1994

Taxonomy and paleobiogeography of permian massive thysanophyllinae

Robert LaChappelle
San Jose State University

Follow this and additional works at: https://scholarworks.sjsu.edu/etd_theses

---

Recommended Citation

LaChappelle, Robert, "Taxonomy and paleobiogeography of permian massive thysanophyllinae" (1994).
Master's Theses. 771.

DOI: <https://doi.org/10.31979/etd.ah49-m9s2>
https://scholarworks.sjsu.edu/etd_theses/771

This Thesis is brought to you for free and open access by the Master's Theses and Graduate Research at SJSU ScholarWorks. It has been accepted for inclusion in Master's Theses by an authorized administrator of SJSU ScholarWorks. For more information, please contact scholarworks@sjsu.edu.

INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

University Microfilms International
A Bell & Howell Information Company
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA
313/761-4700 800/521-0600

Order Number 1358195

**Taxonomy and paleobiogeography of Permian massive
Thysanophyllinae**

LaChappelle, Robert, Jr., M.S.

San Jose State University, 1994

U·M·I

300 N. Zeeb Rd.
Ann Arbor, MI 48106

TAXONOMY AND PALEOBIOGEOGRAPHY
OF PERMIAN MASSIVE THYSANOPHYLLINAE

A Thesis
Presented to
The Faculty of the Department of Geology
San Jose State University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Robert LaChappelle, Jr.

May, 1994

c. 1994

Robert LaChappelle, Jr.

ALL RIGHTS RESERVED

APPROVED FOR THE DEPARTMENT
OF GEOLOGY

Calvin H. Stevens
Dr. Calvin H. Stevens

Ellen Metzger
Dr. Ellen Metzger

Lisa White
Dr. Lisa White

APPROVED FOR THE UNIVERSITY

M. Lou Lewandowski

ACKNOWLEDGMENTS

I would like to thank Dr. Calvin H. Stevens for suggesting this topic and for providing invaluable guidance and supplying materials for study. My appreciation also goes to Drs. Ellen Metzger and Lisa White for their participation on my committee. I would like to thank my friends at San Francisco State University namely Edgardo Bago, Gustavo Estrella and Steve Yata and my friends at San Jose State University namely Jennifer Nelson-Lee and Marc Mullaney for their support. My thanks also goes to the folks at Colonial Bancorp namely Debbie Markantes, Debbi, Sherrie, Dayna, Lynn, Lynette, Cheryl, Susan, Lori, Trish, Mer, Felipa, Joyce, Berry Catterton and George Mahon. Last but not least my thanks goes to my mummy Shimako I. LaChappelle whose support I cherish the most and to Mr. Animal.

TABLE OF CONTENTS

	Page
ABSTRACT.....	vii
INTRODUCTION.....	1
Age and Occurrence.....	2
Previous Work.....	2
Methods.....	4
CLASSIFICATION OF THE THYSANOPHYLLINAE.....	8
Statistical Comparisons.....	9
Visual Comparisons.....	13
THE SUBFAMILY THYSANOPHYLLINAE.....	14
Generic Assignment within the Thysanophyllinae...	15
Overview of Problem.....	15
Solution.....	18
Massive Genera Assigned to the Thysanophyllinae..	28
Genus <u>Thysanophyllum</u>	29
Genus <u>Protowentzelella</u>	31
Genus <u>Stylastraea</u>	33
Genus <u>Sciophyllum</u>	34
New Genus A.....	35
PALEOBIOGEOGRAPHY.....	35
CONCLUSION.....	40
REFERENCES.....	41
SYSTEMATIC PALEONTOLOGY.....	44
APPENDIX A.....	91
APPENDIX B.....	93

LIST OF ILLUSTRATIONS

Figures	Page
1. Areas sampled.....	5
2. The <u>Thysanophyllum</u> belt outlining the northern and western coastlines of Pangea.....	7
3. Dendrogram as a result of clustering.....	11
4. Varieties 1-6 (thysanophylloid).....	20
5. Varieties 7-9 (thysanophylloid), variety 10 (sciophylloid) and variety 11 (with an incomplete wall).....	21
6. Varieties 12-15 (thysanophylloid with columns).....	22
7. Variety 16-18 (stylasteroid).....	23

Plates

1. <u>Thysanophyllum</u> <u>aseptatum</u>	59
2. <u>Thysanophyllum</u> <u>aseptatum</u>	61
3. <u>Thysanophyllum</u> <u>cystosum</u>	63
4. <u>Thysanophyllum</u> <u>cystosum</u>	65
5. <u>Thysanophyllum</u> <u>giganteum</u>	67
6. <u>Thysanophyllum</u> <u>giganteum</u>	69
7. <u>Thysanophyllum</u> <u>perpastum</u>	71
8. <u>Thysanophyllum</u> <u>perpastum</u>	73
9. <u>Thysanophyllum</u> sp. a n. sp.	75
10. <u>Protowentzelella</u> <u>simplex</u>	77
11. <u>Protowentzelella</u> <u>simplex</u>	79
12. <u>Stylastraea</u> <u>tenuiseptata</u>	81
13. <u>Stylastraea</u> <u>tenuiseptata</u>	83
14. <u>Sciophyllum</u> <u>mulleri</u>	85

15. <u>Sciophyllum mulleri</u>	87
16. Genus A n. gen. sp. a n. sp.	89

LIST OF TABLES

Tables

1. Number of identified specimens from each area.....	37
2. Percentage of each species in each subprovince.....	39

ABSTRACT

Early Permian rocks of the Ural Mountains, Russian Platform, Spitsbergen, the Canadian Arctic Islands, British Columbia, southern Idaho, eastern and southern Nevada, western Utah, eastern California, West Texas, and possibly South America have yielded massive rugose corals of the Subfamily Thysanophyllinae. Rocks of this age elsewhere, especially in the Tethys, contain many corals, but not massive Thysanophyllinae.

This study involves a taxonomic analysis of the massive Permian Thysanophyllinae for the purpose of 1) identifying what genera and species of corals are present and how they are distributed geographically, 2) providing a global paleobiogeographic picture of these Permian corals along the coastline of Pangea, and 3) evaluating the basis for generic and specific assignments and revising the current generic concepts so that these corals can be placed more accurately according to their biologic relationships.

The conclusion of this study is that the massive Permian corals of the Subfamily Thysanophyllinae should be assigned to 5 genera: Thysanophyllum, Stylastraea, Sciophyllum, Protowentzelella and a new aphroid genus. These corals define a belt along the coastline of Pangea, but different species dominate in different places. These distributional differences may be the result of differences in the water temperature along the long Pangean coastline.

INTRODUCTION

Early Permian rocks of the Ural Mountains, the Russian Platform, Spitsbergen, the Canadian Arctic Islands, British Columbia, southern Idaho, eastern and southern Nevada, western Utah, eastern California, West Texas and possibly South America have yielded massive rugose corals of the Subfamily Thysanophyllinae. These areas comprise a large part of the western and northwestern coast of the Permian Pangean continent and are the only places in the world where these corals occur in Early Permian rocks (Stevens, 1983). This coral belt is about 15000 km in length and 25 m to 100 km in width and is thus a major biogeographic feature of the Early Permian.

Previous studies have only generally touched upon the issue of distribution of the major coral groups that occur in this belt, and an extensive detailed taxonomic analysis of species has never been attempted. It was hoped here that a study of the coral assemblages could provide insight as to the dispersal and differentiation of this group.

The specific objectives of this study are:

- 1) to better understand the basis for generic and specific assignment of these corals and to revise the current generic concepts to more accurately place these corals according to their biologic relationships; and
- 2) to ascertain how the species are distributed to

provide a paleobiogeographic picture of the Permian corals along the coastline of Pangea from the western United States into the Ural Mountains.

Age and Occurrence

Specimens used in this study were collected by Dr. Calvin H. Stevens from the Early Permian Riepe Spring Limestone of eastern Nevada and western Utah, the Arcturus Formation in eastern Nevada, the Owens Valley Group of eastern California, the Bird Spring Formation of southern Nevada, and the Hueco Canyon Formation of West Texas. A specimen from the Belcourt Formation of British Columbia was made available by Wayne Bamber (Geologic Survey of Canada). No specimens from the Urals or Spitsbergen were available for this study, but the corals from the Urals have been described previously by Dobrolyubova (1936) and Soshkina and others (1941), and the corals from Spitsbergen have been described by Fedorowski (1965, 1967) and Fedorowski (in Birkenmajer and Fedorowski, 1980).

Previous Work

Prior to this work, a considerable number of taxa of massive Permian Thysanophyllinae had been described. A search of localities worldwide indicates that 15 massive species belonging to this subfamily have been described.

They are as follows: Thysanophyllum arcticum, T. aseptatum, T. cystoides, T. cystosum, T. dubiosum, T. giganteum, T. perpastum, T. princeps, T. regressum; Stylastraea minima, S. rowetti, S. tenuiseptata, S. toulai; P. simplex and Sciophyllum mulleri.

Six species have been identified from Russia. Stuckenberg (1895) named and described Stylastraea toulai. Dobrolyubova (1936) named and described Thysanophyllum perpastum, Thysanophyllum aseptatum, and Thysanophyllum cystosum from the Early Permian of Verkhne Chussovskiye Gorodki, in the middle Urals. Soshkina and others (1941) noted the occurrence of Thysanophyllum aseptatum (Dobrolyubova, 1936) in the middle and southern Urals, and Porfiriev (in Soshkina and others, 1941) named Thysanophyllum cystoides and Protowentzelella simplex from the Lower Permian limestones of Shak-tau near Sterlitamak on the western slope of the Urals.

Three species have been named for specimens from the western United States. Easton (1960) described Thysanophyllum princeps from eastern Nevada, and Wilson and Langenheim (1962) described Sciophyllum mulleri and figured Thysanophyllum princeps (Easton, 1960) from the Ely Quadrangle, White Pine County Nevada. Wilson (in Wilson and Langenheim, 1993) described a species he named Stylastraea rowetti from Arrow Canyon, Clark County, Nevada.

LeMone and Stevens (1976) noted the occurrence of

Stylastraea, Thysanophyllum and Protowentzelella in West Texas, but did not propose any specific names, and Meyer (1914) described a single specimen of Stylastraea from the Tarma region of Peru that probably is Permian in age.

Eight species are known from Spitsbergen. Seven of them were first described from Spitsbergen. Fedorowski (1965) assigned some corals from limestones at Hornsund to Thysanophyllum cystosum (Dobrolyubova, 1936) and described five new species: Protowentzelella variabilis, Thysanophyllum arcticum, T. regressum, T. giganteum and S. tenuiseptata from Hornsund. In 1967 Fedorowski named and described Stylastraea minima and Thysanophyllum dubiosum from Treskelodden.

Methods

This study involved the preparation of approximately 431 thin sections representing 153 specimens. Both transverse and longitudinal sections were made from hand samples from all of the areas shown in Figure 1. This includes all areas where these corals are known to occur except for Russia and Spitsbergen, and South America, where they questionably occur. Photographs of these thin sections were taken in order to facilitate comparisons of specimens. The photographs were attached to data sheets which included the sample number, location, and physical characteristics. Genera and species were determined by analyzing physical

Figure 1. Areas sampled.

characteristics observed in photographs and thin sections. All specimens were compared with species already described by Stuckenberg (1895), Dobrolyubova (1936), Soshkina and others (1941), Easton (1960), Wilson and Langenheim (1962), Fedorowski (1965, 1967), Fedorowski (in Birkenmajer and Fedorowski, 1980), and Wilson (in Wilson and Langenheim, 1993).

Physical characteristics studied include the corallite diameters, number of septa, length of septa, presence or absence of lonsdaleoid dissepiments, presence or absence of column, shape of dissepiments, number of ranks of dissepiments, numbers of dissepiments per centimeter, numbers of tabulae per centimeter, shape of tabulae, shape of column, distance major septa extend into the tabularium, width of dissepimentarium, dilation of septa, and thickness of the corallite wall. Statistical analysis using SPSS PC+, an MS-DOS-driven statistical package was used for grouping specimens that are difficult to distinguish due to the great similarities of many species and the high degree of variability within species.

In the paleobiogeographic part of this study, the geographic occurrence of the different coral taxa with respect to the Permian coastline of Pangea (Fig. 2) was analyzed. In this portion of the study, the subprovinces proposed by Stevens and Rycerski (1983) and Stevens (1991) were utilized.

Figure 2. The Thysanophyllum belt outlining the northern and western coastlines of Pangea (from Stevens, 1982).

The number and distribution of samples used in this study are as follows:

<u>LOCATION</u>	<u>NUMBER OF SAMPLES</u>	<u>SAMPLES USED</u>
Clark County, NV	1	0
Elko County, NV	9	9
White Pine County, NV	9	7
Power County, ID	5	5
Millard County, UT	7	4
Grassy County, UT	1	1
Tooele County, UT	1	1
Inyo County, CA	56	37
Franklin Mountains, TX	65	49
British Columbia, Canada	1	1
TOTAL	153	114

Location of individual samples is given in Appendix A.

CLASSIFICATION OF THE THYSANOPHYLLINAE

The foremost problem that arises from this study is separation of the corals into distinct taxonomic groups. Because of morphological variations within a single colony and between colonies, it is difficult to characterize a group at either the generic or specific level. Morphological differences are used to determine the taxonomic group to which fossils are assigned, but the wide variation within a single corallum in specimens studied

results in a lack of explicit or definite form. As observed in this study, some colonies exhibit structures that might allow assignment of individual corallites to several different taxonomic groups. A possible approach to this problem is to use statistical methods to aid in grouping specimens.

Statistical Comparisons

Due to the large number of specimens available for this study, as well as the large number of parameters studied (e.g., diameter, length of septa, etc.), a statistical computer package was employed to facilitate the classification process and to ascertain if such a quantitative method could be successfully used in such a study. SPSS PC+ is designed to evaluate large numbers of variables assigned to a large number of cases, or in this instance, to specimens.

In order for SPSS PC+ to read and process information, the specimens along with their characteristics were formed into a matrix via a text editor, in this instance Word Perfect. The matrix consisted of sixteen columns of information with the left column designating the specimen number and 15 specimen characteristics following (App. B). One hundred and fourteen specimens or cases were used. Once the information was in a format that SPSS PC+ could read, instructions in the form of commands were keyed in and the

analysis started.

Because grouping of specimens into species was the ultimate goal of this portion of the study, cluster analysis was used to group specimens that shared a majority of the characteristics measured or assigned. The SPSS PC+ employs similarity and dissimilarity coefficients that link like entities. In the same respect, it segregates unlike entities. Because of the amount of computer RAM needed to run SPSS PC+, not all 15 characteristics were used in the analysis. After careful consideration, 11 characteristics were considered to be the most important. They are diameter, number of septa, length of septa, presence or absence of lonsdaleoid dissepiments, presence or absence of a column, shape of the dissepiments, number of dissepiments, distance septa extend into the tabularium, width of the dissepimentarium, amount of dilation of septa, and thickness of the walls. These characteristics were chosen because they were observed most frequently and specific measurements of them could be made with greater accuracy than of some others. With these characteristics identified as variables to be analyzed, a run was made and a dendrogram produced.

The dendrogram shows 5 large groupings and 4 small groupings (Fig. 3). Twenty to thirty specimens fell in each of the large groupings, whereas one to six fell in the small groupings. To ascertain whether or not the cluster analysis was successful in grouping corals of similar appearance,

Figure 3. Dendrogram as a result of clustering.

photographs of the corals of each group in the dendrogram were compared. Unfortunately, photographs of specimens within each of the groups showed a wide range of morphological features.

Different combinations and fewer characteristics also were computed with similar results. Thus, with the input given, SPSS PC+ was not successful in clustering similar-appearing specimens. Apparently selection of characteristics is the basic problem concerning input. This has led me to the conclusion that cluster analysis may not be suitable for this type of analysis where a large number of variable specimens is involved. It appears that the differences between taxonomic groups are so subtle that SPSS PC+ is not able to differentiate between different groups well enough to allow recognition of groups that share important common characteristics. It is possible that some of the unimportant characteristics may obscure the important ones.

This inability to cluster also may be the result of a lack of diverse components to measure. During compilation of the data, it was noted that most characteristics that were measured, (e.g., septal length, diameter, etc.) differ by only small amounts. For example, septal length may average 2.0 mm, and range from 0.5 mm to 3.0 mm. This difference may not be enough to cluster or differentiate specimens and the end result is not meaningful.

Visual Comparisons

After the negative results of the cluster analyses were noted, identification and classification proceeded using the more traditional approach of comparing measurements and overall appearance.

First the photographs of each specimen were studied and similar ones grouped together. Of the 431 thin sections made, 378 were photographed. Two hundred twenty seven of these photographs comprising 114 specimens are used in this study. The remainder of the thin sections or photographs were not utilized because they did not exhibit details clear enough for analysis. Some specimens were so recrystallized or silicified, that it was difficult to determine any characteristics.

Features, including diameter, length of septa, etc., essentially the same 11 characteristics that were used in the cluster analysis, were compared keeping in mind the composite image of the photograph. Eventually a specific concept was developed for each group. Finally, these species were compared to descriptions and photographs or illustrations of species defined by previous authors. Of the 114 specimens studied, 112 have been assigned to previously described species; 2 have not. One unassigned specimen is considered to represent a species of a new genus and the other is described as a new species of a pre-existing genus.

Previously described species represented in the collection available for this study are Thysanophyllum aseptatum (Dobrolyubova, 1936), Thysanophyllum cystosum (Dobrolyubova, 1936), Thysanophyllum perpastum (Dobrolyubova, 1936), Thysanophyllum giganteum (Fedorowski, 1965), Sciophyllum mulleri (Wilson and Langenheim, 1962), Protowentzelella simplex (Porfiriev, in Soshkina and others, 1941), and Stylastraea tenuiseptata (Fedorowski, 1965).

THE SUBFAMILY THYSANOPHYLLINAE

Hill (1981) described the Thysanophyllinae as composed of fasciculate and cerioid corals with a weak axial structure composed of a lathlike columella that may or may not be continuous with a cardinal septum or no axial structure at all. The tabulae are mesa-shaped or slightly convex upward. The major septa sometimes are withdrawn from the axis. The minor septa may be discontinuous within a lonsdaleoid dissepimentarium.

Most of these corals are fasciculate or cerioid, although here a new aphroid genus is recognized and described. Corallites generally are 5.0 mm to 11.0 mm in diameter, and a dominant characteristic is the wide tabularium which generally is 3.0 mm to 7.0 mm in diameter. The dissepimentarium, commonly composed of 1 to 2 rows of lonsdaleoid or non-lonsdaleoid dissepiments, ranges from 1.0 mm to 3.0 mm in width. The dissepiments commonly are

concentric to the corallite wall and generally are crescent-like in longitudinal section.

The major septa also are distinctive. They are quite short compared with septa of most other families or subfamilies, and sometimes appear as short stubby projections that extend only 0.5 mm to 3.0 mm into the tabularium. In some instances an unattached lathlike column may be present. In a few instances, a septum (probably the cardinal septum) is connected to the column.

The tabulae are quite close to one other. Generally there are about 16 to 24 tabulae per centimeter. They are flat to slightly upbowed and are continuous across the corallite except where an axial plate is developed. Some longitudinal sections exhibit broken, discontinuous tabulae, but this is due to deformation of the corallite and is not an original physical feature.

On the basis of the general features mentioned above, the following genera of massive corals are assigned to the Subfamily Thysanophyllinae: Thysanophyllum, Stylastraea, Sciophyllum, Protowentzelella, and the newly described Genus A. Other genera assigned to this subfamily by Hill (1981), are phaceloid forms: Corphalia, Dorlodotia, and Pseudodorlodotia.

Generic Assignment Within the Thysanophyllinae

Overview of Problem

A serious problem in the classification of the Thysanophyllinae, as well as of many other coral groups, is the wide range of morphologic variations within single colonies. This leads to ambiguous and unstable taxonomic assignments.

Sutherland (1989) noted profound intraspecific variability within coralla of the Tournaisian to Visean (Mississippian) genus Stelechophyllum from Russia, Mexico, Canada, and the United States. He speculated that this variability was due to remarkably fast growth changes of adjacent corallites. This variability causes confusion in the classification of a specimen because the species concept must be broad enough to embrace all the variations present in the colony. Other species with highly variable corallites may thus partially overlap one another, making separation of species very difficult.

Wilson (1963) also noted that within a single corallum of Thysanophyllum princeps from the Lower Permian of White Pine County, Nevada, several distinctly different morphologies could be observed. Under the existing definitions of various taxa, some of the corallites in this colony could be assigned to different genera rather than being phenotypic variants as is obviously the case in a colonial organism.

The genomorph concept had been proposed earlier by Smith and Lang (1930) as a way of describing different forms

within a colony which appear to produce new genetic individuals. Smith and Yu (1943) continued with the use of the genomorph concept, but in a purely morphological sense. In general, the genomorph concept was developed as a means of taxonomically assigning individual variants within a corallum to different generic groups. It was supposed to describe a "deviant morphologic form that foreshadows the development of a new genus." What it actually does is group certain variants in a single corallum into one taxonomic group whereas other variants are separated because of their different characteristics. Wilson (1963) observed that according to nomenclature used in the framework of the genomorph concept, a single corallum of Thysanophyllum princeps would be assigned the name Lithostrotion {Thysanophyllum} {Stylastraea} {Sciophyllum} princeps because these morphologic forms are present in the same corallum. The nomenclature of this system is too cumbersome, as noted by Wilson (1963), and the biological principle upon which it is built, that some corallites are foreshadowing future evolution, is highly questionable. Actually what has been mistaken for genotypic variants probably are phenotypic variations. Thus, the variations are not due to genetic differences but to other factors, perhaps environmental influences. The basic problem is that phenotypic variants often have been viewed as distinct genotypical mutations and have been separated into different

taxonomic groups or, as in some cases utilizing the genomorph concept, lumped together with other perhaps unrelated forms.

Solution

The basic problem in the classification of corals is that within a single corallum several different forms commonly are present. These morphologic variants probably are phenotypic variants and probably are the result of nurturing by the environment.

A way to incorporate these morphologic variations into the name or concept of a species would be to assign a numerical or alphabetic designation to each variety within a corallum. Varieties would be designated numerically so there would be no possibility of running out of designators if a large number of varieties are present.

Morphologic variants within a corallum must belong to the same species and genus, so instead of assigning different forms to different genera or species, a variation designation is assigned which may appear in different species or even genera. For example, in a colony of Thysanophyllum cystosum, in which there are three variants, we could write the name Thysanophyllum cystosum varieties 1, 2, 3 with one being the most numerous variant and 3 being the least numerous. This idea would then be extended to other colonies of the same species, different species, and

even different genera, so that eventually numerous variants might be documented. Species and genera could then be defined on the relative proportions of the variants present. For example, in Thysanophyllum princeps lonsdaleoid dissepiments are dominant but sciophylloid variants and other variants also are present. Sciophyllum, on the other hand is dominated by sciophylloid variants, although thysanophylloid forms also may be present. Morphologic varieties are described from transverse thin sections because variations are much more discernable in these sections than in longitudinal sections.

In Figures 4 through 7, the morphologic variants recognized in the specimens available for this study are here shown somewhat diagrammatically. The drawings were made from actual corallites with corrections made where structures were broken, not preserved, or deformed. Variants that are dominant in some coralla also may appear in other taxa that are dominated by a different variant.

Descriptions of the morphologic variants are as follows:

Morphologic Variety 1 (Fig. 4): about 9.0 mm in overall diameter; tabularium 5.0 mm in diameter; lonsdaleoid dissepimentarium 2.0 mm in width; 14 thin major septa extend 1.0 mm into the tabularium; some septa are dilated. Morphologic variety 1 has 3 or 4 rows of dissepiments.

Figure 4. Varieties 1-6 (thysanophylloid). x4

Figure 5. Varieties 7 & 8 (thysanophylloid), varieties 9 & 10 (sciophylloid) and variety 11 (with an incomplete wall). x4

Figure 6. Varieties 12-15 (thysanophylloid with columns). x4

Figure 7. Varieties 16-18 (stylasteroid). x4

Morphologic variety 2 (Fig. 4): about 7.0 mm in overall diameter; tabularium 4.5 mm in diameter; lonsdaleoid dissepimentarium 1.25 mm in width; 16 thin major septa extend 0.75 mm into the tabularium. Morphologic variety 2 is characterized by some septa that extend to the wall.

Morphologic variety 3 (Fig. 4): about 7.0 mm in overall diameter; tabularium 4.0 mm in diameter; lonsdaleoid dissepimentarium 1.5 mm in width; 12 thin major septa extend 1.0 mm into the tabularium. This variety differs from morphologic variety 2 in that the septa extend slightly further into the tabularium.

Morphologic variety 4 (Fig. 4): about 10.0 mm in overall diameter; tabularium 5.5 mm in diameter; very intricate lonsdaleoid dissepimentarium 2.25 mm in width with 3 to 5 rows of dissepiments; 16 thin major septa extend 1.25 mm into the tabularium. This variety differs from all other varieties in the number of rows of dissepiments.

Morphologic variety 5 (Fig. 4): about 7.5 mm in overall diameter; tabularium 5.0 mm in diameter; lonsdaleoid dissepimentarium 1.25 mm in width; 16 thick major septa extend 0.75 mm into the tabularium. This variety differs from the other varieties in having a simple dissepimentarium and about half the septa reaching the outer wall. Morphologic variety 5 differs from morphologic variety 2 in that the septa are thicker, and more septa extend to the outer wall.

Morphologic variety 6 (Fig. 4): about 7.0 mm in overall diameter; tabularium 4.0 mm in diameter; lonsdaleoid dissepimentarium 1.5 mm in width; 12 thin major septa extend 0.75 mm into the tabularium.

Morphologic variety 7 (Fig. 5): about 9.0 mm in diameter; tabularium 5.0 mm in diameter; about 10 very short septa extend 0.25 mm to 0.5 mm into the tabularium; lonsdaleoid dissepimentarium 2.0 mm in width. Morphologic variety 7 is completely lonsdaleoid and contains several rows of dissepiments. Major septa appear only as spines extending into the tabularium. Morphologic variety 7 has a slightly wider dissepimentarium than morphologic variety 1 and much shorter septa. This variety is larger than morphologic variety 6.

Morphologic Variety 8 (Fig. 5): about 10.0 mm in overall diameter; tabularium 6.0 mm in diameter; lonsdaleoid dissepimentarium 2.0 mm in width; about 14 thin major septa extend 0.25 mm to 0.5 mm into the tabularium. This variety is slightly larger than other varieties. Its septa are shorter than those of variety 6. This variety differs from morphologic variety 7 in that it has a slightly wider tabularium.

Morphologic variety 9 (Fig. 5): about 5.0 mm in overall diameter; tabularium 3.0 mm in diameter; lonsdaleoid dissepimentarium 1.0 mm in width; thin major septa almost totally lacking. This variety is smaller than any of the

other varieties.

Morphologic variety 10 (Fig. 5): about 11.0 mm in overall diameter; tabularium 7.0 mm in diameter; lonsdaleoid dissepimentarium 2.0 mm in width; no septa are developed.

Morphologic variety 11 (Fig. 5): about 7.0 mm in overall diameter; tabularium 4.5 mm in diameter; lonsdaleoid dissepimentarium 0.5 mm in width; 10 to 12 thin major septa extend 0.75 mm into the tabularium; deterioration of the outer wall so that adjacent corals merge. No other variety exhibits this deterioration of the wall.

Morphologic variety 12 (Fig. 6): about 8.0 mm in overall diameter; tabularium 4.0 mm in diameter; lonsdaleoid dissepimentarium 2.0 mm in width; 15 thick major septa extend 0.75 mm into the tabularium; some septa extend to the outer wall; thick outer walls; lathlike column.

Morphologic variety 13 (Fig. 6): about 10.0 mm in overall diameter; tabularium 4.0 mm in diameter; lonsdaleoid dissepimentarium 3.0 mm in width; 14 thin major septa extend 1.5 mm into the tabularium; lathlike column is connected to 2 septa.

Morphologic variety 14 (Fig. 6): about 8.0 mm in overall diameter; tabularium 4.5 mm in diameter; lonsdaleoid dissepimentarium 1.75 mm in width; 18 thin major septa extend 1.0 mm into the tabularium; small lathlike column connected to one major septum. Morphologic variety 14 is similar to morphologic variety 13 but has slightly shorter

septa and a more complex dissepimentarium.

Morphologic variety 15 (Fig. 6): about 8.0 mm in overall diameter; tabularium 5.0 mm in diameter; lonsdaleoid dissepimentarium 1.5 mm in width; 14 thin major septa extend 1.25 mm into the tabularium. Small lathlike column is attached to one septum. Morphologic variety 15 differs from morphologic variety 14 in that the dissepimentarium is slightly less complex.

Morphologic variety 16 (Fig. 7): about 8.0 mm in overall diameter; tabularium 5.0 mm in diameter; dissepimentarium 1.5 mm in width; few lonsdaleoid dissepiments; 15 thin major septa extend 1.5 mm into the tabularium. Most septa extend to the outer wall.

Morphologic variety 17 (Fig. 7): about 6.0 mm in overall diameter; tabularium 4.0 mm in diameter; non-lonsdaleoid "spiderweb"-like dissepimentarium 1.0 mm in width; about 14 thin major septa extend 1.0 mm into tabularium; lathlike column.

Morphologic variety 18 (Fig. 7): about 9.0 mm in overall diameter; tabularium 5.0 mm in diameter; non-lonsdaleoid "spiderweb"-like dissepimentarium 2.0 mm in width; 16 thin major septa extend 0.75 mm into tabularium. This variety differs from morphologic variety 16 in that the dissepimentarium is slightly more complex and the corallite is slightly larger overall.

With this variability in mind, the underlying question

is what characteristics should be used as a basis for classification? Probably the same criteria that have been used in the past are appropriate. Whether the colonies are fasciculate, cerioid or aphroid is always considered a fundamental difference in corals. Beyond this, however, reliance must be placed on the dominant variant, as there may be several variants present. These variants show differences in the number of septa and the nature of their development, the amount of development of lonsdaleoid dissepiments, number of ranks of dissepiments, complexity of the dissepimentarium, absence or presence of a column, whether or not the column, if present, is attached to septa, dilation of septa or lack of it, and the average diameter of the corallite.

Clearly the species concept needs to be as broad as the variation within a single colony and it should include all coexisting colonies with similar characteristics. A species concept then is developed by comparison of many colonies. Groups of similar species then may be put together to form larger groups that can be considered to be at the generic level.

Massive Genera Assigned to the Thysanophyllinae

Study of a large number of massive Thysanophyllinae here suggests that the following characteristics are useful for differentiating genera: 1) whether the colony is

phacelloid, cerioid or aphroid, 2) whether or not dissepiments are predominantly lonsdaleoid, 3) whether or not a column is generally present and if present, whether or not it commonly is attached to a septum, and 4) whether or not septa are developed. In this study, five genera are used to describe the massive forms assigned to this subfamily. They are: Thysanophyllum, Stylastraea, Sciophyllum, Protowentzelella and a new genus A. These genera can be distinguished from each other by using the physical characteristics listed above. Thysanophyllum is dominated by thysanophylloid varieties of corallites but sciophylloid and/or stylasteroid varieties also may be present; Stylastraea contains primarily corallites in which most septa reach the wall; Sciophyllum contains varieties that largely lack septa; and Protowentzelella contains varieties that have columns commonly connected to 1 or 2 septa.

Genus Thysanophyllum

The genus Thysanophyllum, named by Nicholson and Thomson (1876), typifies the Subfamily Thysanophyllinae. In Permian species the major septa extend only 0.5 mm to 1.5 mm into the tabularium, with some specimens exhibiting dilation of septa at the point where they enter the tabularium. They range in number from 11 to 19. The corallite diameters range from 3.0 mm to 12.0 mm. The dissepimentarium,

consisting largely of lonsdaleoid dissepiments, ranges from 1.0 mm to 3.0 mm in width with 1 to 5 rows of dissepiments. The tabularium ranges from 2.0 mm to 8.0 mm in diameter. The tabulae are closely spaced, 10 to 24 per centimeter. Dissepiments are crescent-shaped and generally occur in only 1 or 2 ranks. A column is present in some species.

T. arcticum, T. aseptatum, T. cystoides, T. cystosum, T. dubiosum, T. giganteum, T. perpastum, T. princeps, T. regressum are the previously described Permian species assigned to Thysanophyllum. Four of these species are recognized among the specimens available for study. They are T. aseptatum, T. cystosum, T. giganteum and T. perpastum. One new species of Thysanophyllum, T. species a, is described here.

T. princeps (Easton, 1960) is placed in synonymy with T. cystosum (Dobrolyubova, 1936) because the former appears to possess the same characteristics as T. cystosum. The other species, including T. dubiosum (Fedorowski, 1967), T. regressum (Fedorowski, 1965), T. arcticum (Fedorowski, 1965), and T. cystoides (Porfiriev, in Soshkina and others, 1941), probably are valid, but they do not occur in the collections studied here.

This genus is distinguished from the other genera of this subfamily by the wide, open tabularium, a predominantly lonsdaleoid dissepimentarium, and medium to short septa. Morphologic variety 7 (Fig. 5) dominates in most species

assigned to this genus and its characteristics are the basis for separating this genus from other genera. Other varieties that may be present in smaller numbers of corallites are morphologic varieties 1 through 6, 8 and 12 through 16 (Fig. 4, 5, 6 and 7).

Genus Protowentzelella

This genus, named by Porfiriev (in Soshkina and others, 1941) was assigned to the Family Durhaminidae by Hill (1981), but due to the similarity of the morphology of the type species to members of the Thysanophyllinae, namely the wide tabularium, the size and number of rows of dissepiments, and the number of septa, it is suggested here that this genus be transferred to the Subfamily Thysanophyllinae.

As with the other genera of the Thysanophyllinae, the typical diagnostic characteristic of this genus is the wide, rather open tabularium ranging in size from 4.0 mm to 6.0 mm in diameter. The dissepimentarium consists of 1 to 3 rows of lonsdaleoid dissepiments and is 1.0 mm to 3.0 mm in width. The corallite diameter ranges from 3.0 mm to 10.0 mm. The major septa are typically short and thin and extend 0.5 mm to 1.5 mm into the tabularium. They range in number from 12 to 19. Some major septa exhibit dilation. Axial structures appear as lathlike columns, typically attached to one or two septa.

Tabulae are close together, 16 to 18 per centimeter, generally are flat with some slightly domed upwards, and are continuous. Dissepiments are slightly globular to flat in longitudinal section. P. simplex (Porfiriev, 1941), the type species, is the only species of this genus recognized among the corals studied here.

The most distinguishing characteristic of this genus that sets it apart from the other genera is the axial structure. In general, this genus is similar to Stylastraea in that columns are present. However, Stylastraea can be distinguished from Protowentzelella because the former possesses a very intricate "spider web"-like dissepimentarium, whereas Protowentzelella does not. Also, in Protowentzelella, the column commonly is attached to a septum and generally the dissepiments are lonsdaleoid. This genus is typified by morphologic variety 3 (Fig. 4) and morphologic varieties 13 and 14 (Fig. 6); it also may possess morphologic variety 15 (Fig. 6).

Other species previously assigned to Protowentzelella include P. borealis (Stuckenberg, 1895), P. longiseptata, Fedorowski (in Birkenmajer and Fedorowski, 1980) and P. variabilis (Fedorowski, 1965) that probably should be placed in another subfamily (probably the Durhaminidae) as they do not possess the major characteristics of the Thysanophyllinae.

Genus Stylastraea

The genus Stylastraea, named by Lonsdale (1845), is characterized by septa that generally reach the wall. In the Permian species they extend 1.0 mm to 4.0 mm into the tabularium and range in number from 12 to 19. Some exhibit dilation. The tabularium ranges from 4.0 mm to 5.0 mm in diameter. The dissepimentarium, consisting predominantly of non-lonsdaleoid dissepiments, exhibits a much more intricate pattern than other genera. It ranges from 1.0 mm to 2.0 mm width. The dissepimentarium has a "spider web" like appearance that is produced by a very complex pattern of non-lonsdaleoid dissepiments. In transverse section, the dissepiments consistently curve along the sides of the major septa, producing a concave toward the center arch, not unlike that of a meniscus in a test tube. In longitudinal section, 1 to 3 ranks of steeply dipping to slightly curved dissepiments can be seen. They range from 16 to 18 per centimeter. Tabulae are close together and dome upwards. Some corallites exhibit well-developed, lathlike columns. The diameter ranges from 3.0 mm to 8.0 mm.

The relatively rare occurrence of lonsdaleoid dissepiments, the complex "spider web"-like dissepimentarium, and a column not attached to a septum distinguishes this genus from other genera in this subfamily. Thus, in species of this genus morphologic varieties 16 and 17 (Fig. 7) are typical although,

morphologic variety 18 (Fig. 7) also occurs in small numbers.

S. tenuiseptata is the only species of this genus recognized in this study. Other Permian species include S. toulai (Stuckenberg, 1895), S. minima (Fedorowski, 1965), and S. rowetti (Wilson, 1993).

Genus Sciophyllum

Permian species of the genus Sciophyllum, named by Harker and McLaren (1950), has an extremely wide tabularium, 3.0 mm to 7.0 mm in width. Major septa generally are not present or appear as bumps sometimes extending 0.5 mm into the tabularium. When developed they range in number from 11 to 18. The dissepimentarium ranges from 1.0 mm to 2.0 mm in diameter. In longitudinal section, the tabulae are almost flat and straight. The dissepiments are crescent-like and form 1 to 2 ranks. The overall size of this coral ranges from 5.0 mm to 11.0 mm in diameter. All dissepiments are lonsdaleoid and columns are not present.

The general lack of, or presence of only very short septa, and a wide tabularium distinguishes this genus from other genera. Morphologic variety 10 (Fig. 5) is the dominant variety represented in species of the genus, although morphologic varieties 8 and 9 (Fig. 5) also occur in the corallum and, in one instance, a thysanophylloid morphologic variety 3 (Fig. 4) can be seen in the corallum.

S. mulleri, the only Permian species of this genus described, is present among the specimens studied here.

New Genus A

This genus is based on a specimen that is aphroid. The dissepimentarium is narrow, about 0.5 mm wide, and exhibits simple lonsdaleoid dissepiments. The major septa extend 0.5 mm to 1.0 mm into the tabularium and range in number from 10 to 20. The tabularium ranges from 4.0 mm to 5.0 mm in diameter. The overall diameter ranges from 5.0 to 7.0 mm. Tabulae appear discontinuous in longitudinal section due to breakage, but they generally bow upward. There is no axial structure. The dissepiments are generally flat with some exhibiting a globular shape.

This new genus is assigned to Thysanophyllinae because it is very similar in morphology to Thysanophyllum in that it possesses a wide tabularium. It is distinguished from all other genera in the subfamily because of its aphroid condition (deterioration of the outer wall). Morphologic variety 11 (Fig. 5) typifies this genus.

PALEOBIOGEOGRAPHY

Stevens (1979, 1991) and Stevens and Rycerski (1983) have noted that a belt of Early Permian corals, which does not include corals of Tethyan affinity, extends from the Ural Mountains of Russia to at least as far as West Texas

via Spitsbergen, the Canadian Arctic Islands, British Columbia, Idaho, Utah, Nevada, and eastern California. Limited data suggest that it possibly extends southward to Peru. This coral belt is approximately 15,000 km in length, is 25 to 100 km in width, and is relatively continuous with the exception of a gap of 1,500 km between British Columbia and southern Idaho and another major gap between eastern California and West Texas (Fig. 2). These gaps probably are due to the paucity of data from these regions because of tectonic burial of the appropriate biofacies as a result of over thrusting in the Rocky Mountains (Stevens, 1982) and metamorphism and intrusion in the southwestern United States.

Stevens and Rycerski (1983) suggested that the Thysanophyllum coral belt can be divided into six faunal subprovinces: Ural, Arctic, Central Great Basin, eastern California, West Texas, and Peru. These subprovinces were based on differences in the overall coral composition and the geographic separation of these areas.

The data derived from corals analyzed in this study suggest that the North American subprovincial subdivisions of Stevens and Rycerski (1983) are reflected in the occurrence of the Thysanophyllinae, although T. aseptatum, T. cystosum, and S. tenuiseptata are common throughout the coral belt and generally constitute the dominant species. Among the other species (Table 1), percentage concentrations

<u>LOCATION\SPECIMEN</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
Elko Co., NV	3	1			4		1		
White Pine Co., NV		1		1	1	2	1		1
Power Co., ID	2	2		1					
Millard Co., UT		1		1		2			
Grassy Co., UT						1			
Tooele Co., UT		1							
Inyo Mts., CA	3	9	2	4		19			
Franklin Mts., TX	12	22		1	3	8	2	1	
Br. Columbia, Canada						1			

SPECIMEN

- 1 = Thysanophyllum aseptatum
 2 = Thysanophyllum cystosum
 3 = Thysanophyllum giganteum
 4 = Thysanophyllum perpastum
 5 = Sciophyllum mulleri
 6 = Stylastraea tenuiseptata
 7 = Protowentzelella simplex
 8 = Thysanophyllum n. sp. a
 9 = Genus A n. genus sp. a n. sp.

Table 1. Number of identified specimens from each area.

(table 2) suggest that the Franklin Mountains, (West Texas Subprovince) and Nevada, Utah and Idaho (Central Great Basin Subprovince) have the greatest concentration of Sciophyllum mulleri. Inyo County, CA (eastern California Subprovince), on the other hand, has the greatest concentration of T. perpastum.

The overall similarity of species at different locations suggests that environmental conditions were fairly similar. Certain concentrations of specimens, however, suggest that certain types of corals may thrive better under certain environmental conditions than others. Presently, temperature is instrumental in determining the occurrence of corals. A reconstructed Pangea based on paleomagnetic and other data (McElhinny, 1973) shows that the Thysanophyllum belt falls mostly within the latitudes that foster contemporary coral growth, namely 30 degrees north and south latitudes. Northward along the Permian coral belt, water temperature probably decreased to the point where certain elements of the fauna ceased to thrive. Brown and Ogden (1993) also pointed out that in the modern oceans variances in temperature affect the way algal zooxanthellae interact with their host coral, and thus aid in determining the distribution of corals. This may explain why different species of corals are present in different locations. However, the lack of occurrence of some species may be the product of bias in the initial collecting process.

<u>SUBPROVINCE\SPECIMEN</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
Central Great Basin	19	22	0	10	19	19	7	0	4
West Texas	25	45	0	2	6	16	4	2	0
eastern California	8	25	5	11	0	51	0	0	0

SPECIMEN

- 1 = Thysanophyllum aseptatum
- 2 = Thysanophyllum cystosum
- 3 = Thysanophyllum giganteum
- 4 = Thysanophyllum perpastum
- 5 = Sciophyllum mulleri
- 6 = Stylastraea tenuiseptata
- 7 = Protowentzelella simplex
- 8 = Thysanophyllum n. sp. a
- 9 = Genus A n. genus sp. a n. sp.

Table 2. Percentage of each species in each subprovince.

CONCLUSION

Corals of the Subfamily Thysanophyllinae from three subprovinces along the Thysanophyllum coral belt, central Great Basin, eastern California and West Texas, show great intraspecific variation such that corallites within a single corallum could be assigned to different genera. This problem is overcome by the recognition of morphologic varieties within the Subfamily Thysanophyllinae. Genera and species are defined on the relative abundance of different morphologic varieties. Thus, the corals studied can be assigned to 5 genera: Thysanophyllum, Sciophyllum, Stylastraea, Protowentzelella, and new genus A. Species recognized are: T. aseptatum, T. cystosum, T. giganteum, T. perpastum, T. n. sp. a, new genus A n. sp. a, Sciophyllum mulleri, Stylastraea tenuiseptata and Protowentzelella simplex.

The distribution of the Thysanophyllinae indicates that certain types of corals are somewhat more abundant in certain locations than at others. Thysanophyllum appears to dominate in the West Texas Subprovince as compared to the northern provinces, especially Nevada, where Sciophyllum appears to occur in greater numbers. These differing dominant occurrences may be due to differences in environmental conditions, perhaps temperature.

REFERENCES

- Birkenmajer, K., and Fedorowski, J., 1980, Corals of the Treskelodden Formation (Lower Permian) at Triasnuten, Hornsund, South Spitsbergen: *Studia Geologica Polonica*, v. 66, p. 4-31.
- Brown, B.E., and Ogden, J.C., 1993, Coral bleaching: *Scientific American*, v. 268, p. 64-70.
- Dobrolyubova, T.A., 1936, The corals of the Upper Carboniferous of the western slope of the middle Urals and their stratigraphic importance: *Transactions of the All Union Scientific Research Institute of Economic Mineralogy*, fascicle 103, 68 p.
- Davis, J.C., 1973, *Statistics and data analysis in Geology*. John Wiley and Sons, New York, 646 p.
- Easton, W.H., 1960, Permian corals from Nevada and California: *Journal of Paleontology*, v. 34, p. 570-583.
- Fedorowski, J., 1965, Lower Permian Tetracoralla of Hornsund, Vestspitsbergen: *Studia Geologica Polonica*, v. 17, p. 1-173.
- , 1967, The Lower Permian Tetracoralla and Tabulata from Treskelodden, Vestspitsbergen: *Norsk Polarinstitutt Skrifter* nr. 142, 44 p., 7 pls.
- Harker, P., and McLaren, D.J., 1950, Sciophyllum, a new rugose coral from the Canadian Arctic: *Geological Survey Canada Bulletin*, v. 5, p. 29-34, pl. iv, text fig. 3.
- Hill, D., 1981, Coelenterata, Part F, Supplement 1, Rugosa and Tabulata, *Treatise of Invertebrate Paleontology*, Teichert, C., Ed: Boulder, Colorado, The Geological Society of America, and Lawrence, Kansas, The University of Kansas Press, 762 p.
- LeMone, D.V., and Stevens, C.H., 1976, The Stylastraea-Lithostrotionella Lower Permian (Middle Wolfcampian) coral zone in the Franklin Mountains, El Paso County, TX: in LeMone, D.V., and Lovejoy, E.M.P., eds., *El Paso Geological Society Symposium on the Franklin Mountains*, p. 77-82, pl. 1.
- McElhinny, M.W., 1973, *Paleomagnetism and plate tectonics*: Cambridge Press, 335 p.

- Meyer, H.L.F., 1914, Carbonfaunen aus Bolivia und Peru: Beitrage zur Geologie un Palaontologie von Sudamerika: Neues Jahrbuch fur Mineralogie usw., Bd. 37, beild, Bd. S., p. 590-652.
- Rycerski, B.A., 1985, Wolfcampian colonial rugose corals from the Stikine Terrane, north-central British Columbia [M.S. thesis]; San Jose State University, San Jose, CA, 138 p.
- Sando, W.J., 1983, Revision of Lithostrotionella (Coelenterata, Rugosa) from the Carboniferous and Permian: U.S. Geological Survey Professional Paper 1247, 52 p.
- Smith, S., and Lang, W. D., 1930, Description of the type specimens of some Carboniferous corals of the genera 'Diphyphyllum,' 'Stylastraea,' 'Aulophyllum,' and 'Chaetetes': Annual Magazine of Natural History, ser. 10, v. 5, p. 177-194.
- Smith, S., and Yu, C. C., 1943, A revision of the coral genus Aulina Smith and descriptions of new species from Britain and China: Quarterly Journal Geologic of the Society of London, 99, pt. 1, p. 37-61.
- Soshkina, E., Dobrolyubova, T.A., and Porfiriev, G., 1941, The Permian rugose corals of the European part of the USSR: Academy of Sciences of USSR, Paleontological Institute, The Academy of Sciences of USSR Press, v. 5, part 3, fasc. 1, 304 p.
- Stearn, C.W., and Carroll, R.L., 1989, Paleontology: John Wiley and Sons, Inc., 453 p.
- Stevens, C.H., 1975, Occurrence and migration of the northern massive Rugosa in the Early Permian, in Drevnie Cnidaria, tom 2: Akademiia Nauck SSR, Sibirskoe Otdelenie, vyp. 202. str. 197-204.
- 1979, Reconstruction of Permian paleogeography based on distribution of Tethyan faunal elements: Compte Rendu 9th International Congress of Carboniferous Stratigraphy and Geology, v. 5, p. 383-393.
- 1979, Lower Permian of the central Cordilleran Miogeosyncline: Geological Society of America Bulletin, Part II, v. 90, p. 381-455.

- ____ 1982, The early Permian Thysanophyllum coral belt: another clue to Permian plate tectonic reconstructions: Geological Society of America Bulletin, v. 93, p. 798-803.
- ____ 1991, Permian paleogeography of the western United States: in Cooper, J.D., and Stevens, C.H., eds., Paleozoic Paleogeography of the Western United States-II: Pacific Section, SEPM v. 67, p. 149-166.
- Stevens, C.H., and Rycerski, B.A., 1983, Permian colonial rugose corals in the western Americas-aids in positioning of suspect terranes: in Stevens, C.H., ed., Pre Jurassic Rocks in western North American Suspect terranes: Pacific Section SEPM, p. 23-36.
- ____ 1989, Early Permian colonial rugose corals from the Stikine River area, British Columbia, Canada: Journal of Paleontology, v. 63, p. 158-181.
- Stuckenberg, A., 1895, Korallen und Bryozoen der Steinkohlenablagerungen des Ural und des Timan: St. Petersburg, Memoires du Comite Geologique, v. 10, no. 3, p. 1-244.
- Sutherland, P.K., 1988, Intraspecific variability in the rugose coral Stelechophyllum? mclareni from the Lower Carboniferous (Visean) of northeastern British Columbia: Memoirs of the Association of Australian Paleontology, v. 8, p. 13-22.
- Wilson, E.C., 1963, An evaluation of the genomorph concept in rugose corals: Systematic Zoology, v. 12, no. 2, p. 83-90.
- ____ 1991, Permian corals from the Spring Mountains, Nevada: Journal of Paleontology, v. 65, no. 5, p. 727-741.
- Wilson, E.C., and Langenheim, R.L., 1962, Rugose and tabulate corals from Permian rocks in the Ely quadrangle, White Pine County, Nevada: Journal of Paleontology, v. 36, no. 3, p. 495-521.
- ____ 1993, Early Permian corals from Arrow Canyon, Clark County, Nevada: Journal of Paleontology, v. 67, no. 6, p. 935-945.

SYSTEMATIC PALEONTOLOGY

The terminology used in the descriptions of morphology is taken from Hill (1981). The specimens are grouped according to genus and are alphabetically ordered. They have been assigned SJSU Museum of Paleontology numbers which consist of SJS followed by a 3, 4 or 5 digit alpha numeric code.

Phylum CNIDARIA
Class ANTHOZOA
Subclass RUGOSA
Order STAURIIDA
Suborder LITHOSTROTIONINA Spasskiy & Kachanov, 1971
Family LITHOSTROTIONIDAE d'Orbigny, 1852
Subfamily THYSANOPHYLLINAE Hill, 1981
Genus THYSANOPHYLLUM Nicholson & Thomson, 1876

Thysanophyllum aseptatum Dobrolyubova, 1936

Plates 1 & 2

Thysanophyllum aseptatum Dobrolyubova, 1936, p.58, plate 14.

Thysanophyllum aseptatum Dobrolyubova (in Soshkina, Dobrolyubova & Porfiriev, 1941) p. 255, plate 19.

External description: Coralla are cerioid.

Transverse section: Corallites are hexagonal, 5.0 mm to 9.0 mm in diameter; major septa number from 11 to 17, are straight and short, and extend 0.5 mm to 1.0 mm into the tabularium; dissepimentarium is 1.0 mm in width and consists of 1 to 2 rows of moderate size, dominantly concentric, lonsdaleoid dissepiments; tabularium ranges from 4.0 mm to 6.0 mm in diameter; external walls are of medium thickness.

Longitudinal section: dissepiments generally in 1 to 3 rows, steeply dipping crescentric, slightly doming upward, about 10 per centimeter; tabulae are flat to slightly domed upward, complete and unbroken with about 20 per centimeter.

Morphologic variations: five morphologic variants (1, 2, 6, 7, and 10) are recognized within colonies of this species. Morphologic variety 7 is dominant in this species. Morphologic variety 7 in corallum SJS 1127 comprises 61% of all corallites. These varieties are very close to each other in terms of form, but they are none the less quite distinguishable because of the structure of the dissepimentarium and the size of the septa.

Specimens: SJS 583, 717, 727, 787, 851, 869a, 881, 903, 911, 1096, 1103, 1108, 1110, 1111, 1115, 1117, 1122, 1127, 1146, 1154, San Jose State University Museum of Paleontology.

Material and occurrence: material available for this study consists of 20 specimens from which 21 transverse and 16 longitudinal thin sections were cut. These specimens were collected from Elko County, NV; Power County, ID; Inyo County, CA; and the Franklin Mountains, TX.

Discussion: the most consistent and diagnostic features of this coral are the wide tabularium and closely spaced, domed tabulae. Septa vary in number and somewhat in length, but do not extend far into the tabularium. The dissepimentarium consists of lonsdaleoid dissepiments that

occur in 1 to 3 ranks. This species differs from the other species of Thysanophyllum in that the septa are very short and thin, almost non-existent in some corallites.

Thysanophyllum cystosum Dobrolyubova, 1936

Plates 3 & 4

Thysanophyllum cystosum Dobrolyubova, 1936, p. 62, plate 16.

Thysanophyllum princeps Easton, 1960 p. 576, plates 5 & 6.

External description: coralla are cerioid.

Transverse section: corallites are polygonal, generally hexagonal; diameter ranges from 3.0 mm to 8.0 mm; major septa thin and locally exhibit some sinuosity; major septa range in number from 12 to 19; minor septa rarely exhibited as tiny spines on the wall; length of major septa into tabularium ranges from 0.5 mm to 2.0 mm; tabularium ranges from 2.0 mm to 4.0 mm in diameter; dissepimentarium 1.0 mm in width and consists of 1 to 2 rows of moderate size, generally lonsdaleoid dissepiments; a column is not present; some dilation of septa is observed in some corallites; external walls are of medium thickness.

Longitudinal section: dissepiments range from slightly curved to curved and form 1 to 2 ranks; dissepiments about 16 per centimeter; tabulae are flat to slightly curved upward, about 10 per centimeter.

Morphologic variations: two morphologic variants (3 and 16) are recognized within colonies of this species.

Morphologic variety 3 is dominant in the corallum SJS 1148 comprising 63% of all corallites and 61% of all corallites in corallum SJS 1131.

Specimens: SJS 607, 616, 676, 743b, 785, 790, 858, 868b, 869b, 873a, 873b, 874, 903a, 905, 1074c, 1087d, 1097, 1098, 1100, 1104, 1105, 1109, 1129, 1130, 1131, 1132, 1133, 1134, 1141, 1142, 1144, 1145, 1148, 1149, 1151, 1153, San Jose State University Museum of Paleontology.

Materials and occurrence: materials available for this portion of the study consist of 36 specimens from which 41 transverse and 28 longitudinal thin sections were cut. These specimens were collected from Elko and White Pine County, NV; Power County, ID; Millard and Grassy Counties, UT; Inyo County, CA; and the Franklin Mountains, TX.

Discussion: This species resembles T. aseptatum but differs in that in T. cystosum the septa extend farther into the tabularium and non-lonsdaleoid dissepiments (as in morphologic variety 16) are more common.

Thysanophyllum giganteum Fedorowski, 1965

Plates 5 & 6

Thysanophyllum giganteum Fedorowski, 1965, p. 116, fig. 46.

External description: coralla are cerioid.

Transverse section: corallites polygonal, 7.0 mm to 10.0 mm in diameter; locally they are sinuous; major septa number from 15 to 16 and extend 0.5 mm to 1.5 mm into the

tabularium, dilated where they enter the tabularium; tabularium ranges from 4.5 mm to 6.0 mm in diameter; dissepimentarium is 2.0 mm in width and consists of 2 to 5 rows of generally lonsdaleoid dissepiments; corallites exhibit an external wall of medium thickness.

Longitudinal section: dissepiments are slightly curved to curved, inclined at a relatively low angle and form 3 to 4 ranks with about 16 per centimeter; tabulae are flat to slightly upbowed and continuous, about 16 to 24 per centimeter.

Morphologic variations: morphologic variety 4, which dominates in this species, is unknown in any other Permian species of Thysanophyllum.

Specimens: SJS 711, 871a, San Jose State University Museum of Paleontology.

Materials and occurrence: this species is represented by 2 specimens from which 2 transverse and 2 longitudinal thin sections were cut. These specimens were collected from Inyo County, CA.

Discussion: this species is characterized by a very complex, rose petal-like dissepimentarium. Up to 4 to 5 rows of dissepiments can be discerned. As in other species of Thysanophyllum, the wide tabularium is the most prominent feature. This species differs from all other Permian species of Thysanophyllum in its large diameter and large number of ranks of dissepiments. The septa are dilated

where they enter the tabularium and are longer than those in T. perpastum.

Thysanophyllum perpastum Dobrolyubova, 1936

Plates 7 & 8

Thysanophyllum perpastum Dobrolyubova, 1936, p.54, plate 13.

External description: coralla are cerioid.

Transverse section: corallites polygonal; diameter is 4.5 mm to 8.0 mm; major septa ranging in number from 14 to 17, are short and stubby, and extend 0.5 mm to 1.0 mm into the tabularium; tabularium ranges from 4.0 mm to 5.0 mm in diameter; dissepimentarium 1.75 mm in width, consists of 1 to 2 rows of lonsdaleoid dissepiments; lathlike columns are sometimes present; septa are rather thick and some extend to the outer wall; external walls are very thick.

Longitudinal section: dissepiments are curved and usually form only one rank, about 14 per centimeter; tabulae are flat to slightly curved and are discontinuous, about 12 per centimeter.

Morphologic variations: two morphologic variants (5 and 12) are recognized within colonies of this species. Variety 12 is dominant in this species and comprises about 54% of all varieties in corallum SJS 743c and 53% in corallum SJS 1095.

Specimens: SJS 636, 743c, 776, 873, 937b, 1095, 1159, San Jose State University Museum of Paleontology.

Material and occurrence: eight specimens, from which 8 transverse and 5 longitudinal thin sections were produced, were available for study. These specimens were collected from Elko and White Pine Counties, NV; Power County, ID; Millard and Tooele Counties, UT; Inyo County, CA; and the Franklin Mountains, TX.

Discussion: the most diagnostic feature of this species is the nature of the septa. They are short and stubby, often exhibiting nothing more than slight bumps on the inner margin of the tabularium. The walls are quite thick and can be viewed as a diagnostic feature. As in other species of Thysanophyllum, the wide tabularium is a very distinctive characteristic.

Thysanophyllum sp. a n. sp.

Plate 9

External description: coralla are cerioid.

Transverse: corallites are polygonal with a diameter ranging from 4.0 mm to 12.0 mm; major septa are thin and wavy, ranging in number from 14 to 15 and extending 0.5 mm to 1.5 mm into the tabularium; tabularium ranges from 4.0 mm to 5.0 mm in diameter; dissepimentarium 3.0 mm in width, consists of up to 3 rows of lonsdaleoid dissepiments; a thin, straight column may be present; some dilation of septa is observed; the wall is of medium thickness.

Longitudinal section: dissepiments occur in 1 to 3

ranks, are slightly curved to curved and number about 14 per centimeter; tabulae number about 14 per centimeter and are wavy.

Morphologic variations: morphologic variety 13 dominates in this species and is unknown in any other Permian species of Thysanophyllum.

Specimens: SJS 1102, San Jose State University Museum of Paleontology.

Materials and occurrences: One specimen from which 1 transverse and 1 longitudinal thin section were produced was available for study. This specimen was collected from the Franklin Mountains, TX.

Discussion: this species is characterized by an unusually wide dissepimentarium, which distinguishes it from the all other species of Thysanophyllum. Morphological affinities place this specimen within the category of Thysanophyllum, although the large dissepimentarium and the presence of a column might possibly place it within a new genus.

Protowentzelella simplex Porfiriev, 1941

Plates 10 & 11

Protowentzelella simplex Porfiriev, (in Soshkina, Dobrolyubova and Porfiriev, 1941) p. 262, plate 41.

External description: coralla are cerioid.

Transverse section: corallites are polygonal with a diameter ranging from 3.0 mm to 8.0 mm; major septa are

short and dilated at the base, extending 0.5 mm to 1.5 mm into the tabularium and ranging in number from 12 to 19; tabularium ranges from 4.0 mm to 5.0 mm in diameter; dissepimentarium 0.5 mm in width, consists of 1 to 2 rows of moderately sized lonsdaleoid dissepiments; lathlike columns commonly are connected to a long septum; corallite exhibits an outer wall of medium thickness.

Longitudinal section: dissepiments in 1 to 3 ranks, are slightly curved to curved, about 16 to 18 per centimeter; tabulae are flat to slightly curved, ranging in number from 13 to 18 per centimeter.

Morphologic variations: four morphologic variants (3, 13, 14 and 15) are recognized within colonies of this species. Morphologic variety 14 dominates in this species and comprises about 56% of all varieties in corallum SJS 1166a and 71% in corallum SJS 1107.

Specimens: SJS 675, 786, 1107, 1166a San Jose State University Museum of Paleontology.

Materials and occurrence: Four specimens from which 4 transverse and 5 longitudinal thin sections were produced were available for study. These specimens were collected from Elko and White Pine Counties, NV; and Franklin Mountains, TX.

Discussion: This genus was placed in the Durhaminidae by Hill (1981) but it is included here in the Thysanophyllinae because of the striking similarity of the

type species to other members of the Thysanophyllinae. The wide tabularium, short septa and narrow dissepimentarium are quite diagnostic. The only unusual attribute is the presence of a column commonly attached to a septum, although similar variants occur in other genera.

Genus STYLASTRAEA Lonsdale, 1845

Stylastraea tenuiseptata Fedorowski, 1965

Plates 12 & 13

Stylastraea tenuiseptata Fedorowski, 1965, p. 83, plate 27.

External description: coralla are cerioid.

Transverse section: corallites are polygonal and measure 4.0 mm to 9.0 mm in diameter; major septa are wavy, extend 0.5 mm to 3.0 mm into the tabularium and number 12 to 18; tabularium ranges from 4.0 mm to 5.0 mm in diameter; dissepimentarium is 1.0 mm to 2.0 mm in width and consists of 2 to 3 rows of non-lonsdaleoid dissepiments; thin lathlike column is present in some specimens; dilation of septa is not observed; walls are very thick.

Longitudinal section: dissepiments are curved and crescent-like, in 1 to 2 rows and range from 14 to 20 per centimeter; tabulae range from 16 to 20 per centimeter and are flat to slightly curved upward, some are interrupted by an axial plate.

Morphologic variations: two morphologic variants (17 and 18) are recognized within colonies of this species.

Morphologic variety 17 comprises 53% of all varieties in corallum SJS 1087c and 64% in corallum SJS 907.

Specimens: SJS 568, 585, 684, 710, 719, 740, 743a, 789, 801, 818, 834d, 836, 853, 856, 879, 907, 910, 921, 1049c, 1049e, 1087b, 1087c, 1087g, 1106, 1112, 1120, 1124, 1126, 1128, 1136, 1157, 1158, 1166b San Jose State University Museum of Paleontology.

Materials and occurrences: Thirty-three specimens from which 39 transverse and 28 longitudinal thin sections were produced were available for study. These specimens were collected from White Pine County, NV; Millard and Grassy Counties, UT; Inyo County, CA; and the Franklin Mountains, TX.

Discussion: This coral is characterized by most septa extending to the wall, its unique "spiderweb" appearance in the dissepimentarium, and rather thin wispy wavy septa. Some corallites have a lathlike column. S. rowetti resembles S. tenuiseptata but has a slightly narrower tabularium and does not possess the intricate septal pattern.

Genus SCIOPHYLLUM Harker & McLaren, 1950

Sciophyllum mulleri Wilson & Langenheim, 1962

Plates 14 & 15

Sciophyllum mulleri Wilson & Langenheim, 1962, p. 513, plate 88.

External description: coralla are cerioid.

Transverse section: corallites polygonal with a diameter of 5.0 mm to 11.0 mm; major septa commonly lacking when developed are 11 to 18 in number, are thin and wavy, and extend 0.25 mm to 1.0 mm into the tabularium; tabularium 3.0 mm to 7.0 mm in diameter; dissepimentarium 1.0 mm to 2.0 mm in width, consists of 1 to 2 rows of lonsdaleoid dissepiments; columns are not present; the corallite walls are of medium thickness.

Longitudinal section: dissepiments are slightly curved to curved, occur in 1 to 2 ranks, and range from 10 to 18 per centimeter; tabulae 16 to 28 per centimeter, are flat to slightly curved, and are generally complete.

Morphologic variations: three morphologic variations (8, 9 and 10) are recognized within colonies of this species. Morphologic varieties 9 and 10 are dominant. Morphologic varieties 9 and 10 comprises 53% of all varieties in corallum SJS 1099 and 68% of all varieties in corallum SJS 1113. Morphologic variety 3 is also seen in SJS 1113.

Specimens: SJS 525, 731, 744, 802, 1072, 1099, 1113, 1143 San Jose State University Museum of Paleontology.

Materials and occurrence: Eight specimens from which 8 transverse and 6 longitudinal sections were produced were available for study.

Discussion: septa are virtually non-existent or generally are very short. This characteristic distinguishes

species of the genus Sciophyllum. In longitudinal section the tabulae are very flat and relatively evenly spaced. Dissepiments are also flat and evenly spaced.

Genus A n. gen. sp. a n. sp.

Plate 16

External description: the single corallum is partially aphroid.

Transverse section: corallites are generally polygonal but have incomplete outer walls; diameter is 4.0 mm to 7.0 mm; major septa range from 18 to 20 in number and extend 0.5 mm to 1.0 mm into the tabularium; tabularium is 4.5 mm in diameter; dissepimentarium 0.5 mm in width, consists of 1 row of lonsdaleoid dissepiments; column is not present; the corallite wall, which shows small gaps, is of medium thickness.

Longitudinal section: dissepiments are slightly curved to curved, about 12 per centimeter; tabulae are slightly curved and are in some instances incomplete, about 18 per centimeter.

Morphologic variations: morphologic variety 11 dominates in this species. This variety is not known in any other species or genus.

Specimens: holotype SJS 640, San Jose State University Museum of Paleontology.

Materials and occurrence: One sample from which 1

transverse and 1 longitudinal thin section were produced was available for this study. This specimen was collected from White Pine County, NV.

Discussion: this specimen exhibits a deterioration of the wall which is the defining characteristic of this new genus. The characteristic wide tabularium with septa extending only a short distance into the tabularium is the primary reason for its being assigned to the Subfamily Thysanophyllinae. This specimen was collected from the Lower Leonardian Arcturus Formation. This stratigraphic position probably is higher than that of any other specimens and apparently represents the final stage of evolution in this group.

PLATES

PLATE 1

Figures 1-2   Thysanophyllum aseptatum. Transverse and
longitudinal sections. SJS 1127 (x4);
Franklin Mountains, TX.

1

2

PLATE 2

Figures 1-2   Thysanophyllum aseptatum. Transverse and longitudinal sections. SJS 727 (x4); Elko County, NV.

1

2

PLATE 3

Figures 1-2   Thysanophyllum cystosum. Transverse and
longitudinal sections. SJS 1148 (x4);
Franklin Mountains, TX.

1

2

PLATE 4

Figures 1-2   Thysanophyllum cystosum. Transverse and
longitudinal sections. SJS 1131 (x4);
Franklin Mountains, TX.

1

2

PLATE 5

Figures 1-2   Thysanophyllum giganteum. Transverse and longitudinal sections. SJS 711 (x4); Inyo County, CA.

1

2

PLATE 6

Figures 1-2   Thysanophyllum giganteum. Transverse and
longitudinal sections. SJS 871a (x4); Inyo
County, CA.

1

2

PLATE 7

Figures 1-2   Thysanophyllum perpastum. Transverse
and longitudinal sections. SJS 743c (x4);
Millard County, UT.

1

2

PLATE 8

Figure 1   Thysanophyllum perpastum. Transverse
section. SJS 1095 (x4); White Pine County,
NV.

PLATE 9

Figures 1-2   Thysanophyllum sp a. n. sp.. Transverse and
longitudinal sections. SJS 1102 (x4);
Franklin Mountains, TX.

1

2

PLATE 10

Figures 1-2   Protowentzelella simplex.   Transverse
and longitudinal sections.   SJS 1166a (x4);
White Pine County, NV.

1

2

PLATE 11

Figures 1-2   Protowentzelella simplex. Transverse
and longitudinal sections. SJS 1107 (x4);
Franklin Mountain, TX.

1

2

PLATE 12

Figure 1-2 Stylastraea tenuiseptata. Transverse
and longitudinal sections. SJS 1087c (x4);
Inyo County, CA.

1

2

PLATE 13

Figure 1   Stylastraea tenuiseptata. Transverse
section. SJS 907 (x4); Inyo County, CA.

PLATE 14

Figures 1-2   Sciophyllum mulleri. Transverse and
longitudinal sections. SJS 1099 (x4);
Franklin Mountains, TX.

1

2

PLATE 15

Figure 1   Sciophyllum mulleri. Transverse section. SJS
1113 (x4); Franklin Mountains, TX.

PLATE 16

Figures 1-2   Genus A n. gen. sp. a n. sp.. Transverse and longitudinal sections. SJS 640 (x4); White Pine County, NV.

1

2

APPENDIX A

Locality Register

SJS 590 - Clark County, NV.

SJS 583, 616, 675, 717, 727, 731, 744, 802 - Elko County,
NV.

SJS 585, 607, 640, 940b, 1072, 1094, 1095a, 1166a, 1166b, -
White Pine County, NV.

SJS 636, 851, 874, 881 - Power County, ID.

SJS 719, 740, 743a, 743b, 743c, - Millard County, UT.

SJS 853 - Grassy County, UT.

SJS 676 - Tooele County, UT.

SJS 568, 684, 699, 704, 710, 711, 768, 770, 771, 776, 801,
818, 822, 825, 830, 832, 834a, 834b, 850, 856, 858, 868b,
869a, 869b, 871a, 873a, 873b, 879, 891, 903a, 903b, 905,
907, 910, 911, 921, 937b, 1020, 1049c, 1049e, 1074c, 1087b,
1087c, 1087d, 1087g, 1150, 1155, 1156, 1157, 1158, 1159 -
Inyo County, CA.

SJS 781, 785, 786, 787, 788, 789, 790, 1096, 1097, 1098,

1099, 1100, 1101, 1102, 1103, 1104, 1105, 1106, 1107, 1108,
1109, 1110, 1111, 1112, 1113, 1114, 1115, 1117, 1118, 1119,
1120, 1122, 1123, 1124, 1125, 1126, 1127, 1128, 1129, 1130,
1131, 1132, 1133, 1134, 1135, 1136, 1137, 1138, 1139, 1140,
1141, 1142, 1143, 1144, 1145, 1146, 1147, 1148, 1149, 1151,
1153, 1154 - Franklin Mountains, West Texas.

SJS 836 - British Columbia, Canada.

All SJS numbers refer to localities from which specimens were collected. More detailed locality information is available in the Museum of Paleontology, San Jose State University.

APPENDIX B

Data used in computer analysis (for key to abbreviations see page 98).

SJS	DIA	NOS	LOS	LON	COL	SOD	NOD	DPC	TPC	SOT	SOC	LIT	WOD	DIL	TOW
640	6	20	.5	1	2	3	1	12	18	1	1	0	.5	2	2
607	6	15	1	1	2	3	2	20	22	2	1	0	2	2	1
676	6	15	1	2	2	0	0	26	0	2	1	0	2.5	1	2
744	4	14	.5	1	1	3	1	18	28	2	0	0	2	3	2
616	7	17	1	1	1	3	2	22	18	1	0	0	2	1	3
1151	6	14	.5	1	2	3	1	17	20	1	1	2.5	1	2	2
711	10	16	1	1	2	1	2	16	16	1	2	0	2	2	2
874	6	15	.5	1	1	0	2	0	0	0	0	0	2	3	3
802	6	18	.5	1	2	3	1	18	18	2	1	0	1	2	1
731	5	0	0	1	1	0	1	0	16	1	0	0	1	1	2
743b	6	22	1	1	2	3	2	18	13	1	3	0	1.5	2	3
903a	5	14	1	1	3	0	2	0	0	0	1	0	1	1	1
1107	6.5	12	.5	1	2	2	1	16	18	1	2	1.5	1.5	2	2
1149	6	14	1	1	2	3	1	16	18	1	1	2.5	1	2	2
868b	6	16	.5	1	1	2	1	16	16	1	0	0	1	1	1
869b	7	16.5	.5	2	1	0	0	0	0	0	0	0	1	2	2
871a	7	15	.5	1	2	3	2	24	24	1	1	0	2.5	2	2
873a	6	14	.8	1	1	3	1	14	20	1	1	0	1	1	1
873b	8	15	.8	1	1	1	1	14	12	2	0	0	2	1	1
1074c	5.5	0	.5	1	1	3	1	10	18	1	0	0	1.5	1	1
1087d	6	14	.8	1	1	3	1	18	22	1	0	0	1	1	2
905	6	14	1	1	1	3	2	16	20	2	0	0	1.5	2	1
858	6	17	.5	1	1	3	1	16	10	2	0	0	.5	2	1

SJS	DIA	NOS	LOS	LON	COL	SOD	NOD	DPC	TPC	SOT	SOC	LIT	WOD	DIL	TOW
1142	5	16.5	1	1	1	3	1	12	18	1	0	0	2	2	1
1141	4.5	14	.5	1	1	0	1	0	0	0	0	0	1	1	1
1153	6	14	.5	1	1	3	1	14	18	1	0	0	2	2	3
1138	4.5	16	.5	1	1	0	1	0	0	0	0	0	1	1	3
1134	6	12	.5	1	1	3	1	16	14	1	0	2	.5	2	1
1133	4.5	12	.5	1	1	0	1	0	0	0	0	0	1	1	1
1102	8	14	.5	1	1	3	1	14	14	1	0	2	2	2	2
1144	6	13	1.3	2	1	0	0	0	0	0	0	0	1.5	2	3
1104	5	15	.8	1	2	3	1	22	16	1	1	0	1	2	3
1148	5.5	18	1	1	1	3	1	16	10	1	0	0	1	2	2
1145	4.5	15	1.3	1	2	3	1	20	14	1	1	0	1.5	1	3
1130	6	16	.5	1	1	3	1	18	16	2	0	0	1.5	2	1
1113	5.5	11	.5	1	1	0	2	0	0	0	0	0	1	1	2
1109	5	13	.5	1	1	0	1	0	0	0	0	0	1.5	2	2
1132	5.5	14	.5	1	1	3	1	20	12	1	0	0	2	1	2
1129	4.5	12	.5	1	1	3	1	16	16	2	0	0	1.5	1	1
1105	5.5	12	1	1	2	1	1	20	16	2	1	0	1.5	1	2
1100	5	12	.8	1	1	3	1	18	0	2	0	0	1.5	1	1
1098	6	14	1.3	1	1	3	1	22	14	1	0	0	1	1	2
1097	6	15	.5	1	2	3	1	20	18	1	1	0	1	1	1
785	8	17	1.3	1	2	3	1	12	15	1	1	0	1	1	1
525	9	14	.3	1	1	3	1	10	10	1	0	0	2	1	3
583	5	15	.8	1	1	3	1	18	18	1	0	0	1	1	2

SJS	DIA	NOS	LOS	LON	COL	SOD	NOD	DPC	TPC	SOT	SOC	LIT	WOD	DIL	TOW
675	4	15	1	1	3	3	1	10	24	1	1	0	.5	1	3
717	8	17	.5	1	1	3	1	12	18	1	0	0	1.5	1	1
727	6	14	.3	1	1	3	1	24	28	2	0	0	1	1	2
787	6	16	1	1	1	3	1	16	22	1	0	0	.5	2	2
851	5	14	.5	1	1	3	1	14	18	2	0	0	.5	1	2
869a	7	14	.5	1	2	3	2	20	16	1	1	0	1	1	2
881	7	19	.5	1	1	2	2	14	20	1	0	0	1	1	2
903	6	15	.8	1	2	3	1	20	14	1	1	0	1	2	2
911	5	0	.5	1	2	0	1	0	0	0	1	0	.5	1	2
1096	5.3	13	1	1	1	3	1	18	14	1	0	0	1	2	3
1103	6.5	14	1	1	1	2	1	16	14	1	0	0	.5	1	2
1108	6.5	15	.5	1	1	0	1	0	0	0	0	0	2	1	1
1110	5.5	14	.5	1	1	3	2	22	14	1	0	0	2	1	2
1111	6	13	1	1	1	3	1	16	16	1	0	0	1.5	1	1
1115	6.5	12	.5	1	1	3	1	16	16	1	0	0	2.5	1	1
1117	7	13	1	1	1	0	1	0	0	0	0	0	2.5	1	2
1122	5.5	13	.5	1	2	0	1	0	0	0	1	0	.5	2	1
1127	7	13	.5	1	1	3	1	10	20	1	0	0	1	1	2
1131	7	12	.5	1	1	3	1	18	18	2	0	0	1.5	2	2
1146	5.5	13	.5	1	1	3	1	22	20	1	0	0	1.5	2	2
1154	5	0	.5	1	1	0	1	0	0	0	0	0	1	1	2
1166a	4.5	17	.5	1	1	2	1	16	18	2	1	0	.5	1	1
636	6	15	.5	1	1	3	1	12	12	2	0	0	1	1	3

SJS	DIA	NOS	LOS	LON	COL	SOD	NOD	DPC	TPC	SOT	SOC	LIT	WOD	DIL	TOW
743C	6	25	1	1	1	3	1	14	12	2	0	0	1	1	3
776	6	14	1	1	2	3	1	16	20	1	1	0	1	1	3
873	6	14	.5	1	1	0	1	0	0	0	0	0	1	1	2
879	9	18	1	1	2	3	2	0	18	2	1	0	1.5	1	2
937b	6	14	.5	1	1	3	1	12	14	1	0	0	1	1	2
1095	5	16	1	1	2	0	1	0	0	0	1	0	1	1	1
1159	6	16	.5	1	2	2	1	20	22	1	1	0	.5	1	2
568	6	14	1.3	1	1	3	1	18	16	2	0	0	2	1	1
585	6	14	1	2	1	3	1	10	22	1	0	0	2.5	1	2
684	6	17	1.5	2	1	0	0	0	0	0	0	0	1	1	3
710	8.5	16	2.5	1	1	2	1	12	16	1	0	0	2	1	1
719	6.5	15	1	1	2	0	1	0	0	0	1	0	2	1	2
740	7	14	1	1	2	0	1	0	0	0	1	0	1.5	2	2
743a	6	15	1.5	1	2	3	2	12	12	2	1	0	1	2	3
790	6	14	1.3	1	1	0	1	0	0	0	1	0	1	1	1
801	6	20	3	1	2	2	1	14	14	1	1	0	1.5	1	2
818	7	13	2	1	1	3	1	16	16	2	0	0	1.5	2	2
834d	4.5	13	.5	1	2	3	1	16	14	2	1	2	2	1	1
836	6	16	1	1	3	3	1	0	16	2	1	0	1	1	2
853	3.5	14	.5	1	3	3	1	14	14	2	1	0	1	1	2
856	8	2	14	1	2	3	1	16	18	3	1	0	1	2	2
879	7	15	1.3	2	1	0	0	0	0	0	0	0	2	1	2
907	6	17	1.3	2	1	0	0	0	0	0	0	0	2	1	2

SJS	DIA	NOS	LOS	LON	COL	SOD	NOD	DPC	TPC	SOT	SOC	LIT	WOD	DIL	TOW
910	7	17	.5	1	2	3	1	18	20	1	1	0	1.5	1	1
921	6	15	.5	1	2	3	1	18	20	1	1	0	2.5	1	2
1049c	7.5	26	2	2	1	0	0	0	0	0	0	0	2.5	1	2
1049e	7.5	17	.5	1	2	3	1	26	16	1	1	0	0	0	0
1087b	7.5	17	1.3	1	3	3	1	20	28	1	1	0	2.5	2	2
1087c	4.5	19	1.5	2	2	3	0	18	22	2	1	0	2	1	2
1087g	7	16	2	2	2	3	0	20	16	1	1	0	2	1	2
1106	5	12	1	2	1	3	0	18	12	1	0	0	1.5	1	3
1112	5	14	1	1	1	0	1	0	0	0	0	0	1	1	2
1120	5	15	1.3	1	1	2	1	16	16	1	0	0	1	1	2
1124	6	14	1.3	1	1	0	1	0	0	0	0	0	1	1	2
1126	6	13	1.3	1	1	3	1	12	18	2	0	0	1	1	2
1128	6	14	1	2	1	3	0	14	12	2	0	0	1.5	1	1
1136	5.5	16	1	1	1	2	1	12	16	1	0	0	1	1	1
1157	10	18	.5	1	2	3	1	16	0	0	1	3	2	1	2
1158	8	16	1	2	1	3	0	14	16	1	0	0	1	1	2
1166b	6	17	1.3	1	2	3	1	18	18	1	1	0	1.5	1	1
1072	5	16	.5	1	1	3	1	14	16	2	0	0	1	1	3
1099	7.5	13	.5	1	1	3	1	10	16	1	0	0	1	2	2
1143	4.5	17	1	1	1	0	1	0	0	0	0	0	1.5	1	1
789	6	14	1	1	1	3	1	16	11	2	0	0	1	2	2
786	5.5	13	1	1	2	2	1	18	13	2	2	0	1	2	1

Abbreviations and codes used in computer analysis

DIA = diameter in millimeters

NOS = number of septa

LOS = length of septa in millimeters

LON = presence or absence of lonsdaleoid: 1=yes, 2=no

COL = presence or absence of column: 1=never, 2=seldom
3=often

SOD = shape of dissepiment: 1=flat, 2=slightly curved,
3=curved

NOD = number of ranks of dissepiments

DPC = dissepiments per centimeter

TPC = tabulae per centimeter

SOT = shape of tabulae: 1=flat, 2=slightly curved, 3=curved

SOC = shape of column: 1=flat, 2=slightly curved, 3=curved

LIT = length of major septa into tabularium in millimeters

WOD = width of dissepimentarium in millimeters

DIL = dilation of septa: 1=no, 2=little, 3=strong

TOW = thickness of wall in millimeters