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SILURIAN HALYSITIDS FROM THE SHIMOARISU DISTRICT, IWATE PREFECTURE, NORTHEAST JAPAN

by

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(with 7 text-figures, 2 tables and 8 plates)

Abstract

Seven halysitids are newly found and described from the Silurian Okuhinotsuchi Formation developed in the Shimoarisu district, Setamai region of Iwate Prefecture. Of them *Halysites arisuensis* is new to science. The Okuhinotsuchi Formation may be, based on halysitids, as a whole, Late Llandoverian to Wenlockian in age. In general halysitids described are much faunistically related to those of Southwest Japan and of Australia.

Introduction

In the southern Kitakami Mountains, Northeast Japan, Silurian deposits have long known to develop in the Hikoroichi region of Onuki (1969). (Text-fig. 1) Onuki (1937) first clarified the presence of Silurian in that region, and later Sugiyama (1940) made stratigraphical and palaeontological studies on the Silurian. Silurian stratigraphy was further studied in the Hikoroichi region by Okubo (1950) and Minato et al. (1959). Minato, Choi and Okabe (1973) later discovered a new locality of Silurian fossils also in the Hikoroichi region. At any rate the distribution of Silurian has been confined in the Hikoroichi region, east of the Tono-Takada line of Onuki (1969) in the southern Kitakami Mountains.

In the autumn of 1975 the author, while engaged in geological mapping of Carboniferous in the Shimoarisu district, Setamai region of Iwate Prefecture, quite unexpectedly discovered a specimen of halysitid at a locality in Okuhinotsuchi. The specimen was later identified by Prof. M. Minato, Drs. M. Kato and I. Niikawa as *Halysites* sp. Thus it became clear that Silurian deposits were actually developed also in the Setamai region which is west of Tono-Takada line. (Text-fig. 1) Geology around the new Silurian locality has been treated in Onuki (1938), Minato et al. (1954), Saito (1966) and Nambu et el. (1970). In these works the area now in problem has been considered as Permian or Carboniferous.

Then in the spring of 1976, Drs. M. Kato, Y. Fujiwara and N. Minoura and many colleagues of the author engaged in extensive fossil collection in that area, which produced many halysitids together with other fossils. The material collected then forms major part of the present study.

The author reported on the Silurian deposits in the Shimoarisu district in a preliminary form (Kawamura, 1977). In 1978 Kawamura orally presented his result of detailed research on stratigraphy of the Silurian of the Shimoarisu district, at the annual Meeting of the Geological Society of Japan, held in Shimizu.

Gradually it has become apparent that the Silurian of the Shimoarisu district, Setamai region is much different from the Silurian already known in the Hikoroichi region in faunal

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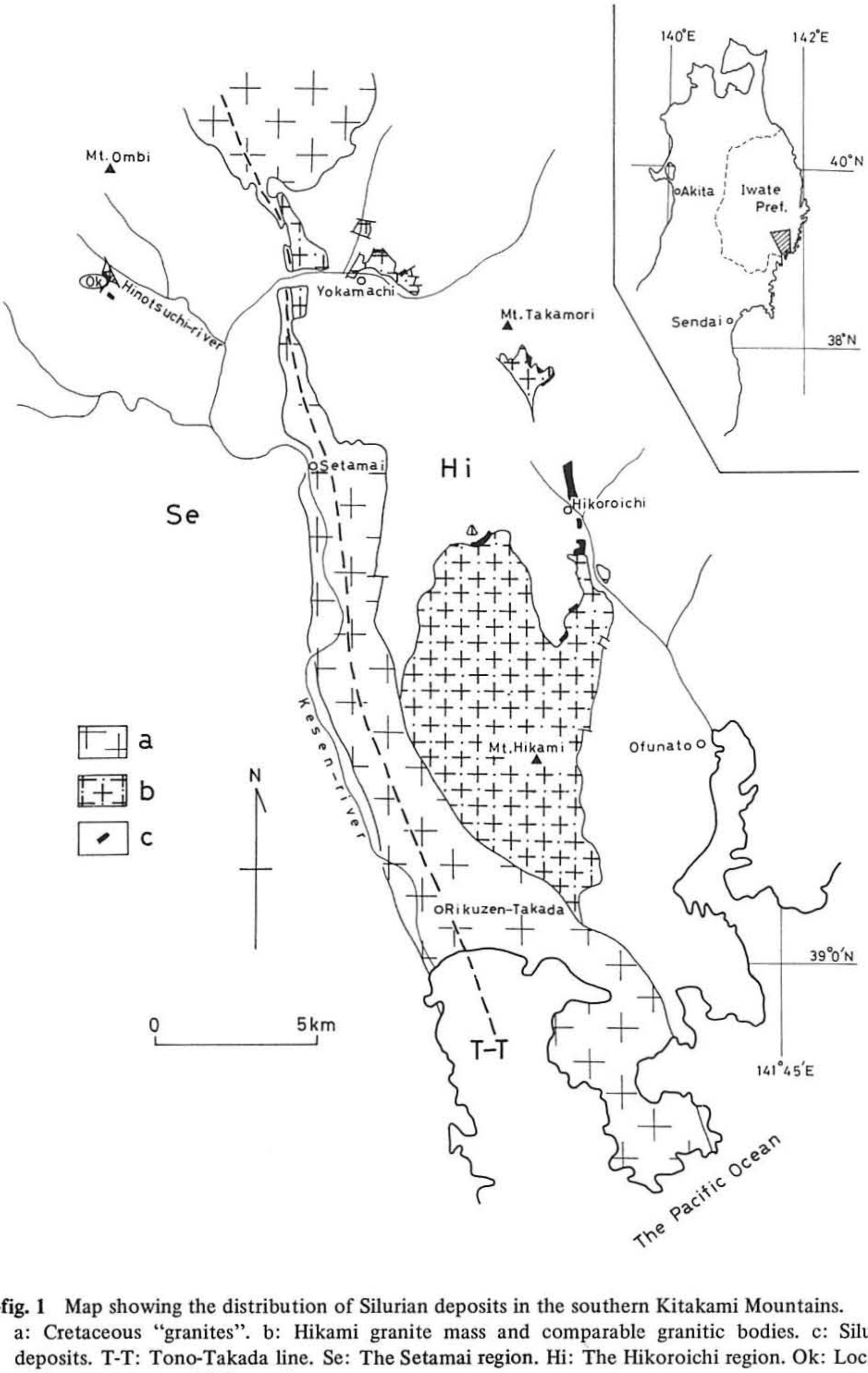


Text-fig. 1 Map showing the distribution of Silurian deposits in the southern Kitakami Mountains.
a: Cretaceous "granites". b: Hikami granite mass and comparable granitic bodies. c: Silurian deposits. T-T: Tono-Takada line. Se: The Setamai region. Hi: The Hikoroichi region. Ok: Locality of the Okuhinotsuchi Formation.
Distribution of granites is after Hoe (1978), partly modified.

as well as lithostratigraphic aspects.

It is the purpose of the present article to describe some halysitids from the Silurian deposits developed in the Shimoarisu district, and to consider the geological age of them based on halysitid evidences.

Outline of the geology of the Shimoarisu district

In the Shimoarisu district, Setamai region, Iwate Prefecture, Silurian to Permian deposits are distributed (Minato et al., 1954; Takeda, 1960; Kawamura, 1977 MS).

The Silurian crops out on the mountain slope along the Hinotsuchi-gawa (river), at about 1 km west of Okuhinotsuchi village of Shimoarisu district. It is distributed very narrowly within the extent of 500 × 750 m, and is accompanied by granite lithologically comparable with the Hikami granite. (Text-fig. 2)

Around the Silurian and granite, younger sediments ranging from the Devonian to the Permian are extensively distributed with a complicated manner. As a whole, geological structure of the district is forming an anticlinorium, along which the Silurian and granite were later uplifted near the dislocated axis of it.

Devonian deposits (over 300 m in thickness) mainly consist of fine-grained acidic vitric tuff, and are correlated lithologically to the Ohno or Nakazato Formation of the Hikoroichi region. They are exposed a little apart from the distribution of Silurian, so that direct field relationship between the Silurian and Devonian cannot be ascertained.

Surrounding the Silurian and Devonian deposits are the Tournaisian sediments with the thickness over than 1,400 m. Lower part of the Tournaisian is characterized by the abundance of acidic tuff, and is correlated with the Hikoroichi Formation of the Hikoroichi region. While basaltic volcanics are dominant in the upper part of the Tournaisian, which is correlatable with the typical Arisu Formation of the Setamai region. The Tournaisian deposits are mostly in fault contact with the Silurian and Devonian, but in parts they cover unconformably the older sediments with a basal conglomerate.

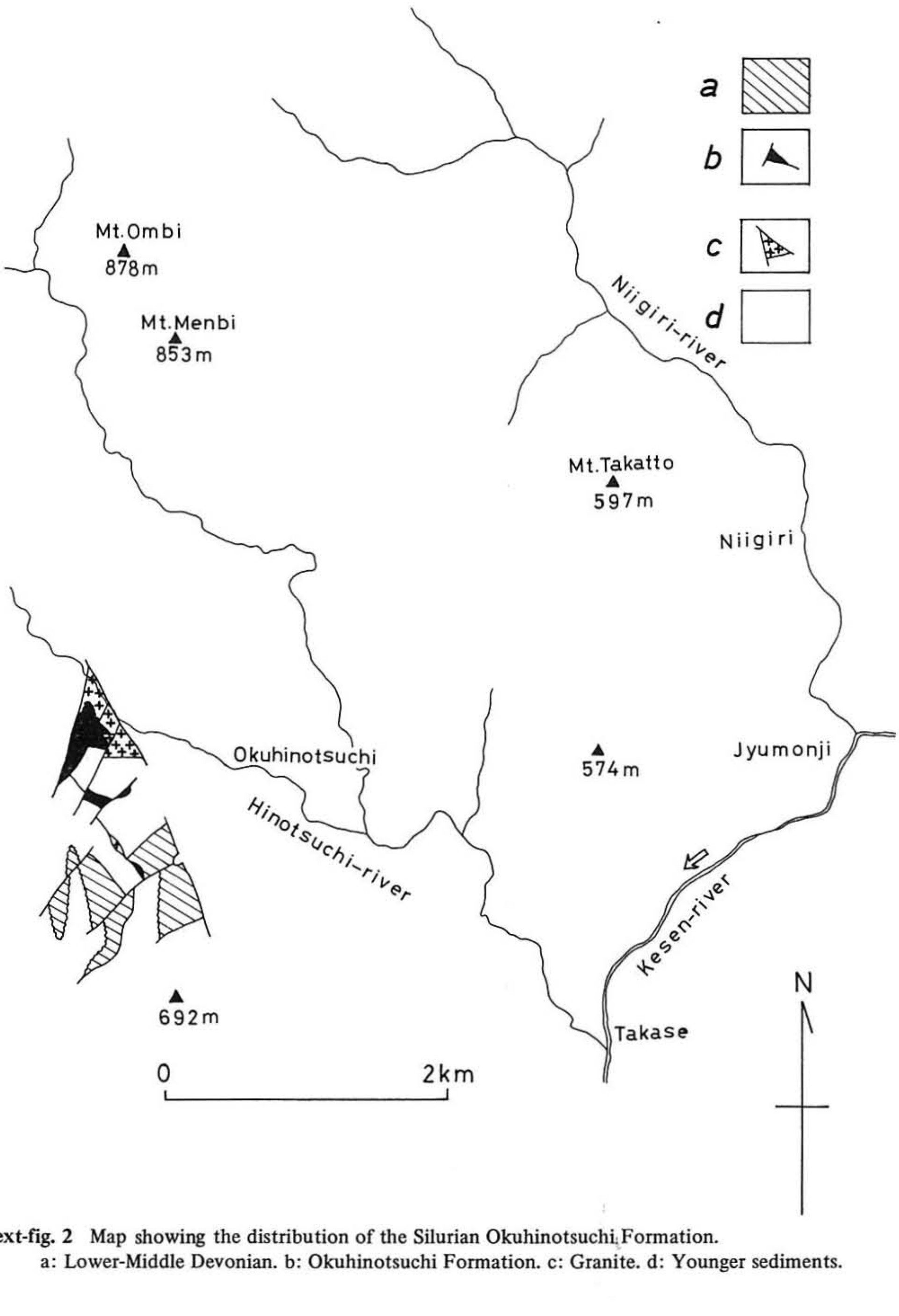
Upper Viséan Onimaru Formation mainly consisting of limestone is developed in the eastern and western wings of the said anticlinorium, less than 150 m in thickness. An unconformable relationship between the Onimaru Formation and the underlying deposits was advocated by Takeda (1960).

The Upper Carboniferous Nagaiwa Formation (over 450 m in thickness) mainly consisting of limestone is distributed in the western wing of the anticlinorium, accompanying with the Onimaru Formation. Although their mutual field relationship has been unobserved, the distribution of Nagaiwa Formation is parallel to that of the Onimaru Formation.

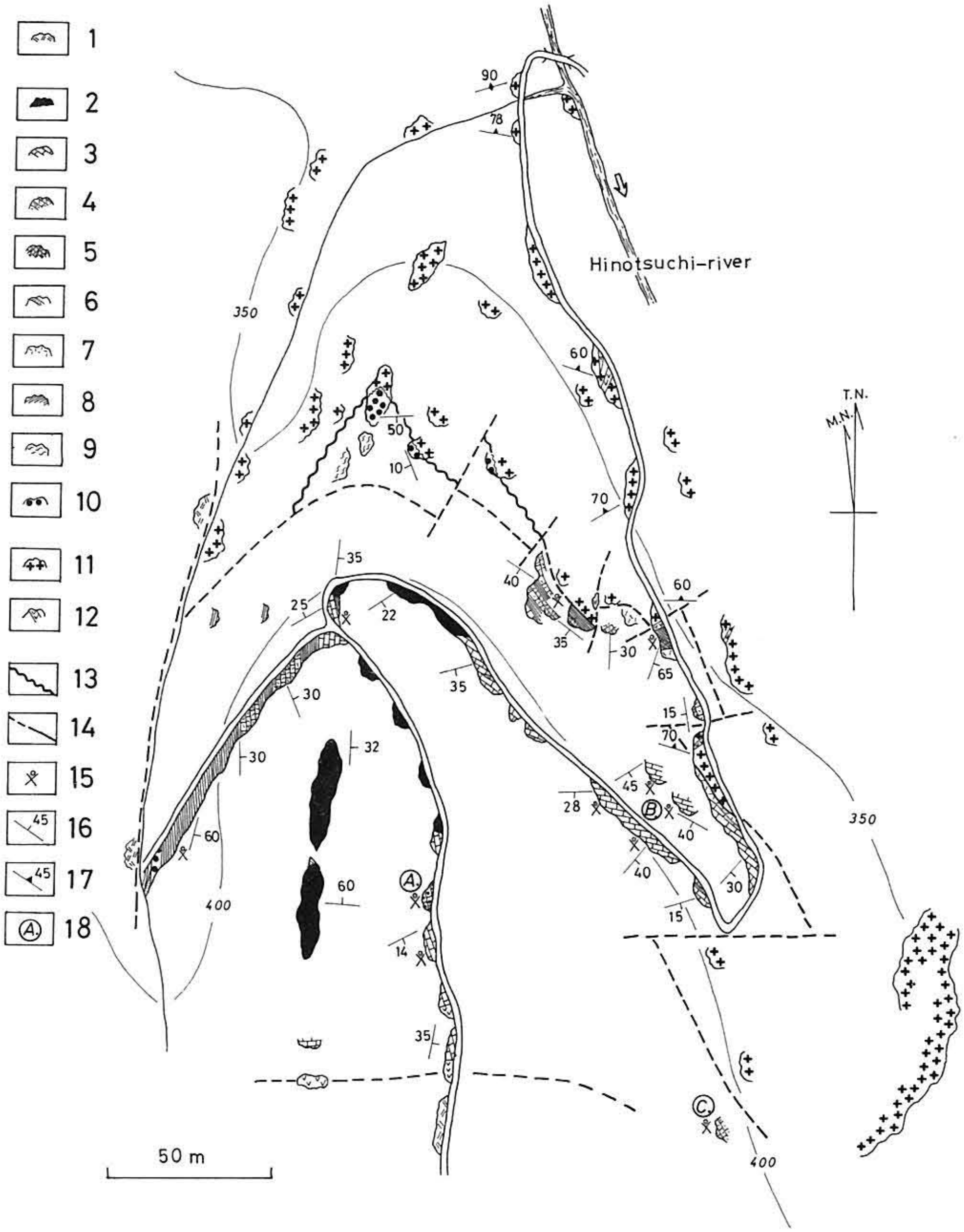
The youngest deposits in this district are Lower Permian in age, consist of conglomerate, sandstone and slate in alternation and thick limestone. They are correlatable with the Sakamotozawa Formation, and unconformably covers the various older formations with a basal conglomerate. Total thickness of the Lower Permian is over 800 m.

Stratigraphy of the Silurian Okuhinotsuchi Formation (new name)

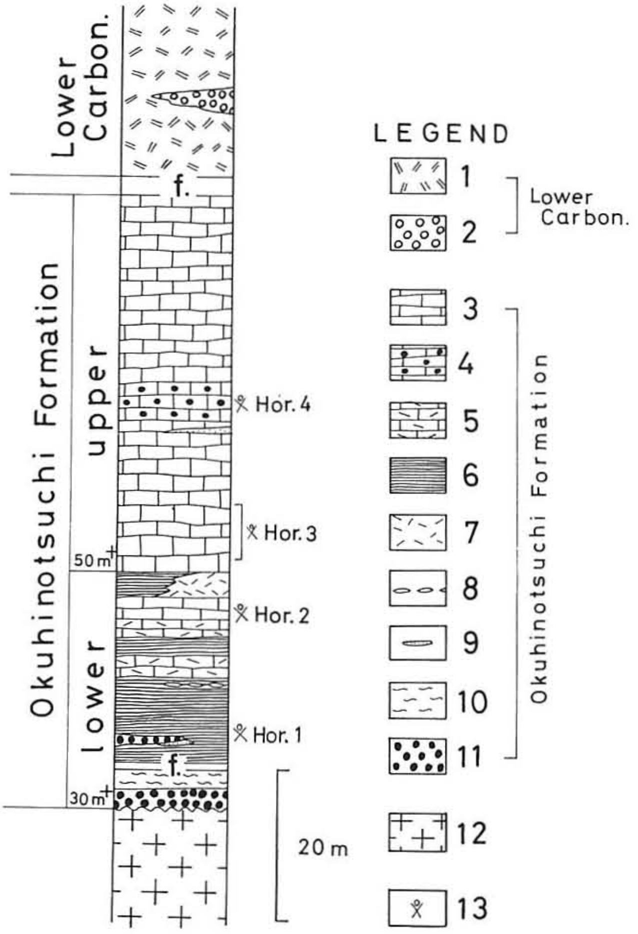
The Silurian formation in the Shimoarisu district is lithologically divided into two



Text-fig. 2 Map showing the distribution of the Silurian Okuhinotsuchi Formation.
a: Lower-Middle Devonian. b: Okuhinotsuchi Formation. c: Granite. d: Younger sediments.



Text-fig. 3 Geological sketch map of the Okuhinotsuchi Formation in the main area of its distribution. 1: Tuffaceous rocks of the Lower Carboniferous Hikoroichi Formation. 2-10: Okuhinotsuchi Formation. (2: Crystalline limestone. 3: Dark gray limestone. 4: Pale greenish impure limestone. 5: Pebbly limestone. 6: Sandstone. 7: Vitric tuff. 8: Tuffaceous slate. 9: Welded tuff. 10: Pebbly part of welded tuff and conglomerate). 11: Granite. 12: Dyke rocks. 13: Unconformity between the Silurian and granite. 14: Faults. 15: Occurrences of fossils. 16: Dip-strike of bedding plane. 17: Dip-strike of shear plane. 18: Localities of described halysitids.



Text-fig. 4 Geological columnar section of the Okuhinotsuchi Formation.
1-2: Lower Carboniferous Hikoroichi Formation. (1: Tuffaceous rocks. 2: Conglomerate.).
3-11: Okuhinotsuchi Formation. (3: Dark gray limestone. 4: Pebbly limestone. 5: Pale greenish impure limestone. 6: Tuffaceous slate. 7: Vitric tuff. 8: Calcareous nodules. 9: Sandstone. 10: Welded tuff. 11: Pebbly part of welded tuff and conglomerate). 12: Granite. 13: Fossil bearing horizons.

members. (Text-figs. 3, 4) The Lower Member (only about 30 m in thickness) commences with a bed of welded tuff (about 5 m), the lower part of which carries small clasts of rhyolite, fine-grained acidic volcanics, granite, basaltic-andesitic rocks and aplite. This bed of welded tuff is judged to unconformably overlie the granite above mentioned. Then comes the alternation of tuffaceous slate, vitric tuff and pale greenish impure limestone. Thickness of this alternation part of the Lower Member is about 25 m. Fossils were collected from the lower part of this alternation (Horizon 1). They are not rich, belonging to Trilobita and Tabulata. No halysitids were obtained from this horizon. Some more fossils were collected from the upper part of the alternation (Horizon 2). Two forms of halysitids were obtained from this horizon at Locality C (Text-fig. 3).

The Upper Member (over 50 m) conformably supersede the Lower Member, and consists of fossiliferous, dark gray limestone (partly recrystallized). From the lower part of the Upper Member (Horizon 3) abundant fossils have been identified (Table 1), including some halysitids from Loc.B. In the middle part, pebbly limestone with pebbles of acidic-andesitic volcanics is intercalated. From this part of the Member (Horizon 4) a halysitid species, *Falsicatenipora shikokuensis* was collected at Loc.A. Upper limit of this Upper Member is unknown, because of fault contact with the Lower Carboniferous Hikoroichi Formation.

As will be described below the Silurian formation of the Shimoarisu district, Setamai region yields a number of *Halysites (s.str.)* and no *Schedohalysites* which is so common in the Silurian Kawauchi Formation of the Hikoroichi region, where *Halysites (s.str.)* is quite rare on the contrary.

From lithological point of view the presence of characteristic welded tuff with granitic clasts for example in the Silurian of the Shimoarisu district is quite distinct nature. Such lithology is quite unknown in the Silurian Kawauchi Formation of the Hikoroichi region.

Therefore a new name, the Okuhinotsuchi Formation is here introduced to the Silurian of the Shimoarisu district.

The geologic age of the Okuhinotsuchi Formation and its correlation will be discussed separately in the following chapter.

Systematic Description

Family Halysitidae Milne-Edwards et Haime, 1850

Taxonomy and morphological terms employed below for halysitid corals are mainly after Hamada (1957 a,b, 1958).

As to the evaluation of taxonomic weight or importance of various morphological features of halysitids, no unaminity has been however achieved so far. The author provisionally considers the following characters to be basically important in classifying halysitids. These characters are so arranged that more fundamental feature comes first.

1. Absence or presence of micro - and/or mesocorallites.
2. Form and size of macrocorallites.
3. Form and size of fenestrules.
4. Absence or presence of septal spinules (and their degree of development).
5. Shape and size of corallum.
6. Other features (e.g. density of tabulae, thickness of corallite wall).

For specimen treated below, however, the corallum shape is not always recognizable owing to the nature of preservation. They have firmly embedded in limestone and are more or less fragmental.

Subfamily Schedohalysitinae Hamada, 1957

Genus *Falsicatenipora* Hamada, 1958

1958. *Falsicatenipora* Hamada, p.98.
Type species: *Halysites japonicus* Sugiyama, 1940

Falsicatenipora shikokuensis Noda et Hamada

(pl. 1, figs.1,2; text-fig. 5a)

1958. *Falsicatenipora shikokuensis* Noda et Hamada, in Hamada. p.99–100; plate 6, figs. 4,5; plate 7, figs. 1–7.

Material: Single thin section (UHR30404) of a squashed, fragmental corallum, from the middle part of Upper Member (Hor. 4) of the Okuhinotsuchi Formation, collected at Loc.A.

Description: Corallum compound, small, exact shape of which is unknown, measures 10 × 35 mm as far as it is preserved.

In transverse section, fenestrules are small and polygonal when properly preserved. They are 2.0–2.5 mm in average diameter. One side of a fenestrule is composed of only one or rarely two corallites. Macrocorallites small, rectangular or suboval. Size of macrocorallites measures 0.5–0.6 × 1.0 mm, and that of visceral chambers 0.2–0.3 × 0.4–0.9 mm. Corallite wall is comparatively thick, being about 0.2 mm. Mesocorallites are triangular, 0.2 mm in diameter. Microcorallites absent.

No longitudinal section is obtainable, however, tabulae are seen in oblique section of some corallites, where they appear to be complete and horizontal, and 0.25 mm apart from one another.

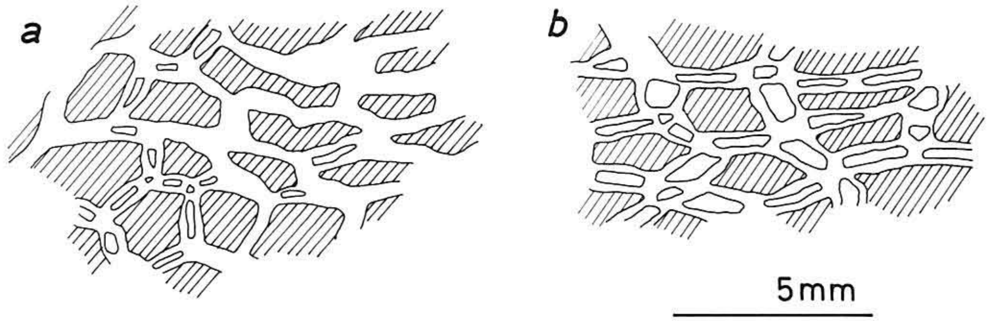
Remarks: Although imperfectly preserved, the present specimen is identical with *Falsicatenipora shikokuensis,* because of having characteristically small and polygonal fenestrules composed of 1 to 2 small, rectangular macrocorallites. The only difference between the two forms, the present one and the type specimen, lies in that the present specimen has a little larger macrocorallites than the latter.

Falsicatenipora hillae Hamada (1957) resembles the present form, but differs from it in having slightly larger and broader macrocorallites (0.75 × 1.0 mm) and distinct septal spinules.

Falsicatenipora sp.

(plate 1, fig.3; text-fig.5b)

Material: A small, fragmental corallum from which a thin a section (UHR30405) was



Text-fig. 5

a: Sketch of *Falsicatenipora shikokuensis* Hamada, UHR30404. Transverse section. Shaded parts are meant to be limestone matrix. The specimen is so much recrystallized that the exact form or shape of visceral chambers are often obscure.

b: Sketch of *Falsicatenipora* sp., UHR30405. Transverse section, slightly oblique.

prepared. The specimen was collected from the lower part of Upper Member (Hor.3) of the Okuhinotsuchi Formation, at the Loc.B.

Description: Corallum compound, small, probably conical in external shape. In a section corallum occupies the area of 15 × 30 mm, revealling transverse section at the center, while at the same time longitudinal sections at periphery.

Fenestrules rather small and polygonal although they are somewhat compressed. They are irregular in size being 1.5–2.0 × 3.0–5.0 mm. One side of a fenestrule is composed of one, sometimes two macrocorallites. Macrocorallites rectangular or elongated oval in form, 0.6–0.8 × 1.25–1.6 mm in size. Thickness of corallite wall ranges from 0.1 to 0.25 mm. Mesocorallites present. Their shape is often obliterated by recrystallization, but is triangular or even quadrangular, 0.4–0.5 mm in average diameter. Septal spinules absent. Microcorallites appear to be absent.

In longitudinal section tabulae in macrocorallites complete and horizontal. They apart 0.35–0.45 mm from one another. Tabulae in mesocorallites are more densely arranged.

Remarks: The present form is distinct from the preceding species, *F.shikokuensis* in possessing much larger macrocorallites than the latter. The present one somewhat resembles *F.japonica* (Sugiyama, 1940; Hamada, 1958) and *F.chillagoensis* Etheridge (1904) in size of macrocorallites. However in the latter two species macrocorallites are more oval and their fenestrules are with a chain of commonly two or more macrocorallites, compared to the present form.

No previously recorded form are identical with the present one which may be a new species. The author wishes to postpone the final assignment of the present form until more abundant and more favourably preserved material will be turned up.

Subfamily Halysitinae Milne-Edwards et Haime, 1850

Genus *Halysites* Fischer von Waldhaim, 1813

1813. *Alyssites* Fischer von Waldheim, p.387. (fide Lang, Smith and Thomas, 1940, p.64–65)
1828. *Halysites* Fischer von Waldheim, p.15. (ditto)
1851. *Halysites,* Milne-Edwards et Haime, p.281 (partim).
1866. *Ptychophloelopas* Ludwig, p.236. (fide Lang, Smith and Thomas, 1940, p.201–202; and Buehler, 1955, p.21)
1940. *Halysites,* Sugiyama, p. 129 (partim).
1954. *Halysites,* Hill, p.37–38.
1954. *Halysites,* Thomas et Smith, p.766.
1956. *Halysites,* Hill et Stumm, F.469.
1957. *Halysites,* Hamada, p.402.
1957. *Acanthohalysites* Hamada, p.404.
1961. *Acanthohalysites,* Strusz, p.353.
1962. *Halysites (Acanthohalysites),* Yü, p.80.
1963. *Halysites,* Yü et al., p. 289.
1963. *Halysites (Acanthohalysites),* Yü et al., p. 289.
1966. *Halysites,* Klaamann, p.59–60.
1967. *Halysites,* Stasińska, p.57.
1977. *Halysites,* Jia et Wu, p.23–24.
1978. *Halysites,* Yang, Kim et Chow, p.228.

Type species: *Tubipora catenularia* Linnaeus

Remarks: Taxonomic importance of septal spinules in halysitids is debatable.

Etheridge, as early as 1904, clearly divided halysitids into two groups, based on the presence or absence of septal spinules in them. Yabe (1915) also considered septal spinules as taxonomically important, although at the same time he admitted the variable nature of this organ. Buehler (1955) described that septal spinules were easily obliterated through fossilization, and thus were not considered as useful criterion. Apparently Buehler's point of view is only practical but not at all correct in aiming at a biological classification. Hamada (1957) created *Acanthohalysites* for cateniform Halysitinae with septal spinules. This procedure is in accordance with the distinction of *Catenipora* from *Quepora,* both of Cateniporinae Hamada (1957). Namely the former genus has long, well developed septal spinules, whereas the latter has none, retaining other features very similar with each other. Yet Hamada (1958) in creating still another genus, *Falsicatenipora,* does not seem to care about the nature of septal spinules as diagnostic, since he put both forms with or without septal spinules in that genus. Yü (1962) regarded this character now in problem as not of generic but of subgeneric one. Klaamann (1966) stated that all *Halysites* species he examined had septal spinules, which, however, were different from a species to the other, or from specimens to specimens in the degree of development. Therefore he did not recognize *Acanthohalysites* as distinct from *Halysites.*

However both forms with septal spinules and forms without septal spinules appear to be present in *"Halysites",* as far as the author examined through literatures. Both forms are actually present also in the present author's collection of *Halysites.* It is true to say that, if present, septal spinules are only weakly or sporadically developed in *Halysites.* They are at least never as conspicuous as in most species of *Catenipora.* In this concern septal spinules in *Halysites* cannot be viewed as a stable biocharacter. Moreover in some cases, as in *Halysites labyrinthicus* described below, spiny projections in transverse section of *Halysites* may well be only cut edges of septal ridges of corallites, instead of real septal spinules.

Such being the case, the author considers the presence or absence of septal spinules is not a generic character to distinguish *Acanthohalysites* from proper *Halysites.* The author still thinks the nature is useful probably for specific distinction.

In the following description, *Acanthohalysites* is thus considered as synonymous with *Halysites.*

Halysites labyrinthicus (Goldfuss)

(plate 3, figs.1–7; plate 4, figs.1–4; text-fig.6a–d)

non *Halysites labyrinthicus,* Yabe, 1915, p.35; plate 3, figs.3, 4; plate 4, figs.1, 2.
1955. *Halysites labyrinthica,* Buehler, p.29–30; plate 3, figs.1–5.

Material: UHR30406, a comparatively large colony embedded in black muddy limestone. Twenty-one thin sections (UHR30406A-U) were prepared from the specimen. From the lower part of Upper Member (Hor. 3) of the Okuhinotsuchi Formation, at the Loc.B.

Description: Corallum compound, medium in size. Measurement of the preserved part of colony is about 5 × 10 cm in the area of transverse section with the height of 15 cm. Faint trace of transverse annulations are seen on the weathered surface of epitheca. Also several longitudinal ridges are present on the internal surface of corallites on one side.

In transverse section, fenestrules labyrinthine, irregularly meandering. Each chain is composed of 5 to 7 (maximum 14) macrocorallites, with 13 to 15 mm (rarely 25 mm) in length. Macrocorallites large, oval or depressed and rounded hexagonal in outline, 1.7–2.5 × 1.9–3.0 mm. Average external size is 2.1 × 2.7 mm. Corallite wall medium in thickness, being 0.2–0.3 mm. Internal surface of macrocorallites is either smooth or a little crenulated. Sometimes spiny projections are seen on the wall. However they may be nothing but cut edges of longitudinal ridges on the internal surface of corallite wall. Mesocorallites may be depressed triangular in shape, with the average diameter of 1.0 mm. But in many cases they are much deformed or crushed owing to ill preservation. Microcorallites well developed, rectangular or slit in form, 0.1–0.2 × 0.4–0.8 mm in size. No distinct "Balken" structure is present.

In longitudinal section tabulae in macrocorallites are complete and horizontal, 0.6–0.8 mm apart. Their thickness is less than 0.1 mm. Tabulae in microcorallites are also complete and horizontal. Their arrangement is slightly denser than those of macrocorallites.

Remarks: According to Buehler (1955) Goldfuss's original material of his *Catenipora labyrinthica* came from "Groningen, Germany and Drummond Island, Michigan". The latter specimen was restudied by Teichert (1937, fide Buehler, 1955) and later selected as the lectotype of *Halysites labyrinthicus* by Buehler (1955) to which the present Japanese form is identical.

The species was often considered as conspecific with *H.catenularius.* However the lectotype of *H.labyrinthicus* is different from the neotype of *H.catenularius* (Thomas & Smith, 1954) in possessing distinctly larger macrocorallites than the latter.

H.labyrinthicus has been described both from North America and Europe. However there seem to be considerable morphological differences present between American type (*e.g.* Buehler, 1955) and European forms (*e. g.* Yabe, 1915). Namely European forms have 1) thicker corallite wall, 2) well developed "Balken" structure, 3) broad, nearly round macrocorallites, and 4) relatively narrow fenestrules compared to *H.labyrinthicus* from America. In the author's opinion those forms of "*H.labyrinthicus*" from Europe are specifically different from the same named species from America, and may be identical with *H.senior* Klaamann and/or *H.junior* Klaamann.

Halysites cfr. *cratus* Etheridge

(plate 1, figs.4,5; plate 2, figs. 1-5; text-fig.6e,f)

compared with;

Halysites cratus Etheridge, 1904, p.27–29; Plate 1, fig. 1; Plate 4, figs. 3, 4; Plate 6, figs. 5, 6.

Halysites cratus, Hamada, 1958, p. 101–102; Plate 22, figs. 5, 6a,b.

Material: Single fragmental colony about 5 x 5 x 3cm, entirely embedded in greenish gray limestone. UHR30407. Five thin sections (UHR30407A–E) were prepared from the specimen. Collected from the upper part of Lower Member (Hor. 2) of the Okuhinotsuchi Formation, at the Loc. C.

Description: Corallum compound, small. Surface characters unknown.

In transverse section fenestrules large, polygonal or slightly elongated, 5–16 × 9–26 mm in size. Average size of the fenestrules is 10 × 20 mm. Two to five (usually four) macrocorallites are present in one side of the fenestrules. In a section (UHR30407A) free end of a chain is seen approaching to another chain (Plate 1, fig. 4), showing the mode of fenestrule formation. Macrocorallites round, oval, medium in size. They measures 1.2–1.5 × 1.75–2.5 mm (average 1.4 × 2.2 mm). Corallite wall comparatively thin, 0.1–0.2 mm in thickness. Septal spinules absent. Mesocorallites triangular or truncated triangular, 0.4–0.5 × 0.75–1.0 mm in size. Microcorallites rectangular, 0.1–0.2 × 0.4–0.7 mm in size.

In longitudinal section all the tabulae are complete and horizontal. In macrocorallites tabulae are regularly and evenly spaced, 0.45–0.6 mm apart, and 0.05–0.1 mm in thickness. Tabulae in microcorallites are thinner and closer than those of macrocorallites, 0.2–0.3 mm apart, 0.05 mm in thickness.

Remarks: In the form and size of macrocorallites with relatively thin corallite wall, the present form quite resembles *H. cratus*.

Hamada (1958) described *H.cratus* from Southwest Japan, to which specimen the present form is almost identical. However original, Australian specimens of this species has decidedly labyrinthine fenestrules (Etheridge, 1904). The author is now inclined to consider that both Japanese forms (Hamada, 1958 and the present form) are comparable with the Australian form, if not identical with it.

In general *H.priscus* Klaamann (1966) has much similarity with the present form. However in this Estonian species mesocorallites are often lacking at the junction of chains. Naturally, if budding and division are introduced only through mesocorallites this can not be observed always. In his Plate 22, figs. 5, 6 for instance almost no mesocorallites may be seen at the junction of chains in fenestrules. Whether this phenomenon merits for the separation of species or not is uncertain, the present Japanese form completely differs from the Estonian form in this connection. Also macrocorallites are slightly smaller in Estonian species which is said to possess septal spinules.

Another ally to the present Japanese form is *H. guizhouensis* Yang (in Yang et al., 1978), which however has fine septal spinules and smaller macrocorallites compared to the Japanese form.

Halysites arisuensis Kawamura, sp. nov.

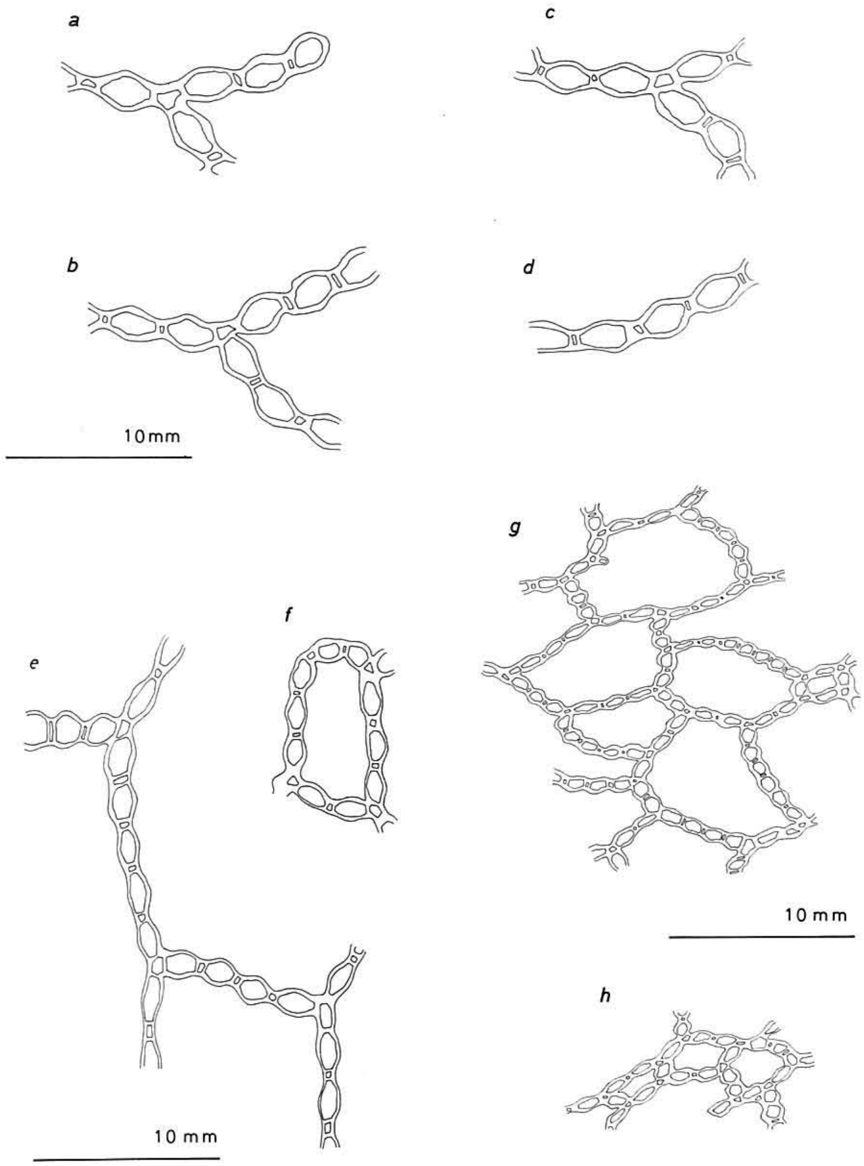
(plate 5, figs.1-6; plate 6, figs.1-6; plate 7, figs.1-3 text-fig. 6g,h)

Material: Holotype, UHR30408, the largest colony embedded in black limestone. Thirteen thin sections (UHR30408A–M) were prepared from the holotype. Several small, fragmental coralla (UHR30409, 30410, 30411, 30412 and 30413) are also at hand. All specimens were collected at Loc. B, from the lower part of Upper Member of the Okuhinotsuchi Formation.

Diagnosis: Halysites with loosely polygonal fenestrules, small,oval macrocorallites in transverse section, and no septal spinules.

Description: Corallum compound, cateniform, medium in size. Largest colony (holotype) measures 5 × 9 cm in breadth, and 10 cm in height. Surface characters are unknown.

In transverse section, fenestrules are somewhat irregularly polygonal, or even elongated polygonal to approach as meandrine. Size of fenestrules 4–8 × 7–20 mm. One side of fenestrules is composed of 3 to 6 (usually 4) macrocorallites. Fenestrules become more tightly polygonal in parts of corallum (Text-fig. 6h), where one or two macrocorallites occupy a chain of each fenestrule. Free margin of a chain is often seen in relatively large fenestrules. Macrocorallites are oval in form, 0.5–0.8 × 0.8–1.6 mm (average 0.7 × 1.2 mm)



Text-fig. 6

a-d: Sketch of *Halysites labyrinthicus* (Goldfuss), showing the forms of corallites and the mode of junction of chains. a: UHR 30406E b: UHR 30406F c,d: UHR30406A

e,f: Sketch of *Halysites* cfr.*cratus* Etheridge. Transverse sections. e: UHR30407A f: UHR30407D

g,h: Sketch of *Halysites arisuensis* sp.nov. Transverse sections. g: UHR30408C, showing form of fenestrules. h: UHR30408D, showing rather tight fenestrules.

in size. Corallite wall is moderately thick, 0.1–0.2 mm in thickness. Mesocorallites are triangular, sometimes irregularly polygonal, and 0.3–0.4 × 0.4–0.5 mm in size. Microcorallites are rectangular in form, 0.1–0.2 × 0.2–0.6 mm (average 0.1 × 0.3 mm) in size. Intercorallite wall is normally thinner than corallite wall. Septal spinules absent and the inner surface of macro- and microcorallites is usually smooth. Outer configuration of a chain of fenestrules is a little undulated.

In longitudinal section tabulae in macrocorallites are complete and horizontal, 0.2–0.9 mm (average 0.5 mm) apart, 0.05–0.07 mm (maximum 0.1 mm) in thickness. Tabulae in microcorallites are also complete and horizontal, somewhat closely spaced than those of macrocorallites.

Remarks: The present new species closely resembles *H.gamboolicus* Etheridge (1904) in the size and form of fenestrules and macrocorallites. But the latter Australian form clearly possesses septal spinules and hemispherical corallum, and is distinct from the present species.

H.süssmilchi Etheridge (1904) has similar sized macrocorallites with the present form. But the form of macrocorallites in *H.süssmilchi* is distinctly eye-shaped, in contrast to weakly undulated configuration of a chain in the present form. A specimen of *H.süssmilchi* from Gotland (Yabe, 1915) reveals thick corallite wall and microcorallites much elongated in the direction of growth of a chain. Hamada (1958) described *H.süssmilchi* from Mt. Yokokura, Kochi Prefecture. His specimens demonstrate clearly labyrinthine coralla. So in these respects above mentioned the present Japanese form is easily distinguished.

Another Japanese species of *Halysites, H.bellulus* Hamada (1958) has small macrocorallites comparable with those of the present form. But in *H.bellulus* fenestrules are more tight and regularly polygonal and its macrocorallites more elongated.

A specimen (UHR30414) with loosely labyrinthine fenestrules is considered here as a variatal form of *H.arisuensis,* although it reveals different type of fenestrules from the typical form. In fact peripheral parts of corallum tend to show loosely formed fenestrules. And also there are series of specimens, though fragmental, in which a chain of somewhat labyrinthine fenestrules has more than 10 macrocorallites. In any case the form and size of macrocorallites are fairly uniform even in these specimens, which character should therefore be more stable than the form of fenestrules. The form of fenestrules in the present new species thus appear to be small and tight to begin with. Then they are judged to grow more loosely polygonal until they get even to meandrine in the periphery of the corallum. In short the form of fenestrules is in general not very reliable criterion in halysitid classification. At

Explanations of Plate 1.

Falsicatenipora shikokuensis Hamada

Fig. 1 Showing much deformed corallum, UHR30404. × 3.0

Fig. 2 Enlarged view of Fig. 1, showing small, polygonal fenestrules and small, rectangular-suboval macrocorallites. Transverse section. ×6.0

Falsicatenipora sp.

Fig. 3 Showing probable conical form of corallum. Oblique section. UHR30405. × 3.0

Halysites cfr. *cratus* Etheridge

Fig. 4 Transverse, partly oblique section showing rather polygonal fenestrules. UHR30407A. × 1.5

Fig. 5 Enlarged view of Fig. 1. × 3.0

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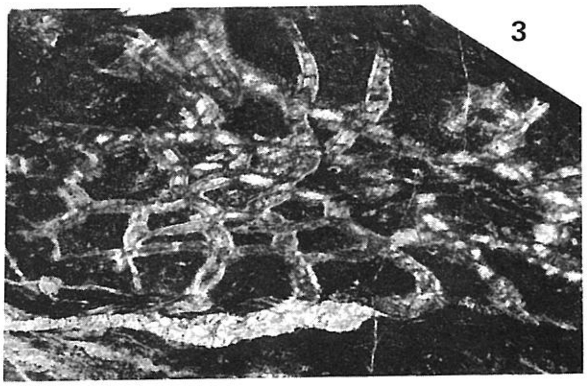

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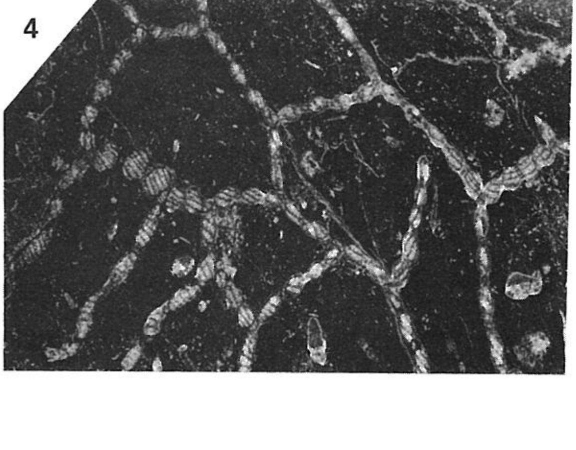

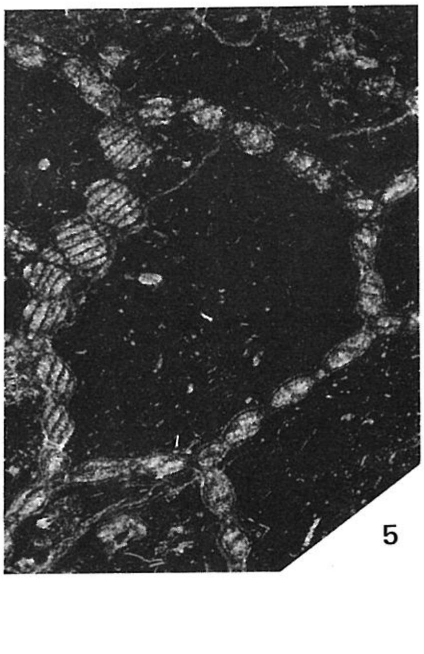

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least this is the case as far as the present species is concerned.

Halysites sp. A

(plate 7, fig.4; plate 8, figs.1,2; text-fig. 7a,b)

Material: Four small, fragmental colonies are at hand. UHR30415, 30416, 30417 and 30418. They are from the lower part of Upper Member (Hor. 3) of the Okuhinotsuchi Formation, at the Loc.B.

Description: Corallum compound, cateniform. Exact shape and size of corallum is unknown owing to the nature of preservation. Specimens are all represented by detached, long chains of corallites, which implies that the fenestrules are originally labyrinthine or meandrine. At least 10 macrocorallites are to be seen in meandering chains of fenestrules, which show strongly undulated external configuration.

In transverse section macrocorallites are oval, medium in size, 1.0–1.5 × 1.5–2.4 mm (average 1.2 × 2.0 mm). Corallite wall is usually thick, 0.2–0.4 mm (maximum 0.5 mm) in thickness. Distinct lamellar structure is observed in wall of some corallites. Mesocorallites can not be observed since chains of corallites are almost always detached, and no place of their junction has been observable under microscope. Microcorallites present, rectangular, 0.2 × 0.35 mm in size. But in many instances the presence of microcorallites is obliterated by recrystallization or masked by secondary stereoplasmic thickening. Septal spinules are present at least in some corallites, where they are partly embedded in lamellar wall. In a corallite several spinules are seen on one side of it. (Plate 8, fig. 2; Text-fig. 7b) However septal spinules are not observed in the other corallites belonging to the same fragmental chain. Still in other corallites belonging to the other fragmental chain, internal surface of corallites is quite smooth. This testifies the septal spinules are quite likely to be lost during the course of fossilization.

In longitudinal section tabulae in macrocorallites are complete and horizontal or presumably slightly concave upwards. They are rather distantly spaced, 0.2–0.75 mm apart from one another. Tabulae in microcorallites are complete, horizontal or slightly convex upwards, 0.2–0.35 mm apart. Intercorallite wall is thin, straight.

Remarks: No precisely identical species with the present form has been noticed. But the form is so imperfect that the author is declined to create a new species.

Halysites meandrina Troost, redescribed by Buehler (1955) may be the closest ally to the present form. This American species reveals corallites of very similar size and form with the present form. Moreover the character of fenestrules of it is very much the same with the Japanese form. Yet the American species does not possess septal spinules.

Another allied form is *H.praecedens* Webby & Semeniuk (1969) from Australia, which is said to have open chains, the character very unique in halysitids. Septal spinules are absent in

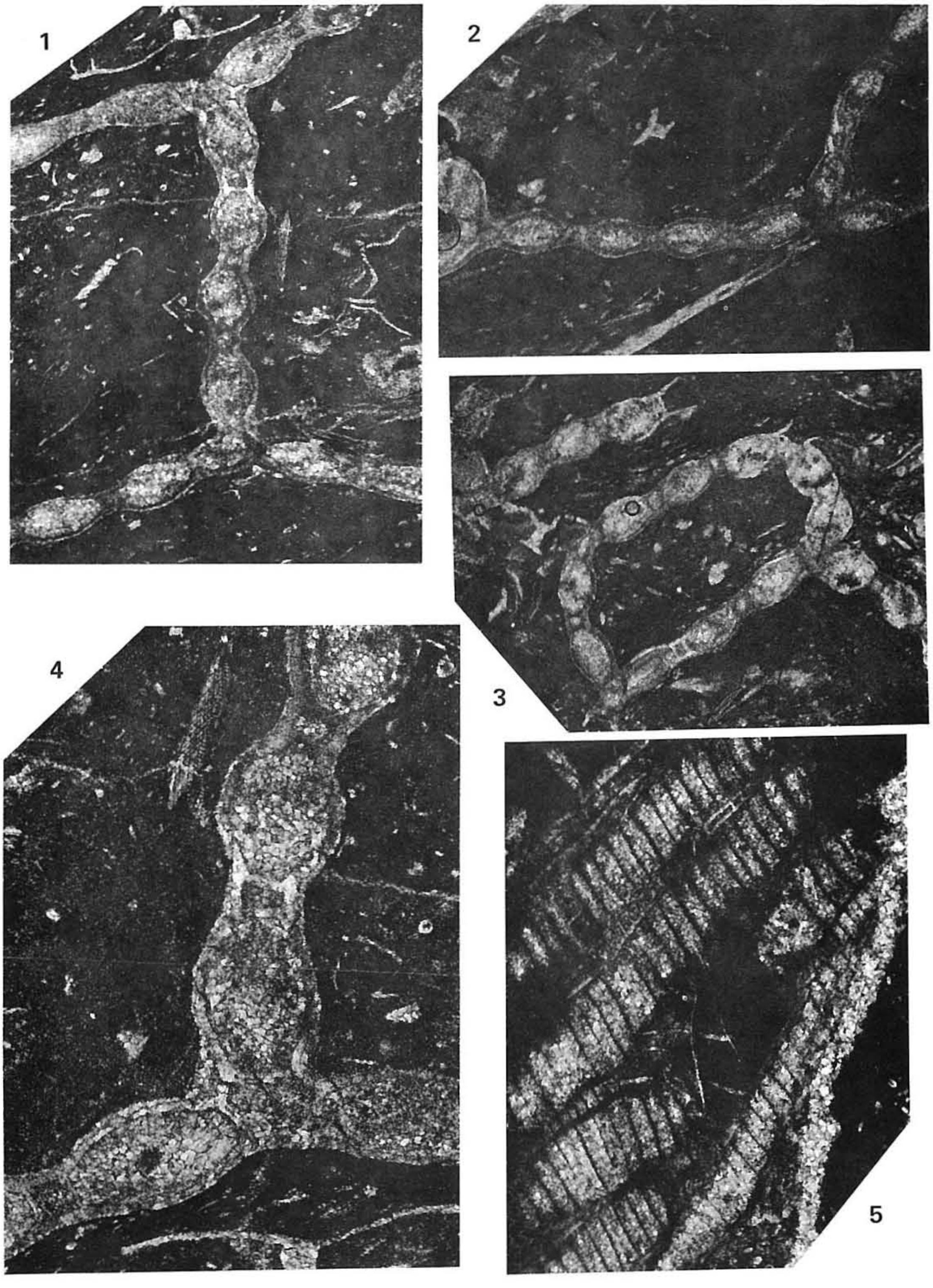
Explanations of Plate 2.

Halysites cfr. *cratus* Etheridge

Figs. 1–3 Showing form of corallites and the mode of junction of chains. Fig. 1; UHR30407A, × 6.0 Fig. 2; UHR30407E, × 5.0. Fig. 3; UHR30407D, × 5.0.

Fig. 4 Transverse section of the same specimen with Fig. 1, much enlarged. × 12.0

Fig. 5 Longitudinal section showing regularly spaced tabulae in macrocorallites. UHR30407B. × 12.0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this Australian species. As far as the form and size of macrocorallites are concerned, however, the Australian species closely resembles the Japanese form.

H.pycnoblastoides Etheridge (1904) and *Acanthohalysites pycnoblastoides yabei* Hamada (1958) are also similar to the present form, but both forms have smaller macrocorallites, thin corallite wall, irregularly polygonal fenestrules. Thus these are also easily distinguishable from the present form.

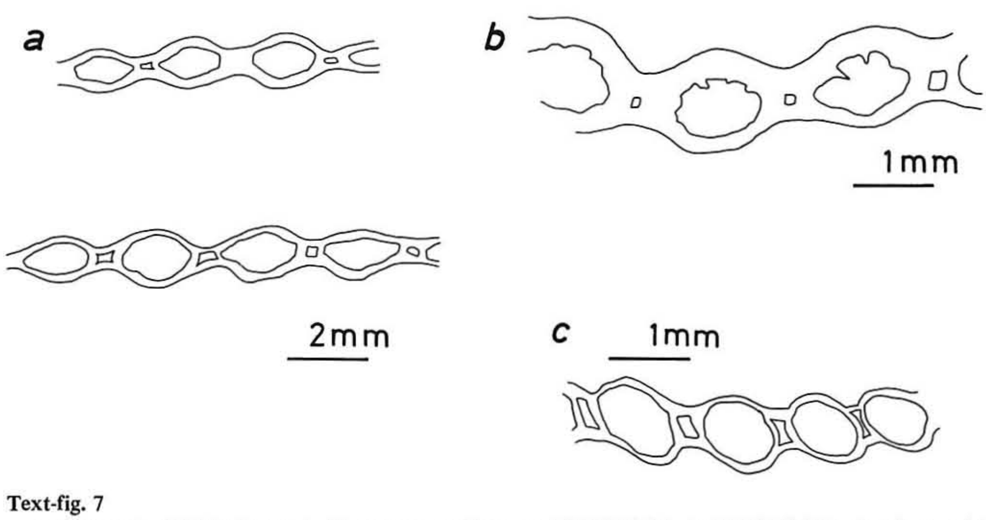
Halysites sp. B

(plate 8, figs.3-5; text-fig. 7c)

Material: Single specimen composed of several fragmental chains, UHR 30419. From the upper part of Lower Member (Hor. 2) of the Okuhinotsuchi Formation, at the Loc. C.

Description: Shape and size of corallum unknown.

Transverse section of a chain of four corallites reveals nearly circular macrocorallites, 0.7–0.9 × 0.9–1.1 mm in size. Corallite wall is thin, 0.06–0.08 mm, as thick as intercorallite wall. Microcorallites rectangular, 0.1–0.15 × 0.4 mm in width. Tabulae seen in an oblique section reveals complete and horizontal nature of them in macrocorallites. Septal



Text-fig. 7

a,b: Sketch of *Halysites* sp.A. Transverse sections. a: UHR30418A. b: UHR30418B, showing weakly developed septal spinules.

c: Sketch of *Halysites* sp.B, UHR30419, showing characteristic form of macrocorallites in transverse section.

Explanations of Plate 3.

Halysites labyrinthicus (Goldfuss)

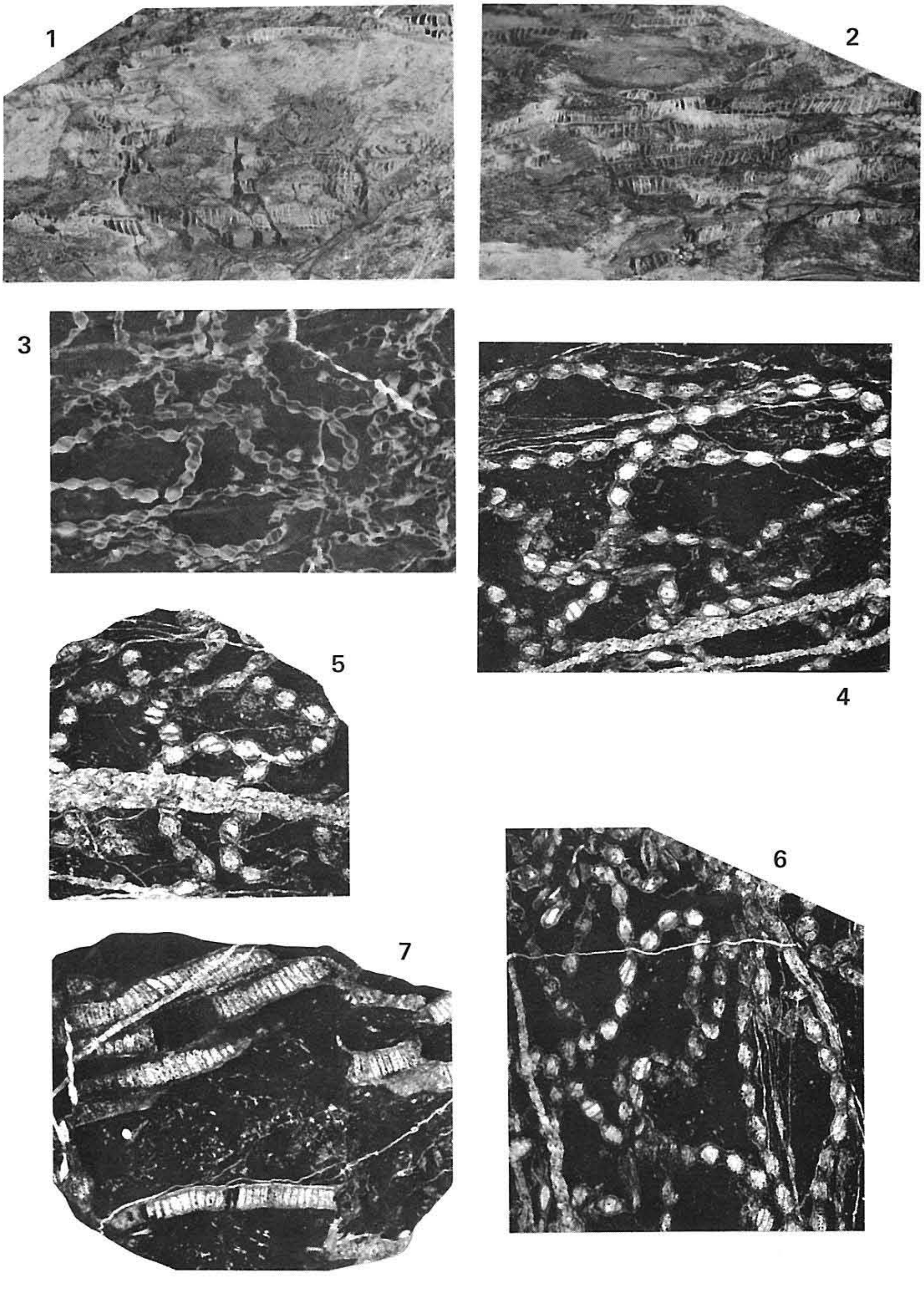
Figs. 1,2 Weathered surface of the specimen, UHR30406, showing tabulae of macro- and microcorallites, and the surface of epitheca. × 1.0

Fig. 3 Polished surface of UHR 30406. ×1.0

Figs. 4,6 Transverse sections showing form of fenestrules. UHR30406A. × 1.5

Fig. 5 Transverse section. UHR30406T. × 1.5

Fig. 7 Longitudinal section. UHR 30406C. × 1.5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spinules absent.

Remarks: No directly comparable form present. *Halysites*? sp. described from Gionyama, Miyazaki Prefecture by Hamada (1958) is morphologically very close to the present form, except that the former has a little smaller macrocorallites than the present one. Hamada (1958) compared his *Halysites*? sp. with *H.pycnoblastoides* Etheridge, which has, however, oval and large macrocorallites with thick wall and distinct septal spinules. The above stated distinction holds also true to the present form, when we compare it with the Australian species.

Geological age of the Okuhinotsuchi Formation

Table 1 is a list of fossils collected from the Okuhinotsuchi Formation. Forms other than halysitids have been provisionally identified by Dr. M. Kato. For age consideration of the Okuhinotsuchi Formation, however, only halysitids can provide useful data at present. As a whole common occurrence of *Halysites (s. str.)* in this formation is quite noteworthy. And they show similarity to those halysitids of Southwest Japan, North America and Australia.

Halysitids do occur, as stated before, in the southern Kitakami Mountains, from the Kawauchi Formation (Series) in the Hikoroichi region of Ofunato city, not very far (about 15 km) from the present locality. Halysitids described from the Kawauchi Formation are as follows (Sugiyama, 1940; Hamada, 1958):

Schedohalysites kitakamiensis (Sugiyama)
Falsicatenipora japonica (Sugiyama)
"Halysites "? sp.

Schedohalysitinae are especially common in the Kawauchi Formation.

So apparently halysitids from two regions of the southern Kitakami Mountains are different in composition, and in fact no common species has been detected between the two. This is, in the author's opinion, due to the difference of their ages.

Amongst two halysitids known from the upper part of Lower Member of the Okuhinotsuchi Formation, *Halysites* cfr. *cratus* resembles *H.cratus, priscus* and *guizhouensis. Halysites cratus* Etheridge (1904) was originally described from New South Wales, Australia, the horizon of which is Llandoverian (Stevens & Packham, 1953; Packham & Stevens, 1954). The same species was recorded from Southwest Japan by Hamada (1958) from his G3 horizon, which is, according to a conodont study of Kuwano (1976), Middle Wenlockian to

Explanations of Plate 4.

Halysites labyrinthicus (Goldfuss)

Fig. 1 Enlarged figure of the species illustrated as Fig. 4 on Plate 3, showing a long, meandering fenestrule. × 3.0

Fig. 2 Enlarged figure of Plate 3, fig. 6, showing the cut edges of longitudinal ridges on the internal surface of corallite wall in some macrocorallites (upper-left). × 3.0

Fig. 3 Enlarged transverse section showing form of macro- and mesocorallites. Intercorallite wall is partly destroyed. UHR30406E. × 10.0

Fig. 4 Enlarged figure of Plate 3, fig. 7, showing tabulae in macro- and microcorallites. × 6.0

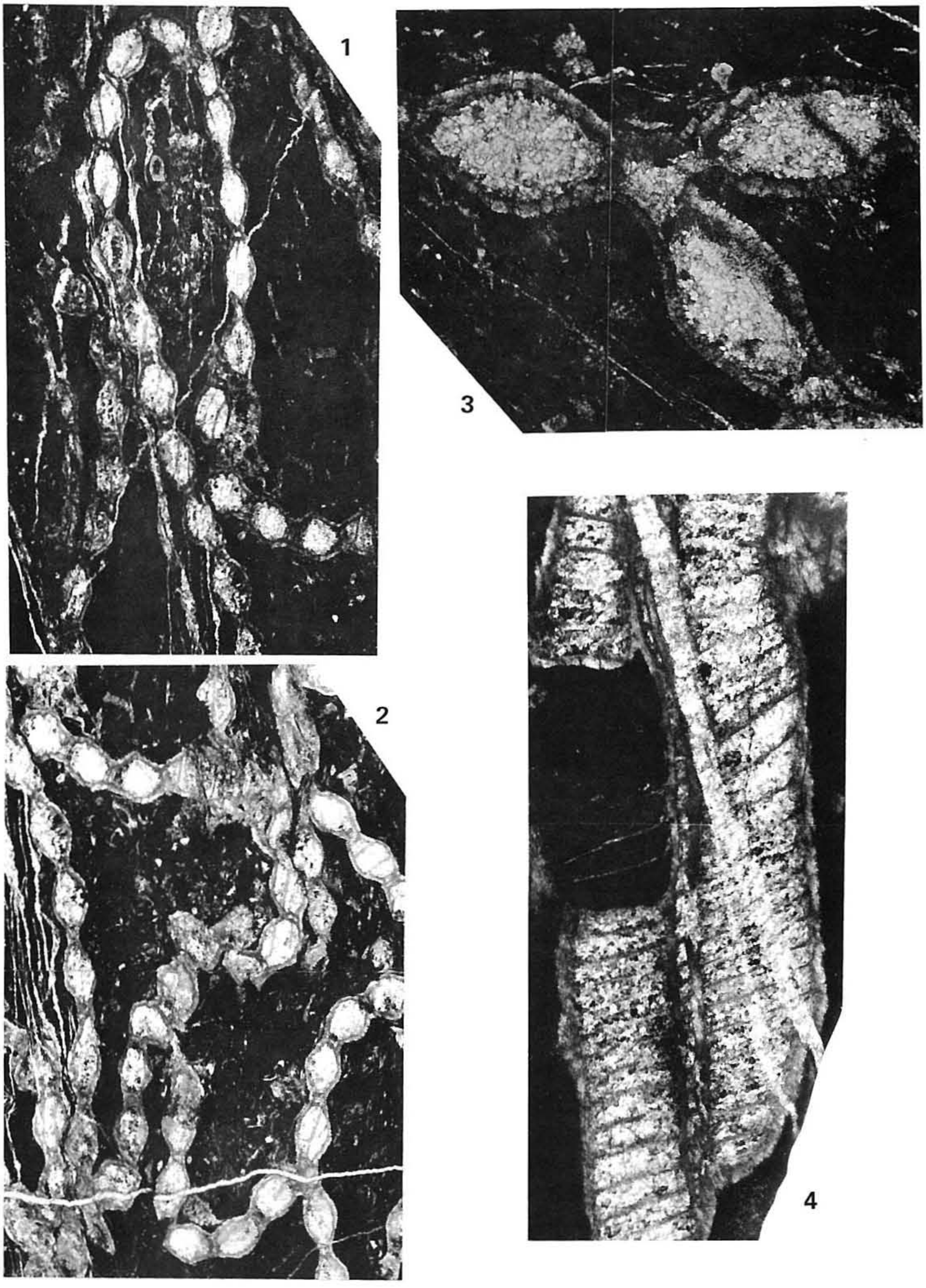
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Table 1 List of fossils obtained from the Okuhinotsuchi Formation.

Middle part of Upper Member (Hor.4)
Falsicatenipora shikokuensis Hamada
Lower part of Upper Meber (Hor.3)
Falsicatenipora sp.
Halysites labyrinthicus (Goldfuss)
H. arisuensis Kawamura sp. nov.
H. sp. A
Favosites sp.
Multisolenia sp.
Heliolites sp.
Alveolites? sp.
Stromatoporoidea gen. et sp. indet.
Pseudamplexus sp.
Tryplasma sp.
Rhizophyllum sp.
Rugosa coral gen. et sp. indet.
Upper part of Lower Member (Hor.2)
Halysites cfr. *cratus* Etheridge
H. sp. B
Favosites sp.
Alveolites sp.
Stromatoporoidea gen et sp. indet.
Amsdenoides sp.
Pseudamplexus sp.
Lower part of Lower Member (Hor.1)
Favosites sp.
Trilobita gen. et sp. indet.

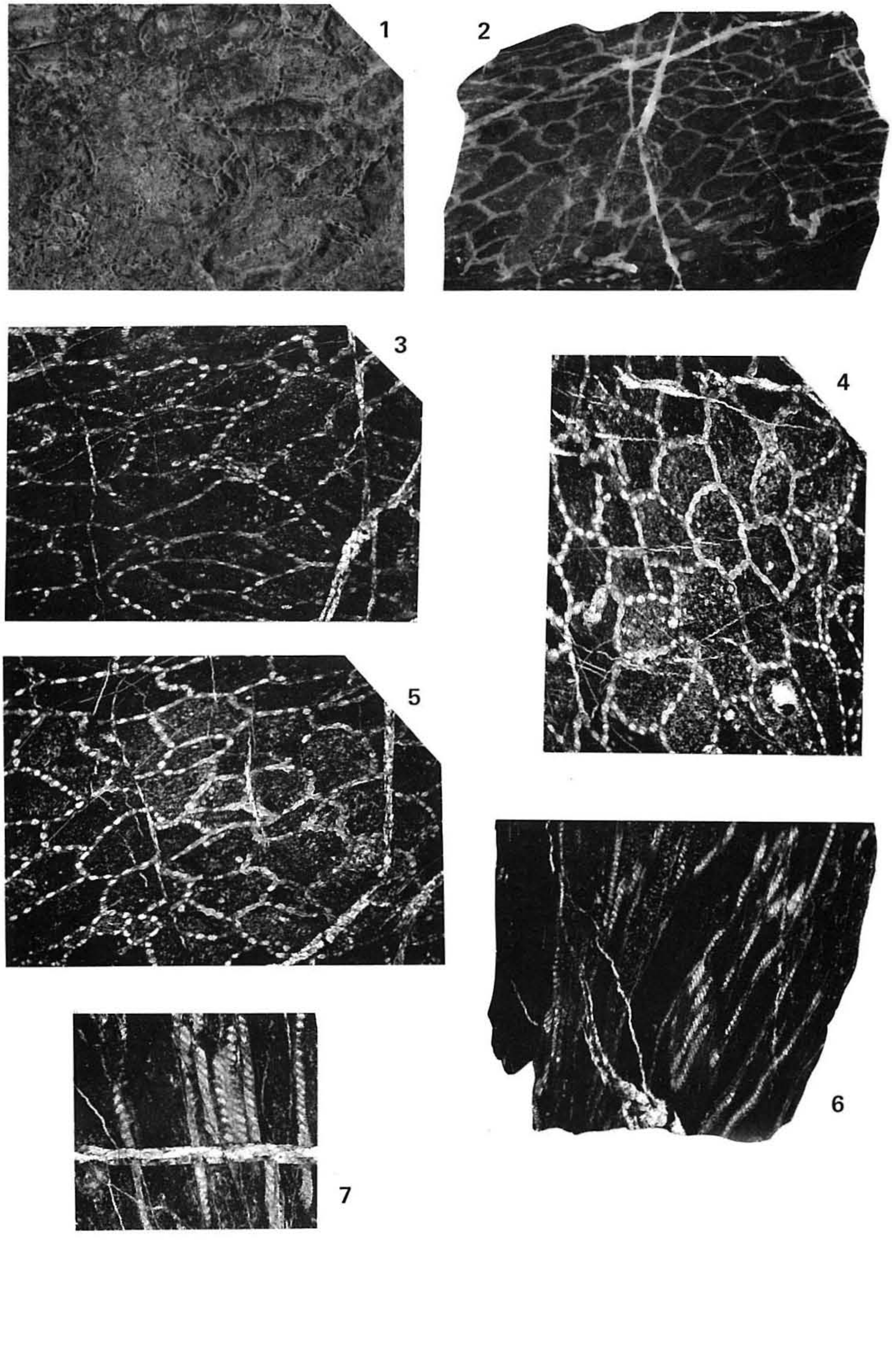
Middle Ludlovian. *Halysites priscus* Klaamann (1966) was described from Lower Llandovery of Estonia. *Halysites* guizhouensis Yang (1978) was described from the Lower Silurian of Kueichow, China.

Another species called as *Halysites* sp. B in the above description somewhat resembles *Halysites*? sp. from G2 of Southwest Japan (Hamada, 1958), and *Halysites pycnoblastoides* Etheridge (1904) from New South Wales. Age of G2 is, according to Kuwano (1976), Late Llandoverian to Early Wenlockian. While the latter Australian species is now known to range from Upper Ordovician to Middle Silurian (Packham & Stevens, 1954; Campbell, 1976).

Although data are not quite sufficient, the age of at least the upper part of Lower Member of the Okuhinotsuchi Formation may be Late Llandoverian.

Amongst halysitids described above from the lower part of Upper Member of the Okuhinotsuchi Formation *Falsicatenipora* sp. is similar to *F.shikokuensis, F.japonica* and *F.chillagoensis. Falsicatenipora shikokuensis* Hamada (1958) is from G2 of Southwest Japan. Also *F.japonica* (Sugiyama) (Sugiyama, 1940; Hamada, 1958) has been known from the upper part of "*Halysites*" limestone of the Kawauchi Formation of Northeast Japan, and from G3 of Southwest Japan. "*Halysites*" limestone of the Kawauchi Formation has been generally correlated to the G3 of Southwest Japan (Hamada, 1958). *Falsicatenipora chillagoensis* (Etheridge, 1904) was described from Queensland, and is now known to range in New South Wales from Upper Ordovician to Lower Llandovery (Strusz, 1960). On the other hand Keyser and Wolff (1964) who studied Chillagoe area of Queensland considered

Explanations of Plate 5.
Halysites arisuensis Kawamura sp.nov.
Fig. 1 Weathered surface of the holotype specimen, UHR30408. x 1.0
Fig. 2 Polished surface of the holotype, UHR30408. x 1.0
Figs. 3–5 Transverse sections showing irregularly or elongated polygonal form of fenestrules. x 1.5
Fig. 3; UHR 30408A. Fig. 4; UHR 30408C. Fig. 5; UHR 30408D.
Fig. 6,7 Longitudinal sections. x 1.5 Fig. 6; UHR 30408B. Fig. 7; UHR 30408G.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the age of Chillagoe Formation, from which *F.chillagoensis* may be inferred to have come from first, to be Upper Silurian. The species seems to be thus quite long ranging.

Another important form from the lower part of Upper Member of the Okuhinotsuchi Formation is *Halysites labyrinthicus*. The lectotype of this species was obtained from Michigan, U.S.A., and the other specimens later described by Buehler (1955) were said to have come from the Fossil Hill Formation (Lower-Middle Silurian) of Manitoulin Island. "*Halysites labyrinthicus*" of authors are, as stated in the above description, not identical with this North American species of *Halysites*.

A new species of *Halysites* introduced in the present paper, *H.arisuensis* is known also from the lower part of Upper Member. The species is morphologically much related to *H.gamboolicus, süssmilchi* and *bellulus*. *Halysites gamboolicus* Etheridge (1904) was described from New South Wales. The author failed to trace the exact horizon of this species. However he suspects that it is within the Gamboola Formation, a part of which produced Lower Silurian trilobites (Joplin et al., 1952). *Halysites süssmilchi* Etheridge (1904) was also originally described from New South Wales. Its horizon there is Barton limestone (bed d. of Süssmilch), which is Ordovician in age (Packham & Stevens, 1954). According to these authors the species are ranging further upward until Quarry Creek limestone (Llandoverian). The same species has been known to occur in Southwest Japan (Hamada, 1958) from G2. Also from Southwest Japan, *Halysites bellulus* Hamada (1958) was described from G3.

From the lower part of Upper Member *Halysites* sp. A is also described above. It closely resembles *H.meandrina* Troost from Tennessee, North America, the exact horizon of which is Lovelville Formation of Upper Silurian. It resembles *Halysites praecedens* Webby & Semeniuk (1969) from the upper Ordovician of New South Wales. Another ally, *Halysites pycnoblastoides* Etheridge (1904) was obtained, as *H.gamboolicus* above mentioned, from Ordovician, although it may range still upward. *Halysites pycnoblastoides yabei* (Hamada, 1958) has been recorded from the Lower Silurian of Hupeh (Jia and Wu, 1977) and Kueichow (Yang et al., 1978).

With regard to the age of the lower part of Upper Member one would think that the assemblage of halysitids may be related to Lower to Middle Silurian halysitids. However it is important that our forms have some similarity even to some genuinely Ordovician forms. In Japan the assemblage is more related to G2 halysitids than to G3 halysitids of Southwest Japan, because it still lacks characteristic occurrence of *Schedohalysites* in G3.

Another horizon of halysitids treated in the present paper is the middle part of Upper

Explanations of Plate 6.

Halysites arisuensis Kawamura sp.nov.

Fig. 1 Enlarged view of Plate 5, fig. 3, showing elongated polygonal fenestrules. × 3.0

Fig. 2 Longitudinal and partly tangential section, showing tabulae in macro- and microcorallites. UHR30408M. × 3.0

Fig. 3 Enlarged view of Plate 5, fig. 5, showing form of fenestrules and corallites. × 5.0

Figs. 4,5 Enlarged view of Plate 5, fig. 4. × 5.0

Fig. 6 Enlarged view of Plate 5, fig. 5, showing small, tightly polygonal fenestrules (sketch is shown in text-fig. 6h). × 5.0

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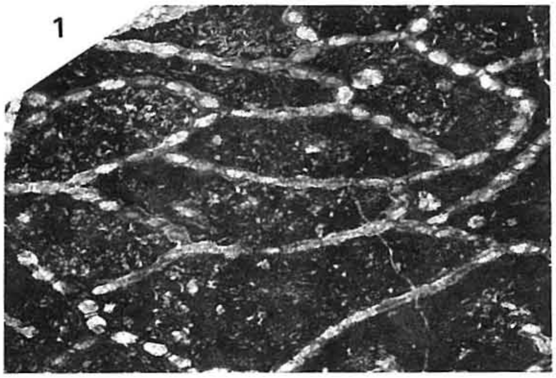

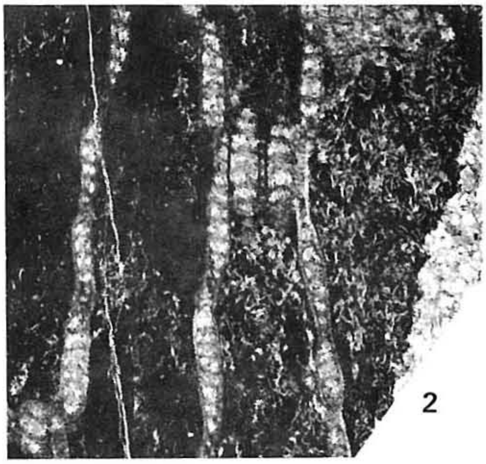

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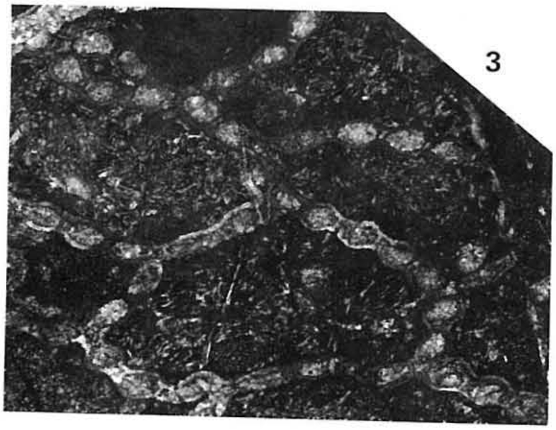

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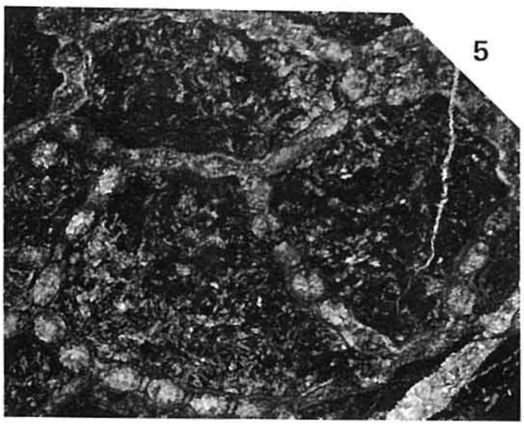

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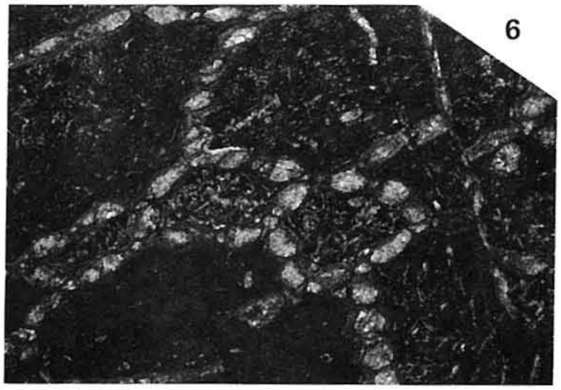
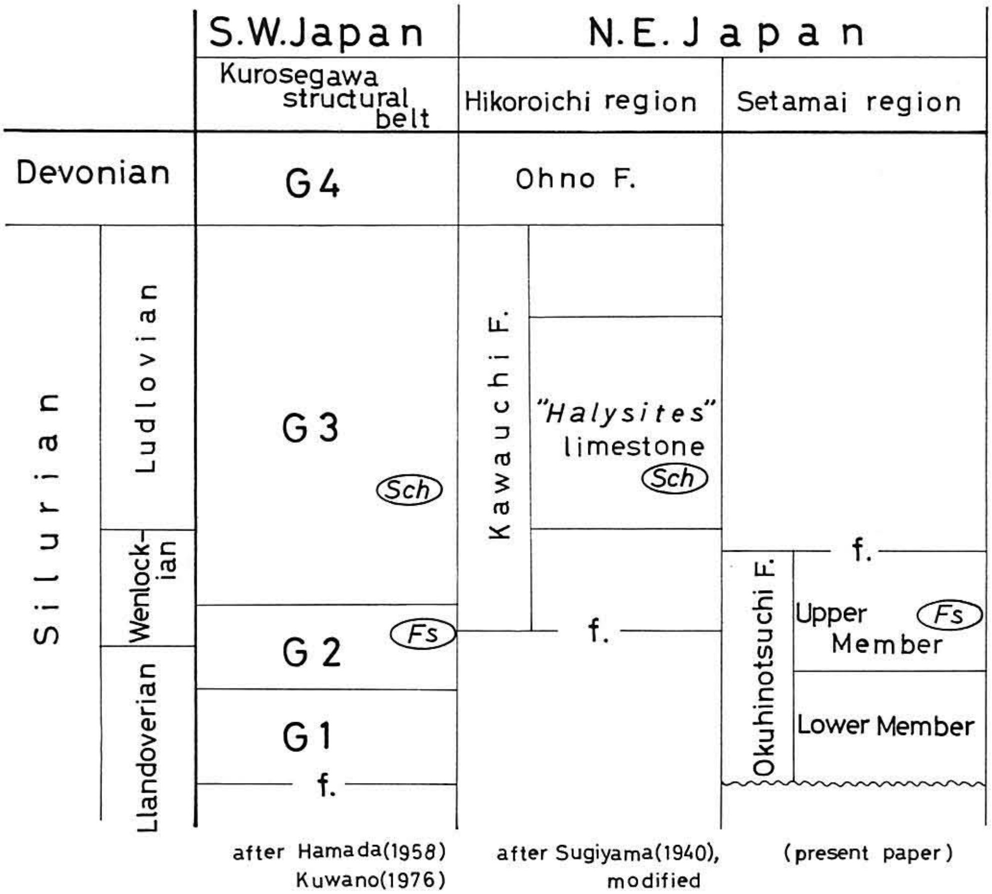


Table 2 Correlation of the Japanese Silurian.
Sch: Horizon of *Schedohalysites kitakamiensis* (Sugiyama) Fs: Horizon of *Falsicatenipora shikokuensis* Hamada. f.: Fault contact with the other rock units. Wavy line indicates unconformable relationship.



Explanations of Plate 7.

Halysites arisuensis Kawamura sp.nov.

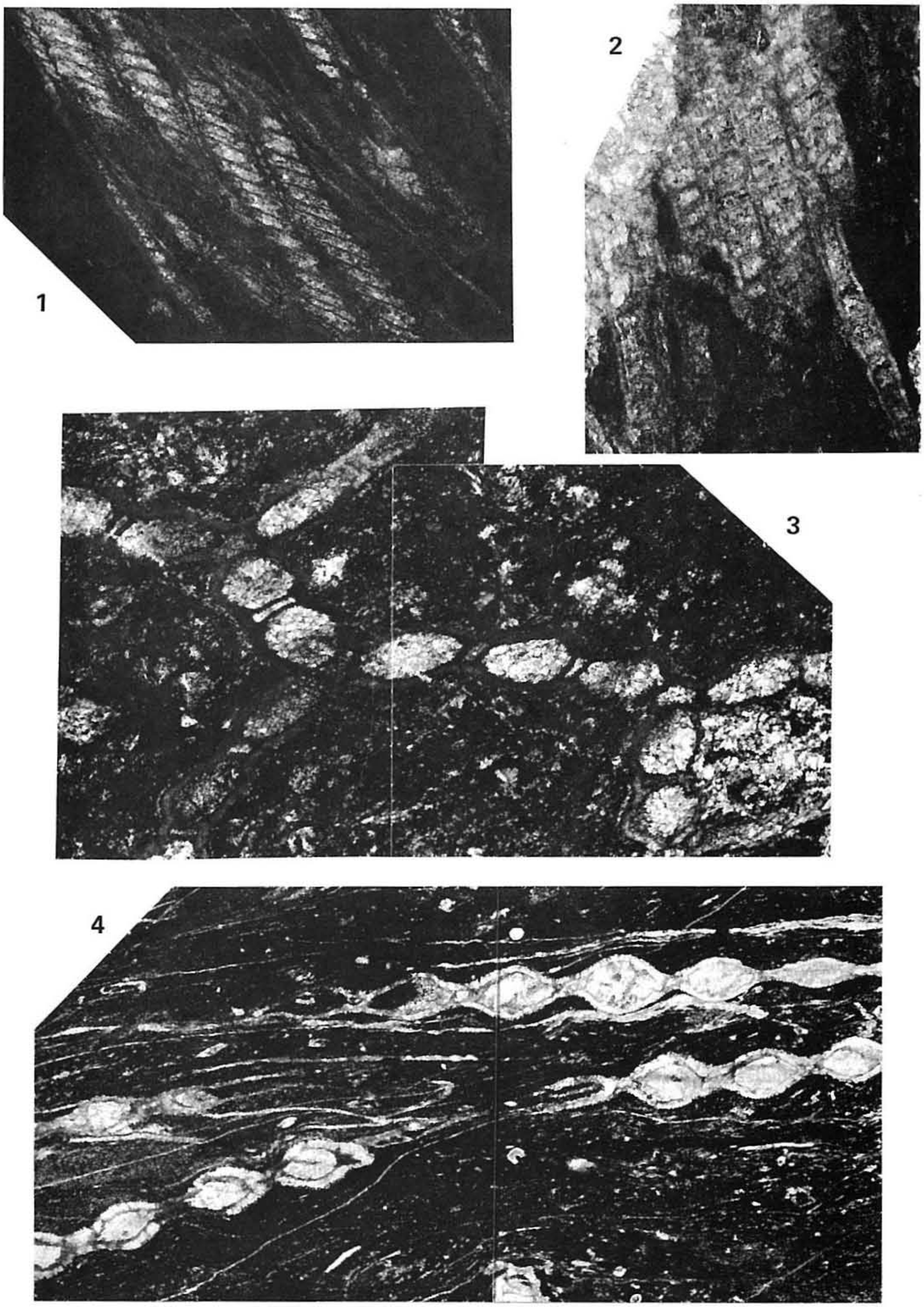
Fig. 1 Enlarged view of Plate 5, fig. 6, showing tabulae in deformed macro-and microcorallites. x 6.0

Fig. 2 Longitudinal section showing tabulae in both macro- and microcorallites. UHR30408M. x5.0

Fig. 3 Enlarged view of Plate 5, fig. 3, showing form of macro-, meso- and microcorallites, and thin intercorallite wall. x 12.0

Halysites sp.A

Fig. 4 Transverse section showing deformed fenestrules and form of macro- and microcorallites. UHR30418A. x 6.0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Member, from which only one form,*Falsicatenipora shikokuensis* was obtained. The species was originally described by Hamada (1958) from his G2 of Southwest Japan. Correlation between G2 and the middle part of Upper Member is thus warrented.

As a whole major part of the Upper Member of the Okuhinotsuchi Formation may be Upper Llandoverian to Wenlockian. Only the upper part of the Member, which lacks halysitids, may be eventually correlated to a part of the Kawauchi Formation below the *"Halysites"* limestone, and the lower part of G3 in southwest Japan. (Table 2)

Acknowledgements

The author acknowledges Professor Emeritus M. Minato of Hokkaido University for his supervision to the present study. He also acknowledges Dr. M. Kato for his guidance and valuable suggestions throughout the present study both in laboratory and field work. Acknowledgement is also due to Drs. Y. Fujiwara, N. Minoura and I. Niikawa for their collaboration in the collection of fossils.

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Explanations of Plate 8.

Halysites sp.A

Fig. 1 Longitudinal, partly tangential section showing tabulae in macro- and microcorallites. Tabulae in macrocorallites slightly concave upwards, while those in microcorallites slightly convex. UHR30418C. × 6.0

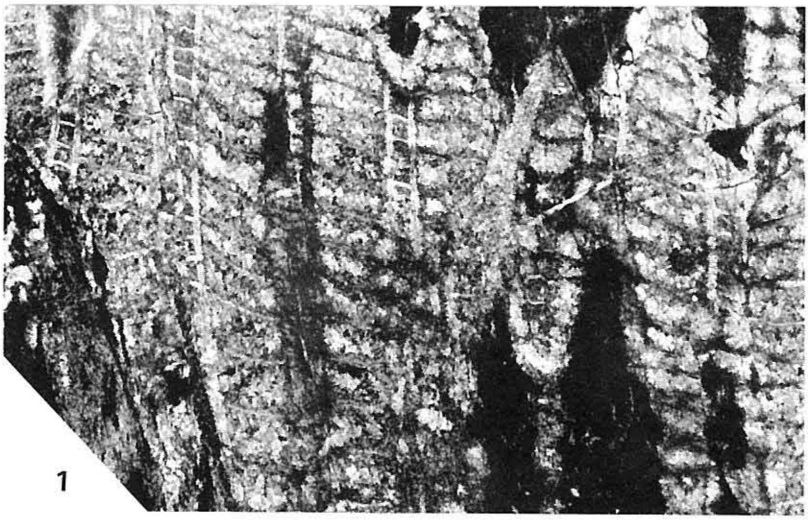
Fig. 2 Transverse section showing weakly developed septal spinules and thick corallite wall with lamellar structure (right-hand). Sketch is shown in Text-fig. 7b. UHR 30418B. × 6.0

Halysites sp.B

Fig. 3 Transverse section showing nearly circular macrocorallites. Sketch is shown in Text-fig. 7c.

Fig. 4 Longitudinal section of a fragmental macrocorallite.

Fig. 5 Oblique section showing a junction of chains.
All UHR 30419. × 12.0



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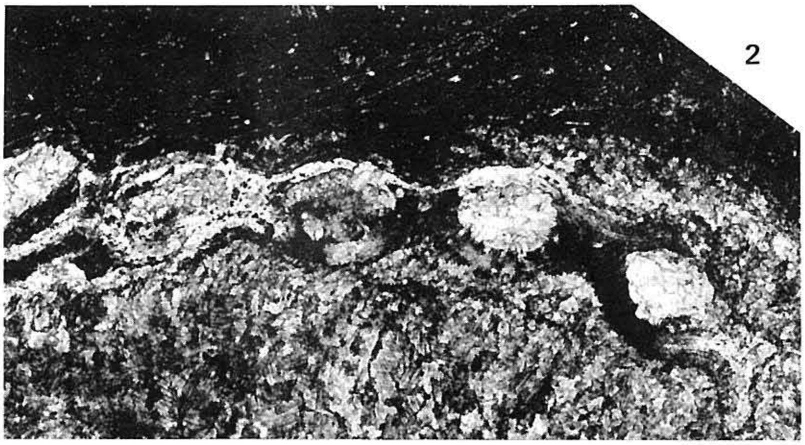

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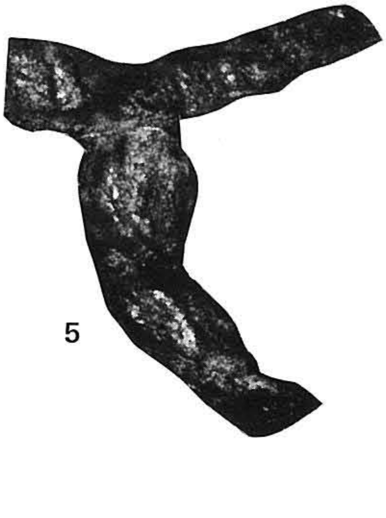
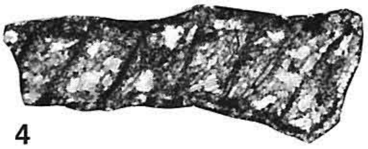


5



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