Wu Ya Sheng

Organisms and Communities of Permian Reef of Xiangbo, China

Calcisponges • Hydrozoans • Bryozoans • Algae • Microproblematica

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Preface

This book intends to make a comprehensive study on all reef-building organisms and communities in a typically developed Middle Permian algal-calcisponge reef in southern China. As a result, 121 species and 86 genera are described, of which 44 genera and 68 species are new. In addition, 12 communities and 7 community-types are recognized. It is the author's wish that this study could establish a basic comparison standard for the Middle Permian reefs of other regions.

The study was started in 1985 and finished in 1987. The field work was done together with Prof. Fan Jia-Song, Prof. Qi Jing-Wen and others. Prof. Fan's materials taken at the same time as mine was published in *Journal of Paleontology*, with the support of Prof. Rigby (1989). However, the publication of my results was delayed because of financial difficulty until its current appearance. Because of the publication of Fan's papers some taxa in my book had to go through revise.

The present publication of the book should be attributed to the support of the following doctors and professors: Dr. & Prof. Fabrizio Bizzarini, Dr. & Prof. Roger J. Cuffey, Dr. & Prof. Jozef Kazmierczak, Dr. & Prof. Donald F. Toomey, Dr. & Prof. Ronald R. West, Dr. Rachel Wood, Prof. Li Xing-Xue, Prof. Liao Shi-Fan, Prof. Liu Bao-Jiu, Prof. Liu Bing-Wen, Prof. Liu Chun, Prof. Sha Qing-An, Prof. Xiang Li-Wen, Prof. Xu Zhi-Chuan, Prof. Xu Wang, Prof. Wu Chong-Yun, Prof. Wu Xi-Chun, Prof. Zeng Ding-Qing, and Prof. Zhang Ji-Yi.

I am indebted to Prof. Fan Jia-Song, who gave me support and help in the study and reviewed some part of the manuscript. Thanks go to Wen Chuan-Fen, Zhang Wei, Sun Xiao-Xing, Wang Jiong-Zhang, Qi Jing-Wen, Zhou Ti-Ming, Wang Jing-Ming, Zhang Xiao-Lin, Xie Gang-Ping, Li Hua for their help during field work, to Ri Lin for his help in identification of fusulinids, to Mo Xi-Nan for his help in identification of algae, to Deng Zhan-Qiu for his copy of document on hydrozoan, to Cheng Ji-Gao and Zhang Yin-Ben for their help in preparation of photographs, to Wu Xi-Chun and Yang Wan-Rong for their encouragement.

I would like to thank Dr. Senowbari-Daryan, Dr. Cheng Gui-Ren and Dr. Rong Xiang for their critical review of the manuscript.

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December 1990

The study of the Xiangbo Permian reef will be of great interest to geologists, paleontologists, or biologists concerned with Late Paleozoic reefs, sponges, bryozoans and algae. Therefore, I hope that this book can be published as soon as possible; there will be many more western scientists who will be able to read it and benefit from the advances made by the Chinese scientists. Fossil reefs of this age are particularly important, both scientifically (because of the stage of evolution of the reef-building fossil organisms represented) and economically (because of their petroleum potential). We would all learn much from being able to compare these Chinese reefs with, for example, the West Texas Permian Capitan reefs.

Dr. & Prof. Roger J. Cuffey

This is a most valuable and comprehensive study, and should be published quickly. This impressive work will extend our knowledge of Middle Permian reef biota tenfold, and indeed is one that all Permian workers will look to for many years to come. I hope the published work would contain some figures on the lithology of the reef, thus aiding foreign workers who are not that familiar with the Chinese Middle Permian succession exposed in southern China. I look forward to seeing this published work with great anticipation!

Dr. & Prof. Donald F. Toomey

This book is the first extensive monograph of a developed Middle Permian reef of southern China. It laid the foundation for understanding the paleontology and paleoecology of the Middle Permian reefs of southern China. Because of the discovery of some gas pools in the Permian reefs of southern China, the study of Permian reefs is most meaningful. Previous studies are mostly concerned with the petrological aspects of the reefs except Prof. Fan's work on sphinctozoans. Thus, this book is the first one concerning the total organisms of a Middle Permian reef. The study on the organisms and communities are profound. The description of 44 new genera and 68 new species makes a great contribution to paleontology, especially to reefal paleontology. This book also contains the paleoecology, petrology and facies of the reef and proposes the new ideas of fabric-facies and fabric-rock-type. Linking reef facies and oil and gas potential, the new approach would be of great importance to the study of ancient reefs and the exploration of reefal resources.

Prof. Xu Zhi-Chuan

The Xiangbo reef is a well-developed and typical one. This book makes a comprehensive systematic study on the reef-building organsims of the reef. Studies on sclerosponges, ino- zoans, sphinctozoans, hydrozoans, bryozoans, algae and microproblematica are detailed and profound; breakthroughs have been made in several groups. Based on the abundant materials and detailed study, the book has established the sequences of organisms, communities and rock-types of the reef, which would become the comparative standards of the Middle Permian reefs of other regions. The book also deals with the lithology and facies of the reef. Therefore, the publication of the book would of be great importance to paleontologists, paleoecologists, petroleum geologists as well as sedimentary petrologists.

Prof. Xiang Li-Wen

Contents

1 Introduction

Reefs are carbonate buildups constructed by organisms or through organic actions.

Reef study includes two aspects: the sedimentological and petrological study of reefs and the paleontological and paleoecological study of reefs. On one hand, reefs are bodies of carbonate rocks. Thus they are the study objects of sedimentary petrologists. On the other hand, reefs are mainly constructed by organisms and composed of skeletons of organisms principally. Thus they are the study objects of paleontologists and paleoecologists as well. To understand reefs fully the two aspects of studies should be combined.

The paleontological and paleoecological study of a reef can be done at three levels: (1) the systematic paleontological studies, (2) population paleoecological studies, and (3) guild paleoecological and community paleoecological studies.

The key to the systematic paleontological study of a reef lies in: (1) the comprehensiveness of the study, that is, all organisms in the reef should be included in the study, and (2) the perfection of sampling method, that is, it should be ensured that all organisms be included in the samples. Sampling method depends on the growth form, size and distribution pattern of organisms in the reef.

Organisms can be divided into reefal organisms and non-reefal organisms. The organisms occurring in reefs are called reefal organisms while those occurring in off-reef environments are called non-reefal organisms. According to their functions in reef formation, reefal organisms can be classified into ten types: (1) framers, (2) bafflers, (3) crybafflers, (4) prebafflers, (5) encrusters, (6) covers, (7) binders, (8) epibionts, (9) dwellers, and (10) destroyers. The framers are calcified organisms which build the framework of reefs. The bafflers are calcified organisms which baffle sediments in reef formation. The crybafflers are non-calcified organisms which baffle sediments in reef formation. The prebafflers are calcified organisms which would have been bafflers if they had been more dense — actually they are too sparse to serve even as bafflers. The encrusters are organisms which encrust on framers or bafflers and strengthen them. The covers are creeping organisms which cover sediments of micrites and bioclasts, protecting them from erosion in reef formation. The binders are filamentous organisms which bind micritic sediments together, protecting them from transporting in reef formation. The epibionts attach to framers, bafflers or prebafflers. The dwellers inhabit the interspaces between framers or bafflers or prebafflers. The destroyers destroy reefs by boring, gnawing or biting soft or hard tissue of reef-building organisms.

Reefal organisms differ from non-reefal organisms in their low tolerance for environmental fluctuation and their high productivity. According to their occurrence probability in reefs, reefal organisms can be divided as the following: (1) in-reefal organisms which occur only in reefs, (2) pre-reefal organisms which prefer reefs to off-reef environments, (3) iso-reefal organisms which can occur in both reef and non-reef environments, and (4) out-reefal organisms which prefer non-reef environments to reefs. It is clear that reefs are mainly constructed by in-reefal and pre-reefal organisms.

Reef-building organisms vary in taxonomic composition with geological time. It is known that Precambrian reefs are mainly constructed by thallophyte; Cambrian reefs are mainly constructed by archaeocyatha and algae; Ordovician reefs are mainly constructed by algae and calcisponges; Silurian reefs are mainly constructed by sclerosponges (included in stromatoporoids previously) and corals; Devonian reefs are mainly constructed by sclerosponges (included in stromatoporoids previously) and corals; Carboniferous reefs are mainly constructed by bryozoans and phylloid algae; Permian reefs are mainly constructed by calcisponges, algae, hydrozoans and extrohydrozoans, and Tubiphytes. These are the cases in China. Post-Triassic reefs are not developed in China although they are reported from Europe to be mainly constructed by hexactiniarians, calcisponges, demosponges, Hippuritacea, algae and oysters.

The reefal organisms in Permian reefs include sclerosponges, inozoans, sphinctozoans, hydrozoans and extrohydrozoans, calcareous algae, bryozoans and microproblematica. Among them, sclerosponges, inozoans, hydrozoans and extrohydrozoans and microproblematica are poorly studied. To advance Permian reef study level, the study of these groups is necessary. In recent years a lot of work has been done on sphinctozoans by researchers such as Senowbari-Daryan, Rigby and Fan. But little work has been done on the above poorly studied groups. Thus it is necessary for us to carry on the study on these groups as soon as possible.

Population, guild and community paleoecological study of reefs are the important ways for determining the development and distribution pattern of reefs and for giving directions to oil and gas survey and exploration. Only in the case that reef-building organisms have been dealt with at guild and community levels can the internal features of reefs be understood in full. The community paleoecological study of reefs depends on sampling method. Only in the case that sufficient samples from outcrops are available can the community paleoecological study of reefs be practicable. Only the organisms of a reef has been studied thoroughly can its community paleoecological study be possible. Because some Permian reef-building organisms are poorly studied the community paleoecological study of Permian reefs has been impractical. The goal of community paleoecological study of reefs is to erect the typical communities of reefs of different geological age and of different geographic scales or different regions.

Permian reefs include algal-calcisponge reefs, *Tubiphytes*-algal crust reefs, stromatolite reefs, bryozoan-algal reefs, *Palaeoaplysina* reefs and phylloid algal reefs (Flugel et al, 1984). The most developed algal-calcisponge reefs are distributed in China, USA, Tunisia and Yugoslavia. As to both preservation state and development degree are concerned, the Permian reefs of China are the most typical. The Permian reefs in China are mainly distributed in Guangxi, Guizhou, Yunnan, Hubei, Sichuan, Hunan, Shanxi and Zhejiang provinces. It is known that the reefs of Ziyun, Guizhou and of Xiangbo, Longlin, Guangxi are the most typical of them. These two reefs are not only well developed but also well exposed. For these reasons, the present study focuses on the reef of Xiangbo, Longlin, Guangxi, or Xiangbo reef for short.

In the November and December of 1985, field work was done on the reef of Xiangbo. Two stratigraphic sections through the reef were measured. More than 400 hand specimens were taken from the outcrops along the sections. More than 400 large thin sections were made by the present author.

Based on all of the materials, the following work has been done: (1) the study of Permian reef-building organisms such as sclerosponges, inozoans, hydrozoans and extrohydrozoans, algae and microproblematica, (2) the identification and description of all organisms in the reef, 86 genera and 121 species — including 44 new genera and 68 new species, (3) the study of the guild and community paleoecology and community replacement of the reef, 7 community-types and 12 communities recognized, and (4) the establishment of a column of organisms and of communities for Middle Permian algal-calcisponge reefs. Besides, a new approach to the classification and description of reef rocks and to the facies division of reefs, i.e., the fabric-rock-types and fabric-facies of reefs, is proposed and 6 fabric-rock-types and 13 element-rock-types are recognized in the reef. The taxonomic composition of the organisms described in the study is illustrated in Table 1.

Table 1. The taxonomic composition of the organisms described in the study

Group	Genera	New genera	Species	New species	New families
Sclerosponge	14	11	18	15	1
Inozoan	15	8	25	14	7
Sphinctozoan	19	6	21	9	6
Hydrozoan & extrohydrozoan	6	6	9	7	0
Bryozoan	7	0	15	1	0
Algae	17	6	20	10	1
Microproblematica	8	7	13	12	5
Total	86	44	121	68	20

2 General Features of Xiangbo Reef

I. Geological Setting and Stratigraphy

The reef studied is located at Xiangbo, a small village 40 km NW of Longlin County, Guangxi Province, southern China (Fig. 1). It crops out on the hills 3 km northeast of Xiangbo village. The outcrops cover a area of more than 10 km^2. Structurally, the outcrops are distributed on the southwestern flank and west nose of Anran anticline (Fig. 2).

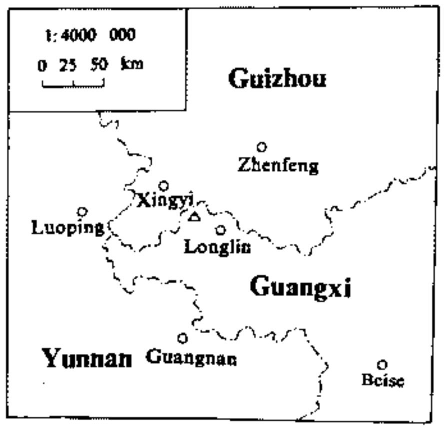


Fig. 1 Location of the reef of Xiangbo, Longlin, Guangxi, southern China. △: Xiangbo; ○: county.

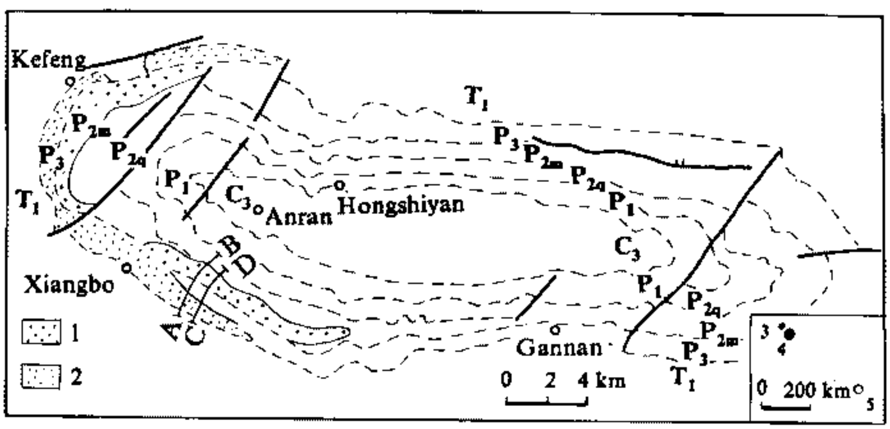


Fig. 2 Distribution of the outcrops of the reef of Xiangbo on the Anran structure. 1: outcrops of the Middle Permian part of the reef; 2: outcrops of the Upper Permian part of the reef; 3: Xiangbo; 4: Longlin; 5: Nanning. A–B, C–D: stratigraphic sections. P_1: Lower Permian; P_{2q}: Middle Permian Qixia Stage; P_{2m}: Middle Permian Maokou Stage; P_3: Upper Permian.

The Xiangbo reef is a component reef of the Dianqiangui barrier reef tract (Fig. 3). The barrier reef tract rims approximately the southern margin of the Dianqiangui carbonate platform (Fig. 3). The platform extended from Late Carboniferous to the end of Permian. It was separated from Tethys sea by the Nanpanjiang basin (Fig. 3) bordering its southern margin. During Permian Period shallow water carbonate sediments were deposited on Dianqiangui platform while deep water carbonate sediments, siliceous sediments and carbonate turbidite were formed in Nanpanjiang basin. Along the southern margin of the platform a series of algal-calcisponge reefs were developed during Middle and Late Permian, typically at Longlin, Ceheng, Wangmo, Ziyun, comprising a barrier reef tract extending for about 1000 km. Xiangbo reef is a typical reef comprising the barrier reef tract.

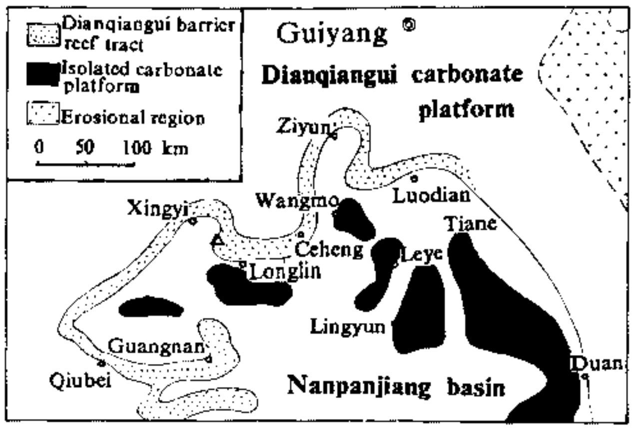


Fig. 3 Paleogeographical setting of the reef of Xiangbo, Longlin, Guangxi, China. △: The reef of Xiangbo.

The Xiangbo reef was mainly developed during Middle Permian Maokou Stage and Upper Permian Changxing Stage. The Permian of China is divided into three series and six stages: Lower Permian Maping Stage and Liangshan Stage, Middle Permian Qixia Stage and Maokou Stage, and Upper Permian Wujiaping Stage and Changxing Stage. Characterized by fusulinids such as *Cancellina, Verbeekina, Neoschwagerina, Yabeina* and *Neomisellina*, the Middle Permian Maokou Stage of China is correlated to the Guadalupian of USA. The Upper Permian Wujiaping Stage is characterized by fusulinids such as *Codonofusiella*. Thus it can be correlated with the Djulfian. The Upper Permian Changxing Stage is characterized by fusulinids such as *Palaeofusulina*. Thus it can be correlated to the Dorashamian. The division and fusulinid zones of Permian of China and their correlation with those of other regions are illustrated in Table 2.

Two stratigraphic sections from the top of the Qixia Stage to the top of the Changxing Stage, through the sequence of Xiangbo reef were measured. The main features of them are summarized in Fig. 4. As seen from the figure, Xiangbo reef includes two reefal phases: the Middle Permian Maokou part and the Upper Permian Changxing part. They are separated by the non-reefal interval of Wujiaping Stage. The present study is concentrated on the Maokou part of the reef. Thus, in the following sections or chapters the Xiangbo reef or the reef of Xiangbo means only the Middle Permian Maokou part of the reef.

Table 2 Division and fusulinids of Permian of China and their correlation with those of other regions

Series	China		Other regions
	Stage	Fusulinid zone	Stage
Upper Permian	Changxing	*Palaeofusulina*-zone	Dorashamian
	Wujiaping	*Codonofusiella*-zone	Djulfian
Middle Permian	Maokou	*Neoschwagerina*-zone *Cancellina*-zone	Guadalupian
	Qixia	*Misellina*-zone	Leonardian
Lower Permian	Liangshan	*Pamirina*-zone	?
	Maping	*Pseudoschwagerina*-zone	Walfcampian

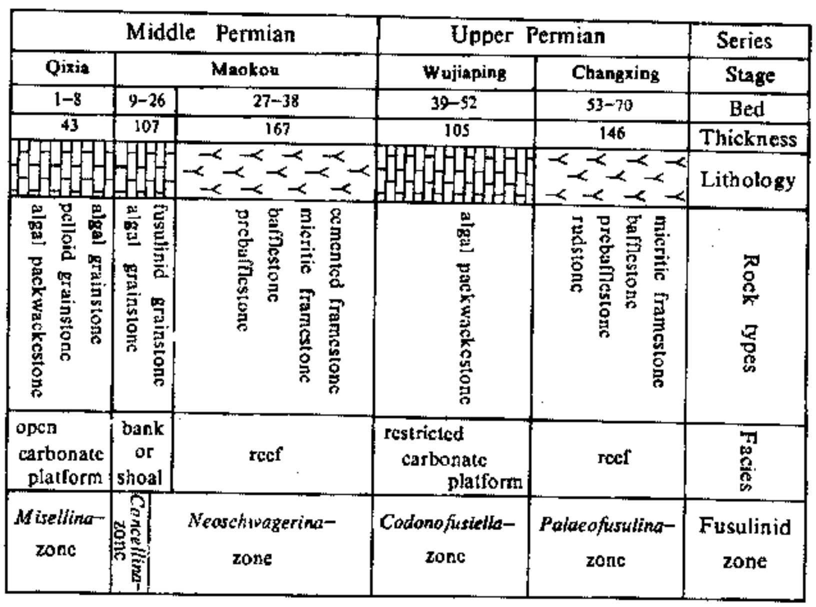


Fig. 4 Main features of the stratigraphical sections of the reef of Xiangbo, Longlin, Guangxi, China.

II. Fabric-rock-types

The classical classification of reef rocks was erected by Embry and Klovan (1971). Their classification was followed by many reef researchers. However, the classification has the following shortcomings: (1) the standards for the classification are indistinct, (2) the description of reef rocks is cyclic, and (3) some rock types are not included. According to previous researchers such as Embry and Klovan, a more systematical scheme is proposed herein. In the scheme rocks are classified only according to their fabric. The rock types in my classification are called fabric-rock-types. Up to the present, 12 types of reef fabric have been recognized (Table 3). Thus, only 12 main fabric-rock-types have been recognized (Table 3).

Table 3 Fabric types and fabric-rock-types of reef rocks

Fabric types	Diagnosis	Fabric-rock-types
Framed fabric	With framework	Framestone
Baffled fabric	With bafflers	Bafflestone
Prebaffled fabric	With prebafflers	Prebafflestone
Crybaffled fabric	With crybafflers	Crybafflestone
Covered fabric	With covers	Coverstone
Bound fabric	With binders	Bindstone
Segmented fabric	With disarticulated segments of framers	Segment stone
Ruded fabric	Composed of reef rock fragments	Rudstone
Floated fabric	Containing some reef rock fragments "floated" in matrix	Floatstone
Sandgraved fabric	Reef rock gravels over 50% and reef rock sands below 50%	Sandgravstone
Gravsanded fabric	Reef rock sands over 50% and reef rock gravels below 50%	Gravsandstone
Boulded fabric	Composed of reef rock boulders above 0.1 m across	Bouldstone

The framestone can be further divided into subtypes as in Table 4.

An alternative division of framestone is first to divide it into 4 subtypes: cemented framestone, cecrusted framestone, micritic framestone, and micrusted framestone. These four subtypes can be further divided into more subtypes according to the form of framers (Table 5).

In the new names of the fabric-rock-types in the divisions, the following abbreviations are used: mic = micritic, ce = cemented, mas = massive, bra = branched, colu = columnar, morphic = diversified morphologically, crusted = encrusted, cecrusted = cemented + encrusted, micrusted = micritic + encrusted.

Table 4 The division of framestone

Fabric types	Diagnosis	Fabric-rock-subtypes
Cemassive framed fabric	Sparry cemented; massive framers	Cemassive framestone
Cebranched framed fabric	Sparry cemented; branched framers	Cebranched framestone
Cecolumnar framed fabric	Sparry cemented; columnar framers	Cecolumnar framestone
Cemorphic framed fabric	Sparry cemented; framers diversified in form	Cemorphic framestone
Cemascrusted framed fabric	Sparry cemented; massive, encrusted framers	Cemascrusted framestone
Cebracrusted framed fabric	Sparry cemented; branched, encrusted framers	Cebracrusted framestone
Cecolucrusted framed fabric	Sparry cemented; columnar, encrusted framers	Cecolucrusted framestone
Cemorphicrusted framed fabric	Sparry cemented; encrusted framers diversified in form	Cemorphicrusted framestone
Micmassive framed fabric	Micritic fillings; massive framers	Micmassive framestone
Micbranched framed fabric	Micritic fillings; branched framers	Micbranched framestone
Miccolumnar framed fabric	Micritic fillings; columnar framers	Miccolumnar framestone
Micmorphic framed fabric	Micritic fillings; framers diversified in form	Micmorphic framestone
Micmascrusted framed fabric	Micritic fillings; massive, encrusted framers	Micmascrusted framestone
Micbracrusted framed fabric	Micritic fillings; branched, encrusted framers	Micbracrusted framestone
Miccolucrusted framed fabric	Micritic fillings; columnar, encrusted framers	Miccolucrusted framestone
Micmorphicrusted framed fabric	Micritic fillings; encrusted framers diversified in form	Micmorphicrusted framestone

Table 5 The second division of framestone

Cemented framestone	Cemassive framestone Cecolumnar framestone Cebranched framestone Cemorphic framestone
Cecrusted framestone	Cemascrusted framestone Cebracrusted framestone Cecolucrusted framestone Cemorphicrusted framestone
Micritic framestone	Micmassive framestone Micbranched framestone Miccolumnar framestone Micmorphic framestone
Micrusted framestone	Micmascrusted framestone Micbracrusted framestone Miccolucrusted framestone Micmorphicrusted framestone

Fabric-rock-types can be subdivided into element-rock-types according to the taxonomic types of the skeletal component in them.

In Xiangbo reef, the fabric-rock-types and element-rock-types recognized are as follows.

1. Framestone

(1) Cemorphic framestone

Diagnosis: Sparry cemented; framers massive, coniform, or spherical generally (Fig. 5A). The element-rock-type included is sponge cemorphic framestone in which sclerosponges, inozoans, sphinctozoans and some hydrozoans are framers.

(2) Cemorphicrusted framestone

Diagnosis: Sparry cemented; encrusted framers columnar, conical, spherical or in other forms (Fig. 5B). The element-rock-type included is sponge cemorphicrusted framestone in which the framers are sclerosponges, inozoans, sphinctozoans and some hydrozoans.

(3) Cecolucrusted framestone

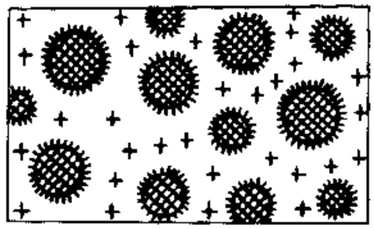
Diagnosis: Sparry cemented; framers columnar and encrusted (Fig. 5C). The element-rock-types included are (A) *Archaeolithoporella-Monostysisyrinx* cecolucrusted framestone in which *Archaeolithoporella* is the encruster while *Monostysisyrinx* is the framer, (B) *Archaeolithoporella-Peronidella* cecolucrusted framestone in which *Archaeolithoporella* is the encruster while thin columnar inozoan *Peronidella* and sphinctozoan *Sollasia* and some other sponges are framers.

(4) Micmorphicrusted framestone

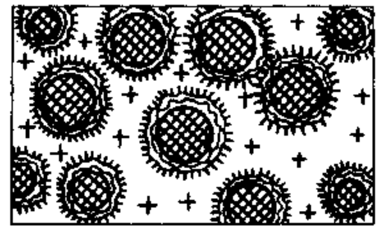
Diagnosis: Micritic interstitial materials; encrusted framers diversified in form (Fig. 5D). The element-rock-type included is sponge micmorphicrusted framestone in which the framers are sclerosponges, inozoans, sphinctozoans and hydrozoans, diversified in form.

(5) Micmorphic framestone

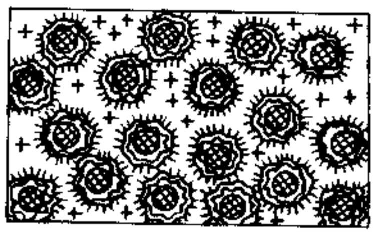
Diagnosis: Micritic interstitial materials; framers massive, coniform, or spherical (Fig. 5E). The element-rock-type included is sponge micmorphic framestone in which sclerosponges, inozoans, sphinctozoans and some hydrozoans are framers.



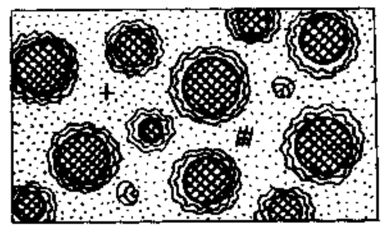
A. Cemorphic framestone



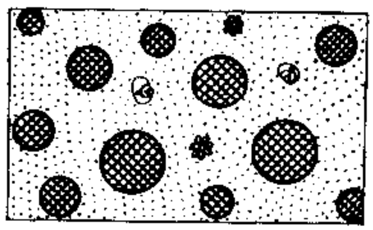
B. Cemorphicrusted framestone



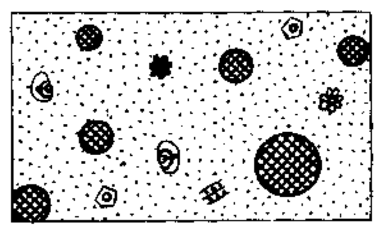
C. Cecolucrusted framestone



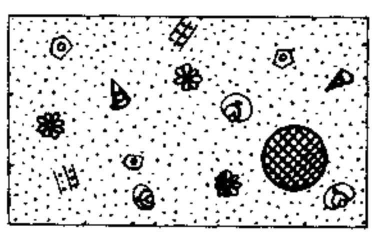
D. Micmorphicrusted framestone



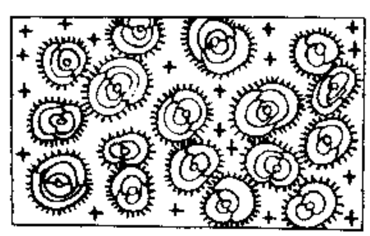
E. Micmorphic framestone



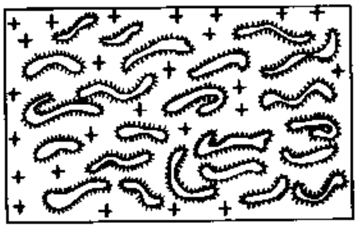
F. Bafflestone



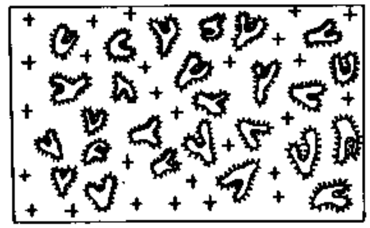
G. Prebafflestone



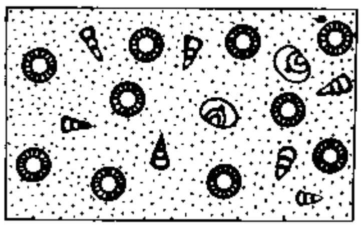
H. Fusulinid grainstone



I. Phylloid algal grainstone



J. *Anthracoporella* grainstone



K. Foraminifera-dasyclad packwackestone

Fig. 5(A–K) Main fabric-rock-types and element-rock-types in the reef of Xiangbo, Longlin, Guangxi, China. : framer or baffler or prebaffler; : encrusters; : *Tubiphytes;* : fusulinid; : phylloid alga; : dasyclad; : micrites; : *Anthracoporella;* : foraminifera; : sparry cements.

2. Bafflestone

It has baffled fabric (Fig. 5F). The element-rock-type included is sponge bafflestone in which sclerosponges, inozoans, sphinctozoans and some hydrozoans are bafflers.

3. Prebafflestone

It has prebaffled fabric (Fig. 5G). The element-rock-type included is *Tubiphytes*-sponge-prebafflestone in which sclerosponges, sphinctozoans, inozoans and hydrozoans are prebafflers while *Tubiphytes* is the main dweller.

4. Floatstone

It has floated fabric.

5. Grainstone

It follows Dunham's definition. It includes three types: (1) fusulinid grainstone (Fig. 5H), (2) phylloid algal grainstone (Fig. 5I), and (3) *Anthracoporella* grainstone (Fig. 5J).

6. Packwackestone

It includes Dunham's packstone and wackestone. It includes the foraminifera dasyclad packwackestone (Fig. 5K).

The sequence of the fabric-rock-types in the reef of Xiangbo is illustrated in Fig. 39.

III. Fabric-Facies

Facies division is an important aspect of sedimentary petrologic study of reefs. Traditionally, reefs are divided into two parts: reef core and reef flank, or into three parts: reef core, reef front and reef back. This division is too simple to reveal the variation of reef features in different parts of a reef. Recently, the method of microfacies analysis is applied to reef study. However, this method has a too small visual field to be adequate for the study of reefs which are often composed of large skeletons of organisms. For these reasons, a new method for dividing reef facies is suggested herein, i.e., the fabric-facies division of reefs. The fabric-facies of reefs are defined as the distribution areas of fabric-rock-types. For example, the distribution area of the framestones in a reef is defined as the framed facies of the reef; and that of the bafflestone is called baffled facies; and those of the others are on the analogy. In Recent and ancient reefs, 12 fabric-rock-types have been recognized. Thus, 12 types of fabric-facies can be recognized totally in Recent and ancient reefs (Table 6). Besides, the distribution area of packwackestones related to reefs is defined as packwacked facies, and that of grainstones as grained facies for unity.

Table 6 The fabric-facies of reefs

Fabric-facies type	Distribution area of	Fabric-facies type	Distribution area of
Framed facies	Framestone	Segmented facies	Segmentstone
Baffled facies	Bafflestone	Ruded facies	Rudstone
Prebaffled facies	Prebafflestone	Floated facies	Floatstone
Crybaffled facies	Crybafflestone	Sandgraved facies	Sandgravstone
Covered facies	Coverstone	Gravsanded facies	Gravsandstone
Bound facies	Bindstone	Boulded facies	Bouldstone

The fabric-facies is between traditional reef facies units (two-divided or three-divided units) and standard microfacies in scale. This division can more thoroughly reveal the internal features of reefs and their spatial variation.

The Xiangbo reef can be divided into 6 types of fabric-facies.

1. **Framed facies** It is the distribution area of the framestones.
2. **Baffled facies** It is the distribution area of the bafflestone.
3. **Prebaffled facies** It is the distribution area of the prebafflestone.
4. **Floated facies** It is the distribution area of the floatstone.
5. **Grained facies** It is the distribution area of the grainstones.
6. **Packwacked facies** It is the distribution area of the packwackestone.

All groups of reef-building organisms in Xiangbo reef will be dealt with in Chapter 3 through Chapter 9 respectively. Then, the guild and community paleoecology of the reef are studied in Chapter 10. Finally, the horizons of all the reafal organisms and the guilds they belong to are given in Chapter 11.

All the species described in Chapter 3 through Chapter 9 are based on thin sections and hand specimens, with only section numbers listed, and all the species are from the Middle Permian Maokou Stage *Neoschwagerina*-zone of Xiangbo reef.

3 Sclerosponges

Sclerosponges are the most important reef-building organisms in the reef of Xiangbo. They are also the most poorly studied one of the Permian reef-building groups.

I. Research History

Sponges with siliceous spicules and a calcareous basal skeleton were first described at the beginning of this century (Lister, 1900; Kirkpatrick, 1910, 1911; Hickson, 1911, 1912). After that, this kind of organisms were forgotten for over half a century. In the late 1960s, this kind of enigmatic organisms were rediscovered in the fore-reef slopes of Jamaica (Hartman & Goreau, 1969, 1970). This discovery has opened a new era for the study of this kind of organisms.

After detailed studies of the specimens from Jamaica, a new class, Sclerospongiae, was established by Hartman & Goreau in 1970 to contain this kind of organisms. Since then, more sclerosponges have been described (Hartman, 1979; Hartman & Goreau, 1972, 1975, 1976; Mori, 1976, 1977; Cuffey, 1979; Cuif, 1974, 1979; Dieci et al, 1974, 1977; Gray, 1980; Kazmierczak, 1974, 1979, 1984), most of which are living ones. In addition, some chaetetids, some tabulatae and some stromatoporoids have been recognized as sclerosponges because of the discoveries of spicule evidences in their skeletons.

Up to now, 7–9 Mesozoic genera of sclerosponges have been reported. Besides, 6 Mesozoic stromatoporoids and 1 Mesozoic chaetetid have been recognized as sclerosponges because of spicule evidences in them. No reliable Paleozoic sclerosponges have been reported except that 1 Paleozoic chaetetid and 1 Paleozoic tabulate have been placed in Sclerospongiae because of spicule evidences.

The scarcity of Paleozoic sclerosponges described means that there are some difficulties in the study of Paleozoic sclerosponges. It is known that spicule evidences are more likely to be preserved in Mesozoic sclerosponges than in Paleozoic ones. And spicule evidences are absent from most fossil sclerosponges, especially from Paleozoic ones. Thus, the main problem in the study of Paleozoic sclerosponges is to determine the standards for the identification of those sclerosponges without spicule evidences preserved.

II. Standards for Identification of Sclerosponges

Sclerosponges are characterized by siliceous spicules and a calcareous basal skeleton which is covered by a veneer of soft tissue. Thus, living sclerosponges can be recognized according to the features of spicules, basal skeletons and even soft tissue. However, this is not the case of all fossil sclerosponges.

What are the criteria for recognizing a fossil sclerosponge? The first one, also regarded as the most important one by most sclerosponge researchers is the spicules, their presence or absence, and their types if present. It is clear that when sclerosponge-type spicules (siliceous, acanthostyles, acanthostrongyles, or tylostyles as megascleres or spirasters as microscleres) are found in a calcareous fossil, the sclerosponge nature of the fossil is easy to determine. Unfortunately, however, only in a few fossil sclerosponges can spicules be preserved. This is due to two facts: (1) some sclerosponges have spicules only in their soft tissue (e.g., *Acanthochaetetes wellsi*), and (2) spicules embedded within calcareous basal skeletons are chemically unstable and apt to suffer from erosion. It is found that only in special environments (e.g., stagnant environments) might spicules be preserved (Kazmierczak, 1979). In fact, up to the present only in a few Mesozoic and few Paleozoic fossil sclerosponges have spicule evidences been found. Therefore, spicules are not a criterion available for the identification of all fossil sclerosponges because of their absence from many fossil sclerosponges, especially Paleozoic reefal ones.

Secondly, the microstructure of skeletons is regarded as a chief criterion by many researchers. However, as found by Wendt (1979, 1984), there is no distinct difference between the microstructure of skeletons of sclerosponges and that of calcareous sponges (i.e., inozoans and sphinctozoans). On the other hand, the type of microstructure can be different among different species of a sclerosponge genus. In addition, the microstructure of sclerosponge skeletons is inclined to be destroyed by diagenetic alterations, thus can not be preserved in all fossils. Therefore, the taxonomic value of the microstructure of sclerosponge skeletons is also limited.

Then, what is the key to the problem? In my opinion, the answer lies in the construction of calcareous basal skeletons.

To discuss this problem, it should be noted that the stromatoporoids with spicule evidences reported as sclerosponges by Wood and Reitner (1986) and as demosponges by Reitner (1987) are also regarded as sclerosponges by the present author. The reason for this is given in the following part. When all spiculate stromatoporoids and chaetetids are taken into account, all known sclerosponges, whether living or fossil ones, can be divided into three types: tube-constructed sclerosponges, pillar-constructed sclerosponges and fibre-constructed sclerosponges.

The tube-constructed sclerosponges are characterized by their tube-constructed skeletons. In the tube-constructed sclerosponges, the calcareous basal skeletons are composed of small tubes or canals (when more or less irregular in form) closely and regularly aggregated. The tubes or canals are generally radially (in columnar or massive forms) or parallely (in encrusting forms) arranged, tabulated or atabulated. Two adjacent tubes or canals share a common wall (Fig. 6A).

The pillar-constructed sclerosponges are characterized by their pillar-constructed skeletons. In pillar-constructed sclerosponges, the calcareous basal skeletons are composed of longitudinal or vertical or radial pillars (when they are rod-like) or vertiplates (when they are plate-like) and horizontal or transversal or concentrical skeletal elements perpendicular to the pillars or vertiplates (Fig. 6B). The transversal or concentric skeletal elements can be crossbars, bridges, laminae, dissepiments or calcifillings. The crossbars are rod-like, perpendicular to the pillars or vertiplates, with one end joined into the pillars or vertiplates and the other end free projecting towards the interspaces between the pillars or vertiplates. When the free ends of two crossbars from adjacent pillars or vertiplates joined together, a bridge is formed. So, a bridge connects two adjacent pillars or vertiplates. The laminae, as previously defined in stromatoporoids, are thin, more or less flat, sheet-like, extending laterally, passing across many, most, or all of the pillars or vertiplates in a basal skeleton. The dissepiments are cystose, generally convex-up, closely and irregularly spaced in the interspaces between pillars or vertiplates. The calcifillings are solid calcareous materials filling the interspaces between pillars or vertiplates.

The fibre-constructed sclerosponges are characterized by their fibre-constructed skeletons. In fibre-constructed sclerosponges, the calcareous basal skeletons are constructed of fibres or parafibres (when they are irregular in form) which are arranged into three-dimensional lattice (Fig. 6C).

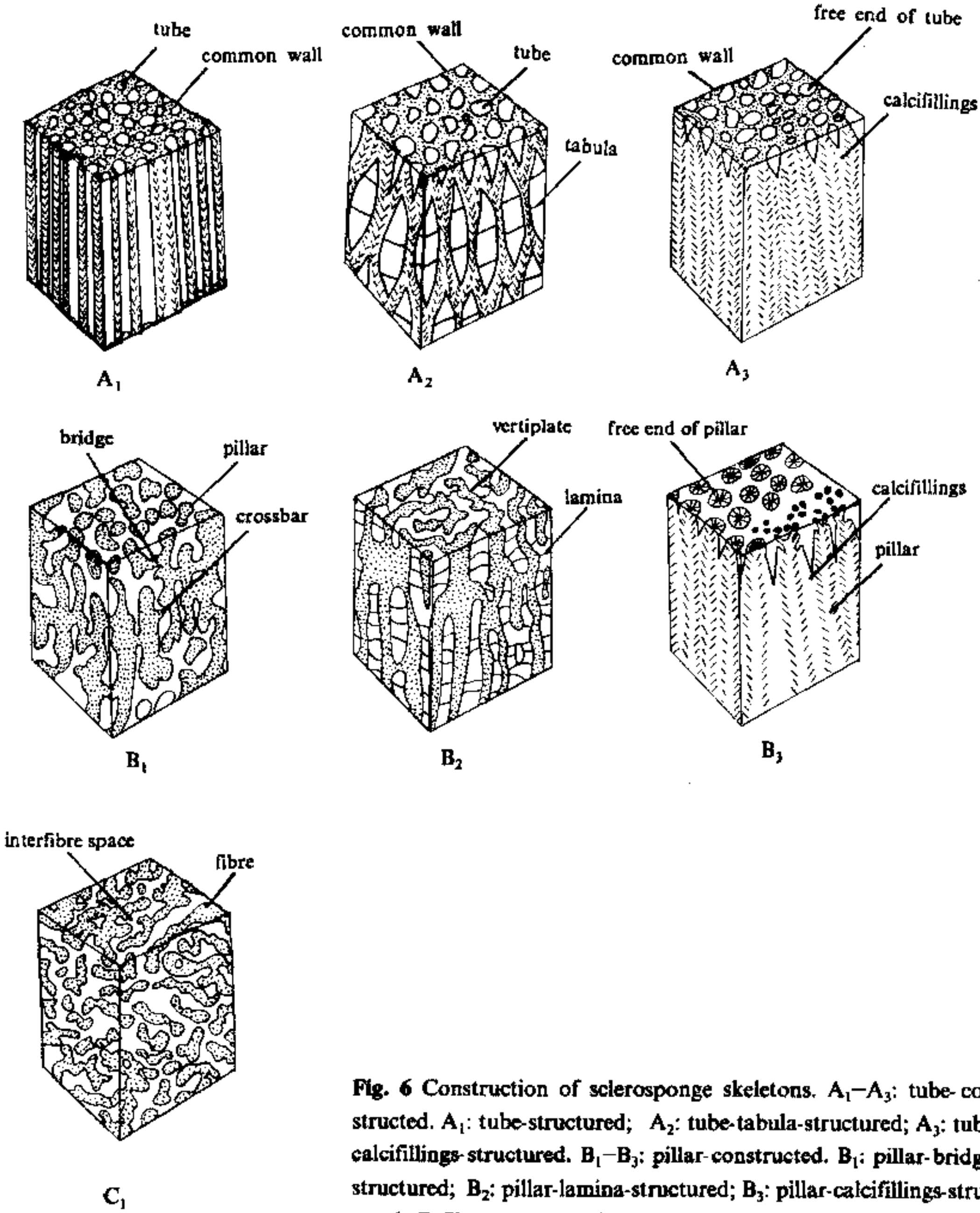


Fig. 6 Construction of sclerosponge skeletons. A_1—A_3: tube-constructed. A_1: tube-structured; A_2: tube-tabula-structured; A_3: tube-calcifillings-structured. B_1—B_3: pillar-constructed. B_1: pillar-bridge-structured; B_2: pillar-lamina-structured; B_3: pillar-calcifillings-structured. C: fibre-constructed.

The tube-constructed sclerosponges can be exemplified by the living genus *Acanthochaetetes* and the fossil genus *Chaetetopsis*; the pillar-constructed sclerosponges can be represented by the living genus *Hispidopetra* and the fossil genus *Euzkadiella*, and the fibre-constructed sclerosponges can take the living genus *Astrosclera* and the fossil genus *Stromatopora* as instances. The construction and terminology of the three types of sclerosponges are illustrated in Fig. 6.

There is no doubt that the construction of the sclerosponge skeletons is determined by their secretion mode which is biologically controlled by their soft tissue. In addition, the construction features of basal skeletons can always be preserved in all fossils. Therefore, it is concluded that the construction of basal skeletons can be used as the chief criterion for the identification and classification of sclerosponges, especially of fossil ones in the absence of spicule evidences.

III. Scheme of Classification

A lot of work has been done by many researchers such as Hartman & Goreau (1980, 1983) on the classification of sclerosponges. However, most of the previous classifications are mainly based on the features of living sclerosponges such as spicules and soft tissue, thus are not always applicable to fossil sclerosponges, especially to those without spicule evidence. Some previous researchers used the microstructure of skeletons as the chief criterion in their classifications. As mentioned above, however, the microstructure of skeletons is not a reliable criterion. Thus, this kind of classifications has some shortcomings. In one word, owing to the recency of the establishment of the class, and hence limited number of fossil sclerosponges described, and owing to the disagreement about the standards for classification, the classification of sclerosponges is far from completion. This is particularly true of those fossil sclerosponges without spicule evidence. Up to date, there is no classification which is applicable to the Paleozoic sclerosponges without spicule evidence. So it is necessary to present a new classification scheme herein in which all living and fossil sclerosponges can find a position even in the absence of spicule evidence.

For reasons mentioned above, the new scheme is mainly based on the construction of basal skeletons. When present or preserved, sclerosponge-type spicules, together with a calcareous basal skeleton are a reliable indication of a sclerosponge, especially a fossil one. When preserved, the microstructure of skeletons may be a helpful criterion in the identification of genera and species. The new classification scheme is as follows.

Class Sclerospongiae Hartman & Goreau, 1970

Definition: Sponges with siliceous spicules and a calcareous basal skeleton which is covered by a thin veneer of soft tissue.The spicules are acanthostyles, acanthostrongyles, or tylostyles as megascleres, or spirasters as microscleres, all within the soft tissue or embedded in the basal skeleton. The basal skeleton can be tube-constructed, pillar-constructed, or fibre-constructed type, aragonite or calcitic. Three subclasses are included.

Geological range: Ordovician to Recent.

Subclass Tubulispongia nov.

Definition: Sclerosponges with a tube (or canal)-constructed basal skeleton. The basal skeleton can be massive, sheet-like, or columnar, composed of small tubes or canals radiating upward from the substrate the sponge attaches to or the grain the sponge encrusts onto. The tubes or canals can be tabulated, or atabulated and empty, or internally filled with calcifillings. Adjacent tubes or canals share a common wall perforated or imperforated. Openings of the tubes or canals make the upper surface of the skeleton honey-combed. Tree orders are included.

Geological range: Ordovician to Recent.

Order Tubulispongiida ord. nov.

Definition: Members of the subclass with a skeleton composed of small tubes or canals atabulated and empty (called a tube-structured skeleton). The common walls between adjacent tubes or canals are often perforated by small pores randomly or regularly arranged. The inner surface of the common walls can be ornamented with small processes.

Family Tubulispongiidae fam. nov.

Definition: As for the order.

Type genus: *Tubulispongia* gen. nov.

Order Chaetetida Okulitch, 1936

Definition (revised): Members of the subclass with a skeleton composed of tabulated small tubes or canals (called a tube-tabula-structured skeleton). The common walls between adjacent tubes or canals are perforated or imperforated. The inner surface of the common walls can be ornamented with spiny processes. Tabulae are regularly or irregularly spaced in the tubes or canals. Only one family is included.

Geological range: Ordovician to Recent.

Discussion: This order was placed in Tabulata in the past. Recently it has been removed to Sclerospongiae by some researchers (Dieci et al, 1977; Kazmierczak, 1979; Gray, 1980) because of the discovery of spicule evidence. This is accepted by the present author. In my opinion, all those chaetetids with a sclerosponge-type skeleton should be regarded as sclerosponges although no spicule evidence has been found in them. According to this principle, most chaetetids are sclerosponges. Thus, it is reasonable to remove this order to Sclerospongiae. Those chaetetids without sclerosponge-type skeleton should be expelled from the order and placed in Tabulata tentatively.

The differences between chaetetid sclerosponges and tabulatae are (1) chaetetid sclerosponges are massive, sheetlike, or columnar, rather than phacelloid, (2) the tubes or canals in chaetetid sclerosponges are relatively small in size, and (3) spicule evidence can never be found in tabulatae.

Three families were erected in the order in the past. They were Chaetetidae Milne-Edwards & Haime (1850), Varioparietidae Schnorf-Steiner (1963), and Acanthochaetetidae Fischer (1970). These families were defined mainly according to the microstructure of skeletons. For the reasons mentioned above, this kind of division is not followed by the present author. Thus, only one family remains in the order.

Geological range: Ordovician to Recent.

Family Chaetetidae Minle-Edwards & Haime, 1850

Definition (revised): As for the order.

Type genus: *Chaetetopsis* Neumayr, 1890

Order Ceratoporellida Hartman & Goreau, 1972

Definition (revised): Members of the subclass with a skeleton composed of small tubes or canals internally filled with calcifillings (called a tube-calcifillings-structured skeleton). The pit-like unfilled distal ends of the tubes or canals make the upper surface of the skeletons honey-combed. One family is included.

Geological range: Upper Triassic to Recent.

Discussion: This order was established by Hartman & Goreau in 1970 to contain all living sclerosponges having a basal skeleton filled with calcifillings internally. Among them, however, some members such as *Hispidopetra* and *Stromatospongia* are pillar (or vertiplate)-constructed rather than tube (or canal)-constructed, thus should be excluded from this order according to the present revised definition of the order.

Family Ceratoporellidae Hickson, 1911

Definition: As for the order.

Type genus: *Ceratoporella* Hickson, 1911

Subclass Columispongia nov.

Definition: Sclerosponges with a pillar (or vertiplate)-constructed skeleton composed of vertical or radial pillars or vertiplates and horizontal or concentrical crossbars, or / and bridges, or laminae, or dissepiments, or calcifillings. The free distal ends of the pillars or vertiplates can make the surface of skeletons meandroid or echinolophate. Three orders are included.

Discussion: Convincing spicule evidences have been found in some stromatoporoids (Wood & Reitner, 1986; Reitner, 1987). These spiculate stromatoporoids were placed in Sclerospongiae (Wood & Reitner, 1986) and Demospongiae (Reitner, 1987). According to the spicule type and the construction of their calcareous skeletons, the present author regards all these stromatoporoids as sclerosponges. Because of the parallel between the pillars and vertiplates (i.e., the irregular pillars) of the typical stromatoporoids (those composed of pillars or vertiplates and lateral or concentrical skeletal elements) and the free ends of pillars and vertiplates projecting above the skeleton surface of the pillar (or vertiplate)-constructed sclerosponges such as *Hispidopetra* and *Stromatospongia*, the typical stromatoporoids are related to pillar (or vertiplate)-constructed living sclerosponges. And they are all grouped into this subclass.

It is interesting to note that the Silurian stromatoporoid *Lophiostroma* bears a skeleton identical to those of the living pillar (or vertiplate)-constructed sclerosponges *Hispidopetra* and *Stromatospongia*.

Geological range: Ordovician to Recent.

Order Euzkadiellida ord. nov.

Definition: Members of the subclass with a skeleton composed of pillars (or vertiplates) and crossbars or / and bridges (called a pillar-crossbar-structured skeleton). The crossbars or bridges are regularly or irregularly arranged. Two families are included.

Discussion: As mentioned above, a stromatoporoid with a spiculate calcareous basal skeleton, *Euzkadiella* was described and placed in Order Haplosclerida (Class Demospongiae, Subclass Ceractinomorpha) by Reitner in 1987 in consideration of its "sclere arrangement characteristic of Order Haplosclerida". However, in my opinion, the spicule type and the presence of the calcareous basal skeleton in the genus are both evidences of its sclerosponge affinity. Because of the special construction of the skeleton in the genus, a new order represented by the genus is established.

Actinostroma-like stromatoporoids bear a calcareous skeleton similar to that of *Euzkadiella*. Thus they are also included in this order.

Family Euzkadiellidae fam. nov.

Definition: Members of the order with a pillar-crossbar-structured skeleton in which the crossbars or / and bridges are irregularly spaced.

Type genus: *Euzkadiella* Reitner, 1987

Family Actinostromatidae Nicholson, 1886

Definition (revised): Members of the order with a pillar-crossbar-structured skeleton in which the crossbars or / and bridges are spaced at the same levels horizontally or concentrically.

Type genus: *Actinostroma* Nicholson, 1886

Order Stromatoporida Stearn, 1980

Definition (revised): Members of the subclass with a skeleton composed of pillars or vertiplates and laminae (called pillar-lamina-structured skeleton). The laminae are generally continuous laterally and can pass across many, most or all of the pillars or vertiplates. One family is included.

Geological range: Ordovician to Cretaceous.

Family Stromatoporidae Winchell, 1867

Definition (revised): As for the order.

Type genus: *Stromatopora* Goldfuss, 1826

Order Labechiida Kuhn, 1927

Definition (revised): Members of the subclass with a skeleton composed of pillars or vertiplates and dissepiments spaced in the interspaces between the pillars or / and vertiplates (called a pillar-dissepiment-structured skeleton). One family is included.

Family Labechiidae Nicholson, 1879

Definition (revised): As for the order.

Type genus: *Labechia* Edwards & Haime, 1851

Order Hispidopetrida ord. nov.

Definition: Members of the subclass with a skeleton composed of pillars or vertiplates and calcifillings internally filling the interspaces between the pillars or / and vertiplates (called pillar-calcifillings-structured skeleton). Only one family is included.

Geological range: Silurian to Recent.

Family Hispidopetridae fam. nov.

Definition: As for the order.

Discussion: The Cretaceous *Murania* Kazmierczak, 1974 is a conspicuous fossil representative of the family. The Silurian stromatoporoid *Lophiostroma* is also included in this family.

Type genus: *Hispidopetra* Hartman, 1969

Subclass Retinispongia nov.

Definition: Sclerosponges with a fibre (or parafiber)-constructed skeleton which is composed of fibres or parafibers (when irregular in form) arranged into three-dimensional lattice. The skeletons are with or without astrorhizae. Only one order is included in it at the present.

Discussion: The subclass includes living members such as *Astrosclera* and *Calcifibrospongia* and fossil ones such as some members of *Stromatopora* which also have a reticulate skeleton.

It is a puzzling fact that no transversal skeletal element has been found within the reticulate skeletons of this subclass.

Geological range: Ordovician to Recent.

Order Astrosclerida ord. nov.

Definition: As for the subclass.

Family Astroscleridae Lister, 1900

Definition: As for the order.
Type genus: *Astrosclera* Lister, 1900

IV. Formation of Skeletons

As has been suggested before, the characteristics of a sclerosponge skeleton are determined by its secretion mode. So, it is significant to discuss the skeleton formation of sclerosponges herein to a moderate extent.

It has been suggested that the siliceous spicules are formed before calcareous skeletons in sclerosponges (Wendt, 1979). This is reasonable because siliceous are generally incorporated in the axial region of skeletal elements, as we know.

According to the construction and microstructure of the sclerosponge skeletons the present author believes that the sclerosponge skeletons are formed in two main stages.

Firstly, the vertical or longitudinal skeletal elements, i.e., the common walls of the tubes or canals in Subclass Tubulispongia, the pillars or vertiplates in Subclass Columispongia, and the fibres or parafibres in Subclass Retinispongia are secreted probably around spicule mats and organic spongin matrixes. For convenience, the skeletal elements formed in the first stage are called primary skeletal elements. According to their form and their orientation within calcareous skeletons, it can be deduced that the primary skeletal elements are secreted only in some parts of the underside surface of the living tissue of sclerosponges. That is to say, only some areas of the underside surface of the living tissue of sclerosponges have the ability to secrete primary skeletal elements. These areas are called precalcifareas. Apparently, the precalcifareas must be regular reticulate in Subclass Tubulispongia with the meshes circular, subcircular or polygonal commonly, be pointlike in pillar-constructed sclerosponges, be vermiform in vertiplate-constructed sclerosponges, and be irregularly reticulate in fibre-constructed sclerosponges as deduced from the shape of the primary skeletal elements. Based on the fact that the top surface of the common walls of the tubes in *Tabulospongia horiguchii* (Mori, 1976, pl. 4, figs. 1, 2) consists of small, hill-like processes, and that the vertiplates in *Stromatopora* (Yabe and Sugiyama, 1935) are beadlike in cross section, it is also assumed that the precalcifarea consists of small, pointlike basic units which are called precalcipoints. Each pointlike precalcifarea consists of one precalcipoint in the pillar-constructed members. The vermiform, the regularly reticulate, and the irregularly reticulate precalcifareas consist of many precalcipoints arranged side by side.

Characters of primary skeletal elements are determined not only by the form of the precalcifareas secreting them but also by the moving mode of the precalcifareas during secretion. In Subclass Tubulispongia, the common walls are secreted by regularly reticulate precalcifareas on the condition that the precalcifareas make only gentle and upward movement. In Subclass Columispongia, the pillars or vertiplates are secreted by pointlike or vermiform precalcifareas on the condition that the precalcifareas move only upward and gently. In Subclass Retinispongia, the fibres or parafibres are secreted by the irregularly reticulate precalcifareas on the condition that the precalcifareas make both upward and lateral irregular motion.

The formation of the transversal skeletal elements (i.e., the tabulae in Subclass Tubulispongia, the crossbars, bridges, dissepiments and laminae in Subclass Columispongia and the calcifillings in the two subclasses) represents the second stage of the formation of sclerosponge skeletons. The skeletal elements formed in this stage are called secondary skeletal elements. It is apparent that the secondary skeletal elements are formed somewhat after the primary skeletal elements.

It is evident that the secondary skeletal elements are secreted by the soft tissue between the precalcifareas. These areas of soft tissue capable of secreting secondary skeletal elements are called subcalcifareas. As deduced from the characteristics of the secondary skeletal elements, the subcalcifareas are generally discretely circular, subcircular, or polygonal in Subclass Tubulispongia, sieve-like with fine meshes, or meandroid in Subclass Columispongia, and discretely irregularly pointlike in Subclass Retinispongia.

Like primary skeletal elements, the type and characters of the secondary skeletal elements are determined by not only the form of the subcalcifareas secreting them but also the motion mode of the subcalcifareas during secretion. In Subclass Tubulispongia, if the subcalcifareas periodically secrete calcareous substances, the tabulae are formed; if they secrete calcareous substances continuously, the calcifillings are formed; if they secrete no calcareous substances, no secondary skeletal element is formed. In Subclass Columispongia, if the subcalcifareas periodically secrete calcareous substance, the crossbars, or bridges, or laminae, or dissepiments are formed; if they secrete calcareous substances continuously, the calcifillings are formed.

It seems that there are certain limits to the size of precalcifareas and subcalcifareas of tube-constructed sclerosponges. During the course of the development of a sclerosponge, the precalcifareas and the subcalcifareas increase in size. When the limit is reached by a precalcifarea between three adjacent meshes, a dead point will appear in the center of the precalcifarea. In the dead point, the soft tissue stops secreting primary skeletal elements and a new subcalcifarea is formed here. It is through the dead point that the cavity of a new tube or canal is formed. This process has been called intramural budding. On the other hand, when the limit is reached by a subcalcifarea, a belt of new precalcifarea which symmetrically divides the subcalcifarea into two parts is formed. And a new common wall will be formed by the new precalcifarea. Eventually, the original tube or canal will be divided into two new ones. This process is what has been called longitudinal fissure. The intramural budding and the longitudinal fissure are the two main ways to produce a new tube or canal in a sclerosponge.

V. Paleoecology

It is known that Recent sclerosponges occur in fore-reef slopes at the depth of 60 to 105 meters, or in the cryptic caves, tunnels and recesses on the upper parts of coral reefs, above 60 meters in depth. When occurring in fore-reef slopes, sclerosponges are important reef formers, commonly framer-builders, while in the shallow-water cryptic environments, they are dwellers. However, this is not the case of Paleozoic sclerosponges.

Paleozoic sclerosponges are important reef framers. In Middle Paleozoic, especially in Devonian, pillar-constructed sclerosponges, especially "stromatoporoids" were numerous and diversified, forming reefs in worldwide scale. In Late Paleozoic, sclerosponges, particularly in Permian, tube-constructed sclerosponges took the role of main reef-builders. In the Middle Permian reef of Xiangbo, sclerosponges are the primary framers, with inozoans and sphinctozoans accessory. According to the measurement made in the field, sclerosponges constitute 43.7–51.2% of the main reef-builders in the reef. It is found that sclerosponges are more abundant in framed facies than in baffled facies. Similarly, in the Upper Permian reefs of Lichuan, Hubei, China, sclerosponges are also important framers.

As we know, "stromatoporoids" are generally large-sized, often up to one to several meters in diameter. It is known that the calcification of hard-bodied organisms can be enhanced via the symbiosis of Zooxanthellae with them. For example, Recent bivalves are commonly small in size, while those in tropical sea can reach large sizes in the presence of symbiotic Zooxanthellae. Thus, it can be deduced that some Devonian stromatoporoid sclerosponges can be with the symbiosis of Zooxanthellae.

According to their occurrence in reefs, Paleozoic sclerosponges should have inhabited normal shallow-water environments. In Permian reefs, sclerosponges are generally accompanied by calcareous algae. Calcareous algae commonly occur in the shallow water environments less than 20 meters in depth. Thus the depth for sclerosponges should be the same. We know that the distinct groove-ridge system and big reef rock blocks are formed near sea level in Recent coral reefs. But the groove-ridge system has not been found in Paleozoic reefs. Thus it can be concluded that the Paleozoic sclerosponges inhabited the shallow-water environments at a depth of 5 to 20 meters.

The living habits of sclerosponges have changed in post-Triassic time, probably because they were out-competed by Hexactiniarians which are more adapted to shallow-water reefal environments. It seems that sclerosponges were accessory reef-formers in Mesozoic.

VI. Geological Range and Evolutionary Tendency

Sclerosponges appeared in Ordovician. As early as in Ordovician, tube-, pillar- and fibre-constructed sclerosponges came into existence. In Middle Paleozoic, pillar-constructed sclerosponges (i.e., "stromatoporoids") were abundant numerically and taxonomically, and constructed many reefs over the world. In Late Paleozoic, they declined, but tube-constructed sclerosponges were common and became dominant reef-formers. In Mesozoic, tube- and pillar-constructed sclerosponges became inconspicuous, contributing little to reef formation; and fibre-constructed sclerosponges were most sparse. After Triassic, sclerosponges were gradually excluded from reefs by Hexactiniarians. By the end of Cretaceous, sclerosponges declined again, with some surviving into Cenozoic. In Recent sea, some pillar-constructed, some tube-constructed, and a few fibre-constructed sclerosponges are still present. Ecologically, they are reef-dwellers in the shallow parts of coral reefs, or reef-formers in deeper fore-reef slopes.

From above it can be concluded that the change of living habits from shallow-water reef-builders in Paleozoic to deeper-water fore-reef slope reef-formers or shallow-water cryptic reef-dwellers is an important evolutionary tendency of sclerosponges.

In addition to their ecological habits and roles in reef formation, the skeletal construction of the sclerosponges has also changed with time. In Early and Middle Paleozoic, the transversal skeletal elements can be dissepiments, crossbars or / and bridges, laminae and tabulae. In Late Paleozoic, the transversal skeletal elements are mainly tabulae, or absent. In Cenozoic and Recent sclerosponges, however, the transversal skeletal elements are mainly calcifillings which seems to appear in Silurian, with the tabulae accessory. This change, probably due to the fact that the calcifillings are a kind of more effective supporting facilities related to low rate of calcification, is the second evolutionary tendency in sclerosponges.

VII. Systematic Description

Class Sclerospongiae Hartman & Goreau, 1970
Subclass Tubulispongia nov.
Order Tubulispongiida ord. nov.
Family Tubulispongiidae fam. nov.
Genus *Tubulispongia* gen. nov.

Derivatio nominis: Tubuli (la. = small tube) refers to the tube-constructed skeleton of this genus.

Diagnosis: Skeletons commonly columnar, composed of small tubes diverging upward and outward from the axis of skeletons. The tubes polygonal or subcircular in cross section, normal to skeleton surface. The common walls between adjacent tubes are perforated. The surface of common walls can be smooth, or provided with hill-like or spiny processes. When the pores in the common walls are arranged into vertical rows and the pores of the adjacent common walls spaced at the same levels, the skeleton appears as concentric belts in sections. No epitheca on skeleton surface. The openings of tubes make skeleton surface honey-combed. The microstructure of skeletons is typically spherulitic. New tubes are produced through intramural budding.

Type species: *Tubulispongia concentrica* gen. et sp. nov.

Tubulispongia concentrica gen. et sp. nov.
(pl. 1 / 4, 6)

Derivatio nominis: The species name calls attention to the concentric appearance of skeletons in sections.

Diagnosis: Skeletons large, columnar. Common walls regularly perforated. Skeletons concentric in sections. Tubes 0.25–0.65 mm in diameter.

Section: xb31–1–7 (holotype) and xb31–1–6 (holotype, from the same specimen as 31–1–7), xb33–1–R1–3, xb36–4–12 (paratype).

Description: Skeletons large, columnar, probably branched, generally 20–26 mm in diameter. Branches in holotype 20 mm wide.

Skeletons composed of small tubes arising vertically from skeleton axis, and gradually curving outward, eventually perpendicular to the skeleton surface. Tubes uniform in size and form, subcircular in cross section, ranging 0.25–0.65 mm in diameter along their length. The common walls between adjacent tubes range 0.12–0.30 mm in thickness, regularly perforated by pores 0.17–0.25 mm across. The pores arranged into regular longitudinal rows in common walls, with the pores in a row spaced at a certain interval. The pores in adjacent rows arranged at the same levels. This makes the skeletons appear as concentric belts in sections, which means that each tube bears at least two rows of pores. The concentric belts range 0.75–1.7 mm in width, commonly 1.0–1.2 mm. Adjacent concentric belts range 0.12–0.25 mm apart.

The surface of the common walls not smooth due to the pores and hill-like processes. New tubes produced by intramural budding.

No epitheca; the openings of tubes make skeleton surface honey-combed.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Tubulispongia continua gen. et sp. nov.

(pl. 1 / 1, 7; pl. 6 / 4)

Derivatio nominis: The species name refers to the continuity of the common walls in sections.

Diagnosis: Skeletons columnar. Pores randomly distributed in common walls. The common walls continuous. Skeletons show no concentric appearance in sections. Hill-like, cone-like, or spiny processes well developed on the surfaces of common walls. Tubes 0.25—0.50 mm across.

Section: xb33—1—R1—5 (holotype), xb33—1—16 (paratype), xb36—4—14, xb28—4, and xb36—4—15.

Description: Skeletons large, columnar, 20—25 mm in diameter.

Skeletons composed of small tubes arising vertically from skeleton axis, then gradually curving outward, eventually perpendicular to skeleton surface. Tubes polygonal to circular in cross section, ranging 0.25—0.50 mm in diameter along their length. The common walls range 0.10—0.30 mm in thickness, perforated by pores 0.075—0.200 mm across. The pores randomly arranged, spaced 0.30—0.75 apart. The common walls continuous and skeletons show no concentric appearance in sections, due to the irregular perforation of common walls. The surface of the common walls is provided with hill-like or spiny processes (they are more striking in longitudinal sections). New tubes are added by intramural budding.

Openings of tubes make skeleton surface honey-combed.

Discussion: This species differs from the previous one in the irregular perforation of common walls and the absence of concentric appearance in sections of the former.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Flabellisclera* gen. nov.

Derivatio nominis: Flabell (la. = small fan) refers to the fanlike arrangement pattern of canals in sections.

Diagnosis: Skeletons conical, composed of canals radiating upward from the substrate the sponges attach to. Common walls irregularly perforated, discontinuous in longitudinal sections. Skeleton surface without epitheca. The underside surface of skeletons generally concave-up due to attachment. The microstructure of skeletons unrecognizable due to diagenetic alternation. New canals are produced through intramural budding.

Type species: *Flabellisclera discreta* gen. et sp. nov.

Flabellisclera discreta gen. et sp. nov.

(pl. 2 / 2, 4)

Derivatio nominis: Discret (la. = discontinuous) calls attention to the discontinuity of common walls.

Diagnosis: Skeletons conical, or like a low column with a domed top. Common walls discontinuous in longitudinal sections, irregularly perforated. The diameter of canals and the thickness of common walls range 0.17—0.30 mm.

Section: xb34—7—3 (holotype) and xb35—1—2 (paratype).

Description: Skeletons small, conical or domed columnar in gross form, high triangulate or tongue-like in outline in longitudinal sections, 10—15 mm wide and at least 15—16 mm high. The underside surface of skeletons always concave-up because of attachment onto substrate.

Skeletons composed of small canals radiating upward from the base of skeletons. The canals 0.17–0.37 mm in diameter, extending through the length of skeletons, reaching the side surface of skeletons at an acute angle. The common walls 0.17–0.30 mm thick, irregularly perforated by pores 0.12–0.25 mm across. The pores irregularly arranged. The perforation makes common walls discontinuous in longitudinal sections. The diameter of canals and the thickness of common walls small at the proximal ends, and gradually increasing toward the distal ends. New canals are produced by intramural budding.

The openings of canals make the surface of skeletons honey-combed.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Flabellisclera sp.
(pl. 5 / 1)

Section: xb33–5–5, xb30–3–10.

Description: Skeletons 9–10 mm wide. Their height unknown because of the inadequate direction of the sections.

Skeletons composed of small canals diverging upward from the base of the skeletons. The canals 0.6–0.7 mm across, subcircular in cross section. The common walls 0.20–0.25 mm thick, irregularly perforated.

Discussion: These specimens differ from *Flabellisclera discreta* gen. et sp. nov. in their thicker common walls and the larger diameter of their canals.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Conosclera* gen. nov.

Derivatio nominis: Con (la. = cone) refers to the conical form of skeletons.

Diagnosis: Skeletons conical generally, composed of small, irregular canals diverging upward from the substrate the sponges attach onto. Canals and common walls irregular or vermiform in sections because of irregular perforation. The underside surface of skeletons generally concave-up because of their encrustation on other sponges.

Type species: *Conosclera vermicula* gen. et sp. nov.

Conosclera vermicula gen. et sp. nov.
(pl. 2 / 1, 3)

Derivatio nominis: The species name calls attention to the vermiculate form of the common walls in sections.

Diagnosis: Canals 0.22–0.25 mm across. Common walls generally 0.10–0.17 mm thick, irregularly perforated, vermiculate in longitudinal sections.

Section: xb30–2–7 (holotype) and xb30–8–13 (paratype).

Description: Skeletons small, coniform. The holotype 12.5 mm in diameter and at least 12 mm in height. The underside surface of skeletons generally concave-up, depending on the substrate they attach to.

Skeletons composed of small canals diverging upward from the substrate they attach to. The canals subcircular in cross section, 0.22–0.25 mm in diameter. Common walls variable in thickness in different parts of skeletons, generally ranging 0.10–0.17 mm, perforated by pores 0.20–0.27 mm across. The pores irregularly arranged, making common walls vermiform in longitudinal sections and transversal sections. The microstructure of skeletons is spherulitic.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Gigantosclera* gen. nov.

Derivatio nominis: Gigant (la. = very great) refers to the large diameter of skeletons.

Diagnosis: Skeletons generally large, columnar in form, composed of small canals diverging from skeleton axis, gradually curving outward, and eventually perpendicular to skeleton surface. The canals irregular, discontinuous. Common walls perforated by pores regularly arranged. Adjacent canals laterally communicated at roughly the same levels via the pores. Pores concentrically arranged in longitudinal sections of skeletons. In transversal sections of skeletons, canals circular in outline, unevenly, generally in small patches, distributed. The common walls vary in thickness, from very thin or even interrupted by the pores to as thick as several times of canal diameter. The microstructure of skeletons is trabecular. The openings of canals make the surface of skeletons honey-combed.

Discussion: This genus resembles *Tubulispongia* gen. nov. in growth form, gross size, and the arrangement pattern of canals. However, the discontinuous and more or less irregular form of canals distinguishes it from the latter.

Type species: *Gigantosclera deformis* gen. et sp. nov.

Gigantosclera deformis gen. et sp. nov.
(pl. 1 / 3; pl. 2 / 5, 8)

Derivatio nominis: Deformis (la. = deformed) calls attention to the more or less irregular form of canals.

Diagnosis: Skeletons large, columnar in form. In longitudinal sections, canals somewhat discontinuous, more or less laterally communicated, forming incomplete concentric pattern. In transversal sections, canals appear as pores unevenly distributed, 0.15–0.37 mm across. The common walls vary in thickness from as much as several times of the canal diameter to very small or even disappearing.

Section: xb34–1–3 (holotype), xb34–1–2 (holotype, from the same specimen as xb34–1–3), xb33–6–7, xb34–1–4 (holotype, from the same specimen as xb34–1–3), and xb30–7–7.

Description: Skeletons large, columnar, with a diameter ranging from 35 to 37 mm and a height of over 50 mm.

Skeletons composed of small, more or less irregular canals diverging from skeleton axis, gradually curving outward, eventually perpendicular to skeleton surface. In longitudinal sections of skeletons, canals discontinuous, and more or less laterally communicated via perforation; pores in common walls concentrically arranged, making skeletons appear as incomplete concentric belts. Each concentric belt 0.7–0.9 mm high. In transversal sections of skeletons, canals appear as circular pores 0.15–0.37 mm across, unevenly, generally in patches distributed. The thickness of common walls shown in transversal sections commonly ranges 0.05–0.20 mm, and varying from as thick as several times of canal diameter to very thin, or even completely disappearing, with the adjacent canals merged into commonly vermiform openings. The common walls not uniform in microstructure, trabecular and yellow in color in the peripheral zone of common walls, but granular with trabecular traces and grey in color in the central zone.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Gracilitubulus* gen. nov.

Derivatio nominis: Gracil (la. = fine) and tubulus (la. = small tubes) call attention to the small size of tubes.

Diagnosis: Skeletons columnar, composed of fine tubes diverging from skeleton axis, gradually curving upward and outward, and eventually perpendicular to skeleton surface. Tubes subcircular in cross section. Common walls thin, perforated by small pores. Pores regularly arranged, making common walls dotted-line-like in longitudinal sections or the peripheral zone of transversal sections of skeletons. Skeletons appear as close or open reticulum in the central zone of transversal sections, with the meshes (i.e., the cross sections of tubes) subcircular to subpolygonal in outline, and in some places, adjacent meshes severely communicated, making skeletons meandroid in appearance. Common walls recrystallized, with some remains of spherulitic microstructure. The openings of tubes make the surface of skeletons honey-combed.

Discussion: The genus is characterized by fine tubes, thin common walls and developed perforation.

Type species: *Gracilitubulus perforatus* gen. et sp. nov.

Gracilitubulus perforatus gen. et sp. nov.
(pl. 1 / 5; pl. 2 / 6, 7; pl. 5 / 5)

Derivatio nominis: Perforatus (la. = perforated) refers to the perforation of common walls.

Diagnosis: Skeletons medial to large, columnar. Tubes 0.05–0.12 mm across, evenly and regularly perforated. Common walls dotted-line-like in longitudinal sections and the periphery of transversal sections, but open reticulate in the central zone of transversal sections.

Section: xb28–4–7 (holotype), xb36–4–10, xb33–6–8 (paratype), xb30–5–14, xb28–4–4, xb28–4–3 (paratype), xb27–8–2, and xb33–6–10.

Description: Skeletons medial to large in size, columnar in form, with a diameter of 10–15 mm.

Skeletons composed of fine tubes diverging from skeleton axis, gradually curving outward, eventually perpendicular to skeleton surface. The tubes range 0.05–0.12 mm in diameter, vertically extending in the axial part of skeletons and horizontally in the peripheral part of them. Common walls 0.02–0.07 mm thick, severely perforated by minute pores. The pores 0.04–0.05 mm across, arranged into longitudinal rows. The pores in a row 0.05–0.07 mm apart. In longitudinal sections or the peripheral zone of transversal sections, skeletons appear as subparallel or radiating dotted-lines. In the central zone of transversal sections, skeletons reticulate, with the meshes open, subcircular to polygonal in outline. Where the meshes severely communicated, skeletons tend to be meandroid to vermiform in appearance.

No epitheca; the openings of tubes make skeleton surface fine honey-combed.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Fungispongia* gen. nov.

Derivatio nominis: Fung (la. = mushroom) calls attention to the growth form of the skeletons.

Diagnosis: Skeletons mushroomlike, composed of canals radiating upward from skeleton bases. The canals small, uniform in size. Common walls not smooth, perforated by pores regularly arranged. From the proximal end to the distal end of skeletons, short canals successively arranged, with the proximal ends of lately formed canals intercalating the distal ends of previously formed canals. Both ends of canals tend to taper. Skeletons recrystallized, in some places with the remains of original spherulitic microstructure.

Epitheca present on the side surface of skeletons. The top surface of skeletons perforated by the openings of canals, and often encrusted by lamellar organisms.

Discussion: This genus differs from *Flabellisclera* gen. nov. in the arrangement of canals. It is distinguished from *Conosclera* gen. nov. via the irregular canals and perforation in the latter.

Type species: *Fungispongia circularis* gen. et sp. nov.

Fungispongia circularis gen. et sp. nov.
(pl. 3 / 2, 3, 8)

Derivatio nominis: The species name calls attention to the circular outline of canals in cross section.

Diagnosis: Skeletons large, mushroomlike. Canals circular in cross section, generally 0.25–0.62 mm across. Pores in common walls numerous, arranged into longitudinal rows with a small interval. Adjacent canals often communicated.

Section: xb33–1–14 (holotype), xb33–1–15 (holotype, from the same specimen), xb33–1–13 (paratype), xb34–7–2 and xb33–2–4.

Description: Skeletons large, mushroomlike or reverse conical, with a width of 10–14 mm and a height of more than 32 mm.

Skeletons composed of relatively thick, short canals successively radiating upward, with the proximal ends of the canals lately produced intercalating the distal ends of the canals previously formed. Canals uniform in diameter, commonly tapering toward both ends. In longitudinal sections of skeletons, canals variable in length, generally 3–7 mm, in some place over 10 mm. In transversal sections, canals appear as circular pores 0.25–0.62 mm across, with adjacent pores commonly communicated. Common walls not smooth, ranging 0.12–0.25 mm thick, perforated with subcircular pores arranged into regular longitudinal rows. The pores 0.15–0.30 mm across, spaced 0.20–0.30 mm apart in rows. Skeletons recrystallized into granular calcites, with some remains of original spherulitic microstructure in the form of scattered dark points.

Epitheca present only on the side surface of skeletons, with a thickness of 0.10–0.20 mm. The top surface of skeletons honey-combed because of the openings of canals, and usually encrusted by lamellar organisms.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Order Chaetetida Okulitch, 1936

Family Chaetetidae Milne-Edwards & Haime, 1850

Genus *Bauneia* Peterhaus, 1927

Diagnosis: Skeletons columnar, hemispheric, or encrusting in form, composed of small tabulated tubes. In columnar forms, tubes arise from the axis of skeletons, gradually curving outward, eventually perpendicular to skeleton surface. In hemispheric forms, tubes radiate upward from the base of skeletons. In encrusting forms, tubes normal to the substrate the sponges attach to. Tubes generally increase distally in diameter. Tabulae generally straight, and thinner than common walls. The common walls imperforated, trabecular in microstructure. New tubes are produced by intramural budding. Furcating distal ends of common walls seen in longitudinal sections of skeletons, representing the early stage of tube production. No epitheca on skeleton surface.

Discussion: Members of this genus are commonly described as "tabulozoans". However, the latter is not a formal taxonomic name.

Because of the similarity in morphology, *Preceratoporella* Termier & Termier, 1977 may be a junior synonym of the genus.

Type species: *Monotrypa multitabulata* Deninger, 1906

Age: Middle Permian to Late Jurassic.

Bauneia ampliata sp. nov.

(pl. 1 / 2; pl. 3 / 6; pl. 6 / 8)

Derivatio nominis: Ampliatus (la. = enlarging) refers to the distally increasing diameter of tubes.

Diagnosis: Skeletons generally columnar or occasionally encrusting. Tubes dramatically increasing in diameter distally, generally 0.06–0.15 mm across at their proximal ends, and 0.12–0.25 mm wide at their distal ends.

Section: xb27–7–1 (holotype), xb33–1–R1–11 (paratype), xb33–1–R1–9 (paratype), xb31–1–8, xb33–6–9, xb33–5–17, xb34–1–5, representatively.

Dimensions (mm):

Section no.	DPET	DDET	TPEW	TDEW	TT
xb33–1–R1–14	0.08–0.15	0.15–0.20	0.05–0.07	0.12	0.02
xb33–6–9	0.08–0.24		0.03–0.09		0.03
xb33–1–17	0.10–0.30		0.04–0.06		
xb33–1R1–7	0.12–0.18		0.05–0.10		
xb33–1–R1–9	0.06–0.12	0.14–0.17	0.03–0.06	0.05–0.06	
xb31–1–8	0.08–0.12	0.12–0.22	0.08–0.10	0.05–0.09	0.02
xb35–8–6	0.15–0.20		0.03–0.05		

DPET: the diameter of the proximal ends of tubes; DDET: the diameter of the distal ends of the tubes; TPEW: the thickness of common walls at the proximal ends of tubes; TDEW: the thickness of common walls at the distal ends of tubes; TT: the thickness of tabulae.

Description: Skeletons medial to large, generally columnar in form, with a diameter of up to 30 mm.

Skeletons composed of tabulated small tubes. In columnar forms, tubes begin from the axis of skeletons, gradually curving upward and outward and eventually perpendicular to skeleton surface, and opening into skeleton surface at a high angle (70–90°). In encrusting forms, tubes always normal to the substrate the sponges encrust onto. The encrusting forms often bear hill-like mamelons on their top surface. In mamelons, the tubes tend to be radially arranged. Tubes subcircular to polygonal in cross section, generally pentagonal to hexagonal, ranging 0.06–0.15 mm in diameter at their proximal ends (in the central part of columnar forms or the lower part of encrusting forms), gradually increasing distally, up to 0.12–0.25 mm at their distal ends (in the peripheral part of columnar forms or the upper part of encrusting forms). Common walls imperforated, commonly 0.05–0.10 mm thick, ranging 0.05–0.20 mm. Tabulae straight, 0.02–0.03 mm thick, spaced at an interval generally larger than the diameter of tubes. In some tubes or some part of tubes, the tabulae more densely spaced. The tabulae in adjacent tubes commonly not arranged at the same levels. But in encrusting forms, the tabulae locally spaced at the same levels. The common walls trabecular in microstructure. Borings by some other organisms examined in some specimens. Interruption partings common in encrusting forms.

No epitheca on skeleton surface. Skeleton surface honey-combed. Skeletons sometimes not recrystallized while the accompanied inozoans recrystallized. This shows that the skeletons of this genus is originally composed of magnesium calcites.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Bauneia epicharis sp. nov.

(pl. 5 / 6; pl. 6 / 6)

Derivatio nominis: Epicharis (la. = beautiful) refers to the appearance of skeletons in sections.

Diagnosis: Skeletons generally encrusting. Tubes generally 0.25–0.45 mm across. Tabulae sparse, straight. Common walls straight.

Section: xb27–6–14 (holotype), xb36–4–16, xb27–2–6 (paratype) and xb27–6–15.

Description: Skeletons large, hemispheric, generally encrusting on small skeletal grains of other organisms, with a thickness or height of up to 18 mm and a diameter of up to 35 mm.

Skeletons composed of tabulated small tubes radiating upward from the substrate the sponges encrust on. Tubes polygonal to subcircular in cross section, ranging 0.25–0.45 mm in diameter along their length, randomly partitioned by tabulae thinner than common walls. The tabulae of adjacent tubes not arranged at the same levels. Common walls smooth, imperforated. New tubes are produced by intramural budding.

Discussion: The larger and more constant diameter of the tubes serves to distinguish this species from *Bauneia ampliata* sp. nov.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Parabauneia* gen. nov.

Derivatio nominis: The generic name refers to the similarity of this genus and *Bauneia* in gross form.

Diagnosis: Skeletons domical, successively stacked, attaching to the skeletons of other sponges, composed of relatively thick tubes radiating upward from the substrate the sponges encrust on and normal to. Tubes relatively short, with their diameter dramatically increasing distally. Tabulae partitioning the tubes straight, thinner than common walls. Common walls smooth, imperforated, trabecular in microstructure. New tubes produced by intramural budding. The openings of tubes make the surface of skeletons coarsely honey-combed.

Discussion: This genus differs from *Bauneia* Peterhans, 1927 in the thicker and shorter tubes in the former.

The genus differs from *Permosoma* Jaekel, 1918 in the larger size and the laminated tube walls of the latter.

Type species: *Parabauneia scalariformis* gen. et sp. nov.

Parabauneia scalariformis gen. et sp. nov.
(pl. 3 / 1; pl. 6 / 2, 5)

Derivatio nominis: The species name refers to the arrangement pattern of common walls and tabulae in longitudinal sections of skeletons.

Diagnosis: Skeletons domelike, successively stacked. Tubes generally 0.37–1.5 mm in diameter at their distal ends. Tabulae much thinner than common walls, spaced at an interval similar to the diameter of tubes. In longitudinal sections, tabulae and common walls form scalariform configurations.

Section: xb35–8–6 (holotype), xb37–2–18 (paratype), xb27–6–9, xb31–1–7, and xb27–6–3.

Description: Skeletons domical, successively stacked, encrusting on the skeletons of other sponges, with each dome 1–4 mm high and about 14 mm wide.

Skeletons composed of relatively short and thick tubes radiating upward from the substrates the sponges encrust onto. Tubes polygonal in cross section, partitioned by straight and complete tabulae spaced at intervals varying from 0.5 mm to 0.75 mm. The diameter of tubes apparently increasing distally, up to 0.37–1.5 mm at the distal end. Tabulae 0.03–0.08 mm thick. The tabulae of adjacent tubes not arranged at the same levels. Common walls imperforated, ranging 0.08–0.32 mm in thickness. In vertical sections of skeletons, tabulae and common walls form scalariform configurations, with the upmost tabulae and common walls U-shaped. The openings of tubes commonly covered by plates 0.25 mm thick. Common walls trabecular in microstructure. New tubes produced by intramural budding.

No epitheca on skeleton surface. The surface of skeletons honey-combed because of openings of tubes.

Dimension (mm):

Section no.	DDET	TW	TT	TP
xb27–6–9	0.62–0.75	0.20–0.32	0.075	0.25
xb31–1–7	0.37–0.67	0.075	0.03	
xb31–2–4	0.40–0.62	0.10		
xb33–7–4	0.45–0.65	0.08–0.12		
xb27–6–3	0.45–0.50	0.08–0.17	0.08	
xb35–8–6	0.50–1.00			
xb37–2–18	0.50–1.50			

DDET: the inner diameter of the distal ends of tubes; TW: the thickness of common walls; TT: the thickness of tabulae; TP: the thickness of the covering plate.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Mirispongia* gen. nov.

Derivatio nominis: Miri (la. = odd) refers to the gross form of skeletons.

Diagnosis: Skeletons mushroomlike, composed of slightly irregular canals diverging upward from the base of skeletons. Canals sparsely partitioned by incomplete tabulae. Tabulae irregular in form and arrangement. Adjacent canals communicated by pores scattered in common walls. Common walls spherulitic in microstructure. Epitheca absent from the top surface of skeletons, but present on the side surface.

Discussion: This genus resembles *Fungispongia* gen. nov. in gross form. However, the more or less irregular canals, and especially the presence of the incomplete tabulae distinguish it from the latter.

Type species: *Mirispongia clathrata* gen. et sp. nov.

Mirispongia clathrata gen. et sp. nov.
(pl. 4 / 2, 6, 7)

Derivatio nominis: Clathratus (la. = checked) refers to the skeletal arrangement pattern in longitudinal sections.

Diagnosis: Skeletons large, mushroomlike. Canals subcircular in cross section, generally 0.25–0.75 mm in diameter. Common walls not straight, sparsely perforated. Tabulae sparse. Epitheca present on the side surface.

Section: xb33–5–4 (holotype), xb33–5–3, and xb35–7–2.

Description: Skeletons large, mushroomlike. The holotype 25 mm high, at least 40 mm wide.

Skeletons composed of canals more or less irregular in form. The canals subcircular in cross section, not uniform in diameter, ranging 0.12–1.00 mm across, generally 0.25–0.75 mm in diameter, sparsely partitioned by incomplete tabulae. Common walls not straight, not uniform in thickness, commonly 0.05–0.25 mm thick, randomly perforated by pores, thus discontinuous in longitudinal sections of skeletons. In transversal sections, skeletons reticulate, with the meshes (representing the cross sections of tubes) subcircular in outline. Adjacent canals commonly communicated with each other because of the perforation. Common walls recrystallized into granular calcite, with some remains of spherulitic microstructure.

Epitheca present only on the side surface of skeletons. The top surface of skeletons encrusted by lamellar organisms.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Order Ceratoporellida Hartman & Goreau, 1972

Family Ceratoporellidae Hickson, 1911

Genus *Reticulocoelia* Cuif, 1973

Diagnosis: Skeletons commonly ramose, composed of small tubes diverging outward from the axis of skeletons. The proximal ends of tubes are filled with calcifillings, while the distal ends of tubes remain empty. Common walls spherulitic in microstructure.

Discussion: The original author regarded this genus as a sphinctozoa according to the spherulitic microstructure of common walls. Then, Fois et al (1980) moved it into Inozoa. In my opinion, however, it is more reasonable to assign it to Class Sclerospongiae according to its skeletal construction.

Type species: *Reticulocoelia arborescens* Cuif, 1973

Reticulocoelia sp.
(pl. 3 / 4, 5; pl. 6 / 3)

Section: xb28–4–7, xb30–8–14, and xb28–1–1.

Description: Skeletons small, circular in cross section and elliptical in oblique sections, with a diameter of 1.5 mm.

Skeletons composed of fine tubes diverging outward from the axis of skeletons, gradually curving outward, eventually perpendicular to skeleton surface. In the inner part of skeletons, tubes filled with calcifillings. In the surface of skeletons, the distal ends of tubes remain empty, U-shaped in sections, with a diameter of 0.04–0.12 mm, generally 0.08–0.10 mm across. Common walls inconstant in thickness, generally 0.03–0.04 mm thick at their distal ends. Common walls recrystallized into light-colored calcites in the inner part of skeletons, but spherulitic in microstructure in the peripheral part. The spherulites minute in size.

No epitheca; the surface of skeletons honey-combed.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Keriocoelia* Cuif, 1974

Diagnosis: Skeletons reverse conical, composed of relatively thick tubes radiating upward from the base of skeletons. The proximal ends of tubes are filled with calcifillings, while the distal ends remain empty. Common walls are ornamented with lamellar or multibranching processes, and perforated by large pores. The microstructure of common walls spherulitic. Styliform spicules probably present in skeletons.

Type species: *Keriocoelia conica* Cuif, 1974

Age: Middle Permian to Late Triassic.

Keriocoelia cf. *conica* Cuif, 1974
(pl. 4 / 5)

Section: xb33–8–2.

Description: Skeletons reverse conical, with a height of over 20 mm and a diameter of 22 mm.

Skeletons composed of thick tubes radiating upward from the base of skeletons. Tubes subpolygonal to subcircular in cross section, ranging 0.5–2.0 mm in diameter. The distal ends of tubes empty, communicated with each other through pores. Common walls provided with multibranching spines.

No epitheca; the surface of skeletons roughly honey-combed.

Discussion: The specimen resembles those illustrated by Cuif (1974). But the present one has a larger tube diameter. Because of the inadequate section, little is known about the calcifillings filling the proximal part of the skeleton. Thus, its assignment to *Keriocoelia conica* Cuif, 1974 is uncertain.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Subclass Retinispongia

Order Astrosclerida ord. nov.

Family Astroscleridae Lister, 1900

Genus *Dendrosclera* gen. nov.

Derivatio nominis: Dendr (gr. = tree) refers to the dendroid form of the internal astrorhiza in skeletons.

Diagnosis: Skeletons reverse conical, composed of fibres arranged into irregular lattice. One dendroid astrorhiza present within each skeleton. Astrorhizal canals irregularly furcate and reduce in diameter downward, with their branches gradually curving outward. Both the fibres and interfibre spaces irregular in form and arrangement. Skeletons recrystallized into granular calcites. No epitheca; the surface of skeletons is densely pitted. The pits small and deep.

Type species: *Dendrosclera irregularis* gen. et sp. nov.

Dendrosclera irregularis gen. et sp. nov.

(pl. 3 / 7; pl. 4 / 1,3; pl. 5 / 7; pl. 6 / 1)

Derivatio nominis: The species name refers to the irregular arrangement of the fibres and the interfibre spaces in skeletons.

Diagnosis: Skeletons reverse conical. Fibres densely and irregularly arranged, generally 0.25–0.30 mm thick. Interspaces commonly 0.05–0.50 mm wide. Astrorhizal canals generally 0.5–1.25 mm in diameter.

Section: xb30–8–8 (holotype), xb30–8–9a (paratype), xb36–4–16 (paratype), xb30–8–9b (paratype), xb30–8–7, xb30–9–9.

Description: Skeletons reverse conical, up to 15–20 mm in diameter.

Skeletons composed of fibres arranged into irregular lattice. Both fibres and interfibre spaces variable in form and thickness. Fibres generally 0.25–0.30 mm thick. Interfibre spaces or the meshes of the fibre lattice commonly 0.05–0.50 mm wide.

One dendroid astrorhiza present within each skeleton. The astrorhiza consists of several astrorhizal tubes vertically extending and apart from each other at their upper part, irregularly furcating and rapidly reducing in diameter downward, meanwhile, the branches gradually curving outward. The astrorhizal canals generally 0.5–1.25 mm in diameter, having a maximal diameter of 1.25 mm at their uppermost ends.

No epitheca; the surface of skeletons densely provided with deep pits. The pits polygonal in outline, 0.13 mm wide and up to 0.50 mm deep, 0.075 mm apart. Skeletons recrystallized into granular calcites. The original microstructure unknown.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Parastrosclera* gen. nov.

Derivatio nominis: The generic name refers to the similarity of this genus to *Astrosclera* Lister, 1900 in the gross morphology of astrorhiza and in skeletal construction.

Diagnosis: Skeletons columnar or globular, composed of fibres arranged into lattice. One to several internal astrorhizae present within each skeleton. Astrorhiza, as in *Astrosclera*, consists of vertical tubes parallel to each other and regularly arranged, with their cross sections forming radial configuration in transversal or tangential sections of a skeleton. Skeleton surface without epitheca.

Discussion: In sections, the gross morphology of the astrorhiza of this genus resembles that of *Sestrostomella* Zittel, 1879 (an inozoa). The difference between them is that the astrorhizal canals of the latter are confined to the axial part of the skeleton, close to each other, forming sieve-like rather than radial configuration in transversal sections.

According to the figures, *Precorynella* cf. *crysantheum* (Parona) Termier & Termier, 1977 probably belong to this genus.

Type species: *Parastrosclera singularis* gen. et sp. nov.

Age: Middle Permian to Late Permian.

Parastrosclera singularis gen. et sp. nov.

(pl. 5 / 2, 3)

Derivatio nominis: The species name refers to the single astrorhiza in skeletons.

Diagnosis: Skeletons columnar in form. Within each skeleton present only one astrorhiza. The astrorhizal tubes 0.25–0.40 mm in diameter. Fibres 0.04–0.05 mm thick. The meshes of fibre lattice 0.05–0.08 mm wide. No epitheca.

Section: xb27–6–1 (holotype), xb27–6–2 (paratype), and xb30–8–1.

Description: Skeletons columnar, ranging 10–16 mm in diameter.

Skeletons composed of fine fibres arranged into fine lattice. The fibres 0.04–0.05 mm in thickness. The meshes of the fibre lattice 0.05–0.08 mm wide.

Each skeleton has only one internal astrorhiza. The astrorhiza consists of vertical tubes parallel to each other. The cross sections of the tubes arranged into a stellate configuration in the transversal sections of the skeleton. The configuration consists of 15–20 lines radiating outward from the center, with each line consisting of a row of circular pores (i.e., the cross sections of the vertical tubes) 0.25–0.40 mm across. The configuration extends to the periphery of the skeleton.

No epitheca on the surface of skeletons.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Parastrosclera polystellaris gen. et sp. nov.

(pl. 5 / 4, 8)

Derivatio nominis: Poly (gr. = many) and stellaris (la. = stellar) refers to more than one stellar configurations of astrorhizae in the transversal or tangential sections of skeletons.

Diagnosis: Skeletons large, globular. Each skeleton with several astrorhizae forming several stellate configurations in the transversal sections or tangential sections of the skeleton. Astrorhizal tubes generally 0.25–0.50 mm in diameter. Fibres 0.04–0.05 mm thick. The meshes of fibre lattice 0.08–0.10 mm wide.

Section: xb33–5–5 (holotype), xb31–2–2 (paratype), and xb31–1–2.

Description: Skeletons relatively large, globular in form, elliptical in sections, 19–20 mm long and 13 mm wide.

Skeletons composed of fine fibres arranged into fine and dense lattice. The fibres 0.04–0.05 mm thick. The meshes of the fibre lattice polygonal to subcircular in outline, 0.08–0.10 mm wide.

Each skeleton has several internal astrorhizae. The astrorhizae consist of vertical tubes parallel to each other and regularly arranged. They appear as several stellate configurations interfering with each other in transversal or tangential sections of skeletons. Each of the stellate configurations consists of 10–15 lines radiating from the center. Each of the lines generally 2–5 mm long, consisting of a row of circular pores (representing the cross sections of the vertical tubes) 0.25–0.50 mm across, with 7–8 pores along 3 mm. The distance between the centers of adjacent stellate configurations generally 4–5 mm.

Dimension (mm):

Section no.	SS	DC	NL	LL	DP	WM	TF
xb31–1–2	13×20	5	12–15	5	0.25–0.50	0.08–0.10	0.05
xb33–5–5	13×19	4	10–13	2–2.5	0.40–0.50	0.08–0.10	0.04–0.05

SS: the size of skeletons; DC: the distance between adjacent configurations; NL: the number of lines; LL: the length of lines; DP: the diameter of pores in lines; WM: the width of meshes; TF: the thickness of fibres.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Spumisclera* gen. nov.

Derivatio nominis: Spum (la. = cystose) refers to the irregular form of fibres.

Diagnosis: Skeletons reverse conical, composed of cystose parafibres irregularly and unevenly arranged. No astrorhiza on or in skeletons. The microstructure of skeletons spherulitic. Epitheca thick, covering only the side surface of skeletons.

Type species: *Spumisclera discreta* gen. et sp. nov.

Spumisclera discreta gen. et sp. nov.

(pl. 4 / 4; pl. 6 / 7)

Derivatio nominis: Discreta (la. = discontinuous) refers to the vertical discontinuity of parafibres in vertical sections of skeletons.

Diagnosis: Skeletons reverse conical. The cystose parafibres vertically discontinuous in longitudinal sections. Epitheca thick, covering the side surface of skeletons.

Section: xb27–6–10 (holotype) and xb27–6–11 (holotype, from the same specimen as xb27–6–10).

Description: Skeletons reverse conical, with the side surface gibbous outward, up to 20 mm in diameter and over 30 mm in height.

Skeletons composed of cystose parafibres irregularly arranged. The parafibres vertically discontinuous and forming several concave-up layers in the longitudinal sections of skeletons. The microstructure of skeletons spherulitic, with a single spherule up to 0.37 mm in diameter.

Discussion: The vertical discontinuity of parafibres probably reflects the periodic reduction of secretion of calcareous materials by soft tissue.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

4 Inozoans

Inozoans are a suborder of Pharetronida. They are also important reef-builders in Permian reefs. Thus the study of these organisms is of great significance to the study of Permian reefs. It is puzzling that spicules can only be preserved in post-Triassic inozoans rather than in Triassic and Paleozoic ones. Up to date, no convincing spicule evidence has been found in Triassic and Paleozoic inozoans. Because of the absence of spicule evidence the study of Triassic and Paleozoic inozoans appears more difficult than that of post-Triassic ones. Up to the present, only 7–8 Permian reefal inozoans have been described. The previous classifications of inozoans were mainly based on spicules and growth form. Thus, they are not applicable to Triassic and Paleozoic inozoans without spicule evidence.

I. Research History

Fossil inozoans were early described by Goldfuss (1831), Munster (1847), Klipstein (1843), d'Orbigny (1849), and others. The work by Zittel (1879), Hinde (1883, 1893) and Steinmann (1883) laid the foundation for the study of this group of organisms. Contributions to the study of inozoans are lately made by Vinassa de Regny (1901, 1908, 1917), Parona (1933), Dieci et al (1970, 1974), Hurcewicz (1972, 1975), Kovacs (1978), Muller (1978, 1984), Russo (1981), Termier et al (1955, 1977), Bizzarini and Russo (1986), and others. The classification of inozoans has been dealt with by Laubenfels (1955), Wagner (1964), Ziegler (1964, 1965), Dieci et al (1968), Hurcewicz (1975), Russo (1981), Bizzarini and Russo (1986), and others. It should be noted that the idea of classifying inozoans according to canal system suggested by Dieci et al (1968) is of importance to the development of classification of fossil inozoans without spicule evidence. The skeletal microstructure of inozoans has been studied by Dieci et al (1974) and Wendt (1979).

II. Characters

Fossil inozoans are characterized by calcareous spicules, calcareous skeletons composed of skeletal fibres, and a canal system. The spicules in inozoans can be triactine, tetractine and monoactine megascleres, or microscleres. It is known that the calcareous spicules are first secreted by the scleroblasts in the mesogloea of living inozoans. Then, the spicules are cemented into skeletal fibres by calcareous materials secreted after spicules. The arrangement of spicules in fibres is variable in different genera or even different species. It is mystic that spicules can only be preserved in post-Triassic inozoans generally. Fortunately, the trace of triactine has been found in the present study (Fig. 7). This seems to be the first report of spicule evidence from Permian inozoans. The fibres can be continuous or discontinuous, generally arranged into irregular or regular three-dimensional lattice. The fibres can be spherulitic, trabecular, lamellar, or micritic in microstructure (Dieci et al, 1974; Wendt, 1979).

Fig. 7 Trace of triactines and holes (probably left by spicules) in *Acoelia ruida* gen. et sp. nov.

The canal systems are the pathways of water systems (that is, the system of the canalways for water circulation) of inozoans left in skeletons after the decay of the soft tissue. It is apparent that water circulation is vital to inozoans. In inozoans a variety of water systems have been developed. Of them, the simplest type consists of ostia (or interfibre spaces), flagellate chambers and oscula (or interfibre spaces), while the most developed type consists of ostia, incurrent canals (epirrhyses commonly), flagellate chambers, aporrhyses, apopores, cloaca and the osculum. In the former case, the water currents flow in through the ostia, then to the flagellate chambers, and then out through the oscula. In the latter case, the water currents run in through the ostia and incurrent canals, to the flagellate chambers, and out through the aporrhyses, apopores, cloaca and finally the osculum.

Up to the present, at least 9 types of water systems have been recognized in fossil inozoans. They are as follows.

(1) Acoelia-type (Fig. 8)

Pathway: ostia (or interfibre spaces) → flagellate chambers → oscula (or interfibre spaces). (Note: the arrows indicate the direction of water currents)

Representative: *Acoelia* gen. nov.

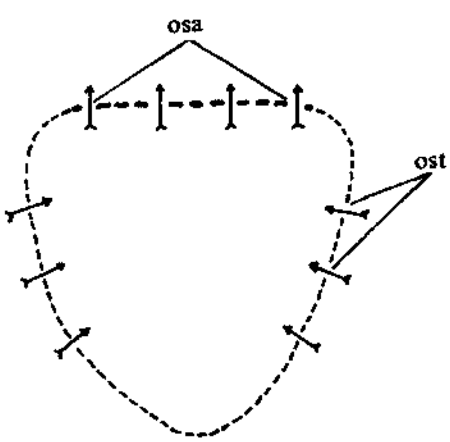


Fig. 8 Acoelia-type water system. Thick dotted line = excurrent surface, in which choanocytes may be present; thin dotted line = incurrent surface. Space enveloped by the two kinds of lines includes fibres. Arrows give the direction of currents. ost: ostia; osa: oscula.

(2) Peronidella-type (Fig. 9)

Pathway: ostia (or interfibre spaces) → flagellate chambers → spongocoel → osculum

Representative: *Peronidella* Hinde, 1893

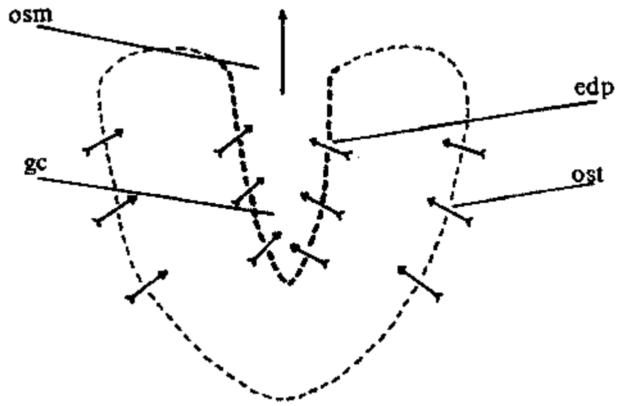


Fig. 9 Peronidella-type water system. Thick dotted line = inner wall, in which choanocytes may be present; thin dotted line = surface of sponge. Space enveloped by the two kinds of lines includes fibres. Arrows give the directions of currents. ost: ostium; edp: endopore; gc: spongocoel; osm: osculum.

(3) Sestrostomella-type (Fig. 10)

Pathway: ostia (or interfibre spaces) → flagellate chambers → multispongocoel → multiosculum

Representative: *Sestrostomella* Zittel, 1878

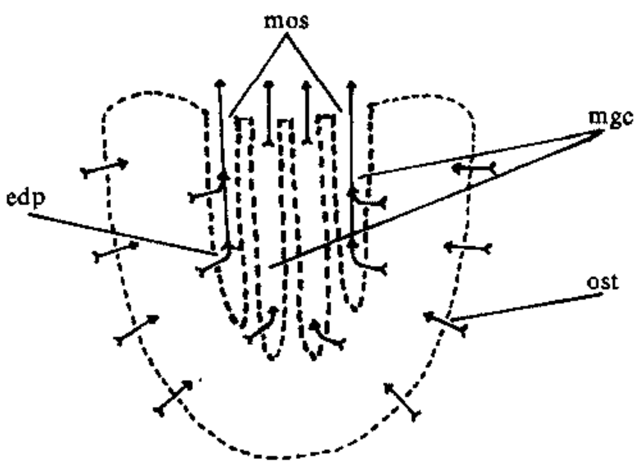


Fig. 10 Sestrostomella-type water system. Thick dotted line = inner wall, in which choanocytes may be present; thin dotted line = surface of sponge. Space enveloped by the two kinds of lines includes fibres. Arrows indicate the directions of currents. ost: ostium; edp: endopore; mgc: multispongocoel; mos: multiosculum.

(4) Polysiphonella-type (Fig. 11)

Pathway: ostia (or interfibre spaces) → flagellate chambers → excurrent tubes (or canals when irregular in form) → oscula

Representative: *Polysiphonella* Russo, 1981 or *Vermispongia* gen. nov.

(5) Paracorynella-type (Fig. 12)

Pathway: ostia (or interfibre spaces) → flagellate chambers → aporrhyses → multicloaca → multiosculum

Representative: *Paracorynella* gen. nov.

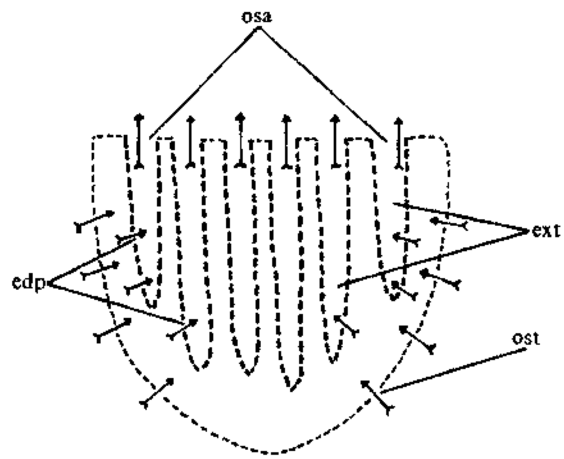


Fig. 11 Polysiphonella-type water system. Thick dotted line = inner wall, in which choanocytes may be present; thin dotted line = surface of sponge. Space enveloped by the two kinds of lines includes fibres. Arrows give the directions of currents. ost: ostium; edp: endopore; ext: excurrent tubes; osa: oscula.

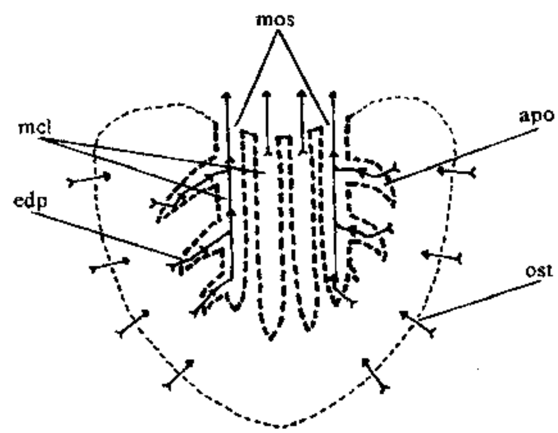


Fig. 12 Paracorynella-type water system. Thick dotted line = inner wall; thin dotted line = surface of sponge. Flagellate chambers may be in between aporrhyses. Space enveloped by the two kinds of lines includes fibres. Arrows give the directions of currents. ost: ostium; edp: endopore; apo: aporrhyses; mcl: multicloaca; mos: multiosculum.

(6) Stellispongiella-type (Fig. 13)

Pathway: ostia (or interfibre spaces) → flagellate chambers → aporrhyses → osculum (in mamelons or in cloaca depressions)

(Note: the cloaca / multicloaca shallowed and absent)

Representative: *Stellispongiella* gen. nov.

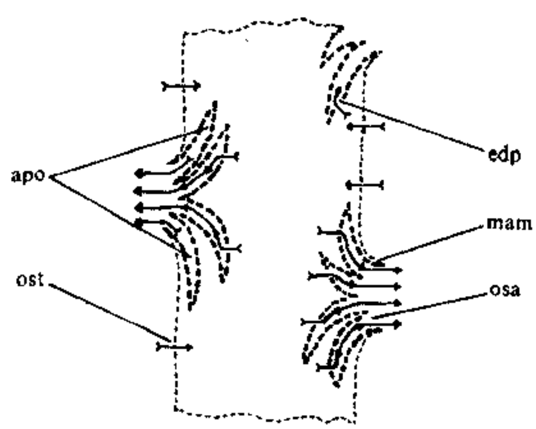


Fig. 13 Stellispongiella-type water system. Thick dotted line = inner wall; thin dotted line = surface of sponge. Flagellate chambers are in between aporrhyses. Space enveloped by the two kinds of lines includes fibres. Arrows give the directions of currents. ost: ostium; edp: endopore; apo: aporrhyses; osa: oscula; mam: mamelon.

(7) Corynella-type (Fig. 14)

Pathway: ostia (or interfibre spaces) → epirrhyses → flagellate chambers → aporrhyses → cloaca → osculum

Representative: *Corynella* Zittel, 1878

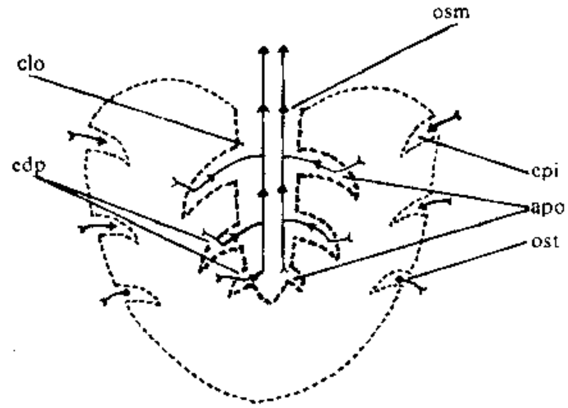


Fig. 14 Corynella-type water system. Thick dotted line = inner wall; thin dotted line = surface of sponge. Space enveloped by the two kinds of lines includes fibres and flagellate chambers. Arrows give the directions of currents. ost: ostium; epi: epirrhyses; edp: endopore; apo: aporrhyses; clo: cloaca; osm: osculum.

(8) Precorynella-type (Fig. 15)

Pathway: ostia (or interfibre spaces) → epirrhyses → flagellate chambers → aporrhyses → multicloaca → multiosculum

Representative: *Precorynella* Dieci et al, 1968

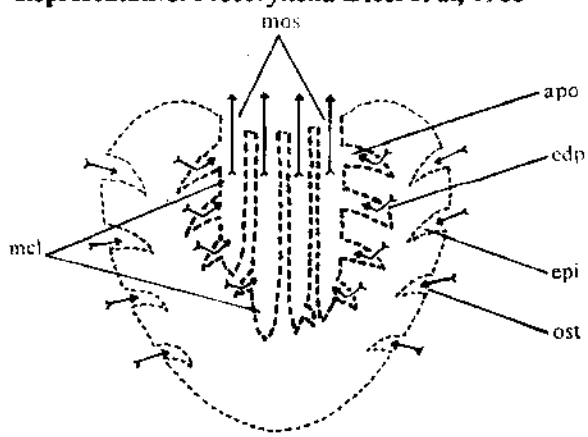


Fig. 15 Precorynella-type water system. Thick dotted line = inner wall; thin dotted line = surface of sponge. Space enveloped by the two kinds of lines includes fibres and flagellate chambers. Arrows give the directions of currents. ost: ostium; epi: epirrhyses; edp: endopore; apo: aporrhyses; mcl: multicloaca; mos: multiosculum.

(9) Stellispongia-type (Fig. 16)

Pathway: ostia (or interfibre spaces) → epirrhyses → flagellate chambers → aporrhyses → multiosculum (in cloaca depressions)

(Note: the cloaca / multicloaca shallowed and absent)

Representative: *Stellispongia* d'Orbigny, 1849

When a sponge becomes dead, its living tissue decays; its fibres and the pathways of its water system, that is, the canal system, are left. The ostia, the canals, and the oscula can all be preserved in fossils. However, it is uncertain whether the flagellate chambers can also be preserved in fossils. It is clear that the canal system can always be preserved in fossil inozoans, whether in post-Triassic ones or in Triassic and Paleozoic ones. Thus it should be valuable in the classification of inozoans. The terminology of inozoans related to canal systems is illustrated in Figs. 8–16.

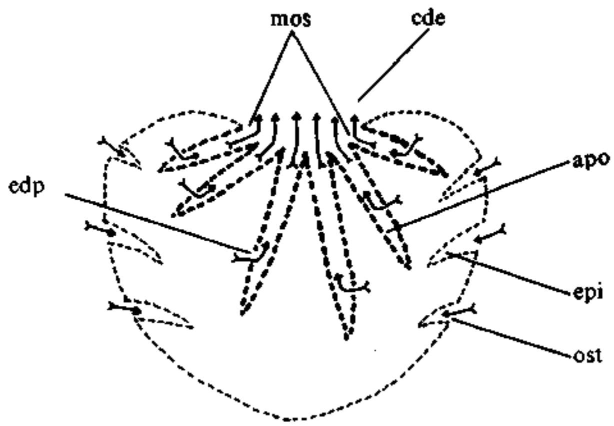


Fig. 16 Stellispongia-type water system. Thick dotted line = inner wall; thin dotted line = surface of sponge. Space enveloped by the two kinds of lines includes fibres and flagellate chambers. Arrows give the directions of currents. ost: ostium; epi: epirrhyses; edp: endopore; apo: aporrhyses; mos: multiosculum; cde: cloaca depression.

As seen in above figures, the canal system of inozoans typically includes two parts: an excurrent system and an incurrent system. The incurrent system consists of the canals for flowing-in water currents; the excurrent system consists of the canals for flowing-out water currents. The two systems are separated by the flagellate chambers. The excurrent system can be four types: (1) being only a spongocoel or multispongocoel, (2) consisting of the cloaca or multicloaca and lateral aporrhyses, (3) consisting of only aporrhyses, with the cloaca / multicloaca shallowed and absent, and (4) consisting of many scattered excurrent tubes / canals not differentiated. The incurrent system generally consists of only epirrhyses.

The skeleton surface of inozoans is pierced with a variety of openings. The openings for flowing-in water currents are known as ostia; the opening of spongocoel or cloaca is called osculum; the opening of multispongocoel (that is, the spongocoel consisting of more than one tube) or multicloaca is cribriform and is called multiosculum. The openings or pores in the wall of canals are called endopores. The openings of aporrhyses in the wall of cloaca or multicloaca are called apopores. In some inozoans, the osculum can be present in a depression which is known as cloaca depression. In some inozoans, there are furrows radiating from the osculum. These furrows are called stellar grooves. Stellar grooves can be on a mamelon as in *Stellispongiella* gen. nov. The surface of skeletons can be with or without epitheca.

Inozoans can be conical, columnar, subspherical, ramose, or phacelloid in growth form (Fig. 17). It is found that the growth form of Recent sponges is determined by their environments (Alexander, 1979). This must be true of ancient inozoans.

The terminology of inozoans used herein is illustrated in Fig. 18 and Fig. 19A–B.

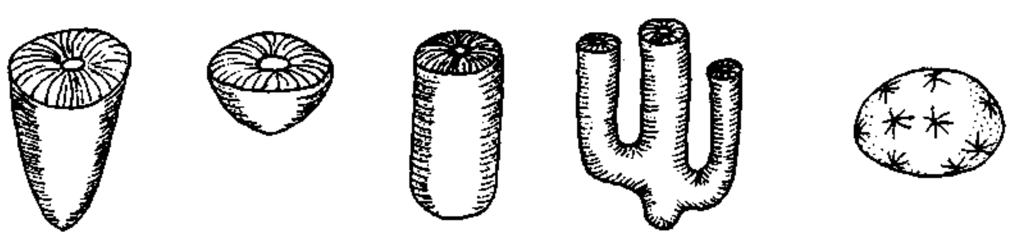


Fig. 17 Common growth forms of inozoans.

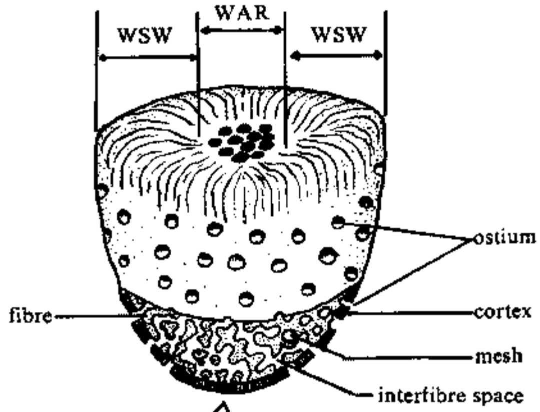


Fig. 18 A generalized sponge illustrating the terms used in systematic description. Its lower part is vertically sectioned. Fibres continuous at the right bottom. WSW: width of the skeleton wall; WAR: width of the axial region. Fibres are enlarged.

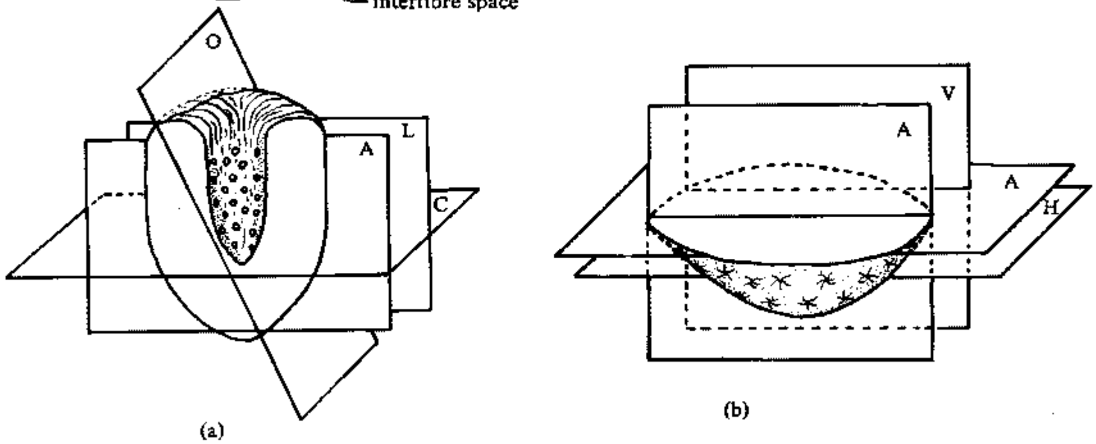


Fig. 19 (a): sections in conical or columnar sponges; (b): sections in subspheric sponges. In (a): C = cross section = Tra = H; Tra = transversal section; H = horizontal section; A = axial section; L = longitudinal section = V = Tan; V = vertical section; Tan = tangential section; O = oblique section. In (b): V = Tan; H = Tan; A, V, H, Tan are the same as in (a).

III. Classification

Many authors have dealt with the classification of inozoans. And many classification schemes of inozoans have been proposed based on different criterions. Some of these schemes are mainly based on spicules (e.g., Hurcewicz, 1975). These schemes are applicable to post-Triassic inozoans rather than to Triassic and Paleozoic ones because spicules can be preserved in post-Triassic inozoans rather than in Triassic and Paleozoic ones. Some other schemes classify inozoans according to their growth forms (e.g., Laubenfels, 1955). These classifications are somewhat unreliable because the growth form of sponges, as found in Recent ones, is mainly controlled by their living environments (Alexander, 1979; Clarkson, 1986). The third type of scheme is that first proposed by Dieci et al (1968) and followed by Russo (1981) and Bizzarini and Russo (1986). This is an informal classification based on the canal system.

As mentioned above, the water circulation of inozoans is mainly controlled by the features of fibres and the canal system, especially by the latter. Thus the fibres and the canal system are valuable criterions in the classification of inozoans. In addition, fibres and the canal system can always be preserved in fossil inozoans, whether in post-Triassic ones or in Triassic and Paleozoic ones. Therefore, it is reasonable to use the fibres and the canal system as the chief criterions in the classification of inozoans, especially of Triassic and Paleozoic ones. This classification is essentially the development of Dieci et al's idea. According to the patterns of canal systems, a new classification for inozoans is proposed as follows.

Order Pharetronida Zittel, 1878

Suborder Inozoa Steinmann, 1882

Superfamily Acoelioidea

Definition: Inozoans with Acoelia-type water system. Both incurrent system and excurrent system are absent. Water circulation is conducted through interfibre spaces. Only one family is included.

Family Acoeliidae fam. nov.

Definition: As for the superfamily.

Type genus: *Acoelia* gen. nov.

Superfamily Homocoelioidea

Definition: Inozoans with only excurrent system. The incurrent system are absent. Four families are included.

Family Peronidellidae fam. nov.

Definition: Members of the superfamily in which the excurrent system consist of only a spongocoel or a multispongocoel in the axial region of sponges. The water system is Peronidella-type or Sestrostomella-type.

Type genus: *Peronidella* Hinde, 1893

Family Paracorynellidae fam. nov.

Definition: Members of the superfamily in which the excurrent system consists of two parts: the cloaca or multicloaca in the axial region of sponges and the aporrhyses laterally and radially arranged in the surrounding region. The water system is Paracorynella-type.

Type genus: *Paracorynella* gen. nov.

Family Stellispongiellidae fam. nov.

Definition: Members of the superfamily in which the excurrent system consists of aporrhyses converging to an osculum. The water system is Stellispongiella-type.

Type genus: *Stellispongiella* gen. nov.

Family Polysiphonellidae fam. nov.

Definition: Members of the superfamily in which the excurrent system consists of tubes or canals scattered in a whole sponge and opening into the surface of the sponge. The water system is Polysiphonella-type.

Type genus: *Polysiphonella* Russo, 1981

Superfamily Heterocoelioidea

Definition: Inozoans with a canal system consisting of both excurrent system and incurrent system. Two families are included.

Family Corynellidae fam. nov.

Definition: Members of the superfamily in which the excurrent system consists of two parts: the cloaca or multicloaca in the axial region of sponges and the aporrhyses laterally and radially arranged in the surrounding region. The water system is Corynella-type or Precorynella-type.

Type genus: *Corynella* Zittel, 1878 or *Precorynella* Dieci et al, 1968

Family Stellispongiidae Laubenfels, 1955

Definition (revised): Members of the superfamily in which the excurrent system consists of aporrhyses converging and opening into a cloaca depression. The water system is Stellispongia-type.

Type genus: *Stellispongia* d'Orbigny, 1849

On the generic level, inozoans are distinguished according to the features of the canal system. On the species level, they are identified according to: (1) the fibres (their continuity, density and arrangement), (2) the cortex (present or absent), (3) the inner walls (the wall of canals), (4) the endopores in inner walls, and (5) the microstructure of fibres.

IV. Paleoecology and Paleogeography

Recent inozoans occur in normal sea, at a depth of 0–392 m, contributing little to reef formation. But in Permian reefs, inozoans are important frame-builders, accessory to sclerosponges or of equal importance as sclerosponges in reef formation. In the reef of Xiangbo, inozoans are main frame-builders, accessory to sclerosponges and account for 22.8–30.3% of the main reef-builders in area. In the Middle and Upper Permian reefs of Ziyun, Guizhou, southern China, inozoans can be primary frame-builders in typical framed facies, with sphinctozoans and others accessory. In the Middle Permian reefs of Tunisia, inozoans are also important reef formers (Termier et al, 1977). In Permian reefs, inozoans are generally accompanied by calcareous algae. Thus, it is deduced that ancient inozoans occur in warm, shallow-water environments, especially in reef environments. Thus it is believed that the inozoans, like sclerosponges, have changed in their living habits and their ecological role in reef formation in post-Permian time. They have moved from warm, shallow-water open environments in ancient sea to deeper or cryptic environments in Recent sea.

Fossil inozoans have been reported from Germany (Muller, 1984), France and Great Britain (Goldfuss, 1826; Zittel, 1878; Hinde, 1893), Poland (Hurcewicz, 1975), northern Hungary (Kovacs, 1978; Flugel, 1973), northern Italy (Steinmann, 1882; Parona, 1933; Dieci et al, 1968; Russo, 1981), Yugoslavia (Flugel, 1984), southern Tunisia (Termier et al, 1955, 1975, 1977), Timor (Regny, 1915), southern China (Rigby et al, 1990) and southern USA (Girty, 1908), of an age from Permian to Jurassic. It is remarkable that all of them occur in the regions of lower latitudes. These regions should be in the tropics or subtropics of Middle Permian, along the Tethys sea.

V. Systematic Description

Order Pharetronida Zittel, 1878

Suborder Inozoa Steinmann, 1882

Superfamily Acoelioidea

Family Acoeliidae fam. nov.

Genus *Acoelia* gen. nov.

Derivatio nominis: A (gr. = without) and coel (or. = cavity) refer to the absence of the canal system.

Diagnosis: Skeletons reverse conical, composed of fibres arranged into lattice, lacking any kind of canal system. Trace of triactines can be preserved in fibres. The spicule cements in fibres are spherulitic in microstructure. Cortex absent.

Discussion: This genus resembles the sclerosponge *Hartmanina* Dieci et al, 1974 in gross form. However, the presence of fibres and the trace of triactines are indicative of its inozoan affinity.

Type species: *Acoelia ruida* gen. et sp. nov.

Acoelia ruida gen. et sp. nov.
(pl. 8 / 7)

Derivatio nominis: Ruida (lat. = thick) refers to the thick fibres.

Diagnosis: Skeletons conical. Fibres thick; interfibre spaces circular in longitudinal sections of skeletons. The trace of triactines preserved in the fibres. Cortex absent.

Section: xb27–6–2 (holotype) and xb27–6–3 (holotype, from the same specimen).

Description: Skeletons moderately large, conical, curved and narrow, with a diameter of 12 mm and a height of over 25 mm. The side surface somewhat flat.

Skeletons lack canal system. Fibres somewhat discontinuous, especially in the axial region of skeletons where fibres commonly pointlike. The thickness of fibres more or less uniform, generally 0.2–0.3 mm. Interfibre spaces circular in the longitudinal sections of skeletons, intercommunicated, 0.25–0.50 mm wide. The trace of triactines seen in some fibres, with single ray 0.20–0.25 mm long and 0.05 mm wide. In fibres, spicule cements spherulitic in microstructure. In some places, holes 0.25 mm long and 0.10 mm wide seen in fibres. The long axis of the holes parallel to the axis of fibres. These holes are probably formed by the erosion of original spicules.

No cortex; the fibres and the interfibre spaces naked on skeleton surface.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Blastinia* Zittel, 1878

Diagnosis: Skeletons single or compound, spheric, hemispheric or irregular in form; sometimes stalked. Fibres arranged into lattice. Canal system absent. The lower part of the side surface of skeletons can be covered with cortex. On the top surface of skeletons present a system of stellar grooves radiating from the center of top surface.

Type species: *Blastinia costata* (Munster) = *Achilleum costatum*

Age: Permian to Jurassic.

Blastinia sp.
(pl. 9 / 13)

Section: xb30–8–17.

Description: The specimen obliquely sectioned, having a diameter of at least 23 mm. At least two furrows are sectioned. The ridges between the furrows 2.60 mm wide. Fibres arranged into irregular lattice.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Elasmostoma* Fromentel, 1860, emend. nov.

Diagnosis: Skeletons ear-like or cup-like, probably with a cortex on one surface. The cortex can be pierced with ostia. The other surface of skeletons without cortex. Skeletons lack canal system. Fibres arranged into lattice.

Discussion: The present author believes that the cortex is of value only in the identification at species level. Therefore, the definition of this genus is emended to include all those which are ear-like in form and lack any type of canal system.

Type species: *Elasmostoma frondescens* Fromentel

Elasmostoma aperien. sp. nov.
(pl. 8 / 2, pl. 9 / 8)

Derivatio nominis: Aperiens (lat. = open) refers to the naked surface of skeletons.

Diagnosis: skeletons cup-like. Fibres vermiform, perpendicular to skeleton surface. Cortex and ostia absent from both sides of skeletons.

Section: xb35–1–1 (holotype), xb37–C–T3 (paratype).

Description: Skeletons relatively large, cup-like, at least 43 mm high and 40 mm wide. The stalk-like base 10 mm high and 19 mm wide. Skeleton wall (see Fig. 18) 4–5 mm thick or wide.

Skeletons lack canal system. Fibres generally 0.15–0.23 mm thick, discontinuous, vermiform in form, more or less normal to the surface of skeletons.

Neither cortex nor ostia on either surface of skeletons.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Elasmostoma sp.
(pl. 8 / 1)

Section: xb33–7–5.

Description: Skeleton jar-like, 25–30 mm in diameter, with the skeleton wall about 10 mm thick.

Skeleton lacks canal system. Fibres straight, discontinuous, and not uniform in thickness, generally 0.08–0.10 mm (maximally 0.18 mm and minimally 0.06 mm) thick. The fibres arranged in two directions: parallel to, and normal to the surface of the skeleton, forming checked web in the vertical sections of the skeleton. The adjacent meshes of the web commonly intercommunicated, 0.10–0.20 mm wide.

No cortex on either side of the skeleton. The fibres and interfibre spaces naked.

Discussion: The specimen is characterized by the absence of cortex and the arrangement pattern of fibres. It can be a new species.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Ramospongia* gen. nov.

Diagnosis: Skeletons ramose in form, lacking canal system, composed of fibres arranged into regular or irregular lattice. The surface of skeletons with or without cortex.

Type species: *Ramospongia minor* gen. et sp. nov.

Ramospongia minor gen. et sp. nov.
(pl. 9 / 3)

Derivatio nominis: Minor (lat. = smaller) refers to the small diameter of skeletons.

Diagnosis: Skeletons small. Fibres discontinuous, more or less radially upward arranged. No cortex on skeleton surface.

Section: xb37–D–D1, xb33–5–10 (holotype).

Description: Skeletons ramose in form, 5 mm in diameter and 14 mm in height.

Skeletons lack canal system, composed of fibres arranged into lattice. The fibres discontinuous, thick, ranging 0.15–0.27 mm in thickness, more or less radially upward arranged. Interfibre spaces 0.20–0.30 mm wide.

The surface of skeletons lacks cortex.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Ramospongia sp.
(pl. 8 / 11)

Section: xb27–8–4.

Description: Skeleton ramose in form, at least 4 mm in diameter and 18 mm in height.

A small, irregular canal, possible the canal system present in the axial region of the skeleton. Fibres discontinuous, vermiform, ranging 0.12–0.17 mm thick, arranged into irregular lattice. The meshes of the lattice 0.13–0.17 mm wide.

A cortex present on skeleton surface. The cortex thin, not smooth, pierced with ostia.

Discussion: The presence of a possible canal makes it uncertain to place the specimen in this genus.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Superfamily Homocoelioidea

Family Peronidellidae fam. nov.

Genus *Bisiphonella* gen. nov.

Derivatio nominis: Bi (lat. = two) refers to the number of excurrent tubes.

Diagnosis: Skeletons columnar in form. The canal system consists of two excurrent tubes vertically running through the axial region of skeletons. Fibres arranged into regular or irregular lattice. Skeleton surface with or without cortex.

Type species: *Bisiphonella cylindrata* gen. et sp. nov.

Bisiphonella cylindrata gen. et sp. nov.
(pl. 7 / 4, 5, pl. 9 / 11)

Derivatio nominis: The species name refers to the cylindrical form of skeletons.

Diagnosis: Skeletons columnar. The two excurrent tubes similar in diameter. The distance between the two tubes similar to that from the tubes to the surface of skeletons. Fibres moderately thick, irregularly arranged. Interfibre spaces similar to fibres in width. No cortex.

Section: xb27–B–2 (holotype), xb34–2–2.

Description: Skeletons columnar in form, slightly curved, with a diameter of at least 5.5 mm and a height of over 24 mm.

The canal system consists of two cylindrical tubes 0.75–0.90 mm across and 0.90 mm apart in the axial region of skeletons. The distance from the tubes to the side surface of skeletons minimally 1.0–1.5 mm. Fibres discontinuous in some places, 0.10–0.18 mm thick, arranged into irregular lattice. Interfibre spaces generally 0.18–0.20 mm wide.

No cortex on skeleton surface.

The dimension of thin section 34–2–2: skeleton 15 mm in diameter; tubes 2.8–3.0 mm across; the two tubes 1.2 mm apart; the minimal distance from the tubes to skeleton surface 2.8–3.0 mm; the fibres 0.10–0.15 mm thick; and the interfibre spaces 0.20–0.25 mm wide.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Peronidella* Hinde, 1893

Diagnosis: Skeletons columnar or ramose, with a canal system consisting of one spongocoel in the axial region of skeletons. Fibres arranged into regular or irregular lattice. The surface of skeletons with or without cortex. In some species skeletons spherulitic in microstructure (Dieci et al, 1974).

Discussion: This is a very common inozoan in strata from Permian to Jurassic. It is also one of the most common genera in the reef of Xiangbo. Since its establishment, several species have been described. However, these species are mainly based on their spicules and growth form. And little has been known about the internal features of their skeletons. Therefore, the original definitions of these species are difficult to use in the identification of Paleozoic inozoans whose spicules are generally not preserved. So it is necessary to emend the criterions for the identification of species in this genus.

In the present study, species in this genus are distinguished according to the following characters: (1) the diameter of spongocoel, and the ratio (R) of the spongocoel diameter (D) to the width of skeleton wall (W) (formulated as $R = D/W$), (2) the thickness and arrangement of fibres, (3) features of the cortex, (4) features of inner walls, and (5) features of endopores.

Type species: *Spongia pistilliformis* Lamouroux, 1821

Peronidella gravida sp. nov.
(pl. 8 / 10)

Derivatio nominis: Gravida (lat. = pregnant) refers to the eggplant-like form of skeletons.

Diagnosis: Skeletons eggplant-like in form. $R >> 1$. Interfibre spaces wide. The inner wall pierced with circular endopores arranged into longitudinal rows. Cortex not well-developed, pierced with small ostia.

Dimension (mm):

Section no.	xb33–2–6	xb33–6–3	xb28–5–1
Diameter of spongocoel	3.1 × 2.3	5	3.0 × 4.8
width of skeleton wall	1.0	2	1.3 × 1.5
Thickness of fibres	0.05–0.07		0.05–0.08
Width of interfibre spaces		0.18–0.30	0.30–0.40

Section: xb33–6–3 (holotype), xb33–6–2, and xb33–2–6.

Description: Skeletons eggplant-like in form, with the bottom end tapering and the top end rounded, having a diameter of at least 8.5 mm and a height of over 25 mm.

The spongocoel resembles skeleton body in form, at least 5 mm in diameter. Skeleton wall

1.0–2.0 mm thick. Thus, R > > 1. Spongocoel wall pierced with circular endopores. The endopores at least 0.15–0.17 mm in diameter, 0.18–0.40 mm apart, arranged into longitudinal rows. Fibres thin, uniform in thickness, ranging 0.05–0.08 mm generally, arranged into irregular latt·ce. The width of interfibre spaces much greater than the thickness of fibres.

On the surface of skeletons present a cortex densely pierced by small ostia.

Discussion: This species resembles *Peronidella metabronnii* Sollas, 1883 in gross form. However, in the latter, the base of skeletons expanded; the cortex absent; and the endopores greater in diameter. Accidentally, *Peronidella* sp. A, Flugel et al, 1984 (pl. 38 / 4, 6), according to its illustration, belongs to this species.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Peronidella labiaformis sp. nov.

(pl. 8 / 6. pl. 9 / 7)

Derivatio nominis: Labiaformis (lat. = lip-like) refers to the form of skeletons in cross section.

Diagnosis: Skeletons conical, lip-like in cross section. Skeleton wall variable in width. Fibres fine. Skeleton surface without cortex.

Section: xb30–5–2 (holotype), xb35–7–1 (paratype) and xb33–2–4.

Description: Skeletons conical, 4–10 mm in diameter, lip-like in cross section.

Spongocoel lip-like or elliptical in cross section, 2 × 6.5 mm in size. Skeleton wall variable in thickness, ranging 0.65–2.30 mm. Fibres continuous, 0.05–0.10 mm thick, arranged into irregular lattice.

Skeleton surface without cortex, probably provided with spiny processes.

Dimension (mm):

Section no.	xb30–5–2b	xb33–2–4
Diameter of spongocoel	0.75 × 2.40	1 × 2.8
Thickness of skeleton wall		0.4–0.8
Thickness of fibres	0.06–0.10	0.05–0.07

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Peronidella minicoeliaca sp. nov.

(pl. 7 / 3. pl. 8 / 3)

Derivatio nominis: Mini (gr. = small) and coeliaca (gr. = abdominal cavity) refer to the small diameter of the spongocoel.

Diagnosis: Skeletons columnar. Spongocoel thin, cylindrical. R < < 1. Fibres thick, like broken lines. Neither inner wall nor cortex present.

Section: xb30–3–3 (holotype), xb30–3–4 (holotype, from the same specimen as xb30–3–3), xb37–2–10.

Description: Skeletons columnar, 13–21 mm in diameter, possibly with shrunk rings on their surface.

Spongocoel cylindrical, uniform in diameter, 3.75 mm across, without wall. Skeleton wall constant in thickness, 4.8–5.7 mm. Fibres thick, ranging 0.13–0.20 mm in thickness, densely arranged into broken lines laterally extending and subparallel to each other in longitudinal and transversal sections of skeletons. Interfibre spaces 0.15 mm wide on the average, laterally extending to skeleton surface. Fibres recrystallized, with remains of original spherulitic microstructure.

Skeleton surface without cortex, with fibres and interfibre spaces naked.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Peronidella recta Hinde, 1893

(pl. 7 / 6, pl. 9 / 14)

1893 *Peronidella recta*: Hinde, p. 217, pl. 15, fig. 1–1c.

Diagnosis: Skeletons phacelloid. Stems thin, cylindrical. The diameter of spongocoel similar to the thickness of skeleton wall (R ≈ 1). Fibres moderately dense. Cortex absent.

Section: xb27–6–5, xb27–6–6, and xb27–6–7.

Description: Skeletons phacelloid in form. Stems thin, cylindrical, with a diameter of 3–7 mm.

Spongocoel cylindrical, 0.75–2.30 mm in diameter. The thickness of skeleton wall generally 0.3–2.3 mm. Thus, R ≈ 1. Fibres moderately dense, generally 0.05–0.12 mm thick, arranged into irregular lattice. The meshes of the lattice generally 0.05–0.25 mm wide.

Dimension (mm):

Section no.	xb27–6–6	xb27–6–5	xb27–6–7
Diameter of stems	6.9	4.9	4.7
Diameter of spongocoel	2.3	1.0	1.3 × 0.9
Thickness of skeleton wall	2.3	1.5	1.7–2.0
Thickness of fibres	0.05–0.10	0.05–0.12	0.05–0.12
Width of interfibre spaces	0.25		

The surface of skeletons without cortex.

Discussion: The specimens are identical to Hinde's in growth form, the dimension of skeleton wall and spongocoel, the features of fibres and skeleton surface. Therefore, they belong to the same species.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Peronidella recta grossa subsp. nov.

(pl. 7 / 7, 8)

Derivatio nominis: Grossa (lat. = thick) refers to the thick fibres.

Diagnosis: Skeletons phacelloid. Stems thin, cylindrical. R ≈ 1. Fibres thick, irregularly arranged. Neither inner walls nor cortex present.

Section: xb34–4–1 (holotype) and xb30–8–7.

Description: Skeletons phacelloid in form. Stems thin, cylindrical, with a diameter of 2.5–4.5 mm.

Spongocoel circular or elliptic in cross section, with a diameter of 1.0–1.8 mm, without wall. Skeleton wall 1.0–1.5 mm thick. Fibres thick, ranging 0.10–0.15 mm in thickness, arranged into irregular lattice.

The surface of skeletons without cortex.

Dimension (mm):

Section no.	xb30–8–7	xb34–4–1
Diameter of stems	4.7	3.6
Diameter of spongocoel	1.8	1.0
Thickness of skeleton wall	1.3–1.5	1.0–1.3
Thickness of fibres	0.13–0.15	0.10–0.15
Width of interfibre spaces	0.20	

Discussion: The difference between the subspecies and *Peronidella recta* Hinde, 1893 is that the fibres of the former are thicker than those of the latter.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Family Paracorynellidae fam. nov.

Genus *Paracorynella* gen. nov.

Derivatio nominis: Para (gr. = apart) refers to the relationship between this genus and *Precorynella* Dieci et al, 1968.

Diagnosis: Sponges single or compound. Skeletons cylindrical or hemispherical, with a canal system consisting of aporrhyses, multicloaca, and multiosculum. Fibres arranged into regular or irregular lattice.

Discussion: This genus differs from *Precorynella* Dieci et al, 1968 in the lack of epirrhyses. Dieci et al stated that the epirrhyses is developed or absent in *Precorynella*. The present author believes that epirrhyses are important to water circulation of sponges, thus those specimens without epirrhyses should be included in a new genus, i.e., the present genus.

Type species: *Paracorynella flexa* gen. et sp. nov.

Paracorynella flexa gen. et sp. nov.

(pl. 9 / 1, 2)

Derivatio nominis: Flexa (lat. = arched) refers to the form of aporrhyses.

Diagnosis: Skeletons reverse conical. Multicloaca consists of tubes 0.25–1.00 mm across, running down to the base of skeletons. Aporrhyses arched, dichotomous. The meshes of fibre lattice arranged into rows parallel to the aporrhyses.

Section: xb30–8–4 (holotype), xb34–5–2 (paratype).

Description: Skeletons relatively large, reverse conical, like an isosceles triangle in vertical sections, with a diameter of 22 mm and a height of over 15 mm. The surface of skeletons may have shrunk rings.

Multicloaca 7 mm wide, composed of several tubes more or less sinuous. The tubes 0.2–1.0 mm across, generally running down to the base of skeletons. Aporrhyses converge into the cloaca, gently curved downward and outward, dibranched for several times, meanwhile greatly decreasing in diameter, up to 0.50–0.75 mm in diameter at their upper end and 0.25 mm across near their lower end. Fibres 0.05 mm thick, arranged into dense, regular lattice. The meshes of the lattice 0.10–0.12 mm wide, generally rectangular or in some places circular, arranged into rows parallel to the aporrhyses.

No cortex on skeleton surface.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Family Stellispongiellidae fam. nov.

Genus *Stellispongiella* gen. nov.

Derivatio nominis: The generic name refers to the relationship between this genus and *Stellispongia* d'Orbigny, 1849.

Diagnosis: Skeletons generally cylindrical in form, with several mamelons on their surface. Each mamelon has an osculum on it. There may be stellar grooves on the mamelons. Converging and opening into the oscula are aporrhyses, which can be sinuous and branched, decreasing in diameter toward the interior of skeletons. Fibres arranged into regular or irregular lattice.

Discussion: This genus differs from *Stellispongia* d'Orbigny, 1849 in the lack of epirrhyses in the former.

Type species: *Stellispongiella termieri* gen. et sp. nov.

Age: Middle Permian.

Distribution: Tunisia; Longlin, Guangxi, China.

Stellispongiella termieri gen. et sp. nov.

(pl. 9 / 6)

Derivatio nominis: This species is named in honor of Prof. Termiers who have contributed a lot to the study of Permian reefal fauna of Tunisia.

Diagnosis: Skeletons rod-like, with several mamelons on their surface. The mamelons 6 mm apart. Aporrhyses 0.5 mm across maximally. Fibres arranged into dense, regular lattice.

Section: xb27–8–3 (holotype).

Description: Skeletons rod-like, 5 mm in diameter, over 38 mm long, with several mamelons on their surface. Adjacent mamelons 6 mm apart.

Aporrhyses more or less sinuous, branched, 0.5 mm across maximally, greatly decreasing in diameter toward the interior of skeletons, inward radially arranged under each osculum. Fibres thin, ranging 0.03–0.07 mm in thickness, continuous, arranged into regular lattice. The meshes of the lattice close, 0.5 mm wide and 0.1 mm high, radially upward arranged.

Discussion: The specimens assigned to *Stellispongia bacilla* by Termier & Termier in 1955 resemble the present specimen in external morphology. Thus they may belong to the same species.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Family Polysiphonellidae fam. nov.

Genus *Polysiphonella* Russo, 1981

Diagnosis: Skeletons conical, columnar or in other elongate forms, with a canal system consisting of vertical excurrent canals / tubes not differentiated, scattered in a whole skeleton, running through the length of a skeleton and opening into skeleton surface. Fibres arranged into regular or irregular lattice. Skeleton surface can be covered with cortex. The microstructure of fibres can be irregular.

Discussion: The genus differs from *Sestrostomella* Zittel, 1879 in that the excurrent canals of the latter are confined to the axial region of skeletons.

Type species: *Polysiphonella diecii* Russo, 1981

Polysiphonella sp. A
(pl. 9 / 10)

Section: xb33–5–2.

Description: Skeletons columnar or in other elongate forms, with a diameter of 5–12 mm.

Excurrent tubes circular in cross section, scattered in a whole skeleton. The two tubes in the axial region of the skeleton 0.80–0.83 mm across. The other tubes 0.25–0.50 mm across. All of the tubes have discontinuous walls built of fibres. Fibres 0.03–0.60 mm thick, arranged into dense lattice. The meshes of the lattice open, polygonal to circular in outline, 0.05–0.10 mm wide.

No real cortex on skeleton surface. The fibres on skeleton surface dense. Interfibre spaces naked.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Polysiphonella sp. B
(pl. 9 / 9)

Section: xb33–7–2.

Description: Skeleton circular in cross section, 14 mm in diameter.

Excurrent tubes circular in cross section, scattered in a whole skeleton. The tube in the axial region of the skeleton 1.7 mm across. The other tubes 0.5–0.8 mm across. All of the tubes have a thin and continuous wall. Fibres 0.06–0.08 mm thick, arranged into probably irregular lattice.

The cortex on skeleton surface thin, smooth.

Discussion: The specimen is characterized by the presence of thin and continuous inner walls.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

?*Polysiphonella* sp.
(pl. 8 / 8)

Section: xb34–2–1.

Description: Skeleton rod-like, 5 mm in diameter, over 15 mm high.

Canal system consists of one spongocoel and at least 13 vertical tubes around the spongocoel. The spongocoel 0.75 mm across. The vertical tubes 0.25–0.30 mm in diameter. The spongocoel and the vertical tubes circular in cross section, running through the length of the skeleton. Fibres 0.05–0.07 mm thick, continuous, arranged into irregular lattice. The meshes of the lattice circular in outline, 0.08 mm wide.

Discussion: The specimen resembles those of *Peronidella subcaespitosa* (Munster) Dieci et al, 1968 in the pattern of canal system. However, their canal systems are by no means

Peronidella-type. Therefore, they should belong to a new genus. Because of the unavailable material, the specimen is placed in this genus temporarily.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Grossotubenella* Rigby et al, 1989

Diagnosis: Skeletons irregular ovate, or subcylindrical in form, with a canal system consisting of subvertical, vermiform excurrent canals not differentiated. The excurrent canals scattered in a whole skeleton, short, opening into the top surface of the skeleton via more than one osculum. Adjacent canals intercommunicated. Fibres arranged into lattice.

Type species: *Grossotubenella Parallela* Rigby et al, 1989

Grossotubenella parallela Rigby et al, 1989
(pl. 7 / 10, pl. 8 / 9, pl. 9 / 4)

Diagnosis: Skeletons irregularly ovate in form. Excurrent canals sinuous, vermiform, 0.6–1.3 mm in diameter and 0.5–1.0 mm apart. In some places, the canals intercommunicated, forming H-shaped configuration in longitudinal sections of skeletons. Fibres very fine and dense.

Section: xb26~27–1, xb27–7–7, and xb34–8–1.

Description: Skeletons irregularly ovate in form, probably with mamelons on their surface, with a maximal diameter of 10–15 mm and a height of over 35 mm.

Excurrent canals variable in diameter, ranging 0.6–1.3 mm across, more or less sinuous, short in the longitudinal sections of skeletons, irregularly and evenly scattered in a whole skeleton, generally 0.5–1.0 mm apart. Adjacent canals commonly intercommunicated, forming H-shaped configuration in the longitudinal sections of skeletons. The canals linking adjacent vertical excurrent canals 0.3–1.0 mm across. Fibres very fine, arranged into dense, irregular lattice.

The cortex on skeleton surface indistinct.

Dimension (mm):

Specimens no.	xb34–8–1	xb26–27–1	xb27–7–7
Diameter of canals	0.6–1.3	0.8–1.0	0.8–1.0
Distance between canals	0.5–1.0	0.6–1.0	0.5–0.6
Diameter of linking canals	0.3–0.9	0.5–0.8	

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Protocoelia* gen. nov.

Derivatio nominis: Proto (gr. = primitive) and coel (gr. = cavity) refer to the indistinct canals.

Diagnosis: Skeletons columnar or conical in form, with a canal system consisting of irregular, sinuous excurrent canals not differentiated, scattered in a whole skeleton. The excurrent canals indistinct in outline. Fibres spherulitic in microstructure, arranged into regular or irregular lattice. Cortex present on or absent from skeleton surface.

Type species: *Protocoelia vermiformis* gen. et sp. nov.

Protocoelia vermiformis gen. et sp. nov.
(pl. 7 / 9)

Derivatio nominis: The species name refers to the form of fibres and excurrent canals.

Diagnosis: Skeletons large, kidney-like, sinuous. Excurrent canals sinuous, irregular in form, 1.0–1.5 mm across. Fibres thick, sparse, discontinuous. Skeleton surface covered with cortex.

Section: xb27–7–8 (holotype) and xb27–7–9.

Description: Skeletons large, kidney-like, with a diameter of at least 22 mm and a height of over 45 mm.

Excurrent canals irregular in form, without walls, indistinct in outline, variable in diameter, generally 1.0–1.5 mm wide, scattered in the inner region of skeletons (absent from the 1.0–3.5 mm wide edge of skeletons). Fibres thick, vermiform, discontinuous, 0.13–0.20 mm in thickness, spherulitic in microstructure. Interfibre spaces 0.25–0.38 mm wide in the edge of skeletons.

Skeleton surface covered with thin cortex.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Vermispongia* gen. nov.

Derivatio nominis: Verm (lat. = vermiform) refers to the form of excurrent canals.

Diagnosis: Skeletons commonly ovate in form, with a canal system consisting of vermiform, intercommunicated, short excurrent canals not differentiated, scattered in a whole skeleton. Fibres arranged into irregular or regular lattice. The free ends of fibres project towards the interior of excurrent canals.

Discussion: The short, vermiform excurrent canals distinguish this genus from others.

Type species: *Vermispongia spiniformis* gen. et sp. nov.

Vermispongia spiniformis gen. et sp. nov.
(pl. 7 / 2)

Derivatio nominis: The species name refers to the spiny free end of the fibres projecting towards excurrent canals.

Diagnosis: Skeletons relatively large, elliptic in sections. Excurrent canals sinuous, vermiform, 1–2 mm wide. Fibres arranged into irregular lattice. The spiny free end of fibres project toward the interior of excurrent canals.

Section: xb37–2–12 (holotype) and xb28–3.

Description: Skeletons ovate in form, elliptic in sections, 20–25 mm long and 10–15 mm wide.

Excurrent canals sinuous, short, without walls, vermiform, generally 1.0–2.0 mm wide and 6.0 mm long, scattered in a whole skeleton, 1.0–3.0 mm apart, opening into skeleton surface. Fibres not uniform in thickness, generally 0.08–0.12 mm thick. The spiny free end of fibres projects toward the center of excurrent canals.

No cortex on skeleton surface. Fibres naked.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Homocoelioidea gen. indet.

(pl. 8 / 4)

Section: xb35–6–3.

Description: Skeleton large, phacelloid, up to 30 mm wide. Stems 5–6 mm in diameter. Spongocoel irregular in cross section. The fibres fine, arranged into irregular lattice. Skeleton recrystallized. Thus, other features unrecognizable

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Superfamily Heterocoelioidea

Family Corynellidae fam. nov.

Genus *Precorynella* Dieci et al, 1968

Diagnosis: Sponges single or compound. Skeletons columnar, pyriform, or hemispherical, with a canal system consisting of ostia, epirrhyses, aporrhyses, a multicloaca and a multiosculum. There can be a cloaca depression on the center of the top surface of skeletons. Stellar grooves can be present, radiating from the cloaca depression. Fibres arranged into irregular or regular lattice. Skeleton surface with or without cortex.

Type species: *Cnemidium pyriformis* Klipstein, 1843

Precorynella dendroidea sp. nov.

(pl. 7 / 1)

Derivatio nominis: Dendroidea (lat. = dendroidal) refers to the dendroidal form of the canal system.

Diagnosis: Sponges compound, comprising two columns merged. Aporrhyses irregularly branched and curved, decreasing in diameter downwards. Epirrhyses thin, more or less normal to aporrhyses. Fibres fine, arranged into dense, irregular lattice.

Section: xb27–7–3 (holotype)

Description: Skeletons compound, comprising two columns merged together.

Multicloaca consists of vertical tubes 0.3–0.5 mm across. Aporrhyses inclined outward and downward, irregularly curved and furcated, greatly decreasing in diameter toward their lower ends. Epirrhyses composed of sparse canals 0.25–0.37 mm across, more or less normal to aporrhyses. Fibres fine, commonly 0.05 mm thick, arranged into irregular lattice. The meshes of the lattice 0.12 mm wide.

No cortex on skeleton surface.

Discussion: The new species differs from *Precorynella auriformis* Dieci et al, 1968 in that in the former the aporrhyses irregularly furcated and curved, and the fibres irregularly arranged; while in the latter the aporrhyses unbranched, and the fibres arranged into regular lattice.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Family Stellispongiidae Laubenfels, 1955

Genus *Stellispongia* d'Orbigny, 1849

Diagnosis: According to d'Orbigny (1849) and Dieci et al (1968), the sponges single or compound, commonly spherical, with one (for single form) or more than one (for compound form) cloaca depression on their surface. The canal system consists of ostia, epirrhyses, aporrhyses and a multiosculum (in a cloaca depression). The epirrhyses converge from skeleton surface toward the center of skeletons. The aporrhyses converge toward the cloaca depression, opening into it.

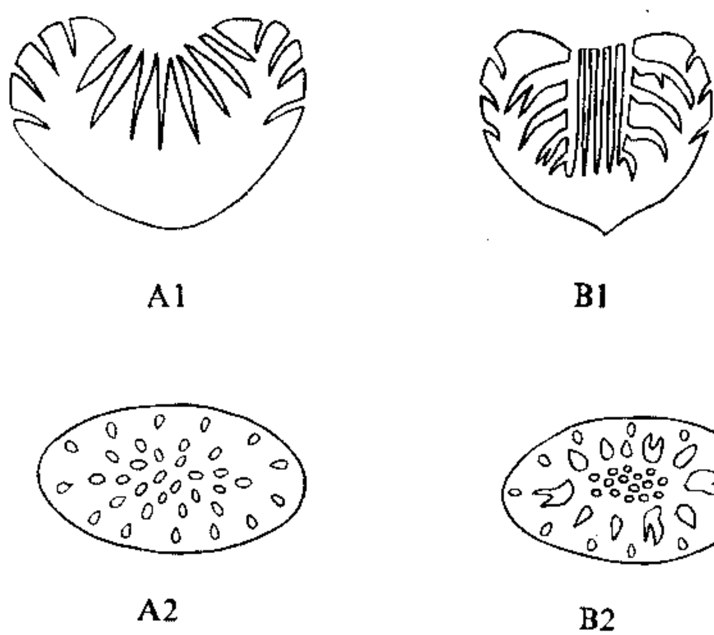


Fig. 20 Comparison of canal system of *Stellispongia* with *Precorynella* in sections. A1–A2: *Stellispongia;* A1: longitudinal section; A2: transversal section; B1–B2: *Precorynella;* B1: longitudinal section; B2: transversal section.

Discussion: According to d'Orbigny, this genus is characterized by stellar depressions (i.e., the cloaca depressions in the present usage) on skeleton surface. However, it is known that stellar depressions are also present in other genera. Thus, the main criterion for the identification of this genus is the features of the canal system.

The genus differs from *Precorynella* in that the excurrent canals differentiate into two parts: multicloaca and aporrhyses in the latter while in the former multicloaca is undeveloped or is given place to a cloaca depression.

Accidentally, the specimens assigned to *Precorynella* by Fois in 1980 actually belong to this genus.

Type species: *Cnemidium variabilis* Munster, 1840

Stellispongia cf. *manon* (Munster) Dieci et al, 1968
(pl. 9 / 12)

Section: xb27–9.

Description: The specimen is a fragment of a vertical section, 14 × 19 mm in size.

The canal system consists of two groups of straight tubes. The tubes of the first group vertical, parallel to each other, below 0.40–0.55 mm apart. The tubes of the second group, probably being aporrhyses, normal to the tubes of the first group, but not parallel to each other (instead, laterally and radially arranged), generally 0.5–0.8 mm apart. All of the tubes of the two groups 0.40–0.55 mm across. Fibres thin, arranged into regular lattice, with the meshes fine, rectangular in outline.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Stellispongia sp.
(pl. 8 / 5)

Section: xb30–8–9.

Description: The available specimen is an oblique vertical section, 13.5 mm high and 15 mm wide.

Two groups of tubes are sectioned. The tubes of the first group, probably being the epirrhyses, normal to skeleton surface; the tubes of the second group, being aporrhyses, oblique or normal to the tubes of the first group. All of the tubes of the two groups straight, generally 0.3 mm across. Fibres thin, arranged into regular lattice. The meshes of the lattice rectangular in outline.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Paristellispongia* gen. nov.

Derivatio nominis: pari (lat. = equivalent to) refers to the relationships between this genus and *Stellispongia*.

Diagnosis: Sponges single or compound. Skeletons generally subspherical in form, with a canal system consisting of ostia, epirrhyses, aporrhyses, and a multiosculum (possibly in a cloaca depression). The epirrhyses consist of tubes vertical, straight, and subparallel to each other. The aporrhyses converge to the multiosculum. In compound forms, there is more than one multiosculum. From each multiosculum a group of aporrhyses radiate downwards. Fibres arranged into regular or irregular lattice.

Discussion: This genus differs from *Stellispongia* d'Orbigny, 1849 in the parallel rather than radial arrangement of the epirrhyses in the former.

Type species: *Paristellispongia parallelica* gen. et sp. nov.

Paristellispongia parallelica gen. et sp. nov.
(pl. 7 / 11, pl. 9 / 5)

Derivatio nominis: Parallelica (lat. = parallel) refers to the parallel arrangement of epirrhyses.

Diagnosis: Skeletons relatively large, spherical. Epirrhyses 0.37–0.65 mm across, generally 0.5–1.0 mm apart. There are more than one cloaca depression. Aporrhyses sinuous, furcated, decreasing in diameter downwards.

Section: xb33–6–5 (holotype), xb33–5–6 (paratype), xb30–8–9 and xb34–6–1.

Description: Skeletons relatively large, circular or elliptic in horizontal sections, 20 × 30 mm in size.

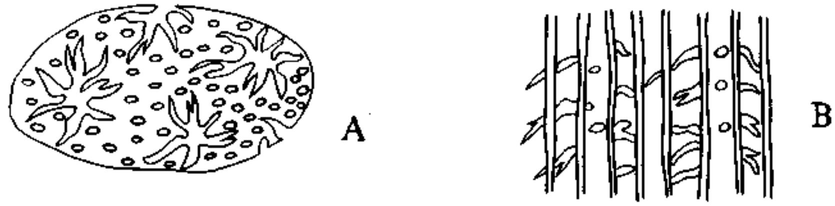


Fig. 21 Canal system in the sections of *Paristellispongia parallelica* sp. nov. A: horizontal section; B: vertical section.

Epirrhyses consist of more than one straight vertical tube, 0.37–0.65 mm across, parallel to each other, extending from the top to the bottom of skeletons, generally 0.5–1.0 mm apart. Aporrhyses sinuous, furcated, inclined downward and outward, decreasing in diameter downward. In horizontal sections of skeletons, the epirrhyses appear as scattered circles, and the aporrhyses arranged into several stellar configurations (Fig. 21A). In the vertical sections of skeletons, the aporrhyses symmetrically arranged under each cloaca depression (Fig. 21B). Fibres fine, commonly 0.05 mm thick, arranged into regular lattice. The meshes of the lattice commonly polygonal in outline, generally 0.08–0.10 mm wide.

No cortex on skeleton surface.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

5 Sphinctozoans and Demosponges

I. Research History

Sphinctozoans are a group of segmented calcareous sponges. They are important reef-building organisms in Permian. The study of this group can be dated back to the end of the last century (Defrance, 1828; Goldfuss, 1833; Laube, 1865). The foundational work for the group was finished by Zittel (1878), Steinmann (1882), and Dunikowski (1883). Contributions to the study of the group were also made by Rauff (1891, 1913), Vinassa (1901, 1908, 1915), Girty (1908), Toula (1913), Mansuy (1913, 1914), Hayasaka (1918), Parona (1933), Yabe & Sugiyama (1934), Wilchens (1937), Herak (1944), and others. Since the 1950s, Seilacher (1962), Ott (1965), Dieci et al (1968), Fan and Zhang (1985), Senowbari-Daryan (1990), Senowbari-Daryan et al (1983, 1986, 1988), and Rigby et al (1989) have done important work on this group.

Sphinctozoans can be reefal or non-reefal organisms. Their geological age ranges from Cambrian to Recent. Permian reefal sphinctozoans are mainly confined to the Permian reefs of China, the Middle Permian reefs of Tunisia, and the Middle Permian reefs of Sicily and USA. Up to now, only the sphinctozoans from the reefs of Tunisia have been thoroughly studied.

II. Characters and Terminology

Sphinctozoans are characterized by chambered calcareous skeletons, water-controlling structures and siliceous spicules embedded in the skeletons.

The spicules in sphinctozoans are generally siliceous monaxons. They can be preserved in some Mesozoic sphinctozoans and a few Paleozoic ones. Thus, they are an unpracticable character in taxonomy.

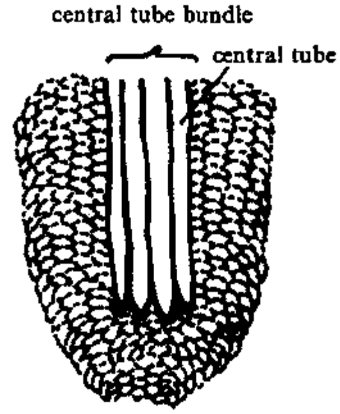
Sphinctozoans are chambered calcisponges without exception. The simplest sphinctozoans are single-chambered (e.g., *Blastulospongia*; Pickett & Jell, 1983). But most sphinctozoans are composed of more than one chamber. The chambers in sphinctozoans can be spherical, domed, doliform, discoid, tube-like and irregular saccate. The arrangement of chambers in sphinctozoans is various, ranging from linear, in diagonal rows, in vertical rows, or irregular, to spiral, producing various regular or irregular forms. The forms of sphinctozoans can be spherical, catenulate, columnar, coniform, plate-like and irregular massive, depending on the arrangement of chambers.

The water-controlling structures in sphinctozoans include (1) exhalent canal system, (2) pores or / and ostia, and (3) chamber-connecting tubes.

An exhalent canal system consists of all of the tubes or canals by which the water currents are pumped out from chambers. The exhalent canal systems in sphinctozoans can be divided as the following types: (1) central tube (Fig. 22a–e, j), (2) central tube bundle (Fig. 22f, g), (3)

a.cryptosiphonate

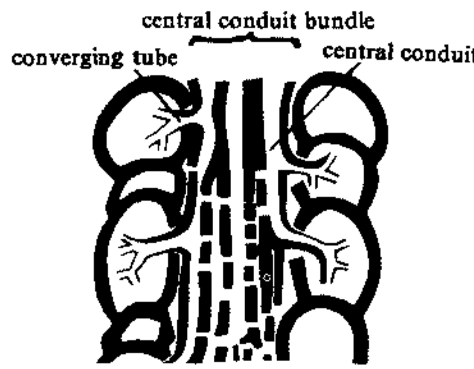
d.retrosiphonate



g.imbrisiphonate

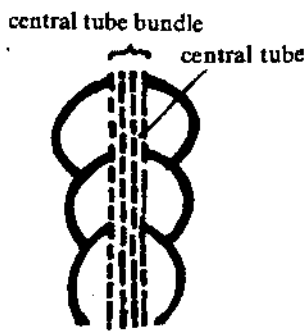
b.pseudosiphonate

e.amblysiphonate

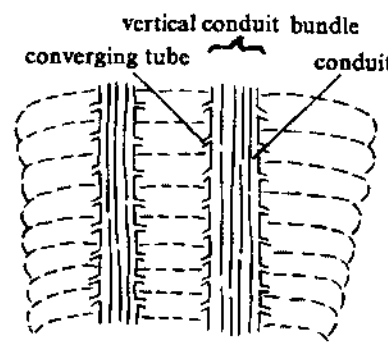


h.pseudoamblysiphonate

c.prosiphonate



f.yukosiphonate



i.zanklisiphonate

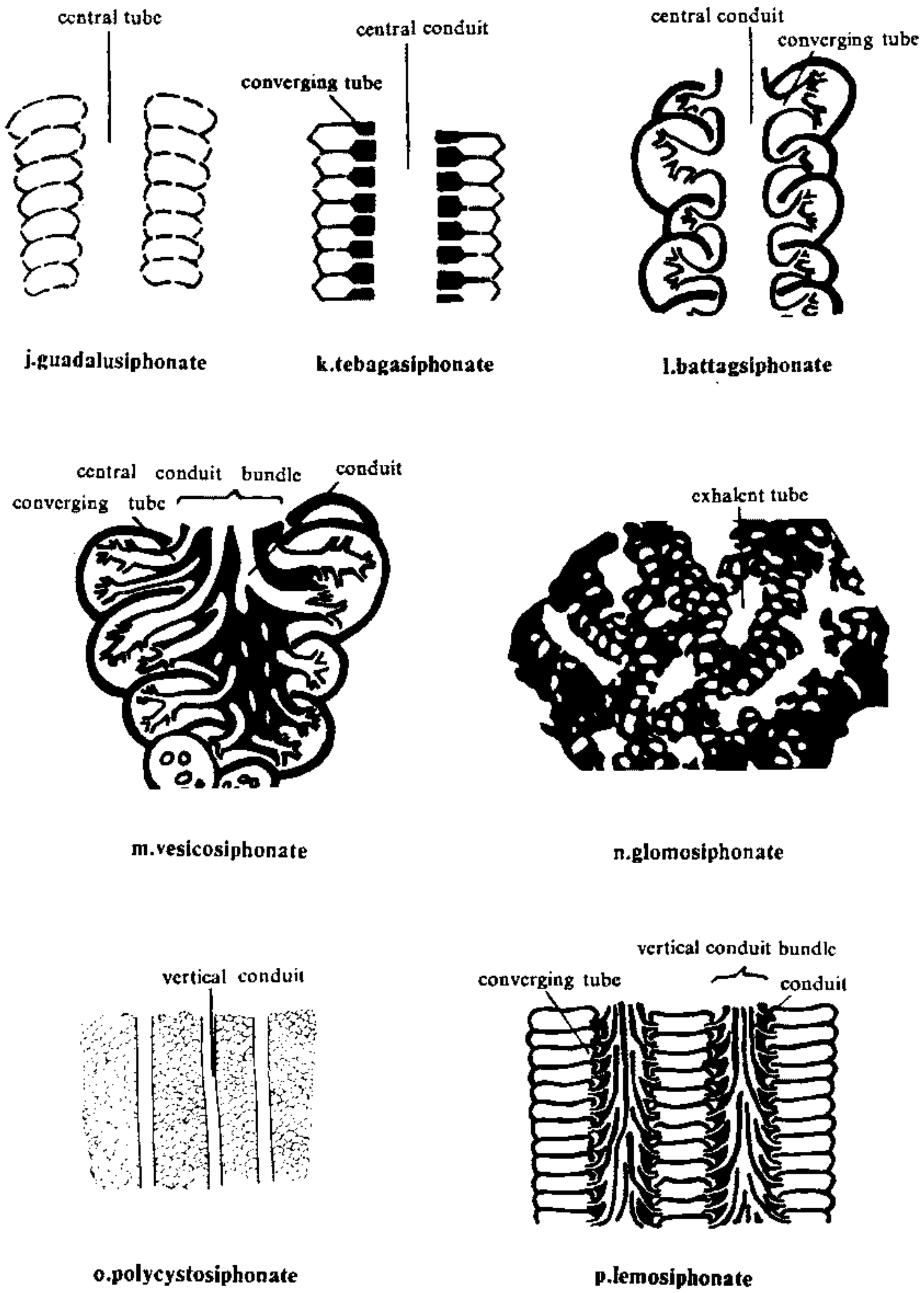


Fig. 22 The types of the exhalent canal system in sphinctozoans.

central conduit (Fig. 22k, l), (4) central conduit bundle (Fig. 22h, m), (5) multiple vertical tubes (Fig. 22n), (6) multiple vertical conduits (Fig. 22o), and (7) multiple vertical conduit bundles (Fig. 22i, p).

The tubes in type (1), (2) and (5) differ from the conduits in type (3), (4), (6) and (7) in that a conduit has a continuous wall of its own, commonly extending into the interior of chambers via small, acroteric tubes (known as converging tubes) while a tube has no wall of its own, or has a discontinuous wall built of chamber walls, lacking converging tube.

Apparently, asiphonate sphinctozoans have no exhalent canal system. Cryptosiphonate, pseudosiphonate, prosiphonate, retrosiphonate and amblysiphonate exhalent canal system have the same definition as Seilacher's. Each of these types consists of a central tube (Fig. 22a–e). It is added to their definitions that chambers in these types are stacked in a series.

A yukosiphonate exhalent canal system consists of a bundle of central tubes having discontinuous walls (Fig. 22f), with chambers stacked in a series, as in *Yukonella* Senowbari-Daryan & Reid, 1987.

An imbrisiphonate exhalent canal system consists of a bundle of central tubes with continuous walls, with the chambers arranged into more than one layer around the central tube bundle (Fig. 22g), as in *Imbricatocoelia* Rigby et al, 1989.

A pseudoamblysiphonate exhalent canal system consists of a bundle of central conduits extending into the interior of each chambers via some converging tubes, with the chambers stacked in a series (Fig. 22h), as in *Pseudoamblysiphonella* Senowbari-Daryan & Rigby, 1988.

A zanklisiphonate exhalent canal system consists of more than one conduit bundle scattered in a whole sponge, with the chambers stacked in a series (Fig. 22i), as in *Zanklithalamia* Senowbari-Daryan, 1990.

A guadalusiphonate exhalent canal system consists of a central tube without any wall of its own, with the chambers arranged into one layer around the central tube (Fig. 22j), as in *Guadalupia* Girty, 1908.

A tebagasiphonate exhalent canal system consists of a central conduit extending into each chamber via a converging tube, with the tube-like chambers arranged into one layer around the central conduit (Fig. 22k), as in *Tebagathalamia* Senowbari-Daryan & Rigby, 1988.

A battagsiphonate exhalent canal system consists of a central conduit extending into the interior of each chamber via some converging tubes, with chamber arrangement spiral (Fig. 22l), as in *Battaglia* Senowbari-Daryan & Schafer, 1986.

A vesicosiphonate exhalent canal system consists of a central conduit bundle extending into the interior of each chamber via converging tubes, with the chambers arranged into one layer around the central conduit bundle (Fig. 22m), as in *Polysiphospongia* Senowbari-Daryan & Schafer, 1986.

A glomosiphonate exhalent canal system consists of more than one guadalusiphonate vertical exhalent tube (somewhat irregular in form), with the chambers arranged into more than one layer around each exhalent tube (Fig. 22n), as in *Glomocystospongia* Rigby et al, 1989.

A polycystosiphonate exhalent canal system consists of more than one vertical conduit, with chambers arranged into more than one layer around each vertical conduit (Fig. 22o), as in *Polycystothalamia* gen. nov.

A lemosiphonate exhalent canal system consists of more than one vertical conduit bundle scattered in a whole sponge, with the chambers arranged into one layer around each vertical conduit bundle (Fig. 22p), as in *Lemonea* Senowbari-Daryan, 1990.

The pores are small, densely and evenly piercing chamber walls. On the contrary, the ostia are larger, sparse, piercing chamber walls, regularly or irregularly distributed. The chamber-connecting tubes penetrate more than one chamber, with or without walls, probably developed from the opposite pores in adjacent chamber walls, intercommunicating adjacent chambers.

The interior of chambers of sphinctozoans can be filled with a variety of calcareous filling structures. The filling structures include the following: (1) vesiculae as in *Colospongia*, (2) septa as in *Radiothalamos*, (3) pore-like tissue as in *Intrasporecoelia*, (4) pillars as in *Cryptocoelia*, and (5) reticulate tissue as in *Prosiphonella* (fine or robust). In some sphinctozoans such as *Battaglia* the central tubes are also filled in with filling structures.

III. Evolutionary Tendencies

The evolutionary tendencies in sphinctozoans lie in the following: (1) the arrangement of chambers, from single-chambered to multiple-chambered; the multiple-chambered varying from irregular aggregations to regular ones; the regular aggregations ranging from catenulate to one-layered or multiple-layered columnar, to spiral forms, (2) water-controlling structure, from asiphonate with perforation and maybe chamber-connecting tubes to siphonate (i.e., with exhalent tube), to vascular (i.e., with exhalent conduit), to multiple siphonate or multiple vascular, and (3) filling structure, from monotonous and simple ones to complicated or combined ones.

IV. Classification

The most important classification of sphinctozoans is Seilacher's (1962). In the classification he divided sphinctozoans into two superfamilies: Porata and Aporata, according to the perforation nature of chamber walls. This classification is followed by many authors (e.g., Ott, 1967; Senowbari-Daryan, 1988). However, this kind of classification has turned out somewhat questionable. For example, in *Guadalupia* some species have chamber walls perforated while others have imperforated chamber walls. Then, which superfamily would the genus be assigned to?

Recently, Senowbari-Daryan (1990) made some revision on Seilacher's classification. He divided sphinctozoans into 5 orders belonging to Demospongea or Calcispongea.

The present author believes that the perforation nature of chamber walls is a criterion only for generic or species-level taxonomy, and that the spicules are not a practicable criterion for the classification of most fossil sphinctozoans. The most important criterion should be the exhalent canal systems (including the central tube, the central tube bundle, the central conduit, the central conduit bundle, the multiple vertical tubes, the multiple vertical conduits, and the multiple conduit bundles) because they are the most important water-controlling structures. The less important criterion is the arrangement pattern of chambers which is also important to water circulation. The perforation nature of chamber walls, the ostia, the chamber-connecting tubes and the filling structures in chambers are the criterions for the identification of genera and species. Based on these standards, a new classification scheme is proposed as follows.

Order Sphinctozoa Steinmann, 1882

Definition: Chambered calcareous sponges with monaxons and various water-controlling structures. The microstructure of chamber walls can be spherulitic, irregular, orthogonal, clinogonal, lamellar, and micritic (as in *Uvanella*).

Suborder Asiphonata nov.

Definition: Sphinctozoans in the suborder have no exhalent canal system (i.e., asiphonate), composed of one or more than one chamber, commonly columnar, plate-like or irregular massive in form.

Family Parauvanellidae fam. nov.

Definition: It includes the members of the suborder irregular in form, composed of chambers irregularly arranged, with chamber walls perforated or imperforated with ostia.

Representative: *Parauvanella* Senowbari-Daryan & Di Stefano, 1988

Discussion: Similar to *Parauvanella* in form, but with a totally different microstructure of chamber walls, *Uvanella* Ott has a problematical position in the family. The micritic (or microgranular) nature of its chamber walls is unusual in sphinctozoans.

Family Polyphymaspongiidae fam. nov.

Definition: It includes the members of the suborder regular in form, commonly plate-like or columnar in form, with chamber walls perforated or imperforated with ostia.

Representative: *Polyphymaspongia* King, 1943

Family Colospongiidae Senowbari-Daryan, 1990

Definition (revised): It includes the members of the suborder catenulate or columnar in form, with chamber walls commonly perforated, probably with chamber-connecting tubes, or imperforated with ostia.

Representative: *Colospongia* Laube, 1865

Discussion: According to the definition, *Rhabdactinia*, *Intrasporecoelia*, and *Guangxispongia* gen. nov. are also included in the family.

Suborder Siphonata nov.

Definition: Sphinctozoans in the suborder have a central tube or a central tube bundle, commonly catenulate or columnar in form. The catenulate forms are composed of a series of chambers stacked. The columnar forms are generally composed of one or more than one layer of chambers arranged around the central tube or central tube bundle. The central tube can be cryptosiphonate, pseudosiphonate, prosiphonate, retrosiphonate, amblysiphonate and guadalusiphonate. The central tube bundle can be yukosiphonate or imbrisiphonate.

Family Thaumastocoeliidae Ott, 1967

Definition (revised): It includes the members of the suborder catenulate in form, with a cryptosiphonate, or pseudosiphonate central tube.

Representative: *Sollasia* Steinmann, 1882

Family Sebargasiidae Laubenfels, 1955

Definition (revised): It includes the members of the suborder catenulate in form, with a prosiphonate, or retrosiphonate or amblysiphonate central tube, with perforate or imperforate chamber walls.

Representative: *Amblysiphonella* Steinmann, 1882

Family Yukonellidae fam. nov.

Definition: It includes the members of the suborder with a yukosiphonate central tube bundle, composed of a series of chambers stacked, columnar in form.

Representative: *Yukonella* Senowbari-Daryan & Reid, 1987

Family Guadalupiidae Girty, 1908

Definition (revised): It includes the members of the suborder composed of lateral tube-like chambers radially arranged into one layer around a guadalusiphonate central tube, with perforate or imperforate chamber walls, commonly columnar in form.

Representative: *Guadalupia* Girty, 1908

Family Cystauletidae fam. nov.

Definition: It includes the members of the suborder composed of subspherical to saccate chambers arranged into one layer around a guadalusiphonate central tube, with chamber walls perforated or imperforated, commonly columnar in form.

Representative: *Cystauletes* King, 1943

Family Cystothalamiidae Girty, 1908

Definition (revised): It includes the members of the suborder composed of saccate chambers arranged into more than one layer around a guadalusiphonate central tube, with chamber walls perforated or imperforated.

Representative: *Cystothalamia* Girty, 1908

Family Imbricatocoeliidae fam. nov.

Definition: It includes the members of the suborder composed of saccate chambers arranged into more than one layer around a imbrisiphonate central tube bundle, with chamber walls perforated or imperforated.

Representative: *Imbricatocoelia* Rigby et al, 1989

Suborder Vasculata nov.

Definition: Sphinctozoans in the suborder have a central conduit or central conduit bundle, with chamber arrangement commonly catenulate or spiral.

Family Pseudoamblysiphonellidae fam. nov.

Definition: It includes the members of the suborder catenulate in form, composed of a series of chambers stacked, with a pseudoamblysiphonate central conduit bundle, with chamber walls perforated or imperforated.

Representative: *Pseudoamblysiphonella* Senowbari-Daryan & Rigby, 1988

Family Tebagathalamiidae Senowbari-Daryan & Rigby, 1988

Definition (revised): It includes the members of the suborder composed of lateral tube-like chambers radially arranged into one layer around a tebagasiphonate central conduit. Each chamber converges into the central conduit through a small converging tube. Chamber walls perforated or imperforated.

Representative: *Tebagathalamia* Senowbari-Daryan & Rigby, 1988

Family Uvacoeliidae fam. nov.

Definition: It includes the members of the suborder composed of spherical chambers arranged into one layer around a tebagasiphonate central conduit, commonly columnar in form. Each chamber converges into the central conduit through a small converging tube. Chamber walls perforated or imperforated.

Representative: *Uvacoelia* Kugel, 1987

Family Battagliidae fam. nov.

Definition: It includes the members of the suborder having a battagsiphonate central conduit, with chamber arrangement spiral, with chamber walls perforated or imperforated.

Representative: *Battaglia* Senowbari-Daryan & Schafer, 1986

Family Vesicocaulidae fam. nov.

Definition: It includes the members of the suborder having a vesicosiphonate central conduit bundle, with chambers arranged into one layer around the central conduit bundle, with chamber walls perforated or imperforated.

Representative: *Polysiphospongia* Senowbari-Daryan & Schafer, 1986

Suborder Polysiphonata nov.

Definition: Sphinctozoans in the suborder have more than one vertical exhalent tube or vertical tube bundle scattered in a whole sponge.

Family Glomocystospongiidae Rigby, Fan & Zhang, 1989

Definition (revised): It includes the members of the suborder having a glomosiphonate exhalent canal system, with chambers arranged into more than one layer around each vertical exhalent tube / canal, with chamber walls perforated or imperforated.

Representative: *Glomocystospongia* Rigby, Fan & Zhang, 1989

Suborder Polyvasculata nov.

Definition: Sphinctozoans in the suborder have more than one vertical conduit or vertical conduit bundle scattered in a whole sponge.

Family Zanklithalamiidae fam. nov.

Definition: It includes the members of the suborder composed of a series of chambers stacked, with a zanklisiphonate exhalent canal system, with chamber walls perforated or imperforated.

Representative: *Zanklithalamia* Senowbari-Daryan, 1990

Family Polycystothalamiidae fam. nov.

Definition: It includes the members of the suborder having a polycystosiphonate exhalent canal system, with chambers arranged into more than one layer around each vertical conduit, with chamber walls perforated or imperforated.

Representative: *Polycystothalamia* gen. nov.

Family Lemoneidae fam. nov.

Definition: It includes the members of the suborder having a lemosiphonate exhalent canal system, with lateral tube-like chambers radially arranged into one layer around each vertical conduit bundle.

Representative: *Lemonea* Senowbari-Daryan, 1990

V. Paleoecology

Sphinctozoans generally occur in shallow-water carbonate rocks or reefs. They are commonly associated with calcareous algae which are indicative of warm, shallow water environments. In Permian reefs, sphinctozoans are generally important reef-builders. In all of the Permian reefs of China (Guangxi, Guizhou, Yunnan, Hubei, Sichuan, etc.), sphinctozoans are without exception important reef-builders. In these reefs, sphinctozoans can serve as (1) bafflers (as in the Upper Permian reefs of Sichuan), and (2) framers (as in the Upper Permian reefs of Hubei, the Middle and Upper Permian reefs of Guangxi and Guizhou). In the Upper Permian reefs of Chongqing, Sichuan, sphinctozoans as well as inozoans are chief bafflers. In the Upper

Permian reefs of Guangxi, Guizhou, and Hubei, sphinctozoans are main framers. In the Middle Permian reef of Xiangbo, sphinctozoans are main framers accessory to sclerosponges and inozoans in generic and individual numbers, constituting 12.7–26.8% of the main reef-builders. In the reef, sphinctozoans can be generally thick columnar, slender columnar, robust branched, slender branched and conical. It is found that the slender columnar and slender branched sphinctozoans are adapted to high-energy environments, representing the climax of reef development. This is also the case in the Upper Permian reefs of Ziyun, Guizhou. It is found that sphinctozoans tend to have a higher richness than inozoans in non-typical reefs or reef facies but a lower richness than inozoans in typical reefs or reef facies. Thus it is believed that sphinctozoans have a living habit similar to but slightly different from that of inozoans.

VI. Comparison with Sphinctozoans from Tunisia

As to the generic composition, the sphinctozoans in the reef of Xiangbo resemble those in the reefs of Lichuan, Hubei, and those in the reefs of Sicily and Tunisia.

To compare two faunas taxonomically, the recurrence coefficient is defined. Suppose that there are fauna A and fauna B and there are more genera in fauna A than in fauna B. If fauna A has n genera while fauna B has m genera, and X genera in fauna B can be found in fauna A, then the recurrence coefficient (REC.) of fauna B to fauna A is calculated from

$$\text{REC.} = X / m \times 100\%$$

It is calculated that the recurrence coefficient of sphinctozoans in the reef of Xiangbo to that in the reefs of Tunisia is 77%. According to fusulinid fauna, the reefs of Tunisia are of the same age as the reef of Xiangbo, Longlin, Guangxi, China.

The sphinctozoan composition of the Permian reef of Xiangbo differs from that of the Triassic reefs of Italy and Alps. The recurrence coefficient of the sphinctozoans in the Triassic reefs of Italy to those in the reef of Xiangbo is 30%.

The comparison shows that sphinctozoan composition in reefs is controlled by geological time as well as environments. Therefore, sphinctozoans are also of stratigraphic value.

VII. Systematic Description

Order Sphinctozoa Steinmann, 1882

Suborder Asiphonata nov.

Family Parauvanellidae fam. nov.

Genus *Parauvanella* Senowbari-Daryan & Di Stefano, 1988

Diagnosis: Sponges nodular or irregular aggregates, consisting of small saccate or irregular chambers irregularly arranged, without exhalent canal system, with chamber walls perforated or imperforated with ostia, without filling tissue. Chamber walls commonly recrystallized.

Type species: *Parauvanella paronai* Senowbari-Daryan & Di Stefano, 1988

Parauvanella sp.

(pl. 10 / 10)

Section: xb33–5–2, xb33–6–2.

Description: Sponges columnar, 5–10 mm in diameter. Chambers irregular in form, generally saccate, not uniform in size, generally 0.5–0.62 mm wide and 0.25–0.42 mm high, irregularly arranged. Chamber walls sparsely perforated. The interior of chambers empty. Chamber walls recrystallized.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Family Colospongiidae Senowbari-Daryan, 1990

Genus *Colospongia* Laube, 1865

Diagnosis: Sponges catenulate, asiphonate, consisting of a series of stacked spherical chambers. Chamber wall perforated. The pores branched or unbranched, making chamber walls cribriform. Chambers generally hollow, in some cases with vesiculae. Chamber walls irregular in microstructure.

Type species: *Colospongia dubia* Laube, 1865

Colospongia sp.
(pl. 11 / 10)

Section: xb33–7–7, xb30–2–6.

Description: Sponges catenulate, consisting of a series of spherical chambers stacked. Chambers 7 mm wide and 5 mm high. Interwalls or top walls up to 0.65 mm thick. Chamber side walls 0.5 mm thick. Chamber walls perforated, with the pores in interwalls more instinct than in side walls, commonly unbranched. Chambers hollow, in some cases with vesiculae.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Intrasporecoelia* Fan & Zhang, 1985

Diagnosis: Sponges columnar, asiphonate, consisting of a series of low chambers stacked. Chamber walls perforated. Interior of chambers with pore-like filling tissue. Chamber-connecting tubes probably present.

Type species: *Intrasporecoelia hubeiensis* Fan & Zhang, 1985

Intrasporecoelia hubeiensis Fan & Zhang, 1985
(pl. 10 / 13; pl. 13 / 1)

Section: xb36–1–5, xb35–8–11, xb27–2–4.

Description: Sponges large, columnar, or branched. Individual branch 15–25 mm in diameter, up to 80 mm in a specimen.

Chambers low, generally 2.0–4.5 mm in height. Chamber walls 1.5–2.7 mm thick, perforated, with the pores 0.1–0.2 mm across. The interior of chambers has pore-like filling tissue, with individual pore-like tissue 0.05–0.65 mm across.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Intrasporecoelia laxa sp. nov.
(pl. 11 / 2, 5)

Derivatio nominis: Laxus (la. = loose) refers to the sparse pore-like filling tissue.

Diagnosis: Sponges columnar or branched. Chamber walls coarsely perforated, with some pores merged into small tubes. Pore-like filling tissue in chambers point-like, sparse.

Section: xb33–3–9 (holotype), xb35–8–1, xb30–5–1, xb36–4–9 and xb30–5–17.

Description: Sponges large, columnar, with individual stem 15–25 mm in diameter.

Chamber low, generally 2–5 mm in height. The top walls of chambers 1.3–2.7 mm thick. Chamber walls pierced by numerous pores 0.10–0.22 mm across. The pores perpendicular to chamber walls, generally unbranched. Some pores merged into small tubes 0.27–0.50 mm in diameter. The interior of chambers with sparse pore-like filling tissue. Individual pore-like tissue 0.10–0.65 in diameter.

Discussion: The new species differs from *Intrasporecoelia hubeiensis* in the small tubes formed by the mergence of pores, and the sparser pore-like filling tissue in the chambers of the former.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Guangxispongia* gen. nov.

Derivatio nominis: The generic name refers to the type locality of the genus.

Diagnosis: Sponges large, columnar, asiphonate, consisting of a series of low chambers stacked. Chambers peltate. Chamber walls dramatically, irregularly perforated. The pores large, branched, enlarged towards the surface of the chamber walls, making the skeletal materials between the pores spiny. Chambers hollow.

Discussion: According to Senowbari-Daryan's (1986, pl. 51, fig. 5) illustration, *Cryptocoelia* sp. 1 described by him is different from *Cryptocoelia*. It can belong to the new genus.

The new genus is similar to *Colospongia*. They may have some affinities and thus may belong to the same family.

The genus is characterized by dramatically and irregularly developed perforation, irregular chamber walls, low chambers and the absence of exhalent canals. It differs from *Rhabdactinia* Yabe & Sugiyama in the presence of chamber-connecting tubes, the regularity and perforation of chamber walls in the latter.

Type species: *Guangxispongia spinalis* gen. et sp. nov.

Guangxispongia spinalis gen. et sp. nov.

(pl. 12 / 3, 5, 6)

Derivatio nominis: Spinalis (la. = spiny) refers to the spiny surface of the interwalls or top wall.

Diagnosis: Sponges large. Chambers very low. The surface of chamber walls spiny, with 25 spines in per 1 mm wide of chamber walls and 7–8 chambers in per 10 mm of height.

Section: xb33–1–R1–3 (holotype), xb36–1–8 (paratype), xb36–1–6 (paratype).

Description: Sponges large, columnar. The holotype over 40 mm in diameter and in height.

Chambers very low. There are 7–8 chambers in per 10 mm of height. Chamber walls wavy. Walls of adjacent chambers often merged and then separated. Thus, chamber walls not long. Chamber walls coarsely and irregularly perforated. The pores in adjacent chamber walls not arranged in the same direction. The surface of chamber walls seems to be spiny, with 25 spines (i.e., the skeletal material between adjacent pores) along per 1 mm wide of chamber walls. Chamber walls 0.37–0.65 mm thick. Chambers hollow.

Discussion: The specimens described as *Cryptocoelia* ? sp. 1 by Senowbari-Daryan (1986) differ from the present specimens in the coarser and more regular pores in the chamber walls of the former.

The specimens described as *Rhabdactinia irregulara* by Rigby, Fan & Zhang (1989) belong to this species.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Cystospongia* gen. nov.

Derivatio nominis: Cysto (gr. = saccate) refers to the form of the chambers.

Diagnosis: Sponges generally columnar or branched, asiphonate, consisting of saccate chambers imbricately arranged. Chambers generally hollow. Chamber walls perforated with pores. The pores uniform in size and regularly arranged, connecting adjacent chambers.

Discussion: The new genus resembles *Cystothalamia*, *Cystauletes*, and *Uvanella* in gross form. The comparison of these four genera is given below.

Genus	*Cystothalamia*	*Cystauletes*	*Cystospongia*	*Uvanella*
Form	Regular	Regular	Regular	Irregular
Central tube	Present	Developed	Absent	Absent
Chamber arrangement	Irregular several layers	Regular one layer	Regular	Irregular
Filling tissue	Present or absent	Absent	Absent	Present
Pores	Regular	Developed	Regular	Irregular

Type species: *Cystospongia guangxiensis* gen. et sp. nov.

Cystospongia guangxiensis gen. et sp. nov.
(pl. 10 / 4, 7, 8)

Derivatio nominis: The species name refers to the type locality of the species.

Diagnosis: Sponges columnar. Chambers 1.5 mm wide and 1.3 mm high, diagonally alternating. Pores numerous.

Section: xb36–4–17 (holotype), xb36–4–10 (paratype), xb34–2–9 (paratype), xb30–5–13.

Description: Sponges columnar, at least 10 mm wide and 13 mm high. Chambers peltate in form, crescentic in longitudinal section, uniform in size, up to 1.5 mm wide and 1.3 mm high, diagonally alternating. Chamber walls pierced by numerous pores. The pores uniform in size, generally 0.075–0.250 mm in diameter, evenly spaced. The distance between adjacent pores somewhat greater than the diameter of pores, generally 0.20–0.25 mm. The top walls of chambers 0.20–0.25 mm thick. Chambers hollow.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Suborder Siphonata nov.

Family Thaumastocoeliidae Ott, 1967

Genus *Sollasia* Steinmann, 1882

Diagnosis: Sponges catenulate, consisting of a series of subspherical chambers stacked.

Chambers imperforate, generally with some large ostia. Adjacent chambers communicated through a cryptosiphonate central tube. Chamber walls spherulitic in microstructure.

Type species: *Sollasia ostiolata* Steinmann, 1882

Sollasia ostiolata Steinmann, 1882
(pl. 11 / 4; pl. 10 / 1)

1882 *Sollasia ostiolata*: Steinmann, p. 151–152, pl. Ⅶ, fig. 3.

Section: xb30–2–6, xb28–4–5.

Description: Sponges catenulate, consisting of several stems from the same attachment base. Individual stem up to 20 mm long, consisting of a series of spherical chambers stacked. The chambers 3 mm high and 3 mm wide at the base of stems, enlarged distally, 4 mm high and 6 mm wide at the distal ends. The boundary between adjacent chambers visible. Chamber walls 0.4–0.6 mm thick, with several ostia 0.4–0.5 mm across. The borders of ostia rimmed. The central tube at least 1 mm wide.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Follicatena* Ott, 1967

Diagnosis: Sponges catenulate. Chamber walls aporate, pierced by ostia in patches (i.e., sieve-fields). Chambers hollow or with vesiculae. Adjacent chambers communicated through ostia in interwall (i.e., cryptosiphonate central tube).

Type species: *Follicatena cautica* Ott, 1967

Follicatena sp.
(pl. 10 / 2)

Section: xb33–7–2, xb33–5–1.

Description: The specimen figured is a part of a longitudinal section. Sponge catenulate. Chambers cydariform or doliform, 6 mm high and 9 mm wide. The interior of chambers with vesiculae. Chamber walls 0.5–0.6 mm thick. The interwalls cribriform due to presence of ostia.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Family Sebargasiidae Laubenfels, 1955

Genus *Amblysiphonella* Steinmann, 1882

Diagnosis: Sponges columnar or branched, consisting of a series of discoid or subspherical chambers stacked. Chambers hollow or with vesiculae. Chamber walls perforated. Central tube amblysiphonate.

Type species: *Amblysiphonella barroisi* Steinmann, 1882

Amblysiphonella sp. indet.
(pl. 11 / 7)

Section: xb33–2–5.

Description: The specimen is a transversal section, with a diameter of 12 mm. Central tube 2–3 mm in diameter. Interior of chambers with vesiculae. Chamber walls and interwalls perforated.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Dictyocoelia* Ott, 1967 (= *Solenolmia* Pomel, 1872)

Diagnosis: Sponges catenulate. Chambers spherical or doliform. Interior of chambers with reticulate tissue. Central tube retrosiphonate.

Type species: *Dictyocoelia manon* (Munster, 1841) Ott, 1967

Dictyocoelia manon (Munster, 1841) Ott, 1967
(pl. 13 / 4)

Section: xb30–1–2.

Description: Sponge thin columnar, somewhat sinuous, 3–5 mm in diameter. Chambers spherical to cydariform, 3–5 mm wide, 2.7–3.0 mm high. Central tube 1.0–1.3 mm in diameter. Interior of chambers has robust reticulate tissue arranged vertically or upward radially.

Discussion: The present specimen is identical with those of Ott (1967), Senowbari-Daryan (1983) and Fois (1981). Thus, they belong to the same species.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Dictyocoelia sp.
(pl. 11 / 11)

Section: xb31–1–8.

Description: Sponge columnar, 8.5 mm in diameter. Chambers spherical to cydariform, with domed top. Central tube approximately 1 mm in diameter. Reticulate tissue in chambers arranged upward radially, 0.075–0.150 mm thick, 0.10–0.20 mm apart.

Discussion: The specimen differs from *Dictyocoelia manon* in the thinner and relatively regularly arranged reticulate tissue.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Stylocoelia* gen. nov.

Derivatio nominis: Styl (gr. = pillar) refers to the type of filling structure.

Diagnosis: Sponges columnar, consisting of a series of low chambers stacked. Chamber walls perforated. Central tube small, with its wall perforated. The interior of chambers has pillars perpendicular to interwalls. The pillars confined to chambers.

Discussion: The new genus differs from *Dictyocoelia* in the reticulate tissue in the latter. It differs from *Cryptocoelia* in the absence of central tube in the latter.

Type species: *Stylocoelia circopora* gen. et sp. nov.

Stylocoelia circopora gen. et sp. nov.
(pl. 10 / 14; pl. 11 / 9; pl. 13 / 6; pl. 14 / 6)

Derivatio nominis: The species name refers to the circular pores in the chamber walls.

Diagnosis: Chambers 0.15–0.30 mm high. Pores in chamber walls numerous, evenly distributed. Pillars evenly spaced, 0.10–0.27 mm apart. Width of central tube 11–25% of that of sponges.

Section: xb30–5–8(holotype), xb30–7–3(paratype), xb31–2–1, xb31–1–R1–4.

Description: Sponges columnar, 8–12 mm in diameter, 14–23 mm high, consisting of a series of very low chambers stacked. Two columns probably merged.

Chambers 0.15–0.30 mm high, arciform in vertical sections of sponges. Chamber walls

0.06–0.15 mm thick, pierced by numerous circular pores. The circular pores intercommunicating two adjacent chambers, 0.12–0.25 mm in diameter, densely and evenly distributed. The pillars in chambers unbranched, 0.06–0.10 mm thick, 0.10–0.27 mm apart, perpendicular to chamber walls, confined to chambers.

Central tube 1.3–2.0 mm in diameter, being 11–25% of sponge width, with its wall perforated.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Family Cystauletidae fam. nov.

Genus *Cystauletes* King, 1943

Diagnosis: Sponges columnar, straight or somewhat sinuous, or branched. Central tube guadalusiphonate, extending through the length of sponges. Chambers spheric, arranged into diagonal rows, around the central tube, in one layer. Chamber walls pierced by numerous pores evenly distributed. Chambers hollow. The surface of sponges warty.

Type species: *Cystauletes mammilosus* King, 1943

Cystauletes sp.

(pl. 10 / 11)

Section: xb34–2–1, xb33–6–1.

Description: Sponges slightly sinuous, columnar, thinner at the proximal part and the distal part, at least 3 mm in diameter, thicker at the middle part, at least 5 mm in diameter, at least 9 mm high.

The central tube 1 mm wide at the proximal part and the distal part, at least 2.5 mm wide at the middle part. The central tube in the same form as the sponge. Chambers spheric, uniform in size, generally 1 mm high and 1 mm wide, arranged into diagonal rows in one layer around the central tube. Chamber walls pierced by sparse small pores.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Family Guadalupiidae Girty, 1908

Genus *Guadalupia* Girty, 1908

Diagnosis: Sponges columnar, with a guadalusiphonate central tube extending through sponge length. Around and perpendicular to the central tube radially arranged a layer of lateral tube-like chambers. The chambers hollow or with vesiculae. The microstructure of chamber walls is spherulitic. Chamber walls perforated, or with sparse ostia or coarse pores.

Discussion: As pointed out by Senowbari-Daryan & Rigby (1988), the genus is originally heterogeneous. Thus, its definition is revised herein. The revised definition does not include those without central tube and those bowl-like in form. Consequently, its type species is replaced by *Guadalupia cylindrica* Girty, 1908. It is also suggested that a new genus should be erected according to the original type species.

Type species: *Guadalupia cylindrica* Girty, 1908

Guadalupia minima Parona, 1933

(pl. 10 / 12)

1933 *Guadalupia minima*: Parona, p.48, tex–fig. 3.

1986 *Guadalupia minima* Parona: Aleotti, Dieci & Russo, p. 222, pl. 3, fig. 1–2.

Section: xb33–3–8, xb30–5–12.

Description: Sponges circular in cross section, 6 mm in diameter.

Central tube circular in cross section, 1 mm in diameter. Chambers thin at the inner ends and thick at the outer ends, 0.6 mm in diameter at the outer ends.

Discussion: The species is characterized by the small central tube.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage. Sicily, Italy; Middle Permian.

Family Cystothalamiidae Girty, 1908

Genus *Cystothalamia* Girty, 1908

Diagnosis: Sponges are columnar or branched aggregation of saccate chambers. Chambers uniform or not uniform in size, irregularly arranged into more than one layer around a guadalusiphonate central tube. Chamber walls with ostia or perforated by coarse pores. Chambers generally empty. The surface of sponges warty.

Discussion: According to the original definition, sponges of the genus have a central tube which extends through a sponge or is present only in the upper part of a sponge. Because of the absence of the thin section of the original type specimens, the definition of the genus is not used in the same sense by the later workers. For instance, the specimen described as *Cystothalamia nana* (Rigby, 1984) has no exhalent canals. Most of the specimens assigned to *Cystothalamia ramosa* (Senowbari-Daryan & Rigby, 1988, pl. 32 / 7–21; pl. 35 / 11–12) have a central tube bundle rather than a central tube.

Thus, the definition of the genus should be revised to exclude those with a central tube bundle, or with scattered exhalent tubes / conduits, or with no exhalent canals. Consequently, the above specimens with a central tube bundle represent a new genus. The specimens without exhalent canals or with scattered exhalent tubes / conduits should be assigned to other new genera.

Type species: *Cystothalamia nodulifera* Girty, 1908

Family Imbricatocoeliidae fam. nov.

Genus *Imbricatocoelia* Rigby et al, 1989

Diagnosis: Sponges columnar, composed of peltate chambers arranged into more than one layer around an imbrisiphonate central tube bundle. The chambers empty. Chamber walls perforated.

Type species: *Cystothalamia ramosa* Senowbari-Daryan & Rigby, 1988

Imbricatocoelia ramosa Senowbari-Daryan & Rigby, 1988

(pl. 10 / 6)

1988 *Cystothalamia ramosa* Senowbari-Daryan & Rigby: pl. 32 / 7–21; pl. 35 / 11–12.

1989 *Imbricatocoelia paucipora* Rigby et al: pl. 13 / 4, 6; pl. 14 / 4.

Section: xb30–5–14.

Description: Sponge columnar or branched, 6 mm in diameter and at least 10 mm high. Chambers low, peltate in form, diagonally alternating. The top walls of chambers 0.15–0.17 mm thick, pierced by numerous pores 0.075–0.130 mm in diameter. The distance between pores similar to the diameter of pores. Probably two central tubes sectioned in the axial region of the sponge, about 0.45 mm in diameter.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Suborder Vasculata nov.

Family Tebagathalamiidae Senowbari-Daryan & Rigby, 1988

Genus *Tebagathalamia* Senowbari-Daryan & Rigby, 1988

Diagnosis: Sponges columnar, with a tebagasiphonate central conduit. Chambers tube-like, lateral, radially arranged into one layer around the central conduit. The conduit has a thick wall. Each chamber converges into the central conduit through a small lateral converging tube penetrating the wall of the central conduit. Chamber walls perforated or imperforated. The surface of sponges commonly with secondary calcareous materials granular or laminated in microstructure.

Discussion: This genus differs from *Guadalupia* in the presence of a central conduit and converging tubes rather than a central tube.

According to the definition, one of the specimens assigned to *Guadalupia cylindrica* by Parona (1933, pl. 9 / fig. 12) and all of those assigned to *Graminospongia girtyi* (Parona) by Senowbari-Daryan and Rigby (1988, pl. 35 / fig. 1–10, pl. 34 / fig. 12, 13) belong to the genus although they are of different species.

Type species: *Tebagathalamia cylindrica* Senowbari-Daryan & Rigby, 1988.

Tebagathalamia lamella sp. nov.

(pl. 11 / 3, 6)

Derivatio nominis: The species name refers to the laminated microstructure of the secondary calcareous materials.

Diagnosis: Sponges columnar. Central conduit 1.5 mm across. Chambers 0.5–1.0 mm across, in vertical rows. Pores 0.05– 0.07 mm across. Converging tubes V-shaped, 0.15–0.37 mm across. Secondary materials laminated.

Section: xb34–2–6 (holotype), xb31–1–R1 (paratype), xb33–5–4.

Description: Sponges columnar, 10–12 mm in diameter.

A B

Fig. 23 Features of *Tebagathalamia lamella* sp. nov. in sections. A: tangential section. Pores and the arrangement of chambers are seen. B: longitudinal section. V-shaped converging tubes and laminated secondary calcareous materials on the surface of sponge are seen.

Central conduit cylindrical, approximately 1.5 mm in diameter. Chambers long, sickle-like in longitudinal section, 0.75 mm at the inner part and 0.5–1.0 mm at the middle part in diameter. The interior of chambers empty. Interwalls pierced by pores. Adjacent two or three chambers intercommunicated through pores. The pores 0.05–0.07 mm across. Chambers hexagonal in cross section at their inner ends and low hexagonal at their outer ends. Each chamber communicated with the central conduit through a small converging tube. The converging tubes V-shaped (Fig. 23), 0.15–0.37 mm in diameter. Each converging tube has its outer end connected with the under side of the inner end of a chamber and the inner end intercommunicated with the central conduit. The converging tubes are cut through by some far thinner, vertical or oblique tubes. Chambers arranged in vertical rows in one layer around the central conduit. On the surface of chambers present laminated secondary calcareous materials, with the lamellae parallel to the surface of chambers. Chamber walls spherulitic in microstructure.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Tebagathalamia diagonalis sp. nov.
(pl. 12 / 1, 2)

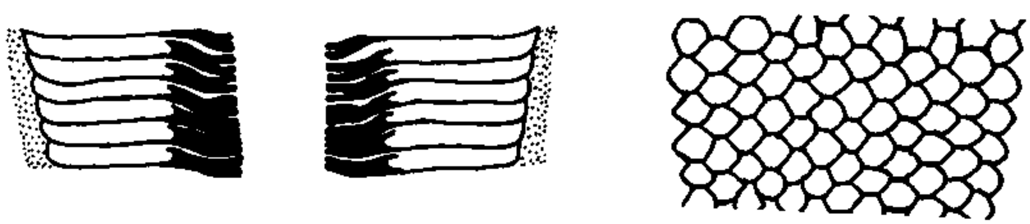
Derivatio nominis: The species name refers to the diagonal arrangement of the chambers.

Diagnosis: Sponges cylindrical. Central conduit cylindrical. Chambers long, with the ratio of length to width being 10–11. Chamber walls imperforated. Chambers rhombic in cross sections, arranged in diagonal rows. Converging tubes S-shaped. Secondary calcareous materials granular.

Section: xb27–2–2 (holotype), xb27–2–3 (holotype).

Description: Sponges columnar, up to 22 mm in diameter.

Central conduit cylindrical, 5.5 mm in diameter. Chambers long, rhombic in cross section, 0.75 mm in diameter, up to 8 mm in length, with the ratio of their length to width being 10–11. Chambers hollow. Chamber walls imperforated. Interwalls one-layered, 0.05 mm in thickness. Each chamber intercommunicated with the central conduit via a small converging tube. Converging tubes 0.25–0.50 mm in diameter, 1.2–1.5 mm long, bent into the form of a lying "S" (Fig. 24). Each converging tube has its outer end connected with the top side of the inner end of a chamber and its inner end opening into the central conduit. The common wall between adjacent chambers thick, with its inner end split.



A B

Fig. 24 Features of *Tebagathalamia diagonalis* sp. nov. A: tangential section, in which the arrangement of chambers is seen. B: longitudinal section, in which S-shaped converging tubes and granular secondary calcareous materials are seen.

The surface of sponges coated with a layer of secondary materials of granular calcites. The boundary between the secondary materials and chamber walls distinct. Chamber walls spherulitic in microstructure.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Graminospongia* Termier et al, 1977

Diagnosis: Sponges columnar, consisting of two parts: the inner part with a central conduit and a circle of small vertical tubes surrounding the central conduit, and the outer part with lateral tube-like chambers radially arranged into one layer around the inner part. Chamber walls perforated or imperforated. The interior of chambers with or without vesiculae.

Discussion: Termier et al (1977) established the genus *Graminospongia* according to *Guadalupia girtyi* Parona, 1933. And this is followed by Aleotti et al (1986) and by Senowbari-Daryan & Rigby (1988). However, the specimens assigned to the genus by Termier et al (1977) and by Senowbari-Daryan & Rigby (1988) are different from what *Guadalupia girtyi* Parona is based on. They should belong to other genus. The specimens assigned to the genus by Aleotti et al are identical with Parona's.

The definition of the genus given by Termier et al (1977) does not include the features of the central conduit because of the inadequate materials they used. The definition was revised by Aleotti et al (1986), thus being perfect as above.

Type species: *Guadalupia girtyi* Parona, 1933

Family Vesicocaulidae fam. nov.

Genus *Solidothalamia* gen. nov.

Derivatio nominis: Solid (la. = solid) refers to the presence of some skeletal structure in the central part of sponges.

Diagnosis: Sponges columnar, or conical, composed of two parts: the inner part and the outer part. In the center of the inner part present a small central conduit somewhat irregular in cross section. Surrounding the central conduit are short and small tubes oblique outward. In the edge of the inner part present some vertical tubes arranged into a circle. In the outer part are lateral tube-like chambers radially arranged into one layer around the inner part. Chamber walls perforated or imperforated. The chambers hollow, or with vesiculae.

Type species: *Solidothalamia lambdiformis* gen. et sp. nov.

Solidothalamia lambdiformis gen. et sp. nov.

(pl. 11 / 8; pl. 12 / 4)

Derivatio nominis: The species name refers to the lambdoid appearance of the inner part of the skeletons in longitudinal sections.

Diagnosis: Sponges somewhat conical. Chambers 0.75 mm across. Interwalls 0.12–0.23 mm thick, imperforated. Oblique tubes 0.4–0.7 mm across. Vertical tubes 0.7–0.8 mm across.

Section: xb37–B (holotype), xb27–6–12.

Description: Sponges columnar, 15 mm long, with one end thick, 7 mm in diameter, and the other end thin, 5 mm in diameter.

Sponges consist of two parts: the inner part and the outer part. In the center of the inner part present a small central conduit. Surrounding the central conduit are oblique thin and short tubes (Fig. 25). They form lambdoid configuration in longitudinal sections of sponges. In the edge of the inner part present thin, vertical tubes arranged into a circle. In the outer part are lateral chambers nephroid to doliform, 1.5–1.7 mm long, 0.75 mm in diameter, radially arranged around the inner part. Interwalls imperforate, 0.12–0.23 mm thick. The inner end of each chamber intercommunicated with the vertical tube; the vertical tubes intercommunicated with the oblique tubes; and the oblique tubes intercommunicated with the central conduit.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

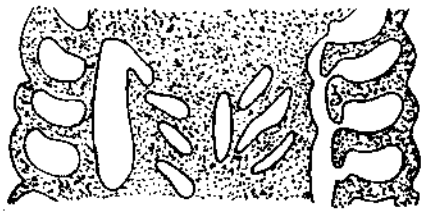


Fig. 25 *Solidothalamia lambdiformis* gen. et sp. nov. in longitudinal section. Exhalent canal system is shown.

Suborder Polyvasculata nov.

Family Polycystothalamiidae fam. nov.

Genus *Polycystothalamia* gen. nov.

Diagnosis: Skeletons columnar, with more than one vertical conduit scattered in a whole sponge (polycystosiphonate). Between adjacent conduits present more than one row of saccate chambers somewhat irregularly arranged.

Discussion: According to the illustration, the specimen described as *Cystothalamia ramosa* Senowbari-Daryan & Rigby, 1988 (pl. 35, fig. 13) belongs to this genus.

Type species: *Polycystothalamia sinuolata* gen. et sp. nov.

Polycystothalamia sinuolata gen. et sp. nov.

(pl. 10 / 5)

Diagnosis: Skeletons columnar. Vertical conduits somewhat sinuous, 0.33 mm across. 3–4 rows of chambers present between adjacent conduits. Chambers 0.49–0.84 mm wide.

Section: xb33–5–2 (holotype).

Description: Skeleton columnar, 10 mm wide.

In the skeleton present more than one conduit. The conduits somewhat sinuous, probably furcated, maximally 0.33 mm across. Chambers fanlike in longitudinal sections, 0.49–0.84 mm wide and 0.34–0.41 mm high.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Polycystothalamia sp.

(pl. 10 / 3, 9)

Section: xb33–5–15, xb34–6–5.

Description: Sponges probably columnar, at least 6 mm in diameter and 12 mm in height. Chambers regular, 0.75–1.30 mm across and 0.55–0.75 mm high, diagonally alternating. The top walls of chambers 0.10–0.17 mm thick. Pores 0.05–0.12 mm across, distributed only near the boundary of adjacent chambers. Several conduits 0.5–0.6 mm across, obliquely spaced in sponges.

Discussion: The specimen is characterized by the pores near the boundary of adjacent chambers and the oblique conduits.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Demosponges

Demosponges are very sparse in the reef of Xiangbc. Only two genera are found. One of them is described as follows.

Class Demospongea Sollas, 1875

Order Lithistida Schmidt, 1870

Genus *Mastostroma* gen. nov.

Derivatio nominis: Masto (gr. = hill-like) refers to the form of the mamelons on the top surface of the skeletons.

Diagnosis: Skeletons sheetlike, with hill-like processes on their top surface. Skeletons consist of two kinds of skeletal elements: knots and shafts. The knots spherical, formed by fusion of clad tips, somewhat irregularly spaced at small intervals. Each knot linked to adjacent ones through several shafts. In the skeleton present two kinds of tubes: vertical and horizontal ones. The vertical tubes thinner, circular in cross section. The horizontal tubes thick, circular or stellar in cross section. They are all exhalent tubes.

Type species: *Mastostroma punctiformis* gen. et sp. nov.

Mastostroma punctiformis gen. et sp. nov.

(pl. 14 / 4)

Diagnosis: Skeleton sheetlike. Processes large, triangular in vertical section. Horizontal tubes 0.30–0.62 mm in diameter. Vertical tubes 0.15–0.22 mm in diameter.

Section: xb36–1–2 (holotype).

Description: Skeleton sheetlike, over 30 mm wide, 1 mm thick generally, up to 8 mm thick at processes.

Skeleton consists of knots and shafts. Knots 0.15 mm in diameter generally, irregularly spaced, 0.02–0.15 mm apart. Each knot connected with adjacent knots via several shafts. Knots spherulitic in microstructure.

In the skeleton present two kinds of tubes: horizontal and vertical ones. The horizontal tubes circular or stellar in cross section, with a diameter of 0.30–0.62 mm. The vertical tubes circular in cross section, 0.15–0.22 mm in diameter.

No epitheca on the surface of the skeleton.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

6 Hydrozoans and Extrohydrozoans

Hydrozoans are also reef-building organisms in the Middle Permian reef of Xiangbo. It is one of the most poorly studied reef-building groups of Permian.

I. Research History

Permian fossil hydrozoans were first described by Waagen & Wentzel (1887) from Salt Range, Pakistan. This study set up the base for the study of fossil hydrozoans. Since then, many workers have contributed to the study of fossil hydrozoans (e.g., Reuss, 1865; Duncan, 1892; Frech, 1890; Vinassa, 1901, 1908, 1915, 1932; Smith, 1927; Yabe & Sugiyama, 1931, 1934; Moiseev, 1944). In 1959 a comprehensive review of Triassic hydrozoans was made by Flugel. This is a important step in the study of the organisms. Since the 1960s, Fenninger (1965), Davies (1971), Chuvashov (1973), and Boiko (1979) have also made contributions to the description of fossil hydrozoans. Up to now, about 23 genera of fossil hydrozoans have been described. Of them, only 11 are from Paleozoic. However, not all of the described fossil hydrozoans are real hydrozoans. Which of them are real hydrozoans? What are the standards for distinguishing real hydrozoans from other similar non-hydrozoan organisms? The answer lies in the understanding of characters of known Recent and fossil hydrozoans.

II. Characters of Hydrozoans

Our knowledge on living hydrozoans is the source of the understanding of fossil hydrozoans.

Hydrozoans are a group of colonial coelentrata. Living hydrozoans have a living habit similar to that of colonial corals. That is, one hydrozoan consists of many zooids. The zooids in a hydrozoan can be differentiated into three types: gastrozooids, gonozooids, and dactylozooids. In most cases each zooid secretes a zooecium which is generally tubiform. In case that the zooids are differentiated, the zooecia of gastrozooids are known as gastropores; those of gonozooids are known as ampulla; and those of dactylozooids are called dactylopores.

The skeleton secreted by a hydrozoan is known as coenosteum. A coenosteum generally consists of coenenchyme secreted by coenosarc and zooecia embedded in the coenenchyme. The coenenchyme is generally porous, or built of rod-like skeletal elements. The longitudinal or radial rods are called longirods or radirods. The concentric or lateral rods are called concentrirods or latirods. The zooecia are generally tubiform, atabulate or tabulate. This is also the case in corals. In some cases, the gastropore has a columnar structure in its axial part. This columnar structure is called gastrostyle. It is clear that the zooecia of hydrozoans are analogous to the calices of corals. Unlike hydrozoans, however, corals do not have coenenchyme generally.

Therefore, fossil hydrozoans can be recognized according to: (1) the presence of zooecia, (2) the presence of coenenchyma, gastrostyles, and tabulae, and (3) the absence of the water canal system and spicules. According to these standards, only a small number of previously described hydrozoans, totally 7–15 genera are real hydrozoans. They are *Heterastridium* Reuss, 1865, *Disjectopora* Waagen & Wentzel, 1887, *Irregulatopora* Waagen & Wentzel, 1887, *Astrostylopsis,* etc. Of them, only 3–9 genera are from Permian.

III. Relationship between Stromatoporoids and Hydrozoans

Stromatoporoids are an old morphological group including all those organisms composed of pillars or the like and transversal skeletal elements such as laminae, dissepiments and crossbars (with the same definition as in Chapter 3). Stromatoporoids are generally related to hydrozoans. To understand hydrozoans, the relationship between stromatoporoids and hydrozoans is an unavoidable problem to be solved.

Stromatoporoids are all fossils. They are included in one group not because of their affinities but their similarity in skeletal construction in case that their taxonomical positions are difficult to determine.

According to their skeletal construction, stromatoporoids can be divided into three types: pillar-lamina-structured, pillar-dissepiment-structured, and pillar-crossbar-structured ones (all with the same definitions as in Chapter 3). It is known that some stromatoporoids have generally tabulated small tubes in their skeletons, and some other stromatoporoids have astrorhizae in their skeletons. The astrorhizae in some stromatoporoids may be tabulated. The astrorhizae of stromatoporoids are interpreted to be zooecia of hydrozoans by some researchers.

Stromatoporoids have been regarded as hydrozoans by most researchers (e.g., Lecompte, 1951–1952, 1956; Galloway, 1957; Mori, 1970; Boiko, 1979) since Carter first placed the organisms in Class Hydrozoa in 1877. A few scholars also consider them as other organisms (e.g., Rosen, 1867; Kirkpatrick, 1911, 1912; Parks, 1935; Kazmierczak, 1976, 1981).

In recent decades, a Poriferan affinity for the group is maintained by Stearn (1972, 1975, 1983).

More recently, convinced spicule evidences have been found in some Mesozoic stromatoporoids (Wood & Reitner, 1986; Reitner, 1987). And these stromotoporoids have been moved into Porifera naturally.

The updated viewpoint is that stromatoporoids are a polyphyletic group rather than a homogeneous one (e.g., pers. comm.: Wood, 1990) .

It seems that this group includes sclerosponges, demosponges, hydrozoans and some other unknown organisms. Thus, the taxonomy of stromatoporoids should not be be simply treated because different families or genera of the group may belong to different natural taxa. We should approach their taxonomy at family or even generic level. Not all stromatoporoids belong to hydrozoan; not all stromatoporoids belong to sclerosponges or demosponges either.

The stromatoporoids without zooecia and previously included in hydrozoan are in reality not hydrozoans. Thus, they should be driven out from hydrozoan. On the other hand, the organisms even with typical stromatoporoid construction, such as *Permostroma* gen. nov., should be included in hydrozoan in the presence of zooecia.

Not all astrorhizae are zooecia, especially those dendroid or irregular in form. Thus, these organisms are not hydrozoans. On the other hand, astrorhizal structure in some stromatomorphs such as *Heptastylis* Frech, 1890 may be zooecia. And these organisms can be hydrozoans.

According to the features of their skeletons, Sphaeractinidae, Palaeoaplysinidae and most Spongiomorphidae are not hydrozoans. Therefore, they should be removed from hydrozoans. To contain these organisms, the term extrohydrozoan is suggested, which is defined to include all those organisms previously included in hydrozoans but later found not to be real hydrozoans and different from typical stromatoporoids.

Table 7 illustrates the differences between hydrozoans, sclerosponges and inozoans.

Table 7 Comparison of hydrozoans with some other groups

Feature	Sclerosponges	Hydrozoans	Inozoans
Soft tissue	On top part of skeletons	On top of Skeletons	In a whole skeleton
Canal system	Commonly absent	Absent	Present
Astrorhizae	In some genera	In some genera	Absent
Zooecia	Absent	Present	Absent
Spicules	Siliceous Acanthostyles Acanthostrongyles Tylostyles Spirasters	Absent	Calcareous Triactines Tetractines
Skeletons	Tube-constructed Pillar-constructed Fibre-constructed	Zooecia and coenenchyme	Fibre-constructed
Calcifillings	In lower part of skeletons	Absent	Absent

IV. Classification

The class Hydrozoa was established by Owen (1943). He divided the class into two subclasses: Hydroidea and Siphonophoria. Since then, many researchers have contributed to the classification of Hydroidea (Chudinova, 1962; Lecompte, 1956; Flugel, 1959, 1979). However, most of their classifications have a common shortcoming, i.e., inclusion of some extrohydrozoans. More reasonable classification should be on the basis of only real hydrozoans. It should be noted that Flugel (1959) has had the idea to distinguish real hydrozoans from possible hydrozoans or other uncertain organisms.

On the basis of all previous classifications a new classification is suggested as follows.

Class Hydrozoa Owen, 1843

Subclass Hydroidea Owen, 1843

Order Hydroida Dana, 1846

Diagnosis: Skeletons consist of coenenchyme and zooecia. Zooecia polymorphic or not, atabulate.

Family Disjectoporidae Tornquist, 1901

Diagnosis: Skeletons consist of coenenchyme and zooecia. Zooecia atabulate, not polymorphic.

Representative: *Disjectopora* Waagen & Wentzel, 1887

Family Heterastridiidae Reuss, 1865

Diagnosis: Skeletons consist of coenenchyme and zooecia. Zooecia atabulate, polymorphic.

Representative: *Heterastridium* Reuss, 1865

Order Hydrocorallida

Diagnosis: Skeletons consist of coenenchyme and zooecia. Zooecia have tabulae or gastrostyles.

Family Milleporidae Milne-Edwards, 1860

Diagnosis: Skeletons consist of coenenchyme and zooecia. Zooecia tabulate, polymorphic.

Representative: *Millepora*

Family Axoporidae

Diagnosis: Skeletons consist of coenenchyme and zooecia. Zooecia have gastrostyles, polymorphic.

Family Stylasteridae Gray

Diagnosis: Skeletons branched, consisting of coenenchyme and zooecia. Dactylopores arranged into cyclosystem around gastropore.

Representative: *Stylaster* Gray

Extrohydrozoan

Definition: The term includes all fossils previously included in hydrozoan and presently found not to be hydrozoan and different from typical stromatoporoids. It includes the following.

Family Sphaeractinidae Waagen & Wentzel, 1887

Diagnosis: Skeletons consist of concentric skeletal elements which are defined as concentrirods herein and radial skeletal elements which are defined as radirods.

Family Spongiomorphidae Frech, 1890

Diagnosis: Skeletons consist of longitudinal skeletal elements called longirods. Transversal skeletal elements called latirods not developed. Regular astrorhizal structure absent.

Family Palaeoaplysinidae

Diagnosis: Skeletons sheetlike, having irregular canal system. Two genera are included: *Palaeoaplysina* and *Ditabulipora* gen. nov.

V. Paleoecology

Hydrozoans can serve as framers and dwellers in the reef of Xiangbo. They can reach large size in baffled facies. Their content is relatively higher in baffled facies and prebaffled facies than in framed facies, especially typical framed facies. Thus it can be deduced that hydrozoans prefer a somewhat lower energy environment than sclerosponges, inozoans and sphinctozoans do. Hydrozoans can account for only 2.2–12.9% of the main reef-builders in the reef of Xiangbo.

VI. Systematic Description

Order Hydroida Dana, 1846

Family Disjectoporidae Tornquist, 1901

Genus *Cancellistroma* gen. nov.

Derivatio nominis: Cancelli (la. = treillage) refers to the arrangement of skeletal elements.

Diagnosis: Skeletons generally ramose, consisting of radirods and concentrirods. Radirods and concentrirods intersect at right angle, forming a regular meshwork. Concentrirods generally discontinuous, not forming concentric layers. Some small tubes, probably zooecia, radially embedded in the meshwork. No epitheca on the surface of skeletons.

Discussion: The genus differs from *Disjectopora* in that there are at least two kinds of tubes: vertical and transversal ones in the skeletons of the latter. The genus differs from *Spongiomorpha* and *Stromatomorpha* in the absence of zooecia in the last two genera.

Type species: *Cancellistroma ramosa* gen. et sp. nov.

Cancellistroma ramosa gen. et sp. nov.

(pl. 15 / 1)

Derivatio nominis: The species name refers to the form of the skeletons.

Diagnosis: Skeletons ramose. Radirods more developed than concentrirods. The intersections of radirods and concentrirods thickened. Radirods and concentrirods 0.07–0.10 mm thick, 0.15 and 0.20 mm apart respectively.

Section: xb27–B–3 (holotype).

Description: Skeleton ramose, 12 mm in diameter before furcation and 9 mm in diameter after furcation.

Radirods relatively continuous. Concentrirods discontinuous. Skeleton thickened at the intersections of radirods and concentrirods. Concentrirods not arranged into concentric layers. In some places, concentrirods not developed. Radirods and concentrirods 0.07–0.12 mm thick. Radirods and concentrirods spaced at uniform intervals, 0.15 mm and 0.20 mm apart respectively. Radirods and concentrirods intersect at right angle, forming meshwork. Most of the meshes close.

Some small tubes radially arranged in the meshwork, with a diameter of 0.37 mm. They can be zooecia.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Cancellistroma divulsa gen. et sp. nov.

(pl. 15 / 2)

Derivatio nominis: Divulsus (la. = fissured) refers to the form of the tubes in longitudinal section.

Diagnosis: Radirods thicker than concentrirods. Radirods spaced at greater intervals than concentrirods, thus forming rectangular meshes in longitudinal sections. Concentrirods confined to radirods, not forming concentric layers.

Section: xb27–B–6 (paratype), xb36–4–5 (holotype).

Description: Skeletons columnar or ramose, 8–10 mm in diameter. Radirods 0.05–0.13 mm thick, 0.10–0.22 mm apart. Concentrirods 0.03–0.07 mm thick, 0.05–0.12 mm apart. Radirods and concentrirods intersect at right angle, forming regular meshwork. The meshes rectangular, laterally or transversally extend. Skeletons pointlike or reticulate in cross section.

In the meshwork present some small tubes parallel to radirods. They can be zooecia. The small tubes enlarged outward in diameter, up to 0.50–0.65 mm at the outer part of skeletons.

No epitheca on the surface of skeletons.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Concentristroma* gen. nov.

Derivatio nominis: The generic name refers to the development of concentric skeletal elements.

Diagnosis: Skeletons spherical, consisting of concentric plates and the pillars perpendicular and confined to the concentric plates. Pillars sparse. Concentrical plates perforated, thickened at their junctions with pillars. In the skeletons present two kinds of tubes: radial and concentric ones. They may be zooecia. Either kind of the tubes long, arranged in the same direction. The edges of adjacent concentric plates overlap, forming pseudoepitheca.

Discussion: The new genus differs from *Disjectopora* in the undeveloped radial skeletal elements and developed concentric skeletal elements in the former.

Type species: *Concentristroma eucalla* gen. et sp. nov.

Concentristroma eucalla gen. et sp. nov.
(pl. 14 / 5)

Derivatio nominis: Eucallus (la. = beautiful) refers to the appearance of skeletons in sections.

Diagnosis: Skeletons domed, massive, regular in form. Concentric plates regular, 0.10–0.12 mm apart, perforated. Pillars sparse, confined to concentrical plates. Radial tubes 0.30–0.42 mm in diameter; lateral tubes 0.25–0.41 mm across.

Section: xb35–8–9 (holotype).

Description: Skeleton domed, 8 mm thick, encrusting on other organism.

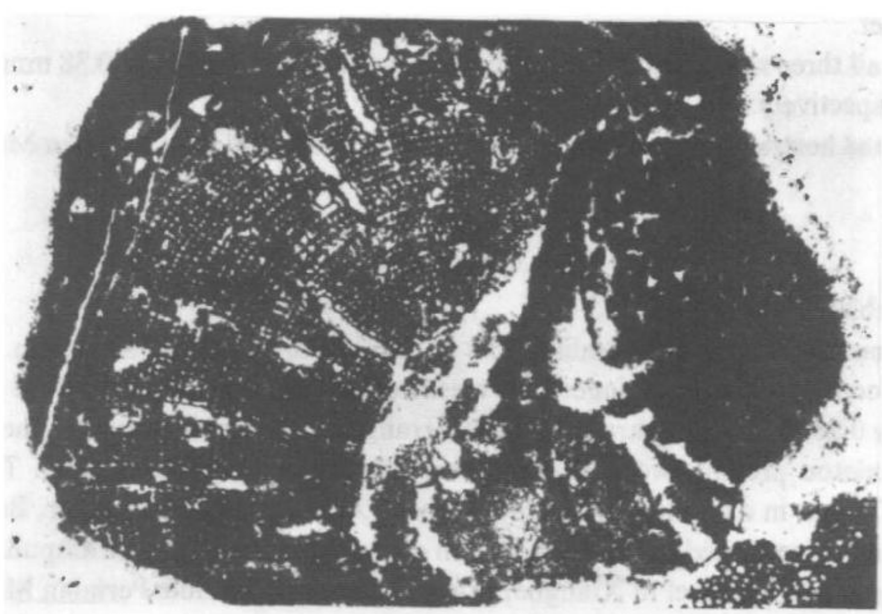


Fig. 26 Vertical section of *Concentristroma eucalla* gen. et sp. nov.

Skeleton consists of concentric plates and radial pillars. Concentric plates regular, spaced at an interval of 0.10–0.12 mm. Radial pillars sparse, confined to and perpendicular to concentric plates, spaced at an interval of 0.08–0.12 mm minimally. Concentric plates thickened at the junctions with pillars, pierced by numerous pores. The pores 0.08–0.12 mm apart generally, making concentric plates dotted-line-like in vertical section.

In the skeleton present two kinds tubes: radial and lateral tubes (Fig. 26). They may be zooecia. All of them circular in cross section. The radial tubes 0.30–0.42 mm in diameter, spaced 0.50–1.0 mm apart. The lateral tubes 0.25–0.41 mm in diameter, extending in the same direction, in some places intersecting with the radial tubes. Some lateral tubes smaller in diameter, only 0.15 mm across.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Tritubulistroma* gen. nov.

Derivatio nominis: The generic name refers to the presence of three type of tubes in the skeletons.

Diagnosis: Skeletons mushroomlike, consisting of rods arranged into irregular meshwork. In skeleton present tubes of all three sizes. They irregularly arranged. They can be zooecia.

Type species: *Tritubulistroma irregularis* gen. et sp. nov.

Tritubulistroma irregularis gen. et sp. nov.
(pl. 14 / 2)

Derivatio nominis: The species name refers to the irregularity of the rods.

Diagnosis: Skeletons mushroomlike. Rods thin, various in diameter. Three types of tubes 0.5 mm, 0.38 mm, and 0.2 mm in diameter respectively.

Section: xb28–4–6 (holotype).

Description: Skeleton mushroomlike, 38 mm high, 30 mm wide.

Skeleton consists of rods. Rods not uniform in diameter, ranging 0.05–0.12 mm thick, thickened at intersections, arranged into irregular meshwork. The meshes generally 0.08–0.20 mm in diameter.

Tubes of all three sizes irregularly scattered in the skeleton, 0.05 mm, 0.38 mm and 0.20 mm in diameter respectively.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Tritubulistroma sp.
(pl. 15 / 3)

Section: xb30–2–7.

Description: Skeleton mushroomlike, 15 × 17 mm in size in an oblique section.

Skeleton consists of rods arranged into meshwork. Rods generally 0.10–0.13 mm in diameter, commonly 0.20–0.25 mm apart, irregularly arranged in the cross section of the skeleton.

In the skeleton present two kinds of tubes: horizontal and vertical ones. The horizontal tubes 0.70–0.75 mm in diameter. The vertical tubes 0.40–0.75 mm in diameter. Besides, a circle 2.5 mm in diameter sectioned in the cross section of the skeleton. It may be ampulla.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Fungistroma* gen. nov.

Derivatio nominis: Fung (la. = mushroom) refers to the form of the skeletons.

Diagnosis: Skeletons mushroomlike, consisting of radial plates upward radially arranged. Radial plates perforated, thus discontinuous in vertical sections of skeletons. Horizontal skeletal elements undeveloped. Skeletons reticulate in horizontal section, with the meshes close and irregular in outline. In the skeletons present the horizontal tubes of all three sizes. They can be zooecia.

Discussion: The genus differs from *Tritubulistroma* in the developement and regularity of radial plates and the undevelopment of horizontal skeletal elements in the former.

Type species: *Fungistroma daemonia* gen. et sp. nov.

Fungistroma daemonia gen. et sp. nov.
(pl. 15 / 4)

Diagnosis: Skeletons mushroomlike. Radial plates 0.12–0.22 mm apart. Three kinds of tubes perpendicular to the side surface of skeletons, 0.22 mm, 0.40 mm and 0.60 mm in diameter respectively.

Section: xb33–5–1 (holotype), xb33–5–2 (paratype).

Description: Skeletons mushroomlike, 25 mm wide and at least 20 mm high.

Radial plates upward radially arranged, forming small canals. Radial plates 0.07 mm thick, pierced by numerous pores, discontinuous in the vertical sections of skeletons. The pores 0.05–0.20 mm across, generally 0.08–0.10 mm in diameter. Adjacent radial plates 0.12–0.22 mm apart. Horizontal skeletal elements undeveloped. Skeletons like irregular meshwork in horizontal section, with most meshes close.

Three kinds of tubes 0.22 mm, 0.40 mm and 0.60 mm in diameter respectively, with generally discontinuous walls, irregularly scattered in the skeletons.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Order Hydrocorallida

Family Milleporidae

Genus *Permostroma* gen. nov.

Derivatio nominis: The generic name refers to the first occurrence of the genus in Permian.

Diagnosis: Skeletons massive, consisting of vertical pillars and horizontal laminae. The laminae thin, wavy. In skeletons present numerous vertical zooidal tubes. The zooidal tubes tabulated. In the top surface of skeletons present a dendroid astrorhiza.

Discussion: The genus has a pillar-lamina-structured skeleton typical of stromatoporoids. Thus, it is a stromatoporoid. On the other hand, the presence of zooidal tubes (that is, zooecia) indicates that it is also a hydrozoan. Therefore, it can be concluded that (1) hydrozoans can have a pillar-lamina-structured skeleton, and (2) hydrozoans can have astrorhizae in their top surface. Therefore, this genus is a bridge connecting stromatoporoids and hydrozoans.

Type species: *Permostroma sinensis* gen. et sp. nov.

Permostroma sinensis gen. et sp. nov.
(pl. 14 / 1)

Derivatio nominis: The species name refers to the first report of the species from China.

Diagnosis: Laminae very thin, wavy, continuous. Pillars 0.17–0.25 mm apart. Dendroid astrorhiza present in the top surface of skeletons. Zooidal tubes 0.37–0.62 mm wide.

Section: xb30–5–5 (holotype).

Description: Skeleton large, probably massive, at least 20 mm thick and 35 mm wide.

Vertical pillars thick, 0.10–0.17 mm in diameter, 0.17–0.25 mm apart. Horizontal laminae very thin, 0.05–0.08 mm thick generally, dark and linear in the vertical sections of skeletons under microscopes, ranging 0.12–0.15 mm apart, wavy, long and continuous laterally, crossing a lot of pillars. In some places, pillars and lamellae arranged into irregular meshwork, with meshes irregular in outline and 0.17–0.22 mm in size.

Numerous vertical tubes present in the skeleton, circular in cross section, tabulated, with a diameter of 0.37–0.62 mm. They should be zooidal tubes. The tabulae 0.20–0.30 mm apart, continuous with the laminae in the surrounding part of the zooecia.

The top surface of skeletons flat, with a dendroid astrorhiza. The canals of the astrorhiza have a maximal diameter of 5 mm.

The pillars trabecular in microstructure, recrystallized. The laminae include three layers in the vertical section: a micritic middle layer, a trabecular lower layer and a trabecular upper layer.

No epitheca on the surface of the skeleton.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Extrohydrozoans

Family Palaeoaplysinidae

Genus *Ditabulipora* gen. nov.

Derivatio nominis: Di (gr. = double) and tabu (la. = plate) refer to the double-layered construction of skeletons.

Diagnosis: Skeletons sheetlike, consist of two layers: a basal layer at the bottom and a body layer on the former. The basal layer thin, constant in thickness, pierced by numerous pores. The body layer thick, comprising most part of a skeleton. It can be divided into three parts vertically: a thin lower part, a middle part, and a thick upper part. The low part very thin, imperforated; the middle part slightly thicker, with horizontal canals extending in the same direction and circular or irregular in cross section; and the upper part the thickest, with an irregular canal system within it. In horizontal sections, the canal system vermiform, extending in the same direction, furcated and merged repeatedly. In the vertical sections normal to the direction in which the canals system extend laterally, the canal system vertically stretch, not furcated, enlarged upward, making the skeletal material between them high dentiform. The soft tissue can be on the top surface of this layer in life.

Skeletons recrystallized into calcites, without what is called "cellular structure" or "porous structure".

Discussion: Krotow (1888) established *Palaeoaplysina*. The new genus resembles *Palaeoaplysina* in growth form and the presence of canal system. Thus, they can have some affinities. The differences between them lie in: (1) *Palaeoaplysina* consists of one layer while the new genus consists of two layers, (2) the canals in *Palaeoaplysina* furcate and taper upward while the canals in the new genus furcate and enlarge upward, (3) the skeletal material between canals can be of cellular structure (Davies et al, 1973) or porous structure in *Palaeoaplysina* while they do not have those structures in the new genus, and (4) the canals in *Palaeoaplysina* can be tabulated while they are atabulated in the new genus.

Palaeoaplysina was included in the family Palaeoaplysinidae which was placed in Class Hydrozoa by Chuvashov. Some researchers have had different opinions. Nevertheless, most of them agreed on the placement of the genus in Class Hydrozoa. The current dispute is about its position in Class Hydrozoa. *Ditabulipora* is similar to *Palaeoaplysina*. Thus, they belong to the same family Palaeoaplysinidae. *Ditabulipora* and *Palaeoaplysina* are peculiar in growth form and construction. Therefore, they represent a family independent of other organisms. Because of the absence of zooecia, the family should not be included in Class Hydrozoa. It is placed in extrohydrozoan temporarily.

Type species: *Ditabulipora longidens* gen. et sp. nov.

Ditabulipora longidens gen. et sp. nov.
(pl. 11 / 1; pl. 13 / 2, 3; pl. 14 / 3)

Derivatio nominis: Longidens (la. = denticular) refers to the appearance of skeletons in the vertical sections.

Diagnosis: Basal layer 0.04–0.09 mm thick, pierced by cylindrical pores irregularly arranged. Body layer 0.12–0.15 mm away from basal layer, with its lower part 0.03–0.04 mm thick. The canals in the middle part of the body layer 0.05–0.10 mm across. The canals in the upper part of the bady layer 0.03–0.06 mm wide.

Section: xb35–8–12 (holotype), xb35–8–11 (paratype), xb36–4–11, xb27–5.

Description: Skeletons sheetlike, wavy, several mm thick and several cm wide generally, not uniform in thickness, probably grown into two layers at their periphery.

Skeletons consist of a basal layer at the bottom of skeletons and a body layer as the main part of skeletons (Fig. 27). The basal layer 0.04–0.09 mm thick, pieced by cylindrical pores. The pores normal to the surface of the basal layer, 0.02–0.03 mm across, irregularly and more or less evenly arranged, generally 0.03–0.06 mm apart.

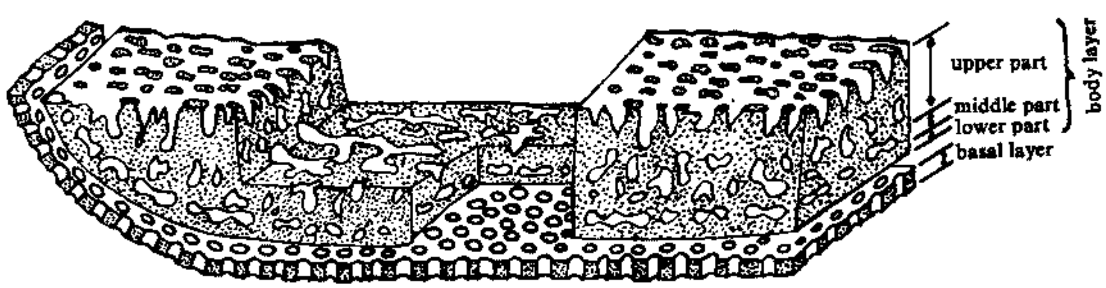


Fig. 27 Reconstruction of *Ditabulipora longidens* gen. et sp. nov.

The body layer 0.12–0.15 mm away from the basal layer. The skeletal structure connecting the basal layer and the body layer is unknown. The body layer includes three parts: a lower part, a middle part and an upper part. The lower part thin, 0.03–0.04 mm thick, imperforated, with its under surface smooth. The middle part thin, with horizontal canals in it. The canals circular or irregular in cross section, 0.05–0.10 mm in diameter. The upper part the thickest, generally measuring several mm thick, with irregular canal system within it. In the horizontal sections of skeletons, the canal system vermiform, extending roughly in the same direction, furcated and merged repeatedly. Adjacent canals can be connected via short canals. In the vertical sections normal to the directions in which the canals laterally extend, the canals vertically extend, subparallel to each other, not furcated generally, enlarged upward, and opening into the top surface of skeletons. In this kind of sections, the canals 0.03–0.06 mm wide at their base, up to 0.1 mm wide at their upper ends; the skeletal materials between the canals high dentiform, about 0.03–0.06 mm wide at their base.

Skeletons recrystallized into calcites, lacking cellular structure or porous structure.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Family Sphaeractinidae Waagen & Wentzel, 1887

Sphaeractinidae gen. indet.

(pl. 13 / 5)

Section: xb30–7–2.

Description: Skeleton low columnar, 19.5 mm high and 20 mm in diameter.

Skeleton consists of concentric layers and radial pillars. Concentric layers relatively continuous. Radial pillars less developed, mostly confined to concentric layers. In longitudinal sections of the skeleton, concentric layers dotted-line-like. The pointlike skeletal materials of adjacent concentric layers can be arranged into radial rows, resulting in canals penetrating several concentric layers. Radial pillars sparsely and irregularly scattered. Concentric layers 0.10–0.25 mm thick, 0.4–0.5 mm apart. The pointlike skeletal materials 0.3–0.5 mm apart in concentric layer.

The lately formed concentric layers can meet previously formed ones at small angles.

Discussion: The specimen is similar to sphinctozoans in skeleton construction. However, the change of concentric layers in growth directions has not been observed in sphinctozoans.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

7 Bryozoans

I. Paleoecology

Bryozoans are accessory reef-building organisms in geologic time. In ancient reefs, bryozoans can serve as: (1) framers, (2) encrusters, (3) bafflers, and (4) sediment producers (Cuffey, 1976). In the reef of Xiangbo, bryozoans mainly function as: (1) encrusters, and (2) dwellers. Some bryozoans can be framers.

Table 8 Function and distribution of bryozoans in the reef of Xiangbo

Function	Orders and common genera	Distribution
Framers (locally)	Fenestrida *Fenestella* Ramose *Eridopora*	Framed facies
Encrusters	Cystoporida *Dybowskiella* *Fistulipora* Encrusting *Eridopora*	Framed facies Baffled facies
Dwellers	Fenestrida *Fenestella* *Polypora* Rhabdomesonida *Rhabdomeson* *Ascopora*	Framed facies Baffled facies Prebaffled facies

In the reef of Xiangbo, cystoporid bryozoans such as *Dybowskiella* and *Fistulipora* are encrusters. Encrusting on framing sponges, they are important encrusters accessory to only *Archaeolithoporella*. Fenestrid bryozoans such as *Fenestella* and *Polypora* and Rhabdomesonid bryozoans are dwellers. Some fenestrid bryozoans such as *Fenestella donaica* and a few cystoporid bryozoans such as *Eridopora* are framers occasionally. In this case they are generally ramose and encrusted by *Tubiphytes*. The paleoecology of bryozoans in the reef of Xiangbo is illustrated in Table 8.

Classification of bryozoans by Gorjunova & Morozova (1979) is followed herein.

II. Systematic Description

Order Cystoporida Astrova, 1964

Suborder Fistuliporina Ulrich, 1882

Family Fistuliporidae Ulrich, 1882

Genus *Fistulipora* McCoy, 1850

Diagnosis: Zoaria massive, ramose or encrusting. Zooecia commonly have diaphragms. Vesicles present between zooecia. Lunaria undeveloped.

Fistulipora sp. indet.
(pl. 16 / 2)

Section: xb33–1–10.

Description: Zoaria sheetlike, encrusting on other organisms, composed of tubiform zooecia and vesicles between the zooecia, with a thickness of up to 2.5 mm. Zooecia 0.30–0.37 mm across, with diaphragms flat or concave and 0.12–0.25 mm apart. The vesicles flat, 0.075 mm high, regularly arranged into generally one row. Zooecial wall composed of a micritic middle layer and two trabecular side layers (orthogonal).

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Dybowskiella* Waagen & Wentzel, 1886

Diagnosis: Zoaria ramose, massive or encrusting, composed of zooecia and the vesicles between zooecia. Diaphragms generally undeveloped in zooecia. Lunaria developed, making zooecia trisected.

Dybowskiella sp.
(pl. 17 / 1, 4)

Section: xb27–8–2, xb33–1–8.

Description: Zoaria encrusting on other organisms, up to 5 mm in thickness. Zooecia trumpet-shaped, somewhat sinuous, increasing in diameter distally, 0.2 mm across at the proximal end and 0.45–0.50 mm wide at the distal end. Lunaria distinct, accounting for 1 / 4 to 1 / 3 of zooecia in zooecium cross section, with two side ends projecting into zooecia, making zooecia trisected. Zooecia without diaphragms. Vesicles regular in form and arrangement, not uniform in size, small at the base of zoaria, enlarged toward the upper surface of zoaria, generally tetragonal or pentagonal in vertical section, commonly 0.075–0.150 mm wide, arranged into one or two regular vertical rows between zooecia.

Discussion: The specimens resemble *Fistulipora timorensis* Bassler, 1929 in growth form, the absence of diaphragms, the form of vesicles, and the size of lunaria. The difference between them lies in the bigger zooecia and the lack of thickening of the lunaria in the present specimens. The present specimens differ from *Dybowskiella hubeiensis* Yang, 1956 in the more rows of more regular vesicles in the former.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Eridopora* Ulrich, 1882

Diagnosis: Zoaria ramose or encrusting, composed of zooecia and vesicles. Apertures inclined. Lunaria project into zooecia, making zooecia trisected in cross section. Zooecia can have diaphragms.

Eridopora sp. indet.
(pl. 16 / 3)

Section: xb30–8–1.

Description: Zoaria ramose. Zooecia isosceles triangular in cross section. Vesicles small, approximately rectangular.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Eridopora sp.
(pl. 17 / 2)

Section: xb27–2–1, xb28–4–4.

Description: Zoaria encrusting or hollow columnar. Zooecia narrow coniform, slightly curved at proximal end. Lunaria U-shaped in cross section, accounting for 2 / 3 of zooecial cross section. Lunaria and anterior zooecial wall form triangular configuration. Zooecia about 0.25 mm in diameter, lacking diaphragms. One to two rows of vesicles present between zooecia. Vesicles 0.07–0.17 mm wide, imbricately arranged.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Order Fenestrida Gorjunova & Morozova, 1979
Family Fenestellidae King, 1850
Genus *Fenestella* Lonsdale, 1839

Diagnosis: Zoaria fenestrate, composed of branches and dissepiments. Each branch has two rows of zooecia separated by a carina.

Fenestella donaica (Lebedev)

Diagnosis: Zoaria doliform. In the tangential sections near the upper surface of zoaria, zooecia trapezoid, alternating, arranged into two rows in the branch. In deep tangential sections of zoaria, zooecia triangular, with angles rounded, arranged into only one row.

Discussion: The sections with different distances from zoaria surface in the species show different features. This causes their assignment to even different genera by some authors. After restudying them, Lebedev (1927) placed them in *Fenestella*, and divided the species into three subspecies according to the size of fenestrules. In the 1950s some researchers regarded them as species. They are still considered to be subspecies herein.

Fenestella donaica subsp.
(pl. 16 / 4)

Section: xb35–1–2.

Description: Zoaria regular fenestrate. Branches 0.20 mm wide. Fenestrules oval, 1.0–1.5 mm long and 0.37–0.50 mm wide. 6–8 fenestrules along per 10 mm of branch. In deep tangential sections of zoaria, zooecia isosceles triangular to trapezoid, 0.15 mm in size, arranged into one row.

Discussion: The specimen differs from all known subspecies in the less fenestrules along per 10 mm of the branch.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Fenestella sp. indet.
(pl. 17 / 5)

Section: xb33–1–8, xb35–1–2.

Description: Zoaria fenestrate. Branches 0.36 mm in diameter. Fenestrules subcircular, 0.45 × 0.50 mm in size. In each branch and dissepiment present two rows of zooecia. Zooecia circular in cross section, 0.06–0.12 mm in diameter.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Polypora* McCoy, 1844

Diagnosis: Zoaria fenestrate, consisting of branches and dissepiments. Branches lack carina, with 3–6 rows, sometimes up to 8 rows of zooecia.

Polypora guangxiensis sp. nov.
(pl. 18 / 3)

Derivatio nominis: The species name refers to the type locality of the species.

Diagnosis: Zoaria fenestrate. Zooecia arranged into transversal rows in branches. Each row has 4–5 zooecia. The zooecia in adjacent rows decussate. Adjacent transverse rows separated by a separator.

Section: xb28–4–7 (holotype), xb27–2–2.

Description: Zoaria fenestrate. Branches 1.80 mm wide. Fenestrules oval, 1.5–1.7 mm wide, with their long axis parallal to branches. Branches and dissepiments similar in diameter. Zooecia in branches arranged into transverse rows. Each transversal row has 4–5 zooecia. Adjacent transverse rows separated by a separator. Zooecia in adjacent transverse rows alternating. Zooecia square or subcircular in cross section, 0.25 mm in diameter. Common walls between zooecia 0.05 mm thick. Zooecia in paratype 0.12 × 0.12 to 0.12 × 0.22 mm in size.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Polypora sp.
(pl. 18 / 2)

Section: xb33–5–15.

Description: The specimen is a part of a tangential section. At least two longitudinal rows of zooecia present in each branch. Zooecia oval or elongate in cross section.

Discussion: The zooecial arrangement typical of the genus makes it possible to assign the specimen into the genus.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Fenestellidae gen. et sp. indet.
(pl. 17 / 6)

Section: xb33–7–3, xb36–4–3.

Description: The specimens are the cross sections of branches, subcircular, 0.88 mm wide. In the cross section, four zooecia symmetrically arranged, separated by a carina. The carina becomes thinner upward. Above the carina present the fifth zooecium. Zooecia enlarged distally, generally 0.15 mm in diameter.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Order Rhabdomesonida Gorjunova & Morozova, 1979

Family Rhabdomesonidae Vine, 1883

Genus *Ascopora* Trautschold, 1876

Diagnosis: Zoaria ramose, commonly branched, composed of primary zooecia in axial region and secondary zooecia in surrounding region. The primary zooecia parallel to each other. The secondary zooecia bud from the primary zooecia, differentiating into an inner immature region and an outer mature region. In the immature region, zooecia can have diaphragms; zooecial wall thickened. In the mature region, aperture oval, arranged into longitudinal rows and diagonal rows. Large acanthopores present between zooecia, reaching the upper surface of zoaria as processes. Small acanthopores present between large acanthopores, not reaching zoaria surface.

Ascopora cf. *quadritubulata* Xia & Liu, 1986
(pl. 18 / 6)

Section: xb33–8–2.

Description: Zoaria ramose, circular in cross section, with a diameter of 1.5 mm. Primary zooecia numerous, triangular in cross section, forming a cylinder 0.5 mm across in the axial region of zoaria. Secondary zooecia bud from the primary zooecia at a small angle, then curved outward, finally perpendicular to zoaria surface. Secondary zooecia circular in cross section, 0.15 mm in diameter. Zooecial apertures arranged into longitudinal rows. One large acanthopore present between adjacent zooecia, projecting above the zoaria surface. Several small acanthopores present between large acanthopores, not reaching the zoaria surface. Zooecial walls 0.02 mm thick in immature region, thickened to 0.05 mm in mature region.

Discussion: The present specimen resembles those described by Xia & Liu in 1986.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Rhabdomeson* Yang & Yang, 1874

Diagnosis: Zoaria rod-like or ramose, with one primary zooecium in the axial region of zoaria. Secondary zooecia bud from the primary zooecium, thickened in mature region. Acanthopores present. Zooecia without diaphragms.

Discussion: The primary zooecium in the specimens from Timor described by Bassler (1929) was filled with micritic sediments. Based on this, Bassler (1929) interpreted the primary zooecium to be the tube left by the decay of other organism on which the zoaria had encrusted rather than a primary zooecium. This interpretation is not followed herein.

Rhabdomeson sp.
(pl. 16 / 1; pl. 18 / 4)

Section: xb33–2–4, xb33–2–9.

Description: Zoaria ramose, circular in cross section, 1.75 mm in diameter. Primary zooecium straight, cylindrical, 0.30–0.35 mm in diameter. Secondary zooecia bud from the primary zooecium at an angle of 30°, curved outward at the peripheral region, finally perpendicular to zoaria surface. Secondary zooecia 0.12 mm across in immature region, 0.20–0.25 mm across in mature region. Apertures arranged into regular longitudinal rows and diagonal rows. Zooecial walls 0.05 mm thick in immature region, and 0.2 mm thick in mature region. Large acanthopores present between apertures, projecting above the upper surface of zoaria. Small acanthopores absent.

Discussion: The difference between the present specimens and those of *R. gracile* Phillips and *R. grande* Bassler from Timor is that the primary zooecia are not straight and the secondary zooecia bud from primary zooecia at a larger angle in the latter.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Rhabdomeson sp. indet.
(pl. 17 / 3)

Section: xb28–4–5, xb27–5–4.

Description: Zoaria rod-like, circular in cross section, 1.9 mm in diameter. Primary zooecium circular in cross section, 0.30 mm in diameter. Secondary zooecia 0.8 mm long, 0.17 mm in diameter at aperture, arranged into 20 longitudinal rows in a branch. Zooecial walls thickened in immature region. Large acanthopores present.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Rhabdomesonidae gen. et sp. indet. A
(pl. 18 / 5)

Section: xb33–7–8, xb28–4–1, xb27–7–1.

Description: Zoaria ramose, circular in cross section. Primary zooecium absent. Secondary zooecia bud from the axial part of zoaria at a small angle, not perpendicular to zoaria surface. Zooecia subcircular in cross section, increasing in diameter outward. Zooecial walls thickened in mature region. Small acanthopores developed in mature region.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Rhabdomesonidae gen. et sp. indet. B
(pl. 16 / 6)

Section: xb30–7–6, xb36–4–4.

Description: Zoaria ramose, subcircular in cross section, 2.0 × 4.0 mm in size. A cylindrical tube 0.5 mm across present in the axial part of zoaria. Zooecia bud from the axial tube at a small angle, opening into zoaria surface. Zooecia rhombic in cross section, 0.2 mm across. Zooecial walls thickened to 0.05 mm in mature region.

Discussion: The present specimens are identical with those described as *Dyscritella* by Flugel (1984, p. 206, pl. 40 / 9–10). However, these specimens differ from *Dyscritella* Girty, 1911 in some aspects, in my opinion.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Order Trepostimida Ulrich, 1882

Trepostimida gen. et sp. indet. 1
(pl. 16 / 5)

Section: xb30–2–7.

Description: The specimen is a tangential section. Zooecia circular in cross section, 0.25 mm in diameter. Adjacent zooecia 0.03–0.17 mm apart. Around each zooecium present 11–14 robust acanthopores arranged into a circle. A mesopore, generally tubiform, 0.12–0.20 mm in diameter, present between several adjacent zooecia. The features of zooecial walls unknown.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Trepostimida gen. et sp. indet. 2

(pl. 18 / 1)

Section: xb27–8–2.

Description: Zoaria composed of tubiform zooecia and acanthopores between the zooecia. Zooecia circular in cross section, 0.20–0.25 mm in diameter. Common walls between adjacent zooecia 0.05 mm thick. One acanthopore present between three adjacent zooecia. The features of zooecial walls unknown. Mesopores absent.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

8 Calcareous Algae

In the reef of Xiangbo, calcareous algae are important reef-building organisms accessory to calcisponges. It seems that Permian calcisponge reefs are always related to calcareous algae. Calcareous algae are commonly the most important encrusters in Permian calcisponge reefs. It is impossible to imagine what Permian reefs would be like without calcareous algae.

I. Paleoecology

In the reef of Xiangbo, calcareous algae can serve as the following.

(1) **Framers**

Monostysisyrinx gen. nov., a possible chlorophyta reported from the reef of Xiangbo for the first time herein, is the only alga to function as framer. Only several cm high, the alga grows into microforest in sea bottom. Being strengthened by the encrustation of *Archaeolithoporella*, the thicket of the alga should have strong resistance to wave action. Therefore, it is an effective framer. Always associated with sparry calcite cement (pectinate structure), the alga forms the most typical framed facies in reefs.

(2) **Encrusters**

This is the most important role taken by calcareous algae in the development of Permian reefs. The role is mainly taken by *Archaeolithoporella*, a problematical rhodophyta. The alga is sheetlike, showing no original internal structure. It always encrusts on other organisms — mainly on framers as well as on bafflers, or even on bioclasts, exhibiting no host preference. It can encrust on living organisms as well as on skeletons. It should be harmless to its host. Otherwise, it would hinder the development of reefs. At present, some researchers propose that *Archaeolithoporella* encrusts on only broken and upturned sponge skeletons. However, this is not the case in the reef of Xiangbo and the reef of Ziyun, another typical Permian reef of southern China. Actually, in the Permian reefs of Xiangbo and Ziyun, about 90 percent of skeletons in framed facies are erect, in situ sponges. The function of *Archaeolithoporella* is similar to that of encrusting corallinaceae in Recent coral reefs. However, the former can be more important to ancient reef formation because in Recent reefs corals are strong framers while in ancient reefs sponges may be framers not as strong as Recent corals. *Archaeolithoporella* is also the chief encruster in the Permian reefs of Guadalupe and Slovenia (Flugel et al, 1984).

(3) **Dwellers**

Solenoporaceae (Rhodophyta) and phylloid algae are common dwellers in Permian reefs. In the reef of Xiangbo solenoporaceae occur in the baffled facies and framed facies of reef core. They also occur in Permian reefs of Guadalupe, also in reef core as well as in fore reef (Klement, 1966). In the reef of Xiangbo, solenoporaceae are generally nodular, massive, or columnar. Because of their small size and growth form they can not be framers.

Table 9 Paleoecology of calcareous algae in Permian reefs

Function	Group and representative	Facies and environments
Framers	Monostysisyrinaceae *Monostysisyrinx*	Framed facies; High-energy
Encrusters	Problematical rhodophyta *Archaeolithoporella*	Framed facies, Baffled facies; High-mediate-energy
Dwellers	Solenoporaceae *Solenopora* *Parachaetetes* Codiaceae *Ivanovia* *Anchicodium*	Prebaffled facies, Baffled facies, Framed facies; Mediate-high-energy
Bafflers	Phylloid algae	Mound; Low-mediate-energy
Bank formers	Dasycladaceae *Anthracoporella* Phylloid algae	Bank; High-energy
Grain producers	Dasycladaceae	Packwacked facies; Low-energy

(4) **Bafflers**

Phylloid algae can be bafflers. In the reef of Xiangbo, phylloid algae form the basis on which the reef develops. In the Carboniferous and Permian of USA, phylloid algae form mounds. These mounds are mainly composed of phylloid algae, micrites, and skeletons or skeletal grains of other organisms. The composition of the mounds indicates that they are mainly formed through the baffling of phylloid algae. Phylloid algae preserved in the mounds of USA and the reef of Xiangbo are segments several cm in length. Never has the whole skeleton of a phylloid alga been observed. We can not imagine that an alga only several cm in height could be an effective baffler. Thus, the present author believes that phylloid algae, like *Halimeda*, have articulated skeletons composed of a series of segments (Fig. 28). After death the organic tissue decay and the skeletons are disintegrated into separated segments. With a height of more than 10 cm, phylloid algae can baffle sediments effectively in the case that they grow into thickets. So long as sediments are sufficient, phylloid alga mound will be formed.

(5) **Bank formers**

Anthracoporella, a dasyclad, and some phylloid algae can form alga banks which can serve as the base for reef development. The two kinds of algae generally grow into monotonous communities. As long as water energy is moderately high, alga banks will be formed. In the reef of Xiangbo, both *Anthracoporella* bank and phylloid alga bank are developed.

(6) Grain producers

In back reef or packwacked facies, dasyclads and foraminifera are main grain producers. The functions of calcareous algae in reef formation are illustrated in Table 9.

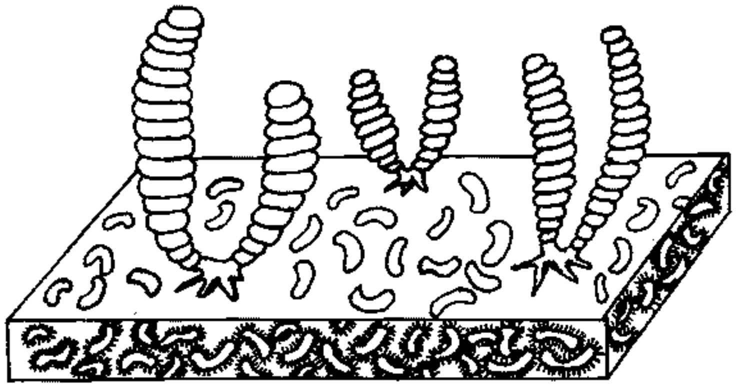


Fig. 28 Reconstruction of phylloid algae.

II. Systematic Description

Phylum Rhodophyta

Class Rhodophyceae

Subclass Florideae

Order Cryptonemiales

Family Solenoporaceae

Genus *Solenopora* Dybowski, 1878

Diagnosis: Thallus nodular, columnar, consisting of filaments radially arranged. The filaments polygonal in cross section generally. The partitions in filaments randomly arranged, not forming lateral or concentric layers.

Solenopora guangxiensis sp. nov.

(pl. 19 / 1)

Derivatio nominis: The species name refers to the type locality of the species.

Diagnosis: Thallus nodular. Cells circular to tetragonal in cross section, 0.015–0.020 mm wide. Partitions within filaments irregularly spaced, 0.02–0.04 mm apart.

Section: xb35–4–1, xb35–7–3 (holotype).

Description: Thallus nodular, or coniform, 5–8 mm high, composed of radial filaments. Filaments circular to polygonal in cross section, 0.015–0.020 mm wide. The radial walls between adjacent filaments conspicuous. The partitions within filaments sparse, irregularly spaced, 0.02–0.04 mm apart. The interior of each cell filled with a calcite sparry.

Discussion: The new species is characterized by the filament width which is between those of *S. texana* and *S. centurionis* and by the presence of partitions.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Solenopora guangxiensis sinuosa sp. et subsp. nov.
(Pl. 19 / 2)

Derivatio nominis: The species name refers to the sinuous nature of the filaments.

Section: xb30–8–11 (holotype), xb30–8–10 (paratype).

Description: Thallus coniform or nodular, composed of radial filaments. The filaments slightly sinuous, 0.015–0.020 mm wide. Partitions absent within the filaments. Interior of filaments mostly filled with micritic sediments.

Discussion: The subspecies is characterized by the sinuous filaments and the absence of partitions.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Parachaetetes* Deninger, 1906

Diagnosis: Thallus composed of filaments. Partitions in filaments regularly arranged, forming lateral or concentric layers.

Parachaetetes lamellatus Konishi, 1954
(pl. 19 / 5, 6)

Section: xb27–6–8, xb30–6–1, xb33–5–3.

Description: Thallus nodular, columnar or sheetlike. Filament arrangement radial in nodular forms, water-jet-like in columnar forms, fanlike in sheetlike forms. Filament width 0.015–0.03 mm. Partitions in filaments 0.03–0.06 mm apart.

Paleoecology: In the species, columnar forms can be bafflers or framers locally. This interpretation can be supported by their in situ preservation and the presence of epibionts on them. The nodular forms are not effective framers.

Dimension (mm):

Section no.	Form and size	Filament width	Partition interval
xb30–6–1	Nodular: 20–30 wide	0.02–0.03	0.05–0.06
xb33–5–3	Columnar: 2–2.75 wide, 5 high	0.02–0.025	0.03–0.05
xb37–6–8	Sheetlike: 2.5 thick, 6.5 wide	0.015–0.02	0.04–0.06

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Family Gymnocodiaceae Elliott, 1955

Genus *Permocalculus* Elliott, 1955

Diagnosis: Thallus composed of joined segments. Segments spheroidal, ovoid or doliform. Calcification state variable in different parts of segments. In the inner part of the hypothallium, filaments thick, extending longitudinally; toward the periphery of the hypothallium, filaments curved outward, furcated and tapered. In the perithallium, filaments the thinnest, perpendicular to the surface of thallus.

Permocalculus sp.
(pl. 19 / 7; pl. 20 / 6)

Section: xb33–8–2, xb31–2–1.

Description: Segments short, columnar, 0.8–1.3 mm long, 0.13 mm in diameter. The outer part of segments calcified, sparry. The inner part of segments poorly calcified. Filaments longitudinal in the inner part of segments, curved outward and dichotomous at large angles in the outer part of segments, finally reaching thallus surface at a high or right angle. Filaments 0.02–0.03 mm thick in the axial part of segments, tapering toward segment surface, 0.01 mm in diameter at segment surface.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Permocalculus cf. *fragilis* (Pia) Elliott, 1955
(pl. 22 / 1; pl. 21 / 6)

Section: xb35–1–3, xb35–4–2.

Description: Segments circular in cross section, 0.62–0.85 mm in diameter. Calcified peripheral part of segments about 0.17–0.25 mm thick. Central part of segments not calcified, left as a cylindrical cavity. Hypothallium 0.25–0.35 mm wide. Filaments 0.04–0.05 mm wide in hypothallium, extending longitudinally. In perithallium filaments gradually curved outward, dichotomous and tapering, finally reaching segment surface at high angles. Filaments 0.015–0.020 mm wide at segment surface.

Discussion: The specimens are characterized by the presence of a hollow central part and the furcating pattern of filaments, resembling *Permocalculus fragilis* (Pia) Elliott, 1955.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Family Corallinaceae Harvey, 1849

Genus *Paralithoporella* gen. nov.

Derivatio nominis: The generic name refers to the similarity of the genus to *Lithoporella* in gross form.

Diagnosis: Thalluses laminar, often encrusting on other organisms, consisting of one layer of cells. Conceptacle absent. Several laminar thallus successively stacked generally.

Discussion: This genus resembles Recent rhodophyta *Lithoporella* Fosilis, 1969 in growth form and the construction of one layer of cells.

Type species: *Paralithoporella sinensis* gen. et sp. nov.

Paralithoporella sinensis gen. et sp. nov.
(pl. 22 / 4)

Derivatio nominis: The species name refers to the first occurrence of the genus in China.

Diagnosis: Cells low and wide, rectangular in vertical section, 0.03–0.08 mm high and 0.06–0.08 mm wide.

Section: xb30–5–6 (holotype), xb33–6–4 (paratype).

Description: Thalluses laminar, encrusting on other organisms. Several laminar thalluses successively stacked generally. Thallus consists of one layer of squat cells. Cells rectangular in vertical section, 0.03–0.08 mm high and 0.06–0.08 mm wide.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Problematical Rhodophyta

Genus *Archaeolithoporella* Endo, 1959

Diagnosis: Thalluses laminar, encrusting on other organisms, constant in thickness, without cellular structure, cryptocrystalline or microcrystalline in microstructure. When recrystallized thalluses show an appearance of cellular construction.

Discussion: According to Endo (1959), thalluses of the genus are laminae without cellular construction. Johnson (1963) revised the definition of the genus. He stated that the genus is composed of one layer of cells; several layers stacked; irregular sheetlike or encrusting on other organisms; conceptacles present in the upper part of thallus; each conceptacle with one opening. Babcock (1974) restudied the syntypes of the genus and concluded that the genus is composed of two layers: one cryptocrystalline dark layer with constant thickness and another thick, microcrystalline layer with some lentiform structure probably being conceptacles. Flugel (1984) believed that the genus is composed of two layers: one dark, microcrystalline layer with constant thickness and another thick layer of fibrous or granular sparrys. On the study of the materials from the reef of Xiangbo, I agreed on Endo's (1959) original definition. According to it, thallus of the genus is composed of one layer of cryptocrystalline calcites, constant in thickness, without cellular structure, lacking conceptacles, generally encrusting on other organisms. The "layer of sparry calcite", I believe, are actually sparry cements of fibrous or granular calcites filling the interspaces between adjacent thalluses.

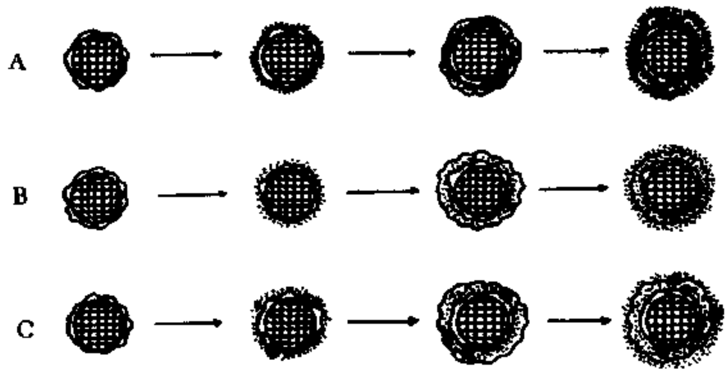


Fig. 29 Growth mode of *Archaeolithoporella* — encrusting on other organisms, covered by and covering: (A) sparry calcites, (B) micrites, (C) epibionts.

Babcock (1977) believed that the genus can encrust on all other kinds of organisms. This is true. According to my observation, the genus tends to be more developed in high-energy reef fabric-facies such as framed facies, commonly encrusting on framers. It is most developed in the framed facies whose framers are thin columnar or thin ramose. It can also occur in baffled facies or occasionally in prebaffled facies. It can also encrust on micritic or bioclastic sediments. When in baffled or prebaffled facies, it shows some host preference to *Tubiphytes*. The encrustation of the genus, the sedimentation of micrites on it and the attachment of epibionts on it can alternate (Fig. 29). The interspaces between adjacent thalluses of the genus can be filled with fine sparry calcite cements. In this case the appearance known as "two-layer structure" is formed.

The interpretation of the affinity of the genus depends on the understanding of its form and construction. It was placed in Solenoporaceae by Johnson (1963). Babcock (1977) also regarded it as an alga. But he could not point out which group of algae it belongs to. On the contrary, Dunham (1972), Schmidt and Klement (1977) believed that it is an inorganic cement structure formed in aerated environments. I believe that this genus can not be an inorganic structure because of its regular form. It can be a rhodophyta on the basis of its encrusting growth habit and high quality of calcification.

Archaeolithoporella hidensis Endo, 1959
(pl. 20 / 5; pl. 21 / 5)

Section: xb28–R, xb34–8–3.

Description: Thallus thin, sheetlike, encrusting on other organisms or sediments. Thallus wavy generally, constant in thickness, 0.005–0.010 mm thick commonly. Thallus cryptocrystalline, lacking cellular structure. When the thallus recrystallized, the boundaries between calcite crystals gives the thallus an appearance of cellular structure.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Guangxilamina* gen. nov.

Derivatio nominis: The generic name refers to the first locality and the form of the genus.

Diagnosis: Thallus thin, sheetlike, encrusting on other organisms. Thallus wavy, inconstant in thickness, lacking cellular structure. Thallus generally recrystallized into small calcites.

It always encrusts on sponges or corals. Thus, it may be a rhodophyta.

Type species: *Guangxilamina incompta* gen. et sp. nov.

Guangxilamina incompta gen. et sp. nov.
(pl. 19 / 4)

Derivatio nominis: Incomptus (la. = not decorated) refers to the simple construction of the species.

Diagnosis: Thallus wavy, 0.02–0.07 mm thick, lacking cellular structure.

Section: xb31–2–3 (holotype), xb27–6–3.

Description: Thallus laminar, encrusting on the top surface of other organisms, commonly sponge. Thallus generally recrystallized into small calcite crystals, lacking cellular structure. Thallus generally wavy, not uniform in thickness, generally 0.02–0.07 mm thick, up to 0.12 mm thick in some places. Thallus up to several cm wide.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Phylum Chlorophyta

Class Chlorophyceae

Family Dasycladaceae Kutzing, 1843

Genus *Anthracoporella* Pia, 1920

Diagnosis: Thallus cylindrical, dichotomous. Central stem cylindrical. Primary branches fine, cylindrical, somewhat enlarged outward. Some primary branches dichotomous. Primary branches aspondyl in arrangement. Thallus several mm to more than 10 mm in diameter.

Anthracoporella spectabilis Pia, 1920
(pl. 19 / 3; pl. 20 / 4)

Diagnosis: The relationship between the length of primary branches (Y) and the diameter of the stem conforms to the equation: $Y = 13X-2$. Primary branches 0.03–0.05 mm across.

Section: xb35–1, xb35–1–7.

Description: Thallus cylindrical, dichotomous, 1 mm to more than ten mm in diameter, broken into cylindrical segments. Central stem cylindrical. Primary branches cylindrical, somewhat enlarged outward, aspondyl in arrangement. Some primary branches dichotomous, forming secondary branches. Primary branches 0.25–0.50 mm long and 0.03–0.05 mm wide. Adjacent primary branches 0.015–0.020 mm apart. The tangential section of thallus reticulate, with branches as circular pores. Segments of thallus generally ring-like in thin sections.

Discussion: The species often forms alga banks. All individuals are similar in the diameter of their branches although they are different in gross size.

The materials of the species are very rich. This makes it possible for me to inquire into the relationship between the diameter of the central stem and the length of branches through statistical analysis. In the study 21 specimens randomly selected are used (Table 10). The length of their branches and the diameter of their central stem are pointed in a coordinate figure (Fig. 30). Thus, a line conforming to equation $Y = 13X-2$ is regressed. It is found that most of the points are in or near the line. This indicates that the specimens represented by these points belong to the same species. Several points are away from the line, representing other species or aberrant individuals. According to the study, one of the specimens described by Endo (1969) as *A. spectabilis* can belong to the species but the other one of them does not belong to the species. Specimens described by Elliott (1968) all belong to the species. Thus, it is concluded that the length of branches increases as the central stem thickens. Their relationship conforms to the linear equation $Y = 13X-2$.

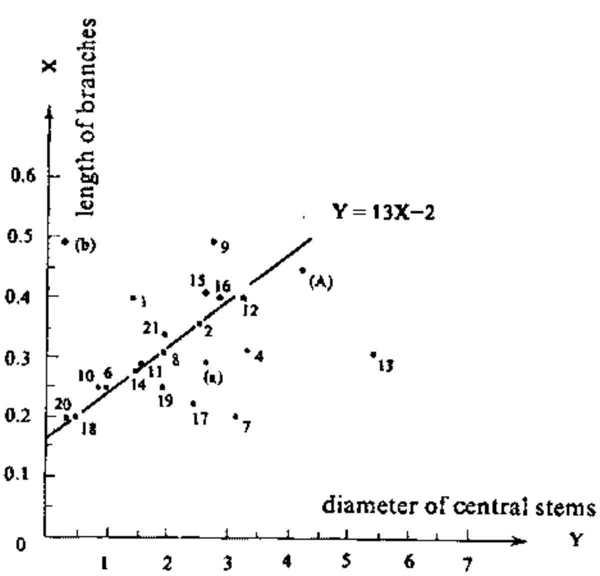


Fig. 30 Regression of the relationship between the length of branches and the diameter of the central stem.

Table 10 Diameter of stems and length of branches of *Anthracoporella spectabilis*

Individual no.	Diameter of stem	Length of branches
1	1.36	0.33–0.50
2	2.5	0.36
3	?	0.17
4	3.25	0.30–0.32
5		0.50
6	0.87	0.25
7	3.1	0.20
8	1.87	0.25–0.37
9	2.7	0.50
10	0.75	0.25
11	1.52	0.29
12	3.2	0.40
13	5.4	0.25–0.37
14	1.44	0.28
15	2.57	0.33–0.50
16	2.75	0.40
17	2.38	0.20–0.25
18	0.42	0.20
19	1.87	0.25
20	0.3	0.2
21	1.25–2.5	0.33–0.35

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Paleoecology: This species grows into monotonous community, forming alga banks generally. In the Permian of Alps, it occurs in packstones (Flugel, 1977, 1979), representing a restricted bank. In the reef of Xiangbo, it occurs in grainstone, representing an open bank. It can also sparsely occur in reef core occasionally. In this case it is encrusted by *Archaeolithoporella*.

Genus *Gyroporella* Gumbel, 1872, emend. Benche, 1876

Diagnosis: Thallus rod-like, with one end swollen, circular or ovoid in cross section. Central stems in the same form as thallus. Primary branches rod-like, euspondyl in arrangement, with the outer end swollen into spherical form. Spectacles can be present in the outer ends of some primary branches.

Gyroporella sp.
(pl. 22 / 2)

Section: xb31–2–4, xb35–4–2b.

Description: Thallus circular in cross section, 1.1–1.7 mm in diameter. Branches 0.25 mm long, with an external diameter of 0.20 mm. Branches euspondyl in arrangement, with 32 branches in a whorl.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Mizzia* Schubert, 1907

Diagnosis: Thallus composed of segments joined end to end in a loosely articulated fashion. Segments spheroidal to cylindrical or pyriform, composed of a generally barrel-shaped stem and unbranched branches radiating from the stem. The branches arranged into regular, alternating horizontal rows. The alternating arrangement and the crowd of branches give the segment surface a hexagonal pattern.

Mizzia sp.
(pl. 22 / 8)

Section: xb30–2–4, xb31–2–4, xb34–2–6, xb37–C–T.

Description: Segments ovoid. Stem 1.0 mm in diameter. Branches euspondyl in arrangement, 0.10 mm in diameter at their base and 0.17 mm at their tip. About 20 branches in a whorl. Each branch leaves a small process on segment surface.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Macroporella* Pia, 1912

Diagnosis: Thallus cylindrical. Stem cylindrical. Primary branches thick, increasing in diameter outward, arranged into irregular whorls. Secondary branches absent. Spectacles can be present in the stem.

Macroporella affinis Endo, 1969
(pl. 22 / 5)

Section: xb31–2–1.

Description: Thallus 1.60 mm in diameter. Stem averages 1.14 mm in diameter. Branches 0.17 mm long, 0.11–0.13 mm in diameter, normal to stem.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Vermiporella* Stolley, 1893

Diagnosis: Thallus cylindrical, dichotomous, sometimes vermiform, commonly being creeper. Branches unbranched, somewhat enlarged outward, normal to stem, not uniform in length.

Vermiporella cf. *nipponica* Endo, 1954
(pl. 21 / 8)

Section: xb35–1–3, xb35–8–11, xb37–C–T.

Description: Thallus small. Stem 0.12 mm in diameter. Branches thin and long, somewhat increasing in diameter outward, 0.01 mm in diameter at their outer ends, 0.015 mm apart. The length of branches not uniform, ranging 0.075–0.100 mm.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Favoporella* gen. nov.

Derivatio nominis: Favo (la. = honeycomb) refers to the appearance of the thallus surface.

Diagnosis: Thallus cylindrical, swollen in the middle part. Stem ellipsoidal. Branches unbranched, normal to stem and irregularly arranged, polygonal in cross section, constant in diameter, with their outer ends perpendicular to thallus surface. Branches intercommunicated with the stem, opening into thallus surface.

Type species: *Favoporella hexagona* gen. et sp. nov.

Favoporella hexagona gen. et sp. nov.
(pl. 20 / 2; pl. 21 / 7; pl. 22 / 6)

Derivatio nominis: Hexagonus (la. = hexagonal) refers to the form of the cross sections of branches.

Diagnosis: Thallus cylindrical, swollen. Branches fine and long, hexagonal in cross section, 0.05 mm in diameter.

Section: xb27–8–4 (holotype).

Description: Thallus swollen, cylindrical, 7 mm wide maximally, at least 17.5 mm high. Stem in the same form as thallus, up to 2.5 mm in diameter. Branches unbranched, hexagonal in cross section, constant in diameter, generally 0.05 mm thick, normal to stem, aspondyl in arrangement.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Family Codiaceae Zanardini, 1843
Genus *Ivanovia* Khvorova, 1946

Diagnosis: Thallus bladed, composed of perithallia and hypothallium. The perithallium composed of cylindrical cells normal to thallus surface. The cells in the perithallia not calcified, preserved as cylindrical pores. The hypothallium hardly calcified, thus hollow.

Discussion: Pray & Wray (1963) suggested that this genus and *Eugonophyllum, Anchicodium, Calcifolium* and rhodophyta *Archaeolithophyllum* can be grouped into phylloid algae in the absence of internal structure. This genus and *Eugonophyllum* were placed in Codiaceae by Johnson (1963). Riding (1977) related the genus to Squamariaceae. Wray (1977) remained the genus in Codiaceae. The present author agrees with Wray.

Ivanovia permica sp. nov.
(pl. 20 / 8; pl. 21 / 1)

Derivatio nominis: The species name refers to the first Permian occurrence of the species.

Diagnosis: Perithallia 0.075–0.120 mm thick. Perithallium cells 0.03–0.05 mm across. Walls between cells 0.015–0.020 mm thick.

Section: xb32–1, xb30–8–10 (paratype), xb30–1–3 (holotype), xb35–7–4.

Description: Thallus bladed, wavy, 0.25 mm thick. Perithallia 0.075–0.120 mm thick, containing cylindrical pores 0.03–0.05 mm across and 0.015–0.020 mm apart. The pores normal to thallus surface. Hypothallium not calcified, filled with sparry calcites or micrites.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Phylloid alga (? *Ivanovia*)
(pl. 21 / 3)

Section: xb26–27–R3.

Description: Thallus bladed, generally wavy, 0.25–0.50 mm thick, up to several cm wide.

The boundary between perithallium and hypothallium indistinct. Perithallia 0.05–0.10 mm thick. Thallus generally recrystallized.

Discussion: The specimen shows some similarities to *Ivanovia*.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Paleoecology: It occurs in monotonous community, forming an alga bank.

Genus *Anchicodium* Johnson, 1946

Diagnosis: Thallus bladed or encrusting, probably with cylindrical stems on its surface. The stems can furcate or be with tubercles. Filaments in central part of thallus poorly calcified, somewhat irregularly arranged. Filaments furcate and taper, parallel to each other in hypothallium, but perpendicular to thallus surface in periphery of thallus. Calcification confined to thallus surface.

Anchicodium expressum sp. nov.

(pl. 20 / 7; pl. 21 / 2)

Derivatio nominis: Expressus (la. = obvious) refers to the form of the thallus in sections.

Diagnosis: Calcified periphery 0.25 mm thick. Filaments 0.025 mm across in hypothallium, 0.01 mm across in periphery.

Section: xb31–2–3, xb35–7–2 (holotype), xb35–7–3 (holotype).

Description: Thallus bladed, 0.67–1.0 mm thick, with one surface flat and the other having tubercles. Calcified peripheral region of thallus 0.25 mm thick. Hypothallium poorly calcified, commonly filled with sparry calcites, with some fine tubes left by filaments. In hypothallium, filaments 0.025 mm in diameter, irregularly sinuous and furcating. In perithallia filaments furcate and taper, generally 0.01 mm in diameter, parallel to each other, finally normal to thallus surface.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Paleoecology: On both sides of thallus epibiont are found. Thus, the species can be erect in life.

Problematical Chlorophyta

Genus *Sinophyllum* gen. nov.

Derivatio nominis: Sin (gr. = China) and phyllus (gr. = frondoid) refer to the type locality and form of the genus.

Diagnosis: Thallus sheetlike, composed of one layer of small tubes normal to thallus surface. The tubes hexagonal in cross section. Several thallus stacked generally.

Discussion: The hexagonal tubes are similar to the cylindrical tubes in perithallium of *Ivanovia* in size.

Type species: *Sinophyllum hexagonum* gen. et sp. nov.

Sinophyllum hexagonum gen. et sp. nov.

(pl. 20 / 1)

Derivatio nominis: Hexagonus (la. = hexagonal) refers to the form of the cross section of the cellular tubes.

Diagnosis: Thallus 0.25–0.50 mm thick. Hexagonal tubes 0.05 mm across. Tube walls 0.015

mm thick.

Section: xb30–8–6 (holotype).

Description: Thallus sheetlike, 0.25–0.50 mm thick. Several thallus stacked successively. Thallus composed of one layer of small tubes polygonal in cross section. The tubes uniform in size, generally 0.05 mm in diameter, generally hexagonal in cross section, normal to the surface of thallus. The common walls between the tubes 0.015 mm thick.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Sphaeroporella* gen. nov.

Derivatio nominis: The genus name refers to the gross form of the thallus.

Diagnosis: Thallus small, spheric or hemispherical, commonly attaching to other organisms. Thallus has a spherical central cavity. The cavity has a continuous, micritic wall. In the micritic wall present radial fine tubes. The tubes normal to thallus surface, uniform in size. The wall between the tubes micritic. The tubes not intercommunicated with the central cavity.

Discussion: The genus resembles dasyclad in form and construction. However, the micritic cavity wall has not been found in dasyclads. Besides, the spherical or hemispherical growth form, and the fine tubes not communicated with the central cavity make it difficult to place the genus in Dasycladaceae. Nevertheless, the genus has some affinities with dasyclad.

The genus differs from *Pseudovermiporella* Elliott, 1958 in the larger body, the long and somewhat irregular tubes and the presence of a separated wall in the cavity of the latter.

According to the illustration the specimens assigned to *Pseudovermiporella* sp. by Termier et al in 1977 belong to the genus.

Type species: *Sphaeroporella minima* gen. et sp. nov.

Sphaeroporella minima gen. et sp. nov.

(pl. 22 / 7)

Derivatio nominis: The species name refers to the minute dimension of the thallus.

Section: xb35–2–1 (holotype).

Diagnosis: Thallus 0.28 mm in size. Central cavity 0.22–0.23 mm in diameter. Radial tubes 0.005–0.007 mm in diameter.

Description: Thallus spherical or hemispherical, attaching to other organisms, 0.28 mm in diameter. Hemispheric forms can be stacked successively. Central cavity 0.22–0.23 mm in diameter. Radial tubes 0.005–0.007 mm in diameter, uniform in length, ranging 0.025–0.030 mm long, normal to central cavity wall. The common walls between adjacent radial tubes below 0.004 mm thick.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Family Monostysisyrinaceae fam. nov.

Definition: Algae included in this family are characterized by small, erect, and unbranched cylindrical thallus. Thallus hollow. The surface of thallus smooth.

Type genus: *Monostysisyrinx* gen. nov.

Genus *Monostysisyrinx* gen. nov.

Derivatio nominis: Mono (gr. = single), stys (gr. = erect) and syrinx (gr. = tube) refer to the form of the thallus.

Diagnosis: Thallus erect, unbranched, tube-like, circular in cross section, uniform in diameter. The interior of the thallus tube lacks cellular structure, filled in with sparry calcites. The wall of the thallus tube thin and thin, microcrystalline. Thalluses grow into dense microforest (Fig. 31). They are commonly encrusted by *Archaeolithoporella*.

Discussion: The fine, unbranched thalluses of the genus indicate that it is a primitive organism. Because of the absence of internal structure, it is difficult to determine its systematic position.

Filaments are present in Cyanophyta, Chlorophyta, Rhodophyta and Phaeophyta. The genus can not be cyanophyta. The reasons are (1) most cyanophyta live in fresh water environments, (2) the filaments in Cyanophyta are generally soft and fragile, and (3) most cyanophyta are not calcified. The genus can not be phaeophyta. This is because: (1) most phaeophyta occupy deep water environments while *Monostysisyrinx* lives in warm, shallow-water environments, (2) most phaeophyta are complicated in growth form, generally being branched, and (3) few phaeophyta leave calcified fossils. It is of little possibility that the genus belongs to Rhodophyta. This is because most rhodophyta are complicated and very developed while *Monostysisyrinx* is a simple and undeveloped one. This genus can belong to Chlorophyta. The reasons are (1) most chlorophyta are warm, shallow water organisms, (2) most chlorophyta can be calcified and preserved as fossils, and (3) many chlorophyta such as those in Ulotrichales and Siphonales are sessile, erect, unbranched filamentous ones.

Thus, the genus is assigned to Chlorophyta. It is difficult to relate it to a known group of Chlorophyta. Hence a new family is established to include it.

The genus was described as sponge root tuft by Rigby & Fan (1988). According to the observation made in field, the present author is convinced that it can not be sponge root tuft. The reasons are (1) all individuals are erect, straight, (2) the individuals are evenly rather than in patches distributed, and (3) no sponge evidence (e.g., spicules) can be found.

Type species: *Monostysisyrinx circularis* gen. et sp. nov.

Monostysisyrinx circularis gen. et sp. nov.
(pl. 20 / 3; pl. 21 / 4; pl. 22 / 3, 9)

Derivatio nominis: The species name refers to the form of the thallus in cross section.

Diagnosis: Thallus several ten cm high, circular in cross section, 0.1–0.5 mm thick.

Section: xb35–2 (holotype).

Description: Thalluses thin, unbranched, tube-like, circular in cross section, 0.1–0.5 mm in diameter. Thalluses sessile, generally more than ten cm high. The diameter of thallus constant. The surface of thallus smooth. Thallus tube walls 0.005 mm thick, probably microcrystalline, in most case recrystallized and thus difficult to be distinguished from the lamellar *Archaeolithoporella* encrusting on them. Thalluses always encrusted by *Archaeolithoporella*. In some cases, thalluses have epibiont of hemispherical *Sphaeroporella*. In this cases thallus tube wall seen apparently thin, recrystallized into granular, small sparrys. Thallus tubes hollow, filled in with sparry calcites. The filling calcites are in two layers: one touching thallus tube wall, fibrous, 0.075 mm thick; the other in the center of tube, granular.

The number of encrustation of *Archaeolithoporella* variable between different individuals. Micritic sediments probably present between thallus and encrustation of *Archaeolithoporella*.

Paleoecology: Thalluses of the species grow into dense micro-forest (Fig. 31). Encrusted by *Archaeolithoporella*, they should be effective reef-framers. This organism should live in warm, shallow and clean water environments.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

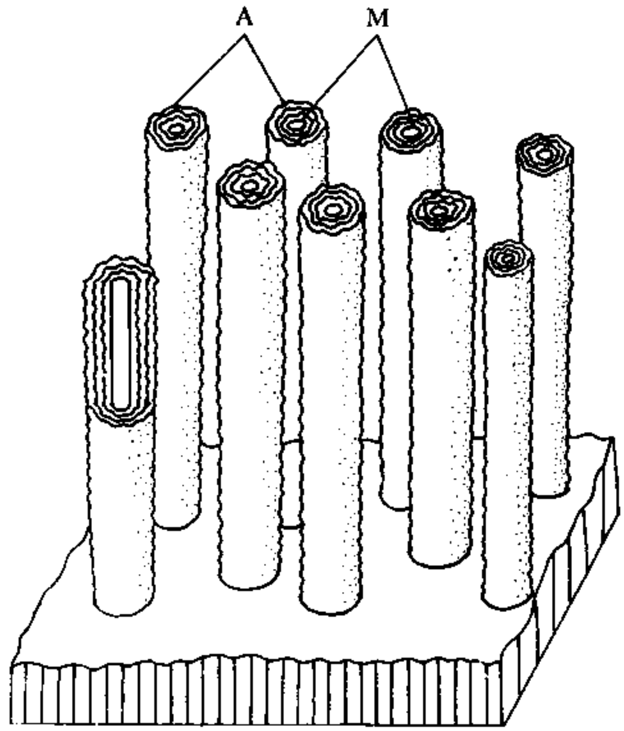


Fig. 31 Reconstruction of *Monostysisyrinx circularis* gen. et sp. nov. M: *Monostysisyrinx circularis* gen. et sp. nov.; A: *Archaeolithoporella*.

9 Microproblematica

I. Generals

Microproblematica is not a formal taxonomical unit. In fact, it is a polyphyletic, morphological group. Like Stromatoporida, it includes members even from different phyla. The organisms are included in the group not because of their affinities but because of: (1) they are all small, and simple in construction, and (2) their systematical positions are difficult to determine for the time being.

Microproblematica can be simple or compound. Simple ones can be saccate, tubiform or spherical. The compound forms are aggregation of small saccate or tubiform parts which are regularly or irregularly, commonly imbricately arranged. The skeletons of microproblematica are generally hollow.

Up to the present, microproblematica described are very limited in generic number (e.g., Flugel, 1964; Flugel et al, 1978; Senowbari-Daryan, 1977; Fois, 1981; Flugel, 1984).

The classification of microproblematica does not reflect their affinities. But it is helpful to the study of the group. Little work has been done about the classification of the group. Because of the simplicity of skeletal construction of microproblematica the classification of them is mainly based on the microstructure of their skeletal walls herein.

In the reef of Xiangbo, microproblematica mainly function as dwellers and epibionts. The microproblematica serving as dwellers are commonly saccate, tubiform or spherical. Those serving as epibionts are generally imbricate compounds. *Tubiphytes,* a familiar one, is the most common member of the group in the reef of Xiangbo although some researchers regarded it as an alga.This genus is a chief reef-builder in the Permian reefs of Urals, Soviet Union. But it is an accessary reef-builder in the reef of Xiangbo. Being rich in the reef, it mainly serves as epibionts and dwellers. Locally it can be a reef-framer.

II. Systematic Description

Family Porivalliidae fam. nov.

Definition: Organisms included in the family have perforated walls. They can be spherical or tubiform. The tubiform forms can be partitioned by tabulae. Members of the family can be related to sphinctozoans or dasyclads.

Representative: *Porivallia* gen. nov.

Genus *Porivallia* gen. nov.

Diagnosis: Organisms elongate saccate, divided into two parts differen in size by a shrinker. The saccate skeleton hollow, with the larger part divided into two chambers by a tabula. Walls of the sac perforated. The pores dense, evenly spaced, normal to and penetrating the sac walls.

Type species: *Porivallia phaseoliformis* gen. et sp. nov.

Porivallia phaseoliformis gen. et sp. nov.
(pl. 23 / 1, 3)

Section: xb28–3–2 (holotype), xb28–3–3 (paratype).

Description: Organisms elongate saccate, somewhat sinuous, with a deep shrinker at 1 / 4 from one end. The sac is divided into two parts different in size: one part short, somewhat spherical; the other part long. The whole sac peapod-like. The organism attached to sea bottom with the short end (in holotype) or with one side surface (in paratype). The sac 1.8–2.5 mm long, 0.45–0.50 mm wide maximally.

The sac hollow. The sac cavity lost where shrunk. The long part of the sac divided into two chambers by a tabula. Both chambers empty. The wall of sac more or less variable in thickness, ranging 0.09–0.10 mm. The tabula 0.06 mm thick. Sac wall and tabula perforated. The pores 0.009–0.012 mm across, normal to and penetrating the sac wall or tabula.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Porivallia sphaerica gen. et sp. nov.
(pl. 23 / 4)

Section: xb30–2–10 (holotype).

Description: Skeleton irregular, spherical, attached. The attached end flat, 0.75–1.12 mm high, 0.60–1.40 mm wide. Skeleton hollow. The wall of the skeleton not uniform in thickness, ranging 0.04–0.18 mm, perforated by pores 0.01–0.02 mm across. The wall where the organisms attach (i.e., the bottom wall) thin and imperforated.

Discussion: The species differs from *P. phaseoliformis* in the spherical form of the former.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Family Lamellivalliidae fam. nov.

Definition: Members included in the family have laminated walls. Skeletons genrally elongate saccate, divided into two parts by a tabula where shrunk. They often encrust on other organisms and can be encrusted by other organisms.

Representative: *Lamellivallia* gen. nov.

Genus *Lamellivallia* gen. nov.

Diagnosis: Skeletons irregular elongate saccate, probably divided into two parts by a thin tabula. Skeletons have a cavity. Skeleton walls laminated, pierced with one or several pores.

Type species: *Lamellivallia grossa* gen. et sp. nov.

Lamellivallia grossa gen. et sp. nov.
(pl. 23 / 2; pl. 24 / 1)

Section: xb30–3–2 (holotype), xb30–2–3 (paratype).

Description: Skeletons irregular elongate saccate, up to 2.0 mm long, not uniform in diameter, maximally 0.55 mm, with one side surface flat and the other not flat. The organisms can be attached to sea bottom on the thinner end or the flat side surface.

Skeletons hollow, divided into two parts by a tabula. In holotype, the tabula at the middle of the skeleton, 0.04 mm thick. Skeleton walls somewhat inconstant in thickness, maximally 0.10–0.12 mm thick, with distinct laminated microstructure. The wall includes 6–8 laminae commonly. The laminae parallel to skeleton surface. In holotype, the skeleton has an opening at the thicker end. The opening 0.05 mm thick. Skeleton wall thinner around the opening.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Family Heterolamelliidae fam. nov.

Definition: Organisms included in the family with a skeleton of aggregation of hemispherical chambers imbricately arranged. Chamber walls in the family with three-layered structure: a central layer and two side layers. The central layer dark, micritic. The side layers laminated. The laminae in the side layers very thin, much thinner than those in Lamellivallidae. The structure of the skeleton walls in the family resembles that of bryozoans and some corals.

Representative: *Heterolamellia* gen. nov.

Genus *Heterolamellia* gen. nov.

Diagnosis: Skeletons composed of many hemispherical chambers imbricately arranged. Chambers hollow. Chamber walls three-layered: one central layer and two side layers. The central layer dark. The side layers translucent, laminated. The organisms encrust on other organisms. The microstructure of skeletons indicates a bryozoan or coral affinity of the genus.

Type species: *Heterolamellia appressa* gen. et sp. nov.

Heterolamellia appressa gen. et sp. nov.
(pl. 24 / 3; pl. 25 / 1)

Section: xb30–5–1A (holotype), xb30–5–1B (paratype).

Description: Skeletons composed of hemispherical chambers imbricately arranged, encrusting on other organisms, 0.8 mm high and 2.5 mm wide. Chambers hollow, 0.25–0.45 mm high, 0.3–1.0 mm wide. Chamber walls three-layered: one micritic central layer and two laminated side layers.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Polyvesica* gen. nov.

Diagnosis: Skeletons composed of saccate chambers imbricately arranged. Chambers more or less irregular in form. Chamber walls dark, micritic, resembling the central layer in *Heterolamellia* gen. nov. Thus it can be related to bryozoans or corals.

Type species: *Polyvesica irregularis* gen. et sp. nov.

Polyvesica irregularis gen. et sp. nov.
(pl. 24 / 2)

Section: xb34–8–3 (holotype).

Description: Skeletons hill-like, about 1.6 mm high and 3.0 mm wide, attached to other organisms.

Skeletons composed of saccate chambers imbricately arranged. Chambers approximately hemispherical, not uniform in size, generally 0.25–0.38 mm high and 0.25–0.43 mm wide.

Chambers hollow. Chamber walls dark, micritic, uniform in thickness, about 0.01 mm.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Family Echinivesidae fam. nov.

Definition: Members included in the family simple or compound. The simple forms saccate; the compound forms composed of two saccate chambers merged. Skeleton walls granular, probably produced by recrystallization.

Representative: *Echinivesica* gen. nov.

Genus *Echinivesica* gen. nov.

Diagnosis: The skeleton composed of one sac or two sacs merged. The sac or sacs hemispherical, hollow, provided with some spines on their surface.

Type species: *Echinivesica robusta* gen. et sp. nov.

Echinivesica robusta gen. et sp. nov.
(pl. 23 / 5; pl. 24 / 4; pl. 25 / 3)

Section: xb28–R6 (holotype), xb35–8–7 (paratype), xb27–2–2(paratype).

Description: In holotype, the skeleton composed of two sacs merged, 1.5 mm high and 2.3 mm wide. In paratypes, the skeleton composed of one sac, with one side surface flat, 1 mm high and 1.12 mm wide. Sac walls provided with some robust spines.

Sac or sacs have a cavity. The cavity spheroidal. Sac walls not uniform in thickness, 0.20–0.28 mm thick in holotype, 0.10–0.20 mm thick in paratypes. Sac walls recrystallized into granular calcites.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Echinivesica incondita gen. et sp. nov.
(pl. 24 / 5; pl. 25 / 5)

Section: xb30–2–10A (holotype), xb30–2–10B (paratype).

Description: Skeletons single saccate, 0.7–1.2 mm in size. Sac hollow. Sac walls 0.08–0.13 mm thick, granular in microstructure.

Discussion: The species differs from the previous one in the single, somewhat irregular form, and thinner sac walls of the former.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Polyechinivesica* gen. nov.

Diagnosis: Skeletons composed of many sacs imbricately arranged. Sacs spherical, similar in size. Each sac with a coniform spine on sac wall surface. Sac walls recrystallized into granular calcites.

Type species: *Polyechinivesica regularis* gen. et sp. nov.

Polyechinivesica regularis gen. et sp. nov.
(pl. 25 / 4)

Section: xb30–7–7 (holotype).

Description: Skeletons composed of many sacs imbricately arranged, 1.8 mm high, attached to other organisms. Sacs spherical, similar in size, 0.5 mm high and 0.50–0.62 mm wide. Interior of sacs empty. Sac walls 0.08–0.10 mm thick, recrystallized into granular calcites.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Family Micritivesidae fam. nov.

Definition: Members in the family with a wall micritic in microstructure.

Representative: *Micritivesica* gen. nov.

Genus *Micritivesica* gen. nov.

Diagnosis: Skeletons composed of one or several irregular sacs. Sac wall thick, micritic in microstructure.

Type species: *Micritivesica granosa* gen. et sp. nov.

Micritivesica granosa gen. et sp. nov.

(pl. 25 / 2)

Section: xb37–2–12 (holotype), xb31–1–R1–2 (paratype).

Description: Skeletons composed of one or several sacs. In holotype, the skeleton composed of two sacs, 1.25 mm high, 2.5 mm wide. In paratype, the skeleton composed of one sac, 1.6 mm high and 1.85 mm wide. The organisms attached to sea bottom or other organisms.

Sac cavity spheroidal, 0.3–0.4 mm high in holotype, 24% of sac height, 0.4 mm high in paratype, 25% of sac height. Sac walls greatly variable in thickness, 0.13–0.56 mm thick in holotype, at least 0.13–0.50 mm thick in paratype. Sac walls dark, micritic in microstructure, with the micrites coarse. In paratype, sac walls more or less irregular, with pores parallel to sac wall surface.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Genus *Tubiphytes* Maslov, 1956

Diagnosis: Skeletons small, generally less than 1 mm in size, up to 10 mm maximally, spherical, ovoid, ramose or encrusting, generally attached to other organisms, with one end thin and the other end thick. Interior of skeletons micritic, commonly showing concentrical growth layers. Some small cavities often present in the inner part of skeletons.

Discussion: Some previous researchers believed the skeletons have a reticulate structure and correlated it to cellular structure of algae. They interpreted the micrites to be secondary fillings in the reticulate structure. However, the present author believes that the reticulate structure irregular, thus different from the cellular structure of algae. The micrites in the interior of the skeletons are all original, secreted by the organisms in life. The cavity in the interior of the skeletons is unique. The construction of the genus has not been found in algae. Thus it is of little possibility that the genus belongs to algae. The genus is worldwide distributed. It is an important Permian reef-builder. It can serve as (1) dwellers, (2) epibionts, (3) framers, and (4) encrusters. It was reported to be important framers in the Permian reefs of Urals, Soviet Union. It is a common dweller, epibiont and local framer in the reef of Xiangbo.

Type species: *Tubiphytes obscurus* Maslov, 1956

Tubiphytes obscurus Maslov, 1956

(pl. 26 / 4)

Section: xb30–8–11, xb30–2–7, xb28–4–1, xb35–1–2.

Description: Skeletons ramose, with stem 0.3–0.4 mm wide and 1.8 mm high, with two concentrical growth layers: the inner one bright, 0.06–0.09 mm thick, the outer one dark, 0.10–0.12 mm thick. A tubiform cavity present in the inner growth layer, variable in diameter, ranging 0.02–0.05 mm across, extending not long. Microstructure of skeletons micritic.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Tubiphytes spinalis sp. nov.

(pl. 26 / 5)

Section: xb35–7–5 (holotype).

Description: Skeleton ovoid, 0.45–0.50 mm wide, 1.0–1.3 mm long. One end of the skeleton provided with one to two spines. The spines 0.25–0.36 mm long, 0.08–0.10 wide. Interior of skeleton showing no growth layer, micritic. One small, tubiform cavity present in the inner part of the skeleton. The cavity 0.1 mm thick at the end with spines, tapering toward the other end. The cavity also extends into the spines. It is constant in diameter in the spines, 0.03 mm across, and extends through the length of the spines.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Tubiphytes tubularis sp. nov.

(pl. 26 / 1)

Section: xb28–4–2 (holotype).

Description: Skeleton ramose and branched, with stem 0.13–0.20 mm wide. Internal cavity thick, tubiform, 0.05–0.08 mm wide. Interior of skeleton dark, micritic, showing no growth layer.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

Tubiphytes polyvesica sp. nov.

(pl. 26 / 2, 3)

Section: xb31–2–3 (holotype).

Description: Skeletons columnar, thin at the base, thick at the top, 1.25–2.25 mm high, 0.45–0.50 mm in diameter maximally. In holotype, skeletons have two growth layers: the inner one ring-like, 0.9 mm thick; the outer one 2.15 mm thick. In the holotype, one spherical cavity 0.05 mm across present in the inner growth layer and at least 9 lanceolate cavities 0.005–0.008 wide and at least 0.10–0.18 mm long present in the outer layer. The interior of skeletons dark, micritic. A bright boundary present between the two layers.

Locality and horizon: Reef of Xiangbo, Longlin, Guangxi; Middle Permian Maokou Stage.

10 Community Paleoecology of Xiangbo Reef

The community study of reefs is an effective way to reveal their development and distribution pattern. Because of the difficulties in the study of some reefal organisms such as sclerosponges and hydrozoans the study of Permian reef communities was hindered in the past. Thanks to the relatively sufficient materials, the present study makes a big step forward in the community study of Permian reefs of China.

The term community refers to all of the organisms living in a certain space and integrating into an organization with a distinctive biological and ecological structure. A reefal community is composed of different guilds. The term guild refers to all of the organisms which have the same ecological habit in a certain space. According to their guild composition, the communities of a reef can be grouped into different community-types (used in this sense herein).

I. Guilds

In the reef of Xiangbo, six types of guild have been recognized. They are as follows:

(1) **Framing guild**

This guild consists of the calcified organisms which form the framework of the reef. It can be further divided into three types: (1) *Monostysisyrinx* guild which is composed of the micro-forest of *Monostysisyrinx* gen. nov., (2) sponge framing guild which is mainly composed of sclerosponges, inozoans, sphinctozoans and some hydrozoans, with the sponges and hydrozoans in the guild diversified morphologically and taxonomically, and (3) *Peronidella* framing guild which is mainly composed of thin columnar or thin ramose *Peronidella recta* and thin catenulate sphinctozoans such as *Sollasia*. In framing guild, the average distance between adjacent component organisms is below 0.1 m.

(2) **Baffling guild**

This guild consists of the calcified organisms which baffle sediments in the development of the reef. Similar to the framing guild, the baffling guild consists of sclerosponges, inozoans, sphinctozoans and hydrozoans diversified in morphology and taxonomy. The difference is that the richness of component organisms in this guild is lower than that in framing guild. The average distance between the adjacent component organisms ranges from 0.1 to 0.5 m.

(3) **Prebaffling guild**

This guild has a taxonomic composition similar to that of baffling guild. But the richness of the component organisms in this guild is much lower than that in baffling guild. In this guild the average distance between adjacent component organisms is over 0.5 m.

(4) **Encrusting guild**

This guild consists of organisms encrusting on framing or baffling organisms. It is mainly composed of *Archaeolithoporella* and encrusting bryozoans *Dybowskiella* and *Fistulipora*.

(5) **Epibiont guild**

This guild consists of epibiont organisms which attach to framing or baffling or prebaffling organisms. It is mainly composed of cystoid microproblematica, especially *Tubiphytes*, some foraminifera, and some small attached calcareous algae. It is clear that the epibiont guild contributes little to reef formation. However, its presence and features can be indicative of the structure of the reefal community.

(6) **Dwelling guild**

This guild consists of the small organisms which dwell in the interspaces between the framing or baffling or prebaffling organisms. It mainly consists of *Tubiphytes*, small spheric microproblematica, some bryozoans such as *Fenestella* and *Polypora*, some foraminifera and some calcareous algae such as *Solenopore*, *Parachaetetes*, *Ivanovia*, and *Anchicodium*. The guild mainly functions as grain-producers in reef development. Its presence and features are indicative of the phase of reef development.

II. Communities and Community-types

In the reef of Xiangbo, five community-types and 12 communities have been recognized. They are as follows:

(1) **Encruster-framer-community (en-F-COM)**

This community-type consists of two guilds: encrusting guild and framing guild. It includes the following communities.

(a) *Archaeolithoporella*-sponge community (Arch.-spon.-com) In this community, *Archaeolithoporella* is an encruster while sponges (including sclerosponges, inozoans and sphinctozoans, diversified in morphology and taxonomy, generally columnar or coniform) and some hydrozoans are framers (Fig. 32).

(b) *Archaeolithoporella-Peronidella* community (Arch.-Pero.-com) In this community, *Archaeolithoporella* is an encruster while thin columnar or thin ramose inozoans (mainly *Peronidella*) and some thin catenulate or ramose sphinctozoans (mainly *Sollasia*) are framers (Fig. 33).

(c) *Archaeolithoporella- Monostysisyrinx* community (Arch.- Mono.- com) In this community, *Archaeolithoporella* is an encruster while *Monostysisyrinx* is a framer (Fig. 34).

(d) *Archaeolithoporella*-bryozoan community (Arch.-bryo.-com) In this community, *Archaeolithoporella* is an encruster while fenestrate bryozoan *Fenestella donaica* and ramose *Eridopora* are framers.

(2) **Epibiont-encruster-framer-community (ep-en-F-COM)**

This community-type consists of three types of guilds: sponge framing guild, encrusting guild and epibiont guild. Community of this type is *Tubiphytes-Archaeolithoporella*-sponge community (Tubi.-Arch.-spon.-com). In the community *Tubiphytes* is an epibiont; *Archaeolithoporella* is an encruster, while sponges (sclerosponges, inozoans and sphinctozoans) and some hydrozoans are framers (Fig. 35). The sponges in the community are diversified morphologically and taxonomically.

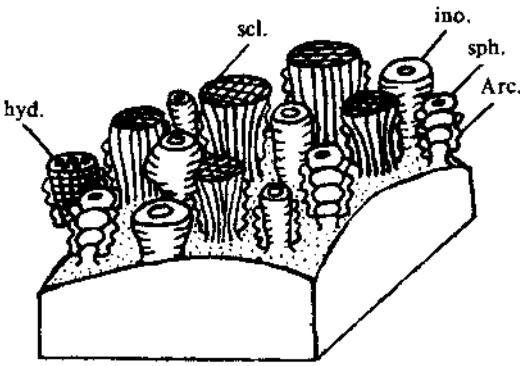


Fig. 32 Reconstruction of *Archaeolithoporella*-sponge community. hyd.: hydrozoan; ino.: inozoan; scl.: sclerosponge; sph.: sphinctozoan; Arc.: *Archaeolithoporella*.

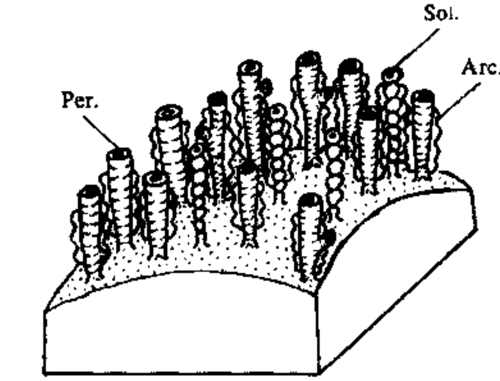


Fig. 33 Reconstruction of *Archaeolithoporella*-*Peronidella* community. Per.: *Peronidella*; Sol.: *Sollasia*; Arc.: *Archaeolithoporella*.

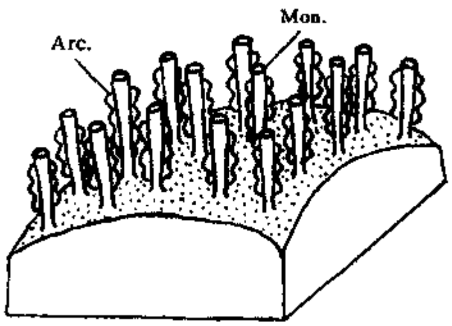


Fig. 34 Reconstruction of *Archaeolithoporella*-*Monostysisyrinx community*. Mon.: *Monostysisyrinx*; Arc.: *Archaeolithoporella*.

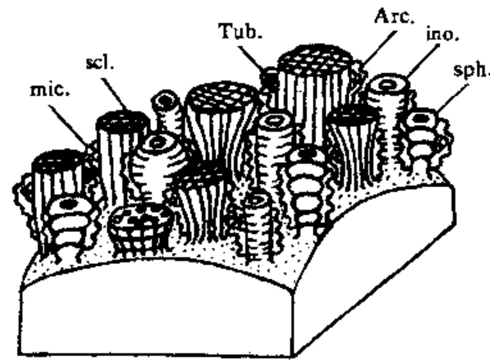


Fig. 35 Reconstruction of *Tubiphytes*-*Archaeolithoporella*-sponge community. scl.: sclerosponge; ino.: inozoan; Arc.: *Archaeolithoporella*; sph.: sphinctozoan; Tub.: *Tubiphytes*; mic.: microproblematicum.

(3) Dweller-framer-community (d-F-COM)

This community-type consists of dwelling guild and framing guild. Community of this type is *Tubiphytes*-sponge community (Tubi.-spon.-com) in which *Tubiphytes* is a dweller while sponges such as sclerosponges, inozoans and sphinctozoans are framers.

(4) Dweller-baffler-community (d-B-COM)

This community-type consists of baffling guild and dwelling guild. Community of this type is *Tubiphytes*-less-sponge community (Tubi.-less-spon.-com) in which *Tubiphytes* is a dweller while sponges such as sclerosponges, inozoans and sphinctozoans are bafflers (Fig. 36).

(5) Dweller-prebaffler-community (d-P-COM)

This community-type consists of prebaffling guild and dwelling guild. Community of this type is *Tubiphytes*-few-sponge community (Tubi.-few-spon.-com). In the community, *Tubi-*

phytes is a dweller while sponges such as sclerosponges, inozoans and sphinctozoans are prebafflers. The sponges in this community are sparsely scattered (Fig. 37).

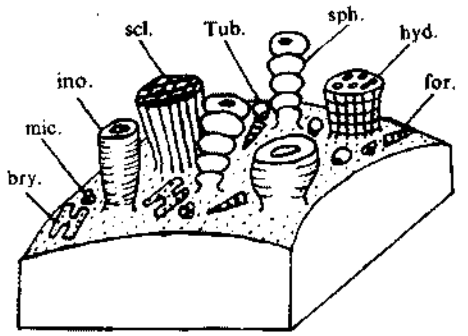


Fig. 36 Reconstruction of *Tubiphytes*-less-sponge community. bry.: bryozoan; ino.: inozoan; mic.: microproblematicum; scl.: sclerosponge; Tub.: *Tubiphytes*; sph.: sphinctozoan; hyd.: hydrozoan; for.: foraminifera.

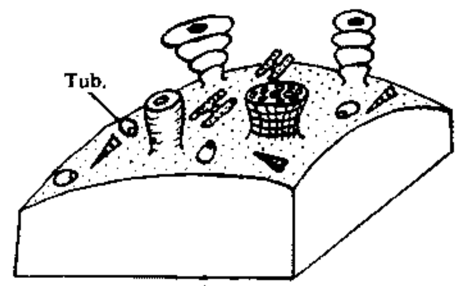


Fig. 37 Reconstruction of *Tubiphytes*-few-sponge community. Tub.: *Tubiphytes*.

All of the communities stated above are reefal communities, that is, they occur in reefs. On the contrary, some other communities do not live in reefs but are related to reefs. They generally form the bank deposits which serve as the base for reef development. We call these communities bank-communities (bank-COM). They include the follows:

(a) fusulinid community (fusu.-com) which is mainly composed of fusulinids.

(b) foraminifera-phylloid alga community (fora.-phyl.-com) which consists of phylloid algae and foraminifera.

(c) *Anthracoporella* community (Anth.-com) which is mainly composed of *Anthracoporella* and a few *Tubiphytes*.

The last community related to the reef is foraminifera-dasyclad community (fora.-dasy.-com). This community is mainly composed of benthic foraminifera and dasyclads. It occurs in the platforms between or after reef development episodes. Thus we call it platform-community (plat-COM).

III. Composition of Community-types

The community-types are different in their composition, especially in the composition of the main components. In encruster-framer-community and epibiont-encruster-framer-community, the percentage of sclerosponges, of inozoans, of sphinctozoans and of hydrozoans in framers is 51.2%, 27.3%, 19.4%, and 2.2%, respectively (Fig. 38A). In the dweller-framer-community, the sclerosponges account for 43.7% of the framers; the inozoans account for 26.6% of the framers; the sphinctozoans make up 24.5% of the framers, and the hydrozoans make up 5.2% of the framers (Fig. 38B). In the dweller-baffler-community and the dweller-prebaffler-community, the composition of the bafflers and of the prebafflers are illustrated in Fig. 38C and Fig. 38D, respectively.

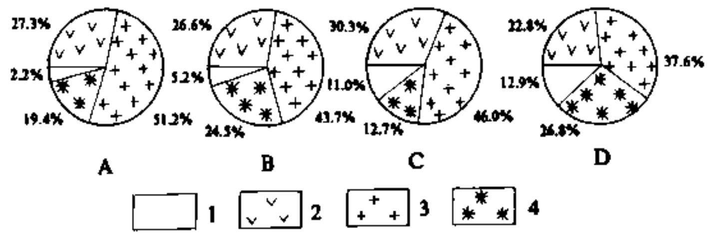


Fig. 38 Composition of main reef-builders in community-types. A: en-F-COM and ep-en-F-COM; B: d-F-COM; C: d-B-COM; D: d-P-COM. 1: hydrozoans; 2: inozoans; 3: sclerosponges; 4: sphinctozoans.

From the figures, it can been seen that the percentage of sclerosponges and inozoans in the encruster-framer-community, epibiont-encruster-framer-community, dweller-farmer-community and dweller-baffler-community is higher than that in the dweller-prebaffler-community. On the contrary, the percentage of hydrozoans in the dweller-baffler-community and dweller-prebaffler-community is higher than that in the encruster-framer-community, epibiont-encruster-framer-community, and dweller-framer-community, and that of sphinctozoans in the dweller-prebaffler-community is much higher than it in the other community-types.

Measurement made in the field shows that the coverage of framing organisms ranges 10–30% in the framed facies of the reef.

IV. Living Environments of Communities

Sedimentological and paleoecological analysis shows that communities and community-types in reefs are controlled by their living environments. On the other hand, the communities and community-types can serve as the indicative of their living environments. I believe that the community-types are more convenient in reflecting their environments. It is found that the encruster-framer-community, epibiont-encruster-framer-community and dweller-framer-community always occur in the framed facies of the reef. This suggests that these community-

Table 11 The relationship between community-types, communities and their environments

Communities & community-types	Fabric-facies	Environments
Encruster-framer-community Arch.-Mono.-com Arch.-Pero.-com Epibiont-encruster-framer-community Dweller-framer-community	Framed facies	High-energy environments
Dweller-baffler-community	Baffled facies	Less-high-energy environments
Dweller-prebaffler-community	Prebaffled facies	Least-high-energy environments

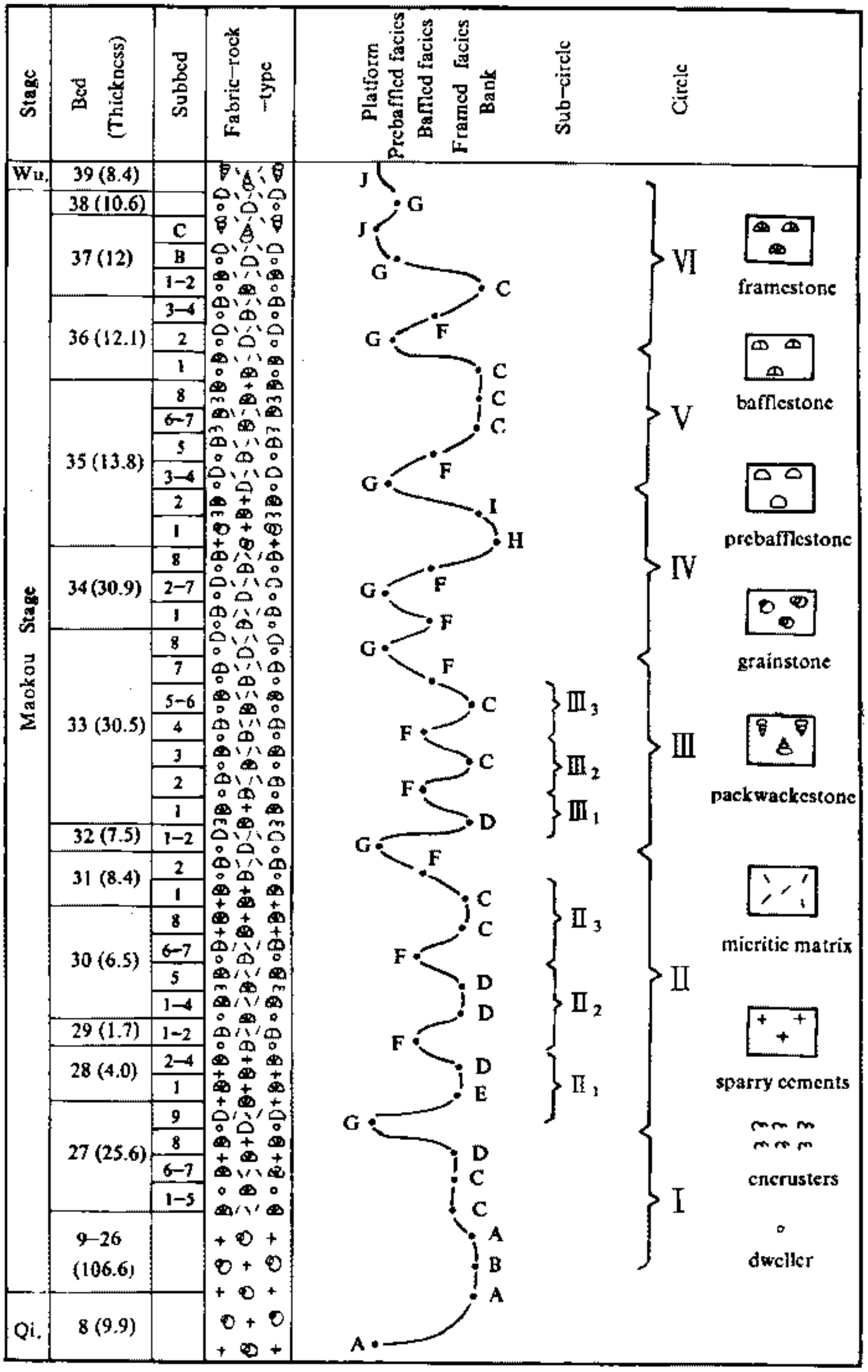


Fig. 39 The sequence of the fabric-rock-types and community-types (community replacement) in the reef of Xiangbo, Longlin, Guangxi, China. Wu: Wujiaping Satge; Qi: Qixia Stage. A–J: community-types or communities. A: fusu.-com; B: fora-phyl.-com; C: d-F-COM; D: en-ep-F-COM; E: en-F-COM; F: d-B-COM; G:d-P-COM; H: Anth.-com; I: Arch.-Mono.-com; J: fora -dasy.-com.

types represent high-energy environments. The *Archaeolithoporella-Monostysisyrinx* community and *Archaeolithoporella- Peronidella* community always occur in the cemented framed facies, representing the most typical high-energy environments in the reef. The two communities indicate the climax of the reef development.

The dweller-baffler-community is found distributed in the baffled facies of the reef, representing the less high-energy or intermediate-energy environments.

The dweller-prebaffler-community occurs in the prebaffled facies of the reef. It represents the least high-energy or intermediate-energy environments.

Table 11 illustrates the relationship between the communities and community-types, and their living environments.

V. Community Replacement in Reef Development

In the reef of Xiangbo, the community replacement is characterized by the cyclic development of the community-types. At least six cycles can be recognized (Fig. 39). Some cycles include smaller cycles (that is, cycle II and cycle III).

The cyclical replacement of the community-types should reflect the cyclic changes of the environments which are mainly controlled by the paleoclimate as well as some local physical-chemical factors. It is clear that the comparative study of the community-type replacement of different Permian reefs over the world would be an effective approach to the paleoclimate of Permian.

11 Horizon and Role of the Organisms

The reef of Xiangbo is divided into 39 beds from the bottom to the top. As illustrated in Fig. 4, bed 27 through bed 38 belong to the *Neoschwagerina*-zone of Middle Permian Maokou Stage; bed 39 belongs to the *Codonofusiella*-zone of Upper Permian Wujiaping Stage. For each bed, the fabric-rock-type, the guild types and the organisms (if identified) in the guilds are stated as follows in descending order.

(Abbreviations: scle. = sclerosponges, inoz. = inozoans, sphi. = sphinctozoans, demo. = demosponges, hydr. = hydrozoans, extr. = extrohydrozoans, bryo. = bryozoans, alga. = calcareous algae, micr. = microproblematica)

Bed	Subbed	Fabric-rock-types	Organisms and their guilds
39		Packwackestone	
38		Prebafflestone	Prebaffling guild
			Dwelling guild
37	37–C	Packwackestone	Grain-producing guild
			inoz. (transported?): *Elasmostoma aperiens*, *Ramospongia minor*
			alga.: *Gyroporella* sp., *Mizzia* sp., *Vermiporella* cf. *nipponica*
	37–B	Prebafflestone	Prebaffling guild
			sphi.: *Solidothalamia lambdiformis*
			Dwelling guild
	37–1~2	Framestone	Framing guild
			scle.: *Parabauneia scalariformis*
			inoz.: *Peronidella labiaformis*, *Vermispongia spiniformis*
			Epibiont guild
			micr.: *Micritivesica granosa*
			Dwelling guild
36	36–3~4	Bafflestone	Baffling guild
			scle.: *Tubulispongia concentrica*, *Tubulispongia continua*, *Gracilitubulus perforatus*, *Bauneia epicharis*, *Dendrosclera irregularis*
			sphi.: *Cystospongia guangxiensis*, *Intrasporecoelia laxa*
			hydr.: *Cancellistroma divulsa*, *Ditabulipora longidens* (covering)
			Dwelling guild
			bryo.: Fenestellidae gen. et sp. indet., Rhabdomesonidae gen. et sp. indet. B

	36–2	Prebafflestone	Prebaffling guild
			Dwelling guild
	36–1	Framestone	Framing guild
			sphi.: *Guangxispongia spinalis, Intrasporecoelia hubeiensis*
			demo.: *Mastostroma punctiformis*
			Dwelling guild
35	35–8	Framestone	Framing guild
			scle.: *Parabauneia scalariformis*
			sphi.: *Intrasporecoelia hubeiensis, Intrasporecoelia laxa*
			hydr.: *Concentristroma eucalla, Ditabulipora longidens* (covering)
			Encrusting guild
			alga.: *Archaeolithoporella hidensis*
			Dwelling guild
			alga.: *Vermiporella* cf. *nipponica*
			micr.: *Echinivesica robusta*
	35–6 ~ 7	Framestone	Framing guild
			scle.: *Mirispongia clathrata*
			inoz.: *Peronidella labiaformis*, Homocoelioidea gen. indet.
			Encrusting guild
			alga.: *Archaeolithoporella hidensis*
			Dwelling guild
			alga.: *Solenopora guangxiensis, Ivanovia permica, Anchicodium expressum*
			micr.: *Tubiphytes spinalis*
	35–5	Bafflestone	Baffling guild
			Dwelling guild
	35–3 ~ 4	Prebafflestone	Prebaffling guild
			Dwelling guild
			alga.: *Solenopora guangxiensis, Permocalculus* cf. *fragilis, Gyroporella* sp.
	35–2	Framestone	Framing guild
			alga.: *Monostysisyrinx circularis*
			Encrusting guild
			alga.: *Archaeolithoporella hidensis*
			Epibiont guild
			alga.: *Sphaeroporella minima*
	35–1	Grainstone	Grain-producing guild
			alga.: *Anthracoporella spectabilis*
			Accessory organisms
			scle. (transported?): *Flabellisclera discreta*
			inoz. (transported?): *Elasmostoma aperiens*
			bryo.: *Fenestella donaica, Fenestella* sp. indet.
			alga.: *Permocalculus* cf. *fragilis, Vermiporella* cf. *nipponica*
			micr.: *Tubiphytes obscurus*

34	34–8	Bafflestone	Baffling guild inoz.: *Grossotubenella parallela* Epibiont guild micr.: *Polyvesica irregularis* Encrusting guild alga.: *Archaeolithoporella hidensis* Dwelling guild
	34–2～7	Prebafflestone	Prebaffling guild scle.: *Flabellisclera discreta, Fungispongia circularis* inoz.: *Bisiphonella cylindrata, Peronidella recta grossa, Paracorynella flexa, Polysiphonella* sp. C, *Paristellispongia parallelica* sphi.: *Polycystothalamia* sp., *Cystauletes* sp., Tebagathalamia lamella Dwelling guild alga.: *Mizzia* sp.
	34–1	Bafflestone	Baffling guild scle.: *Gigantosclera deformis, Bauneia ampliata* Dwelling guild
33	33–8	Prebafflestone	Prebaffling guild scle.: *Keriocoelia* cf. *conica* Dwelling guild bryo.: *Ascopora* cf. *quadritubulata* alga.: *Permocalculus* sp.
	33–7	Bafflestone	Baffling guild inoz.: *Elasmostoma* sp., *Polysiphonella* sp. B sphi.: *Follicatena* sp., *Colospongia* sp. Dwelling guild bryo.: Fenestellidae gen. et sp. indet., Rhabdomesonidae gen. et sp. indet. A.
	33–5～6	Framestone	Framing guild scle.: *Flabellisclera* sp., *Gigantosclera deformis, Gracilitubulus perforatus, Bauneia ampliata, Mirispongia clathrata, Parastrosclera polystellaris* inoz.: *Ramospongia minor, Peronidella gravida, Polysiphonella* sp. A, *Paristellispongia parallelica* sphi.: *Follicatena* sp., *Polycystothalamia sinuolata, Polycystothalamia* sp., *Cystauletes* sp., *Parauvanella* sp., *Tebagathalamia granularis*, hydr.: *Fungistroma daemonia* Encrusting guild bryo: *Polypora* sp. alga.: *Paralithoporella sinensis* Dwelling guild alga.: *Parachaetetes lamellatus*

	33–4	Bafflestone	Baffling guild
			Dwelling guild
	33–3	Framestone	Framing guild
			scle.: ***Bauneia ampliata***
			sphi.: ***Guadalupia minima, Intrasporecoelia laxa***
			Dwelling guild
	33–2	Bafflestone	Baffling guild
			scle.: ***Fungispongia circularis***
			inoz.: ***Peronidella gravida, Peronidella labiaformis***
			sphi.: ***Amblysiphonella*** sp. indet.
			Dwelling guild
			bryo.: ***Rhabdomeson*** sp.
	33–1	Framestone	Framing guild
			scle.: ***Tubulispongia concentrica, Tubulispongia continua, Fungispongia circularis, Bauneia ampliata***
			sphi.: ***Guangxispongia spinalis***
			Encrusting guild
			bryo.: ***Dybowskiella*** sp., ***Fistulipora*** sp. indet.
			alga.: ***Archaeolithoporella hidensis***
			Dwelling guild
			bryo.: ***Fenestella*** sp. indet.
32	32–1～2	Prebafflestone	Prebaffling guild
			Dwelling guild
			alga.: ***Ivanovia permica***
31	31–2	Bafflestone	Baffling guild
			scle.: ***Parastrosclera polystellaris***
			sphi.: ***Stylocoelia circopora***
			Encrusting guild
			alga.: ***Guangxilamina incompta***
			Dwelling guild
			alga.: ***Permocalculus*** sp., ***Gyroporella*** sp., ***Mizzia*** sp., ***Macroporella affinis, Anchicodium expressum***
			micr.: ***Tubiphytes polyvesica***
	31–1	Framestone	Framing guild
			scle.: ***Tubulispongia concentrica, Bauneia ampliata, Parabauneia scalariformis, Parastrosclera polystellaris***
			sphi.: ***Tebagathalamia lamella, Stylocoelia circopora***
			Epibiont guild
			micr.: ***Micritivesica granosa***
			Dwelling guild
30	30–8	Framestone	Framing guild
			scle.: ***Conosclera vermicula, Reticulocoelia*** sp., ***Dendrosclera irregularis, Parastrosclera singularis***
			inoz.: ***Acoelia ruida, Peronidella recta grossa, Paracorynella flexa,***

			Stellispongia sp., *Paristellispongia parallelica*
			bryo.: *Eridopora* sp. indet.
			Dwelling guild
			alga.: *Solenopora guangxiensis, Ivanovia permica, Sinophyllum hexagonum*
			micr.: *Tubiphytes obscurus*
	30–6~7	Bafflestone	Baffling guild
			scle.: *Gigantosclera deformis*
			extr.: Sphaeractinidae gen. indet.
			Epibiont guild
			micr.: *Polyechinivesica regularis*
			Dwelling guild
			bryo.: Rhabdomesonidae gen. et sp. indet. B
			alga.: *Parachaetetes lamellatus*
	30–5	Framestone	Framing guild
			scle.: *Gracilitubulus perforatus*
			inoz.: *Peronidella labiaformis*
			sphi.: *Cystospongia guangxiensis, Imbricatocoelia ramosa, Guadalupia minima, Intrasporecoelia laxa, Stylocoelia circopora*
			hydr.: *Permostroma sinensis*
			Epibiont guild
			micr.: *Heterolamellia appressa*
			Encrusting guild
			alga.: *Archaeolithoporella hidensis, Paralithoporella sinensis*
			Dwelling guild
	30–1~4	Framestone	Framing guild
			scle.: *Conosclera vermicula, Flabellisclera* sp.
			inoz.: *Peronidella labiaformis*
			sphi.: *Sollasia ostiolata, Colospongia* sp., *Dictyocoelia manon* (Munster)
			hydr.: *Tritubulistroma* sp.
			Dwelling guild
			bryo.: Trepostimida gen. et sp. indet. 1
			alga.: *Mizzia* sp., *Ivanovia permica*
			micr.: *Porivallia sphaerica, Lamellivallia grossa, Tubiphytes obscurus*
29	29–1~2	Bafflestone	Baffling guild
			Dwelling guild
28	28–2~4	Framestone	Framing guild
			scle.: *Gracilitubulus perforatus, Reticulocoelia* sp.
			inoz.: *Peronidella gravida, Vermispongia spiniformis*
			sphi.: *Sollasia ostiolata*
			hydr.: *Tritubulistroma irregularis*
			Encrusting guild
			alga.: *Archaeolithoporella hidensis*

			bryo.: *Eridopora* sp., Rhabdomesonidae gen. et sp. A
			Dwelling guild
			bryo.: *Polypora guangxiensis*, *Rhabdomeson* sp. indet.
			micr.: *Porivallia phaseoliformis*, *Echinivesica robusta*, *Tubiphytes obscurus*
	28–1	Framestone	Framing guild
			scle.: *Reticulocoelia* sp.
			Dwelling guild
			micr.: *Echinivesica robusta*
27	27–9	Prebafflestone	Prebaffling guild
			inoz.: *Stellispongia* cf. *manon* (Munster)
			Dwelling guild
	27–8	Framestone	Framing guild
			scle.: *Gracilitubulus perforatus*
			inoz.: *Ramospongia* sp., *Stellispongiella termieri*
			Encrusting guild
			bryo.: *Dybowskiella* sp.
			Dwelling guild
			bryo.: Trepostimida gen. et sp. indet. 2
			alga.: *Favoporella hexagona*
	27–6~7	Framestone	Framing guild
			scle.: *Bauneia ampliata*, *Bauneia epicharis*, *Parabauneia scalariformis*, *Parastrosclera singularis*, *Spumisclera discreta*
			inoz.: *Acoelia ruida*, *Peronidella labiaformis*, *Grossotubenella parallela*, *Protocoelia vermiformis*, *Precorynella dendroidea*
			sphi.: *Solidothalamia lambdiformis*
			Encrusting guild
			alga.: *Guangxilamina incompta*
			Dwelling guild
			bryo.: Rhabdomesonidae gen. et sp. indet. A
			alga.: *Parachaetetes lamellatus*
	27–1~5	Framestone	Framing guild
			scle.: *Bauneia epicharis*
			inoz.: *Bisiphonella cylindrata*
			sphi.: *Tebagathalamia diagonalis*, *Intrasporecoelia hubeiensis*
			hydr.: *Cancellistroma ramosa*, *Cancellistroma divulsa*
			extr.: *Ditabulipora longidens* (covering)
			Encrusting guild
			bryo.: *Eridopora* sp.
			Dwelling guild
			bryo.: *Polypora guangxiensis*, *Rhabdomeson* sp. indet.
			micr.: *Echinivesica robusta*

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Plates and Illustration

(All specimens and sections are deposited in Institute of Geology, Academia Sinica)

Plate 1

Fig. 1, 7 *Tubulispongia continua* gen. et sp. nov.

1: Paratype; Transversal section; × 2. Section no.: xb33–1–16.

7: Holotype; Longitudinal section; × 2. Section no.: xb33–1–R1–5.

Fig. 2 *Bauneia ampliata* sp. nov.

Holotype; Longitudinal section; × 2. Section no.: xb27–7–1.

Fig. 3 *Gigantosclera deformis* gen. et sp. nov.

Holotype (from same specimen as xb34–1–3); Tangential section; × 2. Section no.: xb34–1–2.

Fig. 4, 6 *Tubulispongia concentrica* gen. et sp. nov.

4: Holotype; Longitudinal section; × 2. Section no.: xb31–1–7.

6: Paratype; Longitudinal section; × 2. Section no.: xb36–4–12.

Fig. 5 *Gracilitubulus perforatus* gen. et sp. nov.

Transversal section; × 4. With a boring at left. Section no.: xb28–4–4.

Plate 2

Fig. 1, 3 *Conosclera vermicula* gen. et sp. nov.

1: Holotype; Longitudinal section; × 4. Section no.: xb30–2–7.

3: Paratype; Longitudinal section; × 2. Section no.: xb30–8–13.

Fig. 2, 4 *Flabellisclera discreta* gen. et sp. nov.

2: Paratype; Longitudinal section; × 2. Section no.: xb35–1–2.

4: Holotype; Longitudinal section; × 2. Section no.: xb34–7–3.

Fig. 5, 8 *Gigantosclera deformis* gen. et sp. nov.

5: Holotype; Longitudinal section; × 2. Section no.: xb34–1–3.

8: Holotype (from the same specimen as xb34–1–3); Transversal section; × 2. Section no.: xb34–1–4.

Fig. 6, 7 *Gracilitubulus perforatus* gen. et sp. nov.

6: Holotype; Transversal section; × 4. Section no.: xb28–4–7.

7: Paratype; Tangential section at the left and longitudinal section at the right; × 4. Section no.: xb28–4–3.

Plate 3

Fig. 1 *Parabauneia scalariformis* gen. et sp. nov.

Holotype; Longitudinal section; × 2. Section no.: xb35–8–6a.

Fig. 2, 3, 8 *Fungispongia circularis* gen. et sp. nov.

2: Holotype; Longitudinal section; × 2. Section no.: xb33–1–14.

3: Paratype; Longitudinal section; × 2. Section no.: xb33–1–13.

8: Holotype (from the same specimen as xb33–1–14); Transversal section; × 3. Section no.: xb33–1–15.

Fig. 4, 5 *Reticulocoelia* sp.

4: Tangential section; × 4. Section no.: xb28–4–7.

5: Tangential section; × 4. Section no.: xb28–1–1.

Fig. 6 *Bauneia ampliata* sp. nov.

Paratype; Longitudinal section at the bottom and Tangential section at the top; × 2. Section no.: xb33–1–R1–9.

Fig. 7 *Dendrosclera irregularis* gen. et sp. nov.

Holotype; Transversal section; × 3. Section no.: xb30–8–8.

Plate 4

Fig. 1, 3 *Dendrosclera irregularis* gen. et sp. nov.

1: Paratype; Transversal section; × 3. Section no.: xb30–8–9a.

3: Transversal section; × 2. Section no.: xb30–8–7.

Fig. 2, 6, 7 *Mirispongia clathrata* gen. et sp. nov.

2: Paratype; Transversal section; × 2. Section no.: xb35–7–2a.

6: Holotype; Longitudinal section; × 2. Section no.: xb33–5–4.

7: Transversal section; × 2. Section no.: xb35–7–2b.

Fig. 4 *Spumisclera discreta* gen. et sp. nov.

Holotype; Longitudinal section; × 2. Section no.: xb27–6–10.

Fig. 5 *Keriocoelia* cf. *conica* Cuif, 1974

Oblique section; × 2. Section no.: xb33–8–2.

Plate 5

Fig. 1 *Flabellisclera* sp.

Oblique section; × 3. Section no.: xb33–5–5.

Fig. 2, 3 *Parastrosclera singularis* gen. et sp. nov.

2: Paratype; Transversal section; × 2. Section no.: xb27–6–2.

3: Holotype; Slightly oblique transversal section; × 4. Section no.: xb27–6–1.

Fig. 4, 8 *Parastrosclera polystellaris* gen. et sp. nov.

4: Holotype; Tangential section; × 3. Section no.: xb33–5–5.

8: Paratype; Transversal section; × 4. Section no.: xb31–2–2.

Fig. 5 *Gracilitubulus perforatus* gen. et sp. nov.

Paratype; Longitudinal section; × 3. Section no.: xb33–6–8.

Fig. 6 *Bauneia epicharis* sp. nov.

Holotype; Longitudinal section at the left and tangential section at the right; × 2. Section no.: xb27–6–14.

Fig. 7 *Dendrosclera irregularis* gen. et sp. nov.

Paratype; Transversal section; × 3. Section no.: xb30–8–9b.

Plate 6

Fig. 1 *Dendrosclera irregularis* gen. et sp. nov.

Paratype; Longitudinal section; × 2. Section no.: xb36–4–16.

Fig. 2, 5 *Parabauneia scalariformis* gen. et sp. nov.

2: Holotype; Vertical section; × 2. Section no.: xb35–8–6b.

5: Paratype; Tangential section; × 2. Section no.: xb37–2–18.

Fig. 3 *Reticulocoelia* sp.

Longitudinal section; × 48. Section no.: xb30–8–14.

Fig. 4 *Tubulispongia continua* gen. et sp. nov.

Longitudinal section; × 2. Section no.: xb28–4.

Fig. 6 *Bauneia epicharis* sp. nov.

Paratype; Oblique section; × 2. Section no.: xb27–2–6.

Fig. 7 *Spumisclera discreta* gen. et sp. nov.

Holotype; Longitudinal section (from the same specimen as xb27–6–10); × 2. Section no.: xb27–6–11.

Fig. 8 *Bauneia ampliata* sp. nov.

Paratype; Transversal section; × 2. Section no.: xb33–1–R1–11.

Plate 7

Fig. 1 *Precorynella dendroidea* sp. nov.

Holotype; Transversal section; × 3. Section no.: xb27–7–3.

Fig. 2 *Vermispongia spiniformis* gen. et sp. nov.

Holotype; Longitudinal section; × 2. Section no.: xb37–2–12.

Fig. 3 *Peronidella minicoeliaca* sp. nov.

Holotype; Longitudinal section; × 3. Section no.: xb30–3–3.

Fig. 4, 5 *Bisiphonella cylindrata* gen. et sp. nov.

4: Longitudinal section; × 2. Section no.: xb34–2–2.

5: Holotype; Oblique transversal section; × 2. Section no.: xb27–B–2a.

Fig. 6 *Peronidella recta* Hinde, 1893

Longitudinal section; × 2. Section no.: xb27–6–7a.

Fig. 7, 8 *Peronidella recta grossa* subsp. nov.

7: Holotype; Transversal section; × 2. Section no.: xb34–4–1.

8: Same as 7.

Fig. 9 *Protocoelia vermiformis* gen. et sp. nov.

Holotype; Longitudinal section; × 2. Section no.: xb27–7–8.

Fig. 10 *Grossotubenella parallela* Rigby, Fan & Zhang, 1989

Longitudinal section; × 2. Section no.: xb26–27–1.

Fig. 11 *Paristellispongia parallelica* gen. et sp. nov.

Holotype; Transversal section; × 2. Section no.: xb33–6–5.

Plate 8

Fig. 1 *Elasmostoma* sp.

Vertical section; × 2. Section no.: xb33–7–5.

Fig. 2 *Elasmostoma aperiens* sp. nov.

Holotype; Part of vertical section; × 2. Section no.: xb35–1–1.

Fig. 3 *Peronidella minicoeliaca* sp. nov.

Holotype; Transversal section; × 4. Section no.: xb30–3–4.

Fig. 4 Homocoelioidea gen. indet.

Transversal section; × 2. Section no.: xb35–6–3.

Fig. 5 *Stellispongia* sp.

Oblique section; × 2. Section no.: xb30–8–9.

Fig. 6 *Peronidella labiaformis* sp. nov.

Holotype; Transversal section; × 2. Section no.: xb30–5–2.

Fig. 7 *Acoelia ruida* gen. et sp. nov.

Holotype; Longitudinal section; × 3. Section no.: xb27–6–2.

Fig. 8 ? *Polysiphonella* sp.

Oblique longitudinal section; × 2. Section no.: xb34–2–1.

Fig. 9 *Grossotubenella parallela* Rigby, Fan & Zhang, 1989

Longitudinal section; × 2. Section no.: xb34–8–1.

Fig. 10 *Peronidella gravida* sp. nov.

Holotype; Longitudinal section; × 2. Section no.: xb33–6–3.

Fig. 11 *Ramospongia* sp.

Longitudinal section; × 4. Section no.: xb27–8–4.

Plate 9

Fig. 1, 2 *Paracorynella flexa* gen. et sp. nov.

1: Paratype; Tangential section; × 2. Section no.: xb34–5–2.

2: Holotype; Longitudinal section; × 2. Section no.: xb30–8–4.

Fig. 3 *Ramospongia minor* gen. et sp. nov.

Holotype; Transversal section; × 2. Section no.: xb33–5–10.

Fig. 4 *Grossotubenella parallela* Rigby, Fan & Zhang, 1989

Oblique longitudinal section; × 3. Section no.: xb27–7–7.

Fig. 5 *Paristellispongia parallelica* gen. et sp. nov.

Paratype; Longitudinal section; × 2. Section no.: xb33–5–6.

Fig. 6 *Stellispongiella termieri* gen. et sp. nov.

Holotype; Longitudinal section; × 3. Section no.: xb27–8–3.

Fig. 7 *Peronidella labiaformis* sp. nov.

Paratype; Transversal section; × 4. Section no.: xb35–7–1.

Fig. 8 *Elasmostoma aperiens* sp. nov.

Paratype; Damaged transversal section; × 2. Section no.: xb37–C–T3.

Fig. 9 *Polysiphonella* sp. B

Transversal section; × 2. Section no.: xb33–7–2.

Fig. 10 *Polysiphonella* sp. A

Oblique transversal section; × 2. Section no.: xb33–5–2.

Fig. 11 *Bisiphonella cylindrata* gen. et sp. nov.

Holotype; Longitudinal section; × 2. Section no.: xb27–B–2b.

Fig. 12 *Stellispongia* cf. *manon* (Munster) Dieci et al, 1968

Damaged vertical section; × 2. Section no.: xb27–9.

Fig. 13 *Blastinia* sp.

Oblique transversal section; × 3. Section no.: xb30–8–17.

Fig. 14 *Peronidella recta* Hinde, 1893
Transversal section; ×2. Section no.: xb27–6–7b.

Plate 10

Fig. 1 *Sollasia ostiolata* Steinmann, 1882
Longitudinal section; ×2. Section no.: xb28–4–5.

Fig. 2 *Follicatena* sp.
Longitudinal section; ×3. Section no.: xb33–5–1.

Fig. 3, 9 *Polycystothalamia* sp.
3: Longitudinal section; ×2. Section no.: xb33–5–15.
9: Longitudinal section; ×2. Section no.: xb36–4–5.

Fig. 4, 7, 8 *Cystospongia guangxiensis* gen. et sp. nov
4: Paratype; Longitudinal section; ×2. Section no.: xb34–2–9.
7: Paratype; Oblique longitudinal section; ×2. Section no.: xb36–4–10.
8: Holotype; Oblique longitudinal section; ×2. Section no.: xb36—4–17.

Fig. 5 *Polycystothalamia sinuolata* gen. et sp. nov.
Holotype; Longitudinal section; ×3. Section no.: xb33–5–2.

Fig. 10 *Parauvanella* sp.
Longitudinal section; ×2. Section no.: xb33–6–2.

Fig. 6 *Imbricatocoelia ramosa* Senowbari-Daryan & Rigby, 1988
Longitudinal section; ×3. Section no.: xb30–5–14.

Fig. 11 *Cystauletes* sp.
Longitudinal section; ×2. Section no.: xb34–2–1.

Fig. 12 *Guadalupia minima* Parona, 1933
Transversal section; ×2. Section no.: xb33–3–8.

Fig. 13 *Intrasporecoelia hubeiensis* Fan & Zhang, 1985
Longitudinal section; ×2. Section no.: xb36–1–5.

Fig. 14 *Stylocoelia circopora* gen. et sp. nov.
Longitudinal section; ×2. Section no.: xb31–1–R1–4.

Plate 11

Fig. 1 *Ditabulipora longidens* gen. et sp. nov.
Holotype; Longitudinal section; ×2. Section no.: xb35–8–12.

Fig. 2, 5 *Intrasporecoelia laxa* sp. nov.
2: Holotype; Longitudinal section; ×2. Section no.: xb33–3–9.
5: Oblique longitudinal section; ×2. Section no.: xb30–5–17.

Fig. 3, 6 *Tebagathalamia lamella* sp. nov.
3: Paratype; Transversal section; ×2. Section no.: xb31–1–R1.
6: Holotype; Tangential section; ×2. Section no.: xb34–2–6.

Fig. 4 *Sollasia ostiolata* Steinmann, 1882
Longitudinal section; ×2. Section no.: xb30–2–6.

Fig. 7 *Amblysiphonella* sp. indet.
Transversal section; ×2. Section no.: xb33–2–5.

Fig. 8 *Solidothalamia lambdiformis* gen. et sp. nov.

Holotype; Longitudinal section; × 2. Section no.: xb37–B.

Fig. 9 *Stylocoelia circopora* gen. et sp. nov.

Paratype; Slightly oblique longitudinal section; × 3. Section no.: xb30–7–3.

Fig. 10 *Colospongia* sp.

Longitudinal section; × 2. Section no.: xb33–7–7.

Fig. 11 *Dictyocoelia* sp.

Slightly oblique longitudinal section; × 2. Section no.: xb31–1–8.

Plate 12

Fig. 1, 2 *Tebagathalamia diagonalis* sp. nov.

1: Holotype; Longitudinal section; × 2. Section no.: xb27–7–3.

2: Holotype; Transversal section; × 2. Section no.: xb27–7–2.

Fig. 3, 5, 6 *Guangxispongia spinalis* gen. et sp. nov.

3: Holotype; Longitudinal section; × 2. Section no.: xb33–1–R1–3.

5: Paratype; Tangential section; × 2. Section no.: xb36–1–8.

6: Paratype; Oblique section; × 2. Section no.: xb36–1–6.

Fig. 4 *Solidothalamia lambdiformis* gen. et sp. nov.

Transversal section; × 2. Section no.: xb27–6–12.

Plate 13

Fig. 1 *Intrasporecoelia hubeiensis* Fan & Zhang, 1985

Longitudinal section; × 2. Section no.: xb35–8–11.

Fig. 2, 3 *Ditabulipora longidens* gen. et sp. nov.

2: Holotype; Vertical section; × 40. Section no.: xb35–8–12.

3: Same as 2.

Fig. 4 *Dictyocoelia manon* (Munster, 1841) Ott, 1967

Longitudinal section; × 3. Section no.: xb30–1–2.

Fig. 5 Sphaeractinidae gen. indet.

Longitudinal section; × 2. Section no.: xb30–7–2.

Fig. 6 *Stylocoelia circopora* gen. et sp. nov.

Longitudinal section; × 2. Section no.: xb31–2–1.

Plate 14

Fig. 1 *Permostroma sinensis* gen. et sp. nov.

Holotype; Longitudinal section; × 3. Section no.: xb30–5–5.

Fig. 2 *Tritubulistroma irregularis* gen. et sp. nov.

Holotype; Longitudinal section; × 4. Section no.: xb28–4–6.

Fig. 3 *Ditabulipora longidens* gen. et sp. nov.

Longitudinal section; × 4. Section no.: xb27–5.

Fig. 4 *Mastostroma punctiformis* gen. et sp. nov.

Holotype; Longitudinal section; × 2. Section no.: xb36–1–2.

Fig. 5 *Concentristroma eucalla* gen. et sp. nov.

Holotype; Vertical section; × 2. Section no.: xb35–8–9.

Fig. 6 *Stylocoelia circopora* gen. et sp. nov.

Holotype; Longitudinal section; × 3. Section no.: xb30–5–8.

Plate 15

Fig. 1 *Cancellistroma ramosa* gen. et sp. nov.
Holotype; Longitudinal section; × 4. Section no.: xb27–B–3.

Fig. 2 *Cancellistroma divulsa* gen. et sp. nov.
Holotype; Longitudinal section; × 2. Section no.: xb36–4–5.

Fig. 3 *Tritubulistroma* sp.
Oblique section; × 4. Section no.: xb30–2–7.

Fig. 4 *Fungistroma daemonia* gen. et sp. nov.
Holotype; Longitudinal section at top part and transversal section at bottom part; × 3. Section no.: xb33–5–1.

Plate 16

Fig. 1 *Rhabdomeson* sp.
Transversal section; × 48. Section no.: xb33–2–4.

Fig. 2 *Fistulipora* sp. indet.
Oblique longitudinal section; × 48. Section no.: xb33–1–10.

Fig. 3 *Eridopora* sp. indet.
Transversal section; × 48. Section no.: xb30–8–1.

Fig. 4 *Fenestella donaica* subsp.
Tangential section; × 48. Section no.: xb35–1–2.

Fig. 5 Trepostimida gen. et sp. indet. 1
Tangential section; × 48. Section no.: xb30–2–7.

Fig. 6 Rhabdomesonidae gen. et sp. indet. B
Oblique section; × 48. Section no.: xb30–7–6.

Plate 17

Fig. 1, 4 *Dybowskiella* sp.
1: Transversal section; × 48. Section no.: xb27–8–2.
4: Longitudinal section; × 48. Section no.: xb27–8–2.

Fig. 2 *Eridopora* sp.
Vertical section; × 48. Section no.: xb28–4–4.

Fig. 3 *Rhabdomeson* sp. indet.
Transversal section; × 48. Section no.: xb28–4–5.

Fig. 5 *Fenestella* sp. indet.
Tangential section; × 48. Section no.: xb33–1–8.

Fig. 6 Fenestellidae gen. et sp. indet.
Transversal section of a branch; × 48. Section no.: xb33–7–3.

Plate 18

Fig. 1 Trepostimida gen. et sp. indet. 2
Tangential section; × 48. Section no.: xb27–8–2.

Fig. 2 *Polypora* sp.

Tangential section; ×48. Section no.: xb33–5–15.

Fig. 3 *Polypora guangxiensis* sp. nov.
Holotype; Tangential section; ×48. Section no.: xb28–4–7.

Fig. 4 *Rhabdomeson* sp.
Longitudinal section; ×48. Section no.: xb33–2–9.

Fig. 5 Rhabdomesonidae gen. et sp. indet. A
Oblique section; ×48. Section no.: xb28–4–1.

Fig. 6 *Ascopora* cf. *quadritubulata* Xia & Liu, 1986
Transversal section; ×48. Section no.: xb33–8–2.

Plate 19

Fig. 1 *Solenopora guangxiensis* sp. nov.
Holotype; Longitudinal section; ×48. Section no.: xb35–7–3.

Fig. 2 *Solenopora guangxiensis sinuosa* sp. et subsp. nov.
Holotype; Longitudinal section; ×48. Section no.: xb30–8–11.

Fig. 3 *Anthracoporella spectabilis* Pia, 1920
Longitudinal section; ×48. Section no.: xb35–1–7;.

Fig. 4 *Guangxilamina incompta* gen. et sp. nov.
Holotype; Vertical section; ×48. Section no.: xb31–2–3.

Fig. 5, 6 *Parachaetetes lamellatus* Konishi, 1954
5: Longitudinal section; ×48. Section no.: xb33–5–3.
6: Transversal section; ×120. Section no.: xb30–6–1.

Fig. 7 *Permocalculus* sp.
Oblique section; ×48. Section no.: xb31–2–1.

Plate 20

Fig. 1 *Sinophyllum hexagonum* gen. et sp. nov.
Holotype; Vertical section; ×48. Section no.: xb30–8–6.

Fig. 2 *Favoporella hexagona* gen. et sp. nov.
Holotype; Part of longitudinal section; ×48. Section no.: xb27–8–4.

Fig. 3 *Monostysisyrinx circularis* gen. et sp. nov.
Transversal section of many individuals; Cemented framestone. ×4. Section no.: xb35–2.

Fig. 4 *Anthracoporella spectabilis* Pia, 1920
Sections of segments. Grainstone. ×2. Section no.: xb35–1.

Fig. 5 *Archaeolithoporella hidensis* Endo, 1959
Vertical section; ×48. Section no.: xb34–8–3.

Fig. 6 *Permocalculus* sp.
Tangential section; ×48. Section no.: xb31–2–1.

Fig. 7 *Anchicodium expressum* sp. nov.
Holotype; Vertical section; ×48. Section no.: xb35–7–2.

Fig. 8 *Ivanovia permica* sp. nov.
Holotype; Vertical section; ×48. Section no.: xb30–1–3.

Plate 21

Fig. 1 *Ivanovia permica* sp. nov.
Holotype; Oblique section; × 48. Section no.: xb30–1–3.

Fig. 2 *Anchicodium expressum* sp. nov.
Holotype; Vertical section; × 48. Section no.: xb35–7–3.

Fig. 3 Phylloid alga: (? *Ivanovia*)
Vertical section, with epibionts; × 48. Section no.: xb26–27–R3.

Fig. 4 *Monostysisyrinx circularis* gen. et sp. nov.
Holotype; Longitudinal section, with epibiont of *Sphaeroporella minima* gen. et sp. nov.; Thallus tube walls seen; × 120. Section no.: xb35–2.

Fig. 5 *Archaeolithoporella hidensis* Endo, 1959
Vertical section; Sparry cements between thallus seen; × 120. Section no.: xb28–R.

Fig. 6 *Permocalculus* cf. *fragilis* (Pia) Elliott, 1955
Oblique section; × 48. Section no.: xb35–4–2.

Fig. 7 *Favoporella hexagona* gen. et sp. nov.
Holotype; Longitudinal section; × 48. Section no.: xb27–8–4.

Fig. 8 *Vermiporella* cf. *nipponica* Endo, 1954
Longitudinal section; × 48. Section no.: xb35–1–3.

Plate 22

Fig. 1 *Permocalculus* cf. *fragilis* (Pia) Elliott, 1955
Oblique section; × 48. Section no.: xb35–4–2.

Fig. 2 *Gyroporella* sp.
Transversal section; × 48. Section no.: xb35–4–2B.

Fig. 3, 9 *Monostysisyrinx circularis* gen. et sp. nov.
3: Longitudinal section, with encrustation of *Archaeolithoporella*; × 48. Section no.: xb35–2.
9: Holotype; Transversal section; thallus tube wall seen; × 120. Section no.: xb35–2.

Fig. 4 *Paralithoporella sinensis* gen. et sp. nov.
Holotype; Vertical section, boundary between cells seen; × 48. Section no.: xb30–5–6.

Fig. 5 *Macroporella affinis* Endo, 1969
Transversal section; × 48. Section no.: xb31–2–1.

Fig. 6 *Favoporella hexagona* gen. et sp. nov.
Holotype; Tangential section; × 120. Section no.: xb27–8–4.

Fig. 7 *Sphaeroporella minima* gen. et sp. nov.
Holotype; Radial section; Attaching to *Monostysisyrinx circularis*; × 120. Section no.: xb35–2–1.

Fig. 8 *Mizzia* sp.
Transversal section; × 48. Section no.: xb30–2–4.

Plate 23

Fig. 1, 3 *Porivallia phaseoliformis* gen. et sp. nov.
1: Holotype; Longitudinal section; × 40. Section no.: xb28–3–2.
3: Paratype; Longitudinal section; × 40. Section no.: xb28–3–3.

Fig. 2 *Lamellivallia grossa* gen. et sp. nov.

Holotype; Longitudinal section; × 40. Section no.: xb30–3–2.

Fig. 4 *Porivallia sphaerica* gen. et sp. nov.

Holotype; Vertical section; × 40. Section no.: xb30–2–10.

Fig. 5 *Echinivesica robusta* gen. et sp. nov.

Paratype; Vertical section; × 40. Section no.: xb27–2–2.

Plate 24

Fig. 1 *Lamellivallia grossa* gen. et sp. nov.

Paratype; Longitudinal section; × 40. Section no.: xb30–2–3.

Fig. 2 *Polyvesica irregularis* gen. et sp. nov.

Holotype; Vertical section; × 40. Section no.: xb34–8–3.

Fig. 3 *Heterolamellia appressa* gen. et sp. nov.

Holotype; Vertical section; × 100. Section no.: xb30–5–1A.

Fig. 4 *Echinivesica robusta* gen. et sp. nov.

Paratype; Radial section; × 40. Section no.: xb35–8–7.

Fig. 5 *Echinivesica incondita* gen. et sp. nov.

Holotype; Radial section; × 40. Section no.: xb30–2–10A.

Plate 25

Fig. 1 *Heterolamellia appressa* gen. et sp. nov.

Paratype; Vertical section; × 40. Section no.: xb30–5–1B.

Fig. 2 *Micritivesica granosa* gen. et sp. nov.

Holotype; Vertical section; × 40. Section no.: xb37–2–12.

Fig. 3 *Echinivesica robusta* gen. et sp. nov.

Holotype; Radial section; × 40. Section no.: xb28–R6.

Fig. 4 *Polyechinivesica regularis* gen. et sp. nov.

Holotype; Vertical section; × 40. Section no.: xb30–7–7.

Fig. 5 *Echinivesica incondita* gen. et sp. nov.

Paratype; Radial section; × 40. Section no.: xb30–2–10B.

Plate 26

Fig. 1 *Tubiphytes tubularis* sp. nov.

Holotype; Transversal section and oblique section of branches; × 40. Section no.: xb28–4–2.

Fig. 2, 3 *Tubiphytes polyvesica* sp. nov.

2: Holotype; Longitudinal section; × 40. Section no.: xb31–2–3.

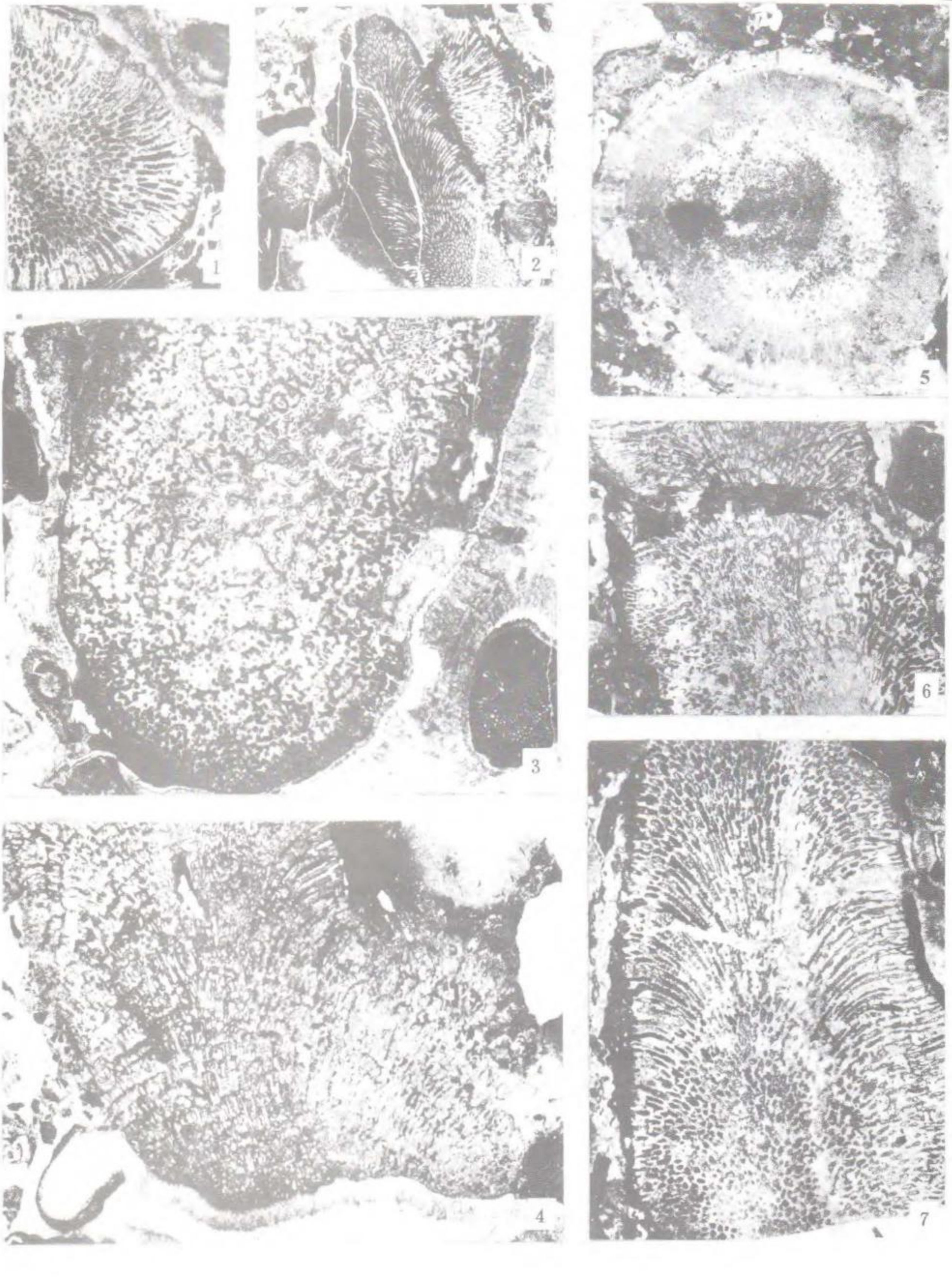
3: Paratype; Longitudinal section; × 40. Section no.: xb31–2–3.

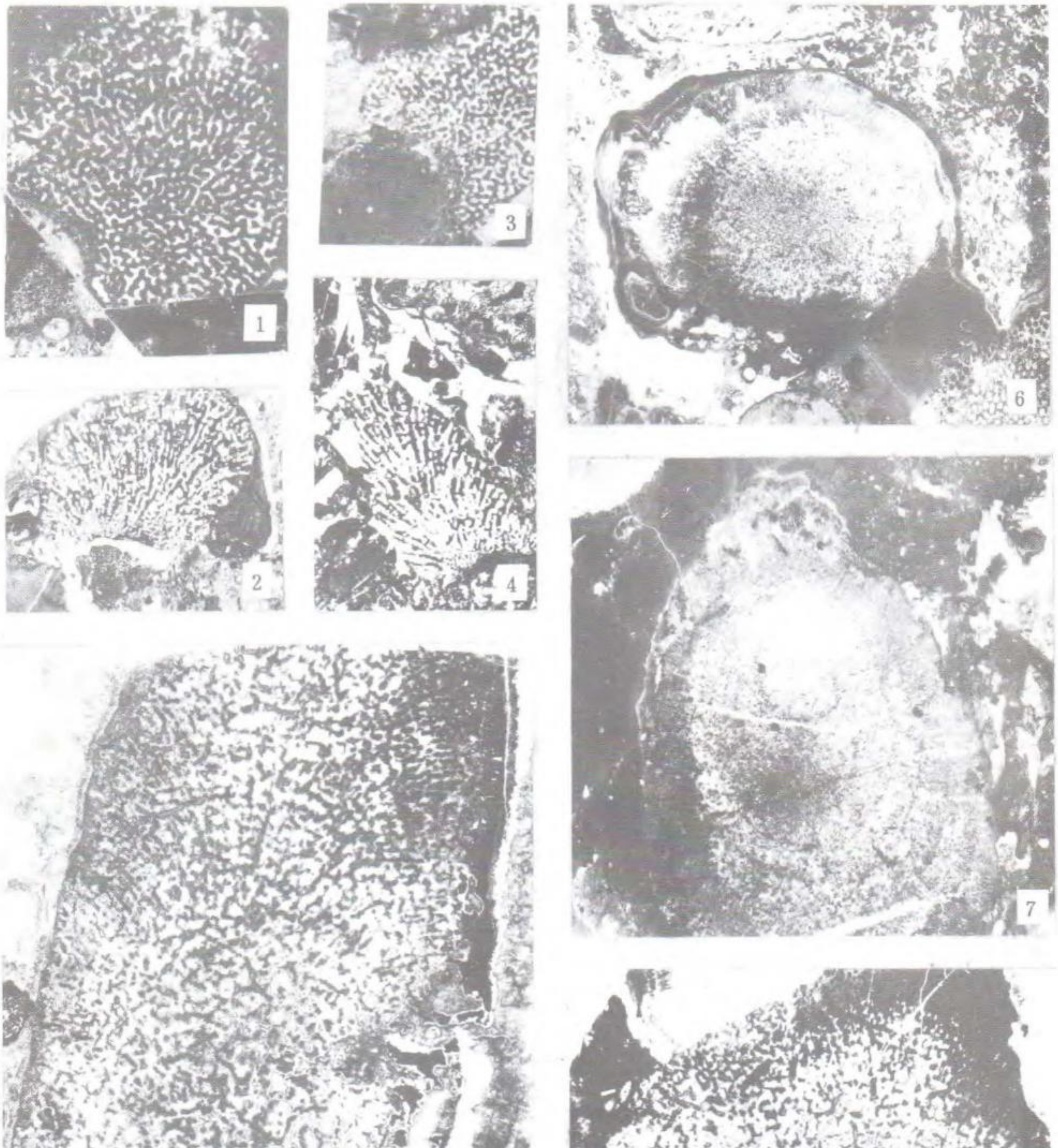
Fig. 4 *Tubiphytes obscurus* Maslov, 1956

Longitudinal section; × 40. Section no.: xb30–8–11.

Fig. 5 *Tubiphytes spinalis* sp. nov.

Holotype; Longitudinal section; × 40. Section no.: xb35–7–5.

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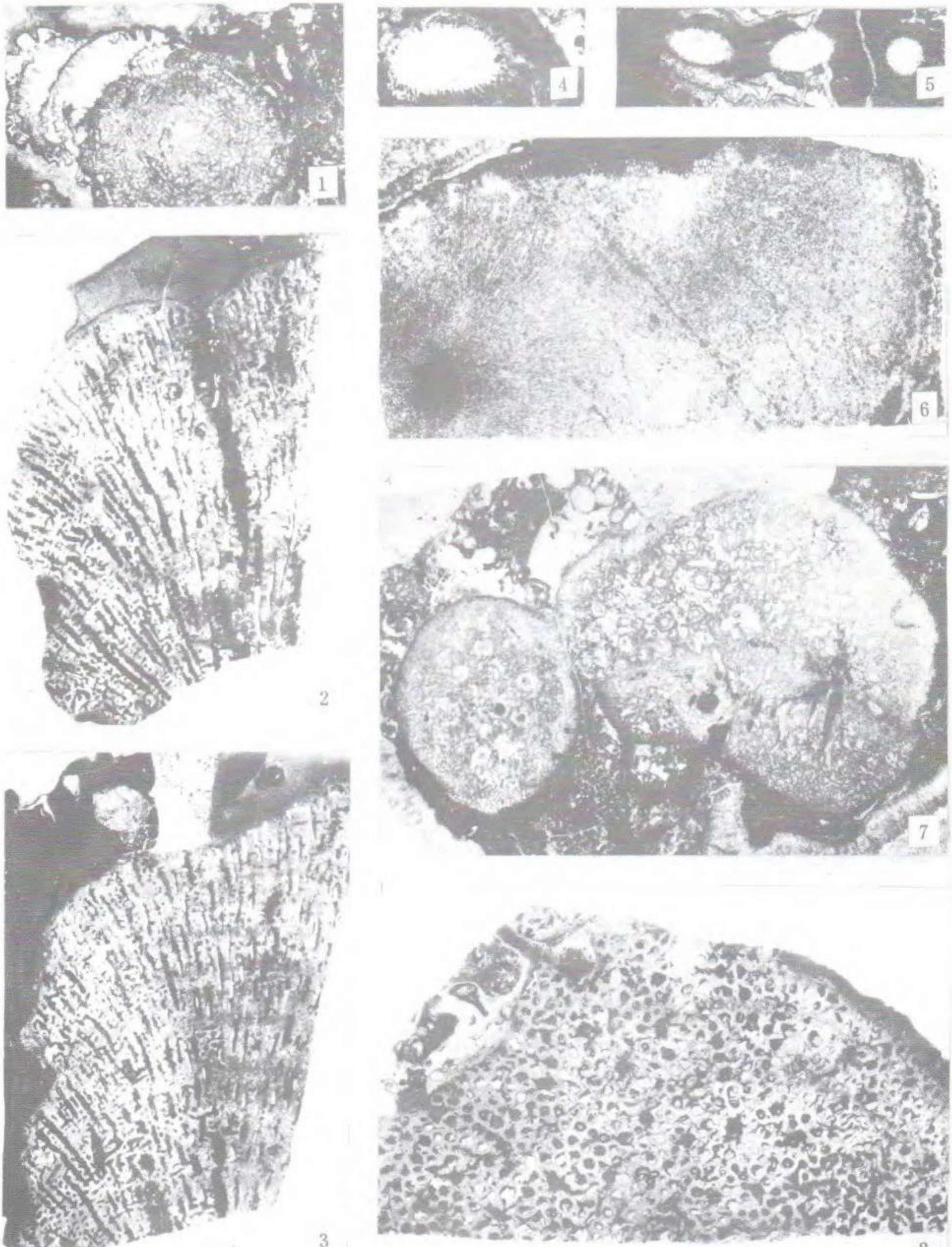
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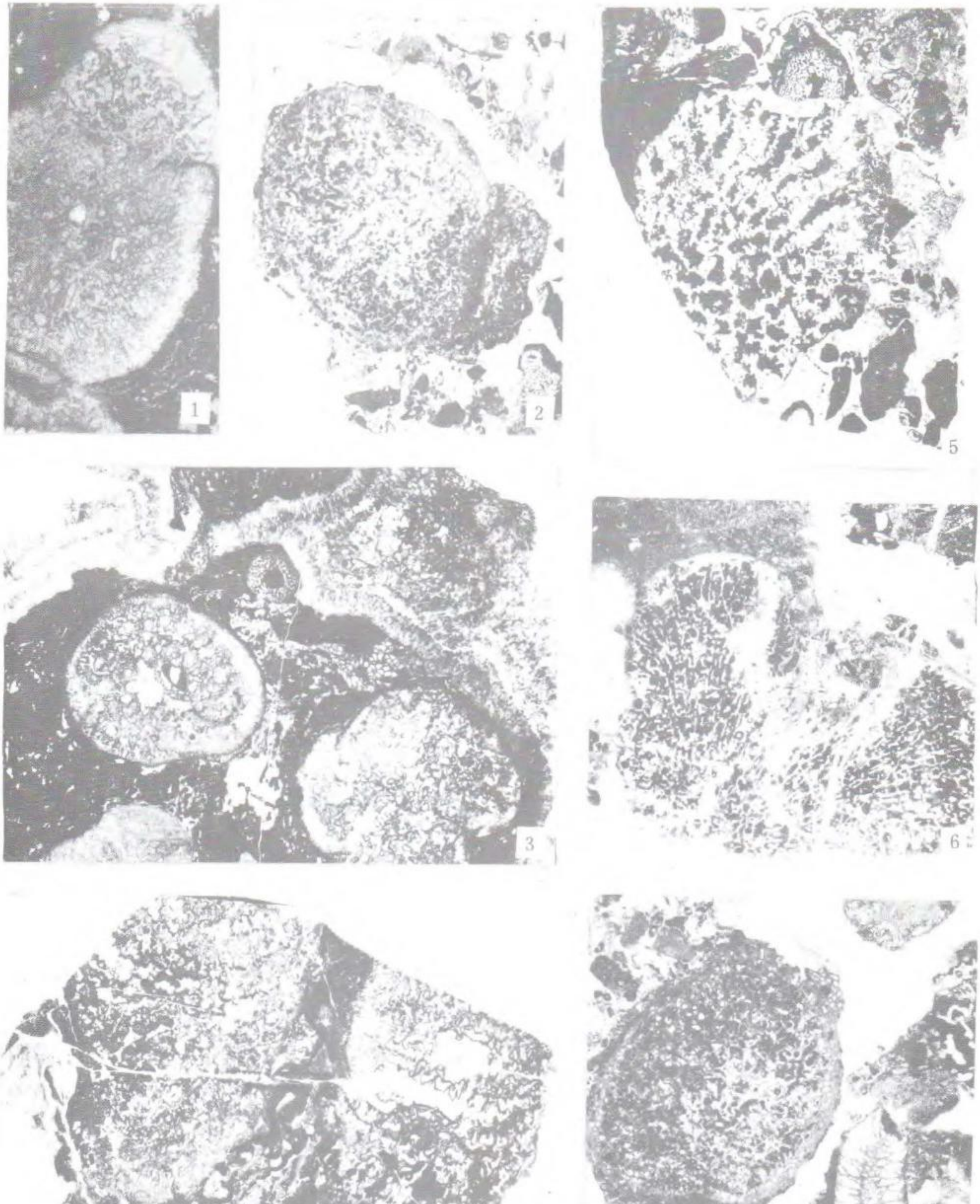
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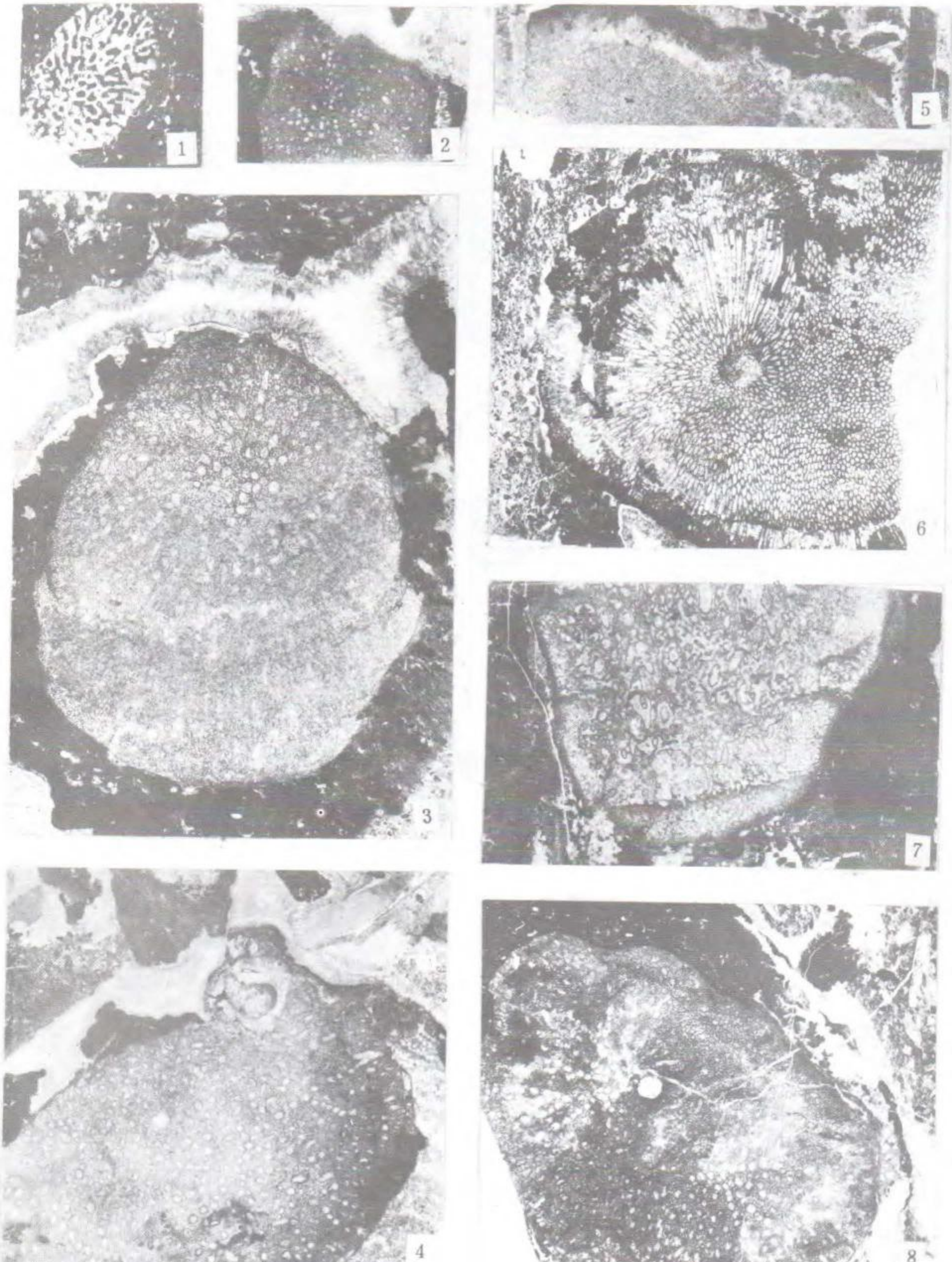
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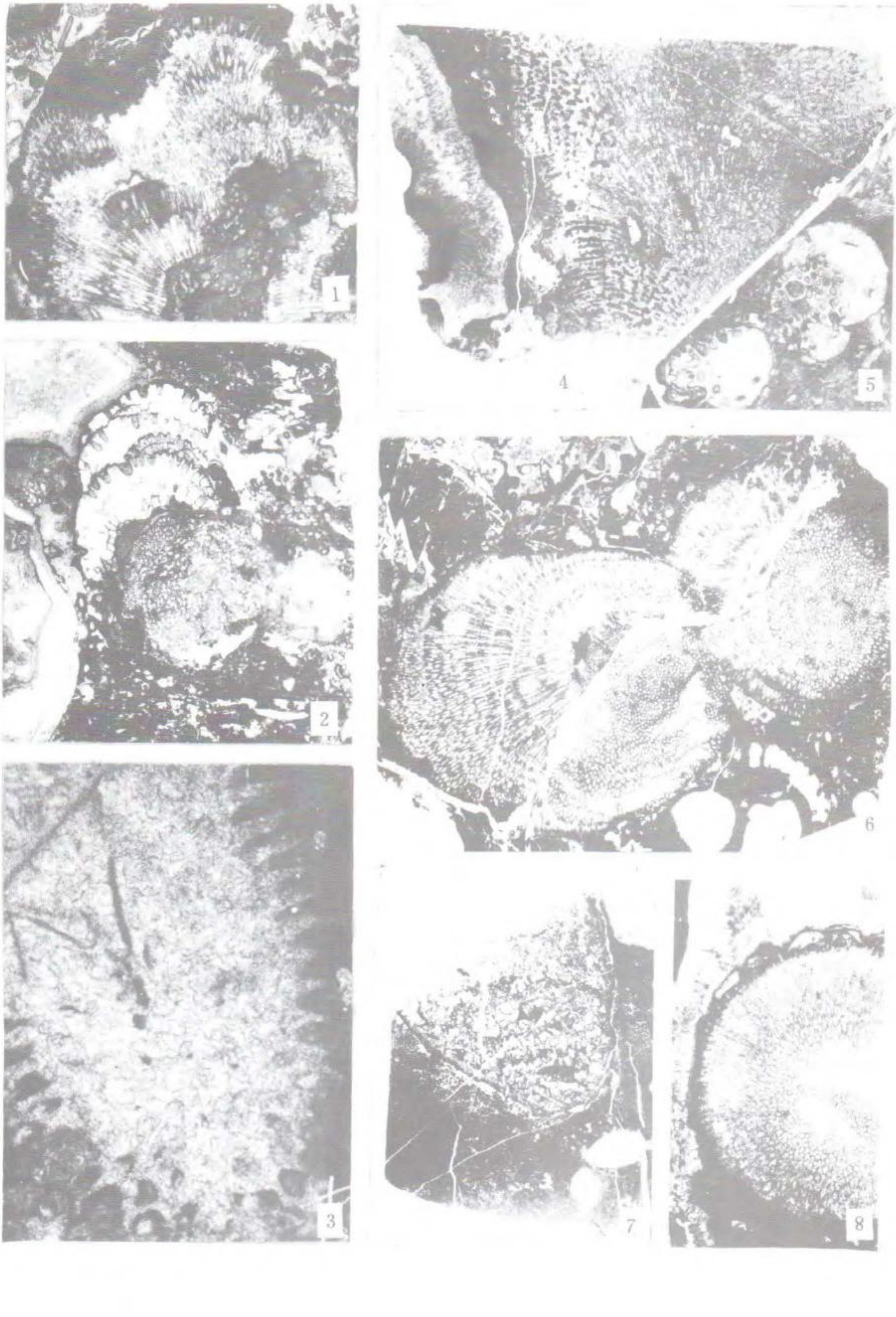
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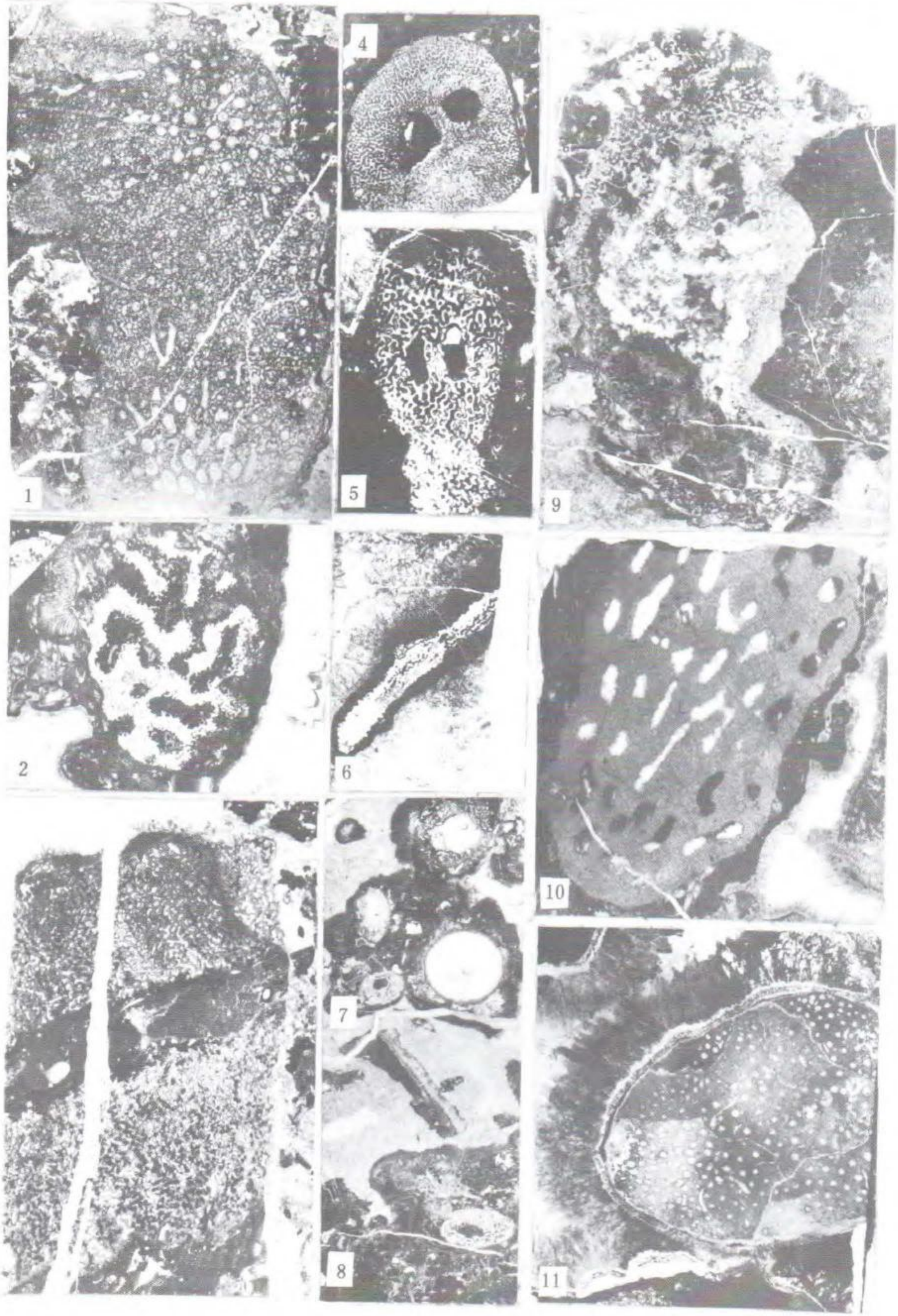
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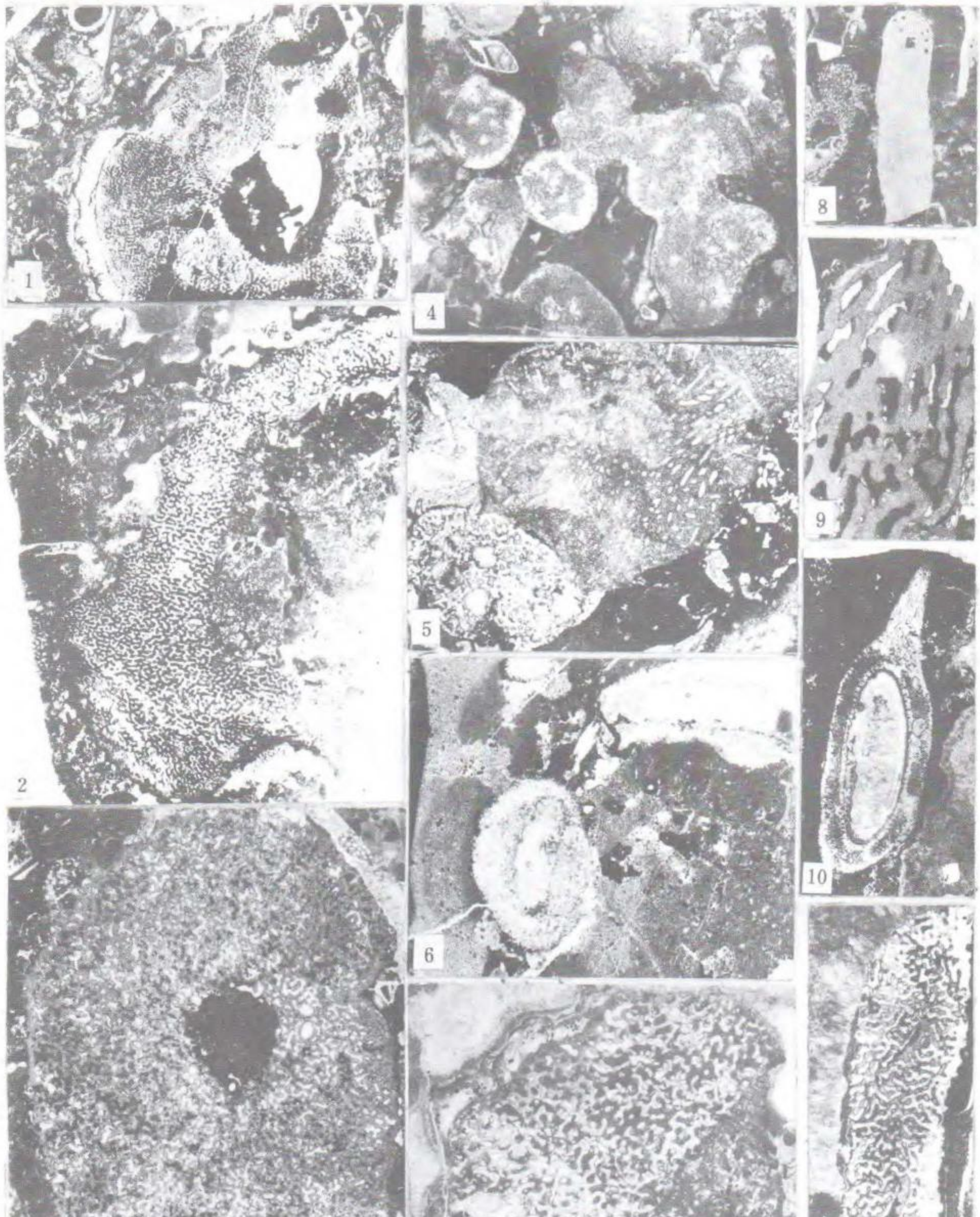
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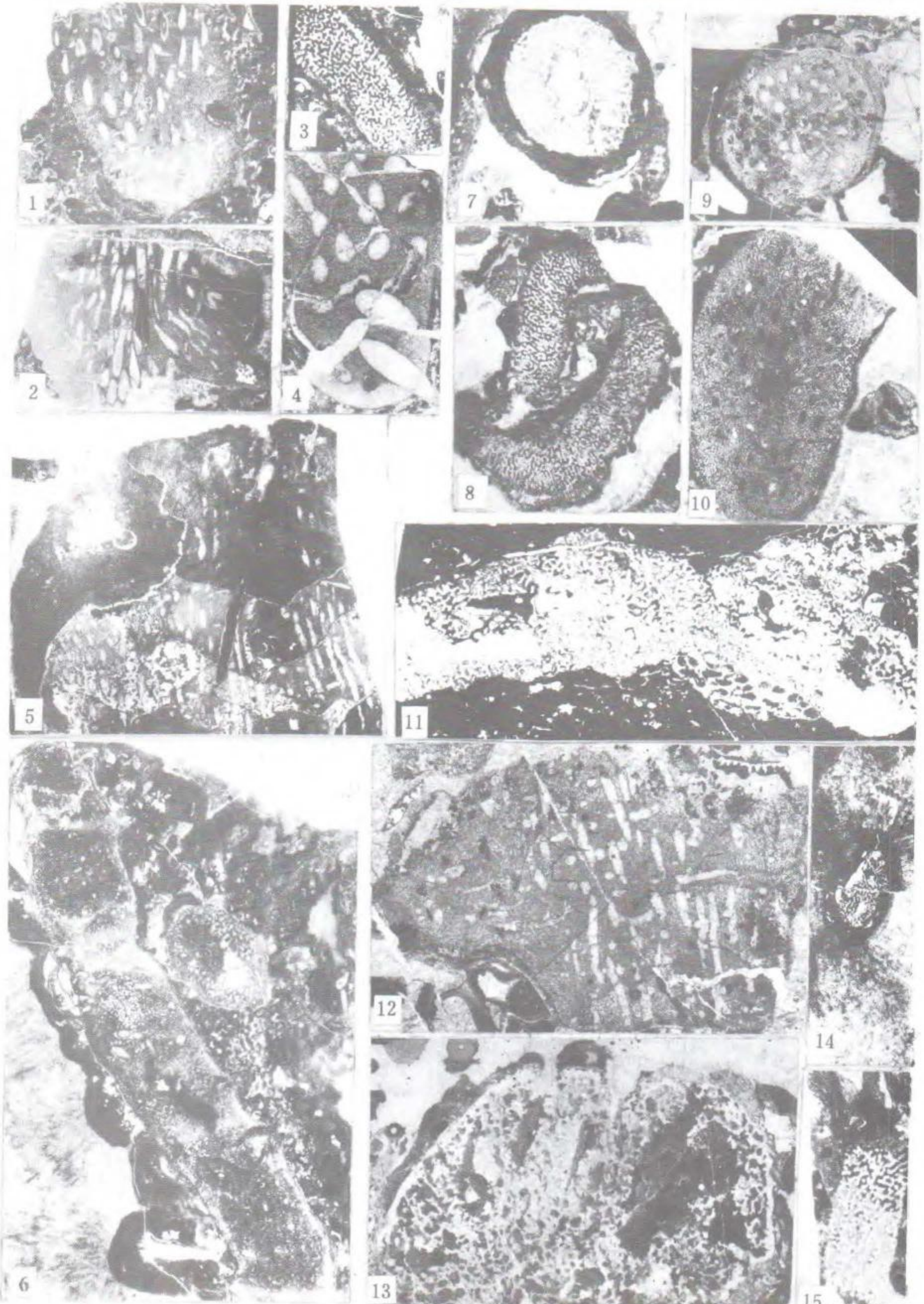
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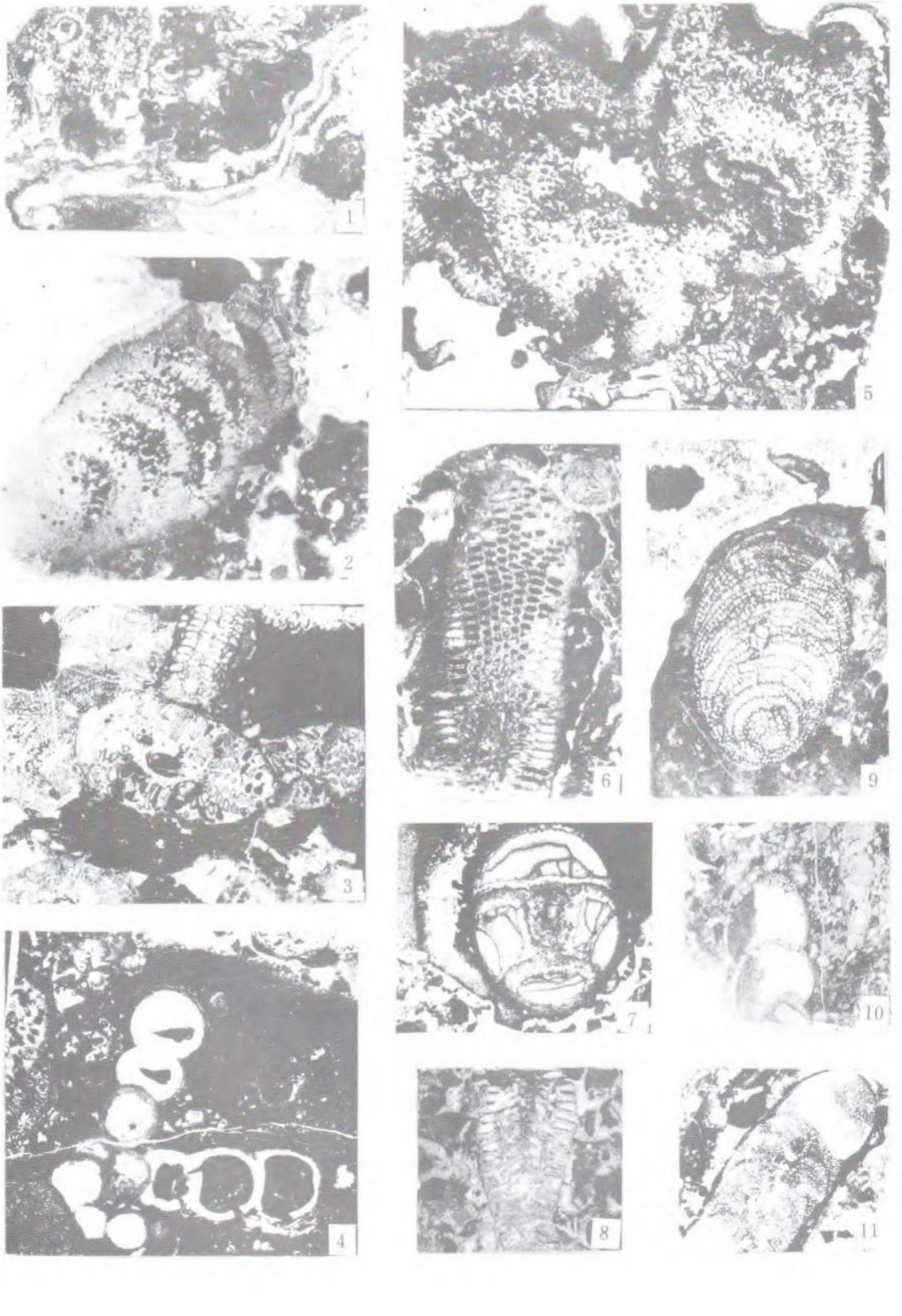
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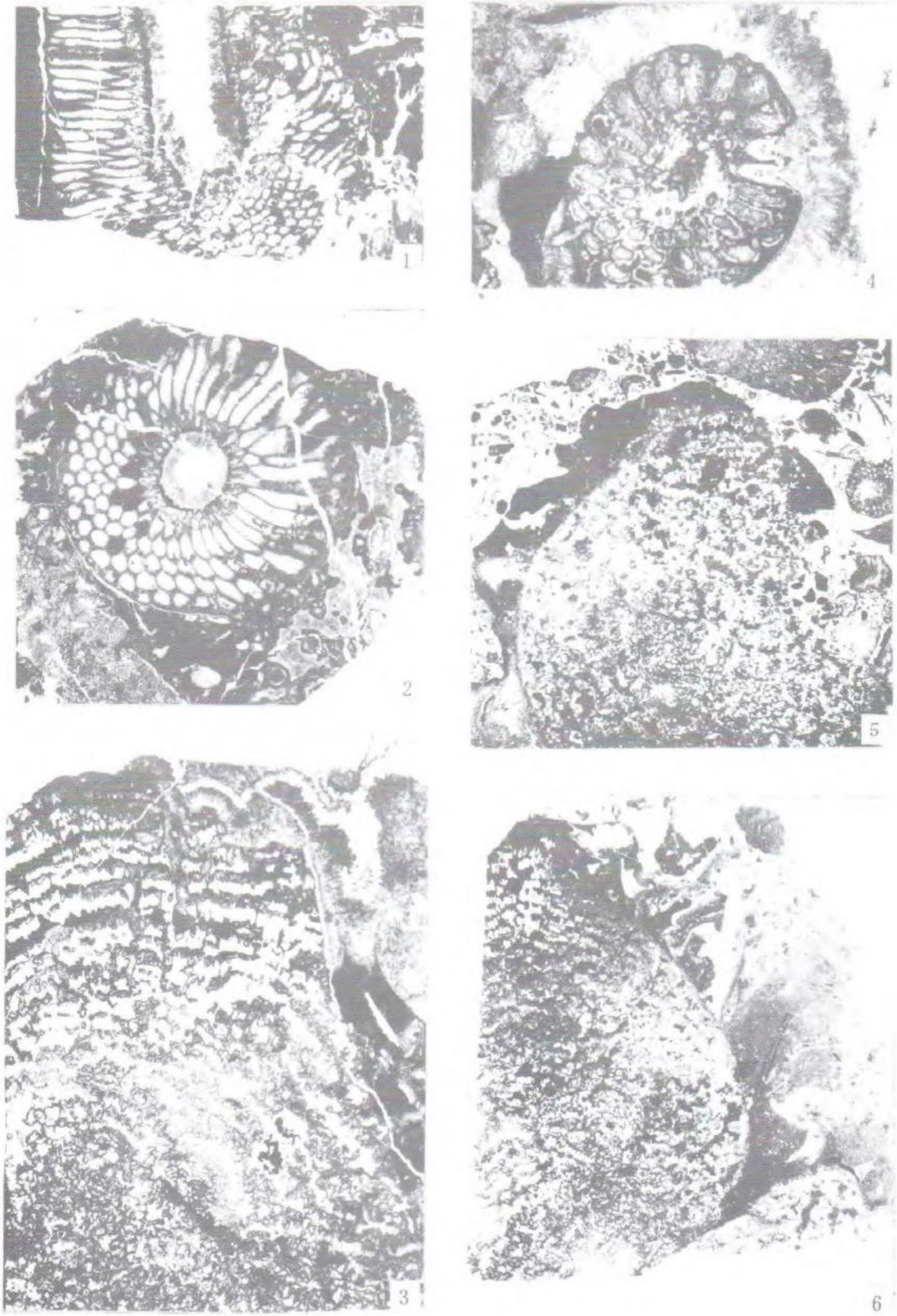

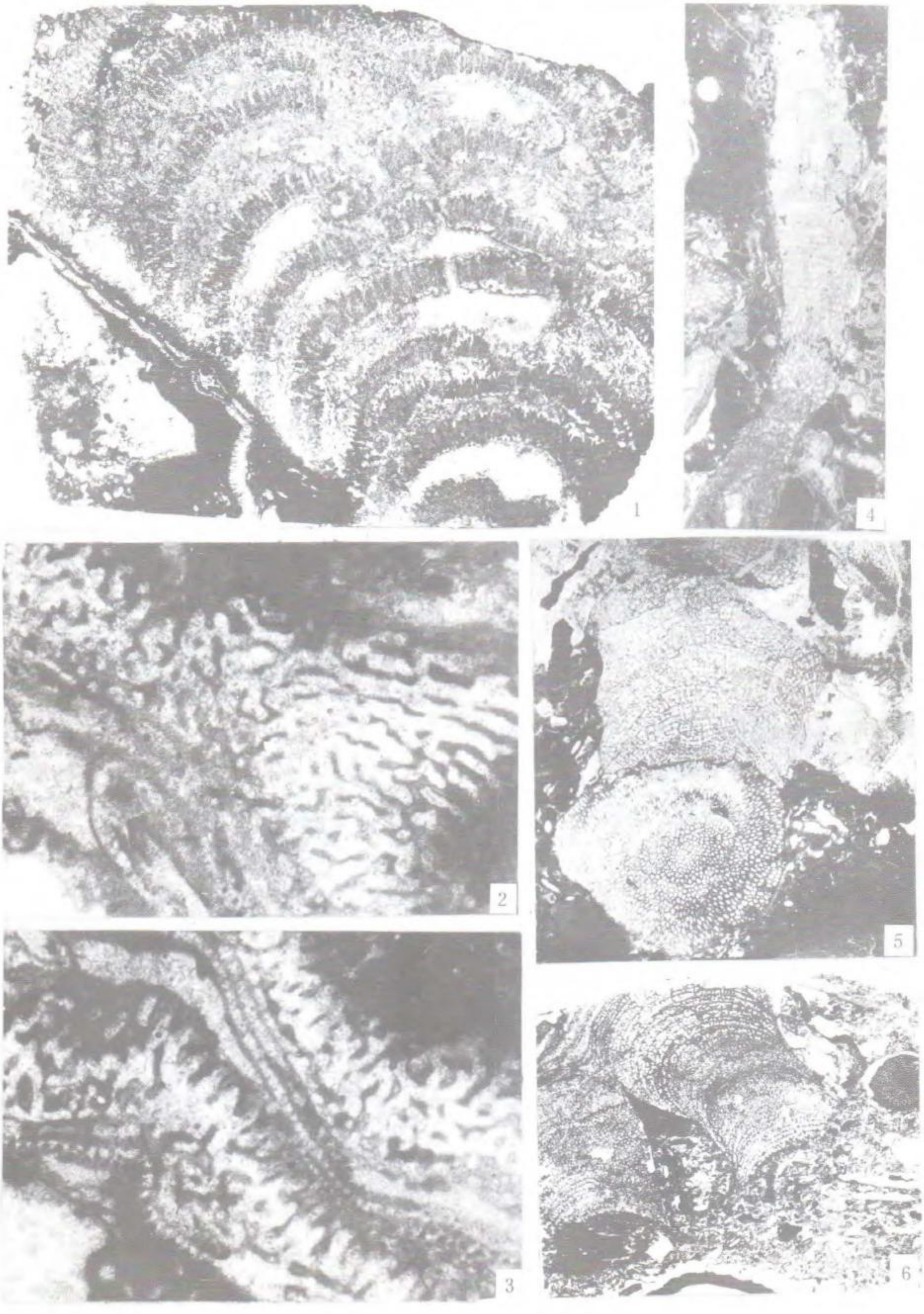
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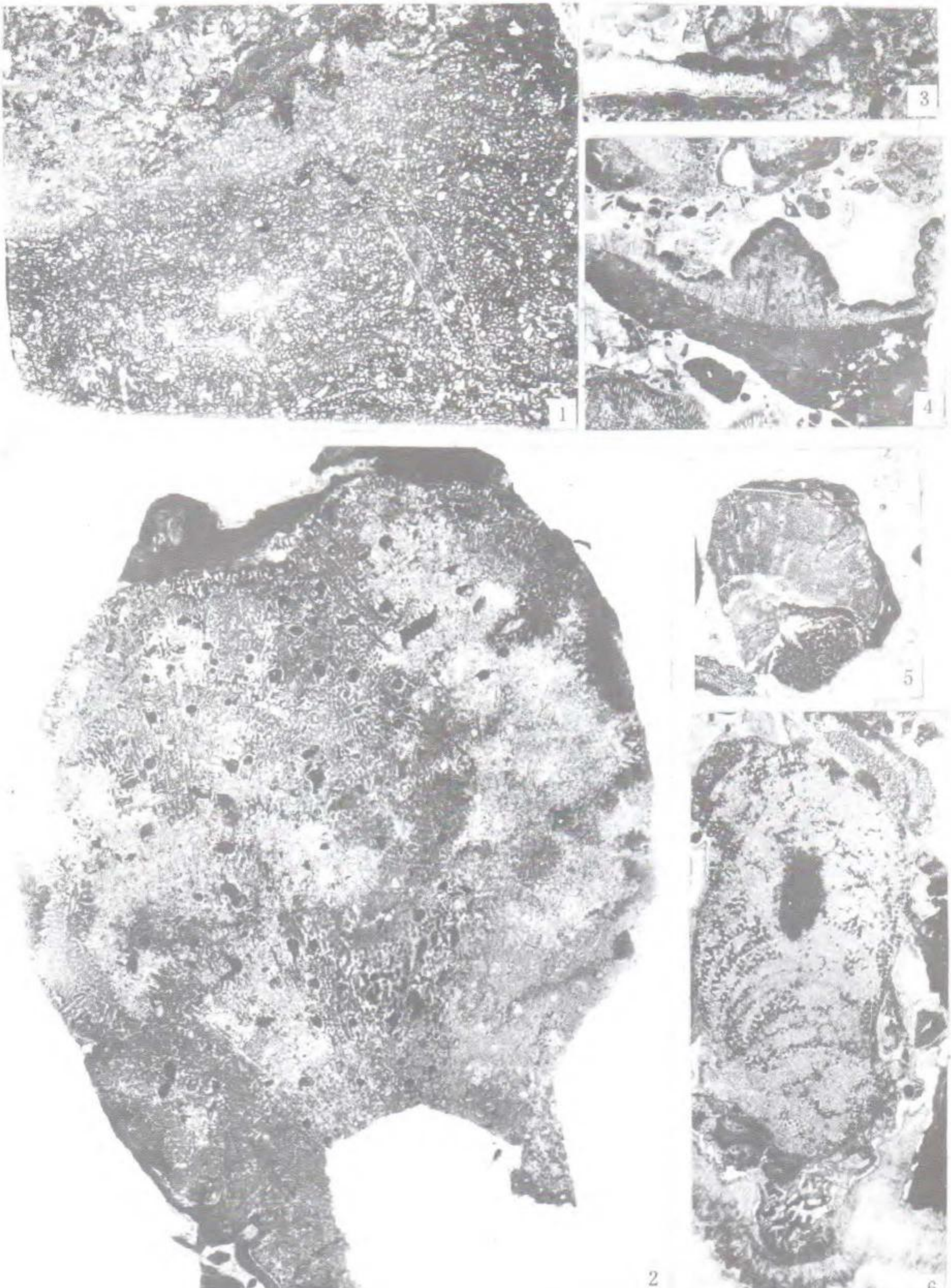
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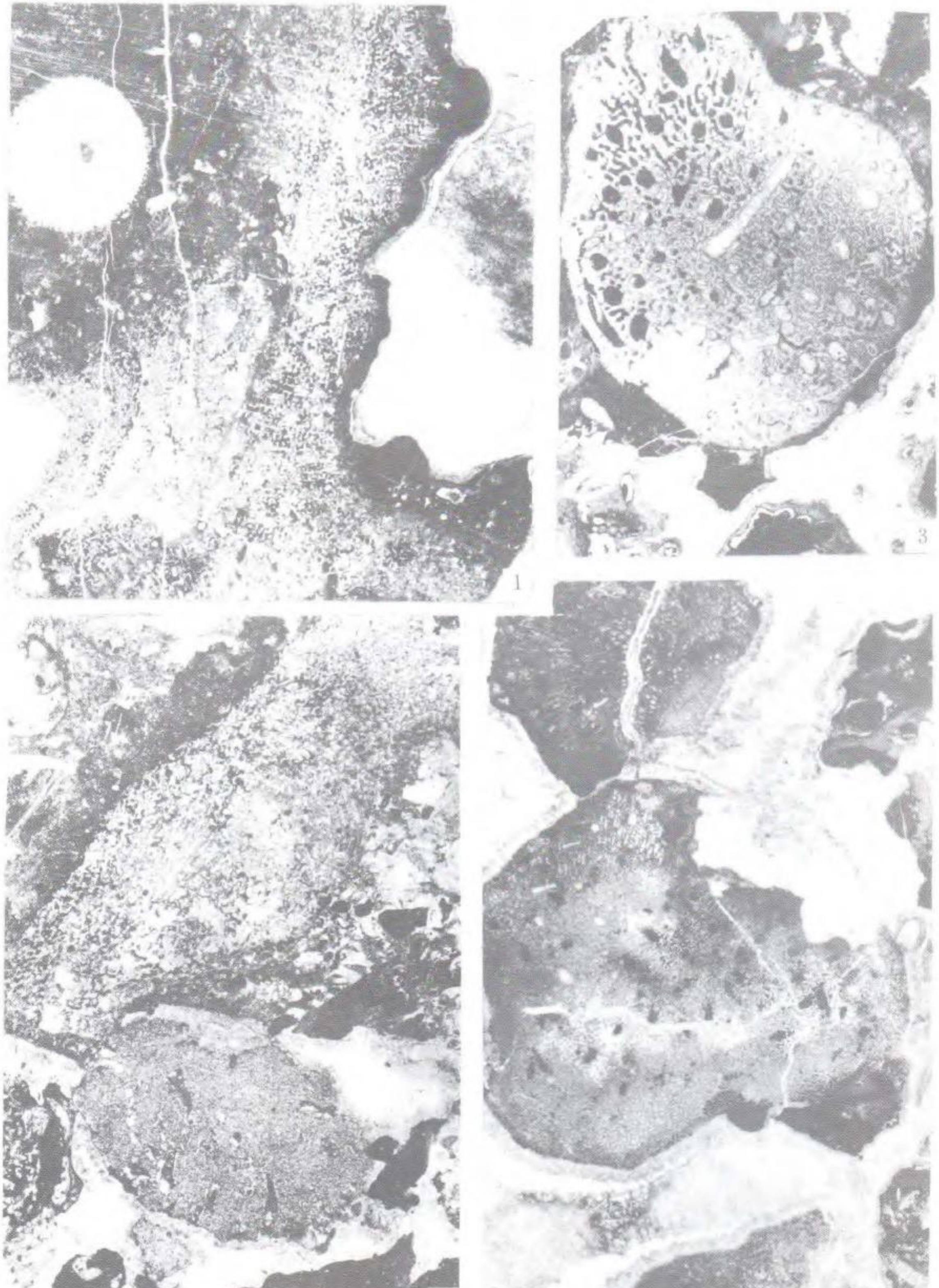

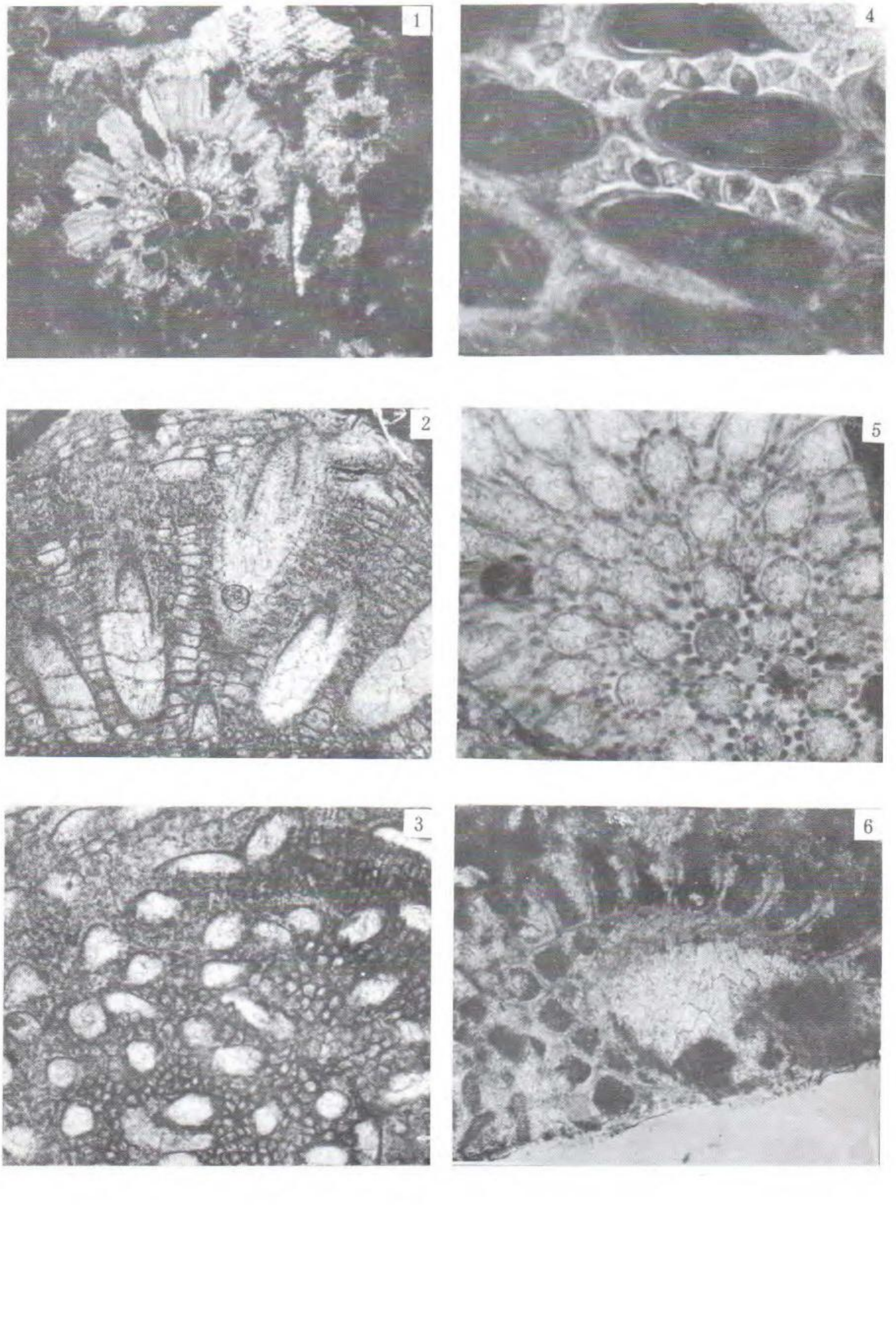
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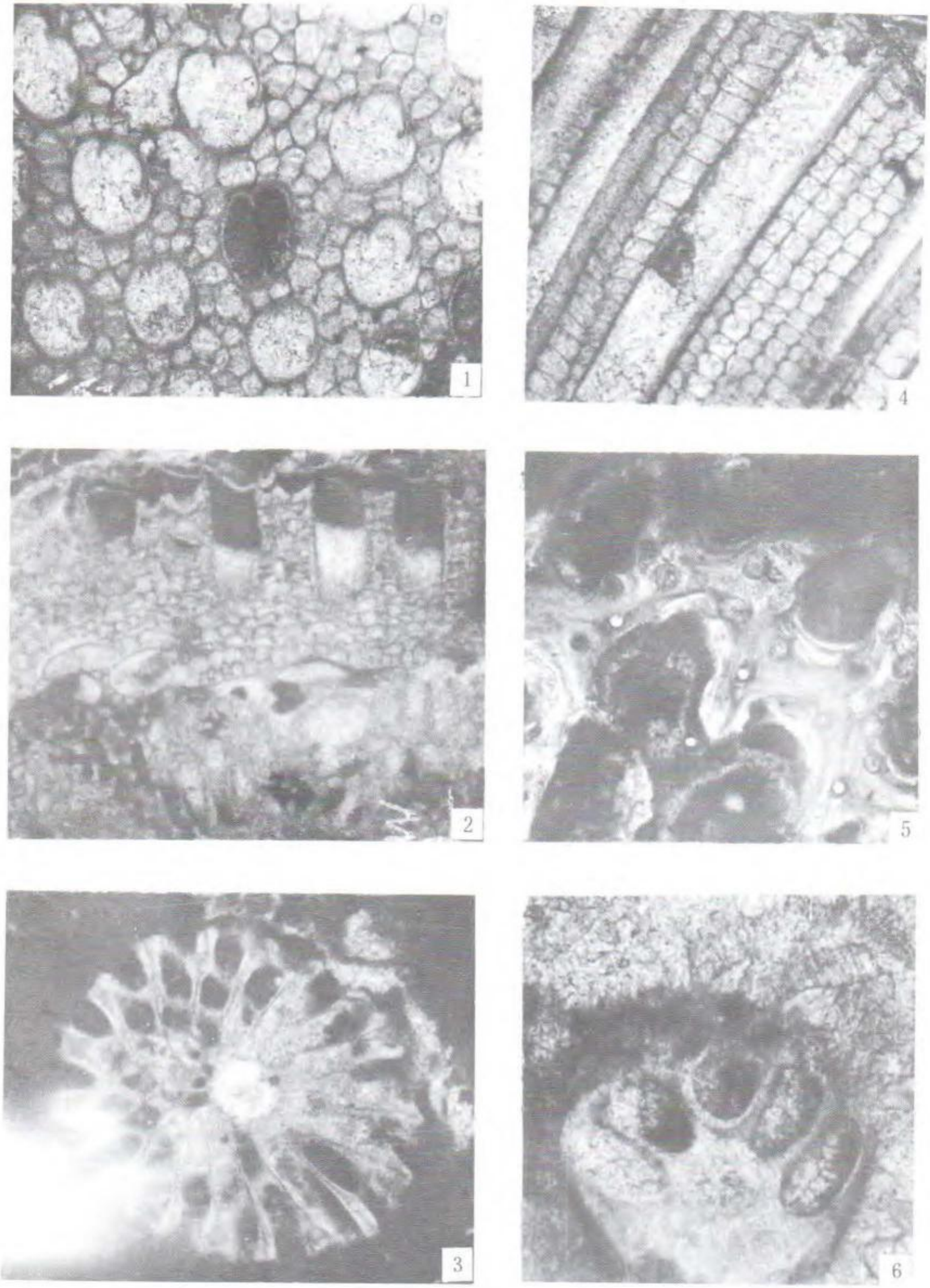
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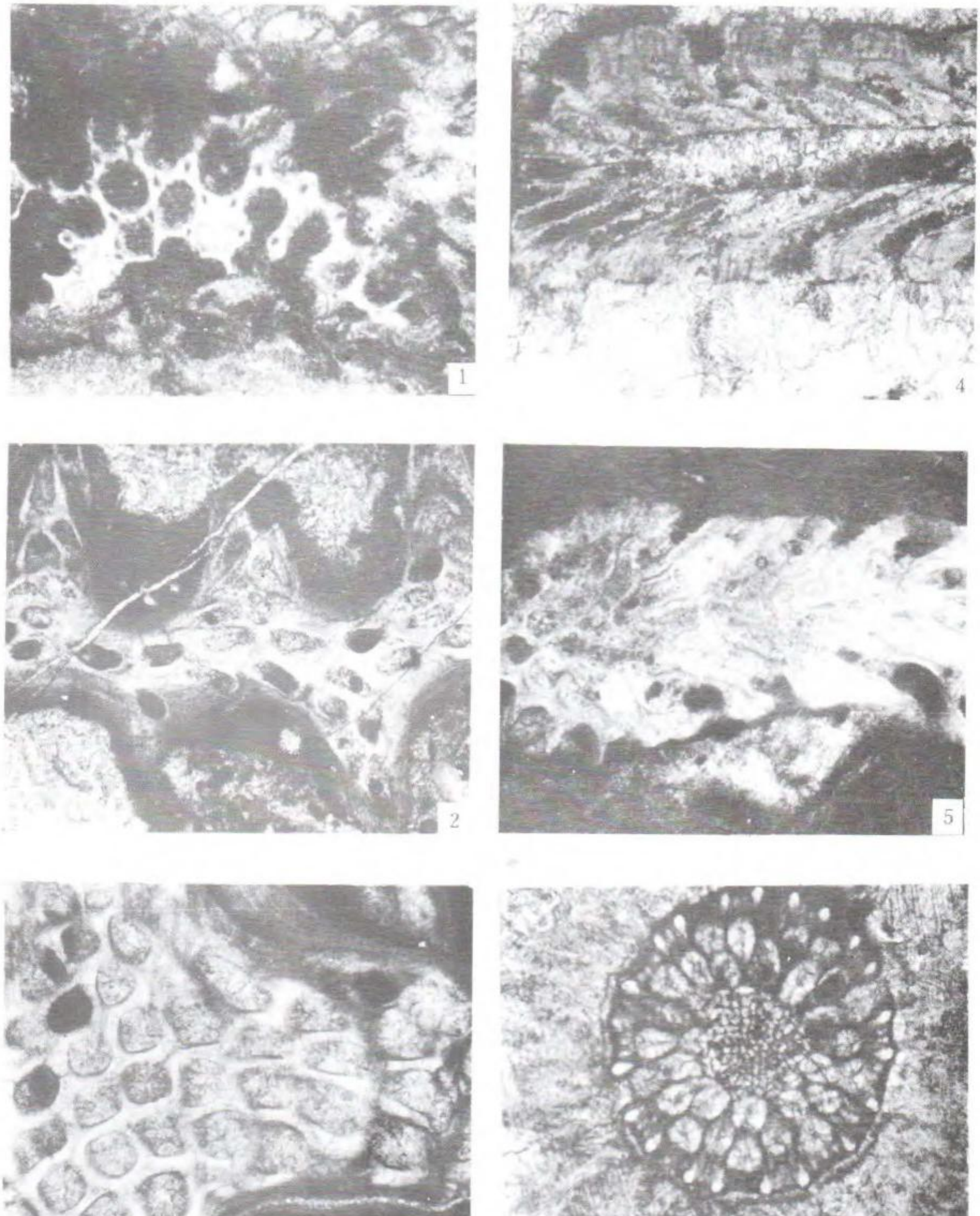
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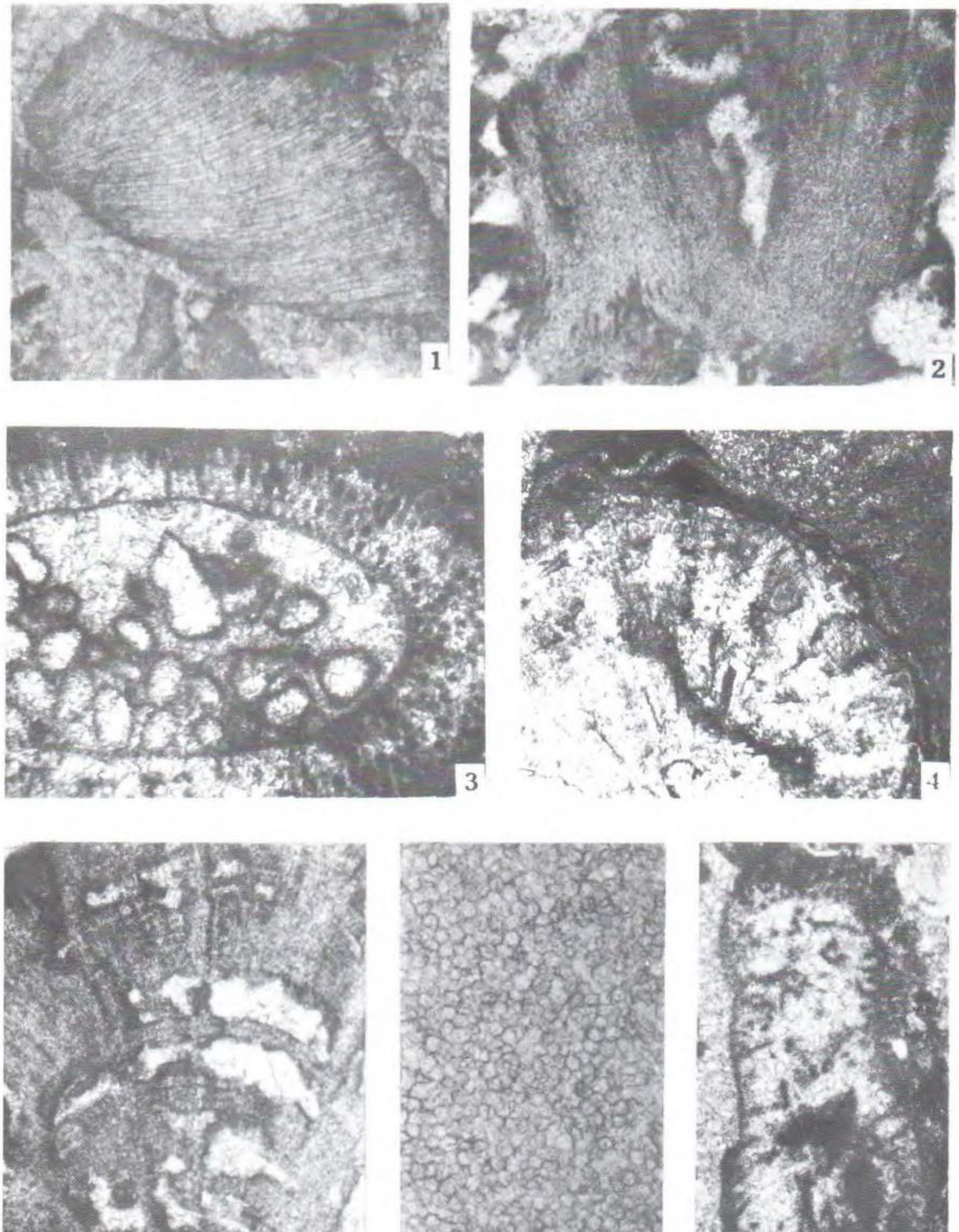
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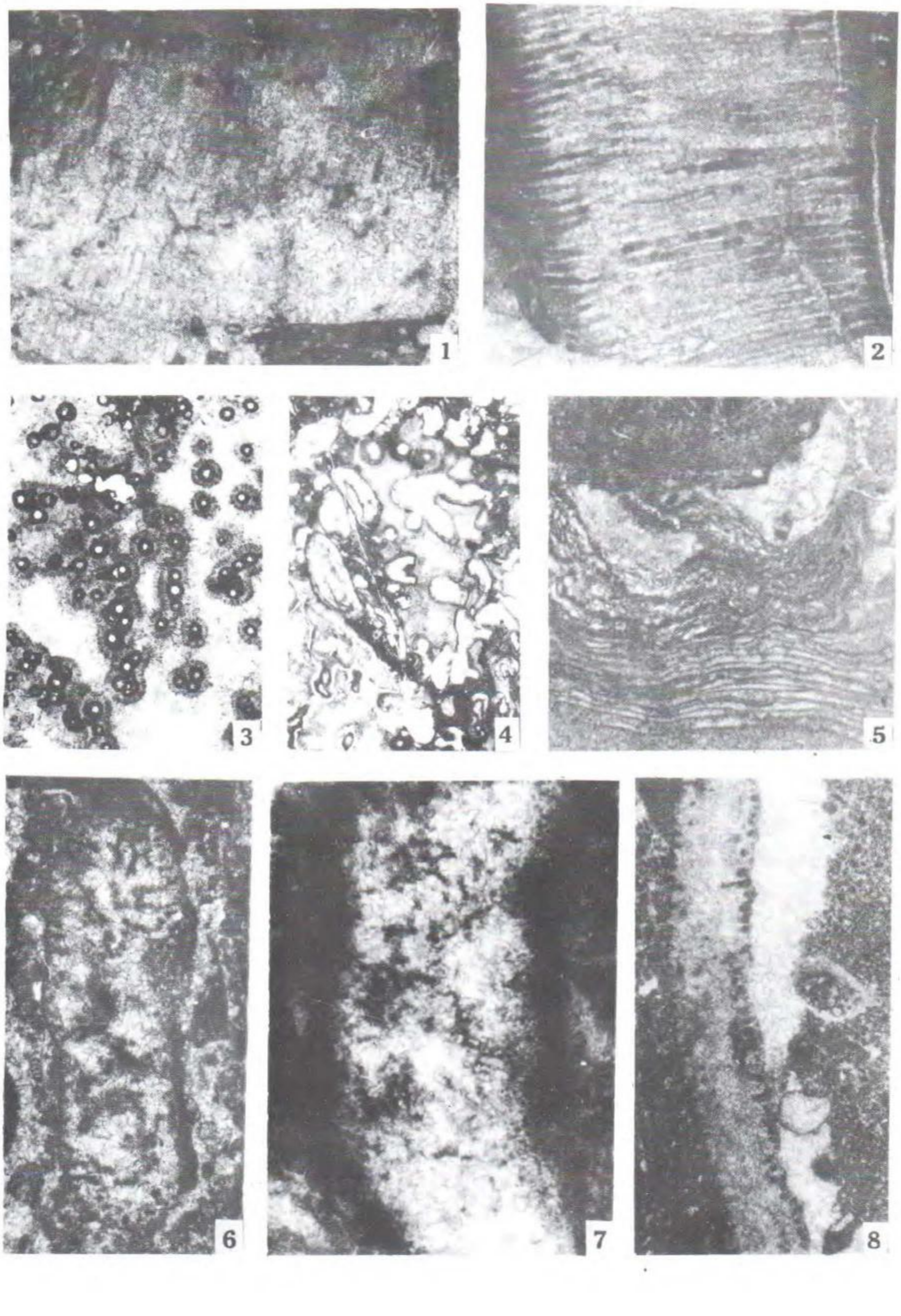
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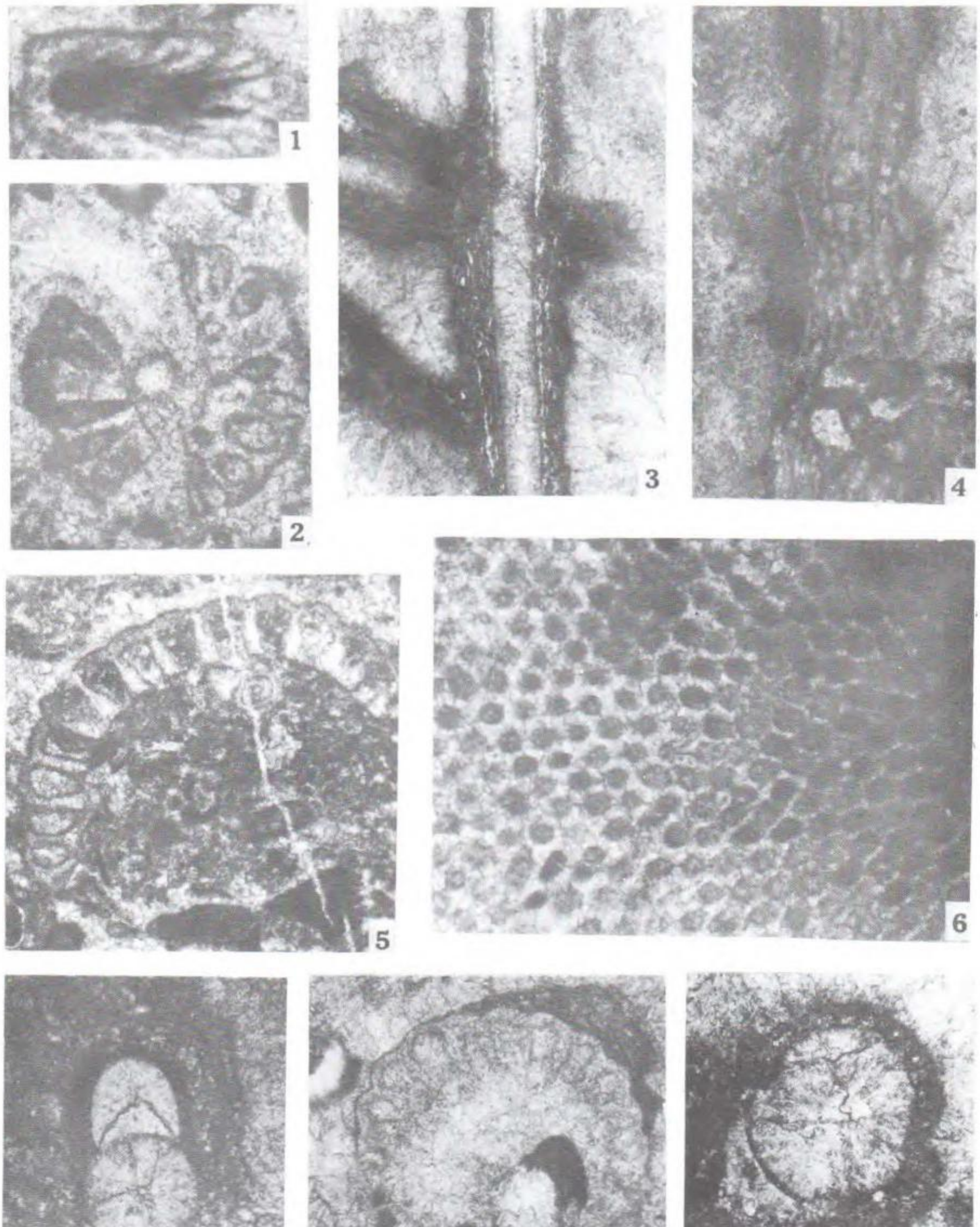

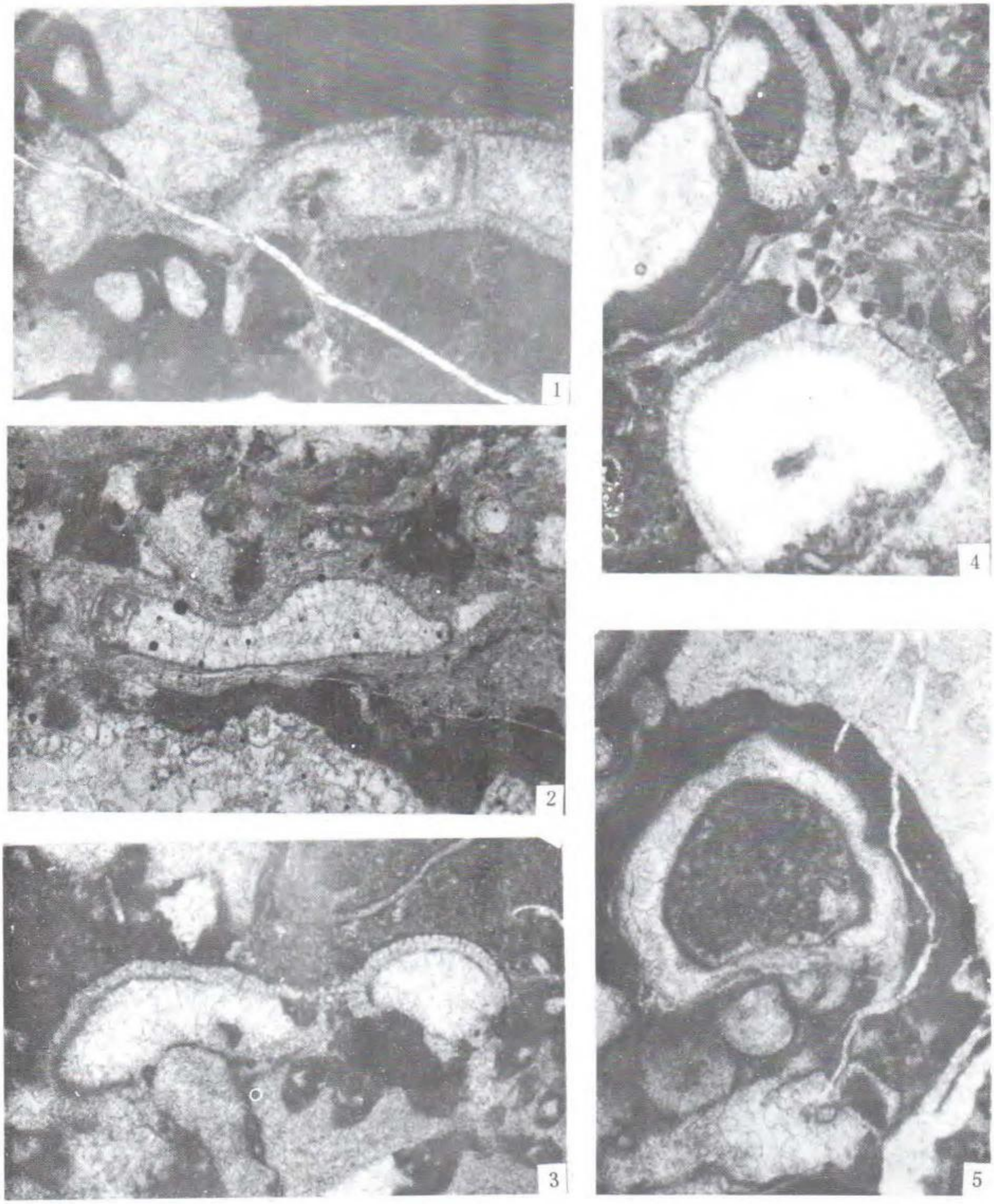

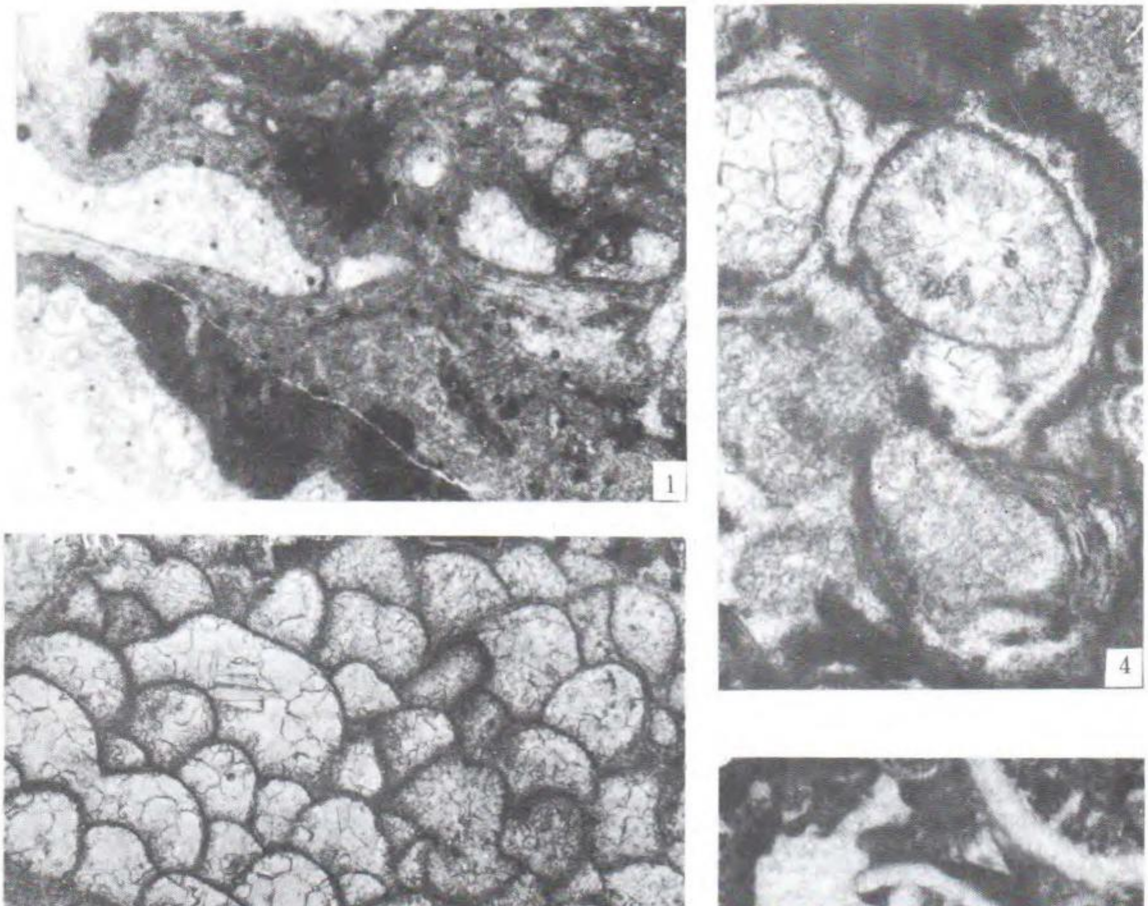
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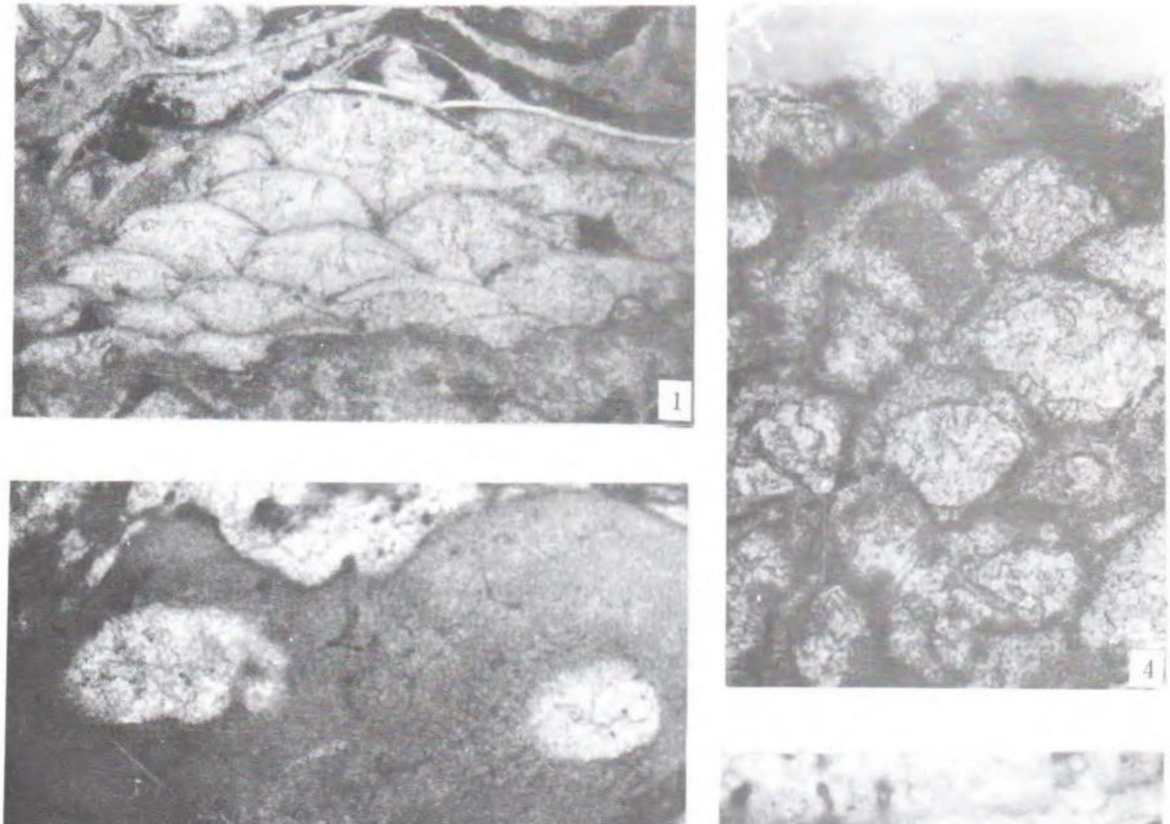

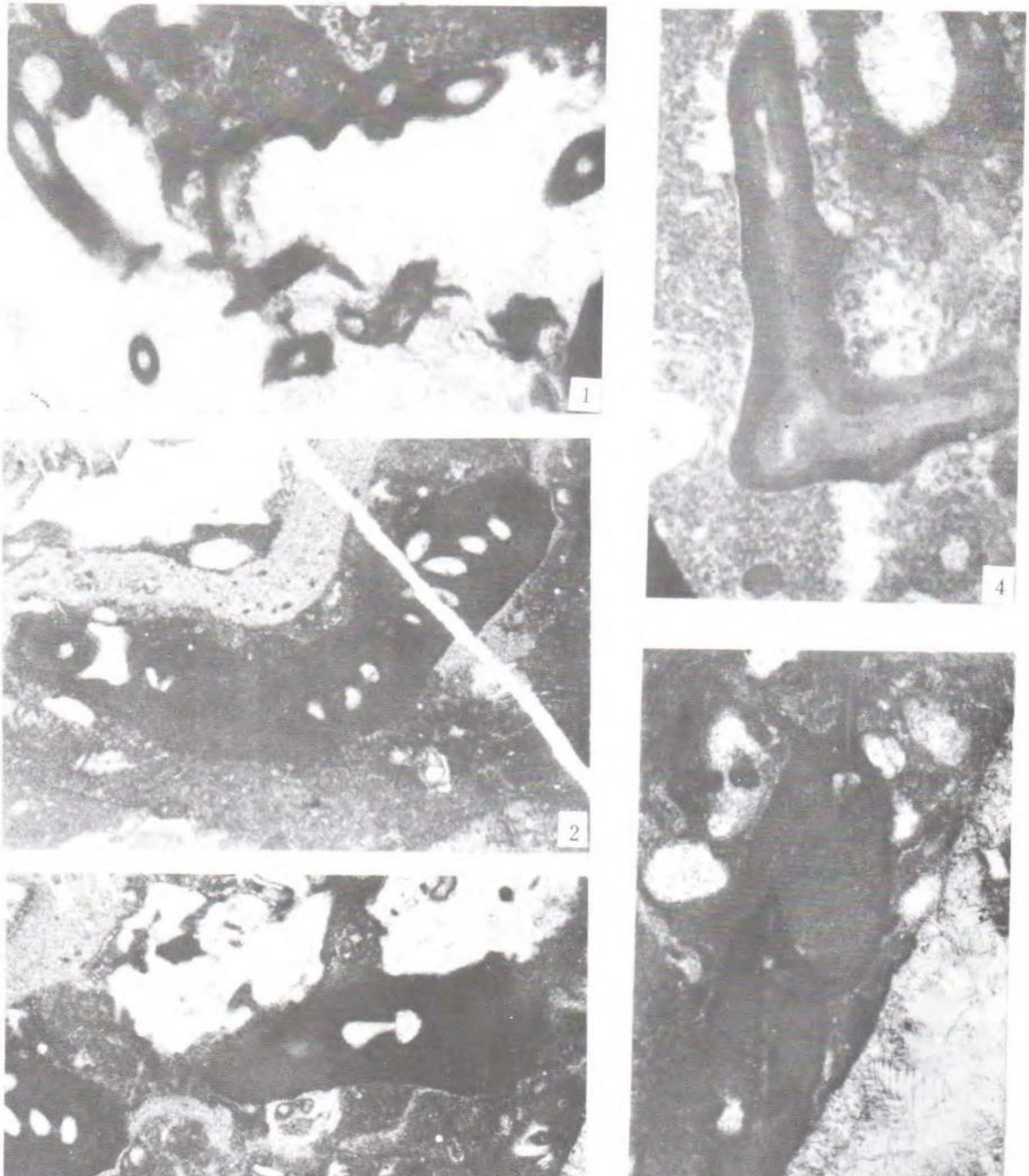
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