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Late Silurian halysitid corals from the Okanaro Group in Ehime Prefecture, Southwest Japan

Shuji Niko*

Department of Environmental Studies, Faculty of Integrated Arts and Sciences, Hiroshima University, Higashihiroshima 739–8521, Japan

*Author for correspondence: niko@hiroshima-u.ac.jp

Abstract Three species of halysitid tabulate corals, *Halysites miyazakiensis* Niko and Adachi, 2014, *Schedohalysites kitakamiensis* (Sugiyama, 1940) and *Catenipora seiyoensis* sp. nov., are described from limestones of the Okanaro Group in southwestern Ehime Prefecture, Shikoku Island, Southwest Japan. Distinctive features of *C. seiyoensis* from other Silurian species of the genus are as follows: large corallites with low form ratios (length/width); thickened corallite walls; and poorly developed septal spines. The age given by the present halysitid assemblage is the Ludlow (early late Silurian).

Key words: Ludlow, Halysitidae, Halysitinae, Cateniporinae, Tabulata

ZooBank registration:
https://www.zoobank.org/urn:lsid:zoobank.org:pub:87150C53-FC8F-4DFF-8A7D-52E0F9B8E407

Introduction

Miki (Ishii) and Eguchi (1950) discovered the "Gotlandian" limestones containing coral fossils, namely *Halysites*, *Heliolites*, *Favosites* and *Tryplasma*, at an area from Nomura to Shirokawa of southwestern Ehime Prefecture, Shikoku Island, Southwest Japan and provisionally named them the Okanaro Formation. Subsequently, Ishii (1952) documented new occurrences of *Encrinurus* (= *E. ishii* Kobayashi and Hamada, 1974: trilobite), crinoids and brachiopods from tuffaceous mudstone adjoining the coral-baring limestone. These rocks ware formally defined as the Okanaro Group and assigned to the middle or upper Silurian by Ichikawa *et al.* (1956). After that there were the following important researches in the area; discoveries of Silurian conodonts from limestones (Kuwano, 1976) and late Silurian to late (?) Devonian radiolarians from mudstones (Umeda, 1994). Their geological investigations have revealed that the Okanaro Group deposited during the period ranging from Silurian to Devonian and consists mainly of rhyolite, rhyolitic tuff and tuffaceous sandstone to mudstone with some intercalations of limestones in its lowest part. The group forms the Kurosegawa Belt with the Terano Metamorphic Rocks and the Mitaki Igneous Rocks. More definitive age determination was provided by the recent paleontological investigation of Hori *et al.* (2022) who discovered brachiopod from limestone nodule and radiolarians from tuff at Okanaro (= locality 1 in this report) and assigned these two rocks to the probably early Ludlow (early late Silurian).

Here the author describes halysitid corals from the Okanaro Group as the first fascicle of a serial paper concerning the tabulate coral fauna of the group. Occurrences of halysitids are known at ten localities belonging to the three districts (Fig. 1). They are Okanaro in the Nomura area (locality 1, a riverside outcrop on the right bank of Hijikawa River), Kagio in the Shirokawa area (locality 2, an abandoned quarry on the left bank of Kurosegawa River; locality 3, a riverside outcrop on the right bank of Kurosegawa River; locality 4, a roadside outcrop; locality 5, an abandoned quarry in Yoshinosawa hamlet), and Kubono in ditto (locality 6, an outcrop in a small tributary of Mitakigawa River; locality 7, a roadside outcrop; locality 8, some floating blocks of limestones in Mitakigawa River; locality 9, a roadside outcrop; locality 10, a roadside outcrop). Material actually examined in my laboratory was collected from limestone pebbles to boulders occur in taluses near these fossil localities, except for localities 3, 6, 8 that are protected as a natural monument by Ehime Prefecture, and thus I

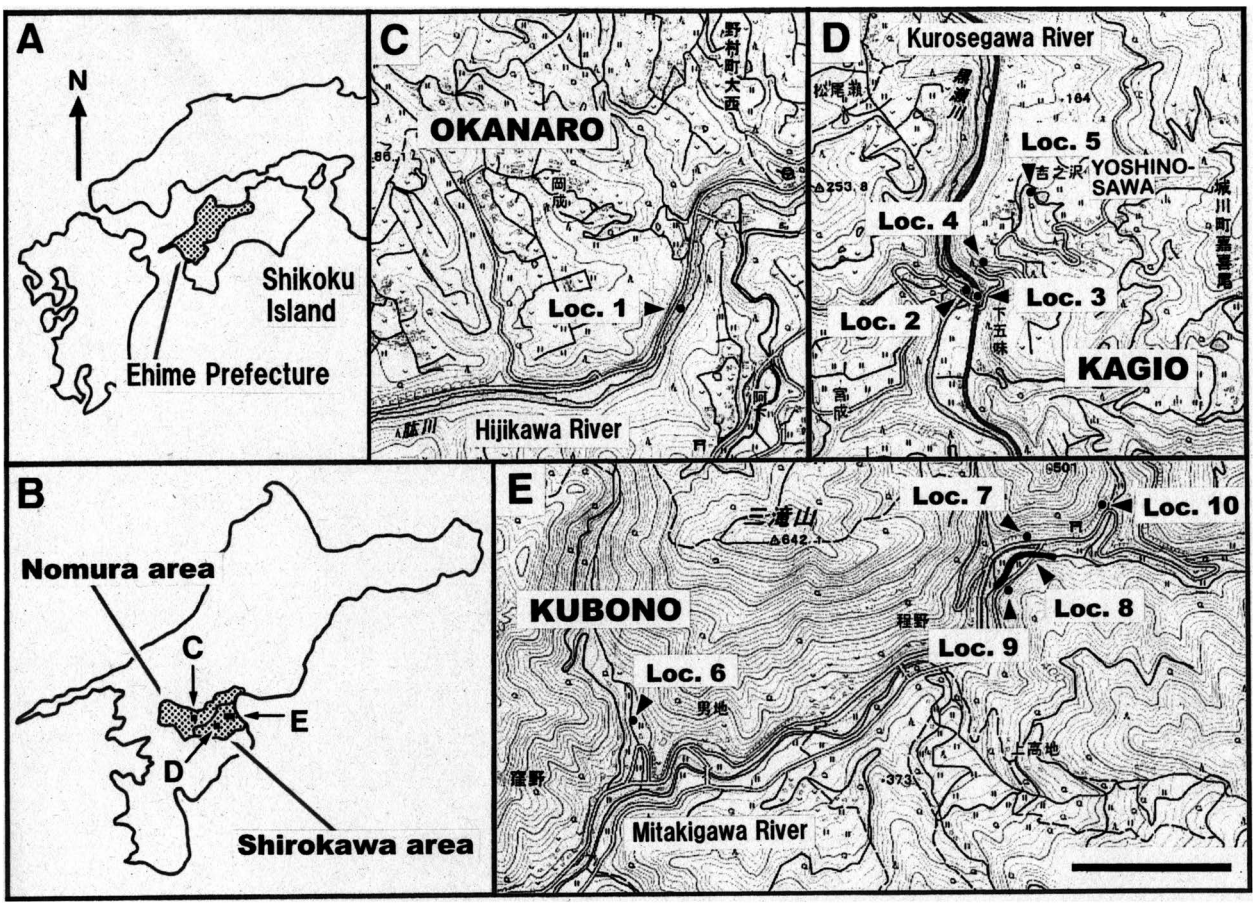

Fig. 1. Maps showing locations of Shikoku Island and Ehime Prefecture in Southwest Japan (**A**), Nomura and Shirokawa areas in Ehime Prefecture with places of maps C–E (**B**), locality 1 (**C**), localities 2–5 (**D**), and localities 6–10 (**E**). Scale bar in inset at lower right corner is 500 m and applies to maps C–E. Used base maps are "Digital Japan Basic Map" published by Geospatial Information Authority of Japan.

avoided change of the status quo.

Repository: Department of Geology and Paleontology, National Museum of Nature and Science (prefixed NMNS), Tsukuba, Ibaraki Prefecture, Japan.

Halysitid assemblage and age

Constituents of the halysitid assemblage in the Okanaro Group are *Halysites miyazakiensis* from locality 2, *Schedohalysites kitakamiensis* from localities 1, 2, 4, 5, 7, 9, 10 and *Catenipora seiyoensis* sp. nov. from localities 2, 4. Previously recorded ages of *H. miyazakiensis* and *S. kitakamiensis* are exclusively and mainly concentrated in Ludlow (early late Silurian), respectively. Because *C. seiyoensis* is a new, this species cannot be an index fossil, but at least it differs from the middle Silurian species, *C. nishioi*, that is another species of the genus *Catenipora* in the Kurosegawa Belt (see the below discussions). These facts suggest that limestones in the lowest part of the group are the Ludlow. This age is consistent with those of the previous most workers on the basis of different taxa.

Systematic paleontology

Subclass Tabulata Milne-Edwards and Haime, 1850
Order Halysitida Sokolov, 1947
Family Halysitidae Milne-Edwards and Haime, 1849
Subfamily Halysitinae Milne-Edwards and Haime, 1849
Genus ***Halysites*** Fischer von Waldheim, 1828

Type species: *Tubipora catenularia* Linnaeus, 1767.

Halysites miyazakiensis Niko and Adachi, 2014
Fig. 2A–C

Halysites miyazakiensis Niko and Adachi, 2014, p. 11–13, fig. 1-1–5; Niko, 2015, p. 21, fig. 2-5.

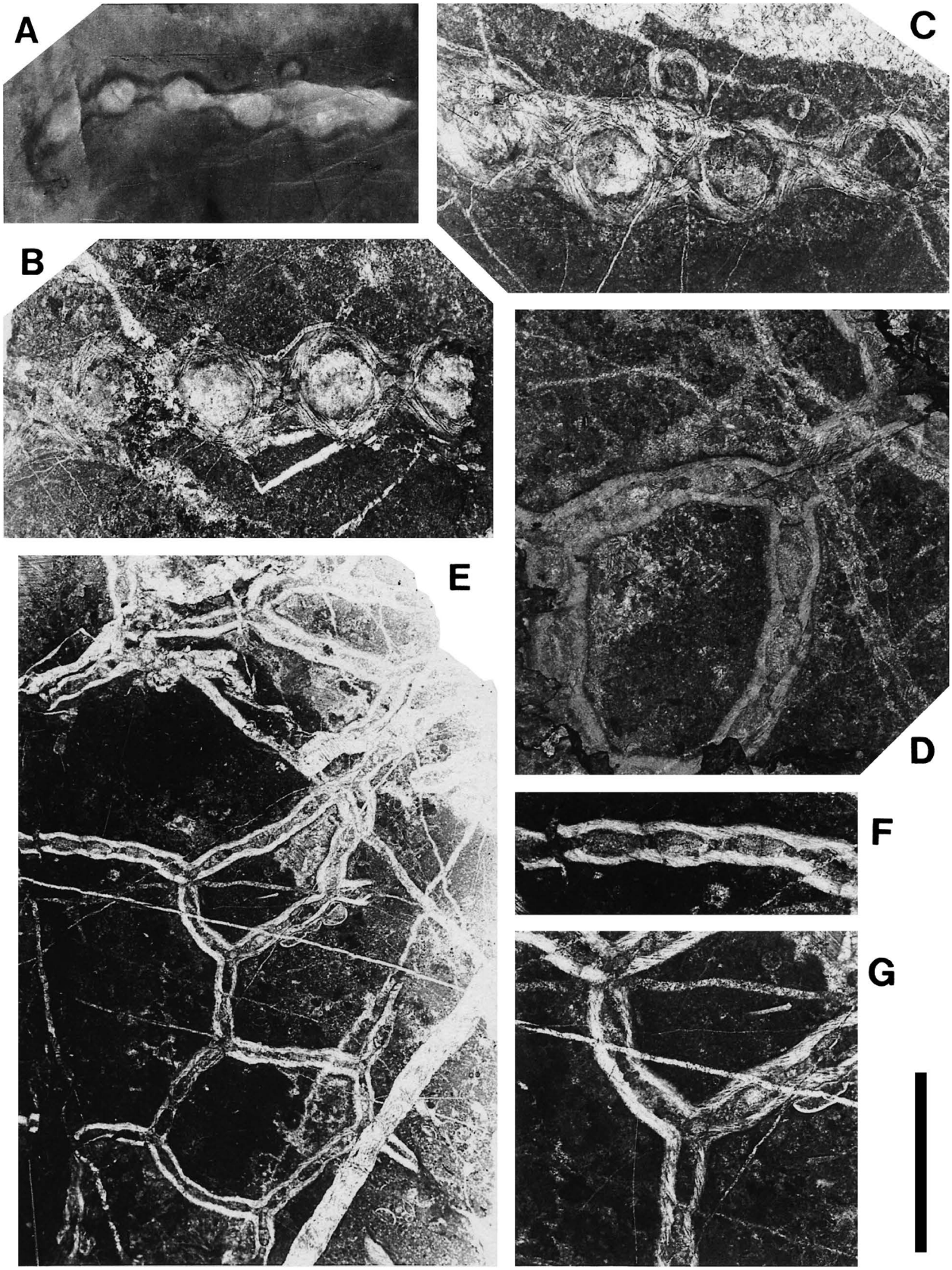

Fig. 2. **A**–**C**, *Halysites miyazakiensis* Niko and Adachi, 2014, NMNS PA20511; A, transverse polished section, B, C, transverse thin sections. **D**–**G**, *Schedohalysites kitakamiensis* (Sugiyama, 1940), transverse thin sections; D, NMNS PA20513, E–G, NMNS PA20517, F, G, partial enlargements of E, to show details of corallites and coenenchymal tubes. Scale bar: 6 mm in A, E; 3 mm in B–D, F, G.

Material examined: NMNS PA20511.

Occurrence: locality 2.

Discussion: A single fragmentary specimen is examined. Its characteristics are as follows: corallum cateniform; rank long, composed by at least seven corallites; transverse sections of corallites are subcircular to inflated elliptical with 1.4–2.3 mm in length and 1.6–2.1 mm in width; corallite walls thick, usually 0.25–0.35 mm; septal spines well-developed, short conical; tabulae complete; coenenchymal tubes indicate nearly quadrate to elongated rectangular transverse sections. Among them, profiles of the corallites and coenenchymal tubes, the thickened corallite walls and the well-developed septal spines of the specimen clearly correspond to the diagnosis of *Halysites miyazakiensis*.

The type locality of *Halysites miyazakiensis* is the Ludlow G3 Member of the Gionyama Formation in the Kuraoka area, Miyazaki Prefecture (Niko and Adachi, 2014). This species also occurs from the Ludlow part of the Fukami Formation in the Fukami area, Kumamoto Prefecture (Niko, 2015).

Genus ***Schedohalysites*** Hamada, 1957

Type species: *Halysites orthopteroides* Etheridge, 1904.

Schedohalysites kitakamiensis (Sugiyama, 1940)
Fig. 2D–G

Schedohalysites kitakamiensis (Sugiyama, 1940): Niko and Adachi, 2013, p. 33, 34, figs 10-1–5, 11-1–7 [with earlier synonymy]; Hamada, 1959a, p. 41, 1959b, p. 690; Adachi and Niko, 2015, p. 81, 86, fig. 7A–E; Niko, 2015, p. 21, 22, fig. 3-1, 2, 5.

Halysites kitakamiensis; Ichikawa *et al.*, 1956, p. 94.

Material examined: NMNS PA20507–20510, 20512–20514, 20517–20528, 20530–20537.

Occurrence: Localities 1 (NMNS PA20507–20509), 2 (NMNS PA20510, 20512–20514, 20517–20526), 4 (NMNS PA20527, 20528), 5 (NMNS PA20530–20533), 7 (NMNS PA20534), 9 (NMNS PA20535), and 10 (NMNS PA20536, 20537).

Discussion: Although all examined specimens in this study are fragmentary, the following features much well with *Schedohalysites kitakamiensis*: corallum cateniform; ranks relatively short, consist of one to five corallites, and form subprismatic lacunae; corallites weakly inflated indicating subrectangular in transverse section with 1.0–1.5 mm in length and 0.7–0.9 mm in width; coenenchymal tubules occur commonly at rank and uncommonly at corallite junctions; corallite walls weakly thickened, usually 0.13–0.23 mm; septal spines sporadic, short conical; tabulae well-developed, complete.

Schedohalysites kitakamiensis is the most common species of halysitids in Japan and widely distributes in the South Kitakami and Kurosegawa belts (e.g., Sugiyama, 1940; Hamada, 1956, 1958; Niko, 2015). Stratigraphically, *S. kitakamiensis* rarely occurs in the Wenlock, and is dominant in the Ludlow limestones (Niko and Adachi, 2013).

Subfamily Cateniporinae Hamada, 1957

Genus ***Catenipora*** Lamarck, 1816

Type species: *Catenipora escharoides* Lamarck, 1816.

Catenipora seiyoensis sp. nov.
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Fig. 3A–H

Type material: Holotype, NMNS PA20516. Paratype, NMNS PA20515. Both from locality 2.

Other material examined: A fragmentary corallum, NMNS PA20529, was also assigned to the new species.

Occurrence: Localities 2 (NMNS PA20515, 20516) and 4 (NMNS PA20529).

Diagnosis: Species of *Catenipora* with long ranks; corallites large, 1.4–2.3 mm in length and 1.3–1.9 mm in width, and mostly rectangular to nearly quadrate in transverse section; corallite form ratios (length/width) low, approximately 1.2; corallite walls thickened, attaining 0.46 mm; septal spines very rare; tabulae well-developed, complete.

Description: Two fragmentary cateniform coralla designated as a type series. They have gently curved and long ranks consisting of more than 16 corallites; sides of ranks are nearly flat or shallowly constricted at corallite junctions; no complete lacuna preserved. Corallites large for the genus; measurements of corallites are 1.4–2.3 mm in length and

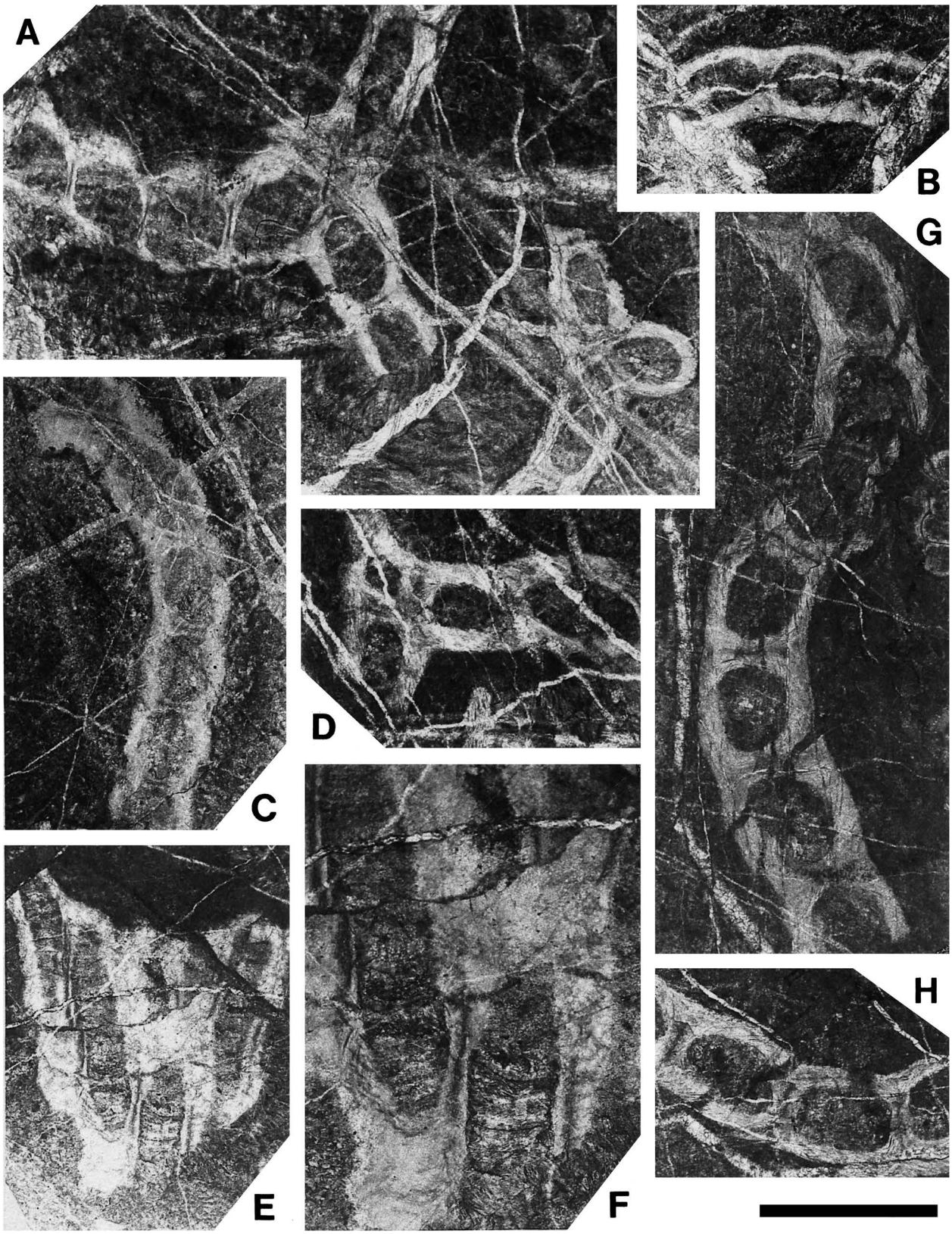

Fig. 3. *Catenipora seiyoensis* sp. nov., thin sections. **A**–**F**, holotype, NMNS PA20516; A–D, transverse sections, E, longitudinal section, F, partial enlargement of E, to show details of tabulae. **G**, **H**, paratype, NMNS PA20515, transverse sections. Scale bar: 3 mm in A–D, F–H; 6 mm in E.

1.3–1.9 mm in width; in transverse sections, rectangular to nearly quadrate corallites are most common, but weakly inflated subrectangular ones also present; form ratios (length/width) of corallites are low for the genus, 1.1–1.5, with 1.2 in mean; tabularia indicate rounded subrectangular to oval pro-

files; coenenchymal tubule neither developed rank nor corallite junctions; increase of corallite is not detected in sectioned portion. Corallite walls thick, usually 0.29–0.46 mm; intercorallite walls at corallite junctions also thick, usually 0.21–0.52 mm, where they differentiated into median line (= fused epitheca) and stereoplasmic layers; microstructure of stereoplasmic layers is not preserved; septal spines very rare, short conical having approximately 0.08 mm in length; mural pore absent; tabulae well-developed, complete, and weakly concave proximally in most cases; there are 2–5 tabulae in 2 mm of corallite length.

Etymology: The specific name is derived from Seiyo City, in which the type locality of the new species is located.

Discussion: *Catenipora seiyoensis* sp. nov. is well differentiated from comparable Silurian species, such as *C. arctica* (Chernyshev, 1941, p. 37, 38, text-fig. 13, pl. 14, fig. 1, 2; Klaamann, 1966, p. 40, 41, pl. 22, fig. 8) from Taymyr, Siberia and Estonia, *C. gracilis* (Hall, 1851, p. 212, 213, pl. 29, fig. 1a, b; Buehler, 1955, p. 36–38, pl. 4, fig. 7, pl. 5, fig. 1) from Manitoba, Canada, *C. quadrata* (Fisher-Benzon, 1871, p. 21, pl. 3, fig. 6, 7; Buehler, 1955, p. 41; Stasińska, 1967, p. 53, pl. 3, fig. 3, 4a, b) from Latvia and Sweden and *C. quadrataeformis* Stasińska (1967, p. 54, pl. 2, fig. 5a, b) from Norway, by the combination of its larger corallites with 1.4–2.3 mm in length and 1.3–1.9 mm in width, thicker corallite walls attaining 0.46 mm, and much fewer septal spines.

Previously *Catenipora nishioi* Niko and Adachi (2013, p. 34, 36, 39, fig. 12-1–5) from the Wenlock G2 Member of the Gionyama Formation was an only representative of the genus in Japan. The principal difference between the Gionyama species and *C. seiyoensis* is the more elongated corallites having higher form ratios, approximately 1.5, in *C. nishioi*, whereas approximate ratio of the new species is 1.2.

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