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Tabulate Corals from the Lower Devonian Ohno Formation in the Hikoroichi area, Iwate Prefecture, Northeast Japan

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Abstract This study identifies diverse tabulate corals from the Lower Devonian Ohno Formation exposed in the Hikoroichi area, Iwate Prefecture, Northeast Japan. Stratigraphically, they are classified as three assemblages. *Schedohalysites kitakamiensis*, *Hillaepora gionensis*, *Striatopora* sp. cf. *S. sugiyamai*, from limestone pebbles in the basal conglomeratic limestone represent Assemblage 1, that is Ludlow (early late Silurian) in age. These three species are derived from the underling Kawauchi Formation. Assemblage 2 is composed of seven species, *Sapporipora*? sp., *Egosiella*? sp., *Acaciaporella*? sp., *Squameostriatopora tachibanai* sp. nov., *Thamnopora ohnoensis* sp. nov., *Alveolites* sp., *Crassialveolites* sp. cf. *C. niigataensis*, and occurs in "the Nameriishi Limestone" belonging to the Lower Member of the formation. Constituents of Assemblage 3 are the following seven species, *Pachyfavosites hikoroichiensis* sp. nov., *Egosiella*? sp., *S. tachibanai*, *T. ohnoensis*, *Heliolites* sp., *Kanashiropora okuboi* sp. nov., *Syringopora sanrikuensis* sp. nov. They occur in greenish tuffaceous shale of the Lower Member. The age of the latter two assemblages is best constrained as Emsian (late Early Devonian).

Key words: South Kitakami Belt, Favositida, Heliolitida, Auloporida, Emsian

Introduction

The Ohno Formation in the South Kitakami Belt is a representative Devonian marine sequence in Japan. Since the first discovery of tabulate corals including *Favosites* cf. *styriaca*, *Thamnopora cristata*, and *Alveolites* sp., by Yabe and Sugiyama (1937), a considerable amount of species has been recorded from the formation, namely *Favosites baculoides*, *F*. cf. *forbesi*, *F*. cf. *pseudosocialis*, *F. reticulatus*, *F*. sp., *Squameofavosites* sp., *Pachypora* sp., *Thamnopora* sp. nov., *Coenites* sp., *Heliolites bohemicus*, *H*. sp., *Thecostegites* sp. (Sugiyama, 1941; Okubo, 1950; Onuki, 1956; Minato *et al.*, 1959, 1979a). Murata and Mori (1973, figs. 1-1–3) discovered a Silurian tabulate coral, *Schedohalysites kitakamiensis*, from the basal part of the formation, but it was probably reworked from the Kawauchi Formation (see below). It is thought that "*Favosites*" sp. in Murata *et al.* (1974, pl. 1, fig. 5) also has originated in the underlining formation. Except for *Thamnopora* sp. (Minato *et al.*, 1979a, pl. 7, fig. 1) and these derived fossils, unfortunately their taxonomic placements have not been verified because they are not figured or described yet. This precludes accurate chronologic and biogeographic competitions with other faunas. The present study provides the first detailed descriptions for the Ohno tabulate corals on the basis of new material collected from three collecting sites in the Hikoroichi area of Ofunato City, Iwate Prefecture, Northeast Japan (Fig. 1).

Repository: All specimens examined here are reposited in Department of Geology and Paleontology, National Museum of Nature and Science (prefixed NMNS), Tsukuba, Ibaraki Prefecture, Central Japan.

Geologic setting and locality

Yabe and Sugiyama (1937) divided the Middle Paleozoic rocks in the Hikoroichi area into five groups and named them Kawauchi, Takainari, Ōno, Nakazato, and Ōmori. The former two were assigned to the as the Silurian (Gotlandian) and other than groups regarded as the Devonian. In the recent definition given by Murata *et al.* (1974), the Ohno Formation comprises the uppermost Kawauchi, the uppermost Takainari and the Ōno groups. The

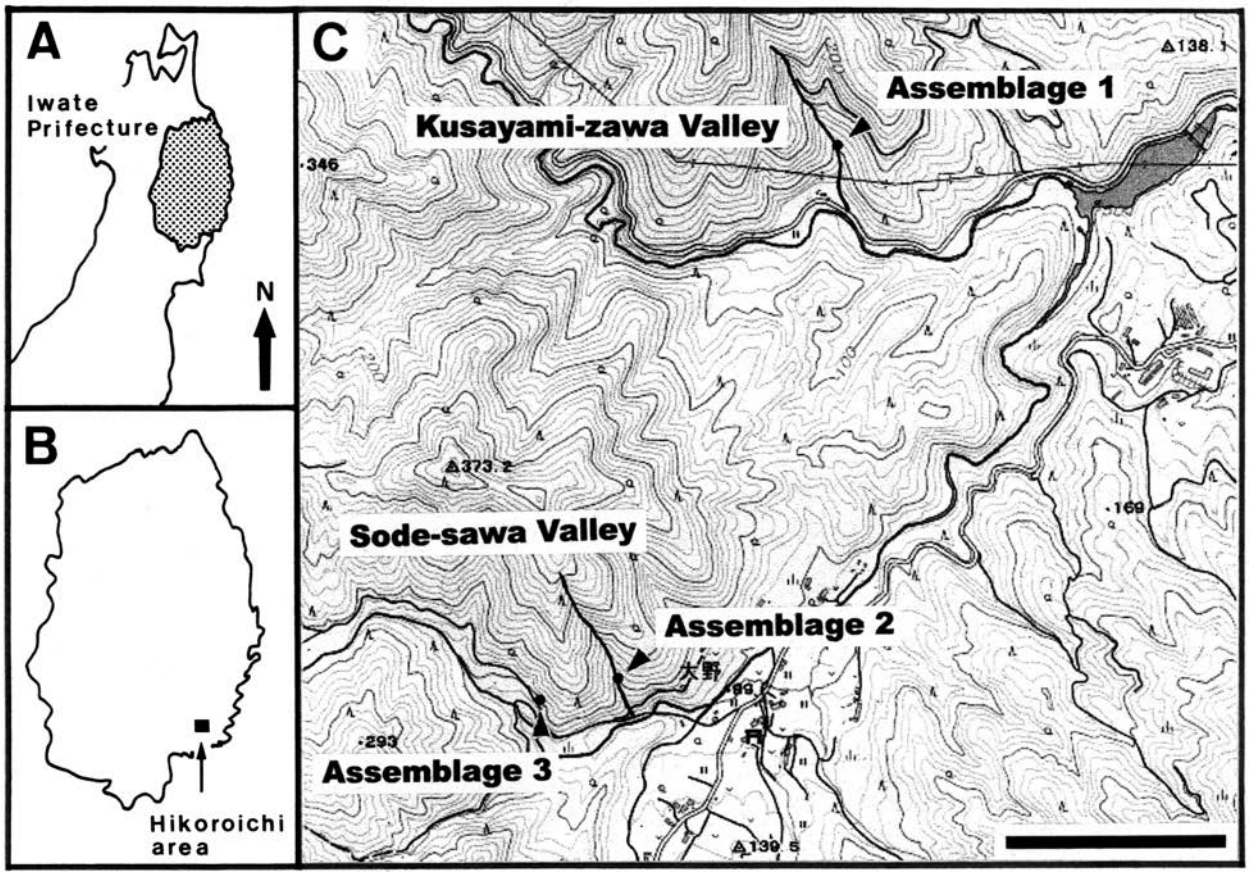

Fig. 1. Map showing locations of Iwate Prefecture in Northeast Japan (**A**), the Hikoroichi area in Iwate Prefecture (**B**), and collecting sites of Assemblages 1–3 in the Hikoroichi area (**C**). Scale bar in inset at lower right corner is 500 m. Used base map is "digital Japan Basic Map" published by Geospatial Information Authority of Japan.

formation (approximately 450 m thick) begins with conglomeratic limestone (= the uppermost part of the Kawauchi Group in Yabe and Sugiyama's scheme; *Solenopora*-limestone in Sugiyama, 1940), then it shifts to reddish tuffaceous shale (= the uppermost part of the Takainari group in Yabe and Sugiyama's scheme), greenish tuffaceous shale, alternating beds of acidic tuff and sandstone with a thin lens, up to 6 m, of "the Nameriishi Limestone," and acidic to dacitic tuff (Okubo, 1950; Onuki, 1969; Minato *et al.*, 1979a; Mori, 1989; Ehiro, 2017). On the basis of the present new observations at the Kusayami-zawa Valley, the Ohno Formation unconformable covers the Middle to Upper Silurian Kawauchi Formation. Relationship between the formation and the overlying Nakazato Formation is conformable (e.g., Ehiro, 2017).

Tabulate corals ware collected from angular pebbles in the basal conglomeratic limestone at an outcrop in a Kusayami-zawa Valley (Assemblage 1), float blocks of red spotted white limestone derived from "the Nameriishi Limestone" in a Sode-sawa Valley (Assemblage 2), and tuffaceous shale crops out along a road cut (Assemblage 3). All fossil-bearing horizons belong to the Lower Member in Mori (1989)'s stratigraphic subdivision (Fig. 2). Locality of Assemblage 3 is probably identical with that of *Thecostegites* sp. (Minato *et al.*, 1959; = *Ohnopora hayasakai* Minato and Minoura, 1977; = *Pernerocrinus hayasakai* in Minoura, 1987).

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 ***Sapporipora*** Ozaki *in* Shimizu, Ozaki and Obata, 1934

Type species: *Sapporipora favositoides* Ozaki *in* Shimizu, Ozaki and Obata, 1934.

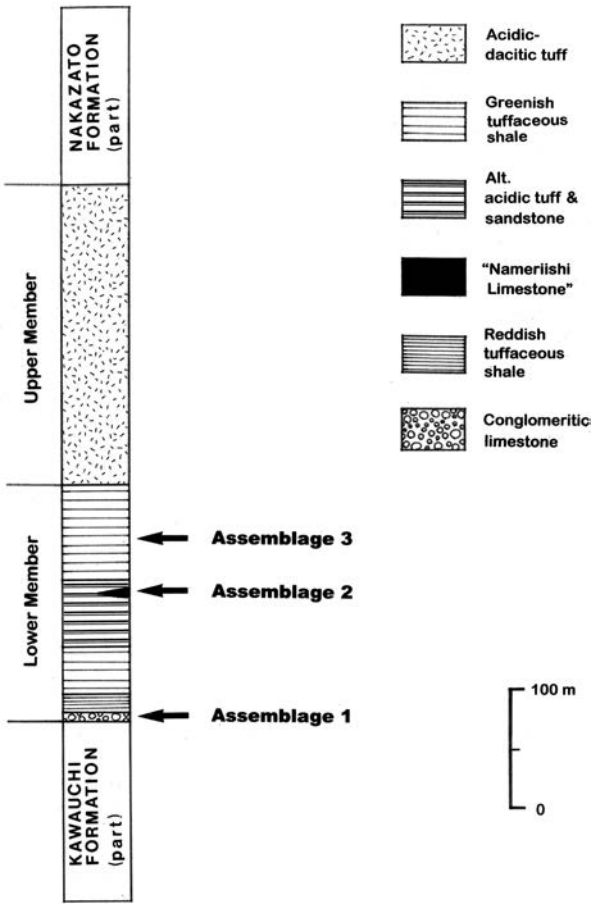

Fig. 2. Generalized and simplified stratigraphic column of the Ohno Formation on the basis of research results by previous workers (Okubo, 1950; Onuki, 1969; Murata *et al.*, 1974; Minato *et al.*, 1979a; Mori, 1989; Kurihara *et al.*, 2005; Ehiro, 2017) and new information gained during the present study, showing horizons of Assemblages 1–3.

Sapporipora? sp.
Figs. 3A, B

Material examined: NMNS PA20546, 20547.

Occurrence: Red spotted white limestones, Assemblage 2.

Description: Two fragments of poorly preserved coralla were examined; they are cerioid and attain 45 mm in diameter. Corallites prismatic with 4–6 sides; diameters of corallites are small, 0.4–0.7 mm. Intercorallite walls weakly thickened, 0.08–0.13 mm; mural pores may occur on corallite faces. No distinct septal spines observable. Tabulae complete and nearly horizontal.

Discussion: Although the examined specimens are poor in preservation, their narrow corallites and weakly thickened corallite walls suggest relationship with the Silurian? to Devonian genus *Sapporipora*.

Subfamily Pachyfavositinae Mironova, 1965
Genus ***Pachyfavosites*** Sokolov, 1952

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

Pachyfavosites hikoroichiensis sp. nov.
Figs. 4A–F

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Type material: Holotype, NMNS PA20550. Paratypes, NMNS PA20548, 20552–20554, 20556, 20557.

Other material examined: NMNS PA20549, 20551, 20555.

Occurrence: Greenish tuffaceous shales, Assemblage 3.

Diagnosis: Species of *Pachyfavosites* with nodular to longitudinally elongated coralla; corallites large for the genus, 0.5–3.0 mm (2.7 mm mean near corallum periphery); intercorallite walls 0.20–0.53 mm in thickness; mural pores well develop mostly on corallite faces; septal spines well-developed, low conical; tabulae common, mostly complete; there are 3–8 tabulae in 5 mm.

Description: Coralla cerioid; the most usual corallum growth forms are nodular to subspherical, and longitudinally elongated types also recognized in rare cases; the holotype has 65 mm in diameter and 34 mm in height; an elongated corallum of a paratype (NMNS PA20557) leaches 18 mm in diameter and 66 mm in height. Corallites prismatic with 3–10 sides to rounded subprismatic; except for longitudinally elongated coralla where corallites indicate weak outward curvature, corallite arrangement is radial; diameters of corallites large for the genus, range from 0.5 mm to 3.0 mm with 2.7 mm mean near corallum periphery; calices shallow to very sallow: openings of calices are perpendicular for corallum surface in nodular and obliquely upward, approximately 50° for surface, in elongated types; lumina indicate rounded sub-polygonal transverse sections; increases of new corallites frequent, probably lateral. Intercorallite walls uniformly thickened, 0.20–0.53 mm and differentiated into thin median line and transparent stereoplasm; microstructure of stereoplasm is rect-radiate fibers; distinct growth lamellae in stereoplasm is not

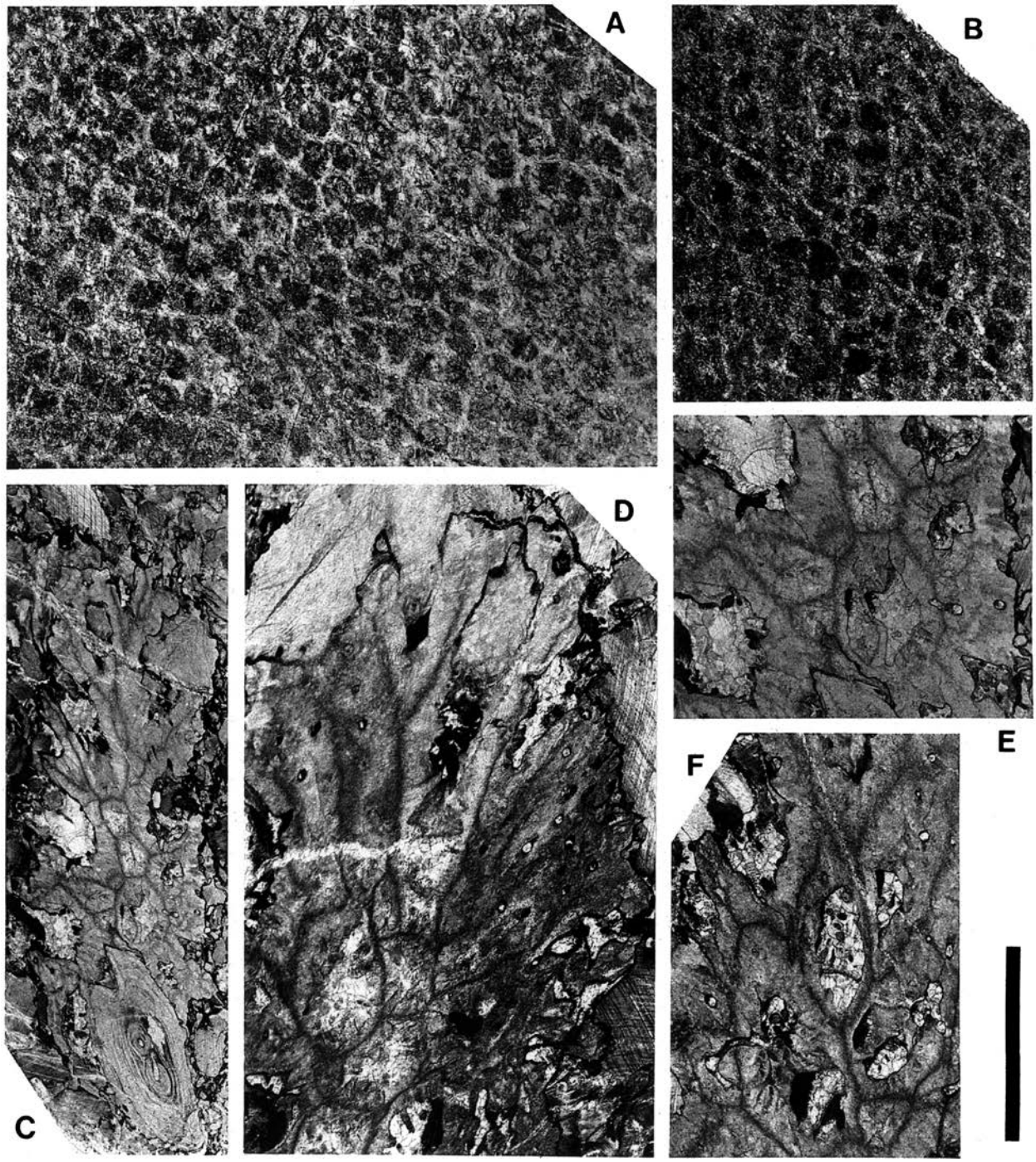

Fig. 3. **A**, **B**, *Sapporipora*? sp., NMNS PA20547, thin sections; A, transverse sections of corallites, B, longitudinal sections of corallites. **C**–**F**, *Acaciapora*? sp., NMNS PA20558, thin sections; A, longitudinal section of corallum; D–F, transverse to longitudinal sections of corallites. Scale bar: 3 mm in A, B, D–F; 6 mm in C.

observable; mural pores well-developed, mostly occur on corallite faces and rarely near angles and form a single to rarely two row(s); profiles of pores are circular to longitudinally elongated; typical pores have 0.10–0.23, 0.21 × 0.27 mm in diameter; septal spines well-developed, low conical with wide bases; lengths of spines are 0.05–0.19 mm; tabulae common and complete or incomplete in very are cases; in longitudinal section, they exhibit nearly flat, weakly concave or convex, weakly to moderately oblique profiles; there are 3–8 tabulae in corallite length of 5 mm; some tabulae thickened, attaining 0.21 mm.

Etymology: The specific name derives from the Hikoroichi area, from which this new species was recovered.

Discussion: The absence of the distinct growth laminae in stereoplasm suggests that the Ohno

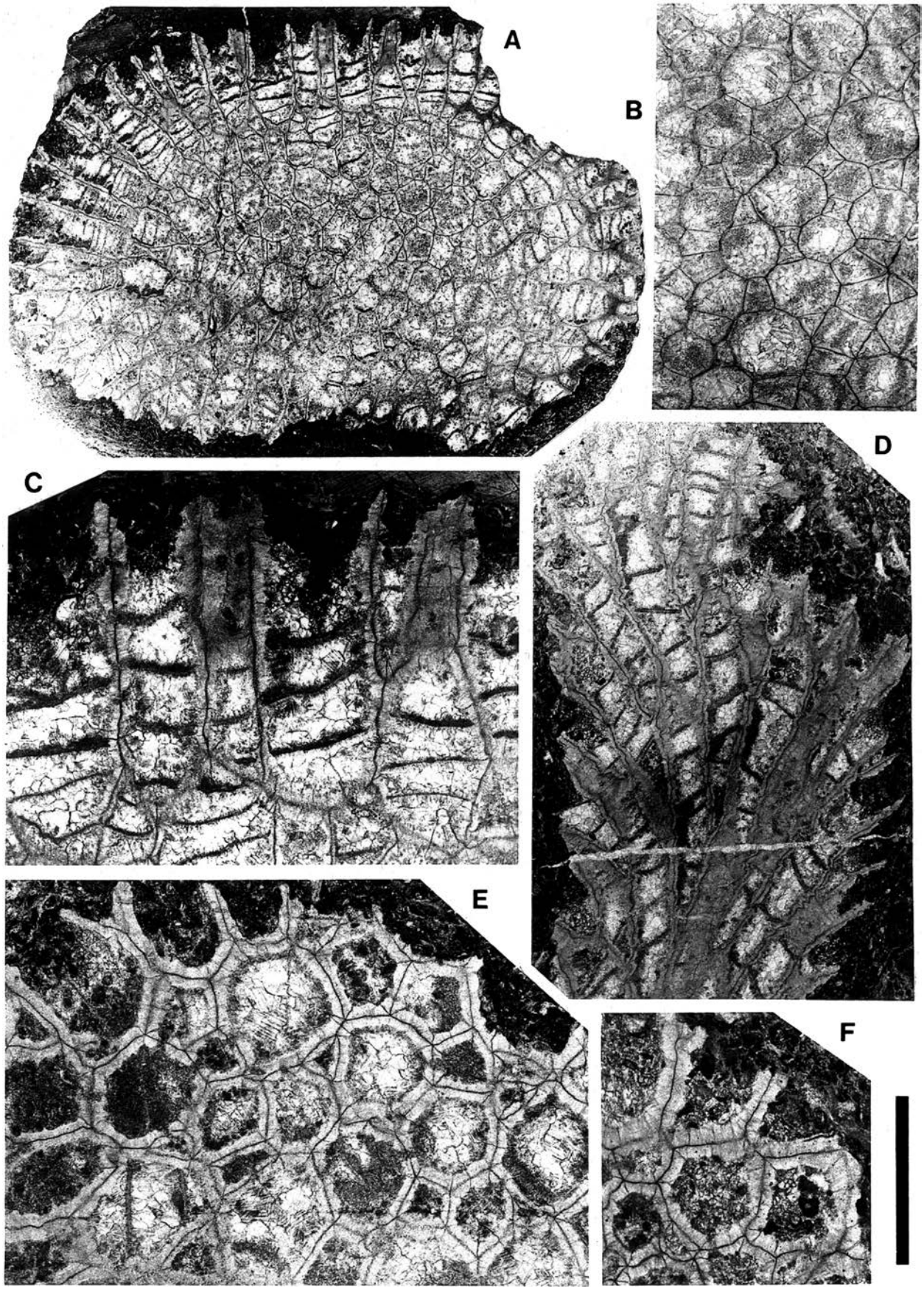

Fig. 4. *Pachyfavosites hikoroichiensis* sp. nov., thin sections. **A**–**C**, holotype, NMNS PA20550; A, transverse section of corallum, B, transverse sections of proximal corallites, C, longitudinal sections of distal corallites. **D**, paratype, NMNS PA20556, longitudinal section of corallum. **E**, paratype, NMNS PA20552, transverse sections of distal corallites. **F**, paratype, NMNS PA20554, transverse sections of distal corallites. Scale bar: 10 mm in A; 6 mm in B, D; 3 mm in C, E, F.

species places within *Pachyfavosites* rather than *Lamellaeoporella* (Smirnova *in* Cherkesova *et al.* 1968). *Pseudopachyfavosites* (Tchi, 1976) is diagnosed by the possessions of the pinnately arranged microstructure in stereoplasm and the squamulae-like septa. These characters are not developed in the species.

Pachyfavosites hikoroichiensis sp. nov. is comparable with two previously known species of the genus from Japan, namely *P. katoi* Niko (2007, p. 66, 68, figs. 6-1–5) from the Emsian to Eifelian (late Early to early Middle Devonian) Ozako Member of the Fukuji Formation in Gifu Prefecture and *P. hidensiformis* (Mironova, 1961, p. 149, 150, pl. 5, figs. 1a, b, v. g; Niko and Senzai, 2011, p. 29, 31, figs. 1-1–8) from the Lochkovian (early Early Devonian) part of the Oisedani Member, the Kamianama Formation in Fukui Prefecture. The type locality of the last species is the Lochkovian rocks of Salair, southwestern Siberia. After that it known to occur in the Yana River Basin, eastern Siberia (Dubatolov, 1969). The principal difference between *P. hikoroichiensis* and these known spices is mean corallite diameters; 2.7 mm in the new species versus 1.2 mm in *P. katoi* and 1.6 mm in *P. hidensiformis*.

An Eifelian species, *Pachyfavosites gurievskiensis* Dubatolov (1959, p. 66, 67, pl. 18, figs. 5a, b; Tchi, 1980, p. 156, pl. 72, figs. 3a, b) from the Kuznetsk Basin, southwestern Siberia (Dubatolov, 1959) and Jilin, Northeast China (Tchi, 1980), also resembles *P. hikoroichiensis*, but its small corallite diameters (up to 2 mm) and fewer septal spines distinguishes *P. gurievskiensis* from *P. hikoroichiensis*.

Superfamily Pachyporoidea Gerth, 1921
Family Pachyporidae Gerth, 1921
Genus ***Acaciaporella*** Tchi, 1980
Type species: *Acaciaporella jilinensis* Tchi, 1980.

Acaciaporella? sp.
Figs. 3C–F

Material examined: NMNS PA20558.

Occurrence: Red spotted white limestone, Assemblage 2.

Description: A single cerioidal corallum attached on brachiopod spine was available for study; it is short cylindrical having 7 mm in diameter and 19 mm in length; no branching observable. Corallites prismatic with 3–8 sides; diameters of corallites are 0.6–2.2 mm; number of corallite consisting corallum is few for the family; calices very deep, oblique. Intercorallite walls strongly thickened, attaining 0.96 mm and differentiated into median line and stereoplasm; mural pores well developed on corallite faces and near corallite angles. Both spines and squamulae are recognized as septal element. Tabulae very rare, complete.

Discussion: The material clearly resembles the type species of *Acaciaporella* from Inner Mongolia, North China (Tchi, 1980) by its corallite number in transverse section of corallum, thickened intercorallite walls and the coexistences of septal spines and squamulae. However, previously known range of the genus is exclusively in the early Permian (Lin *et al.*, 1988).

Genus ***Egosiella*** Dubatolov *in* Sokolov, 1955
Type species: *Egosiella safonoviensis* Dubatolov *in* Sokolov, 1955.

Egosiella? sp.
Figs. 5A–D

Material examined: NMNS PA20559–20563.

Occurrence: Red spotted white limestones, Assemblage 2 (NMNS PA20561–20563) and greenish tuffaceous shales, Assemblage 3 (NMNS PA20559, 20560).

Description: Coralla ramose, formed by cylindrical branches, and cerioid; anastomosed branches may present; diameters of branches are 3.2–4.9 mm. Corallites slender, probably prismatic; their transverse profiles are unclear by despairing median line; approximate corallite diameters 0.2–0.4 mm; proximal portions of corallite run parallel with branch axis and form axial zone, then distal corallites in peripheral zone curve outwardly to form oblique calices; transverse sections of lumina are nearly circular. Intercorallite walls thin, 0.02–0.09 mm, in axial zone and rapidly thickened attaining 0.33 mm in peripheral zone; distinct mural pore not observable. Tabulae probably absent.

Discussion: The preserved characters above correspond to those of the Middle Silurian to Middle Devonian genus *Egosiella*, but the present Ohno specimens are not complete to enough for the generic determination.

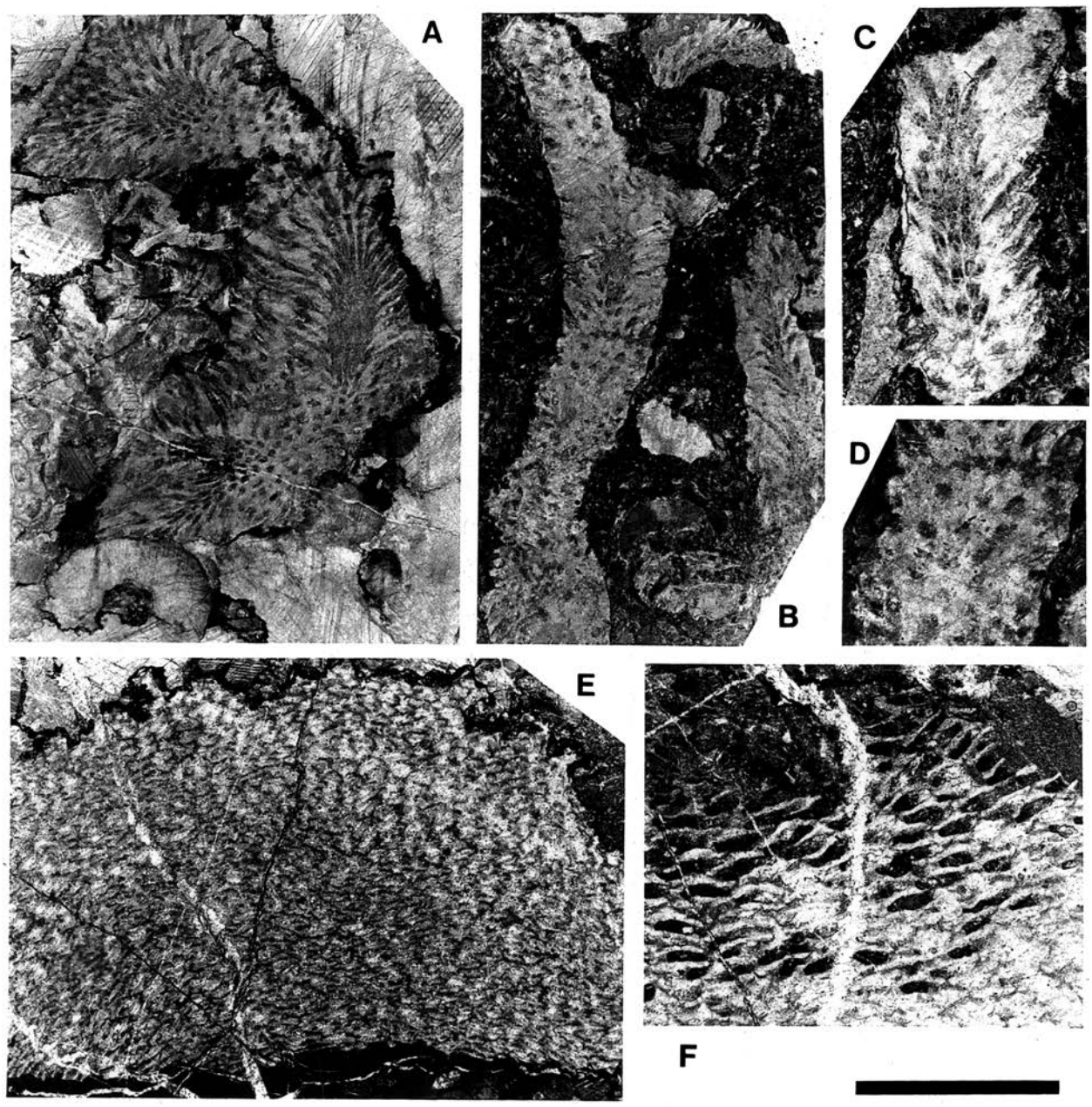

Fig. 5. **A**–**D**, *Egosiella*? sp., thin sections; A, NMNS PA20561, longitudinal to oblique sections of branches, B–D, NMNS PA20559, B, C, longitudinal sections of branches, D, longitudinal (off branch axis) section of branch, showing transverse sections of distal corallites. **E**, **F**, *Alveolites* sp., NMNS PA20611, thin sections; E, longitudinal section of corallum, F, transverse sections of corallites. Scale bar: 6 mm in A, B, E; 3 mm in C, D, F.

Genus ***Hillaepora*** Mironova, 1960

Type species: *Hillaepora spica* Mironova, 1960.

Hillaepora gionensis Niko and Adachi, 1999

Fig. 10E

Hillaepora gionensis Niko and Adachi, 1999, p. 112, figs. 1-1–5; Niko, 2003, p. 9, 10, figs. 1-5, 6.

Material examined: NMNS PA20564.

Occurrence: Limestone pebble, Assemblage 1.

Discussion: A single specimen of fragmentary branch is assigned to *Hillaepora gionensis* based on the following characters: branch relatively narrow with approximately 4 mm in reconstructed diameter and cerioid except for peripheral zone of branch, where distal corallites become free; corallite nearly straight to gradually bend outwardly; dimeters of corallites are small, 0.3–0.6 mm; intercorallite walls 0.10–0.25 mm in thickness; no septal spine observable; tabulae complete, rare.

Hillaepora gionensis was elected on the four type specimens from the Ludlow (early late Silurian) G3

Member of the Gionyama Formation in Miyazaki Prefecture (Niko and Adachi, 1999). This species also occurs from the Ludlow part of the Suberidani Group in Tokushima Prefecture (Niko, 2003).

Genus ***Squameostriatopora*** Tchi, 1980

Type species: *Squameostriatopora ferospina* Tchi, 1980.

Squameostriatopora tachibanai sp. nov.
Figs. 6A–G

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Type material: Holotype, NMNS PA20565. Paratypes, NMNS PA20566, 20570.

Other material examined: NMNS PA20567–20569, 20571.

Occurrence: Red spotted white limestones, Assemblage 2 (NMNS PA20570–20571), and greenish tuffaceous shales, Assemblage 3 (NMNS PA20565–20569).

Diagnosis: Species of *Squameostriatopora* with large corallite diameters indicating 0.2–1.8 mm (1.5 mm mean near branch surface); intercorallite walls 0.15–0.49 mm in thickness; mural pores rarely occur on corallite faces; septal spines well developed, low conical; squamulae relatively rare, very long attaining 0.46 mm; tabulae sporadic, complete or incomplete; there are 0–4 tabulae in 5 mm.

Description: Only isolated branches are available for study; they are subcylindrical, 6–11 mm in diameter, cerioid. Corallites prismatic to sub-prismatic with somewhat irregular transverse sections having 4 to indistinct 9 sides; diameters of corallite are large for the genus, 0.2–1.8 mm, 1.5 mm mean near branch surface; each corallite run parallel with branch axis, then it gradually bent outward to form upwardly oblique calice; opening angles of calices for branch surface are 30°–65°; calical depths very deep to deep; lumina rounded sub-polygonal in transverse section; lateral increases of new corallites commonly occur in axial zone of branch. Intercorallite walls uniformly thickened and differentiated into median line and stereoplasm; in longitudinal section, walls exhibit weak sinus; microstructure of stereoplasm is rect-radiate fivers; thicknesses of walls are 0.15–0.49 mm; mural pores small, rarely occur on corallite faces and have circular profiles; diameters of pores are 0.08–0.14 mm; septal element consists of well-developed spines and relatively rare squamulae; septal spines low conical, 0.06–0.10 mm in length; squamulae very long, 0.35–0.46 mm, and upwardly directed; tabulae sporadic, complete or incomplete in rare cases, directly transverse for corallite to more or less oblique; there are 0–4 tabulae in 5 mm of corallite length; some tabulae weakly thickened attaining 0.10 mm.

Etymology: The specific name honors the late Koichi Tachibana for recognition of his paleontological and geological contributions in the South Kitakami Belt.

Discussion: *Squameostriatopora* is a very rare genus. Previously only the type species, *S. ferospina* Tchi (1980, p. 169, pl. 69, figs. 4a, b) from the Lower Devonian in Jilin have been known (Lin *et al.*, 1988). This species differs from *S. tachibanai* sp. nov. by its smaller corallite diameters; 0.4–0.7 mm versus attaining 1.8 mm in *S. tachibanai*. In addition, restricted distribution of its septal elements in the peripheral zone is not developed in the new species.

Genus ***Striatopora*** Hall, 1851

Type species: *Striatopora flexuosa* Hall, 1851.

Striatopora sp. cf. ***S. sugiyamai***
Niko and Adachi, 1999
Fig. 10F

Compare with:

Coenites sp., Sugiyama, 1944, p. 46, pl. 3, figs. 2a, b.

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; Niko, 2024a, p. 4, pl. 2, figs. 4–7.

Striatopora sp. cf. *S. sugiyamai*, Niko, 2003, p. 10, figs. 1-1–4.

Material examined: NMNS PA20572.

Occurrence: Limestone pebble, Assemblage 1.

Discussion: A single oblique section of fragmentary branch was examined. Its characters are as follows: diameter of branch is very small, 1.4 mm; corallites outwardly curved and have 0.2–0.4 mm in diameter; intercorallite walls thin in axial zone of branch, then rapidly increase in thickness, attaining

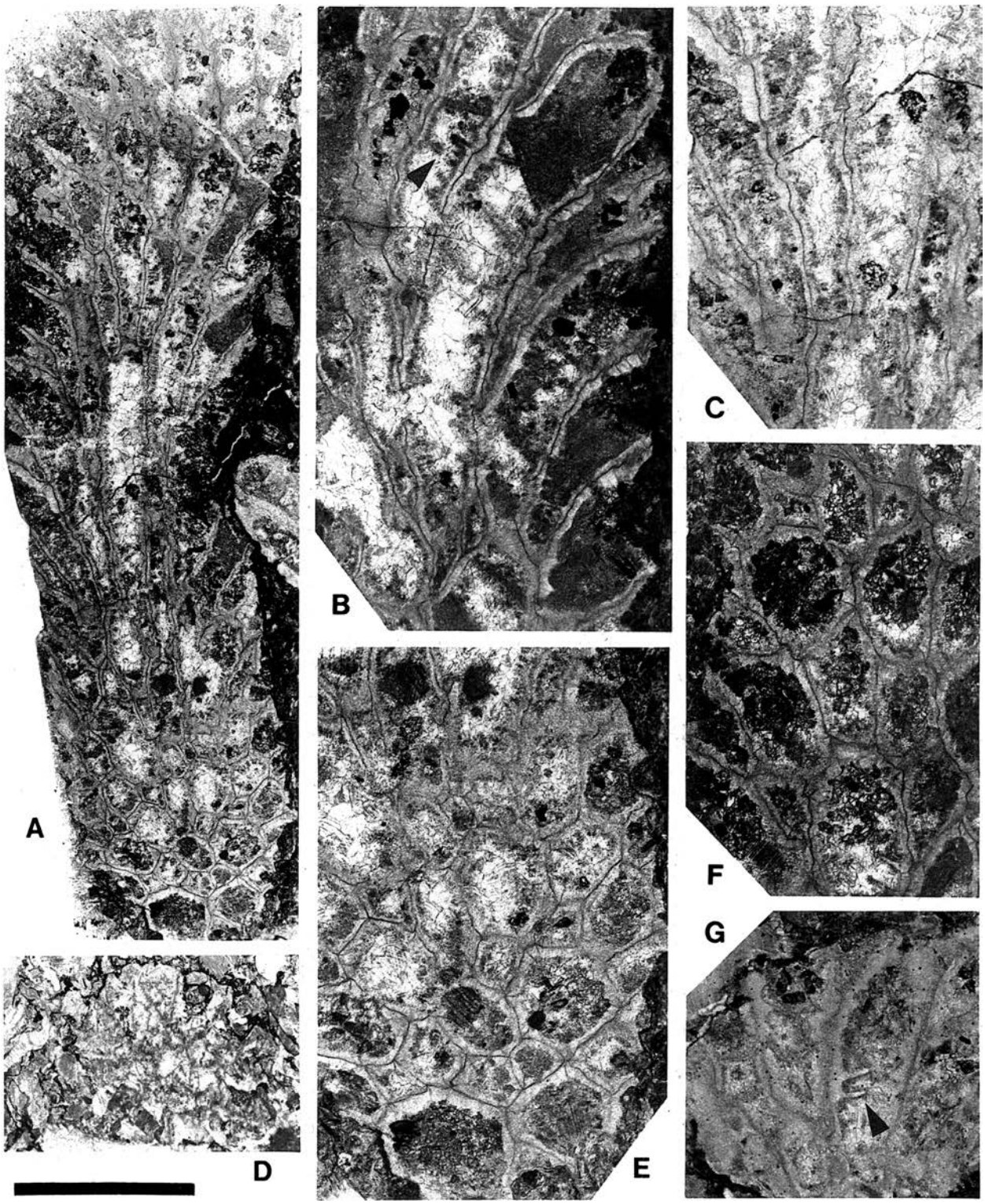

Fig. 6. *Squameostriatopora tachibanai* sp. nov., thin sections. **A**–**C**, **E**, **F**, holotype, NMNS PA20565; A, longitudinal section of branch, B, longitudinal sections of distal corallites, arrow indicates squamulae, C, longitudinal sections of proximal corallites, E, F, transverses to oblique sections of corallites; **D**, paratype, NMNS PA20570, transverse section of branch; **G**, paratype, NMNS PA20566, longitudinal sections of corallites, arrow indicates squamulae. Scale bar: 6 mm in A, D; 3 mm in B, C, E–G.

approximately 0.2 mm, to form peripheral stereozone; no septal spine observable; tabulae complete, common. The Ohno specimen agrees well with the type specimens of *Striatopora sugiyamai* from the G2 and G3 members of the Gionyama Formation in Miyazaki Prefecture except for its much smaller branch diameter. It thinks that this dimensional difference may be intraspecific varia-

tion, but the material is insufficient for a confident specific identification.

Striatopora sugiyamai and closely related species with it occur abundantly from the Wenlock and commonly from Ludlow in the Kurosegawa Belt in Southwest Japan (Niko and Adachi, 1999; Niko, 2003, 2024a).

Genus ***Thamnopora*** Steininger, 1831

Type species: *Thamnopora madreporacea* Steininger, 1831.

Thamnopora ohnoensis sp. nov.
Figs. 7A–E

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[?] *Thamnopora cristata* (Blumenbach). Yabe and Sugiyama, 1937, p. 418.
[?] *Thamnopora* sp. nov., Sugiyama, 1941, p. 548.
Thamnopora sp., Minato *et al.*, 1979a, pl. 7, fig. 1.

Type material: Holotype, NMNS PA20578. Paratypes, NMNS PA20573, 20574, 20576, 20577, 20580, 20594, 20596, 20599, 20600.

Other material examined: NMNS PA20575, 20579, 20581–20593, 20595, 20597, 20598, 20601–20608.

Occurrence: Red spotted white limestones, Assemblage 2 (NMNS PA20583–20608) and greenish tuffaceous shales, Assemblage 3 (NMNS PA20573–20582).

Diagnosis: Species of *Thamnopora* with relatively small corallite diameters, 0.3–1.4 mm, 1.0 mm in mean near branch surface, and narrow peripheral zone; intercorallite walls 0.25–0.71 mm in thickness; peripheral stereozone absent; mural pores common, very small in diameter, up to 0.15 mm; septal spine relatively rare, low conical to needle-like; tabulae complete or incomplete, closely spaced; there are 5–13 tabulae in 5 mm.

Description: Coralla ramose with frequent anastomoses, cerioid; the largest specimen (holotype) has 102 mm in diameter and 55 mm in height; branches usually cylindrical; branching bifurcate or umbelliferous in rare cases; usual diameters of branches are 4–12 mm. Corallites prismatic with 4–9 sides; dented angles and faces of corallites commonly developed; there are 76–107 corallites in transverse section of branch; corallite diameters relatively small for the genus, 0.3–1.4 mm, with 1.0 mm mean near branch surface; in axial zone of branch, corallites run parallel with branch axis, then they turn outward to form narrow peripheral zone; calices shallow to very shallow and open nearly perpendicular for branch surface; transverse sections of lumina are circular to rounded subpolygonal; increases of new corallites occur frequently in axial and rarely in peripheral zones, lateral. Intercorallite walls uniformly thickened, 0.25–0.71 mm; peripheral stereozone not developed; structurally, walls differentiated into thin median dark line and stereoplasm; microstructure of stereoplasm is rect-radiate fibers; mural pores commonly occur on corallite faces; profiles of pores are circular to oval with very small diameters, indicating 0.06–0.13, 0.06 × 0.15, 0.08 × 0.10 mm in typical ones; septal spine relatively rare, low conical to needle-like, and 0.08–0.23 mm in length; tabulae well-developed, mostly complete, but incomplete tabulae are not rare; complete tabulae variable in transverse section, ranging from directly transverse to more or less oblique for corallites, or concave proximally; spacing of tabulae close; there are 5–13 tabulae in corallite length of 5 mm.

Etymology: The specific name is derived from the type stratum named the Ohno Formation.

Discussion: *Thamnopora ohnoensis* sp. nov. is comparable with three Early Devonian species, including *T. kolodaensis* Dubatolov (1959, p. 83–85, pl. 24, figs. 3–5, 6a, b, v, 7) from the Lochkovian of the Kuznetsk Basin, southwestern Siberia, *T. plumosa* Yanet *in* Dubatolov *et al.* (1968, p. 86, 87, pl. 36, figs. 4a, b) from the Lochkovian of the Urals, and *T. xinjiangensis* Lin and Wang *in* Wang (1983, p. 228, 229, pl. 73, figs. 3a, b) from the Xinjiang Uygur Autonomous Region, Northwest China. Distinctive features of these species from *T. ohnoensis* are as follows: *T. kolodaensis* has the large mural pores, 0.2–0.3 mm, versus up to 0.15 mm in the new species; *T. plumosa* differs by its very small corallite diameters, 0.4–0.75 mm, versus attaining 1.4 mm in ditto; and septal spines are not observable in *T. xinjiangensis*.

Two closely related Givetian species, namely *Thamnopora angusta* Lecompte, 1939, p. 115, 116, pl. 16, figs. 17–20) from Belgium and *T. reedi* Dubatolov (1959, p. 107, 108, pl. 38, figs. 1a, b, v, g, 2, 3a,

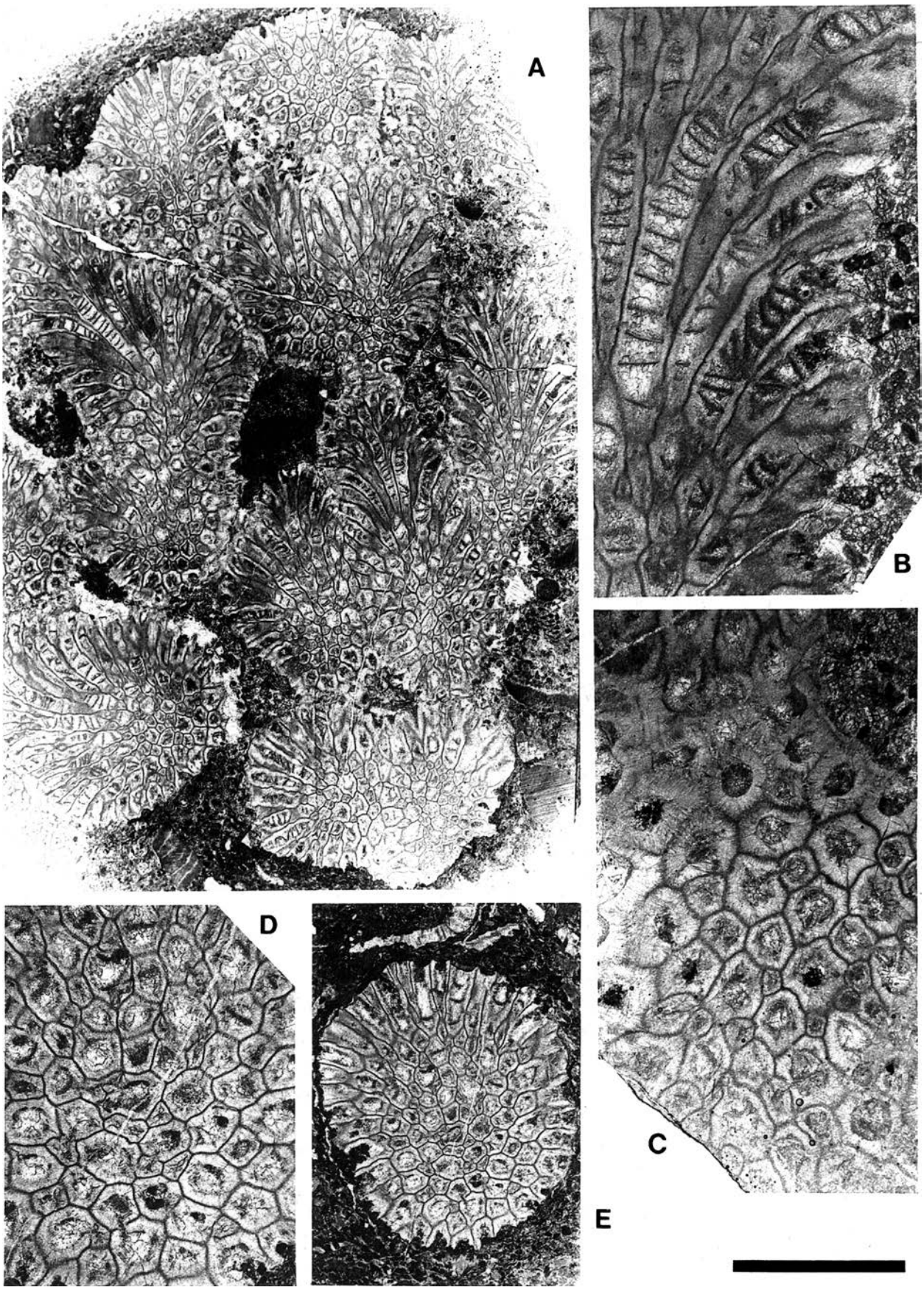

Fig. 7. *Thamnopora ohnoensis* sp. nov., thin sections. **A**–**C**, holotype, NMNS PA20578; A, longitudinal section of corallum, B, longitudinal to oblique sections of corallites, C, transverse sections of corallites. **D**, **E**, paratype, NMNS PA20577; D, transverse to oblique sections of corallites, E, transverse section of branch. Scale bar: 10 mm in A; 3 mm in B–D; 6 mm in E.

b, v) from the Kuznetsk Basin, are also comparable with *T. ohnoensis*. However, their tabulae spacings are much wider than that of the new species.

Yabe and Sugiyama (1937) documented *Thamnopora cristata* (Blumenbach, 1803, p. 25, 26, pl. 3, fig. 12), whose type series known to occur from the Upper Devonian of Spain, in the faunal list of the Ohno Formation as mentioned above. The diagnostic characters of *T. cristata cristata* provided by Flügel and Flügel (1979, p. 52, 53, pl. 1, figs. 1–4) are 1) corallite diameters moderate up to 1.9 mm, 2) intercorallite walls form peripheral stereozone, 3) septal spines absent, and 4) tabulae sparse having 3.0–4.5 mm in distance between adjacent tabulae. It thinks that there is no direct relationship between this species and at least the examined specimens of *T. ohnoensis* in the present study.

Suborder Alveolitina Sokolov, 1950
Family Alveolitidae Duncan, 1872
Subfamily Alveolitinae Duncan, 1872
Genus ***Alveolites*** Lamarck, 1801

Type species: *Alveolites suborbicularis* Lamarck, 1801.

Alveolites sp.
Figs. 5E, F

[?] *Alveolites* sp., Yabe and Sugiyama, 1937, p. 418.

Material examined: NMNS PA20609–20611.

Occurrence: Red spotted white limestones, Assemblage 2.

Description: Coralla thick tabular, alveolitoid; the largest specimen (NMNS PA20611) has 53 mm in diameter and 28 mm in height. Corallites reclined throughout all growth stages with nearly horizontal directions; transverse sections of corallites are crescentic to laterally elongated sub-elliptical and 0.7–0.9 mm in width and 0.2–0.3 mm in height. Intercorallite walls thin to relatively thin, 0.06–0.19 mm; mural pores occur at corallite angels. No septal spine and tabula observable.

Discussion: *Alveolites* sp. in faunal list of the Ohno Formation by Yabe and Sugiyama (1937) is probably conspecific with the present species. Unfortunately, the examined material here is not sufficient for a reliable specific determination. Stratigraphically, the genus *Alveolites* ranges the Middle Silurian to the Upper Devonian (Lin *et al.*, 1988).

Genus ***Crassialveolites*** Sokolov, 1955

Type species: *Alveolites crassiformis* Sokolov, 1952.

Crassialveolites sp. cf. ***C. niigataensis***
Niko, Ibaraki and Tazawa, 2015
Figs. 8A–E

Compare with:
Crassialveolites niigataensis Niko, Ibaraki and Tazawa, 2015, p. 19, 20, figs. 2-1–6.

Material examined: NMNS PA20612.

Occurrence: Red spotted white limestone, Assemblage 2.

Description: A single corallum is available for study; it is alveolitoid, low domical in growth form, 21 mm in diameter and 9 mm in height. Corallites very narrow for the family, sub-prismatic having fan-shaped to sub-trapezoidal transverse sections, 0.5–0.7 mm in width and 0.3–0.4 mm in height; proximal corallites reclined with nearly horizontal growth direction, then distal ones turn upward; form ratios (width/height) of corallites range from 1.2 to 1.8; lumina circular to oval in transverse section. Intercorallite walls uniformly thickened throughout, relatively thick in comparing with corallite diameters, 0.04–0.25 mm; structurally walls differentiated into median line and stereoplasm; mural pores commonly occur at corallite angles or narrow sides of corallite faces; profiles of pores are circular; diameters of pores are 0.02–0.03 mm; septal spine absent; tabulae complete, directly transverse for corallites; distribution of tabulae is variable ranging from almost absent to well-developed; there are 0–6 in 2 mm of corallite length.

Discussion: The above features of the present Ohno specimen especially in the gross corallite shape and intercorallite wall nature are characteristic of *Crassialveolites niigataensis*, described by Niko *et al.* (2015) from the Middle Devonian pebbles in Mesozoic conglomerate of Niigata Prefecture. However, its thinner intercorallite walls (up to 0.25 mm) than those of the types of *C. niigataensis* (attaining 0.36 mm) preclude an identification between them. Furthermore, uneven distribution of the tabulae is not developed in a type series of *C. niigataensis*.

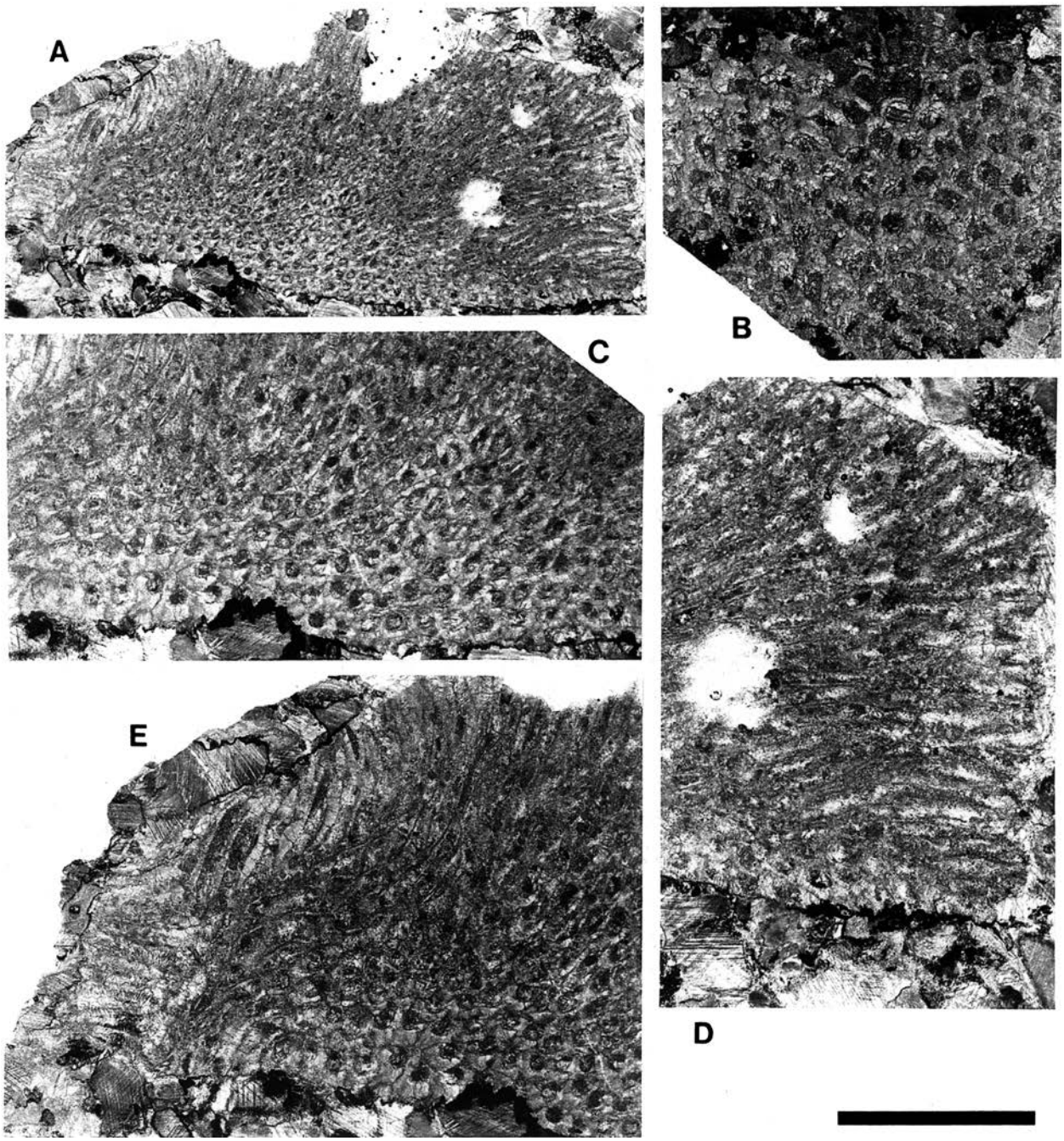

Fig. 8. *Crassialveolites* sp. cf. *C. niigataensis* Niko, Ibaraki and Tazawa, 2015, NMNS PA20612, thin sections. **A**, longitudinal section of corallum, **B**, transverse sections of corallites, **C**, transverse to oblique sections of corallites, **D**, **E**, longitudinal to transverse sections of corallites. Scale bar: 6 mm in A; 2.5 mm in B; 3 mm in C, D.

Order Heliolitida Frech, 1897
Suborder Heliolitina Frech, 1897
Superfamily Heliolitoidea Lindström, 1876
Family Heliolitidae Lindström, 1876
Genus ***Heliolites*** Dana, 1846
Type species: *Astraea porosa* Goldfuss, 1826.

Heliolites sp.
Figs. 9A, B

Material examined: NMNS PA20613.

Occurrence: Greenish tuffaceous shale, Assemblage 3.

Description: A single specimen of nodular corallum was examined; its diameter approximately 21 mm. Corallites cylindrical and surrounded by prismatic coenenchymal tubules; corallite diameters

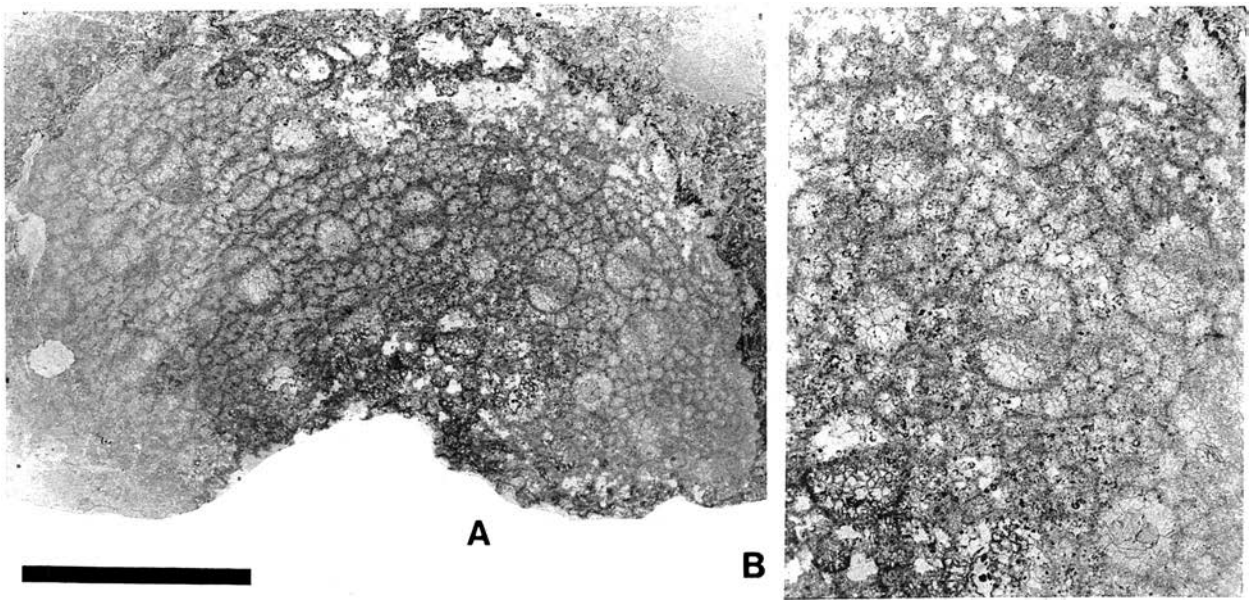

Fig. 9. *Heliolites* sp., NMNS PA20613, thin sections. **A**, transverse section of corallum; **B**, transverse sections of corallites and coenenchymal tubes. Scale bar: 6 mm in A; 3 mm in B.

range from 1.2 to 1.5 mm; there are 2–5 tubules between adjacent corallites; tubule diameters 0.3–0.6 mm. Corallite walls relatively thin, 0.06 mm; no distinct septal element recognized; tabulae complete.

Discussion: Previous records of the genus *Heliolites* from the Ohno Formation include *H. bohemicus* Wentzel, 1895, by Okubo (1950) and *H*. sp. by (Sugiyama, 1941). Because it is unclear that what material was based on their identifications, comparisons between the present and these reported species are impossible. Stratigraphic range of the genus *Heliolites* is the Middle Ordovician to the Middle Devonian (Hill, 1981).

Suborder Halysitida Sokolov, 1947
Family Halysitidae Milne-Edwards and Haime, 1849
Subfamily Halysitinae Milne-Edwards and Haime, 1849
Genus ***Schedohalysites*** Hamada, 1957

Type species: *Halysites orthopteroides* Etheridge, 1904.

Schedohalysites kitakamiensis (Sugiyama, 1940)
Figs. 10A–D

Schedohalysites kitakamiensis (Sugiyama, 1940): Niko, 2023, p. 76, figs. 2D–G [with earlier synonymy].

Material examined: NMNS PA20614, 20615.

Occurrence: Limestone pebbles, Assemblage 1.

Discussion: Two fragmentally coralla were assigned to *Schedohalysites kitakamiensis* based on the following characters: coralla cateniform with elongated lacunas; ranks composed by 3–6 corallites; in transverse section, corallites weakly inflated with 1.0–1.3 mm in length and 0.6–0.8 mm in width; coenenchymal tubes between adjacent corallites sometimes absent; corallite wall thickness ranges from 0.08 to 0.17 mm; tabulae complete. This species dominantly occurs from the Ludlow limestone in the South Kitakami and Kurosegawa belts in Japan (e.g., Sugiyama, 1940; Hamada, 1956, 1958; Niko, 2015, 2023).

Order Auloporida Sokolov, 1947
Superfamily Auloporoidea Milne-Edwards and Haime, 1851
Family Palaeofavosiporidae Stasinska, 1976
Genus ***Kanashiropora*** Niko, 2001

Type species: *Kanashiropora kozui* Niko, 2001.

Kanashiropora okuboi sp. nov.
Figs. 11A–E

urn: Isid:zoobank.org:act:87398E2F-9094-4548-8E03-96C0F6F43CA5

Type material: Holotype, NMNS PA20617. Paratype, NMNS PA20616.

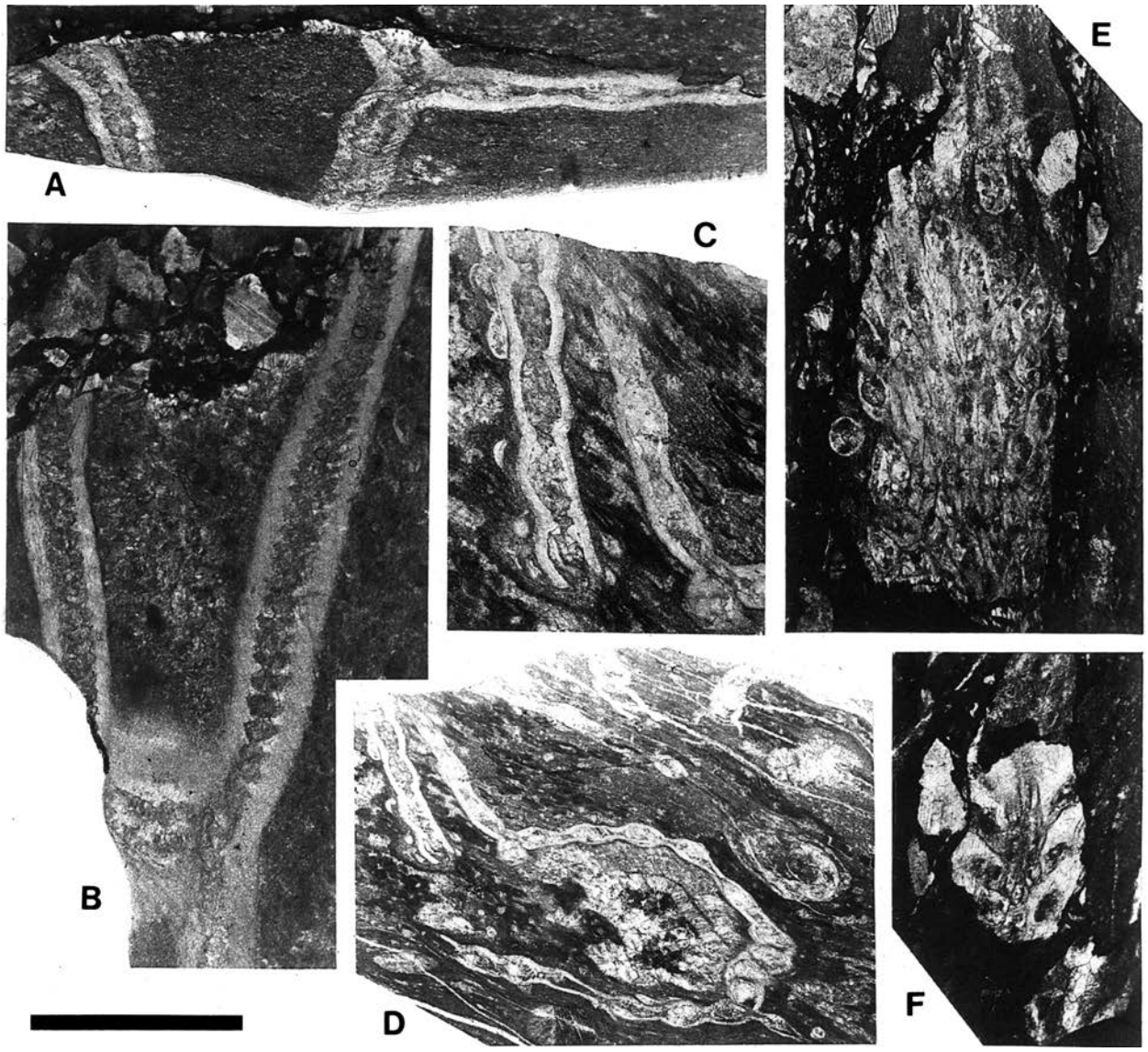

Fig. 10. **A**–**D**, *Schedohalysites kitakamiensis* (Sugiyama, 1940), thin sections. A, B, NMNS PA20615; A, transverse section of corallum, B, longitudinal section of corallum. C, D, NMNS PA20614, transverse sections of corallum. **E**, *Hillaepora gionensis* Niko and Adachi, 1999, NMNS PA20564, longitudinal thin section of branch. **F**, *Striatopora* sp. cf. *S. sugiyamai* Niko and Adachi, 1999, NMNS PA20572, oblique thin section of branch. Scale bar: 3 mm in A–C, E; 6 mm in D; 2.1 mm in F.

Occurrence: Greenish tuffaceous shales, Assemblage 3.

Diagnosis: Species of *Kanashiropora* with relatively large corallite diameters, mostly 0.4–1.9 mm, 1.3 mm in mean, and thickened intercorallite walls, 0.23–0.92 mm; mural pores rare; tabulae very rare, complete.

Description: Among the examined two specimens, a lager specimen, 18 mm in diameter and 29 mm in height, assigned the holotype and a smaller one, 20 mm in diameter and 10 mm in height, assigned the paratype; coralla phacelo-cerioid, high to low domical, and encrusting on rugose coral as substratum; intra-corallum lacunae frequently developed; connecting tubule absent. Early juvenile corallites alveolitoid-like with semi-circular to fun-shaped transverse sections; in cerioidal portions, transverse sections of corallites are prismatic with 4–8 sides to rounded subpolygonal; phaceloidal portions tend to occur vicinity of corallum periphery, where corallites usually free and cylindrical to subcylindrical; except for early juvenile corallites that have 0.9×0.6, 1.4×0.8 mm in diameters of typical ones, corallite diameters relatively large for the genus, range from 0.4–1.9 mm with 1.3 mm mean; lumina narrowed by wall thickening and have nearly circular to subpolygonal transverse sections; calices upwardly oblique to perpendicular to corallum surface, very deep to deep;

increase of new corallite commonly occur at lateral position. Intercorallite walls thickened and differentiated into median line and stereoplasm on its both sides; corallite walls composed by thin epitheca and inner thick stereoplasm; microstructure of stereoplasm is not preserved; thickness of intercorallite walls are 0.23–0.92 mm; mural pores rare, occur on corallite faces or near angles: profiles of pores are circular with 0.13–0.19 mm in diameter; septal spine absent; tabulae very rare, complete, and directly transverse to weakly uparched; some tabulae thickened, attaining 0.10 mm.

Etymology: This species is named in honor of the late Masahiro Okubo in recognition of his contributions in the geology of the Hikoroichi area.

Discussion: Until now *Kanashiropora kozui* Niko (2001, p. 82, 84, 86, figs. 5-1–5, 6-5, 6) from the Lochkovian Takaharagawa Member of the Fukuji Formation was an only representative of the genus. When compared with the type species, *K. okuboi* sp. nov. is characterized by its larger corallite diameters (0.4–1.9 mm with 1.3 mm mean versus 0.3–1.1 mm with 0.9 mm mean in *K. kozui*) and thicker intercorallite walls (0.23–0.92 mm versus 0.06–0.56 mm in ditto). A rareness of the mural pore developments in this new species also serves specific separation from *K. kozui* whose pores are abundant in the proximal and common in the distal portions.

Superfamily Syringoporoidea de Fromentel, 1861
Family Syringoporidae de Fromentel, 1861
Genus ***Syringopora*** Goldfuss, 1826

Type species: *Syringopora ramulosa* Goldfuss, 1826.

Syringopora sanrikuensis sp. nov.
Figs. 12A–E

urn: lsid:zoobank.org:act:3D17C25B-DD9B-43E2-BAE4-770758AAB074

Type material: Holotype, NMNS PA20618.

Occurrence: Greenish tuffaceous shale, Assemblage 3.

Diagnosis: Species of *Syringopora* with corallite diameters of 1.5–2.4 mm, 2.2 mm in mean; spacing of corallites very close and coalescence of neighboring corallites frequently occurs; connecting tubuli well-developed, short; corallite walls thick, 0.38–0.52 mm; septal spines rare; tabulae numerous and form intermittent axial syrinxes; positions of syrinxes central to sub-marginal.

Description: An only available specimen of phaceloid corallum assigned the holotype; it indicates tabular growth form with 49 mm in maximum observable diameter and 27 mm in height. Corallites cylindrical, moderate in diameter, 1.5–2.4 mm with 2.2 mm mean, and close in spacing; neighboring corallites frequently coalesce to form lax mass containing up to four corallites; distance (center-to-center) between adjacent corallites are 1.6–2.7 mm; there are 15–18 corallites in 1 cm^2; increase of new corallite is not developed in sectioned part; calices lacks external modification with relatively shallow pits; lumina circular in transverse section; connecting tubuli well-developed, having short lengths, 0.1–0.5 mm, and relatively large diameters, 0.7–1.2 mm. Corallite walls thick for the genus, 0.38–0.52 mm, and differentiated into thin epitheca and inner thick stereoplasm; no microstructure of stereoplasm preserved; in coalesced part, connecting tubuli replaced by mural tunnels; diameters of tunnels are 0.22–0.27 mm; septal spines rare, high conical to rod-like, and short, 0.08–0.13 mm; tabulae numerous, incomplete, and infundibuliform or dissepiment-like in rare cases; there are 5–11 tabulae in 5 mm of corallite length; axial syrinxes intermittently formed by crowded tabulae, present at central to sub-marginal positions, and have circular to elliptical transverse sections; diameters of typical syrinxes are 0.4, 0.6, 0.5 × 0.7, 0.4 × 0.8 mm.

Etymology: This species is named after Sankiku that is the old place name including the type locality.

Discussion: *Syringopora sanrikuensis* sp. nov. is similar to *S. tarejaensis* Chernyshev (1941, p. 33, 34, 56, pl. 12, figs. 1–3, text-fig. 10) from the Lower Devonian in the Taimyr Peninsular, the Far North of Russia and *S. xuguitensis* Tchi (1980, p. 178, 179, pl. 82, figs. 5a, b) from the Middle Devonian of Jilin, Northeast China. Distinctive features of *S. sanrikuensis* separating from latter two species are its moderate corallite diameters (approximately 2.2 mm versus 1.3–1.5 mm in *S. xuguitensis*), thick corallite walls (0.38–0.52 mm versus 0.1 mm in *S. tarejaensis* and 0.2 mm in *S. xuguitensis*), and septal spine occurrences (rare versus well-developed in *S. tarejaensis* and *S. xuguitensis*).

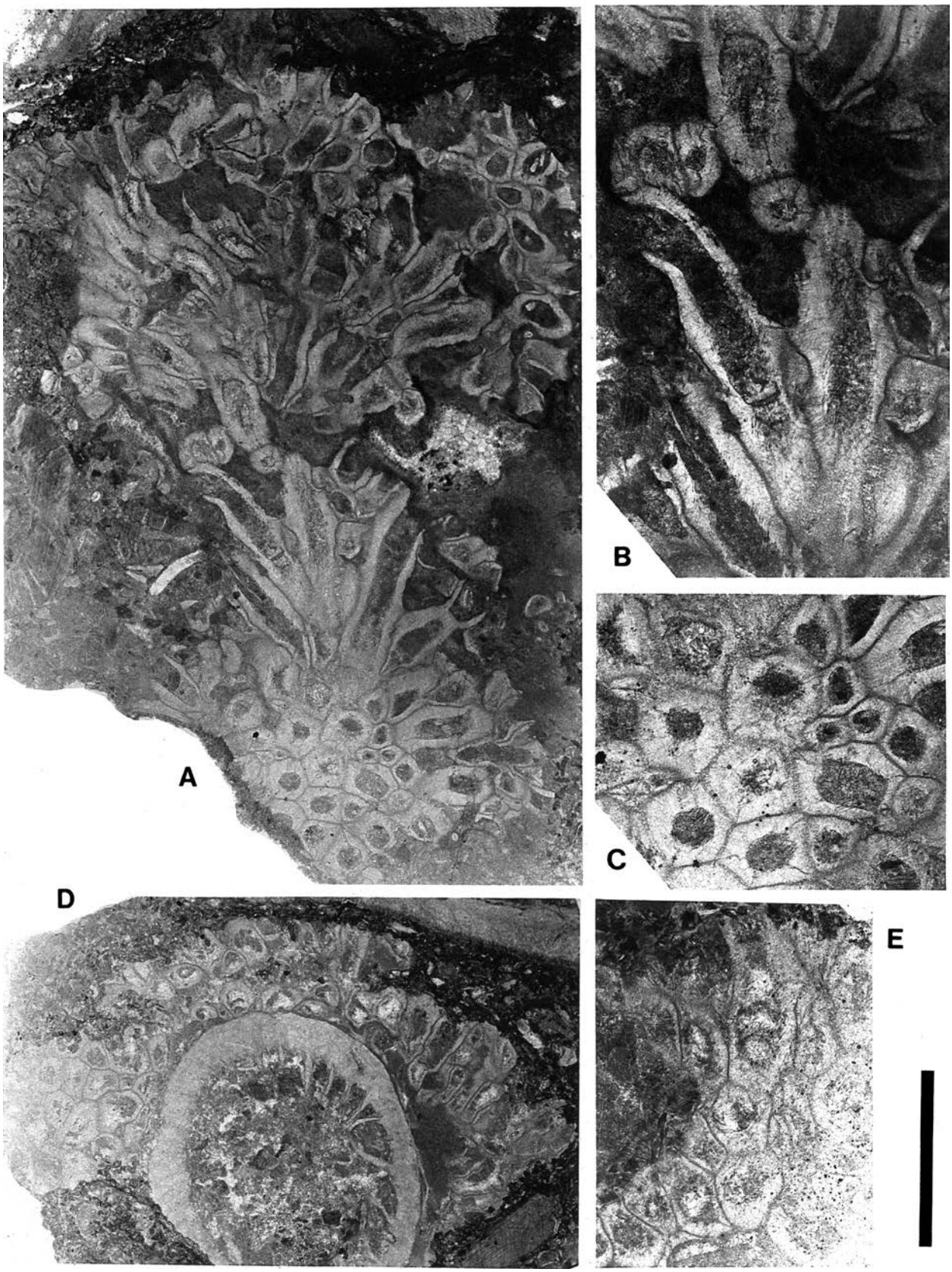

Fig. 11. *Kanashiropora okuboi* sp. nov., thin sections. **A**–**C**, holotype, NMNS PA20617, A, longitudinal section of corallum, B, longitudinal to transverse sections of corallites, C, transverse to oblique sections of corallites. **D**, **E**, paratype, NMNS PA20616, thin sections; D, longitudinal section of corallum, E, longitudinal to oblique sections of corallites. Scale bar: 6 mm in A, D; 3 mm in B, C, E.

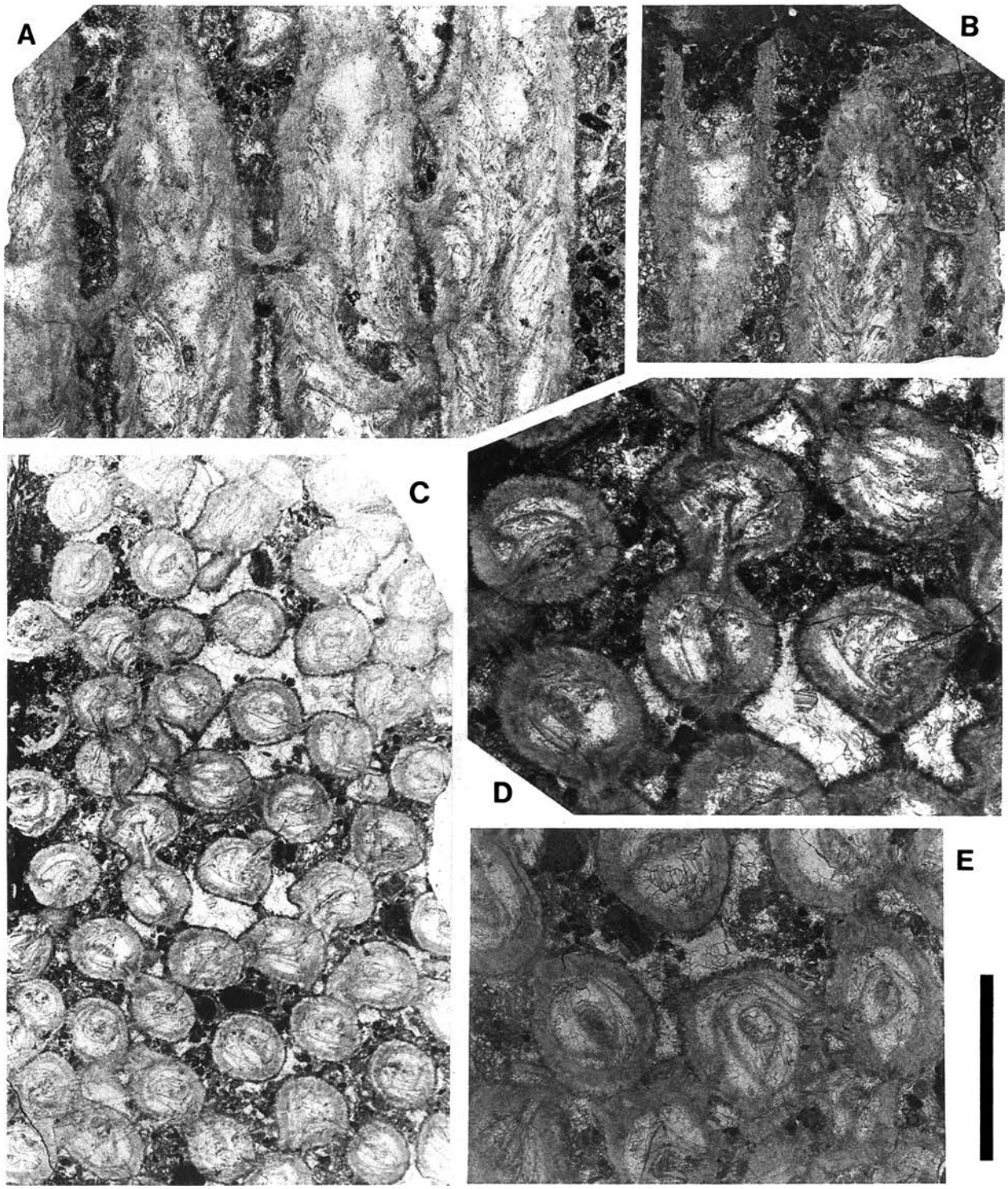

Fig. 12. *Syringopora sanrikuensis* sp. nov., holotype, NMNS PA20618, thin sections. **A**, **B**, longitudinal sections of corallites, **C**, transverse section of corallum, **D**, **E**, transverse sections of corallites. Scale bar: 3 mm in A, B, D, E; 6 mm in C.

Syringopora sp. (Niko, 2012, p. 55, 57, figs. 6-1–7), described from the Lochkovian Takaharagawa Member in the Fukuji area, apparently distinguished from *S. sanrikuensis* by its larger corallite diameter attaining 3.8 mm and fewer connecting tubuli than those of the new species.

Assemblages and age

Identified tabulate corals and their inferred ages in each assemblage are as follows.

Assemblage 1: *Schedohalysites kitakamiensis*, Ludlow (see the discussions in the previous chapter, the same shall apply hereinafter); *Hillaepora*

gionensis, Ludlow; *Striatopora* sp. cf. *S. sugiyamai*, Wenlock–Ludlow.

Assemblage 2: *Sapporipora*? sp., Silurian?–Devonian; *Egosiella*? sp., Middle Silurian–Middle Devonian; *Acaciaporella*? sp., early Permian; *Squameostriatopora tachibanai* sp. nov., Early Devonian; *Thamnopora ohnoensis* sp. nov., Lochkovian–Givetian; *Alveolites* sp., Middle Silurian–Late Devonian; *Crassialveolites* sp. cf. *C. niigataensis*, Middle Devonian.

Assemblage 3: *Pachyfavosites hikoroichiensis* sp. nov., Lochkovian–Eifelian; *Egosiella*? sp., see above; *S. tachibanai*, ditto; *T. ohnoensis*, ditto; *Heliolites* sp., Middle Ordovician–Middle Devonian; *Kanashiropora okuboi* sp. nov., Lochkovian; *Syringopora sanrikuensis* sp. nov., Early–Middle Devonian.

The age of Assemblage 1 can be considered as Ludlow. Among constituents of this assemblage, *S. kitakamiensis* is a characteristic tabulate coral of the underling Kawauchi Formation. Ehiro (2017) suggested that coral fossils in a basal slump bed (= conglomeratic limestone in this paper) are derived from the formation. The present detailed taxonomic and biostratigraphic examinations come to a similar conclusion. Although there are considerable dispersions in chronological ranges of species, the age of Assemblage 2 is probably constrained as Emsian taking into account the Nakazato Formation's age that ranges from Eifelian to Givetian (e.g., Cooper *et al.*, 1982; Tazawa and Chen, 2001; Niko, 2024b). The formation has conformable relationship with the underlying Ohno Formation (e.g., Minato *et al.*, 1979b). It is considerable that Assemblage 3 also suggests Emsian age because there are three common species with Assemblage 2 and the both assemblages are in close stratigraphic distance, approximately 45 m. Biostratigraphic study using radiolarians by Kurihara *et al.* (2005) provided Lochkovian (or Pragian) to Emsian for the age of a tuff bed that situates approximately 14 m below of a horizon bearing tabulate corals of Assemblage 3. These micro- and macropaleontological results are not mutually contradictory.

Acknowledgements

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References

Adachi, T. and Niko, S. (1996) Some Silurian tabulate corals from the Gionyama Formation, Miyazaki Prefecture. *Chigakukenkyu*, **45**: 67–73. (in Japanese)

Blumenbach, J. F. (1803) Specimen Arachaeologiae telluris terrarumque inprimis Hannoveranarum, 28 pp., 3 pls. Apvd Henricvm Dieterich, Goettingae.

Cherkesova, S. V., Smirnova, M. A. and Kravtsov, A. G. (1968) Lower Devonian of south-western Novaya Zemlya and descriptions of some Tabulata, pp. 145–169. In: Bondareva, V. I., (Ed.), The stratigraphy, conditions of sedimentation, and fauna of the Ordovician and Lower Devonian deposits on the islands Novaya Zemlya and Vaygach and the Pai-Kai Peninsula. *Trudy Nauchno-Issledovatel'skogo Instituta Geologii Arktiki*, **157**. (in Russian)

Chernyshev, B. B. (1941) Silurian and Lower Devonian corals from the Tareia River Basin (southwest Taimyr Peninsula). *Trudy Vsesojuznogo Arktichi Instituta*, **158**: 9–64, pls. 1–14. (in Russian with English abstract)

Cooper, P., Tazawa, J., Mori, K. and Kato, M. (1982) *Atrypa* (Devonian Brachiopoda) from Japan. *Transactions and Proceedings of the Palaeontological Society of Japan*, New Series, **127**: 368–374, pl. 59.

Dana, J. D. (1846) Structure and Classification of Zoophytes: United States Exploring Expedition. During the Years 1838, 1839, 1840, 1841, 1842. Under the Command of Charles Wilkes, U. S. N. Vol. VII, 740 pp., 61 pls. Lea and Blanchard, Philadelphia.

Dubatolov, V. N. (1959) Silurian and Devonian Tabulata, Heliolitida, and Chaetetida from the Kuznetsk Basin. *Trudy Vsesoyuznogo Neftianogo Nauchno-Issledovatel'skogo Geologo-Razvedochnogo Instituta*, **139**: 1–293, pls. 1–88. (in Russian)

Dubatolov, V. N. (1969) Tabulata and biostratigraphy of the Lower Devonian of north-eastern USSR. *Trudy Academii Nauk SSSR*, *Sibirskoe Otdelenie*, *Instituta Geologii i Geofiziki*, **70**: 1–179, pls. 1–67. (in Russian)

Dubatolov, V. N., Chekhovich, V. D. and Yanet, F. E. (1968) Tabulata of the boundary beds of the Silurian and Devonian in the Altay-Sayan mountain region and Urals, pp. 5–109, pls. 1–48, In: Ivanovskiy, A. B., (Ed.), Corals of the boundary beds of the Silurian and Devonian in the Altay-Sayan mountain region and Urals. Nauka, Moscow. (in Russian)

Duncan, P. M. (1872) Third report on the British fossil corals. *Report of the Forty-first Meeting of the British Association for the Advancement of Science*, *held at Edinburgh in August 1871*, 116–137.

Ehiro, M. (2017) Lower-Middle Paleozoic, pp. 185–195. In: Yoshida, T. *et al.*, (Eds.), Regional Geology of Japan, Part 2, Tohoku. Asakura Publishing, Tokyo. (in Japanese)

Etheridge, R. Jr. (1904) A monograph of the Silurian and Devonian corals of New South Wales; with illustrations from other parts of Australia. Part I. The genus *Halysites*. *Memoirs of the Geological Survey of New South Wales*, *Palaeontology*, **13**: 1–39, pls. 1–9.

Flügel, E. and Flügel, H. W. (1979) Tabulata Sclerospongia und Stromatopora aus dem Devon von Menorca. *Mitteilungen der Österreichischen Geologischen Gesellschaft*, **70**: 49–73.

Frech, F. (1897) Referat. J. Wentzel: Zur Kenntniss der Zoantharia tabulata. *Neues Jahrbuch für Geologie und Paläontologie*, **1897(2)**: 212–214.

Fromentel, E. de (1861) Introduction à l'Étude des Polypiers Fossiles, 357 pp. F. Savy, Paris.

Gerth, H. (1921) Die Anthozoën der Dyas von Timor. *Paläontologie von Timor*, **9**: 65–147, pls. 145–150.

Goldfuss, A. (1826) 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.

Hall, J. (1851) New genera of fossil corals from the report by James Hall, on the palaeontology of New York. *American Journal of Science*, *Series 2*, **11**: 398–401.

Hamada, T. (1956) *Halysites kitakamiensis* Sugiyama from the Gotlandian formation in the Kuraoka district, Kyûshû, Japan. *Japanese Journal of Geology and Geography*, **27**: 133–141, pl. 9.

Hamada, T. (1957) On the classification of the Halysitidae, I. *Journal of the Faculty of Science*, *University of Tokyo. Section 2*, **10**: 393–405.

Hamada, T. (1958) Japanese Halysitidae. *Journal of the Faculty of Science*, *the University of Tokyo*, *Series 2*, **11**: 91–114, pls. 6–10.

Hill, D. (1981) Part F, Coelenterata. Supplement 1, Rugosa and Tabulata, pp. F1–F762. In: Moore R. C. *et al.*, (Eds.), Treatise on Invertebrate Paleontology. The Geological Society of America, INC. and the University of Kansas, Boulder, Colorado and Lawrence, Kansas.

Kurihara, T., Sato, Y. and Tazawa, J. (2005) Early Devonian radiolarians from the Ohno Formation in the Hikoroichi area of the South Kitakami Belt, Northeast Japan. *The Journal of the Geological Society of Japan*, **111**: 187–190. (in Japanese with English abstract)

Lamarck, J. B. P. A. de M. de (1801) Systême des animaux sans vertèbres, ou tableau général des classes, des orders et des genres de ces animaux; présentant leurs caraetères essentiels et leur distribution, d'après la considération de leurs rapports naturels et de leur organisation, et suivant l'arrangement établi dans les grleries du Muséum d'Hist. Naturelle, parmi leurs dépouilles conservées; précédé du discours d'ouverture du Cons de Zoologie, donné dans le Muséum National d'Histoire Naturelle l'an 8 de la République, 432 pp., Privately published, Paris. (Reissued by Culture et Civilisation, Bruxelles, 1969.)

Lecompte, M. (1939) Les Tabulés du Dévonien moyen et supérieur du Bord sud du Bassin de Dinant. *Mémoires du Musée Royal d'Histoire Naturelle de Belgique*, **90**: 1–229, pls. 1–23.

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

Lindström, G. (1876) On the affinities of the Anthozoa Tabulata. *The Annals and magazine of natural history*; *zoology*, *botany*, *and geology*, *Series 4*, **18**, 1–17.

Milne-Edwards H. and Haime, J. (1849) Mémoire sur les polypiers appartenant aux groupes naturels des Zoanthaires perforés et des Zoanthaires tabulés. *Comptes Rendus de l'Académie des Sciences*, *Paris*, **29**: 257–263.

Milne-Edwards, H. and Haime, J. (1850) A Monograph of the British Fossil Corals. First Part. Introduction; Corals from the Tertiary and Cretaceous Formations, 71 pp., 11 pls. Monographs of the Palaeontographical Society, London.

Milne-Edwards, H. and Haime, J. (1851) Monographie des polypiers fossiles des terrains paléozoïques, précédée d'un tableau général de la classification des polypes. *Archives du Muséum d'Histoire Naturelle*, **5**: 1–502, pls. 1–20.

Minato, M., Hunahashi, M., Watanabe, J., Kato, M., Okubo, M., Fujiwara, Y., Minoura, N., Hashimoto, T., Yato, S., Hoe, S. G., Takahashi, T., Sugiyama, S., Niikawa, I., Sato, K., Haga, S., Kawamura, M., Chitoku, T., Nakai, H., Sakaguchi, T., Iwabuchi, Y., Seta, O., Suga, M., Nozawa, K. and Watanabe, Y. (1979a) Lower Devonian, pp. 62–65, 128, pls. 7–10. In: Minato, M. *et al.*, (Eds.), Variscan Geohistory of Northern Japan: The Abean Orogeny. Tokai University Press, Tokyo.

Minato, M and Minoura, N. (1977) A new tabulate coral from the Lower Devonian of Japan. *Journal of the Faculty of Science*, *Hokkaido University*, *Series 4*, **17**: 555–573.

Minato, M., Okubo, M., Kato, M., Hunahashi, M., Watanabe, J., Hashimoto, T., Yato, S., Hoe, S. G., Takahashi, T., Sugiyama, S., Okabe, Y., Haga, S., Kawamura, M., Chitoku, T., Niikawa, I. and Nakai, H. (1979b) Middle Devonian, pp. 66–68, 128, 129, pl. 11. In: Minato, M. *et al.*, (Eds.), Variscan Geohistory of Northern Japan: The Abean Orogeny. Tokai University Press, Tokyo.

Minato, M., Takeda, H., Hashimoto, T. and Kato, M. (1959) On the volcanic rocks in the Japanese Palaeozoic. 1st report: Gotlandian and Devonian. *The Journal of the Geological Society of Japan*, **65**: 71–79. (in Japanese with English abstract)

Minoura, N. (1987) Lower Devonian crinoid *Pernerocrinus* from the Southern Kitakami Mountains, N.E. Japan. *Journal of the Faculty of Science*, *Hokkaido University*, *Series 4*, **22**: 337–355.

Mironova, N. V. (1960) Two new genera of Tabulata. *Trudy Sibirskogo Nauchno-Issledovatel'skogo Instituta Geologii*, *Geofizikii, Mineral'nogo Syrya*, **8**: 95–98, pl. 11. (in Russian)

Mironova, N. V. (1961) Tabulata and Heliolita from Tom-Chumych (ostracodes) beds in Salair. *Trudy Sibirskogo Nauchno-Issledovatel'skogo Instituta Geologii*, *Geofizikii, Mineral'nogo Syrya*, **15**: 148–163, pls. 1–6. (in

Russian)
Mironova, N. V. (1965) On the problem of generic variability in some favositid genera, pp. 79–86. In: Sokolov, B. S. and Dubatolov, V. N., (Eds.), Tabulatomorph corals of the Devonian and Carboniferous of the USSR. Trudy I Vsesoyuznogo Simpoziuma po Izucheniyu Iskopaemykh Korallov, Nauka, Moscow. (in Russian)
Mori, K. (1989) The Devonian System, pp. 16, 17. In: Oide, K. *et al.*, (Eds.), Regional Geology of Japan, Part 2, Tohoku. Kyoritsu Shuppan, Tokyo. (in Japanese)
Murata, M., Kanisawa, S., Ueda, Y. and Takeda, N. (1974) Base of the Silurian System and the Pre-Silurian granites in the Kitakami Massif, Northeast Japan. *The Journal of the Geological Society of Japan*, **80**: 475–486, pls. 1–3. (in Japanese with English abstract)
Murata, M. and Mori, K. (1973) Discovery of *Schedohalysites* from the Ono Formation. *The Journal of the Geological Society of Japan*, **79**: 125–126. (in Japanese)
Niko, S. (2001) Devonian auloporid tabulate corals from the Fukuji Formation, Gifu Prefecture. *Bulletin of the National Science Museum*, *Series C*, **27**: 73–88.
Niko, S. (2003) Ludlow (Late Silurian) pachyporid tabulate corals from the Suberidani Group, Tokushima Prefecture. *Bulletin of the National Science Museum*, *Series C*, **29**: 9–18.
Niko, S. (2007) Stratigraphy of the Devonian Fukuji Formation in Gifu Prefecture and its favositid coral fauna. *Bulletin of the National Science Museum*, *Series C*, **33**: 57–79.
Niko, S. (2012) Additional material of favositid and auloporid tabulate corals from the Devonian Fukuji Formation, Gifu Prefecture, Japan. *Bulletin of the National Museum of Nature and Science*, *Series C*, **38**: 47–62.
Niko, S. (2015) Halysitid tabulate corals from the Silurian Fukami Formation, Kumamoto Prefecture, Japan. *Bulletin of the National Museum of Nature and Science*, *Series C*, **41**: 17–23.
Niko, S. (2023) Late Silurian halysitid corals from the Okanaro Group in Ehime Prefecture, Southwest Japan. *Bulletin of the National Museum of Nature and Science*, *Series C*, **49**: 73–79.
Niko, S. (2024a) Silurian tabulate corals from the Imose Limestone in the Ino area, Kochi Prefecture, Southwest Japan. *Bulletin of the Akiyoshi-dai Museum of Natural History*, **59**: 1–10, pls. 1–4.
Niko, S. (2024b) Tabulate corals from the Middle Devonian Nakazato Formation in the Kamiarisu area, Iwate Prefecture, Northeast Japan. *Bulletin of the Akiyoshi-dai Museum of Natural History*, **59**: 11–18, pls. 5–7.
Niko, S. and Adachi, T. (1999) Silurian pachyporicaes (Coelenterata: Tabulata) from the Gionyama Formation, Miyazaki Prefecture. *Bulletin of the National Science Museum*, *Series C*, **25**: 111–120.
Niko, S., Ibaraki, Y. and Tazawa, J. (2015) Devonian tabulate corals from pebbles in Mesozoic conglomerate, Kotaki, Niigata Prefecture, central Japan. Part 2: Alveolitina. *Science Reports of Niigata University (Geolology)*, **30**: 15–25.
Niko S. and Senzai Y. (2011) Additional material of favositid tabulate corals from the Devonian Kamianama Formation, Fukui Prefecture, Japan. *Bulletin of the National Science Museum*, *Series C*, **37**: 29–41.
Okubo, M. (1950) On the Gotlandian and Devonian deposits of Hikoroichi, Kesen-district, Iwate-Prefecture. *The Journal of the Geological Society of Japan*, **56**: 345–350. (in Japanese with English abstract)
Onuki, Y. (1956) Explanatory Text of the Geological Map of Iwate Prefecture, II. Geology of the Kitakami Massif, 187 pp. Iwate Prefecture Office, Morioka. (in Japanese)
Onuki, Y. (1969) Geology of the Kitakami Massif, Northeast Japan. *Contributions from the Institute of Geology and Paleontology*, *Tohoku University*, **69**: 1–239. (in Japanese with English abstract)
Shimizu, S., Ozaki, K. and Obata, T. (1934) Gotlandian deposits of northwest Korea. *The Journal of the Shanghai Science Institute*, *Section 2*, **1**: 59–88, pls. 8–18.
Sokolov, B. S. (1947) New syringoporids from the Taymyr. *Byulleten' Moskovskogo Obschestva Ispytatelei Prirody*, *Otdel Geologicheskii*, **22**, 19–28. (in Russian)
Sokolov, B. S. (1950) Systematics and history of the development of the Paleozoic corals Anthozoa Tabulata. *Voprosy Paleontologii*, **1**: 134–210. (in Russian)
Sokolov, B. S. (1952) Paleozoic Tabulata of the European parts of the USSR. Part 4. Devonian of the Russian Platform and the western Urals. *Trudy Vsesoyuznogo Nauchno-Issledovatel'skogo Geologo-Razvedochnogo Instituta*, *Novaya Seriya*, **62**: 1–292. (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. *Trudy Vsesoyuznogo Nauchno-Issledovatel'skogo Geologo-Razvedochnogo Instituta*, *Novaya Seriya*, **85**: 1–527. (in Russian)
Stasinska, A. (1976) Structure and blastogeny of *Palaeofavosipora clausa* (Lindström, 1865), Tabulata, Silurian. *Acta Palaeontologica Polonica*, **21**: 365–371, pls. 29–30.
Steininger, J. (1831) Bemerkungen über die Versteinerungen, whlche in dem Uebergangs-Kalkgebirge der Eifel gefunden werden, 44 pp., Trier.
Sugiyama, T. (1940) Stratigraphical and palaeontological studies of the Gotlandian deposits of the Kitakami Mountainland. *The Science Reports of the Tohoku Imperial University*, *Series 2*, **21**: 81–146, pls. 13–33.
Sugiyama, T. (1941) The Devonian System of China (part 3). *The Journal of Geography*, **53**: 543–552. (in Japanese)
Sugiyama, T. (1944) On the Gotlandian fossils from Imose, Kusaka-mura, Kôchi-Prefecture. Research Bulletin, *The Geological and Mineralogical Institute*, *Tokyo Bunrika Daigaku*, **1**: 41–51. (in Japanese)
Tazawa, J. and Chen, X. (2001) Middle Devonian brachiopods from the Nakazato Formation, South Kitakami Belt, Northeast Japan and their palaeobiogeographic affinity with those of western Inner Mongolia. *The Journal of the Geological Society of Japan*, **107**: 706–710. (in Japanese with English abstract)
Tchi, Y. (1976) Tabulata. In: Inner Mongolia Institute of Geology and Mineral Resources *et al.*, (Eds.), Paleontological Atlas of North China, Inner Mongolia Volume. (1), Paleozoic Volume, pp. 101–129, pls. 43–60, Geological

Publishing House, Beijing. (in Chinese)
Tchi, Y. (1980) Tabulata. In: Shenyang Institute of Geology and Mineral Resources, (Ed.), Paleontological Atlas of Northeast China. (1), Paleozoic Volume, pp. 153–188, 646–649, pls. 67–87, Geological Publishing House, Beijing. (in Chinese)
Wang, H. (1983) Tabulata, pp. 217–249, 704–710, pls. 66–80. In: Geological Bureau of Xinjiang *et al.*, (Eds.), Paleontological Atlas of the Northeastern Region, Fascicle of Xinjiang Uygur Autonomous Region, 2, The Late Paleozoic, Geological Publishing House, Beijing. (in Chinese)
Wedekind, R. (1937) Einführung in die Grundlagen der Historischen Geologie. II. Band. Mikrobiostratigraphie. Die Korallen- und Foraminiferenzeit, 136 pp., 16 pls. Ferdinand Enke, Stuttgart.
Wentzel, J. (1895) Zur Kenntniss der Zoantharia Tabulata. *Denkschriften der Kaiserlichen Akademie der Wissenschaften*, *Mathematisch-Naturwissenschaftliche Classe*, **62**: 479–516, pls. 1–5.
Yabe, H. and Sugiyama, T. (1937) Preliminary report on the fossiliferous Gotlandian and Devonian deposits newly discovered in the Kitakami Mountainland. *Proceedings of the Imperial Academy*, **13**: 417–420.