Upper Carboniferous Corals from the Yayamadake Limestone, Kyushu

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Upper Carboniferous Corals from the Yayamadake Limestone, Kyushu*

By

Kametoshi KANMERA

Abstract

One new species each of *Clisiophyllum*, *Axolithophyllum*, and *Pseudopavona*, an unnamed species of *Koninckophyllum?*, and one previously described species each of *Amygdalophylloides* and *Chaetetes* are described from the middle Upper Carboniferous of the Yayamadake Limestone, Kyushu. *Pseudopavona*, which has been considered to be a Scleractinia, is herein concluded to be a Rugosa and whose close relationship to *Taisyakuphyllum* is discussed.

Contents

Introduction

This paper deals with descriptions of several Upper Carboniferous corals from the Yayamadake Limestone, Kumamoto Prefecture, Kyushu, in which the middle Upper Carboniferous to the Lower Permian fusulinid zones of *Beedeina**, *Triticites*, and *Pseudoschwagerina* are discriminated in ascending order (KANMERA, 1952; 1954). The corals were obtained from the *Beedeina* zone (Kurikian stage) of the limestone and include species belonging to the genera *Clisiophyllum*, *Koninckophyllum?*, *Amygdalophylloides*, *Axolithophyllum*, *Pseudopavona*, and *Chaetetes*.

Many species of corals were described by authors from the *Millerella*, the *Profusulinella* and the *Fusulinella* zone of the lower and the middle Upper Carboniferous, which are widely distributed in the Japanese Islands, and all the species known up to 1954 were summarized by MINATO (1955) in his comprehen-

* Received September 28, 1960.

* Formerly known under the name of the *Fusulina* zone (ref. ISHII, K. 1959, On the phylogeny, morphology and distribution of *Fusulina*, *Beedeina* and allied fusulinid genera. Jour. Inst. Polytechnics, Osaka City Univ., [G], 4, 29-63, 6 pls.)

sive paper "Japanese Carboniferous and Permian corals". Whereas the *Beedeina* zone has been known in a few scattered areas, from only one of them, the Shimozaisho Limestone of Itoshiro-mura, Fukui Prefecture, central Japan, three unnamed species of *Caninia* were described (KONISHI, 1954).

The Yayamadake corals are dominated by columellate forms with a stout axial structure and have similarities to certain Upper Carboniferous species from the Donetz and the Moscow Basin (DOBROLYUBOVA, 1937; DOBROLYUBOVA and KABAKOVITCH, 1948; FOMICHEV, 1953) and the Carnic Alps (HERITSCH, 1936). They constitute a different faunal assemblage from that of the subjacent *Fusulinella* zone. An interesting compound coral, *Pseudopavona*, that has been considered as a Scleractinia (YABE, SUGIYAMA, and EGUCHI, 1943; MINATO, 1955; YOKOYAMA, 1957; KAWANO, 1959), and to which one of the Yayamadake corals is refered, is herein concluded to be a Rugosa. In this study minute skeletal structures of corals have been taken into consideration for identification and classification of them.

Stratigraphic remarks

General remarks.—The Yayamadake Limestone is a thick series of limestone occuring in basic pyroclastic rocks and lava flows of the Tobiishi group which is distributed along the upper course of the Hikawa Valley, Kumamoto Prefecture. It is best exposed at the crest of and the sides of Mt. Yayamadake of Izumi-mura*, where it is about 500 meters thick, and extends for about 9 kilometers from east to west.

The limestone is white to white-grey, massive, without visible bedding plane throughout the thickness, and is composed mostly of bioclastic calcarenites with some oolites. It is divided into three fusulinid zones on the basis of abundant fusulinid contents. The *Beedeina* zone which occupies the lowest part of the Yayamadake Limestone is about 100 meters thick and comprises three subzones, the lower *Staffella pseudophaeroidea* DOUTKEVITCH-*Fusulinella* sp., the middle *Beedeina higoensis* (KANMERA)-*Wedekindellina prolifica* KANMERA, and the upper *Fusulina ohtanii* KANMERA-*Fusulinella gracilis* KANMERA.

The material described in this paper were obtained from the middle subzone and the lowest part of the upper subzone. They include the following species:

Clisiophyllum subramosum n. sp.
Koninckophyllum? sp.
Amygdalophylloides gracilis (HAYASAKA)
Axolithophyllum frothyvesiculare n. sp.
Pseudopavona crassisepta n. sp.
Chaetetes tangshanensis CHU

Of these, *Amygdalophylloides gracilis* and *Chaetetes tangshanensis* occur in the rocks ranging from the *Beedeina higoensis* subzone to the lowest part of the

* 泉村 [Previously called Kakisako-mura (柿迫村) and Shimodaké-mura (下岳村)]

Fusulina ohtanii subzone. So far as is known, the remaining species were found in a limited thickness of the lowest part of the *Fusulina ohtanii* subzone, which lies at about 20 meters below the boundary between the *Beedeina* and the *Triticites* zone. The stratigraphic sequence of the Carbonifrous of the Yayamadake Limestone and the stratigraphic position of the fossils are shown in the accompanying text-figure 1.

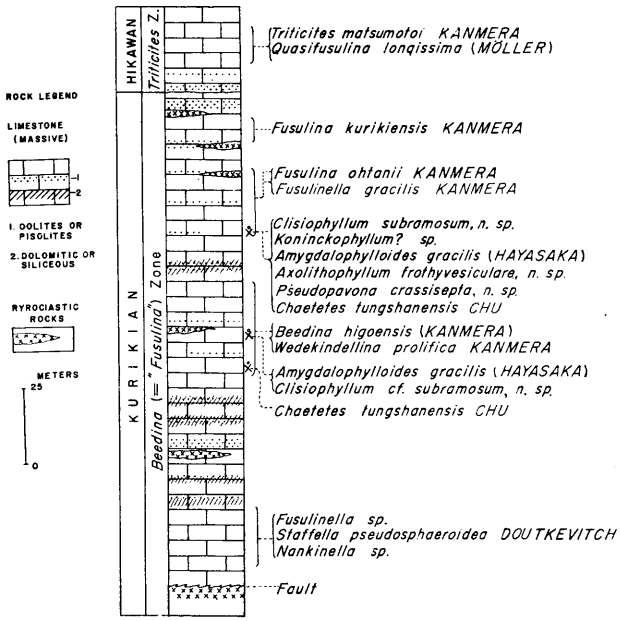

Fig. 1. Columnar section of the *Beedeina* zone of the Yayamadake Limestone showing the stratigraphic position of the obtained corals. (Parts of the *Triticites* and *Pseudoschwagerina* zones are not shown in this section.)

Localities and mode of fossil occurrence.—The corals herein described came from the following localities:

(a) *Ya. 116.*—This locality is at an altitude of 740 meters on a foot path which runs from Hiate* to the east crest of Mt. Yayamadake, along which one of the type sections of the *Beedeina* and the *Triticites* zone can be seen. At this locality a coral bed of about 2.5 meters thick is exposed for about 15 meters distance. It lies in the lowest part of the *Fusulina ohtanii* subzone, being associated with it and *Fusulinella gracilis* in the matrix. It is composed mostly of numerous interlocked colonies of *Chaetetes* and abundant zoechia of amalgamate bryozoas and calcareous algae, and is accompanied with a fairly large number of coralla of *Clisiophyllum* and with some *Pseudopavona*. A much greater abundance of algae and tabulate corals compared with a small amount of matrix, which fills interstices between the colonies, and a preservation of coral colonies keeping their calices upward normal to the inferred stratification plane suggest that the coral

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bed may have been a small patch reef.

(b) *Ya. 4.*—This locality is a cliff between the 620- and 660-meter-contours about 100 meters northward of a foot path running from Nozoe* to the east crest of Mt. Yayamadake. Here *Chactetes, Clisiophyllum, Koninckophyllum?,* and *Axolithophyllum* were obtained. They sparsely occur as isolated specimens or small colonies in a dark grey to black tufa bed, being associated with *Fusulina ohtanii* and *Fusulinella gracilis,* and abundant bryozoan zoechia and calcareous algae. Rocks of the tufa bed have similar lithological characters to those of front reef complexes of the Derbyshire Dome (e.g. PARKINSON, 1953) and in the Cracoe area, England (e.g. BOND, 1949).

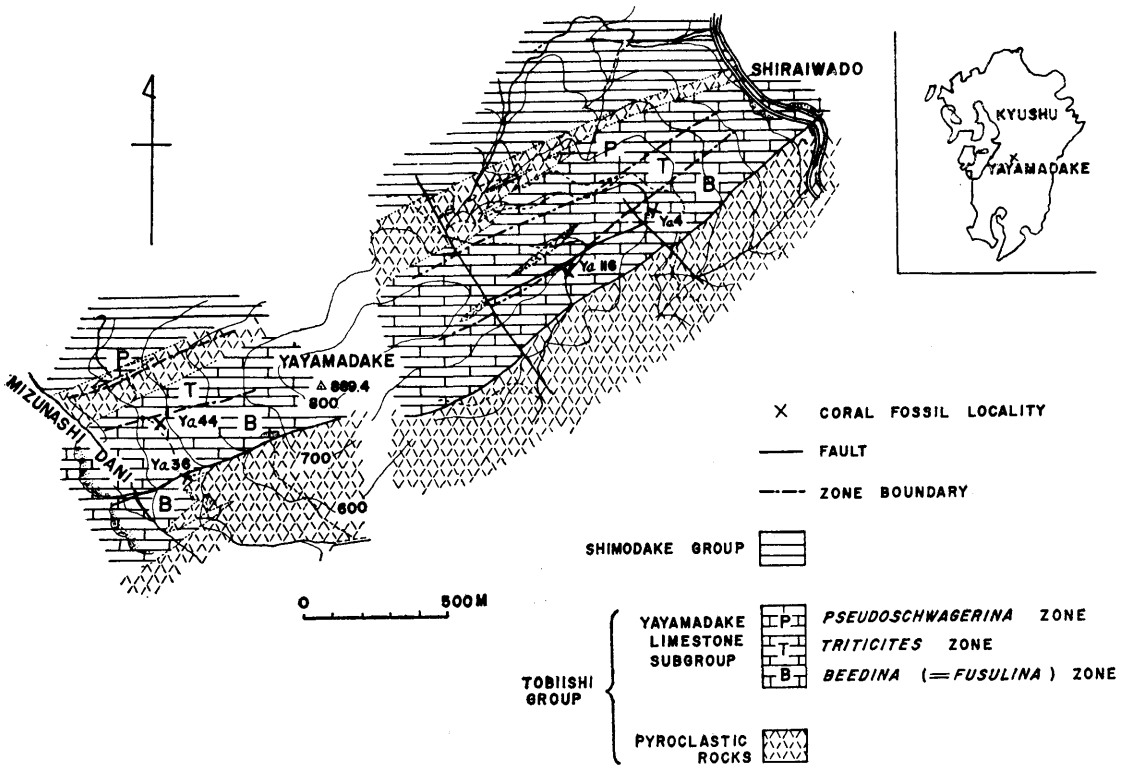

Fig. 2. Geological sketch map of the Yayamadake area showing coral localities.

(c) *Ya. 36 and 44.*—These localities are in a valley called Mizunashidani** which crosses meridionally the west flank of Mt. Yayamadake. Their stratigraphic horizon lies between the *Beedeina higoensis* and the *Fusulina ohtanii* subzone. Rocks of these localities are crinoidal calcarenites with abundant algal remains, and the contained corals are mostly fragmental or water-worn. Several specimens of *Amygdalophylloides* were obtained at Ya. 36, associated with *Beedeina higoensis* and *Wedekindellina prolifica,* and some specimens of *Clisiophyllum* and *Chaetetes*

* 野添 ** 水無谷

at Ya. 44.

Besides the materials from the localities noted above, several specimens of *Clisiophyllum* and *Chaetetes* were obtained in limestone-boulders derived from other localities. Those specimens are definitely associated with *Fusulina ohtanii* or *Fusulinella gracilis*, so that it is considered that the specimens are of the same horizon as Ya. 116.

No specimens of the corals under consideration have been found in the overlying *Triticites* and *Pseudoschwagerina* zones.

All specimens collected are embedded in hard, indurated limestones and are inseparable from the matrix, so the described characters are mostly observed by means of microscopical examination of thin sections and polished specimens.

Systematic descriptions

Order Rugosa MILNE-EDWARDS and HAIME, 1850

Family Aulophyllidae DYBOWSKI, 1873

Genus *Clisiophyllum* DANA, 1846

Type-species.—*Clisiophyllum keyserlingi* M'COY, 1849

Clisiophyllum subramosum n. sp.

Pl. 14, figs. 1-12; Pl. 15, fig. 11; Text-fig. 3

Material.—Holotype Reg. no. GK-D50051 from loc. Ya. 116; paratypes 50052-50070, 50081 from loc. Ya. 116; 50071-50073, 50083 from loc. Ya. 4. Many other sections and polished specimens were also examined, which are also referred to the same species.

Description.—Corallum dendroid, occasionally simple, characterized by moderately large, long cylindrical and gently curved corallites. Dendroid forms consist of a long parent corallite and two or three short branched corallites which arise simultaneously by lateral increase and are not parricidal. New offsets have some confluent septa with those of a parent corallite, are not defined by a dividing wall (Pl. 14, fig. 2), and are immediately followed by a cerioid form longer than 2 cm, and in succeeding stages the corallum becomes a dendroid.

Theca thin, with obtuse, low wrinkles, without well-defined septal grooves.

Mature corallites are often more than 130 mm in length, 23 to 28 mm in diameter, have 32 to 36 septa of two orders, major and minor. Major septa, except the cardinal septum, are of equal length, nearly or completely reach the outermost tabellae, or are connected with some of the septal lamellae, of the axial area. They are often curved aside at their inner edges towards the cardinal side except some septa adjacent to the cardinal septum. Cardinal septum usually a little shorter than other major septa in the mature stage, and there is a shallow cardinal fossula there, but retreat of the cardinal septum does not extend to the dissepimentarium.

Septa composed, for the most part, of simple trabeculae whose fibres are

radiating from a median lamina of calcification centers outwards normal to the side walls of septa, but in the most peripheral area, they are often made up of composite trabeculae whose bundles are minute and radiating upwards and outwards from the central part of the septa at a moderate angle of inclination; there is no median lamina of calcification centers there (see Text-fig. 3).

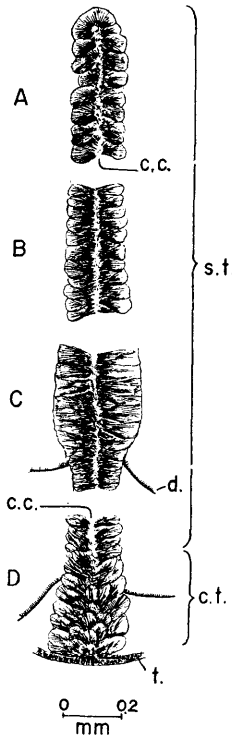

Fig. 3. Diagram of the transverse section of a septum of *Clisiophyllum subramosum* n. sp., showing the septal structure. A, distal part; B, septum in the central tabularium; C, septum in the outer margin of the tabularium; D, septum in the peripheral area.
c. c., calcification centers of trabeculae; d, dissepiments; t, theca; s. t., simple trabeculae; c. t., composite trabeculae.

Septa are thickest at the outer margin of the tabularium, gradually attenuate towards their inner ends and sharply thin in the dissepimentarium, although they are thickened in the outermost area. They are usually straight in the tabularium, but rather flexuous in the dissepimentarium. Minor septa are two-thirds, or a little more, the length of the major, and extend into the tabularium at a fairly long distance. Dissepimentarium occupying less than half the radius of corallite, is composed of dissepiments of more than 9 series in the mature stage; dissepiments of the outer series are semi-globose, gently inclined, and of the inner series somewhat elongate, inclined steeply. Dissepiments are arranged concentrically in young stages, but in the mature stage often disposed facing their convex sides obliquely, or nearly in parallel, to the septa, that may inosculate to each other like a herring-bone pattern.

Tabularium is usually wider than the dissepimentarium in the mature stage, composed of incomplete vesicular tabulae, which slope up at the inner periphery to merge with tabellae of the axial area and are flat or ascending up onto dissepiments at the outer periphery.

Axial area, occupying less than one-third the diameter of corallites, is

ellipsoidal in cross-section with a large axis in the cardinal-counter plane, and one end of the axis is usually drawn out into a short point, directed to the cardinal septum. It is composed of numerous, small, vesicular axial tabellae, often many, occasionally a few, axial lamellae, and a median plate which greatly varies in development with ages and in different corallites. In the young and early mature stages the median plate is usually distinct and may sometimes be connected with the cardinal septum, but in the mature stage it is very short or disappeared. Axial tabellae are disposed concentrically on both sides of the median plate, even in case of being no median plate, with a roughly bilateral symmetry to the cardinal-counter plane. They always face their convex sides outwards in cross-section. Inward facing of convex sides of tabellae as in *Clisiophyllum keyserlingi* M'COY and *C. multiseptata* GARWOOD and GOODYEAR is never seen in this form. In longitudinal sections the axial tabellae are semiglobublar or elongated, slope up to the median plate generally at 45 degrees, sometimes steeper or gentler, and merge with tabulae without distinct inner wall. Axial lamellae also vary greatly; many of them are long, attached to the distal ends of the major septa on one end, abut onto the median plate on the other, and some may be short or represented by discontinuous crests. They are often curved, especially at their junctions with the axial tabellae. They are less developed in immature stages, where axial tabellae dominate the axial structure, but increase in number as a corallite grows. However, they may sometimes be a few even in the mature stage (Pl. 14, fig. 4), and the axial area is mostly composed of rather loosely arranged, semiglobular axial tabellae, or sometimes there are many, long axial lamellae in young stages, most of which are attached to inner edges of the major septa. In the mature stage axial lamellae are always crowded so many as to give the axial structure a very finely complicated network being combined with the axial tabellae (Pl. 14, fig. 1a).

Axial lamellae and a median plate are the same in structure as the septa of the inner area, and composed of simple trabeculae, and axial tabellae have the same structure as dissepiments, and composed of a very dense lamellar layer.

Ontogeny.—The earliest stage obtained of this form is represented by a section of an offset arisen from a parent corallite (Pl. 14, fig. 2), but unfortunately it shows a section that was cut probably at the calyx which was filled with a matrix, so that the proper structure at the stage can not be observed. The corallite of 5.57 mm in diameter has 17 thickly dilated septa of two orders, of which minor ones are very short, partly has one ring of dissepiments, and three, nearly parallel, slightly twisted, thick and short plate at the center, which are composed of thick trabeculae.

A late immature stage of this form is shown by a section of 7-9 mm in diameter which has 24 septa of each order and partly developed dissepiments in one to three rows. Its central area is composed of a thin, long median plate which is discontinuous with the cardinal and counter septa, many vesicular tabellae, and several septal lamellae which are mostly attached to inner edges of major septa on the distal ends and abut on the median plate on the other.

In the early mature stage the axial structure greatly varies in different corallites; in some being composed dominantly of semiglobular vesicles on both sides of a median plate, if it is present, and accompanied with a few short axial lamellae in the marginal part; some have a number of long axial lamellae as to give a typical clisiophylloid axial structure, being combined with axial tabellae. However there can be recognized a gradual variation in the development of axial lamellae between both extremities of the axial structure mentioned above.

Remarks.—This new species is very similar to *Clisiophyllum awa* (MINATO) (1951, p. 5, text-figs. c1, 2, d1-3; 1955, p. 137, pl. 5, fig. 1; pl. 37, fig. 4, etc.) and its subspecies *atetsuense* (MINATO and NAKAZAWA) (1957, p. 18, pl. 3, figs. 3, 4), but it is distinguished in having a dendroid corallum with long cylindrical corallites, many, well-developed and continuous axial lamellae, especially in the mature stage, and a less prominent median plate.

No dendroid form of *C. awa awa* and *C. awa atetsuense* has been known. Both forms have a very prominent, thick median plate from which short, discontinuous trabecular "septal lamellae-like ridges or crests" are radiating on the upper surfaces of the axial tabellae. The trabecular fibres of the septal lamellae are radiating outwards at an acute angle in cross-section, whereas those of the present new species are radiating always normal to the side walls of the septa.

Occurrence.—Abundant at loc. Ya. 116 and common at loc. Ya. 4; *Fusulina ohtanii* subzone.

Genus *Koninckophyllum* THOMSON and NICHOLSON, 1876

Type-species.—*Koninckophyllum magnificum* THOMSON and NICHOLSON, 1883

Koninckophyllum? sp.

Pl. 16, figs. 9, 10

Material.—Only three incomplete, partly crushed, longitudinal sections have been obtained: Reg. no. GK-D50101-50103 from loc. Ya. 4.

Descriptive remarks.—Some of their characteristics shown in the two illustrated specimens are those of *Caninia,* but the presence of lath-like discontinuous axial plate and the dendroid growth habit exhibited in the remaining specimen suggest affinities with the koninckophylloids.

Dissepiments small, gently inclined in outer rings, and large, steeply inclined in inner ones. Tabulae closely set, complete or incomplete and inosculating; tent-shaped in young stages, but become nearly flat later, downturned at their peripheral margin only.

Occurrence.—Rare at loc. Ya. 4; *Fusulina ohtanii* subzone.

Family Amygdalophyllidae GRABAU in CHI, 1935

Genus *Amygdalophylloides* DOBROLYUBOVA and KABAKOVITCH, 1948

Type-species.—*Amygdalophyllum ivanovi* DOBROLYUBOVA, 1937

Generic diagnosis.—Simple, small trocoid to ceratoid Rugose corals with usually thick septa, a stout solid columella, and relatively large and a little convex dissepiments. Columella connected with probably cardinal septum almost throughout corallites. Tabulae inclined inwards in outer series, nearly horizontally disposed and almost plane or slightly sagging near the columella, and seldom ascending up to the columella.

Remarks.—This genus is apparently similar to *Lophophyllidium* GRABAU and *Stereostylus* JEFFORD but differs in having a wide dissepimentarium, and tabulae which slope down towards the columella or are disposed nearly horizontally. Whereas the tabulae of *Lophophyllidium* and *Stereostylus* slope up to the columella. According to DOBROLYUBOVA and KABAKOVITCH (1948, p. 23), the most remarkable character which distinguishes the present genus from *Lophophyllidium* and its allied genera is in that the columella is connected with the cardinal septum.

The present genus also resembles small forms of *Amygdalophyllum*, such as *A. valum* HILL (1934, p. 70, pl. 8, figs. 9-13) and *A. conicum* HILL (1934, p. 70, pl. 8, figs. 14-48) from the Lower Carboniferous of Queensland, but it can be distinguished in having fewer and larger dissepiments and less developed, shorter minor septa.

Four species of the genus have been known from the C_{II}^{3} to the C_{III}^{0} horizons in the Donetz and the Moscow Basin (DOBROLYUBOVA, 1937, 1940; DOBROLYUBOVA and KABAKOVITCH, 1948). I regard *Lophophyllidium profundum* described by HERITSCH (1936, p. 108, pl. 17, figs. 15-18; text-fig. 9) from the Upper Carboniferous of the Carnic Alps as another example of this genus, because it has a stout solid columella and a distinct dissepimentarium.

Amygdalophylloides gracilis (HAYASAKA)

Pl. 15, figs. 1-8

1924. *Axophyllum gracile* HAYASAKA, Sci. Rep. Tohoku Imp. Univ., 2nd Ser., Vol. 8, no. 1, p. 23, pl. 5, figs. 10-13*.

Types.—This species was established by HAYASAKA (1924) on some syntypes. Although I have not seen the actual specimens, the figured specimen (HAYASAKA, 1924, pl. 4, figs. 11, 12) is here designated as the lectotype.

Material.—Ill preserved specimens, Reg. no. GK-D50104-50112 from loc. Ya. 36, and 50113 from loc. Ya. 116.

Description.—Corallum simple, small, and trocoid. Outer wall is composed of an extremely thin theca and a very thick, crenated inner pseudotheca (0.4-0.5 mm thick), and has shallow septal grooves and broad lateral annulations on the surface. Corallites obtained are 12-13 mm in diameter, about 25 mm in length. Internal structure is obliterated to some extent due to later recrystallization of

* The numbering of the original figures of this species on the Plate 4 has been erroneously printed. The correct numbers are read fig. 10 for fig. 5, fig. 11 for fig. 8, fig. 12 for fig. 7, and fig. 13 for fig. 6.

the structural elements.

Septa are of two orders, major and minor, 26-28 of each; the incomplete largest specimen obtained has more than 34 septa. Major septa nearly or completely reach columella almost throughout corallites except near calyx, where they may be withdrawn from columella at fairly long distances. Septa are straight in the peripheral region, but in the mature stage they may be zigzag in their distal parts and sometimes provided with carinae-like short processes that seem to be produced by extraordinarily expanded trabeculae at random positions on sides of the septa. Details of these carinae-like processes are not clearly known because of recrystallization of septa. Minor septa appear in the late immature stage, and are a little more than half to two-thirds as long as the major.

Septa of each order are usually highly dilated almost throughout corallites, especially in the immature and early mature stages. The dillation is variable in individuals or different stages of a corallite, so that septa may sometimes be wedge-shaped, sharply thinning distally and in contact peripherally with neighbouring septa, or sometimes much more thickened in the inner area than in the peripheral area.

Septa are composed of simple trabeculae in the main part of their length and of very fine composite trabeculae in only the peripheral region. In the former there is a distinct median lamina consisting of a linear successive series of calcification centers of trabeculae, from which fine fibres are radiating normal to the lamina. In the latter bundles of trabeculae are short and minute, often not well shaped, and their apices are not disposed in a linear series, but follow one by one to form packed fasciculate rods which are directed inwards and upwards at a rather high angle. These two parts are gradually merge into each other. The linear series of the calcification centers of the simple trabeculae is splitted into composite centers, increasing in numbers from a few to many points towards the periphery along the median part of septa. Trabecular bundles become longer and larger towards the periphery so as to make slender rods of trabeculae.

Axial columella persists throughout corallites, and is stout, solid, oval to pendulum-shaped in cross-section, and firmly joined to the cardinal septum. It is also connected with the counter septum almost throughout corallites except in the full-grown stage. The large columella in section is 2-2.5 mm wide and 3-4 mm long.

The columella consists of a median trabecular lamina and many, radial, and closely packed, cone-shaped trabecular rods or bundles of fibrous calcites. Median lamina completely bisects the columella and seems to be essentially continuous to that of the cardinal septum. In some sections this continuity is well observable and the median laminae of the cardinal septum and also of the counter septum penetrate into the nearly central part of the columella, but in some other cases the structure is not clear due to recrystallization of the skeletal elements. Trabecular rods radiate from the median lamina with a slight curvature, expand peripherally, and are sometimes diverged outwards into 2 or 3 bundles; in

longitudinal sections they are disposed in broadly turbinate layers superimposed one upon the other. Between the adjacent rods is seen a faint suture line. Each rod, 0.2-0.3 mm in diameter at the periphery, is composed of very fine trabecular fibres radiating outwards from the apex and the central part of a rod.

Dissepimentarium occupies less than half to one-third of the radius of corallite. Dissepiments are very large, arranged anguloconcentrically or highly obliquely to septa, steeply inclined and are elongate in longitudinal sections. Most of them are thickly reinforced on their convex surfaces by a stereoplasmic deposit which is the same in nature as the trabecular fibres of septa.

Unfortunately no longitudinal sections which show structures of the tabulae have been obtained. No distinct fossulae observed.

Remarks.—The specimens are identical with the original types of *Axophyllum gracile* HAYASAKA (1924, p. 23, pl. 5, figs. 10-13) described from the Omi Limestone of Niigata Prefecture, central Japan, in having a trocoid to ceratoid corallite with a large solid columella, thickly dilated septa of nearly equal numbers, large dissepiments and a very thick pseudotheca. A little differences are seen in that the columella of the Yayamadake specimens is larger than that of the type specimens and the septa sometimes have carinae-like ridges.

The present species was originally referred to *Axophyllum* M.-EDWARDS and HAIME, but it is distinguished from the latter in having a massive columella throughout a corallite. Later it was transferred to the genus *Amygdalophyllum* DUN and BENSON with a query by MINATO and KATO (1955, 1957). However, the diagnostic characteristics of the species are those of *Amygdalophylloides* DOBROLYUBOVA and KABAKOVITCH rather than of *Amygdalophyllum* in having fewer septa and larger dissepiments.

The species is long ranging and has been known from the Upper Viséan *Gigantoproductus edelburgensis* zone to the *Fusulinella biconica* zone in the Omi Limestone, and also from the *Clisiophyllum awa* zone in the Akiyoshi Limestone, which was considered by MINATO and KATO (1957) to be equivalent to the *Millerella, Profusulinella,* and *Fusulinella biconica* zones of TORIYAMA (1954) in the limestone.

Ontogenetic developments in the late immature stage of the Yayamadake specimens is quite similar to that of *A. ivanovi,* the type-species of the genus, of the Myatshkovo horizon (C_{II}^{4}) of the Moscow Basin, but it is distinguished by its stouter columella, and thicker septa which sometimes have carinae-like ridges. The structure in the early mature stage of this species is similar to *A. monoseptatus* DOBROLYUBOVA and KABAKOVITCH (1948, p. 26, pl. 14, fig. 1) (C_{II}^{3}) and *A. monoseptatus robustus* DOBROLYUBOVA and KABAKOVITCH (1948, p. 27, pl. 14, figs. 2-8) (C_{II}^{3}), but the species differs from them in having thicker septa, a stouter columella and much better developed, regular dissepiments.

The present species somewhat resembles *Amygdalophyllum conicum* HILL (1934, p. 70, pl. 8, figs. 14-48) and *A. valum* HILL (1934, p. 70, pl. 8, figs. 9-13) from the Lower Carboniferous of Queensland but is distinguished from *A.*

conicum by its stouter columella and from *A. valum* by its much larger vesicles of dissepiments.

Occurrence.—Common at loc. Ya. 36, *Beedeina higoensis* subzone; rare at loc. Ya. 116, *Fusulina ohtanii* subzone.

Family Carciniphyllidae HUDSON, 1942

Genus *Axolithophyllum* FOMICHEV, 1953

Type-species.—*Axolithophyllum mefferti* FOMICHEV, 1953

Axolithophyllum frothyvesiculare n. sp.

Pl. 16, figs. 1-9

Material.—Holotype, Reg. no. GK-D50202; paratypes, GK-D50114, 50115, 50118-50201, 50203; all from loc. Ya. 4.

Description.—Corallum consists of a simple, turbinate corallite, which is curved probably in the counter-cardinal plane with a convex and highly flanged counter side. Calyx seems to be rather deep. No external surface is shown in the examined specimens, but longitudinal sections show that the theca is slightly annulated.

Theca about 1 mm thick, internally bears strong crenations, to the inner ends of which septa are attached. The largest example is 23 mm in diameter, and presumably 25 mm in length.

There are 21 septa in each of two orders, major and minor, at a diameter of 7 mm, 28 at 10 mm, 31-32 at 13 mm, 38 to 17 mm, and the largest corallite mentioned above, has 35 septa, including minor, in a half-cycle defined by the counter-cardinal plane. Major septa usually reach axial column in immature stages, but are withdrawn as a corallite grows, being notably separated from the column in the mature stage. Minor septa are half as long as major ones in the late immature stage, where one series of dissepiments first appears in the counter quadrants, and about two-thirds in the early mature stage. Since major septa retreat from the central region in the mature stage, minor septa become three-quarters to four-fifths the length of the major and nearly equal to each other at the calyx. Minor septa extend into the tabularium at fairly long distances.

Septa of both orders in the tabularium are generally straight, or occasionally flexuous or zigzag, but in dissepimentarium remarkably zigzag in accordance with irregularity of dissepiments. In the peripheral area the septa are partly discontinuous in the early mature stage and mostly or wholly so in the mature stage, and large lonsdaleoid dissepiments occur.

Septal dilation is conspiceous in the tabularium of the mature stage; so remarkable at the outer margin of the tabularium at the full-grown stage that septa are laterally in contact with adjacent ones, forming an inner wall there; while it is not distinct in the dissepimentarium, so that septa are suddenly thinned at the boundary of the tabularium and the dissepimentarium.

A transverse section of a full-grown corallite exhibits two peripheral stereozones; one along inside of theca and the other, a thick inner wall, formed by laterally coalescing of highly dilated septa on the internal surfaces of a row of lonsdaleoid dissepiments at a short distance from theca. These stereozones are crenated on their inner surface. In immature stages before dissepiments appear, septa are evenly and slightly thickened. The most distinct feature of this coral is seen in dissepiments, which are irregular in shape, size, and configuration, and composed of rather large, longitudinally elongate vesicles. Intercepts of dissepiments in transverse sections show that dissepiments are not evenly convex, but on some parts strongly convex, on other parts broadly convex or nearly plane or even have a concave hollow usually at their central parts. Large lonsdaleoid dissepiments occur in the peripheral area where septa are represented by short crests on the inner surface of dissepiments. They occasionally occur in the early mature stage, but in the late mature stage the peripheral area is wholly occupied by them. They are also irregular in shape and size like small dissepiments, elongate, steeply inclined, unevenly convex; some are strongly convex and others nearly flat.

Dissepimentarium is narrower on the cardinal side than on the counter side. Dissepiments first appear in the late immature stage.

Axial column in the mature stage is one-third to one-fourth the diameter of corallite, oval in cross-section, consisting of compact stereoplasmic deposits, and surrounded by several steeply uparched axial tabellae which are also reinforced by a deposit on their upper surface. A short median plate is commonly seen in the center of the column, but sometimes not present. There are no septal lamellae. Axial column in the late immature stage composed of a thin median plate, which appears to be continuous to the counter septum, and a few, sparsely disposed tabellae reinforced by a fairly thick stereoplasmic deposit. At the early mature stage the axial column is clearly defined, but not completely solid. As a corallite grows, it is gradually strengthened by a thick stereoplasmic deposit which covers both sides of the median plate and upper surfaces of tabellae so as to be nearly solid. Major septa completely or nearly reach the outermost tabellae. Counter septum and also sometimes cardinal septum are extended almost to the center of column or bent aside and attached to one of axial tabellae. At the full-mature stage the column is completely or nearly completely solid with a few caverns underneath tabellae; at this stage major septa are separated from the column, but the counter septum remains latest in withdrawing from the column. In transverse sections may be seen traces of a short median plate and several anastomosed or twisted tabellae in the solid column (Pl. 16, figs. 7, 9). A longitudinal section of a mature corallite shows that the column is composed of steeply inclined (about 45 degrees) conical layers superimposed one upon the other, in which a discontinuous median plate occurs in the center and intercepts of axial tabellae here and there.

Tabularium is wide, occupying more than half to two-thirds the diameter of corallites, and made up of three elements of tabulae: inner tabulae steeply

inclined, less convex and abut onto axial column; central ones nearly flat or gently inclined, rather loosely spaced and covered with a thick stereoplasmic deposit; outer ones which seem to slope up onto dissepimentarium. No distinct fossulae observed.

Remarks.—The primordal elements of the axial column in immature stages of this species seem to be composed of a median plate which is connected with the counter and the cardinal septum. In the mature stage the median plate tends to be discontinuous by itself and is separated from the counter and the cardinal septum, but a stereoplasmic deposit become so strong as to form a large solid column. The column is accompanied with several short or long tabellae which are also thickly strengthened by a deposit so as to be united with the central column.

This new species is very similar to *Axolithophyllum mefferti* [forma *a* and *b*] described by FOMICHEV (1953, p. 417, pl. 33, figs. 7, 8a-b, 9, 10, 11a-b, 12-16; pl. 29, fig. 1) from the uppermost part of the C_{II}^{6} and the C_{III}^{2} of the Donetz Basin, but it differs in that the axial column of the former species is less massive in immature stages and much stouter in the mature stage than that of the latter and the dissepiments are much more steeply inclined.

Amygdalophyllum wangi CHI (1935, p. 23, pl. 11, fig. 4) from the Middle Carboniferous of Yunnan, China, is undoubtedly referred to *Axolithophyllum* in having a stereoplasmic column, dissepiments of the same type of the structure as those of the latter genus, lonsdaleoid dissepiments in the peripheral area and crenated pseudotheca. The axial column of the former is, according to CHI's description, composed of "a central median plate with fine lamellae and axial tabellae".

The present species is somewhat similar to *Kionophyllum broilii* (HERITSCH) (1936, p. 133-134, pl. 18, figs. 6, 14, 15; text-fig. 38) which was described from the Upper Carboniferous of the Carnic Alps originally under *Geyerophyllum*. It differs from the latter in its zigzag septa, irregular dissepiments, a thicker, crenated pseudotheca and longer minor septa.

The present species is also similar to *Kionophyllum dibunum* CHI (1931, p. 40-41, pl. 9, figs. 1a, b; 1935, p. 24, fig. 5) described from the Middle Carboniferous of Kueichou and Yunnan, South China. But it is distinguished by having a thicker, crenated pseudotheca, zigzag septa, more irregular and more steeply inclined dissepiments including lonsdaleoid ones, a larger axial column, and better developed stereozones.

This species somewhat resembles *Amygdalophyllum nantanense* HUANG (1932, p. 115, pl. 1, fig. 2a-b) from the Lowest Permian of Kwangsi, China, but differs in having much more irregular dissepiments and lonsdaleoid dissepiments. The latter species also seems to be better referable to *Axolithophyllum* by its different type of dissepiments and probably different structures of the axial column rather than to *Amygdalophyllum*.

Occurrence.—Rare at loc. Ya. 4; *Fusulina ohtanii* subzone.

Family Pseudopavonidae YABE, SUGIYAMA, and EGUCHI, 1943

Type-genus.—*Pseudopavona* YABE, SUGIYAMA, and EGUCHI, 1943

Other genus included.—*Taisyakuphyllum* MINATO, 1955

Diagnosis.—Simple?, fasciculate to thamnasterioid Rugose corals with very thick, composite trabecular septa in larger part of their length, and a stout, massive columella composed of cone-shaped trabecular rods superimposed one upon the other and directed outwards and upwards from its axis or the median lamina. Septa of two orders, major and minor, or sometimes of three orders provided with tertiary septa, though they are short and not always present in the system. Septa sharply attenuate in the inner area, but so thick in the peripheral area that interseptal loculi usually become slit-like or are represented by only sutures between the two adjoining septa which are often laterally in contact with each other.

Thamnasterioid forms have confluent septa which are sometimes united with neighbouring ones at their inner edges. Septa usually extended very close or even attached to columella, but do not intrude into it except the cardinal septum. Tabularium narrow, mostly occupied by nearly flat tabulae which are disposed horizontally or slightly inclined towards the columella. Dissepimentarium wide, composed of globular vesicular dissepiments.

Geological age.—Middle Upper Carboniferous [*Fusulinella* zone to the *Beedeina* zone (=*Fusulina* zone)], Middle Permian?

Remarks.—Family Pseudopavonidae was established by YABE, SUGIYAMA, and EGUCHI on the basis of monotypic genus *Pseudopavona* from the *Fusulinella* zone of the Taishaku Limestone of Okayama Prefecture, western Honshu, with a suggestion of refering it to a Scleractinia, to which opinion MINATO (1955, p. 180), YOKOYAMA (1957, p. 80) and KAWANO (1959, p. 183) followed. In this paper it is proved that this interesting coral should be regarded as a Rugosa as discussed below.

The most striking features of the type-species of *Pseudopavona*, according to the original descriptions, are:

> "characterized by its meandroid corallum with narrow corallites lacking proper wall, connected by confluent, distinctly trabecular septa which are apparently disposed radially, and provided with variably papillar columella surrounded by an incompete cycle of pali or pali-like elements."

Regarding the meandroid structure, YABE *et al* stated:

> "A transverse section shows the presence of distinct intercorallite common walls, — which are probably to be represented as collines at the calicular surface —, being surrounded by which there are several corallites arranged in meandering rows."

However it is very doubtful whether the corallum is really meandroid, because *Pseudopavona* has a very variable habit in form at different stages. Young corallites arise often in groups or in rows, and their septa are often not confluent but their peripheral edges abut aside alternately, or attached half the width of septa, onto those of neighbouring corallites. In case a section is

cut obliquely to the corallites, the junctions of septa may assume a structure as though a wall. A wall-like structure of this kind can also be seen in the new form of the genus described in this paper.

"Presence of pali or pali-like structure" of the original specimen of the type-species may probably be taken place by intercepts of extended ridges of papillar rods of the columella onto tabellae, or broken pieces of those papillar rods or inner edges of septa. In fact intercepts of projecting papillar rods or broken pieces* of inner edges of septa are often seen in sections of some specimens of *P. taisyakuana* when they are cut near the calyx.

One of the reasons that *Pseudopavona* has been referred to a Scleractinia is in that the septa of the type-species are composed of very striking trabeculae, which the authors considered to be seen most commonly in Scleractinia, but seldom in Rugosa. However, composite trabeculae of septa have been recognized not uncommonly in Rugosa as shown by an important work of WANG (1950). Composite trabeculae can be seen even in parts of septa of *Clisiophyllum,* as shown in Text-figure 3.

The ontogenetic development of the type-species of the genus has not been known at all. In the new species described below the septal arrangement of mature corallites retains a tetrameral symmetry. The cardinal, counter and alar septa are long and rather easily discriminated, and a few septa in the counter quadrants adjacent to the alar septa are usually short and pinnately arranged and sometimes make a wall by uniting together at their inner edge. Ontogenetic development of the new species clearly shows that the genus should be referred to a Rugosa, but the type-species should be reexamined before the final conclusion is made.

A close relative of *Pseudopavona* is *Taisyakuphyllum* which was established by MINATO, with *T. rostfer* MINATO (1955, p. 143, pl. 22, fig. 12; pl. 25, fig. 4; pl. 34, fig. 8; text-fig. 15) as the type-species. This species has been found in the *Fusulinella* zone, especially from its lower part, of the Taishaku Limestone of Okayama Prefecture, and of the Akiyoshi Limestone of Yamaguchi Prefecture, both in western Honshu. It was described as a simple coral, but it is very probable that the specimens are parts of a fasciculate form. Minato considered it as being similar to the genus *Amygdalophyllum* and referred it to the family Amygdalophyllidae GRABAU, but the essential structures of *Taisyakuphyllum* are identical with those of *Pseudopavona.* The diagnosis of the genus *Taisyakuphyllum* may be given as follows:

Simple? or probably fasciculate Rugose corals with a number of thick septa of three orders, major, minor, and tertiary, and a solid columella. Septa composed, for the most part, of composite trabeculae; sharply attenuate distally, and are so thick that often attached laterally with neighbouring ones. Major and minor septa often united with abjacent ones at their inner edges. Columella massive, composed of cone-shaped rods of trabeculae superimposed one upon the other, radiating outwards from the axis and directed slightly

* It is easy to distinguish broken pieces of septa from projecting papillar rods by the disposition of trabeculae in the septa and the papillar rods.

upwards. Tabularium narrow, occupied by nearly flat tabulae disposed horizontally or a little inclined towards the columella. Dissepimentarium wide, consisting of vesicular dissepiments.

Type-species.—*Taisyakuphyllum rostfer* MINATO, 1955

Geological age.—Middle Upper Carboniferous, *Fusulinella* zone.

Taisyakuphyllum should be referred to Pseudopavonidae. MINATO (1955, p. 63, text-fig. 4-1, p. 144, text-figs. 15-3-8) mentioned that one of the characteristics of the genus is a "septal grating". The septal grating is nothing but a composite trabecular structure of septa, and is represented by sutures between the trabecular rods of septa which are superimposed one upon the other. Each rod is composed of fine fibres of a trabecula radiating from the axis of a rod. If these rods are recrystallized, the sutures become very distinct and apparently show a strong grating structure.

Genus *Pseudopavona* YABE, SUGIYAMA, and EGUCHI, 1943

Type-species.—*Pseudopavona taisyakuana* YABE, SUGIYAMA, and EGUCHI, 1943

Diagnosis.—Thamnasterioid Rugose corals with thick confluent septa, lacking intercorallite common walls, and a stout, massive or papillary columella. Septa composed mostly of composite trabeculae except in a small part of the inner area, where they consist of simple trabeculae; sharply attenuate in the inner area but are so thick in the peripheral area that they are often completely or almost attached laterally with adjacent ones with only a suture or a very narrow slit-like interseptal loculi between them. Major septa nearly or completely reach the columella; minor ones two-thirds as long as the major, or a little longer; tertiary septa may be present, but are short and do not always occur in the system.

Cardinal, counter and alar septa usually prominent; a few septa adjacent to alar septa in counter quadrants may be pinnately arranged and their inner edges are often united together so as to make a septal wall.

Columella composed of cone-shaped trabecular rods which are superimposed one upon the other, radiating from the median lamina or the axis of columella and directed slightly upwards. Papillar columella is sometimes provided with fairly long ridges.

Tabularium narrow, occupied by nearly flat or slightly convex tabulae which are disposed horizontally or slightly inclined towards the columella. Dissepimentarium wide, composed of globular vesicles which incline very gently in the peripheral area and steeply in the inner area.

Remarks.—The present genus somewhat resembles *Orionastraea, Phyllipastraea,* and *Protolonsdaleiastraea,* but it is easily distinguishable from the latters in having much thicker septa, which are often attached laterally in the peripheral area, and a stouter columella. Only one unnamed species of *Orionastraea* was described from Japan by HAYASAKA (1932, p. 273-275, text-figs. 1, 2) from the

Omi Limestone of Niigata Prefecture, central Honshu. As discussed by YABE *et al* (1943), the coral has a closer similarity to *Pseudopavona* than to *Orionastraea* in having thicker septa and a stouter columella.

The type-species of the genus is known from the middle Upper Carboniferous (*Fusulinella* zone), but KAWANO (1957) described *Pseudopavona taisyaku- and izutoensis* from the Middle Permian Izuto Limestone of Yamaguchi Prefecture.

Pseudopavona crassisepta n. sp.

Pl. 15, figs. 12, 13; Pl. 17, figs. 1-7; Pl. 18, figs. 1-9; Text-figs. 4, 5

Material.—Holotype, Reg. no. GK-D50204 from loc. Ya. 116; paratypes, 50205, 50206, 50209, 50214 from loc. Ya. 116; 50208, 50210 50211, 50215-50217, 50219 from loc. Ya. 4. Many other sectioned and polished specimens have also been examined.

Description.—Corallum massive, thamnasterioid in the mature stage and partly astreoid or sometimes aphroid in immature stages. Some coralla obtained more than 15 cm in diameter with a discoid base arisen from a small initial corallum consisting of one or a few corallites, and enclosed by an irregularly annulated holotheca of about 1 mm thickness. Longitudinal sections show that a small columnar boss rises from a rather deep calicular pit.

Diameters of corallites greatly vary in individuals and can not be exactly measured because of no corallite walls, but columellae of mature corallites are disposed apart at distances of mostly 9-10 mm, occasionally 11-13 mm or 6-8 mm.

Corallites arise by intermural increase, and new offsets frequently grow in groups especially at peripheral areas of a corallum, but parents and offsets in all stages of growth are met with in any section of a corallum. Form-habit of a corallum is variable; corallites of the mature stage thamnasterioid with confluent septa, but those of early stages are aphroid, united by a fairly wide lonsdaleoid dissepimental zone. When a single young corallite arises between mature corallites, septa are mostly confluent. In the early part of the mature stage septa are fully developed and the septa of adjacent corallites are in alternating position and are in contact with each other on a half width at their peripheral edges. In such a case parts of a corallum assume astreoid. The shape of young corallites is variable even in an offset, being some parts aphroid, astreoid or other parts thamnastreoid. Septa of the mature stage are mostly confluent with, sometimes abut onto, those of adjacent corallites; they are straight, flexuous or strongly geniculated.

Septa are of two orders, major and minor, but in addition supplimentary, short, wedge-shaped septa of the third order are sometimes developed in the peripheral area in the mature stage. Septa extremely closely set; rather sharply attenuate distally, but very thick for the most length, so interseptal loculi are very narrow, slit-like, retaining nearly the same space not only laterally for the whole length of minor septa but also vertically almost throughout corallites.

In the peripheral area septa are laterally in contact with adjacent ones, with only a suture between them.

Major septa completely or nearly reach the columella almost throughout corallites except near the calyx where they leave free a small space around the columella, and only the cardinal septum often remains to be joined to it. Minor septa first appear in the early immature stage, alternate with major ones, being three-quarters to four-fifths the length of major ones. Septa alternately vary in thickness and the minor ones are often thicker than the major.

Septa are radially disposed, but retain a tetrameral arrangements, though they are not always of equal number in each of corresponding quadrants. Cardinal septum is essentially connected with the columella almost throughout the corallite and its median lamina is continuous with the median lamina of the columella. Median laminae of other septa do not enter the columella.

As in zaphrentoid corals cardinal lateral septa and two or three adjacent septa are pinnately arranged and joined together at their inner edges to make a septal wall which is parallel to the cardinal septum, but there is no distinct cardinal fossula. Alar and counter septa extend to the columella except near the calyx. Similarly, in counter quadrants three or four septa adjacent to alar septa are also pinnately disposed and united together at their inner edges to make a septal wall which is parallel to alar septa.

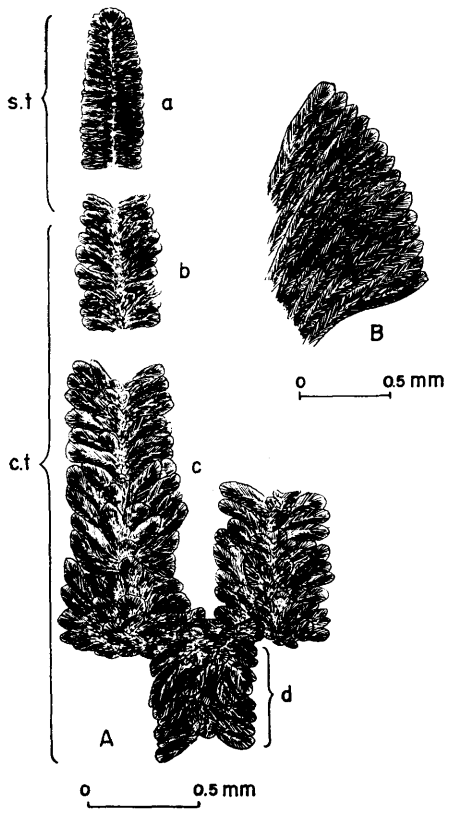

Fig. 4. Diagram of the transverse and longitudinal sections of septa of *Pseudopavona crassisepta* n. sp., showing the septal structure.
A. Transverse section of septa: a, distal part; b, septum in the tabularium; d, septum in the peripheral area of the adjacent corallite; s. t., simple trabeculae; c. t., composite trabeculae.
B. Longitudinal section of a septum showing trabeculae.

In counter quadrants of the mature stage two adjacent septa may sometimes be alternately joined to each other at their inner edges, and minor septa also sometimes united to one of adjacent major ones at their inner ends as if the septa are bifurcated.

Tertiary septa occur in only the peripheral area of mature corallites, especially at the place where confluent septa are highly curved or geniculated, and do not extend to a halfway from the outer margin. They do not occur in the system but are inserted sporadically so as to fill interseptal loculi between longer septa.

Septal formula in corallites of 9-11 mm in diameter is K15-20A11-14C in a half side of corallites, excluding a few short tertiary septa.

Two types of the septal structure can be recognized in this coral (see Text-fig. 4); inner small part of septa composed of simple trabeculae; peripheral larger part of septa of composite trabeculae, that is, many, closely set bundles or rods of trabeculae which are directed upwards as well as inwards. In the former each trabecula has a calcification center from which very fine fibres are radiating outwards nearly normal to the septal wall. The calcification centers are successively connected with underlying ones to make a median lamina of the septum which is straight or slightly zigzag. In the latter type of the structure each trabecular rod is built up of very fine fibres radiating outwards from its axis. Trabecular rods are nearly parallel, extremely closely set, and often bifurcated into two or three fascicles. Between the rods only a suture or an extremely narrow slit can be seen, and neither lamellar sclerenchyme

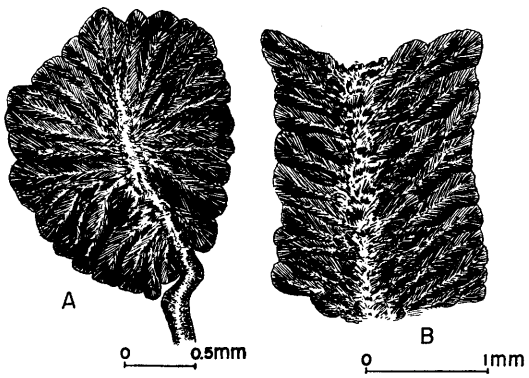

Fig. 5. Diagram of the transverse and longitudinal sections of a columella of *Pseudopavona crassisepta* n. sp., showing the columellar structure. A, transverse section; B, longitudinal section

which encircles the rods of trabeculae as in rhabdacanthine septa nor median lamina which is seen in the septa of simple tabeculae can be recognized. Rods of composite trabeculae become thinner and shorter as the septa are followed distally, and the composite trabeculae are merged into simple trabeculae rather sharply at their transitional part. In the peripheral area the trabeculae are coarse and long, and 0.3-0.4 mm in diameter. It should be noted that in early

stages the composite trabeculae are confined to the peripheral part of septa, but as a corallite grows they become gradually extended so as to reach the half way or more of the septa from the periphery in the late immature stage, and the simple trabeculae are restricted only in the distal area of the mature stage.

Axial columella first appears as a swollen end of the cardinal septum in the early immature stage, to which a little later major septa are attached. The columella is completely solid throughout growth, and composed of a median lamina and a number of slightly curved, cone-shaped rods or bundles radially placed and outwardly and slightly upwardly directed about the axis or the axial lamina of the columella (Text-fig. 5). These rods expand outwards and are sometimes bifurcated into two or rarely three bundles completely in contact with one another with only a faint suture between them. Each rod is composed of very fine fibres radiating outwards from its axis. In longitudinal sections it is built up of slightly upwardly directed bundles superimposed one upon the other (Text-fig. 5B), and is coalesced at the center of the columella. Rods are 0.2-0.5 mm, usually 0.4-0.5 mm, thick at their outer ends.

Median lamina of the columella bisects the columella, and is often continuous with the lamina of calcification centers of trabeculae of the cardinal septum. Near the calyx the above mentioned structure of the columella cannot usually be seen and the columella appears to be composed of uniformly fine fibrous tissues radiating from the center or the median bisecting axis of the columella, with no clear markings in it. However this may be due to obliteration of structures by recrystallization of the columella.

Tabularium narrow, one-third or a little less than that of the radius of corallites. Inner main part of the tabularium is occupied by nearly plane or occasionally sagging tabulae which are disposed horizontally or gently inclined inwards. Tabulae are attached to the columella at their inner edges at about a right angle, closely spaced to the number of 12-15 in an interval of 3 mm. The area of flat tabulae is 1.0-1.2 mm wide. The outer part of the tabularium has plane or a little concave, anastomosed tabulae which are either steeply bent up as to merge with dissepiments or abut onto them with large angles. Tabulae very thin, but often covered with a thick stereoplasmic deposits on the upper surfaces.

Dissepimentarium occupies about half or a little more than half of the radius of corallites. Since this species has no intercorallite wall, a dissepimental area of a corallite is continuous with those of adjacent corallites, arranged dome-wise over the position of the lost wall, where the dissepiments are markedly convex upwards, globose, and gradually increase in their inclination towards the inside, and some inner rings of dissepiments face their concex sides inwards. Dissepiments very variable in size and shape, but inner ones usually larger in size, less convex, and more elongated than those of the outer.

Remarks.—The present new species is undoubtedly referable to the genus *Pseudopavona* by a thamnasterioid corallum with thick confluent septa consisting of composite trabeculae, a solid and stout columella and a narrow tabularium with

nearly horizontal tabulae.

It is similar to *P. taisyakukana*, the type-species of the genus, but differs in having much larger corallites, more numerous and longer septa, most of which are attached to the columella almost throughout growth, and a stouter columella with no papillary ridges on the sides. It has a much more complicated structure than *P. taisyakuana* but its essential structure of the corallum is very similar to that of the latter.

Occurrence.—Common at locs. Ya. 116 and Ya. 4; *Fusulina ohtanii* subzone.

Order TABULATA MILNE-EDWARDS and HAIME, 1850

Family Chatetedae MILNE-EDWARDS and HAIME, 1850

Subfamily Chatetenae MILNE-EDWARDS and HAIME, 1850

Genus *Chaetetes* FISHER in EICHWALD, 1829

Type-species.—*Chaetetes cylindraceus* OAKLEY, 1936

Chaetetes tangshanensis CHU

Pl. 16, figs. 10–13

1923. *Alveolites tangshanensis* GRABAU, Stratigraphy of China, Pt. 1, p. 256 (listed, nom. nud.)

1928. *Chaetetes tangshanensis* (GRABAU) CHU, Bull. Geol. Soc. China, Vol. 8, nos. 3-4, p. 234, pl. 1, fig. 2a-c.

Type.—CHU's original specimen (1829, pl. 1, fig. 2a-c), from the Tangshan Limestone, Tangshan, China, is here designated as the lectotype of this species.

Material.—Numerous specimens were examined. The followings are the selected examples: Reg. on. GK-D50236-50246 from loc. Ya. 116.

Description.—Corallum is massive, as large as 10 cm in diameter, but the shape and size are not precisely observable because the coralla, interlocking together, are embedded in hard, indurated limestones.

Corallum composed of long, curved often flexuous, radiating corallites, which are polygonal, largely pentagonal or hexagonal in cross-section, fairly uniform in size. Inner diameter of corallites ranges 0.25-0.32 mm and sometimes longer diameter of irregular corallites attains 0.4 mm.

Walls imperforated, rather thick, 0.14-0.16 mm, rarely 0.20 mm; composed of a palisade of trabecular rods which are linearly juxtaposed and longitudinally long and erected. Each rod comprises extremely fine fibrous tissues radiating upwards and slightly outwards. A wall on one side of polygonal corallites contains usually 3 to 4 trabecular rods, and between the adjacent rods a faint or a distinct suture line is recognized, traversing the wall. No stereoplasmic deposits are observed. Owing to longitudinal grooves along those suture lines the inner surface of corallites is rough.

Neither septa nor any kind of septal ridges can be detected, but corallites sometimes exhibit inward projections of trabecular rods from the wall, which are

usually accompanied by others on the opposite side. These projections are in due course attached to each other and make a new wall, dividing a corallite into two.

Tabulae are mostly obliterated because of crystallization of matrix, but so far as is seen, they are very thin, less than 0.04 mm in thickness, complete, flat, attached normal to walls, and disposed at intervals of 0.16-0.25 mm.

Remarks.—The present specimens are identical with *Chaetetes tangshanensis* CHU, from the Tangshan Limestone of the Moscovian Penchi series of North China, in the size of corallites, a wall thickness and intervals of tabulae. CHU stated that the corallites of *C. tangshanensis* were irregular in shape and probably divided into a rounded and an elongate type. However, his illustrations, fig. 2b and a part of fig. 2a on plate I of CHU (1928), seem to represent the sections which were cut obliquely to the corallites.

Occurrence.—Abundant at locs. Ya. 116 and Ya. 4; rare at loc. Ya. 44; *Beedeina higoensis* subzone and *Fusulina ohtanii* subzone.

Faunal analysis and correlation

There has been so far one record of coral fauna of the *Beedeina* zone (= "*Fusulina*" zone) in the Japanese Islands, that is, three species of *Caninia*, *C.* sp. A (sp. nov. ?), *C.* sp. B, cf. *mapingense* LEE and YU, and *C.* cf. *simpliseptata* CHI, were described by KONISHI (1954) from the Shimozaisho Limestone of Itoshiro-mura, Fukui Prefecture, central Honshu. On the other hand, corals of the *Fusulinella* zone, which is mostly represented by the *Fusulinella biconica* zone in Japan, are well known as occurring from the Omi limestone (HAYASAKA, 1924), and the Ichinotani Limestone (IGO, 1956), both of central Honshu, and the Taishaku Limestone (YABE, SUGIYAMA, and EGUCHI, 1943; FUJIMOTO, 1944; MINATO, 1955; YOKOYAMA, 1957), and the Akiyoshi Limestone (OZAWA, 1925; MINATO, 1955; MINATO and KATO, 1957), both of western Honshu. They include *Clisiophyllum ofukuense* (OZAWA), *C. awa* (MINATO), *Lonsdaleia katoi* (OZAWA), *Amygdalophylloides gracilis* (HAYASAKA), *Taisyakuphyllum rostfer* MINATO, *Pseudopavona taisyakuana* YABE, SUGIYAMA, and EGUCHI, *Nagatophyllum satoi* OZAWA, *Stylidophyllum yokomizoi* YOKOYAMA, *Cystophora manchurica* YABE and HAYASAKA, *Arachnastraea* cf. *mölleri* (STUCKENBERG), and so on. Of these species, only *Amygdalophylloides gracilis* (HAYASAKA) is a common coral species between the *Fusulinella* zone and the *Beedeina* zone of the Yayamadake Limestone. In spite of the smallness in specific constitution, the Yayamadake coral fauna shows a unique assemblage of species which is distinct from any of the hitherto known coral faunas of the *Beedeina* zone and also supra and subjacent zones in the Japanese Islands.

In th Asian continent the *Fusulinella-Fusulina* zone is represented by the Penchian of North China and the Weiningian of South China. It is well known that the two series have few affinities in coral faunas. Of the Yayamadake corals, however, species of *Chaetetes* is identical with *C. tangshanensis* CHU which

was originally described from the Penchian on one hand, and *Axolithophyllum frothyvesiculare,* on the other, closely resembles *"Amygdalophyllum" wangi* CHI of the Weiningian Limestone of Yunnan, which is better assigned to *Axolithophyllum* than to *Amygdalophyllum.*

Axolithophyllum has been known from the C_{II}^{6} to the C_{III}^{3} horizon of the Donetz Basin, and *A. frothyvesiculare* is similar to *A. mefferti* (forma *a* and *b*) from the uppermost part of the C_{II}^{6} and the C_{III}^{3}. *Kionophyllum dibunum* CHI of the Weiningian, which is a representative of a probably allied group of the same family, has a similar structure to that of *Axolithophyllum.*

Amygdalophylloides has been known from the C_{II}^{3} to the C_{III}^{0} beds of the Donetz and the Moscow Basin, and *Lophophyllidium profundum* described by HERITSCH (1936) of the Upper Carboniferous of the Carnic Alps is also considered to be assigned to the genus under consideration. *A. gracilis* (HAYASAKA) is similar to *A. ivanovi* DOBROLYUBOVA of the Matshkovo horizon (C_{II}^{4}) of the Moscow Basin.

As has been described in my previous papers (1952, 1954), the zone of *Beedeina* (="*Fusulina*" zone) of the Yayamadake Limestone contains highly advanced forms of *Fusulina* and *Beedeina,* and at about 20 meters above the *Fusulina ohtanii* subzone comes the lowest part of the *Triticites* zone (*Triticites matsumotoi* subzone), between both of which no great geological hiatus can be recognized. On the basis of fusulinid fossils, the *Beedeina* zone under consideration is referable to the upper part of the *"Fusulina"* zone of the international sense, that is represented by the Desmoinesian stage of North America and by the Moscovian of Russia.

SHENG (1958) correlated the *Beedeina* zone of the Yayamadake Limestone with the *Fusulinella-Fusulina* zone of the middle to the upper part of the Penchi series of the Taitzeho Valley, Liaoning. As he mentioned, however, there are no common fusulinid species between the two regions. In my opinion the Yayamadake fusulinids seem to be more advanced than those of the Taitzeho in respective genera, and it is suggested that the *Beedeina* zone of the Yayamadake Limestone is as a whole younger than the Penchian and also the equivalent Weiningian of South China.

Acknowledgements

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Plate 14

Explanation of Plate 14

(All figures x 2; unretouched)

Figs. 1-12. *Clisiophyllum subramosum* n. sp. .....page 211

1a-d. Serial transverse sections of the mature part of the holotype, GK-D50051.

2. Transverse section of the dendroid part of a paratype, GK-D 50052.

3-5. Transverse sections of paratypes, GK-D50081, 50071, and 50055, respectively.

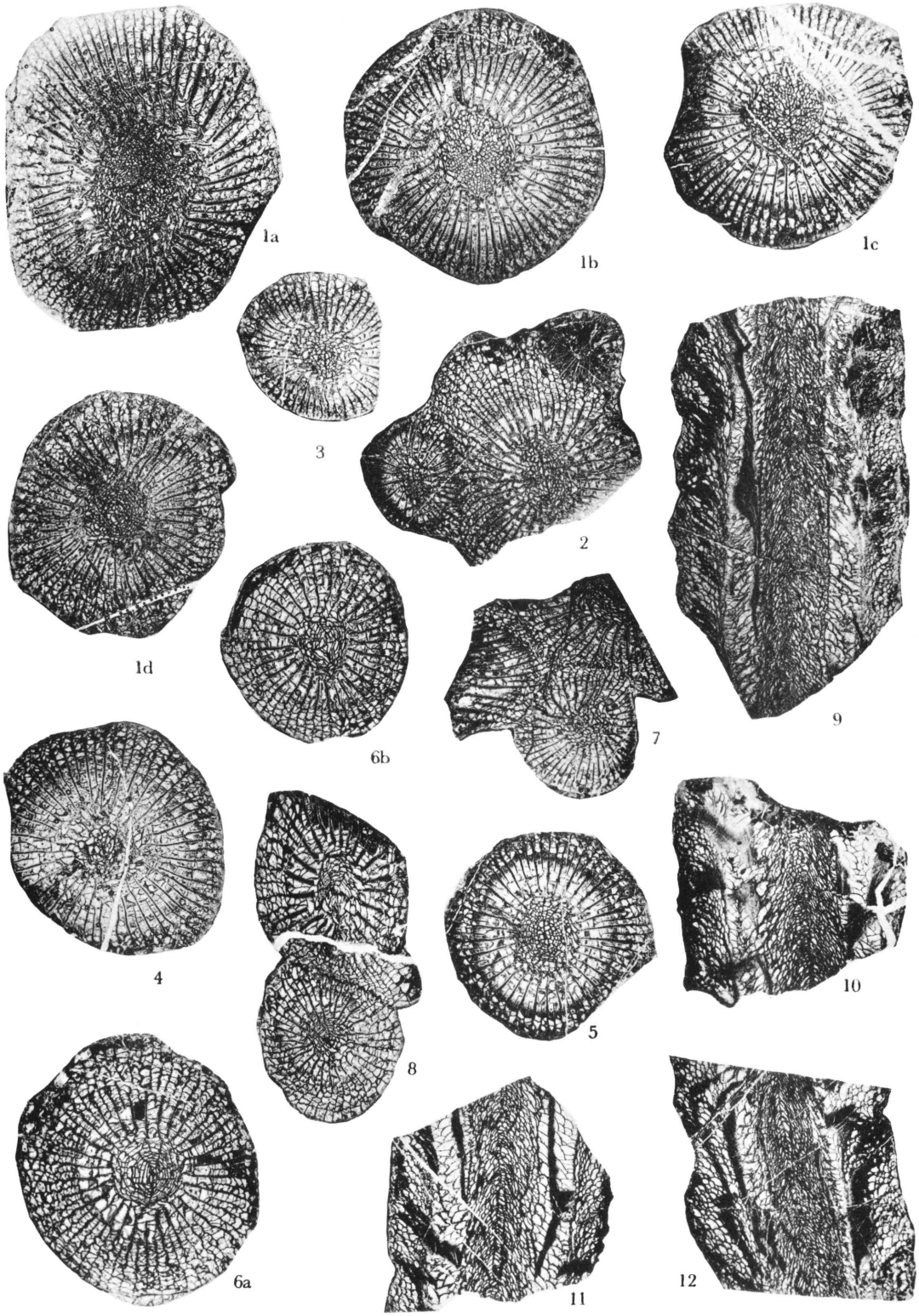
6a-b. Serial transverse sections of a paratype, GK-D 50056.

7, 8. Transverse sections of the dendroid part of paratypes, GK-D 50059 and 50057, respectively.

9-12. Longitudinal sections of paratypes, GK-D50053, 50069, 50058, and 50061, respectively.

All specimens are from loc. Ya. 116, except for the specimen of fig. 3 which is from loc. Ya. 4.

Photos by KANMERA.



K. KANMERA: Upper Carboniferous Corals from Yayamadake

Plate 15

Explanation of Plate 15

(Figures x 3, unless otherwise stated; unretouched)

Figs. 1–8. *Amygdalophylloides gracilis* (HAYASAKA).....Page 215

1. Transverse section of a specimen, GK–D50113.
2a–b. Serial transverse sections of a specimen, GK–D50105.
3a–b. Serial transverse sections of a specimen, GK–D50106.
4. Transverse section of a specimen, GK–D50110.
5a–b. Serial transverse sections of a specimen, GK–D50104.
6. Transverse section of an immature specimen, GK–D50108.
7. Longitudinal section of a specimen, GK–D50109.
8. Enlarged part of a transverse section illustrated as fig. 2a showing an axial columella. x 10.

All specimens are from loc. Ya. 36.

Figs. 9, 10. *Koninckophyllum?* sp.....Page 214

Longitudinal sections, GK–D50102 and 50101, from loc. Ya. 4.

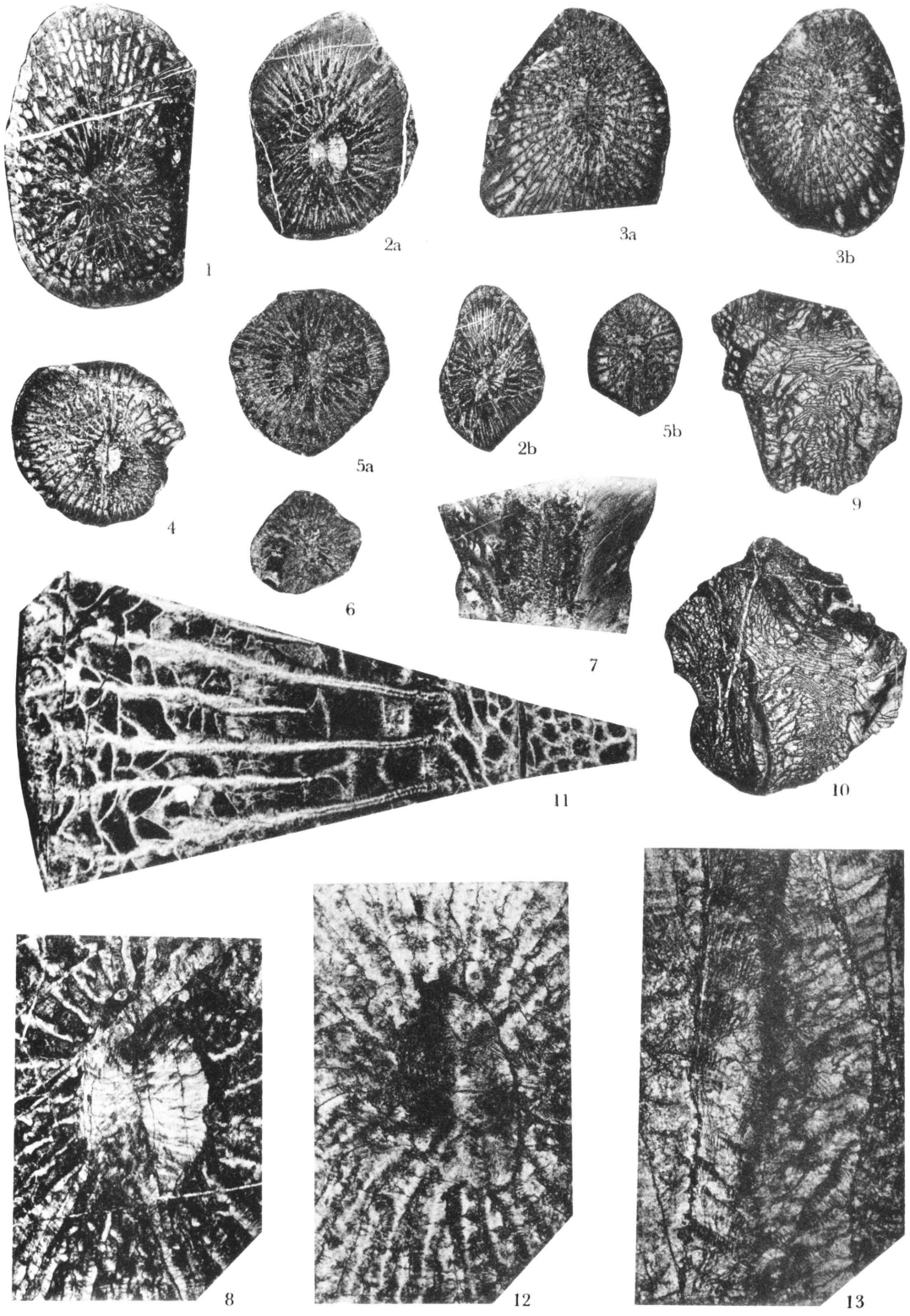
Fig. 11. *Clisiophyllum subramosum* n. sp. (See also Pl. 14) .....page 211

Enlarged part of a transverse section of a paratype (GK–D50051) showing simple trabeculae of septa. x 10.

Figs. 12, 13. *Pseudopavona crassisepta* n. sp. (See also Pl. 18).....page 224

12. Enlarged part of a transverse section of the holotype (GK–D 50204), illustrated as fig. 1 on Plate 17 showing the structure of a columella. x 15.
13. Enlarged part of a longitudinal section of a paratype (GK–D 50217) illustrated as fig. 9 on Plate 17 showing the structure of a columella. x 15.

Photos by KANMERA.



K. KANMERA: Upper Carboniferous Corals from Yayamadake

Plate 16

Explanation of Plate 16

(Figures 1–6, x 2; 7, x 3; 8, 9, x 10; 10–13, x 5; unretouched)

Figs. 1–9. *Axolithophyllum frothyvesiculare* n. sp. .....page 218

1. Transverse section of the holotype, GK–D50202.
2a–b. Serial transverse sections of a paratype, GK–D50200.
3, 4. Transverse sections of paratypes, GK–D50114 and 50118, respectively.
5, 6. Transverse sections of paratypes (immature), GK–D50201 and 50115, respectively.
7. Longitudinal section of a paratype, GK–D50203.
8. Transverse section of a axial column; the same specimen as fig. 1.
9. Longitudinal section of a axial column; the same specimen as fig. 7.

All specimens are from loc. Ya. 116.

Figs. 10–13. *Chaetetes tangshanensis* CHU .....page 228

10. Transverse section of a specimen, GK–D50240.
11. Transverse section of a specimen, showing the largest corallites among the obtained specimens, GK–D50241.
12. Transverse and longitudinal section of a specimen, GK–D50240.
13. Longitudinal section of a specimen, GK–D50238.

All specimens are from loc. Ya. 116.

Photos by KANMERA.

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2a

2b

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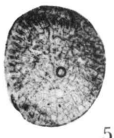

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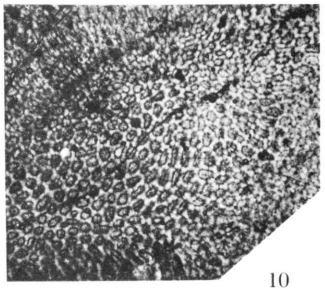

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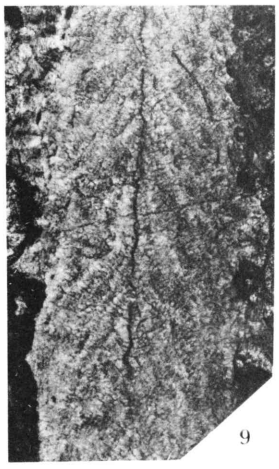

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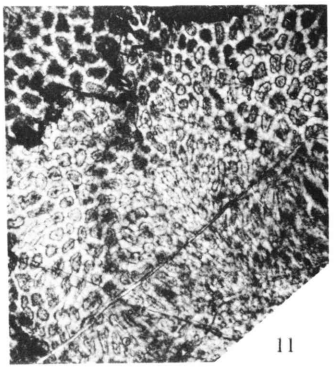

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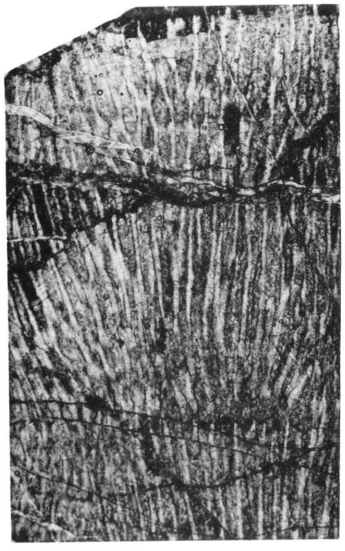

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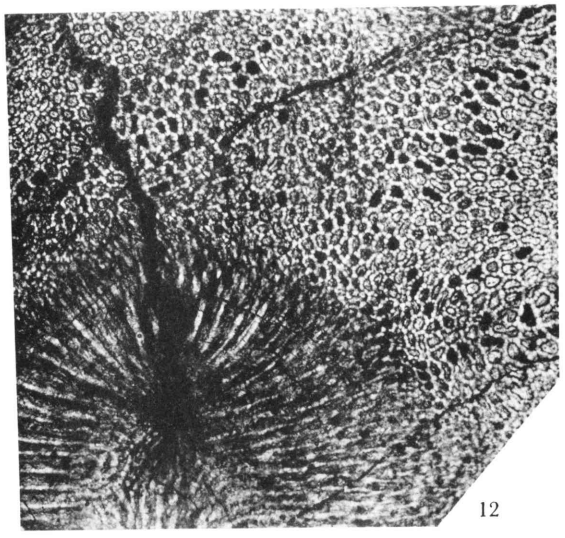

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K. KANMERA: Upper Carboniferous Corals from Yayamadake

Plate 17

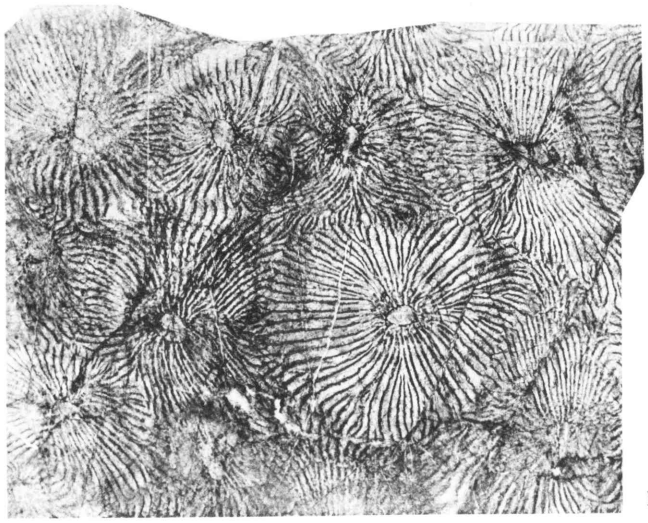
Explanation of Plate 17

(All figures, x 2.5; unretouched)

Figs. 1–9. *Pseudopavona crassisepta* n. sp. .....page 224

1. Transverse section of the holotype (See also Pl. 18, fig. 1), GK-D50204, from loc. Ya. 116.
2, 3. Transverse sections of paratypes, GK-D50208 and 50214, respectively, from loc. Ya. 116.
4, 5. Slightly oblique sections of immature parts of a paratype, GK-D50221, from loc. Ya. 116.
6. Transverse section of a paratype, GK-D50210, from loc. Ya. 4.
7. Transverse section of an immature part of a paratype, GK-D 50209.
8, 9. Longitudinal sections of paratypes, GK-D50206, from loc. Ya. 116, and 50217, from loc. Ya. 4, respectively.

Photos by KANMERA.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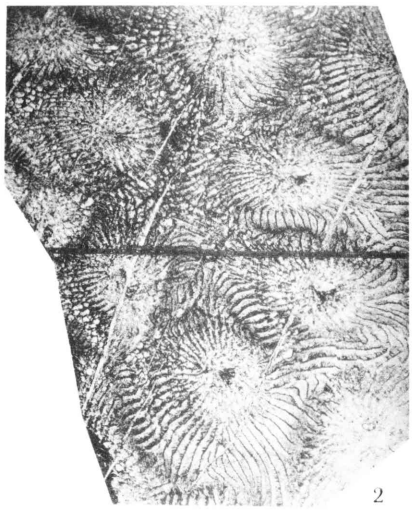
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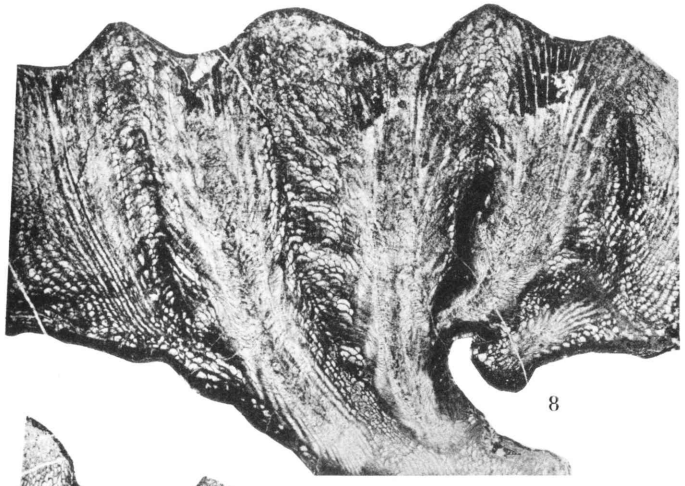
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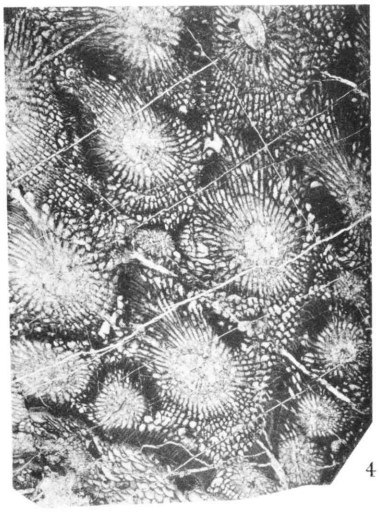
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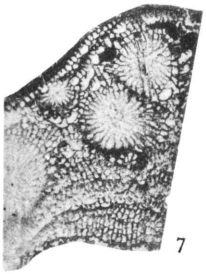
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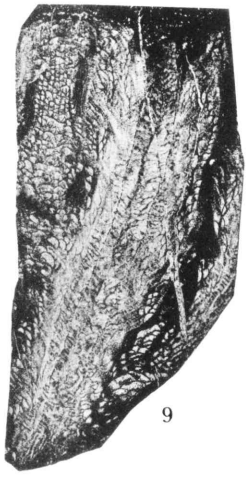
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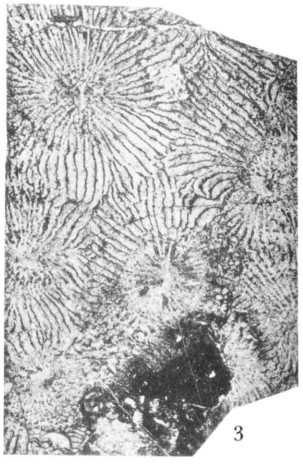
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K. KANMERA: Upper Carboniferous Corals from Yayamadake

Plate 18

Explanation of Plate 18

(All figures, x 2.5; unretouched)

Figs. 1–8. *Pseudopavona crassisepta* n. sp. (See also Pls. 16 and 17)
.....page 224

1–3. Transverse sections of parts of the holotype, GK–D50204, from loc. Ya. 116. 1, 3, mature stages; 2, shows many young corallites arisen in groups. (See also Pl. 17, fig. 1).

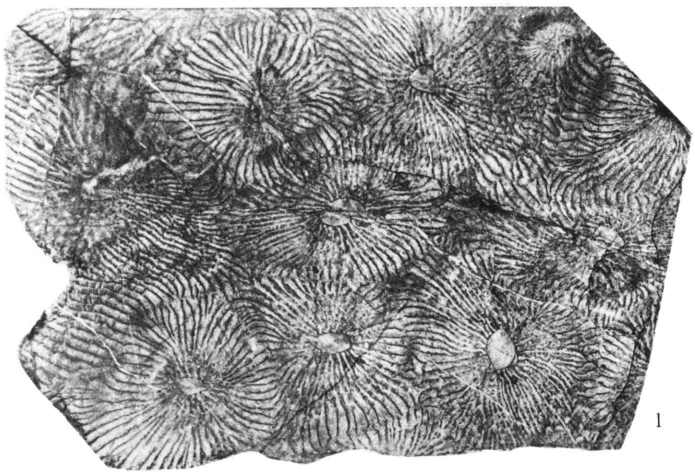
4, 5. Slightly oblique transverse sections of a paratype, GK–D50216 from loc. Ya. 4. 3, early immature stage, 5, late immature stage.

6. Slightly oblique transverse section of an immature paratype, GK–D50215, from loc. Ya.116.

7. Transverse section of an immature paratype, GK–D50207, from loc. Ya. 116.

8. Longitudinal section of a paratype, GK–D50211, from loc. Ya. 4.

Photos by KANMERA.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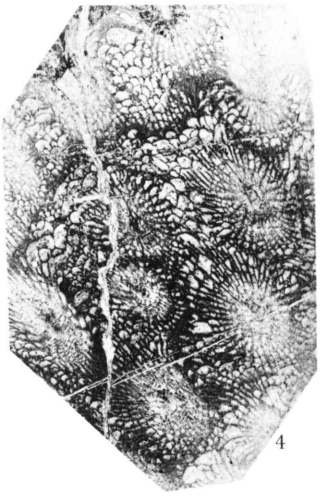
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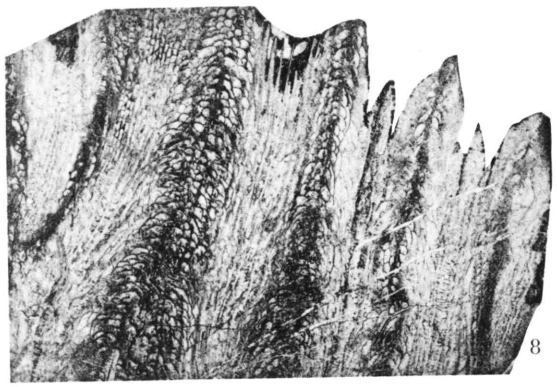
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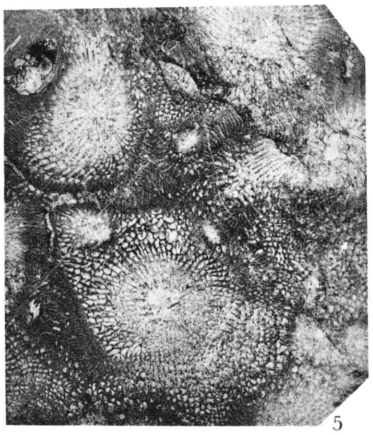
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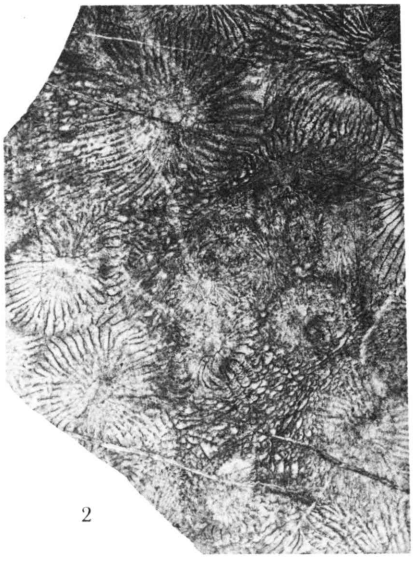
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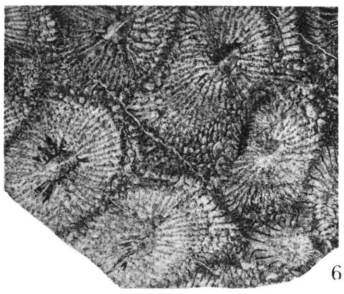
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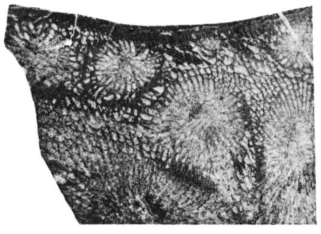
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3

K. KANMERA: Upper Carboniferous Corals from Yayamadake