studies of the Akasaka Limestone. *Earth Science (Chikyu Kagaku)*, (26, 27): 10–18. (In Japanese with English abstract.)

Coney, P. J., D. L. Jones & J. W. H. Monger, 1980. Cordilleran suspect terranes. *Nature*, **288**: 329–333.

Goldfuss, A., 1829. Petrefacta Germaniae, tam ea, quae in Museo Universitatis Regiae Borussicae Fridericiae Wilhelmiae Rhenanae servantur, quam alia quaetunque in Museis Hoeninghusiano, Muenstriano aliisque extant, iconibus et descriptionibús illustrata. Abbildungen und Beschreibungen der Petrefacten Deutschlands und der angranzenden Länder, unter Mitwirkung des Herm Grafen Georg zu Münster. pp. 77–164, pls. 26–50, Arnz & Co., Düsseldorf.

Gottsche, C., 1884. Uber japanisches Carbon. *Zeit. Deutschen Geol. Gesell*., **36**: 653, 654.

Hashimoto, H., 1981. Anthozoa. *In* Kinshozan Fossil Re-

Fig. 5. *Akasakapora masutomii* gen. et sp. nov., holotype, KFM 00429, thin sections. **1**, longitudinal sections of corallites, ×10. **2**, transverse sections of corallites, note septal spines, ×14. **3**, longitudinal sections of corallites, note mural pore, ×10. **4**, transverse sections of corallites, ×10. **5**, transverse sections of distal corallites, note intercorallite wall thickening, ×10. **6**, partial enlargement of transverse sections of corallites to show intercorallite wall structure and septal spine (arrow), ×25. **7**, partial enlargement of longitudinal sections of corallites to show intercorallite wall structure, ×25. **8**, longitudinal section of branch, note oblique calices, ×5.

search Association (ed.), Kinshozan –Its Culture and Nature–, pp. 135–143, Ogaki. (In Japanese.)

Hattori, I. & K. Hirooka, 1979. Paleomagnetic results from Permian greenstones in central Japan and their geologic significances. *Tectonophysics*, **57**: 211–235.

Hill, D., 1981. Part F, Coelenterata. Supplement 1, Rugosa and Tabulata. *In* R. C. Moore *et al*. (eds.), Treatise on Invertebrate Paleontology, pp. F1–F762, Geol. Soc. America and Univ. Kansas, Boulder, Colorado and Lawrence, Kansas.

Hill, D. & J. S. Jell, 1970. The tabulate coral families Syringolitidae Hinde, Roemeriidae Počta, Neoroemeriidae Radugin and Chonostegitidae Lecompte, and Australian species of *Roemeripora* Kraicz. *Proc. Royal Soc. Victoria, N. S*., **83**: 171–190, pls. 16–20.

Irwin, W. P. & J. L. Wooden, 1999. Plutons and accretionary episodes of the Klamath Mountains, California and Oregon. *U.S. Geol. Surv. Open-file Rep. 99-374.*

Ishii, K., M. Murata & N. Nishiwaki, 1981. Geology of the Akasaka Limestone. *In* Kinshozan Fossil Research Association (ed.), Kinshozan—Its Culture and Nature—, pp. 98–105, Ogaki. (In Japanese.)

Ishii, K., Y. Okimura & K. Ichikaawa, 1985. Notes on Tethys biogeography with reference to Middle Permian fusulinaceans. *In* K. Nakazawa & J. M. Dickins (eds.), The Tethys: Her Paleogeography and Paleobiogeography from Paleozoic to Mesozoic, pp. 139–155. Tokai Univ. Press, Tokyo.

Jell, J. S. & D. Hill, 1970. Redescription of the lectotypes of the Devonian tabulate corals *Roemeria infundibulifera* (Goldfuss), *Roemeripora minor* (Schlüter) and *Favosites goldfussi* d'Orbigny. *Geol. Mag*., **107**: 159–167, pls. 1, 2.

Kamiya, T. & S. Niko, 1995. A Permian tabulate coral *Sinopora* from the Akasaka Limestone, Gifu Prefecture. *Chigakukenkyu*, **44**: 23–26. (In Japanese.)

Kobayashi, F., 1997. Middle Permian biogeography based on fusulinacean faunas. *In* C. A. Ross *et al*. (eds.), Late Paleozoic Foraminifera; Their Biostratigraphy, Evolution, and Paleoecology; and the Mid-Carboniferous Boundary, Cushman Found. Foram. Res. Spec. Publ. 36, pp. 73–76

Konishi, K., 1960. *Sinopora dendroidea* (Yoh), auloporid coral, from Late Permian of western Honshu. *Trans. Proc. Palaeont. Soc. Japan, N. S*., (40): 325–328.

Koto, B., 1898. Classification of the Carboniferous limestone of Akasaka. *Jour. Geol. Soc. Japan*, **5**: 349–352. (In Japanese.)

Kraicz, I., 1934. Die systematische Stellung von *Roemeria bohemica* Barrande. *Lotos*, **82**: 38–46, pl. 3.

Langenheim, R. L. Jr., & V. A. McCutcheon, 1959. *Bayhaium merriamorum*, a new Permian tabulate coral from California. *Jour. Paleont*., **33**: 99–102, pl. 19.

Lin, B., Y. Tchi, C. Jin, Y. Li & Y. Yan, 1988. Monograph of Palaeozoic corals. Tabulatomorphic corals. Volume 1, 467 pp., Geological Publishing House, Beijing. (In Chinese with English abstract.)

Makiguchi, T., 1995. Corals. *In*, The Illustrated Collection of Asami Fossil Museum. Fossils of Kinsyozan, pp. 63–68, pl. L, Bisaisha, Nagoya. (In Japanese.)

Masutomi, K. & T. Hamada, 1966. Fossils in Colour. 268 pp. Hoikusha, Osaka. (In Japanese.)

Milne-Edwards, H. & J. Haime, 1851. Monographie des polypiers fossiles des terrains paléozoïques, précédée d'un tableau général de la classification des polypes. *Arch. Mus. Hist. Nat., Paris*, **5**: 1–502, pls. 1–20.

Minato, M., 1955. Japanese Carboniferous and Permian corals. *Jour. Fac. Sci., Hokkaido Univ., Ser. 4*, **9**: 1–202, pls. 1–43.

Niko, S., 1999. Tabulate corals from the Carboniferous Hina Limestone, Okayama Prefecture. *Bull. Natn. Sci. Mus., Tokyo, Ser. C*, **25**: 29–44.

Niko, S., 2001. Auloporid tabulate corals from the Lower Permian Ryozensan Limestone, Shiga Prefecture. *Bull. Natn. Sci. Mus., Tokyo, Ser. C*, **27**: 15–23.

Obata, I. (ed.), 1994. Seibido Handy Library. Japanese Fossils. 360 pp., Seibido Shuppan, Tokyo. (In Japanese.)

Ozawa, T., 1987. Permian fusulinacean biogeographic provinces in Asia and their tectonic implications. *In* A. Taira & M. Tashiro (eds.), Historical Biogeography and Plate Tectonic Evolution of Japan and Eastern Asia, pp. 45–63, Terra Sci. Pub., Tokyo.

Ozawa, T. & N. Nishiwaki, 1992. Permian Tethyan biota and sedimentary facies of the Akasaka Limestone Group. *In*, 29th IGC Field Trip Guide Book Vol. 1. Paleozoic and Mesozoic Terranes: Basement of the Japanese Island Arcs. pp. 189–195, Nagoya University, Nagoya.

Ozawa, Y., 1927. Stratigraphical studies of the *Fusulina* limestone of Akasaka, Province of Mino. *Jour. Fac. Sci., Imp. Univ. Tokyo, Sec. 2*, **2**: 121–164, pls. 34–46.

Počta, F., 1902. Anthozoaires et Alcyonaires. *In* J. Barrand, Systême Silurien du centre de la Boheme. 1 Partie: Recherches Paléontogiques. Volume 8, part 2, 347 pp. pls. 20–118. Privately published, Prague, Paris.

Ross J. R. P. & C. A. Ross, 1990. Late Palaeozoic bryozoan biogeography. *In* W. S. McKerrow & C. R. Scotese (eds.), Paleozoic Palaeogeography and Biostratigraphy, Geol. Soc. London, Mem. 12, pp. 353–362.

Sakagami, S., 1980. Preliminary note on the upper part of the Akasaka Limestone Group, Japan. *Proc. Japan Acad*., **56**: 25–29.

Sokolov, B. S., 1950. Systematics and history of the development of the Paleozoic corals Anthozoa Tabulata. *Vopr. Paleont*., **1**, 134–210. (In Russian.)

Sokolov, B. S., 1955. Paleozoic Tabulata of the European parts of the USSR. Introduction to the general study of the systematics and development of the tabulates. *Tr. Vses. Neft. Nauchno-Issled. Geol.-Razved. Inst. N. S.*, **85**: 1–527, pls. 1–90. (In Russian.)

Tazawa, J., 1997. *Coscinophora* (Permian Brachiopoda) from the Akasaka Limestone, Mino Belt, Central Japan and its palaeobiogeographic significance. *Earth Science (Chikyu Kagaku)*, **51**: 447–451. (In Japanese.)

Tokai Fossil Society, 1974. Fossils of Kinsyozan, 93 pp., Nagoya. (In Japanese.)

Wakimizu, T., 1902. Limestone beds of Kinshōzan, Akasaka, Mino Province. *Jour. Geol. Soc. Japan*, **9**: 71–73, 163–169, 205–212, 331–339, pls. 4, 5. (In Japanese.)

Yabe, H., 1904. A trip to Kinshōsan, Akasaka, Mino. *Jour. Geol. Soc. Japan*, **11:** 12–21. (In Japanese.)

Yabe, H. & I. Hayasaka, 1915a. Palaeozoic corals from Japan, Korea and China. I. *Michelinia* and *Favosites*. *Jour. Geol. Soc. Tokyo*, **22**: 55–70.

Yabe, H. & I. Hayasaka, 1915b. Palaeozoic corals from Japan, Korea and China. II. *Halysites, Syringopora, Romingeria, Striatopora*, *Tetrapora* and *Sylindropora*. *Jour. Geol. Soc. Tokyo*, **22**: 79–92.

Yabe, H. & T. Sugiyama, 1941. *Pseudoromingeria*, a new genus of auloporids from Japan. *Proc. Imp. Acad. Japan*, **17**: 379–382.

Yoh, S. S. & T. K. Huang, 1932. The coral fauna of the Chihsia Limestone of the lower Yangtze Valley. *Palaeont. Sinica, Ser. B*, **8**: 1–72, 1–10.

Zaw Win, 2000. Paleoenvironmental and paleogeographical consideration on the Akasaka Limestone, Gifu Prefecture, Japan. *Bull. Kitakyushu Mus. Nat. Hist*., **19**: 9–23.