

Tabulate Corals from the Carboniferous Hina Limestone, Okayama Prefecture

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Abstract This paper represents the first record of tabulate corals from the Carboniferous Hina Limestone in Okayama Prefecture, Southwest Japan. The following three favositid and two auloporid tabulate coral species are described for taxonomic, biostratigraphic and paleobiogeographic purposes: *Pseudofavosites hinaensis* sp. nov., *Donetzites kibiensis* sp. nov., *D. vermiculatus* sp. nov., *Cladochonus* sp. indet. and *Mandulapora yamagiwai* sp. nov. With the exception of *Mandulapora yamagiwai*, whose decided range is late Visean to late Bashkirian, these corals occur within the *Eostaffella-Millerella* Zone of late Visean to early Bashkirian age. *Donetzites* and *Mandulapora* were not previously known in Japan.

Key words: Carboniferous, Favositida, Auloporida, Hina Limestone, Okayama

Introduction

The Hina Limestone (Choh, 1939) is one of the several allochthonous units in the Akiyoshi Terrane, and it evidently formed as seamount-type reef complex in low latitudes during the Late Paleozoic. Diverse and well-preserved Carboniferous corals were recently found in this limestone due to the intensive collecting efforts of Mr. Y. Hirata. Systematic study of the Hirata's large collection, along with some additional specimens, has resulted in recognition of three favositid and two auloporid species. Among these, *Pseudofavosites hinaensis*, *Donetzites kibiensis*, *D. vermiculatus* and *Mandulapora yamagiwai*, are new species. Other than a chaetetid that was erroneously reported as *Tabulata* (Umeda & Shimada, 1990; Umeda, 1996), the present paper is the first account of the Hina Limestone tabulate coral fauna. Tabulate coral-bearing samples (HL 1–10, 14) were recovered from several float blocks of milky white to gray limestone, in the riverbed of the Shigi-gawa River in the Yoshii area, Situki-gun, Okayama Prefecture, Southwest Japan (Fig. 1). The geology of this area is referable in Nakano (1952), Yoshimura (1961), Hase and Yokoyama (1975) and Sano *et al.* (1987).

Tabulate corals are not effective for determining precise age, so the associated foraminiferal faunas are also examined in each coral-bearing sample. Two main foraminiferal assemblages were recognized, Assemblage I (samples HL 1, 3, 4, 5, 7, 8) characterized by *Earlandia*, *Pseudoglomospira*, *Eostaffella* and *Millerella*, and As-

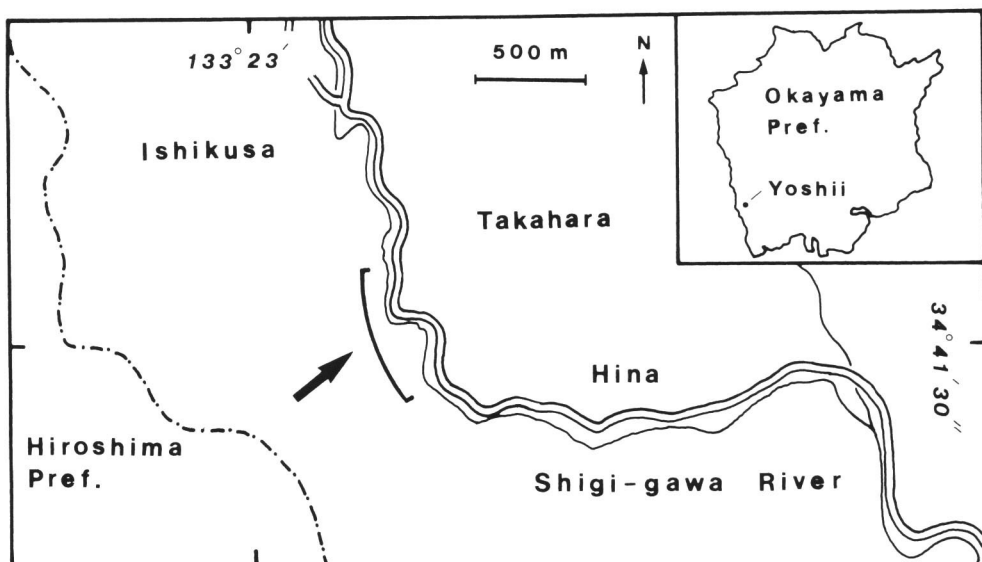


Fig. 1. Index map of the Yoshii area, Okayama Prefecture showing area of most coral-bearing limestone blocks were collected.

seemblage II (samples HL 6, 10, 14) characterized by *Pseudostaffella*, *Nankinella* and *Eoschubertella*. Samples HL 2 and 9 were barren of index foraminifers, with the exception of *Tetrataxis*. Hase and Yokoyama (1975), Fujimoto and Sada (1994, 1995) and Mizuno and Ueno (1997) have determined the stratigraphic distribution of foraminifers in the Hina Limestone, which comprises the *Endothyra*, *Eostaffella-Millerella*, *Pseudostaffella* and *Profusulinella* Zones in ascending order. Recent biostratigraphic research using conodonts (Mizuno, 1997) confirms that the Early/Late Carboniferous boundary lies in the middle part of the *Eostaffella-Millerella* Zone. The present Assemblages I and II are assigned, respectively, to the *Eostaffella-Millerella* Zone of late Viséan (middle Early Carboniferous) to early Bashkirian (early Late Carboniferous) age and to the *Pseudostaffella* Zone of middle Bashkirian age. In concerning with the remaining two samples, HL 9 contains a Rugosa, *Hiroshimaphyllum* aff. *simplex* Yoshida, Okimura & Kato, that indicates a late Viséan age, however the tabulate coral in HL 2 suggests only an early Viséan to late Bashkirian age.

The coral specimens studied herein are deposited in the National Science Museum, Tokyo (NSM).

Systematic Paleontology

In cerioid forms, diameter of corallite was measured between median wall lines

of the both sides, or between mid-points of corallite walls when median line can not be determined.

Order Favositida Wedekind, 1937

Suborder Favositina Wedekind, 1937

Superfamily Favositicae Dana, 1846

Family Pseudofavositidae Sokolov, 1950

Genus *Pseudofavosites* Gerth, 1921

Type species: *Pseudofavosites stylifer* Gerth, 1921.

***Pseudofavosites hinaensis* sp. nov.**

Figs. 2, 9-2

Holotype: NSM PA14522, from which two thin sections were made.

Diagnosis: Species of *Pseudofavosites* with maximum corallite diameters usually 2.9–3.3 mm, prismatic lumina, relatively thin intercorallite walls, 0.05–0.21 mm in thickness, and very long but sporadic squamulae; fewer mural pores than type species of genus.

Description: Corallum domed growth form with maximum observed size 38 mm in diameter and 20 mm in height, cerioid. Corallites and lumina prismatic, divergent in arrangement; cross sections of corallites almost 6–8 sides, diameters of corallites somewhat variable even in peripheral corallum, attain 2.5–3.6 mm, usually 2.9–3.3 mm; increase of corallites common, probably lateral; early growth stages of new corallites indicate 3 sided in cross section. Intercorallite walls relatively thin for genus, ranging from 0.05 to 0.21 mm in thickness, with radially fibrous microstructure; mural pores common on corallite faces, but not so abundant in this species as type of genus, circular to laterally compressed in section, 0.17–0.26 mm in diameter, forming 1–2 series of longitudinal row(s); tabula absent; squamulae sporadic, very long, attain 1.05 mm in length, concave and strongly upturned.

Discussion: *Pseudofavosites* is a relatively rare genus characterized by the domed to hemispherical and cerioid coralla lacking tabula. Only two preliminary records of this genus (or closely related tabulate corals with the genus) were previously documented in Japan as follows: “*Pseudofavosites*” sp., from the Middle Permian of the Akasaka Limestone, Gifu Prefecture (Gottsche, 1884; Masutomi & Hamada, 1966), has the ramose corallum that is unusual for *Pseudofavosites*, it may be a different genus; and *Pseudofavosites* sp., was listed by Yoshida *et al.* (1987) in the lowest part (late Viséan) of the Omi Limestone, Niigata Prefecture. Thus, the present description based on a new material from the Hina Limestone is the first detailed systematic report of the genus in Japan.

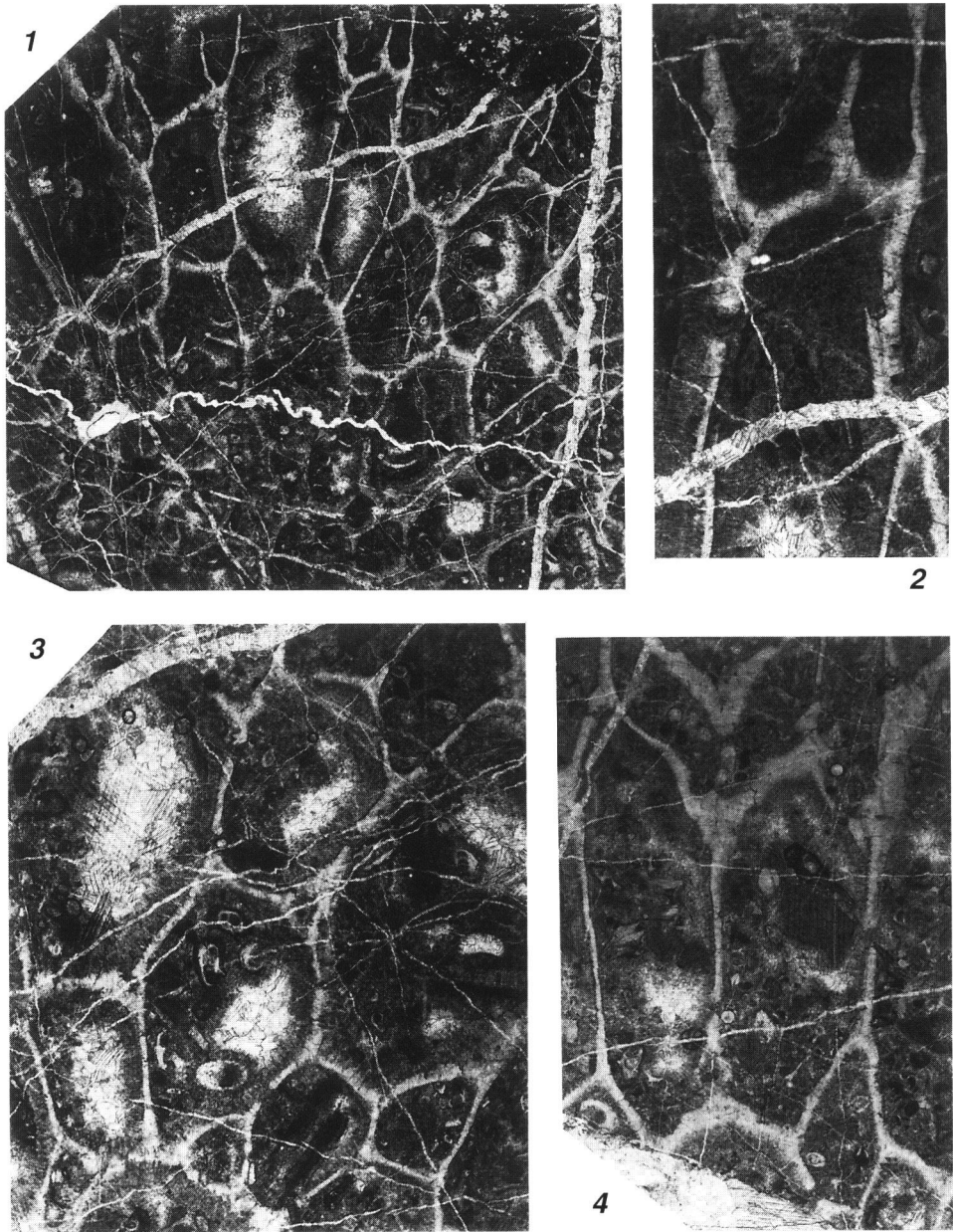


Fig. 2. *Pseudofavosites hinaensis* sp. nov., holotype, NSM PA14522, transverse thin sections. 1, note sporadic squamulae, $\times 5$. 2, partial enlargement of Fig. 2-1, indicating mural pores, $\times 14$. 3, transverse sections of corallites, $\times 10$. 4, oblique sections of corallites, $\times 10$.

Pseudofavosites guangxiensis Lin (1963, pl. 1, figs. 3a–c), from the Upper Carboniferous Maping Limestone in Guangxi, South China, also has the relatively thin corallite walls (0.1–0.25 mm in thickness) and the prismatic lumina, but it indicates the more abundant squamulae and the mural pores than those of *P. hinaensis* sp. nov. *Sutherlandia xizangensis* Lin (1984, pl. 1, figs. 1a–d), from the upper Lower Carboniferous of Tibet, is somewhat similar to the present new species. However, the possessions of rounded lumina and numerous squamulae easily distinguish *S. xizangensis* from *Pseudofavosites hinaensis*.

Etymology: The specific name is derived from the Hina Limestone.

Occurrence: Sample HL 7.

Family Cleistoporidae Easton, 1944

Genus *Donetzites* Dampel, 1940

Type species: *Donetzites milleporoides* Dampel, 1940.

***Donetzites kibiensis* sp. nov.**

Figs. 3, 4

Holotype: NSM PA14516, from which four thin sections were made.

Other specimen: Three thin sections were studied from a single paratype, NSM PA14519.

Diagnosis: Species of *Donetzites* with discoid coralla lacking holotheca; corallite diameters approximately 2.0 mm; intercorallite walls partly non-perforate; count of tabulae relatively few, 3–5 in 5 mm of corallite length.

Description: Coralla encrusting, discoid with nearly flat surface and weakly pointed base in growth form, maximum observed size of largest corallum (holotype) is 101 mm in diameter and 38 mm in height, cerioid; holotheca absent. Corallites subprismatic; each corallite consists of proximal prostrate portion and erect distal portion that has shallow calice opening to surface of corallum at right to oblique (declining 55°) angles; cross sections of corallites indistinct 4–8 sides, diameters of corallites attain 1.8–2.5 mm, with 2.0 mm mean; tabularia subcircular in cross section with irregular margins; increase of new corallites lateral, relatively rare. Intercorallite walls usually cribriform, very thick, attaining 0.54–1.00 mm, but thin non-perforate walls of 0.05–0.09 mm in thickness partly recognized; microstructure of intercorallite walls not preserved; mural pores represented by numerous and partly branched connective tunnels in cribriform intercorallite walls; each tunnel indicates subcircular in cross section with 0.09–0.26 mm in diameter; tabulae complete, mostly rectangular to corallites and straight to slightly concave in longitudinal section; number of tabulae few for genus, 3–5 in 5 mm of corallite length; cribriform intercorallite walls form septal spine- or septal comb-like strong projections into tabularia.

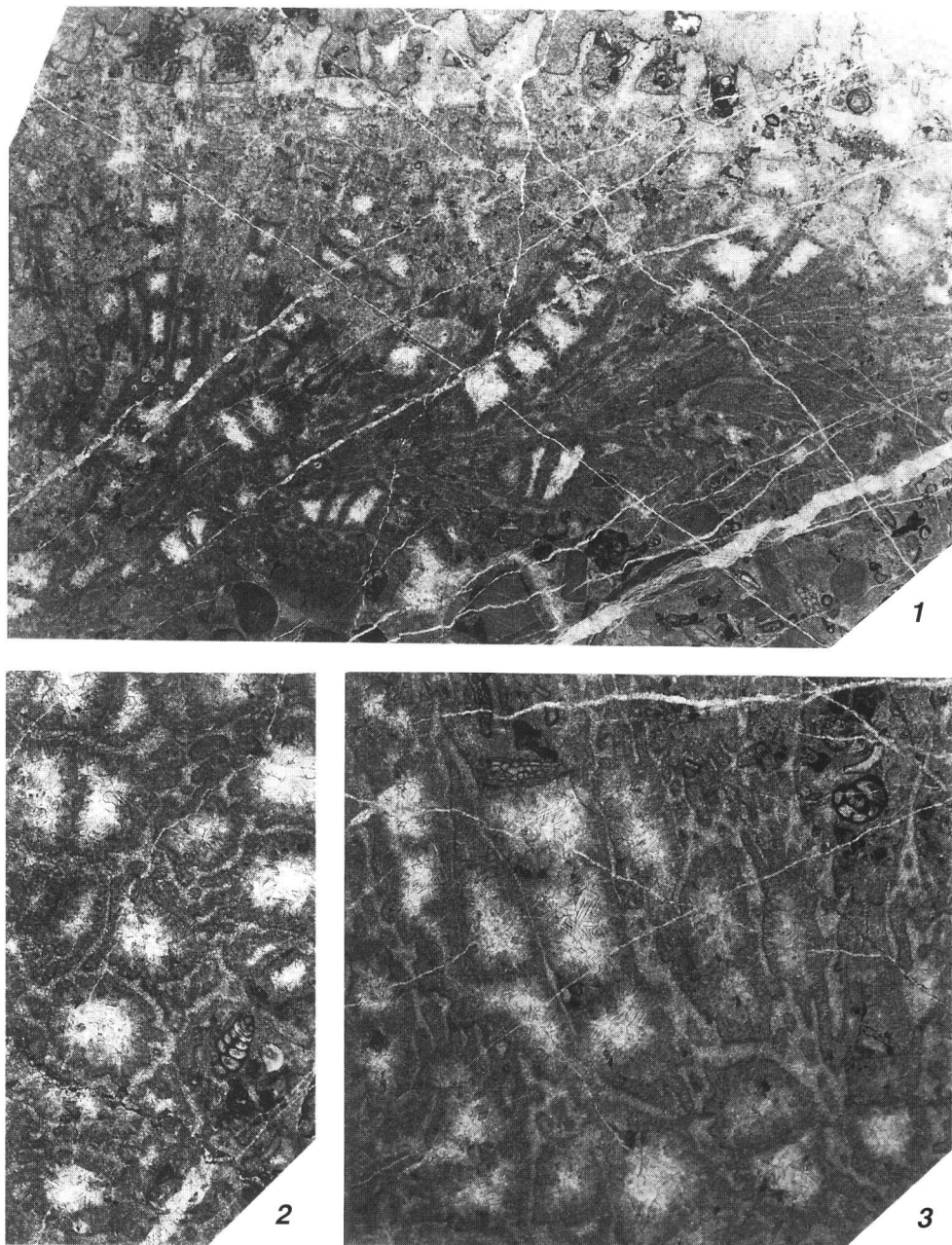


Fig. 3. *Donetzites kibiensis* sp. nov., holotype, NSM PA14516, thin sections. 1, longitudinal section, $\times 5$. 2, transverse section, $\times 10$. 3, longitudinal section, note thin-walled portions, $\times 10$.

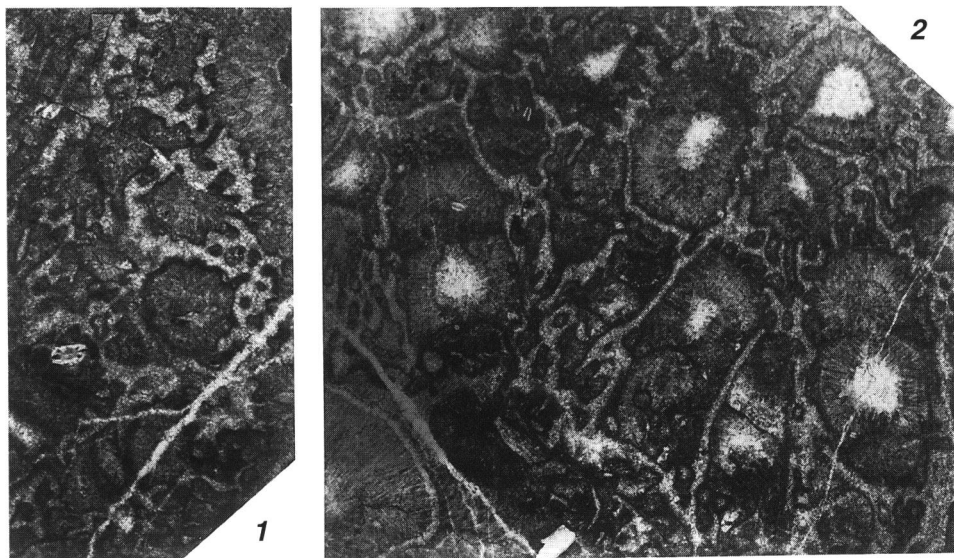


Fig. 4. *Donetzites kibiensis* sp. nov., paratype, NSM PA14519, thin sections. 1, 2, transverse sections, $\times 10$.

Discussion: This species is most similar to *Donetzites dovjicovi* Dubatolov and Tong-dzuy (1965, pl. 6, figs. 3a, b; Tong-dzuy, 1965, pl. 2, fig. 6) from the Middle Carboniferous in northern Vietnam, but is distinguished by its smaller corallite diameters (ca. 2.0 mm versus 2.6 mm in *D. dovjicovi*) and fewer tabulae (number of tabulae in 5 mm of corallite length: 3–5 versus usually 6–7 in *D. dovjicovi*). *Donetzites multispinosus* Lin (1985, pl. 1, figs. 2a, b), from the Middle Carboniferous in Gansu, North China, also resembles the present new species. However, the stellated cross sections of tabularia in *Donetzites multispinosus* separate it from *D. kibiensis* sp. nov.

This discovery, together with *Donetzites vermiculatus* sp. nov, represents the first record of the genus in Japan.

Etymology: The specific name is derived from Kibi, which is an ancient name of the territory including the type locality.

Occurrence: Samples HL 1 (NSM PA14516) and HL 4 (NSM PA14519).

Donetzites vermiculatus sp. nov.

Fig. 5

Holotype: NSM PA14520, from which six thin sections were made.

Diagnosis: Species of *Donetzites* with discoid, holothecate corallum with exceptionally thick intercorallite walls, attaining 1.56–2.44 mm; corallite diameters large, approximately 3.3 mm; count of tabulae 6–8 in 5 mm of corallite length.

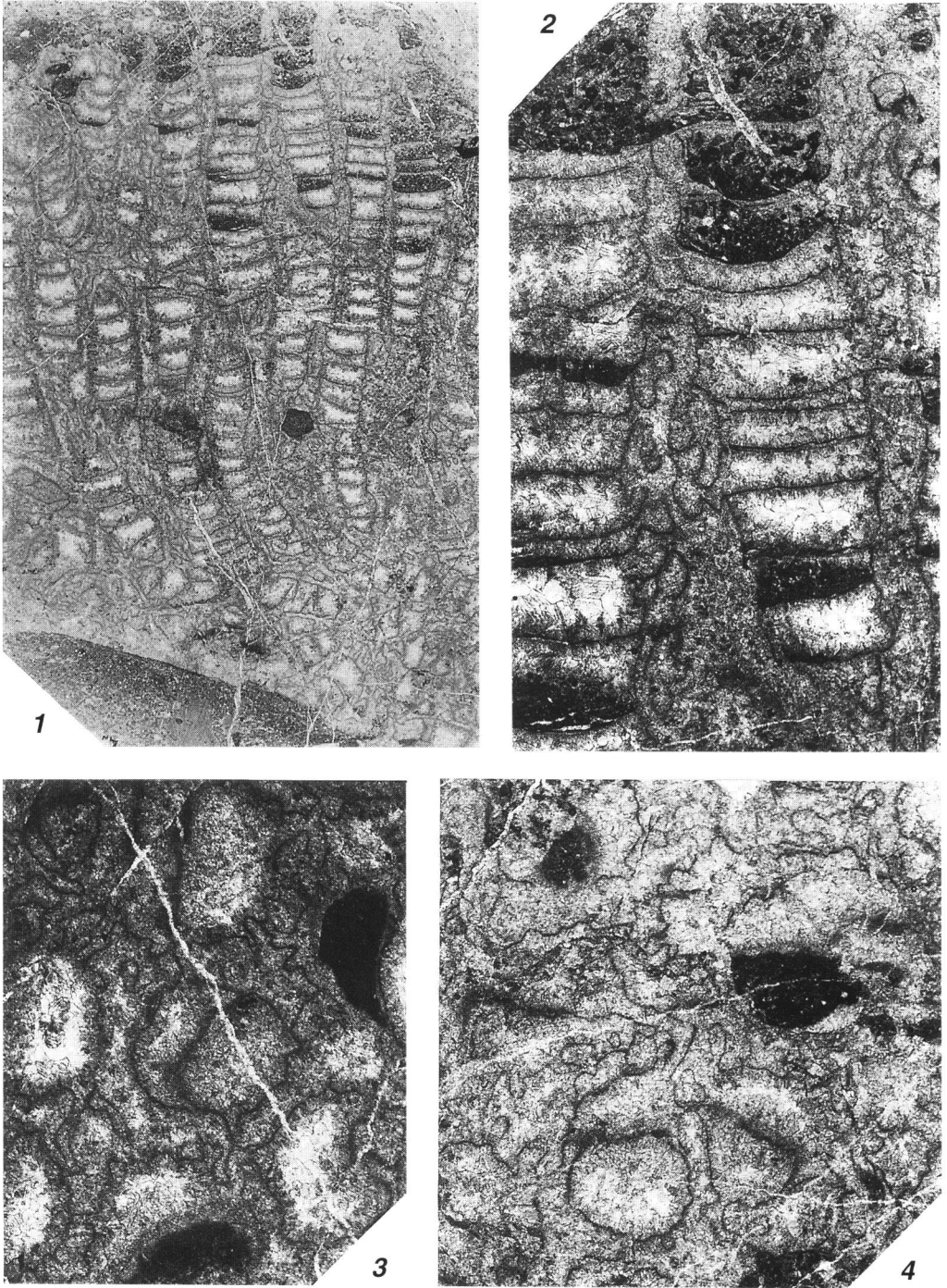


Fig. 5. *Donetzites vermiculatus* sp. nov., holotype, NSM PA14520, thin sections. 1, longitudinal section, note holotheca, $\times 3$. 2, longitudinal section, $\times 10$. 3, transverse section, $\times 10$. 4, transverse section at peripheral corallum, $\times 10$.

Description: Corallum thick discoid with nearly flat surface and pointed base in growth form, maximum observed size of holotype 108 mm in diameter and 48 mm in height, holothecate, cerioid. Corallites subprismatic; each corallite consists of proximal prostrate portion and erect distal portion that has shallow calice opening to surface of corallum at nearly right angles; cross sections of corallites indistinct 6–8 sides, diameters of corallites large, attain 2.8–4.8 mm with 3.3 mm mean; tabularia subcircular in cross section with somewhat irregular margins; increase of new corallites lateral, relatively rare. Intercorallite walls cribriform, exceptionally thick attaining 1.56–2.44 mm; microstructure of intercorallite walls not preserved; mural pores represented by numerous, branched and anastomosed connective tunnels; each tunnel indicates subcircular to somewhat irregular profile in cross sections with 0.16–0.49 mm in diameter; tabulae mostly complete, rectangular to corallite and straight to concave in longitudinal sections, continuous into connecting tunnels in rare cases; number of tabulae moderate for genus, 6–8 in 5 mm of corallite length; cribriform intercorallite walls form septal spine- or septal comb-like projections into tabularia.

Discussion: The large diameter of the corallites and the exceptionally thick intercorallite walls separate *Donetzites vermiculatus* sp. nov. from the most previously described species of the genus. Only *Donetzites mariae* Flüel (1975, pl. 1, figs. 1, 2), from the lower Bashkirian of Iran, possesses similar corallite size and intercorallite wall thickness. *Donetzites vermiculatus* apparently differs from *D. mariae* in its more irregular profile of the tabularia and its larger number of the tabulae (6–8 versus ca. 2 in *D. mariae* in 5 mm of corallite length).

The distinct holotheca of *Donetzites vermiculatus* clearly separates this species from *D. kibiensis* sp. nov. Although the possession or lacking of the holotheca is still unknown in the generic type, there is a possibility that *Donetzites* can be divided into two groups by this criterion.

Etymology: The specific name is derived from the Latin *vermiculatus* (worm-hole-like), referring to appearance of the intercorallite walls.

Occurrence: Sample HL 5.

Order Auloporida Sokolov, 1947

Superfamily Auloporicae Milne-Edwards & Haime, 1851

Family Pyrgiidae Fromentel, 1861

Genus *Cladochonus* M'Coy, 1847

Type species: *Cladochonus tenuicollis* M'Coy, 1847.

Cladochonus sp. indet.

Fig. 6

Material: A single corallum NSM PA14523.

Description: Corallum encrusting, mat-like in growth form; each corallite consists of short proximal prostrate portion, approximately 3 mm in length, and cylindrical distal free portion, approximately 6 mm in length, forming oblique calice; cross sections of distal corallites are subcircular, attain 1.8–2.2 mm in diameter; new (daughter) corallite of offset arises at basal portion of preceding free portion of corallite. Corallite walls mostly very thick, attain 0.55 mm, composed of epitheca and microlamellar stereoplasm; tabula not observed; septal spines short, common.

Discussion: The only known specimen has the diagnostic corallite shape of *Cladochonus*, but the examined material is too insufficient for specific identification. This species covers a corallite of *Rugosa*, *Hiroshimaphyllum*? sp. indet.

Occurrence: Sample HL 8.

Superfamily Syringoporicae Fromentel, 1861

Family Periphaceloporidae Hill, 1981

Genus *Mandulapora* Ding in Ding *et al.*, 1984

Type species: *Mandulapora permica* Ding in Ding *et al.*, 1984.

Remarks: Lin *et al.* (1988) placed *Mandulapora* in the Periphaceloporidae rather than the original assignment of the Syringolitidae. Its phaceloid coralla surrounding cerioid base with connecting tubuli confirm this opinion that is followed herein.

Mandulapora yamagiwai sp. nov.

Figs. 7, 8, 9-1

Cf. *Pseudoromingeria kotoi* (Yabe & Hayasaka); Yabe and Sugiyama, 1941, p. 382, fig. 4.

Pseudoromingeria kotoi (Yabe & Hayasaka); Minato, 1955, p. 186, pl. 17, fig. 3.

Tabulata gen. et sp. indet.; Haikawa and Ota, 1978, pl. 3, figs. 2, 3.

Auloporidid Tabulata gen. et sp. indet.; Sugiyama and Nagai, 1990, p. 12–24, pl. 3, figs. 1, 2, pl. 4, figs. 1, 2, pl. 5, figs. 1–6, text-figs. 4-1–6, text-figs. 5-1–4, text-figs. 6, 7.

Multithecopora sp.; Sugiyama and Haikawa, 1993, p. 71.

Holotype: NSM PA14517, from which five thin sections were made.

Other specimens: Eighteen thin sections were studied from the five paratypes, NSM PA14521, 14524–14527. In addition, a single poorly preserved corallum, NSM PA14518, was also examined.

Diagnosis: Species of *Mandulapora* characterized by laminar to ramose corallum forms with corallite diameters approximately 1.7 mm and relatively narrow peripheral phaceloid portions; connecting tubuli rare; tabulae sporadic for genus, 0–4 in 2.5 mm of corallite length.

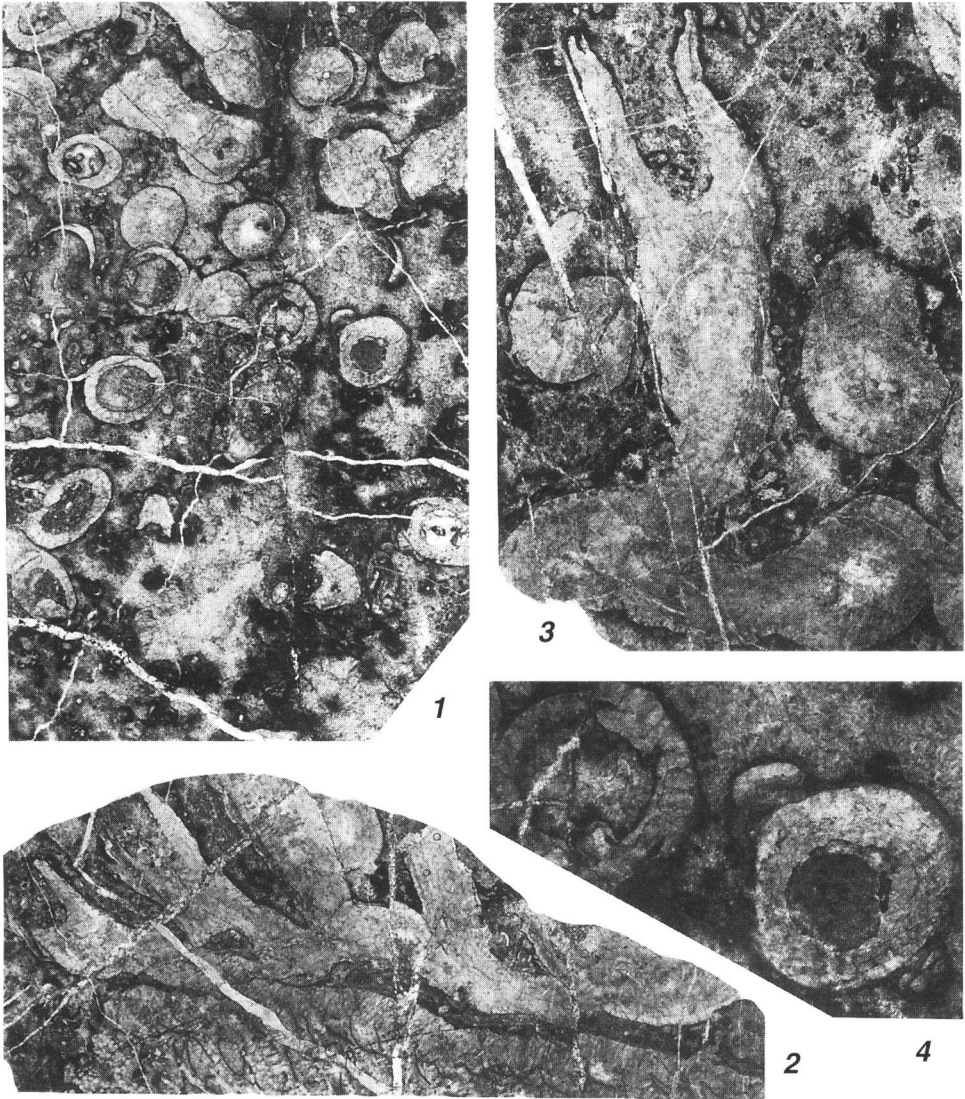


Fig. 6. *Cladochonus* sp. indet., NSM PA14523, thin sections. 1, transverse section, $\times 5$. 2, longitudinal section, $\times 5$. 3, longitudinal section of corallite, indicating calice, $\times 10$. 4, transverse sections of corallites, indicating lamellar corallite wall microstructure, $\times 14.4$.

Description: Coralla have variable growth forms, encrusting and laminar to ramose with subcylindrical branches; maximum observed size of largest ramose corallum (holotype) 55 mm in diameter and 30 mm in height, maximum diameters of each branch attain approximately 13 mm. Proximal portions of both laminar and ramose coralla composed of alveolitoid-like corallites with semicircular, quarter-cir-

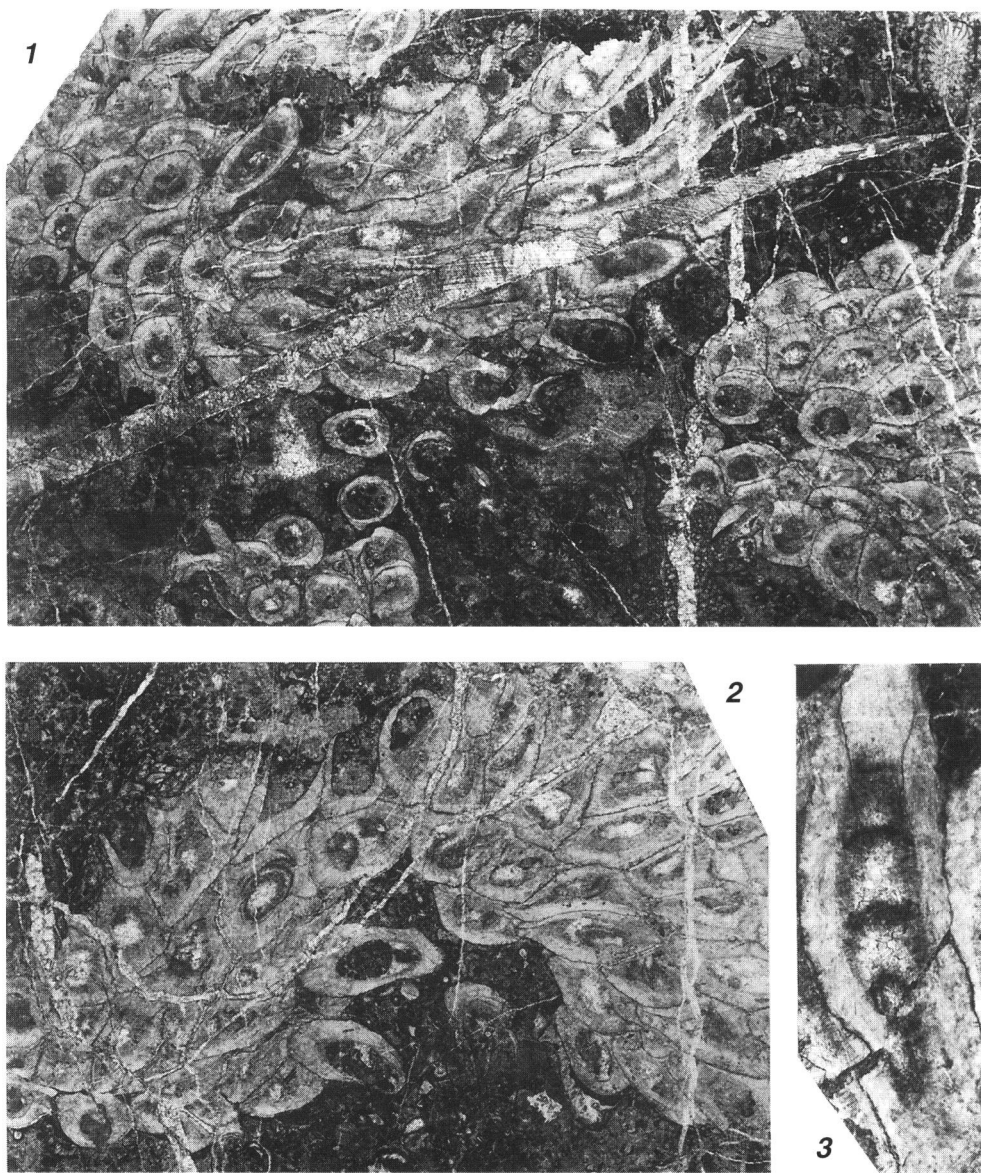


Fig. 7. *Mandulapora yamagiwai* sp. nov., holotype, NSM PA14517, thin sections of ramoses corallum. 1, longitudinal section, $\times 5$. 2, oblique section, $\times 5$. 3, longitudinal section of corallites, indicating complete tabulae and lamellar corallite wall microstructure, $\times 13.8$.

cular to fan-shaped cross sections, then forming cerioid coralla with subcylindrical or subprismatic corallites that have subcircular, semicircular, indistinct 4–6 sided sub-polygonal cross sections; most peripheral portions of ramoses coralla are phaceloid

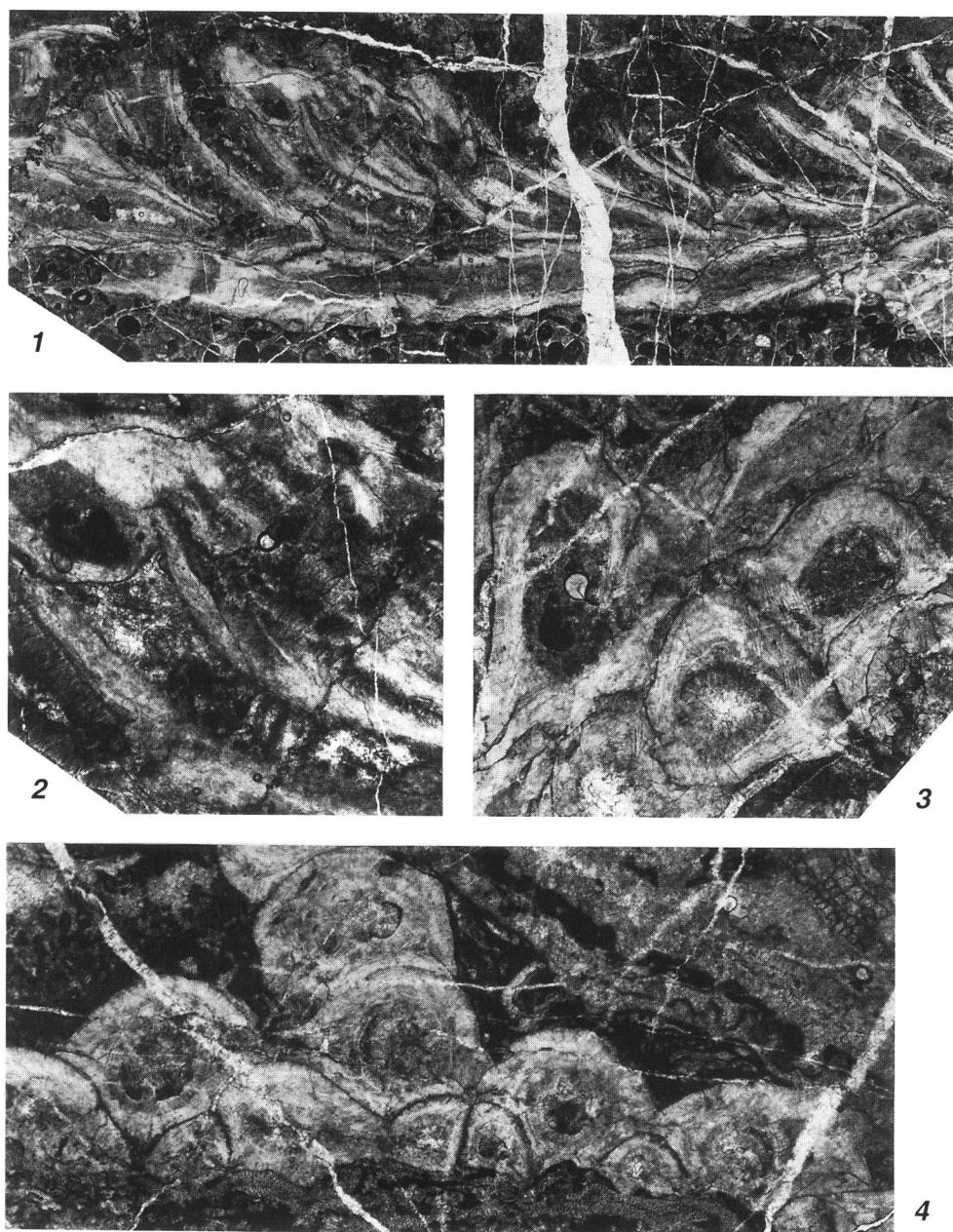


Fig. 8. *Mandulapora yamagiwai* sp. nov., thin sections. 1, 2, paratype, NSM PA14521, laminar corallum, 1, longitudinal section, $\times 5$, 2, partial enlargement of Fig. 8-1, $\times 14.5$. 3, holotype, NSM PA14517, proximal portion of ramose corallum, transverse section, $\times 14.5$. 4, paratype, NSM PA14525, proximal portion of laminar corallum, transverse section, $\times 14.3$.

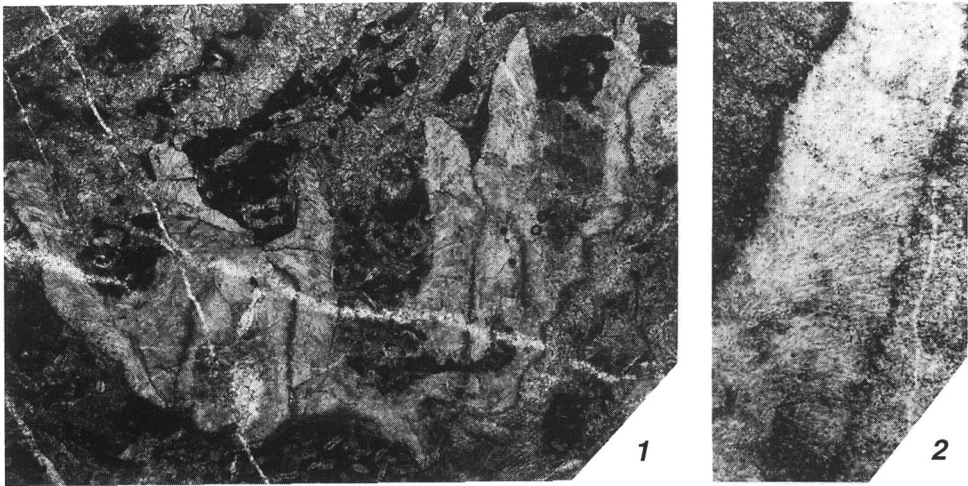


Fig. 9. 1, *Mandulapora yamagiwai* sp. nov., paratype, NSM PA14525, longitudinal thin section, note connecting tubuli, $\times 14.5$. 2, *Pseudofavosites hinaensis* sp. nov., holotype, NSM PA14522, longitudinal thin section indicating radially fibrous intercorallite wall microstructure, $\times 100$.

with cylindrical corallites of nearly circular cross sections, but phaceloid portions narrow for genus; diameters of corallites attain 1.4–1.9 mm, with 1.7 mm mean; calice deep, external surface of calice cylindrical; increase of corallites lateral, rare. Intercorallite walls composed of thin median dark line and moderately to exceptionally thick stereoplasm with lamellar microstructure, variable in thickness, ranging from 0.38 to 1.26 mm, usually 0.55–1.05 mm; corallite walls in phaceloid portions thinning towards calice; mural pores sporadic, elliptical to subcircular cross section with approximately 0.08 mm in maximum diameter, connecting tubuli rare; tabulae sporadic, 0–4 in 2.5 mm of corallite length, usually complete and convex distally; septal spines rare, short and thick, 0.06–0.17 mm in length.

Discussion: Although several identification was given to the same species in the Akiyoshi Limestone, Yamaguchi Prefecture, as noted by the above-mentioned synonym list, the combination of the alveolitoid-like proximal corallites (also illustrated in the type species by Ding *et al.*, 1984, pl. 23, fig. 1), the cerioid coralla, the connecting tubuli and the usually complete tabulae are the diagnostic feature of *Mandulapora*. Documented age of the Akiyoshi specimens ranges from late Visean (in *Nagatophyllum-Hiroshimaphyllum* coral colony, Haikawa & Ota, 1978) to late Bashkirian (in *Profusulinella beppensis* Zone, Sugiyama & Nagai, 1990).

Mandulapora yamagiwai sp. nov. can be distinguished in specific level from the type species *M. permica* Ding in Ding *et al.* (1984, pl. 23, figs. 1, 2, 3a, b, pl. 24, figs. 1, 2a–c, c', d, d', 3a, b) from the Lower Permian of Inner Mongolia (Nei Mongol

Zizhiqu) by its smaller diameter of the corallites (approximately 1.7 mm versus 2.0–3.0 mm in *M. permica*), narrower peripheral phaceloid portions and fewer connecting tubuli. *Zhesipora permica* Ding in Ding *et al.* (1984, pl. 22, figs. 1a, b, b', c, c', d, pl. 23, figs. 6a–c) from the Lower Permian of Inner Mongolia has the more closely spaced tabulae than those of *Mandulapora yamagiwai*. There is a possibility that *Zhesipora* is a subjective junior synonym of *Mandulapora*.

This paper represents the first identified occurrence of *Mandulapora* in Carboniferous and outside of Inner Mongolia.

Etymology: The specific name honors Dr. Nobuo Yamagiwa, in recognition of his contributions to the study of the Paleozoic corals found in East Asia.

Occurrence: Samples HL 2 (NSM PA14517), HL 3 (NSM PA14518), HL 6 (NSM PA14521, 14526), HL 9 (NSM PA14524), HL 10 (NSM PA14525) and HL 14 (NSM PA14527).

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