COMPARATIVE VALUE OF FOURIER SHAPE, MOSAIC-STRUCTURAL, AND BINARY SKELETAL CHARACTERS IN A LATE DEVONIAN BRYOZOAN FAUNA (THREEFORKS FM., MONTANA)

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ABSTRACT

COMPARATIVE VALUE OF FOURIER SHAPE, MOSAIC-STRUCTURAL, AND BINARY SKELETAL CHARACTERS IN A LATE DEVONIAN BRYOZOAN FAUNA (THREEFORKS FM., MONTANA)

By

Dennis Prezbindowski

The purpose of this study is to introduce and examine the relationships among three independently derived sets of morphological characters in a Paleozoic stenolaemate bryozoan fauna. These characters including both intrazoarial means and standard deviations, are sources of biological information. The bryozoan fauna was collected from seven localities within the Upper Devonian Threeforks Formation (Famennian) of southwestern Montana. The fauna consisted of a usable sample of 61 zoaria. The three character sets are Fourier harmonic amplitudes, quantitative (multistate) nonfourier continuous variates, and binary (two-state) characters. R-mode principal components analysis of the six Fourier shape variables and nine quantitative variables reduced the data to the most independent sources of information which accounted for 86.3 percent of the variance observed within

the total sample used. Nine of the 15 selected characters were intrazoarial standard deviations. Fisher's exact probability matrix of association was generated for the 53 binary characters used. An R-mode factor analysis of this probability matrix showed that based, on their lack of association, 20 binary characters were the most independent. The residual character sets analyzed with Parks' (1970) R-mode and Q-mode program using simple distance based on principal component values with results illustrated in dendrogram form.

Four phenograms were produced using the three basic character sets and various combined sets of characters. The binary character set alone produced the best phenogram (nine misclassifications), followed by Fourier harmonic amplitudes (10 misclassifications) and the nonfourier continuous variates (15 misclassifications). The combined set of all characters produced five misclassifications. The use of intrazoarial standard deviations measures colony variation within a localized area. This variation is a measure of disorder within the measured area. These measures of variation generally captured more independent information than their associated means. The amount of disorder or variation can be related to the budding pattern. The results of this study strongly support the hypothesis that species have characteristic astogenetic variation patterns. This variation can be used to classify bryozoans. Binary and Fourier shape characters provide more independent information than the standardly used quantitative characters. The newly introduced quantitative characters of nearest neighbor statistc (controlled by budding) and interzooecial area per unit volume have proven to be two of the more important quantitative characters used. Through the use of these three independent character sets, Sokal and Sneath's (1963) Hypothesis of Nonspecificity appears to be only partially true. The resulting phenograms show only a tendence toward similiarity.

Two species dominated the bryozoan fauna of the Threeforks Formation, the trepostome Leptotrypella pellucida Duncan, and Nicklesopora renzettiae n. sp.. The fauna also includes two single specimens, a cystoporate (Fistulipora sp.), and an indeterminate phylloporinid. The unabraded zoaria of Leptotrypella and Nicklesopora invariably have very thin exozones, suggesting that periodic burial by terrigenous muds prevented the development of mature populations of these bryozoans.

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A THESIS

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Dedicated to my wife, Debbie,
for her help and understanding
throughout this study.

ACKNOWLEDGMENTS

Terry Chase, Jim Welch, and Philip Zink are to be thanked for their assistance in the collection phase of this study. I would like to thank Alan S. Horowitz, curator of the Indiana University Paleontological Collection, for making the loan of specimens in his custody. I would like to thank Sam Upchurch and Chilton Prouty for their constructive criticism of the manuscript. I would finally like to thank Robert L. Anstey for his timely suggestions, interest and perseverance in all phases of this study.

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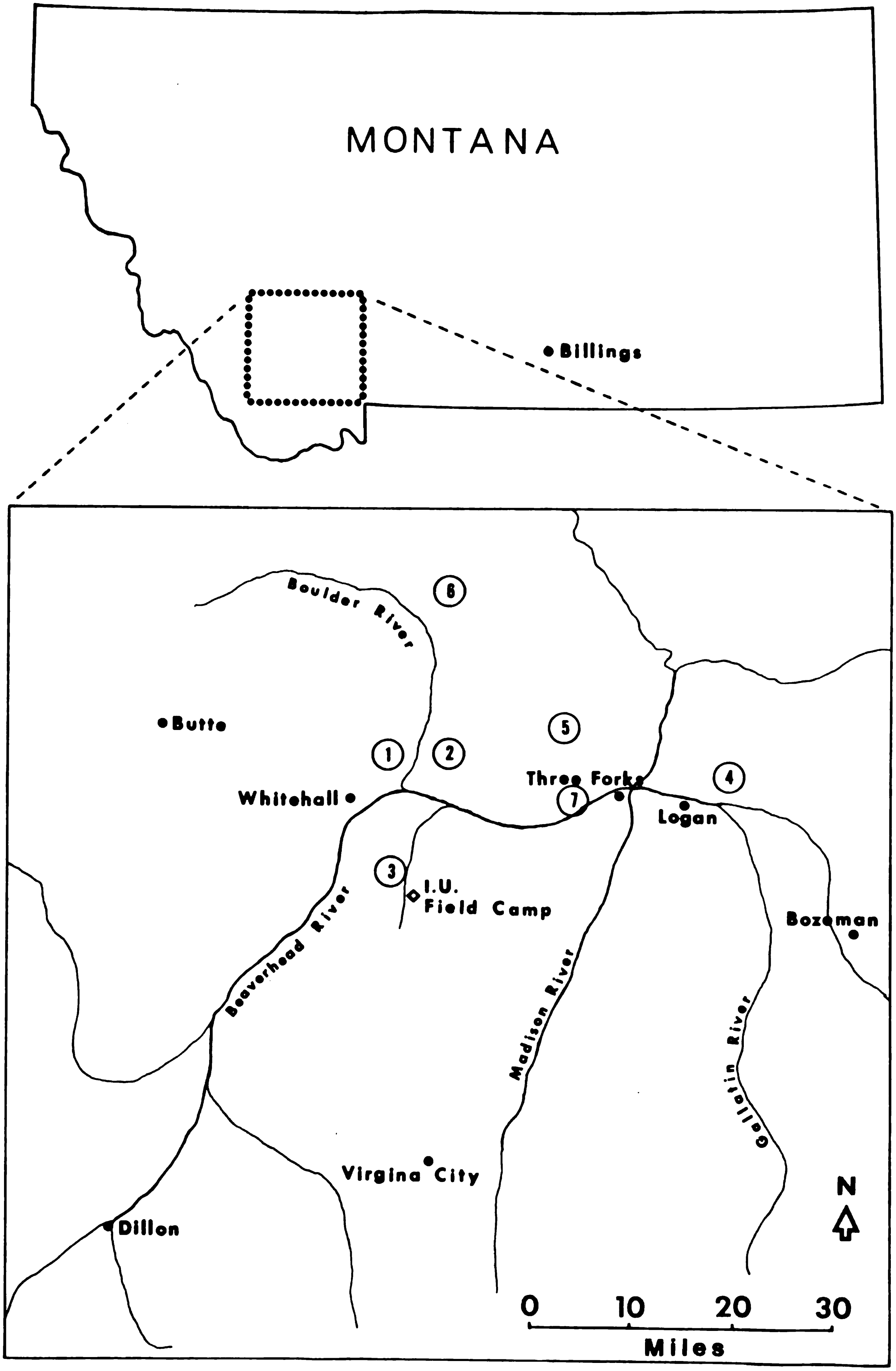
INTRODUCTION

The purpose of this study is to introduce and examine the relationships and information content of three independently derived morphological character sets in a stenolaemate bryozoan fauna. Secondly, a description and discussion of the bryozoan fauna from seven localities (Figure 1) in the Upper Devonian Threeforks Formation (Famennian) of southwestern Montana is based upon the analysis of the morphological information.

The character sets used in this study were designed to obtain information from as many aspects of a fossil bryozoan skelton as possible, including shape, spatial arrangement of individuals in the colony, measurements of internal structures, and coding of nominal state characters.

It is generally accepted now that Sokal and Sneath's (1963) Hypothesis of Nonspecificity, is only partially true (Sneath and Sokal, 1973). This hypothesis states "there are no distinct large classes of genes affecting exclusively one class of characters such as morphological, physiological, or ethological, or affecting special regions of the organism such as head, skeleton, or leaves" (Sokal and Sneath, 1963). The partial failure of this

Figure 1. Map showing location of the seven collecting localities (exact locations in Table 1).


MONTANA
Billings
Boulder River
Butte
Whitehall
Three Forks
Logan
I.U. Field Camp
Beaverhead River
Madison River
Gallatin River
Bozeman
Virgina City
Dillon
N
0
10
20
30
Miles
1
2
3
4
5
6
7

hypothesis is accepted, although the extent of this failure is subject to debate. Sokal and Sneath (1963) suggested a possible test for the hypothesis of nonspecificity. If separate classifications could be formed by the division of taxonomic characters into logically independent sets, testing their degree of concordance would test the theory of nonspecificity. This test may shed more light on this problem. The search for new descriptive characters and the evaluation of old as well as new characters within groups of organisms is essential to provide a meaningful basis for numerical taxonomic analysis. Because different parts of an organism carry varying degrees of independent information, an R-mode intercharacter analysis is necessary to understand this distribution.

In most numerical taxonomic studies the investigator is faced with several basic questions; how many characters should be measured and which characters will provide the most independent information? Generally the answer to the former question is determined by the structural complexity of the organism and the time and resources of the investigator. Michener and Sokal (1966) stated "The number of characters to be recorded and used is a problem in both orthodox and numerical taxonomy. Further studies are badly needed to determine how many characters are likely to be sufficient to satisfactorily classify groups of various sizes." This problem remains unsolved and because it is not the object of this study, it will not be treated further. The latter question presupposes the existence and use of a large number of taxonomic characters and methods of measurement. In terms of provious bryozoan studies, such is not the case and only a dozen or so measurements are generally used. As noted by Oxnard (1969), numerical taxonomy is an attempt to delineate mathematically, shape as a means of classification. The more precisely we can define the shape both internally and externally, the more taxonomic information can be retrieved. Throckmorton (1968) demonstrated that different taxonomic characters carry different amounts of independent information. The use of characters should be justified by R-mode analysis to determine whether standard or newly introduced characters contribute significant independent information. This study intends to focus on these questions.

MATERIAL

The fauna used in this study was collected from seven localities in the trident member of the Threeforks Formation (Upper Devonian) of southwestern Montana (Figure 1). This formation extends from southwestern and central Montana through southeastern Idaho. The characteristic lithology is reddish and yellow brown argillaceous shale with numerous lenticular beds of greenish gray argillaceous limestone. The Threeforks Formation is underlain by the Jefferson Formation, (Middle Devonian) and overlain by the spongiostromated bearing sandstone, and shale of the Sappington Formation (Upper Devonian). The bio-stratigraphic position of the Threeforks Formation is with the Scaphignathus subserratus-Pelekysgnathus inclinatus conodont zone, and the upper Polygnathus styriacus conodont zone of the Upper Famennian Stage (Klapper, 1971).

The bryozoan fauna was collected from weathered slopes, The general scarcity of good material necessitated the use of purposeful sampling of as many weathered exposures as were easily accessible in the study area. Additional specimens were obtained from the Renzetti (1963) material, in the Paleontological Collections of Indiana University.

A sample of 134 specimens were sectioned using standard sectioning techinques from the seven localities collected. A severe limitation was placed on the amount of material that could be sectioned and feasibly studied because preservation was generally poor. Siderite and pyrite replacement had occured to varying degrees in nearly all material, making the zoaria brittle and difficult to section. Many of tha colonies have had their axial areas bored out by other organisms (Plate 1, Figure 7), resulting in crushing and varying degrees of distortion of the zoaria during postdepositional compaction of the sediments. Only 61 sectioned specimens were suitable for study on the basis of their quality. Unfortunately certain localities were better represented than others by this method of selection (Table 1).

Table 1. Localities and Specimen Distribution, Indiana University accession numbers.

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1. Red Hill

NW¼, NW¼, SE¼, Sec. 22, T2N, R3W Jefferson Island Quad. Montana.

Nicklesopora renzettiae: figured paratypes 6102-1, 6103-19, 6102-2, 6104-1; unfigured paratypes 6101-R, 6102-3R, 6103-1R, 6103-9, 6103-12, 6103-13R, 6103-24, 6103-32, 6103-47, 6103-48, 6103-49, 6103-50, 6101-R; unfigured specimens 6102-2, 6103-15, 6103-19, 6103-31, 6103-33, 6103-36, 6103-38, 6103-42, 6105-15

Leptotrypella pellucida: figured hypotypes 6100-R, 6103-20, 6103-22R, 6103-43; unfigured hypotypes 6102-3, 6103-1, 6103-4, 6103-5, 6103-6, 6103-7, 6103-11, 6103-13, 6103-21, 6103-22, 6103-23, 6103-27, 6103-28, 6103-29, 6103-30, 6103-45; unfigured specimens 6102-1, 6102-4, 6103-3, 6103-2, 6103-8, 6103-10, 6103-14, 6103-16, 6103-18, 6103-25, 6103-26, 6103-34, 6103-37, 6103-39, 6103-40, 6103-41, 6103-46, 6103-48, 6105-33.

2. Mt. Doherty

Sec. 21, T2N, R2W Jefferson Island Quad. Montana.

Nicklesopora renzettiae: figured holotype 6107-1; unfigured paratypes 6105-11, 6105-18, 6105-23, 6108-10, 6108-12; unfigured specimens 6104-1, 6104-2,

Table 1. Continued.

6105-3, 6105-4, 6105-6, 6105-8, 6105-17, 6105-20, 6105-25, 6105-27, 6105-29, 6105-31, 6105-34.

Leptotrypella pellucida: unfigured hypotypes 6105-1, 6105-9, 6105-12, 6105-13, 6105-14, 6105-19, 6105-21, 6105-22, 6105-24; unfigured specimens 6105-2, 6105-7, 6105-10, 6105-16, 6105-26, 6105-28, 6105-30, 6105-32, 6108-11.

3. Carmichael

Sec. 33, T1N, R3W Jefferson Island Quad. Montana

Inadequate material for sectioning

4. Logan Gulch

SE¼, Sec. 25 T2N, R2E Manhattan Quad. Montana

Nicklesopora renzettiae: figured paratype 6105-R; unfigured specimens 6107-3, 6107-4.

Leptotrypella pellucida: unfigured hypotype 6107-2; unfigured specimen 6107-1.

Phyloporinid: 6107-5. figured.

5. Nada Mine

SE¼, Sec. 5, T4N, R1W Radersburg Quad. Montana

Nicklesopora renzettiae: unfigured paratype 6108-2.

Leptotrypella pellucida: unfigured hypotype 6108-1; unfigured specimen 6108-3.

Table 1. Continued.

6. Horse Gulch

NW¼, SW¼, Sec. 6, T5N, R2W Devils Fence Quad. Montana

Leptotrypella pellucida: unfigured specimens 6109-1, 6109-2, 6109-3, 6109-4, 6109-5, 6109-6, 6109-7, 6109-10, 6109-11, 6109-12.

7. Milligan Canyon

SW¼, NE¼, Sec. 36, T2N, R1W Threeforks Quad. Montana

Nicklesopora renzettiae: unfigured paratypes 6111-3, 6111-4, 6110-1; unfigured specimens 6110-2, 6110-3, 6110-6, 6111-2.

Leptotrypella pellucida: figured hypotype 6110-9; unfigured hypotype 6110-8; unfigured specimens 6110-4, 6110-5, 6110-10, 6110-11, 6111-1.

Fistulipora sp. figured 6110-7.

METHODS

Fourier Shape Analysis

The Fourier method of shape characterization (harmonic analysis) was first developed and used in studies of closed forms in geology by Ehrlich and Weinberg (1970). Recently Anstey and Delmet (1972, 1973), and Delmet and Anstey (1974) have demonstrated applications of this method to the study of fossil, tubular bryozoans. Descriptions of the underlying mathematics and techniques are provided in the four previously cited papers and Davis (1973). The important aspect of this particular Fourier method is the quantification of closed form shapes as a series of independent harmonic amplitudes (Appendix 2).

Twenty, randomly selected, zooecial outlines from the tangential section of each specimen were visually centered and traced onto a starburst pattern. The starburst consisted of 48 equiangular lines radiating from a center point at 7.5 degree intervals. The intersections of the traced outline and the radiating lines of the starburst pattern were automatically digitized and punched in Cartesian coordinates. The punched coordinates for the 20 outlines of each specimen were used as input to program Fourier (Appendix 2). A zoarial mean and intrazoarial standard deviation for the harmonics amplitudes 2-20 and the normalized roughness coefficient were subsequently calculated from the 20 shape replicates per zoarium (zoarium = thin section). The roughness coefficient is the square root of one half the sum of the squared normalized Fourier coefficients (Ehrlich and Weinberg, 1970). In calculating the roughness coefficient, all Fourier amplitudes are normalized by dividing each value by its overall mean in the entire sample.

Quantitative Measurements

Thirteen quantitative characters were randomly and repetitively measured 20 times in each speimen, nine of these measures are shown in (Figure 2). These characters include several that are commonly used by bryozoan taxonomists, as for example, those used by Cuffey (1967). Measurements were made on a projected image of the slide on a horizontal screen. Means and intrazoarial standard deviations of the 20 replicates per character per specimen were calculated and punched onto cards for later analysis. Mean radius is the average length of the 48 radial lines from the calculated center of gravity to the zooecial margin for each zooecial shape. The mean and standard deviation of the mean radius were calculated for each section.

Included in the quantitative data was the calculation of the nearest neighbor statistic. This statistic, developed by Clark and Evans (1954) in plant ecology,

Figure 2. Diagrammatic illustration of Non-Fourier quantitative characters measured.

A. Characters measured in tangential section; DA, diameter of acanthopores; ZWT, zooecial wall thickness; APZ, acanthopores per zooecium.

B, C. Characters measured in longitudinal section; AN, angle at which zooecial tubes meet surface of colony; DLC, depth of living chamber (mm); NDPR, number of diaphrams in axial region per 2.5 mm. distance; DAR, diameter of endozone (mm); TMR, thickness of exozone (mm). See table 2 for discription of quantitative and Fourier shape characters.

ter

nm).

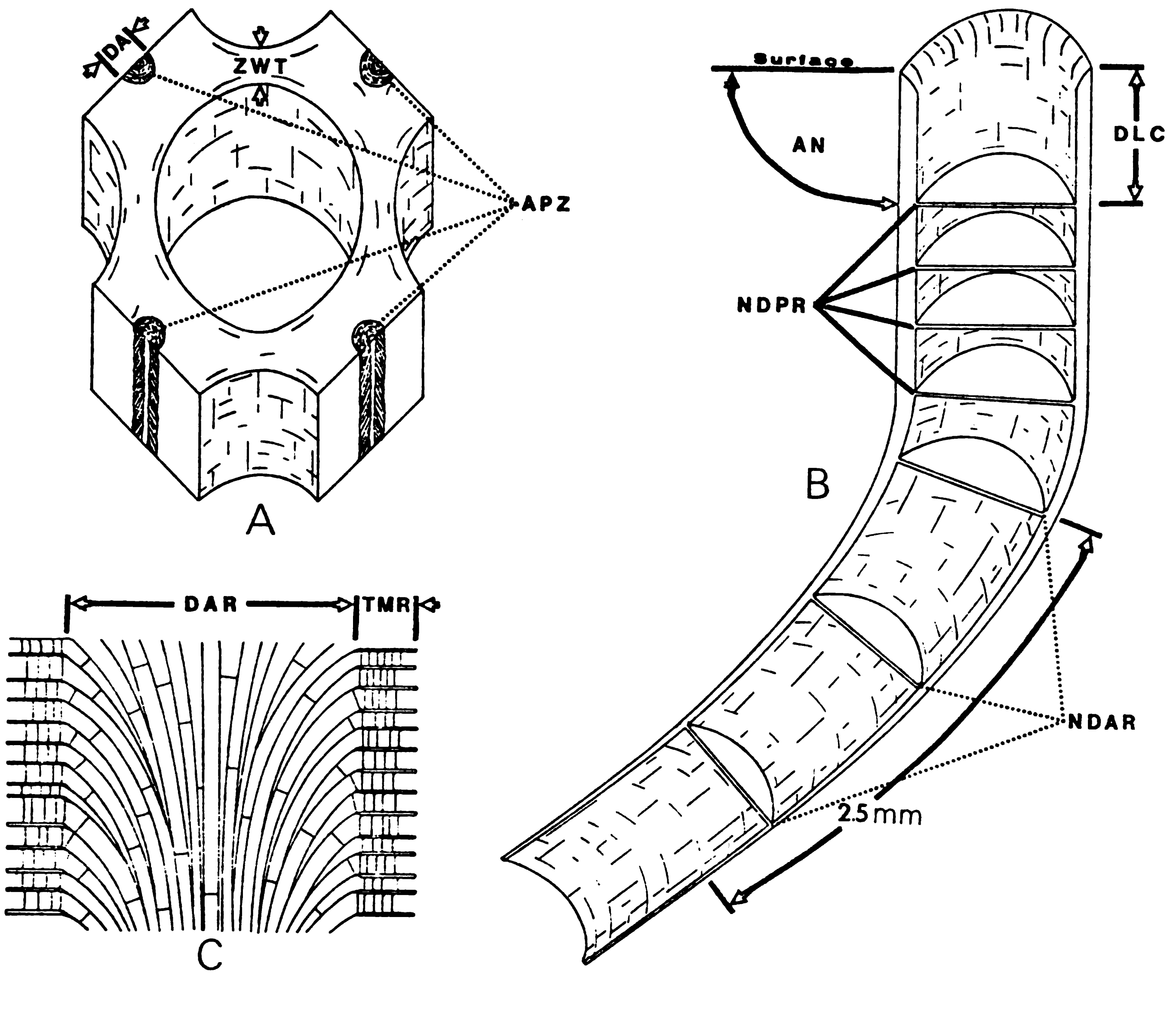


Table 2. Fourier shape and standard quantitative characters, all means and standard deviations are based on 20 random measurements per colony, see appendix 3 for raw data of the 61 specimens studied.

ZRM	Zooecial Radius, Mean (mm)
ZRS	Zooecial Radius, Standard Deviation
ZWTM	Zooecial Wall thickness, Mean (mm)
ZWTS	Zooecial Wall Thickness, Standard Deviation
APZM	Number of Acanthopores per Zooecium Mean (mm)
APZS	Number of Acanthopores per Zooecium, Standard Deviation
TMRM	Thickness of Exozone, Mean (mm)
TMRS	Thickness of Exozone, Standard Deviation
DARM	Diameter of Endozone, Mean (mm)
DARS	Diameter of Endozone, Standard Deviation
ANM	Angle at which Zooecial Tubes meet Surface of Colony, Mean (degrees)
ANS	Angle at which Zooecial Tubes meet Surface of Colony, Standard Deviation
NDPRM	Number of Diaphragms in the Exozone, Mean
NDPRS	Number of Diaphragms in the Exozone, Standard Deviation
NDARM	Number of Diaphragms in the Endozone per 2.5 mm Distance, Mean
NDARS	Number of Diaphragms in the Endozone per 2.5 mm Distance, Srandard Deviation
DLCM	Depth of Living Chamber, Mean (mm)
DLCS	Depth of Living Chamber, Standard Deviation

Table 2. Continued.

DAM	Diameter of Acanthopores, Mean (mm)
DAS	Diameter of Acanthopores, Standard Deviation
AREAM	Interzooecial Surface Area per cubic mm, Mean
AREAS	Interzooecial Surface Area per cubic mm, Standard Deviation
NNS	Nearest Neighbor Statistic
HM2 to HM20 -	Harmonic Mean 2 through Harmonic Mean 20
HS2 to HS20 -	Harmonic Standard Deviation 2 through Harmonic Standard Deviation 20
RCM	Roughness Coefficient, Mean
RCS	Roughness Coefficient, Standard Deviation

was used to quantify the spatial arrangement of zooecia in the colony. A randomly selected location on the tangential section was projected onto a horizontal screen. The center points of all neighboring zooecia were visually located and marked, to attain a standard sample size of 33 in a roughly circular area. A noncircular sample area would strongly bias the result. The spatial patterns of the zooecial centers for each specimen were digitized and punched in Cartesian coordinates. The nearest neighbor statistic was calculated from these data by the NABOR module of the GEOSYS package (Wittick, 1973).

Interzooecial Surface Area

Zooecial tubes in the mature region of a colony can be thought of as a series of dispersed particles or empty volumes in a matrix of skeletal material. The surface area of zooecial walls to skeletal volume can be quantified by the following equation: SV = 4Nl (mm^2 / mm^3). The surface area per cubic mm is equal to four times the number of zooecial tubes to skeletal wall intersections in a random 1 mm line in tangential section (Nl). This method is discussed in detail by Underwood (1970). This method provides an absolute measure of surface area only for randomly oriented sections. Because tangential sections are not random in orientation, the measurement is only relative, but serves as a compariative statistic. The intersects for each of the 20 random 1 mm lines were counted and averaged. This average number of intersections was used to calculate the surface area per cubic mm for each specimen.

Binary Characters

Fifty-three binary characters (Table 3) were choosen from a list of 150 binary characters used by Eftaxiadis (1973). Characters were scored one for positive and zero for negative statement responses. The characters not used were redundant in all of the Threeforks material.

Table 3. Binary characters taken from Eftaxiadis (1973), characters were scored one for positive response and zero for negative response, see Appendix 3 for raw binary data values for the 61 specimens studied.

I. Characters of Zoarial Growth

A. Budding Patterns

1. Zooecia arranged in longtdinal rows, parallel to long axis of zoarium.

2. Zooecia arranged in diagonal rows, oblique to long axis of zoarium.

3. Budding of new zooecia mostly limited to base of colony.

4. Intercalated budding particularly prominent in vicinity of endozone-exozone boundary.

5. Zoarial growth characterized by numerous rejuvenated zones (recurrent mature zones) of zones of iterative budding, commonly containing brown bodies just posterior to plane of rejuvenation.

B. Nonzooidal Colony Structures

7. Longitudinal ranges of zooecia separated by continuous dark line in wall.

8. Dark lines in wall forming unbroken polygons around each zooecial aperture.

II. Characters Observable in Tangential Section

A. Zooecial Apertural Outlines

9. Circular or elliptical to subpolygonal, having rounded corners.

10. Polygonal, having angular corners.

Table 3. Continued.

11. More elongate than equidimensional.

12. Rhombic or quadrate.

13. Pentagonal or hexagonal.

14. Invaginated, having a kidney, peanut or dumbbell shape.

B. Zooecial Size and Spacing

15. Maximum intermacular diameter generally greater than 0.15 mm.

16. Maximum intermacular diameter generally greater than 0.20 mm.

17. Maximum intermacular diameter generally greater than 0.25 mm.

18. Minimum intermacular diameter generally greater than 0.20 mm.

19. Maximum interzooecial distance generally greater than one zooecial diameter.

C. Wall Structure

20. Dark divisional line in wall in thick-walled areas between adjacent zooecial apertures.

21. Wall amalgamate, having bread nonlaminated central area in wall in thick-walled areas between adjacent zooecial apertures.

22. Apertural walls lined by sharply differentiated peristome or cingulum.

23. Maximum wall thickness between adjacent zooecial apertures generally greater than 0.04 mm.

D. Intrazooecial Structures

25. Single cystiphragms or curved diaphragms very large, generally constricting more than one third of zooecial aperture.

Table 3. Continued.

E. Acanthopores

26. Small dark spots observable at junction angles of intergrated walled zooecial apertures.

27. Acanthopores of junction angles of most adjacent zooecial apertures.

28. Acanthopores numerous, ringing zooecial apertures.

29. Centered acanthopores common along zooecial walls.

30. Acanthopores differentiated into two distinct size classes (endacanthopores and exacanthopores, or magacanthopores and micracanthopores).

31. Lumen diameter generally greater than one-half acanthopore diameter.

32. Generally more than two acanthopores associated with each zooecial aperture.

33. Acanthopore diameter (of larger class if bimodal) generally greater than 0.03 mm.

III. Characters Observable in Longitudinal Section

A. Zooecial Geometry

34. Zooecia in exozone inclined at less than 60 degrees to zoarial surface.

35. Zooecia displaying conspicuous bend at endozone-exozone boundary.

36. Zooecia in overgrowth layers displaying short recumbent endozone.

B. Wall Structure

37. Zooecial walls crenulated in endozone.

38. Zooecial walls granular appearing, may be poorly laminated locally.

39. Wall laminae sharply arched, resembling inverted V's, not broadly convex outward (as seen in thick-walled regions of monilae).

Table 3. Continued.

40. Zooecial walls generally amalgamate, lacking divisional line.

41. Amalgamate wall structure, area of central flexure broad with respect to total wall thickness.

42. Amalgamate wall structure, portions of wall laminae parallel to zooecial length extending posteriorly for a distance greater than one zooecial diameter.

43. Diaphragm laminae continuous across two or more adjacent mesopores or zooecia, representing an unconformity in laminar deposition.

44. Zones of wall laminae separated anteriorly and posteriorly by growth unconformities, the laminae of which do not pass into any diaphragms.

45. Diaphragm (or cystiphragm or hemiphragm) laminae forming lining inside zooecial walls passing upward beneath one or more diaphragms and merging anteriorly with mural laminae, producing a structure resembling a stack of nested tumblers.

C. Diaphragms

47. Diaphragms present in endozonal portions of most zooecia.

48. Distance between successive diaphragms in exozone generally less than one zooecial diameter.

49. Depth of living chamber generally greater than one zooecial diameter.

50. Most diaphragms oriented obliquely to zooecial walls.

51. Most diaphragms slightly curved, concave outward.

52. Most diaphragms slightly curved, convex outward.

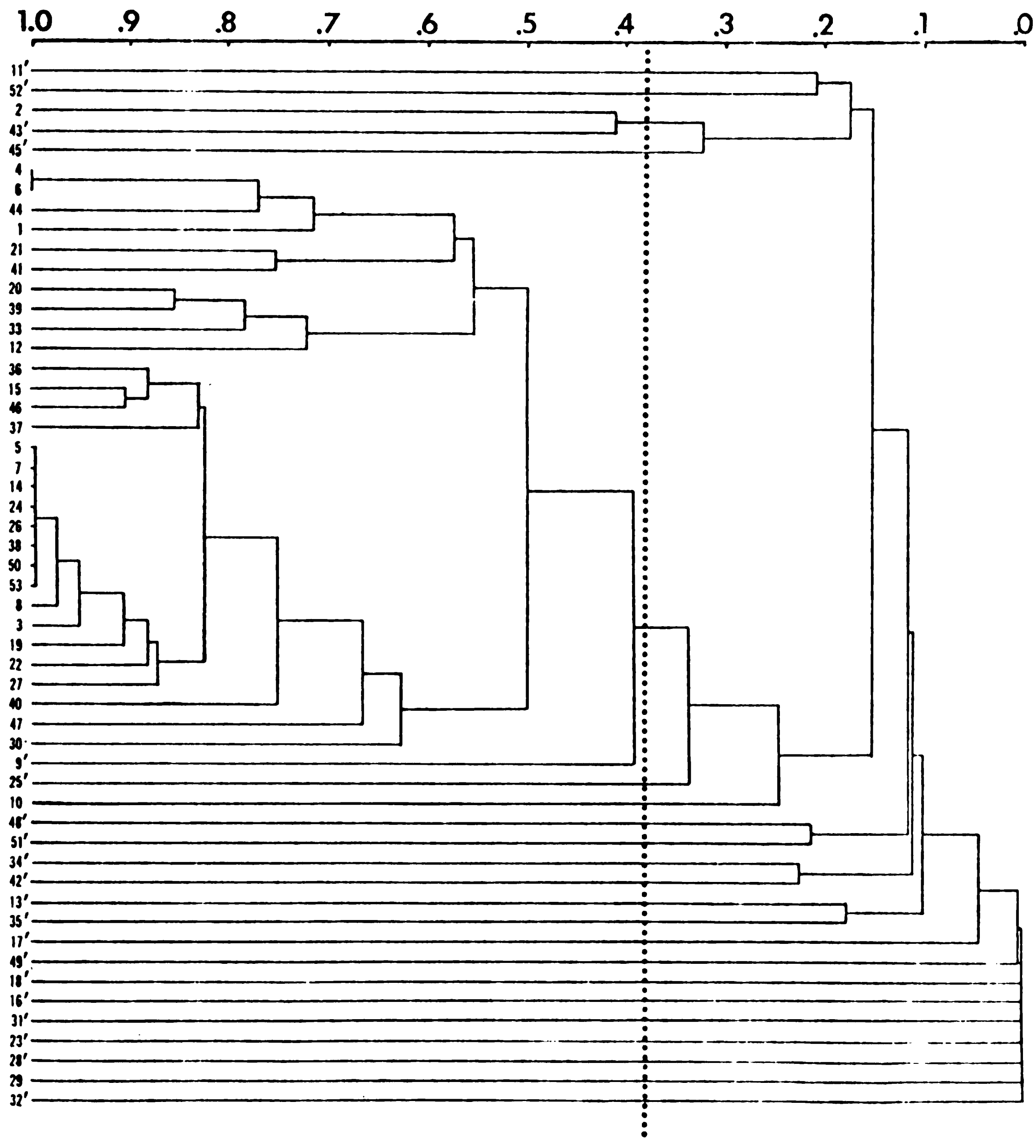
D. Cystiphragms

53. Cystiphragms present in most zooecia in exozone.

DATA ANALYSIS

Fisher's exact probability (Siegel, 1956) was calculated for all possible 2X2 contingency tables for the 53 binary characters, thus generating an R-mode probability matrix. Unlike χ^2 approximation values, Fisher's values are exact measures of the probability of dependence of one character state on the other. (Appendix 1 provides a listing of Fisher's exact probability program DMAT) This R-mode probability matrix was clustered by means of Bonham-Carter's (1967) CLUST3 program using the weighted pair-group average linkage method. The resulting dendrogram (Figure 3) was the basis for the final selection of the twenty most independent binary characters to be used in the final Q-mode analysis. The 0.38 level of Fisher's exact probability of association was arbitrarily selected as the cutoff level for independent characters, because that level reduced the data to 20 characters. The limit of 20 binary characters for the final analysis was determined by a initial R-mode principal components analysis using the Fisher matrix as input to the FACTOR program of the SPSS package with PA1 and VARIMAX options (Nie, Bent, and Hull 1970), which extracted

Figure 3. R-mode dendrogram of Fisher's exact probability of the 53 initial binary characters; the 0.38 level of probability was used as level of character selection. Characters 10 and 29 were dropped from further analysis. These two characters correlated at a zero of a one level with other characters in an off diagonal position in the initial R-mode analysis of Parks' CLUST6 program. This program will not execute with a zero of one in an off diagonal position. The 20 characters selected at the 0.38 level of probability are indicated by an apostrophe.


1.0
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.6
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.4
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.2
.1
.0
11′
52′
2
43′
45′
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51′
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42′
13′
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49′
18′
16′
31′
23′
28′
29
32′

20 rotated principal components that collectively accounted for 82.0 percent of the total variance.

The standard quantitative and Fourier shape characters were subjected to an R-mode principal components analysis. This analysis was carried out by means of program FACTOR using PA1 and VARIMAX rotation options (Nie, Bent, and Hull, 1970). Fifteen rotated principal components accounted for 86.3 percent of the total variance. The variable showing the highest loading on each component was chosen as the best representative of that component axis. These 15 variables represent the 15 sources of information closest to the rotated components. These 15 variables were converted to logarithms for the final R- and Q-mode analysis. The data were converted in order to approximate better the logarithmic growth pattern of these organisms. These 15 variables included six Fourier shape, and nine quantitative variables (Table 4).

The final analysis using Parks' (1970) CLUST6 program with all options set to default values was carried out using the 20 binary characters, six Fourier harmonics, and nine quantitative non-Fourier characters, both independently and in combination. CLUST6 is a program designed for use with mixed qualitative and or quantitative data, which uses simple distance as a measure of association. This program first normalizes all data to a 1.0 scale.

Table 4. Initial R-mode principal components results on quantitative and Fourier shape characters.

P.C.[1]	E.[2]	P.V.[3]	C.P.[4]	V.H.L.P.C.[5]
1	25.10327	44.0	44.0	HM8
2	5.21582	9.2	53.2	HM18
3	2.86882	5.0	58.2	TMRS
4	2.26567	4.0	62.2	HS15
5	2.05877	3.6	65.8	RCS
6	1.79911	3.2	69.0	NNS
7	1.59421	2.8	71.8	ANM
8	1.47802	2.6	74.4	NDARM
9	1.24979	2.2	76.6	NDARS
10	1.08057	1.9	78.4	ZWTS
11	1.02140	1.8	80.2	ZRS
12	.94752	1.7	81.9	HS2
13	.90617	1.6	83.5	DARS
14	.83662	1.5	85.0	RCM
15	.76730	1.3	86.3	AREAS

1. Principal component
2. Eigenvalue
3. Percent of variance explained
4. Cumulative percent of variance explained
5. Variable with highest loading on principal component

It then performs an R-mode principal components analysis on the data, and extracts the principal components which explain 80. percent or more of the variation in the data provided. Factor loadings are calculated and used to convert the original data to orthogonal coordinate values. A final Q-mode cluster analysis using unwieghted pair group average linkage method is carried out using principal component values generated in the R-mode analysis. The results of the Q-mode cluster analysis are then displayed on a line printer generated dendrogram.

R-MODE RESULTS

Twenty binary characters were chosen from the initial 53 as representing the most independent sources of variation (Figure 3).

The SPSS R-mode principal components analysis on the combined quantitative and Fourier shape data sets indicated that the shape characters loaded significantly higher on the first two components than the non-Fourier quantitative characters. Harmonic means three through 16 collectively loaded on the first component at a high level. The standard deviations of harmonics four through 14 also loaded on the first component at a high level. Variable HM8 had the highest laoding on component one. All other variables loaded with significantly lower values. The second factor was closest to the higher harmonics and their standard deviations. Harmonic means 17 through 20 and harmonic standard deviations 15 through 20 loaded on principal component two at a high level. Harmonic mean 18 had the highest loading on principal component two. All other variables had significantly lower loading. Principal components three through 15 were characterized by single characters loading at very high values on each, with all others loaded at very low values (Table 4).

Parks' CLUST6 program was also used with the six independent Fourier shape variables alone. Two principal components were extracted in the initial R-mode analysis. All variables loaded on the first principal component at high levels (Table 5). Variable RCM had the highest loading on component two. The resulting phenogram was thus based on two non-Fourier quantitative variables, and six shape variables (Figure 4).

Three principal components were extracted from the initial R-mode analysis using Park's CLUST6 program on the quantitative character set (Table 6). Variable ZRS loaded the highest on principal component one. All other variables loaded at significantly lower values. Variable NDARM loaded significantly on principal component two. Only variable AREAS loaded on principal component three at a significant level.

Nine principal components were extracted from the 20 binary characters. These nine principal components explained 80.553 percent of the variation (Table 7).

The final CLUST6 analysis incorporated all the characters previously used in the first three analyses. This combined analysis used 35 binary and continuous variables. Nine principal components were generated which explained 79.34 percent of the variation observed in the data (Table 8).

The shape characters and most of the standard quantitative characters loaded at a very high level on the first principal component (Table 5). This

Table 5. Principal component loadings for Fourier shape characters (CLUST6 Program), total percent of variance explained by the two components is 84.829 percent.

Character	Component 1	Component 2
HM8	0.853	-0.382
HM18	0.912	-0.146
HS2	0.868	0.271
HS15	0.898	-0.236
RCM	0.833	0.404
RCS	0.898	0.111
Eigenvalues	4.619	0.471
Percent of Variance Explained	76.978	7.851

Table 6. Principal component loadings for quantitative character set (CLUST6 Program), total percent of variance explained by the three components is 81.826 percent.

Character	Component 1	Component 2	Component 3
ZRS	0.858	-0.092	-0.004
ZWTS	0.858	0.034	0.229
TMRS	0.793	-0.393	-0.223
DARS	0.814	-0.335	-0.197
ANM	0.765	0.497	0.084
NDARM	0.729	0.576	-0.003
NDARS	0.713	0.483	-0.313
AREAS	0.817	-0.209	0.335
NNS	0.762	-0.446	-0.037
Eigenvalues	5.638	1.330	0.397
Percent of Variance Explained	62.640	14.778	4.408

Table 7. Principle component loading of binary character set for initial R-mode analysis of Park's CLUST6 program. Character 1,9: 2, 11: 3, 13: 4, 16: 5, 17: 6, 18: 7, 23: 8, 25: 9, 28: 10.31: 11, 32: 12, 34: 13, 35: 14, 42: 15, 43: 16, 45: 17, 48: 18, 49: 19, 51: 20, 52.

PRINCIPAL AXIS FACTOR LOADINGS

Character	F 1	F 2	F 3	F 4	F 5	F 6	F 7	F 8	F 9
1	.541	.264	.514	.138	.033	.234	-.097	-.024	.272
2	.562	.287	.233	.350	.217	.060	.212	-.030	-.119
3	.563	-.439	-.039	-.218	-.131	-.047	.240	-.174	-.119
4	.537	-.330	.455	.153	-.042	-.241	-.173	-.013	.344
5	.572	-.553	.159	-.112	-.046	-.130	.299	.103	.199
6	.575	-.575	.034	-.097	-.113	-.040	.352	.039	.000
7	.602	.506	.036	.078	.078	.020	.157	.114	-.107
8	.563	-.276	-.394	-.067	.065	.324	-.023	.226	.093
9	.549	.567	-.242	-.080	-.134	-.253	-.013	.019	.084
10	.641	.575	-.224	-.059	-.144	-.244	.010	.023	.067
11	.643	.531	-.246	-.103	-.150	-.200	.004	.048	.034
12	.554	-.230	-.250	.401	.326	-.182	-.051	-.019	-.120
13	.550	.195	.233	-.397	-.251	.390	-.123	-.114	-.091
14	.702	-.251	-.242	-.039	.078	-.002	-.167	-.329	.029
15	.597	-.259	-.423	-.072	.235	.227	-.199	.249	.113
16	.825	-.162	-.035	.039	.052	.010	-.096	-.276	.063
17	.545	-.300	.387	-.030	-.145	-.208	-.339	.358	-.271
18	.538	.441	.079	.105	.102	.252	.229	.103	.004
19	.548	.120	.252	-.399	.486	-.097	-.099	-.114	-.232
20	.545	-.158	-.115	.466	-.459	.181	-.108	-.038	-.237
Eigenvalue	7.177	2.983	1.544	1.029	.886	.791	.662	.547	.490
Percent of variance accounted for	35.887	14.917	7.721	5.144	4.430	3.957	3.310	2.734	2.452

Table 8. Principle component loading of combined character sets Fourier shape, quantitative and binary character sets for initial R-mode analysis of Park's CLUST6 program. Character 1, HM8; 2, HM18; 3, HS2; 4, HS15; 5, RCM; 6, RCS; 7, ZRS; 8, ZWTS; 9, TMRS; 10, DARS; 11, ANM; 12, NDARM; 13, NDARS; 14, AREAS; 15, NNS; 16, 9; 17, 11; 18, 13; 19, 16; 20, 17; 21, 18; 22, 23; 23, 25; 24, 28; 25, 31; 26, 32; 27, 34; 28, 35; 29, 42; 30, 43; 31, 45; 32, 48; 33, 49; 34, 51; 35, 52.

[illegible]

Character	F 1	F 2	F 3	F 4	F 5	F 6	F 7	F 8	F 9
1	.799	-.159	-.267	-.037	.155	-.07[illegible]	-.023	-.178	-.1[illegible]6
2	.455	-.053	-.054	.034	-.041	-.064	-.091	-.233	-.031
3	.831	.050	-.055	.155	-.064	-.014	-.044	-.020	.133
4	.843	-.110	-.115	.024	-.000	-.000	-.036	-.013	-.013
5	.429	.024	-.243	.035	.040	.004	-.047	.033	.043
6	.545	.079	.032	-.023	-.115	.071	-.027	-.042	.143
7	.652	.013	-.121	.045	-.070	-.031	-.000	-.031	.071
8	.313	.255	-.111	.040	-.066	.114	-.012	.063	.054
9	.332	-.150	-.034	-.114	.033	.014	.002	-.107	-.040
10	.828	-.038	-.090	-.140	.038	-.055	-.015	-.153	-.039
11	.566	.353	-.465	.017	-.091	.125	-.054	.1[illegible]3	-.131
12	.399	.0[illegible]2	.025	.023	-.026	.019	-.045	-.043	.098
13	.649	-.359	.526	-.070	-.135	.129	-.077	.202	-.147
14	.815	.124	-.034	-.030	-.003	-.073	-.107	.059	[illegible]
15	.519	-.342	.543	-.050	-.139	.131	-.082	.204	-.130
16	.529	.461	-.250	-.007	-.223	.246	.003	.130	-.130
17	.507	.400	-.004	.213	-.333	-.073	.203	-.003	-.201
18	.599	-.424	.334	-.004	-.078	.111	-.044	.120	-.11[illegible]
19	.558	-.052	-.523	.055	.071	-.105	-.073	.1[illegible]	-.032
20	.502	-.341	-.386	-.001	.216	-.091	.376	.127	-.017
21	.500	-.410	-.208	-.037	.235	-.008	.434	.105	-.0[illegible]4
22	.546	.51[illegible]	.222	-.013	-.083	-.017	.215	.113	.045
23	.603	-.381	.238	-.057	-.019	.133	.220	.047	.100
24	.571	.442	.481	.049	.334	-.161	-.023	.045	-.005
25	.565	.46[illegible]	.470	.001	.280	-.171	-.008	.050	-.004
26	.575	.427	.462	-.013	.296	-.150	.027	.030	-.029
27	.567	-.270	.078	.402	-.244	-.339	-.035	.073	.1[illegible]
28	.558	.320	-.069	-.303	.108	.450	-.059	-.102	.0[illegible]1
29	.714	-.243	.069	-.021	.044	-.079	-.078	-.114	-.141
30	.605	-.395	.244	-.075	-.113	.015	.044	-.041	.207
31	.812	-.133	.037	.031	.004	-.039	-.045	-.115	-.1[illegible]
32	.554	-.055	-.415	-.041	.216	-.002	-.244	.03[illegible]	.202
33	.541	.445	.206	.115	-.188	.117	.262	-.079	.135
34	.551	.225	-.070	-.511	-.237	-.299	-.053	.049	.133
35	.543	-.121	-.008	.533	.214	.342	-.090	-.035	.047
Eigenvalue	16.578	3.125	2.794	1.041	.915	.860	.695	.651	.573
Percent of variance accounted for	47.365	8.929	7.984	2.975	2.615	2.456	1.987	1.861	1.638

principal component accounts for 47.365 percent of the observed variance in the data. Blackith and Reyment (1971) noted that the first principal oomponent often represents size variation of a growth vector. In this study characters which are accepted as controlled by growth, such as thickness of the mature region and number of diaphragms per unit area loaded at very high levels on the first factor. This would tend to confirm the idea that the first principal component generally represnets a growth vector. Because the loading of the Fourier shape variables are generally larger than the standard quantitative characters, these shape variables must be to a large extent controlled by growth. Binary characters, on the other hand, are far less sensitive to this source of variation due to their nominal level of measurement. These characters dominate principal components two through nine.

Oxnard (1969) stated, "The mathematical delineation of shape has frequently been aimed at problems of classification; some of the most recent attempts have been described as numerical taxonomy by Sokal and Sneath." Quantitative measurements are commonly used as a crude attempt at the description of the internal and external structure of the organism being studied. As noted by Oxnard, "The shape of a biological specimen may be represented by a series of measurements of different kinds taken on the specimen." The Fourier shape analysis provides an exact description of shape. This description represents an advancement over the use of one or two measures of length or width as a measure of shape.

The degree and rate of astogenetic variation of different species may be as diagnostic as the measures of characters free from such variation. Blackith and Reyment (1971) have pointed out that astogenetic variation differs from one species to another. This variation is thought to be a product of both genetic and environmental influence. A combined influence of these factors makes the interpretation of variation in widely scattered localities representing substantially different environments difficult. In this study a generally uniform lithology points to an environment in which genetic influences might possibly outweigh environmental ones.

The importance of intracolonial variation is indicated by the large proportion of standard deviations that were better measures of the rotated components than the means. Nine of the 15 Fourier shape and quantitative characters so chosen were standard deviations or measures of localized intra-colony variation.

The nearest neighbor statistic loaded significantly on both principal components one and three, and thus contribute significantly independent information. Clark and Evans (1954) pointed out that the pattern of distribution of a population of plants or of animals is a fundamental characteristic of that population. Inasmuch as a colony can be treated as a collection of individuals with varying degrees of interdependence, the pattern of distribution of the individuals, in the case of this study, the zooids, should also be of fundamental importance. The only apparent control on the spatial pattern of distribution is the degree of budding. This pattern is spatially controlled, as demonstrated by Anstey and Pachut (1974) in *Amplexopora filiasa*. "The distributions exhibited by populations of living organisms in their natural environments include an almost infinite variety of patterns" (Clark and Evans, 1954). Such a variety of spatial budding patterns are certain to exist in colonial organisms, especially the ectoprocts.

The standard deviation of interzooecial surface area (Underwood, 1970), also contributed independent information. This character also appears to be controlled by the budding pattern. In this study the variance of the characters measured in the exozone of the zoarium appear to be controlled by the budding pattern. The budding of *Leptotrypella pellucida* for the most part takes place in the exozone. This budding leads to a wide range of zooecial sizes and shapes at the surface and subsequently to large degrees of variation for all characters measured in this region. In *Nicklesopora renzettiae* n. sp. budding generally occurs in the endozone and zooecia at the surface are for the most part ontogenetically uniform. Such uniformity leads to lower standard deviations and more consistent spatial patterns and surface area per unit volume. This difference explains the greater information content of most standard deviations in comparison with their associated means. Further studies are needed to determine if this discrimination holds true at lower, more similar taxonomic levels.

Q-MODE RESULTS

The taxonomic placement of the specimens was based on comparison with previously published literature (Tables 14, 15, and 21). The two species were sufficiently distinct to make visual sorting easy and reliable. The two species clusters were constructed so as to minimize misclassifications. The number of misclassifications was determined by counting the number of OTU's (Operational Taxonomic Units) of one species found in the other species' cluster. The phenograms generated from the three character sets, (shape, quantitative, and binary) (Figure 4, 5, 6, 7), indicate that the binary character set provided the best phenogram on the basis of the fewest misclassifications. The Fourier shape character set provided nearly as good a phenogram, while the quantitative character set provided the worst phenogram. The same OTU misclassifications are not always present in any two of the character set generated phengorams, and never in all three basic phenograms. Each of these sets provide a certain amount of independent information.

One can not say exactly how much unique information is being carried by each character set. It has been

Figure 4. Phenogram based on six Fourier shape variables; HM8, HM18, HS2, HS15, RCM, RCS; ten misclassifications present in phenogram, asterisks indicate misclassifications; see Table 1 for explanation of character abbreviations.

Asterisk indicates specimen clustered in the wrong group, or is misclassified.

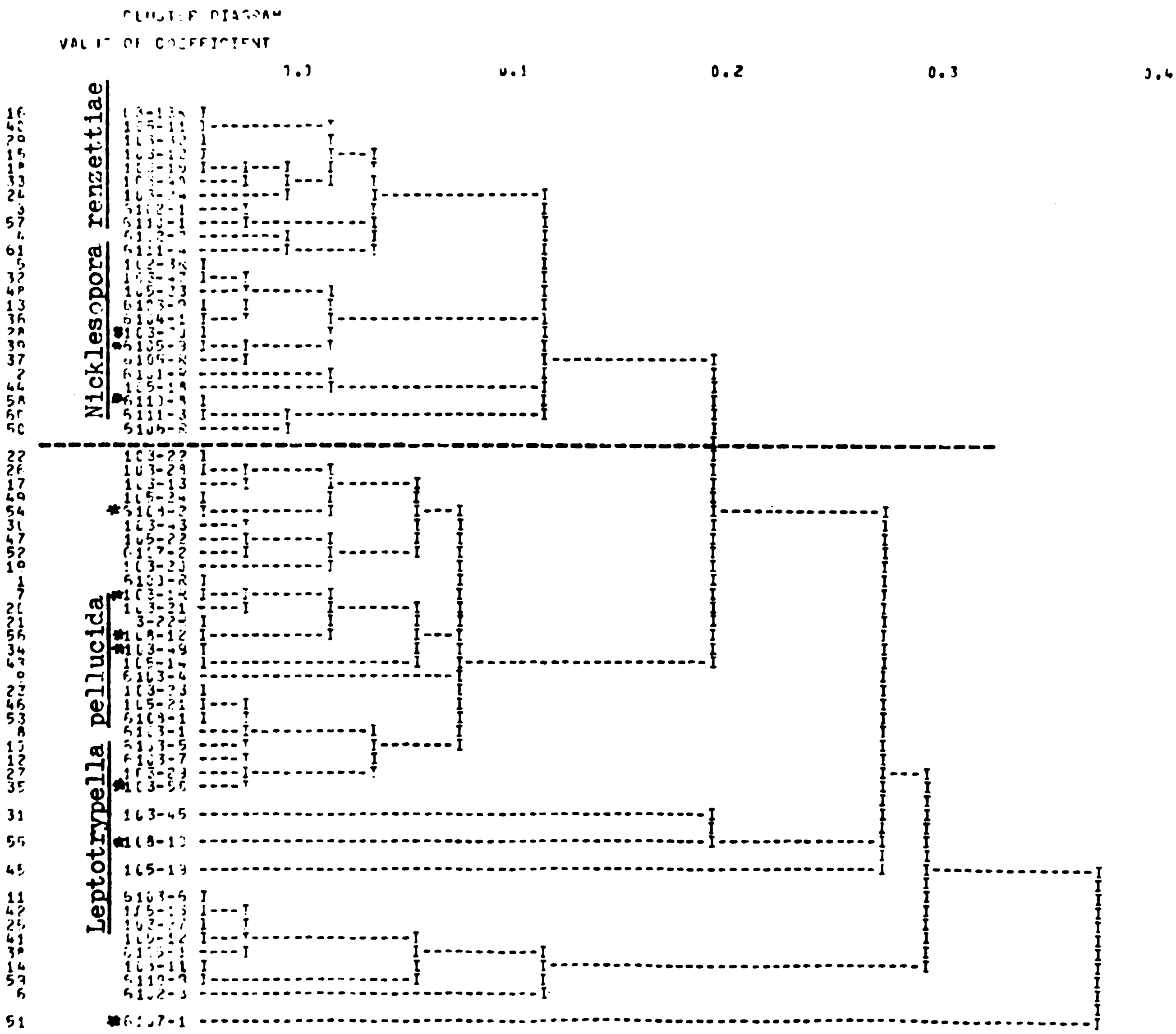

0.2
0.3
Nicklesopora renzettiae
Leptotrypella pellucida

Figure 5. Phenogram based on nine quantitative variables; TMRS, NNS, ANM, NDARM, NDARS, ZWTS, ZRS, DARS, AREAS; 15 misclassifications present in phenogram, asterisks indicate misclassifications; see Table 1 for explanation of character abbreviations. Asterisk indicates specimen clustered in the wrong group (misclassified).

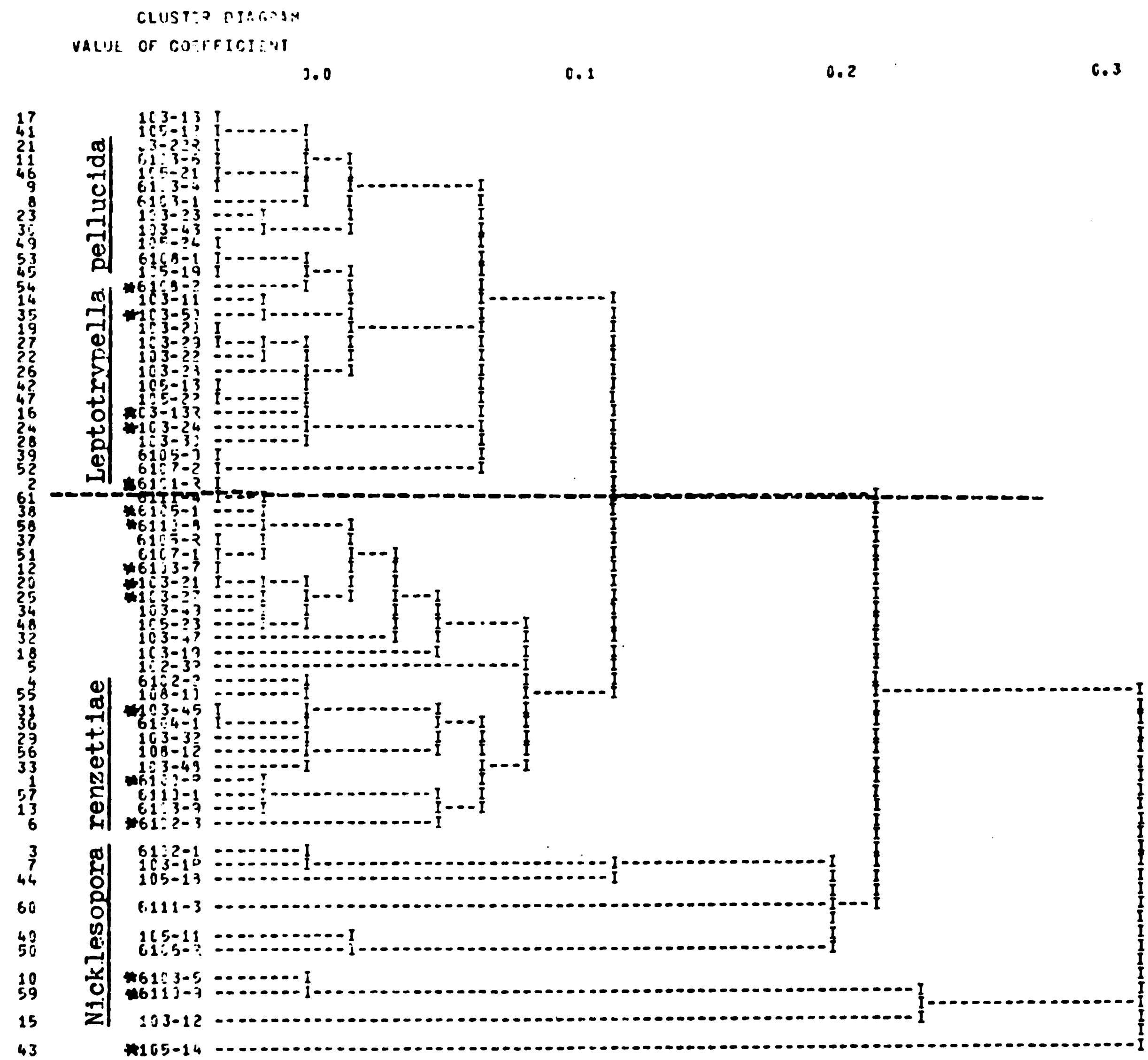

CLUSTER DIAGRAM
VALUE OF COEFFICIENT
0.0
0.1
0.2
0.3
Leptotrypella pellucida
renzettiae
Nicklesopora

Figure 6. Phenogram based on 20 binary characters; 9, 11, 13, 16, 17, 18, 23, 25, 28, 31, 32, 34, 35, 42, 43, 45, 48, 49, 51, 52; nine misclassifications present in phenogram; asterisks indicate misclassifications; see Table 1 for explanation of character abbreviations.

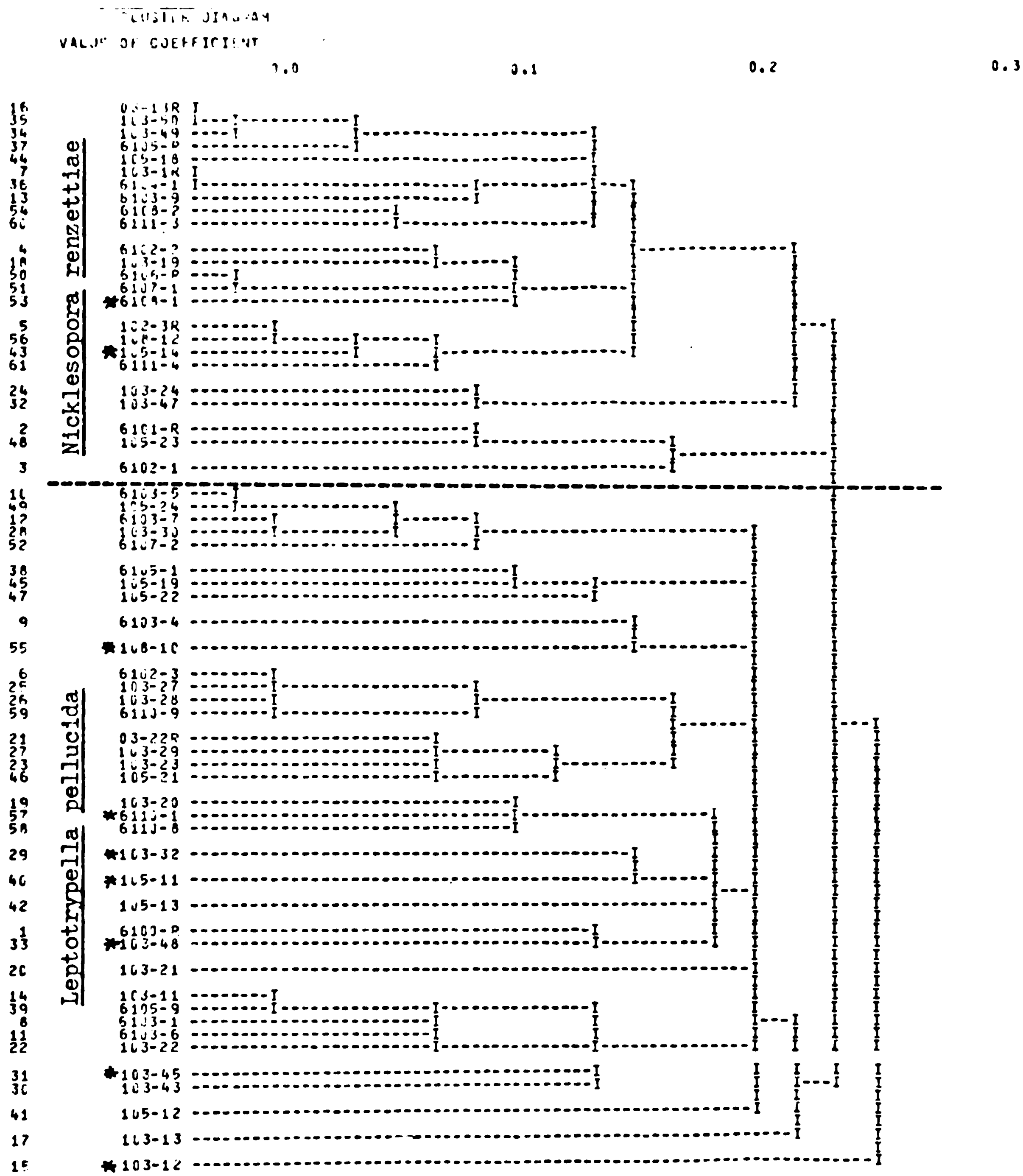
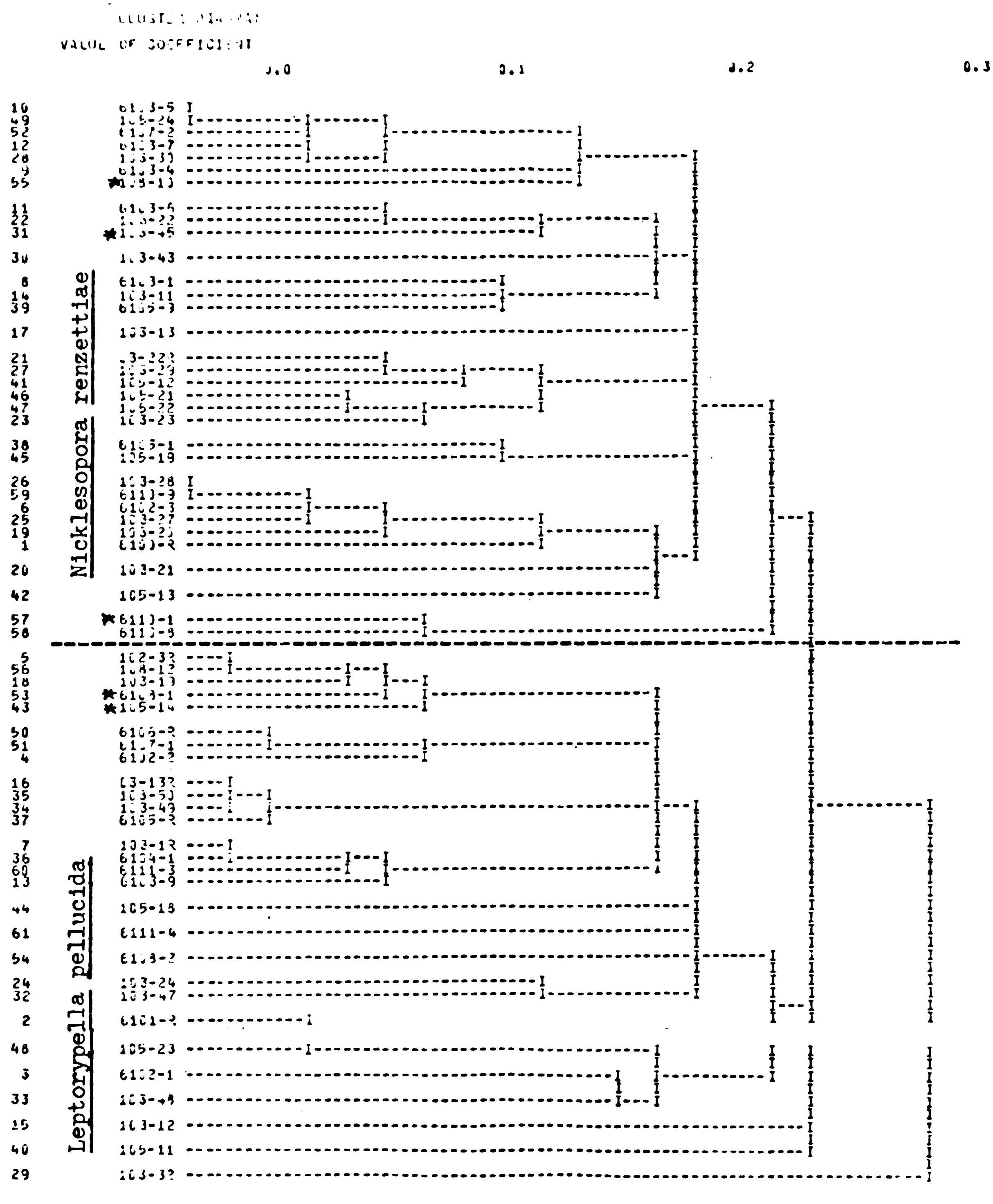

CLUSTER DIAGRAM
VALUE OF COEFFICIENT
0.0
0.1
0.2
0.3
Nicklesopora renzettiae
Leptotrypella pellucida

Figure 7. Phenogram based on combined set of characters, Fourier shape, quatitative, and binary character sets; five misclassifications present in phenogram; asterisks indicate misclassifications.


VALUE OF COEFFICIENT
0.0
0.1
0.2
0.3
Nicklesopora renzettiae
Leptorypella pellucida

demonstrated that the standard quantitative character set does not provide as much independent information as the other two sets. As seen in Figures 4, 5, and 6 the quantitative character based phenograms generate no clear boundary between the two species, whereas the other two basic phenograms demonstrate a somewhat shaprer break between the two species.

In the case of the binary character set, the larger amount of independent information retrieved can be accounted for by the larger number of characters measured. This large number of characters makes up for the information loss due to the nominal level of measurement as opposed to the ratio level of the quantitative and Fourier shape character sets.

The larger amount of independent information retrieved by the Fourier shape character set can be attributed to its greater accuracy of mathematical description of the zooecial shape. The failure of the standard quantitative character set to provide a comparable classification of the studied OTU's appears to be due to the lesser ability, accuracy and number of these characters to describe the skeletal shapes both internally and externally. As expected, the combined character sets provided a substantially better phenogram. Sneath and Sokal (1973) suggest the use of all possible characters, and indeed this study indicates that the greater the number of characters used, the better the resulting phenograms.

THE THREEFORKS BRYOZOAN FAUNA

Paleoecology

The bryozoan fauna of the Threeforks Formation is characterized by juvenile forms, which lack well developed exozones. Zoaria are generally small and ramose. The predominatly shaley lithology indicated deposition of large amounts of terrigenous muds. The sporadic deposition of muds apparently prevented the growth of fully mature bryozoan colonies.

The two species *Leptotrypella pellucida* Duncan, and *Nicklesopora renzettiae* n. sp. dominate the fauna of the Threeforks Formation. These two species, although widely separated by systematists, are morphologically quite similar in external form. This suggest functional morphological selection of these zoarial forms. As suggested by the abundance of juvenile zoaria, the environment was one of stress leading to a large environmentally induced change in skeletal morphology, which probably brought about convergence of gross colony form in divergent taxa.

Systematic Paleontology

Phylum Ectoprocta Nitsche, 1869

Superclass Tubulobryozoa Cuffey, 1973

Class Stenolaemata Borg, 1926

Subclass Curtaulata Cuffey, 1973

Order Cryptostomida Vine, 1883

Suborder Habrovirgatina Cuffey, 1973

Infraorder Rhabdomesita Astrova and Morozova, 1956

Family Rhabdomesidae Vine, 1883

Genus *Nicklesopora* Bassler, 1952

Type species.-*Nicklesopora elegantula* (Ulrich), 1882

Nicklesopora renzettiae n. sp.

pl. 1, figs. 1-7

pl. 2, figs. 1-5

Diagnosis- Zoarium ramose, low monticules, generally 4 mm apart, composed of larger zooecia. In longitudinal section, endozonal walls uncrenulated diverge gently outward, abruptly thickening at base of exozone, numerous well defined simple diaphragms in endozone. Well developed superior hemisepta; inferior hemisepta present. B-acanthopores observable in thickened exozonal walls as series of pustule like grains. In tangential section, zooecia thick walled, generally ovate, surrounded by single row of poorly defined small B-acanthopores centered on walls, forming polygonal zooecial outlines.

Description- Qualitative and quantitative characters given in tables 9-13.

Discussion- Due to the confused status of the genus _Rhombopora_, and _Nicklesopora_, generic placement of the Threeforks taxa was carried out by compariosns of the type species of each genus with the Threeforks material (Table 14). _Nicklesopora renzettiae_ is compared with named species of _Nicklesopora_ in (Table 15). _Nicklesopora renzettiae_ is most similar to _N. elegantula_ (Ulrich), the type species of the genus, but differs in having superior and inferior hemisepta, and well developed numerous diaphragms in the axial region. In the description of _N. elegantula_, Ulrich (1884, p. 33) stated, "... it seems quite certian that an occasional diaphragm crosses the tubes in the axial region, but as they are not sharply defined in my sections, and might not really be such structures, I have not allowed them to appear in the figure." The presenee of axial diaphragms in the type species remains in doubt but _Nicklesopora renzettiae_ has well defined and numerous axial diaphragms which are very distinct; _Nicklesopora_ has not previously been reported from the Devonian.

Origin of name- _Nicklesopora renzettiae_ is named after Dr. Phyllis Renzetti for her unpublished study of the Threeforks fauna in 1963. Through the recollections of Dr. Renzetti's localities and the use of material previously collected by her, this study was made possible.

Type specimens- Holotype: 6107-1

Paratypes; Figured, 6102-1, 6102-2, 6103-19, 6104-1, 6105-R. Unfigured, 6101-R, 6102-3R, 6103-1R, 6103-9, 6103-12, 6103-13R, 6103-24, 6103-32, 6103-47, 6103-48, 6103-49, 6103-50, 6106-R, 6105-11, 6105-18, 6105-23, 6108-10, 6108-12, 6108-2, 6111-3, 6111-4, 6110-1.

Suborder Fenestrina Elias and Condra, 1957

Family Phylloporinidae

Genus Indeterminate

pl. 3, figs. 7-8

Diagnosis- Zoaria composed of anastomosing branches with four rows of apertures on celluliferous side and none on back. Zooecia and fenestrules sharply ovate in outline. Fenestrule mean length 1.75 mm; mean width of 1.00 mm; branches average 0.35 mm wide; zooecial apertures 0.1 mm x 0.04 mm.

Remarks- Only one specimen of this taxon was found. This is the first reported occurence of a phylloporinid of Devonian age. This specimen closely resembles the genera Cariniphylloporina and Phylloporina but lacks hexagonal fenestrules and a sharp keel in compariosn with the former, and lacks observable mesopores and possesses elongate zooecia which are strongly diagonally aligned in contrast to the latter. Therefore, this specimen possibly belongs to a new genus. This specimen was collected from locality four.

Subclass Leptaulata Cuffey, 1973

Infraclass Expletocystata Cuffey, 1973

Order Expletocystida Cuffey, 1973

Suborder Trepostomina Ulrich, 1882

Family Heterotrypidae Ulrich, 1890

Genus *Leptotrypella* Vinassa de Regny, 1920

Subgenus *Leptotrypella* Vinassa de Regny emend. Boardman

Type species Leptotrypella barrandei (Nicholson), 1874

Leptotrypella pellucida Duncan, 1939

pl. 4, figs. 1-6

pl. 5, figs. 1-5

Diagnosis- Zoarium ramose, monticles average 3 mm apart, walls thin, crenulate with complete simple diaphragms in axial region. Walls thin to moderately thick, thickening slightly irregular in peripheral region. Numerous complete simple diaphragms. Mesopores absent; occasionally small zooecia present. A-acanthopores occasionally present, zooecial subpolygonal to subcircular.

Description- Qualitative and quantitative characters given in tables 16-20.

Remarks- This taxon agrees with Duncan's *L. pellucida* in all respects (Table 21) except in length of mature zone, axial ratio and substantially larger size of zooecia. Because of the very narrow mature region and high axial ratio, this material probably represents astogenetically younger stages of Duncan's *L. pellucida*.

Hypotypes Figured, 6100-R, 6103-20, 6103-22, 6103-43, 6110-9. Unfigured, 6102-3, 6103-1, 6103-4, 6103-5, 6103-6, 6103-7, 6103-11, 6103-13, 6103-21, 6103-22, 6103-23, 6103-27, 6103-28, 6103-29, 6103-30, 6103-45, 6105-1, 6105-9, 6105-12, 6105-13, 6105-14, 6105-19, 6105-21, 6105-22, 6105-24, 6107-2, 6107-5, 6108-1, 6110-8.

Suborder Cystoporina Astrova, 1964
Family Fistuliporidae Ulrich, 1882

Genus Fistulipora McCoy, 1850

Type species.- Fistulipora minor McCoy

pl. 3, figs. 1-6

Diagnosis- Zoarium lamellate, well developed lunaria projected into zooecial chamber almost appearing trilobate in cross section. Three to four upright series of vesicular material between zooecia, mean redius of zooecia 0.26 mm, mean distance between zooecia, 0.21 mm diaphrams average one zooecial width apart. This zoarial fragment measured 1.0 cm x 1.7 cm x 0.4 cm, and was collected from locality number six.

Remarks- Depending upon generic revision of fistuliporids, this specimen conforms in all respects to the genus Dybowskiella, and could be assigned to that genus pending clarification of the concepts of Fistulipora, Dybowskiella, and Cyclotrypa.

Table 9. *Nicklesopora renzettiae* n. sp. binary character frequences for 28 colonies.

Character (Table 3)	Frequency of positive character states (percent of all zoaria)	Character	Frequency of positive char. states (percent of all zoaria)
1	13.8	19	6.9
2	86.2	20	3.4
3	0.0	21	96.6
4	3.4	22	10.3
5	96.6	23	86.2
6	3.4	25	10.3
7	0.0	26	3.4
8	0.0	27	10.3
9	96.6	28	65.5
10	3.4	29	65.5
11	89.7	30	20.7
12	3.4	31	69.0
13	13.8	32	58.6
14	0.0	33	13.8
15	96.6	34	31.0
16	58.6	35	62.1
17	27.6	36	0.0
18	17.2	37	3.4

Table 9. Continued.

38	3.4	47	93.1
39	93.1	48	51.7
40	89.7	49	86.2
41	10.3	50	96.6
42	17.2	51	58.6
43	6.9	52	41.4
44	3.4	53	3.4
45	58.6		

Table 10. *Nicklesopora renzettiae* n. sp. means of quantitative character data, means based on 28 colonies of N. *renzettiae*.

Character	Mean	Standard Deviation	Minimum	Maximum
ZRM	0.111	0.023	0.072	0.166
ZWTM	0.229	0.078	0.054	0.423
APZM	16.860	11.783	0.0	38.200
TMRM	0.294	0.173	0.070	0.607
DARM	4.027	1.565	1.488	6.943
ANM	79.389	17.880	9.00	90.00
NDPRM	0.716	1.660	0.0	5.8
NDARM	2.324	0.939	0.0	4.0
DLCM	0.357	0.153	0.103	0.685
DAM	0.020	0.015	0.0	0.083
AREAM	19.263	4.340	10.11	29.800
NNS	0.841	0.142	0.651	1.449

Table 11. Nicklesopora renzettiae n. sp. standard deviations of quantitative character data, represents mean of 28 colony standard deviations.

Character	Mean	Standard Deviation	Minimum	Maximum
ZRS	0.014	0.004	0.006	0.023
ZWTS	0.042	0.016	0.001	0.077
APZS	4.273	2.829	0.0	10.89
TMRS	0.046	0.039	0.011	0.156
DARS	0.195	0.192	0.035	0.883
ANS	3.093	3.576	0.0	13.39
NDPRS	0.116	0.305	0.0	1.056
NDARS	0.576	0.257	0.0	1.005
DLCS	0.074	0.065	0.011	0.333
DAS	0.006	0.008	0.0	0.043
AREAS	1.461	0.242	1.046	1.963

Table 12. *Nicklesopora renzettiae* n. sp. Fourier Harmonic Means data statistics, based on 28 colonies.

Character	Mean	Standard Deviation	Minimum	Maximum
HM2	0.184	0.046	0.106	0.300
HM3	0.410	0.011	0.021	0.066
HM4	0.036	0.013	0.015	0.072
HM5	0.018	0.007	0.008	0.040
HM6	0.013	0.005	0.007	0.024
HM7	0.008	0.004	0.005	0.019
HM8	0.006	0.003	0.004	0.015
HM9	0.005	0.002	0.003	0.012
HM10	0.004	0.001	0.002	0.009
HM11	0.003	0.001	0.002	0.005
HM12	0.003	0.001	0.002	0.006
HM13	0.002	0.001	0.002	0.005
HM14	0.002	0.001	0.001	0.004
HM15	0.002	0.001	0.001	0.004
HM16	0.002	0.000	0.001	0.002
HM17	0.001	0.000	0.001	0.003
HM18	0.001	0.000	0.001	0.002
HM19	0.001	0.000	0.001	0.002
HM20	0.001	0.000	0.001	0.001
RCM	3.417	0.037	3.324	3.506

Table 13. *Nicklesopora renzettiae* n. sp. Fourier Harmonic standard deviation data statistics, based on 28 colonies.

Character	Mean	Standard Deviation	Minimum	Maximum
HS2	0.063	0.016	0.040	0.102
HS3	0.023	0.008	0.013	0.042
HS4	0;018	0.007	0.007	0.033
HS5	0.010	0.004	0.004	0.019
HS6	0.007	0.003	0.003	0.014
HS7	0.005	0.002	0.002	0.011
HS8	0.003	0.002	0.002	0.007
HS9	0.003	0.001	0.001	0.006
HS10	0.002	0.001	0.001	0.004
HS11	0.002	0.001	0.001	0.003
HS12	0.001	0.000	0.001	0.003
HS13	0.001	0.000	0.001	0.003
HS14	0.001	0.000	0.001	0.002
HS15	0.001	0.000	0.001	0.002
HS16	0.001	0.000	0.001	0.002
HS17	0.001	0.000	0.001	0.001
HS18	0.001	0.000	0.000	0.001
HS19	0.001	0.000	0.000	0.001
HS20	0.000	0.000	0.000	0.001
RCS	0.740	0.302	0.302	1.723

Table 14. Comparison of the type species of the genera <u>Nicklesopora</u> and <u>Rhombopora</u> with <u>Nicklesopora renzettiae</u>.

	longitudinal rows of zooecial openings	diagonal rows of zooecial openings	a row of micracanthopores around each zooecia	megacanthopores at junctions of zooecia	crenulated axial walls	noncrenulated axial walls	sharp angular change of zooecial wall from axial to pripheral region	gently angular change of zooecial wall from axial to peripheral region	hemisepta present
N. <u>elegantula</u>			X			X	X		
R. <u>lepidodendroides</u>	X		X	X	?	?		X	X
N. <u>renzettiae</u>			X			X	X		X

diaphragms in axial region	abrupt thickening of zooecial walls	gradual thickening of zooecial walls	sharp spiral budding from central axis	zooecia divided into pentagonal or hexagonal shapes	Number of character matches with N. <u>renzettiae</u>
X	X			X	13
	X		X	X	6
X	X			X	14

Table 15. Comparison of Nicklesopora renzettiae n. sp. with all previously described species of the genus Nicklesopora.

	Characters	N. crenulata Ross	N. fitzroyensis Ross	N. geuriensis Ross	N. flexuosa Chapman	N. leopoldensis Ross	N. westralis Ross
1.	Number of character matches with N. renzettiae	5	6	4	5	6	6
2.	zooecial openings form longitudinal ranges	X		X		X	X
3.	zooecial openings form diagonal ranges		X		X		
4.	crenulate zooecial walls in axial region	X	X		X	X	X
5.	non-crenulated axial walls						
6.	abrupt thickening of walls at base of peripheral zone	X	X		X	X	X
7.	superior hemisepta		X				X
8.	inferior hemisepta		X				
9.	diaphragms in axial region				X		
10.	single series of acanthopores surrounding zooecia	X	X			X	X
11.	tight spiral budding pattern	?	X	X			
12.	meg- and micracanthopores						
13.	megacanthopores at junction of zooecia					X	X

Table 15. Continued.

Characters	N. *acanthoporata* Stcherbatych	N. *elegantula* (Ulrich)	N. *sexagula* Troitzkaia	N. *graciosa* Troitzkaia	N. *taidonesis* Trizna	N. *angustioperturata* Trizna	N. *carnosa* Trizna	N. *tersiensis* Nekhoroshev	N. *simulatrix* (Ulrich)
1.	9	10	9	8	6	4	9	8	8
2.			X	X	X	X			?
3.				?					?
4.					X	?			
5.	X	X	X	X		?	X	X	X
6.	X	X	X	X	X	?	X	X	X
7.	X		X	X	X		X	X	X
8.	?			X					
9.	X	X	X	X	X	X	X		
10.	X	X							X
11.									
12.	X				X	X	X		X
13.	X			X		X		X	X

Table 15. Continued.

Characters	N. *tabulata* (Ulrich)	N. *wortheni* (Ulrich)	N. *decipiens* (Ulrich)	N. *varians* (Ulrich)	N. *dichotoma* (Ulrich)	N. *exigua* (Ulrich)	N. *persimilis* (Ulrich)	N. *attenuata* (Ulrich)	N. *renzettiae* sp. nov.
1.	9	5	9	9	3	2	6	4	
2.		X		X		X	X	X	
3.				X	X	X	X	X	
4.			X		?	?		?	
5.	X	X	X	X	?	?	X	?	X
6.	X	X	X	X	?	?		?	X
7.	X	X	X	X	?	?	X	?	X
8.		?	X		?	?		?	X
9.	X			X	?	?		?	X
10.				X	X	X	X	X	X
11.					X	X			
12.						X			
13.	X	X	X		X	X	X	X	

Table 16. Leptotrypella pellucida Duncan binary character frequences for 33 colonies.

Character (Table 3)	Frequency of positive char. states (percent of all zoaria)	Character	Frequency of positive char. states (percent of all zoaria)
1	0.0	19	3.1
2	90.6	20	9.4
3	9.4	21	84.4
4	0.0	22	0.0
5	10.0	23	25.0
6	18.8	25	18.8
7	3.1	26	0.0
8	3.1	27	0.0
9	71.9	28	15.6
10	28.1	29	15.6
11	53.1	30	0.0
12	12.5	31	15.6
13	62.5	32	15.6
14	3.1	33	0.0
15	93.8	34	34.4
16	93.8	35	62.5
17	75.0	36	9.4
18	68.8	37	9.4

Table 16. Continued.

38	0.0	47	93.8
39	100.0	48	87.5
40	93.8	49	25.0
41	3.1	50	100.0
42	65.6	51	53.1
43	21.9	52	50.0
44	9.4	53	0.0
45	84.4		

Table 17. Leptotrypella pellucida quantitative means data statistics, based on 33 colonies.

Character	Mean	Standard Deviation	Minimum	Maximum
ZRM	0.153	0.019	0.083	0.183
ZWTM	0.080	0.061	0.015	0.283
APZM	2.117	6.329	0.000	27.800
TMRM	0.878	1.096	0.194	6.631
DARM	6.812	2.627	0.567	15.110
ANM	74.132	11.453	53.000	90.0
NDPRM	5.093	2.793	0.00	13.750
NDARM	2.823	0.620	0.850	3.800
DLCM	0.155	0.121	0.061	0.581
DAM	0.002	0.007	0.000	0.024
AREAM	26.241	3.836	14.200	31.400
NNS	0.879	0.122	0.703	1.237

Table 18. *Leptotrypella pellucida* quantitative standard deviation data statistics, based on 33 colonies.

Character	Mean	Standard Deviation	Minimum	Maximum
ZRS	0.809	0.206	0.522	1.376
ZWTS	0.027	0.030	0.008	0.157
APZS	0.768	2.260	0.000	10.030
TMRS	0.148	0.148	0.014	0.798
DARS	0.388	0.339	0.038	1.573
ANS	5.613	4.357	0.000	22.890
NDPRS	1.031	0.676	0.000	2.719
NDARS	0.577	0.269	0.000	1.164
DLCS	0.028	0.013	0.010	0.066
DAS	0.001	0.002	0.000	0.008
AREAS	1.506	0.230	1.099	2.038

Table 19. *Leptotrypella pellucida* Fourier Harmonic means data statistics, based on 33 colonies.

Character	Mean	Standard Deviation	Minimum	Maximum
HM2	0.135	0.030	0.081	0.193
HM3	0.056	0.101	0.035	0.074
HM4	0.048	0.011	0.018	0.068
HM5	0.029	0.007	0.013	0.038
HM6	0.020	0.005	0.008	0.031
HM7	0.014	0.003	0.006	0.020
HM8	0.011	0.003	0.004	0.016
HM9	0.008	0.002	0.003	0.012
HM10	0.006	0.002	0.002	0.009
HM11	0.005	0.001	0.003	0.008
HM12	0.004	0.001	0.002	0.006
HM13	0.003	0.001	0.002	0.005
HM14	0.003	0.001	0.002	0.004
HM15	0.002	0.001	0.001	0.004
HM16	0.002	0.000	0.001	0.003
HM17	0.002	0.000	0.001	0.003
HM18	0.001	0.000	0.001	0.002
HM19	0.001	0.000	0.001	0.002
HM20	0.001	0.000	0.001	0.002
RCM	3.401	0.030	3.342	3.475

Table 20. *Leptotrypella pellucida* Fourier Harmonic standard deviation data statistics, based on 33 colonies.

Character	Mean	Standard Deviation	Minimum	Maximum
HS2	0.062	0.015	0.033	0.092
HS3	0.029	0.006	0.016	0.042
HS4	0.024	0.006	0.010	0.038
HS5	0.015	0.004	0.005	0.024
HS6	0.010	0.003	0.003	0.015
HS7	0.007	0.002	0.003	0.010
HS8	0.005	0.002	0.002	0.010
HS9	0.004	0.001	0.001	0.007
HS10	0.003	0.001	0.001	0.006
HS11	0.003	0.001	0.001	0.005
HS12	0.002	0.001	0.001	0.003
HS13	0.002	0.001	0.001	0.004
HS14	0.001	0.000	0.001	0.003
HS15	0.001	0.000	0.001	0.002
HS16	0.001	0.000	0.000	0.002
HS17	0.001	0.000	0.000	0.001
HS18	0.001	0.000	0.000	0.001
HS19	0.001	0.000	0.000	0.001
HS20	0.001	0.000	0.000	0.001
RCS	0.017	0.004	0.010	0.027

Table 21. Comparison of species of the genus Leptotrypella with Threeforks material.

	Characters	L. aequahilis Duncan	L. amplectens (Grabau)	L. asterica Boardman	L. barrandi (Nicholson)	L. devonica (Duncan)
1.	Irregular thickening of mature wall			X		
2.	Monticules present	X	X	X	X	
3.	small acanthopores ringing zooecial opening, not inflecting walls				X	
4.	walls thin in mature region		X		X	
5.	axial walls crenulated					X
6.	diaphragms simple well defined	X	X	X	X	X
7.	zooecia diverge sharply from axis of axial region	X			X	X
8.	zooecia sub-polygonal	X	X	X	X	X
9.	walls thick in mature region	X		X		
10.	axial walls uncrenulated	X	X	X	X	X
11.	zooecia diverge gently from axis of axial region		X	X		X
12.	large acanthopores not inflecting zooecial walls	X				
13.	large acanthopores inflecting zooecial wall		X	X		X
14.	diaphragms in axial region		X	X	?	
15.	cystoidal diaphragms, cysts, mural spines					

L. furcata (Hall)	L. gemmata Duncan	L. kwangsiensis Yang	L. magninodosa Duncan	L. magniporta Boardman	L. mesostena mesostena Boardman	L. mesostena provecta Boardman	L. moniliformis (Nicholson)	L. multitecta Boardman	L. ohioensis (Stewart)
		X	X						X
X	X		X	X	X	X	X	X	
		X							
			X					X	
X			X		X			X	
X	X	X	X	X	X	X	X	X	X
					X	X			
	X	X	X	X	X	X	X	X	X
X	X	X	X		X	X	X		X
	X	X		X		X	X		X
X	X	X	X				X	X	X
	X						X		X
X			X	X	X	X		X	
	X		X		X	X	X		
X						X			

Table 21. Continued.

L. *parva* Duncan	L. *pellucida* Duncan	L. *unica* Duncan	Threeforks material (L. *pellucida*)	Character
	X		X	1.
	X	X	X	2.
X	X		X	3.
	X	X	X	4.
	X		X	5.
X	X	X	X	6.
	X		X	7.
X	X	X	X	8.
X				9.
X				10.
X				11.
				12.
		X		13.
X	X		X	14.
				15.

CONCLUSIONS

1. Standard deviations of characters within colonies provide significant amounts of independent taxonomic information. This astogenetic variation appears diagnostic for each of the two species studied. A measure of the dispersion (standard deviation) of the data may give more information than its associated mean.

2. The Fourier harmonic amplitudes and binary characters provide significant amounts of independent information, leading to a better phenetic classification, than the standardly used quantitative characters measured in previous taxonomic studies of ectoprocts.

3. The nearest neighbor statistic and interzooecial surface area statistic are shown to carry significant independent information.

4. Characters carry varying amounts of independent information. The reduction of the work involved in future data collection, and the in-depth understanding of character interaction and information content make the inclusion of R-mode analysis in future numerical taxonomic studies desirable.

5. Leptotrypella pellucida and Nicklesopora renzettiae n. sp. dominate the fauna of the Threeforks Formation.

One specimen belonging to the genus *Fistulipora* was found, and one specimen belonging to the Family Phylloporinidae, previously unreported from the Devonian.

6. Spasmodic deposition of terrigenous muds prevented the development of fully mature bryozoan zoaria.

LIST OF REFERENCES

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Anstey, R. L. and Delmet, D.A. 1972. Genetic Meaning of Zooecial Chamber Shapes in Fossil Bryozoans: Fourier Analysis. Science, v. 177, p. 1000-1002.

________, and Delmet, D. A. 1973. Fourier Analysis of Zooecial Chamber Shapes in Fossil Tubular Bryozoans. Geol. Soc. of America Bulletin, v. 84, p. 1753-1764.

________, and Pachut, J. F. 1974. Size, Shape, and Surface Area Variation of Zooecia and Monticular Mosaics within Zoaria of Paleozoic Tubular Bryozoans. AAPG Abstract national meeting 1974, p. 2.

Blackith, R. E. and Reyment, R. A. 1971. Multivariate Morphometrics. Academic Press, New York. p. 412.

Bonham-Carter, G. F. 1967. FORTRAN IV Program for Q-mode Cluster Analysis of Nonquantitative Data Using IBM 7090/7094 Computers. Computer Contribution 17, Kansas Geological Survey.

Clark, C. J. and Evans, F. C. 1954. Distance to Nearest Neighbor as a Measure of Spatial Relationships in Populations. Ecology., vol. 35 no. 4, p. 445-453.

Cuffey, R. J. 1973. An Improved Classification, Based upon Numerical-Taxonomic Analysis, for the Higher Taxa of Entoproct and Ectoproct Bryozoans. Proceedings of the International Bryozoology Assoc. Conference, Living and Fossil Bryozoa. p. 549-564.

Davis, J. C. 1973. Statistics and Data Analysis in Geology. John Wiley and Sons Inc., New York. 550 pp.

Delmet, D. A. and Anstey, R. L. 1974. Fourier Analysis of Morphological Plasticity within an Ordovician Bryozoan Colony. Paleontol., V. 48, pp. 217-226.

Eftaxiadis, T. 1973. Numerical Taxonomy and Phylogeny of Paleozoic Fasciculate Bryozoans (Ectoprocts). Michigan State University, Unpub. M.S. Thesis, 103 p.

Ehrlich, R., and Weinberg, B. 1970. An Exact Method for Characterization of Grain Shape. Journal Sed. Petrol. V. 40, p. 205-212.

Klapper, G., Sandberg, C. A., Collinson, C., Huddle, J.W., Orr, R. W., Rickard, L. V., Schumacher, D., Seddon, G., and Uyeno, T.T. 1970. North American Devonian Conodont Biostratigraphy. Geological Society of America Memoir v. 127, p. 285-316.

Michener, C. D. and Sokal, R. R. 1966. Two Tests of the Nonspecificity in the Hoplitis Complex (Hymenoptera: Megachilidae) Ann. Entomological Society of America., v.,59, p. 1211-1217.

Nie, N. H.,Bent, D. H., and Hull, C. H. 1970. SPSS: Statistical Package for the Social Sciences. McGraw-Hill Book Co., New York. 343 p.

Oxnard, C. E. 1969. Mathematics, Shape and Function: A Study in Primate Anatomy. American Scientist, v. 57,11, p. 75-96.

Parks, J. M. 1970. FORTRAN IV Program for Q-mode Cluster Analysis on Distance Function with Prnted Dendrogram. Computor Contribution 46., Kansas Geological Survey, 32pp.

Renzetti, P. 1961. Fauna of the Threeforks Shale (Devonian) of Southwestern Montana. Indiana University, unpub. Ph. D. Thesis, 342 pp.

Siegel, S. 1956. Nonparametric Statistics for the Behavioral Sciences. McGraw-Hill Book Co., New York. 301 pp.

Sneath, P.H.A. and Sokal, R.R. 1973. Numerical Taxonomy. W. H. Freeman and Company, San Francisco. 573 pp.

Sokal, R. S. and Sneath, P. H. A. 1963 Principles of Numerical Taxonomy. W. H. Freeman and Co., San Fracisco. 359 pp.

Throckmorton, L. H. 1968. Concordance and Discordance of Taxanomic Characters in Drosophila Classification. Systematic Zoology., V. p. 355-387.

Underwood, E. E. 1970. Quantitative Stereology. Addison-Wesley Publishing Co., 274 pp.

Wittick, R. I. 1973. GEOSYS, and Information System for the Description and Analysis of Spatial Data (Version 2) Michigan State University Computor for Social Science Research, Technical Report. 73-6. 42 pp.

APPENDIX I

Listing of program DMAT, with Fisher's exact probability option.

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      PROGRAM DMAT (INPUT,OUTPUT,PUNCH)
C   CODED IN FORTRAN IV FOR CDC 6500 BY R. ANSTEY AND J. MRAKOVICH, DEPARTMENT
C   OF GEOLOGY-MSU, FALL 1972.  PROGRAM DMAT CALCULATES A DISTANCE MATRIX IN
C   EUCLIDEAN SPACE FOR INPUT TO CLUST. 3 ANALYSIS PROGRAM.  OUTPUT FOR PROGRAM
C   DMAT IS CONTAINED IN MATRIX DIST.  DATA IS NORMALIZED AND RANGES IN VALUE
C   FROM 1.0 TO 0.0 WITH 1.0 MEANING THE GREATEST SIMILARITY AND 0.0 THE LEAST.
C   FIRST DATA CARD MUST CONTAIN THE FOLLOWING INFORMATION IN 4I4 FORMAT ...NF IS
C   NUMBER OF FEATURES....NS IS NUMBER OF SAMPLES....NOR=0 IF Q-MODE,=1 IF R-
C   MODE.
C      NFM=1 CALLS FISHERS EXACT PROBABILITY  NFM=0 FISHERS EXACT PROB IS SKIPPED
C   SECOND DATA CARD IS FORMAT OF INPUT IN 10A8 FORMAT.  THIS CARD IS FOLLOWED
C  THIRD DATA CARD CAN BE USED FOR EXTENDED FORMATES IF NOT NEED USE BLANK CARD
C   BY INPUT DATA WHICH IS READ INTO MATRIX HRMSPL.
      DIMENSION HRMSPL(100,100),RMEAN(100),FMT(20),DIST(100,100)
      DIMENSION FACT(9),NFACT(9)
      DOUBLE PRECISION FACT,FNUM,FDEN
      READ5,NF,NS,NOR,NFM,FMT
      READ FMT,((HRMSPL(I,J),I=1,NF),J=1,NS)
C   TOTAL ROWS AND CALCULATE MEANS
      IF (NFM)150,150,151
  150 CONTINUE
      DO15I=1,NF
      SUM=0.0
      DO10J=1,NS
   10 SUM=SUM+HRMSPL(I,J)
   15 RMEAN(I)=SUM/NS
C   NORMALIZE HRMSPL ARRAY BY DIVIDING EACH ROW BY  ITS RESPECTIVE MEAN
      DO20I=1,NF
      DO20J=1,NS
   20 HRMSPL(I,J)=(HRMSPL(I,J)/RMEAN(I))
C   CALCULATE DISTANCE MATRIX WITH VALUES RANGING FROM ZERO TO ONE
C   SPECIFY Q OR R-MODE
  151 IF(NOR)70,25,30
   70 CONTINUE
   25 NM=NS$NS=NF$NF=NM
   30 DO40I=1,NF
      M=I+1
      IF(M.GT.NF)GOTO39
      DO40K=M,NF
      DIST(I,K)=0.0
      IF (NFM)153,153,154
  153 CONTINUE
      IF(NOR)80,85,34
   80 CONTINUE
   85 DO90J=1,NS
   90 DIST(I,K)=DIST(I,K)+(HRMSPL(J,K)-HRMSPL(J,I))**2
      GO TO 34
   34 DO35J=1,NS
      IF(NOR) 35,35,37
   35 DIST(I,K)=DIST(I,K)+(HRMSPL(K,J)-HRMSPL(I,J))**2
   36 DIST(I,K)=SQRT(DIST(I,K))
      GO TO 37
  154 CONTINUE
      A=0.0
      B=0.0
      C=0.0
      D=0.0
      NSUM=NS
      DO 100 JJ=1,NS
      IF (NOR) 600,600,601
  601 CONTINUE
      IF (HRMSPL(K,JJ)-2) 202,201,201
```

```
202 IF (HRMSPL(I,JJ)-2) 200,201,201
201 NSUM=NSUM-1
    GO TO 100
200 Q=HRMSPL(I,JJ)+HRMSPL(K,JJ)
    IF(Q-2)2,1,2
  1 A=A+1
    GO TO 100
  2 IF(Q) 4,3,4
  3 D=D+1
    GO TO 100
  4 QQ=HRMSPL(I,JJ)-HRMSPL(K,JJ)
    IF (QQ) 8,201,7
  7 B=B+1
    GO TO 100
  8 C=C+1
    GO TO 100
DMAT

600 CONTINUE
    IF(HRMSPL(JJ,K)-2)502,502,501
502 IF(HRMSPL(JJ,I)-2) 500,501,501
501 NSUM=NSUM-1
    GO TO 100
500 Q=HRMSPL(JJ,I)+HRMSPL(JJ,K)
    IF (Q-2)511,512,511
511 A=A+1
    GO TO 100
512 IF(Q)514,513,514
513 D=D+1
    GO TO 100
514 QQ=HRMSPL(JJ,I)-HRMSPL(JJ,K)
    IF (QQ) 518,501,517
517 B=B+1
    GO TO 100
518 C=C+1
    GO TO 100
100 CONTINUE
    NFACT(1)=NSUM
    NFACT(2)=A
    NFACT(3)=B
    NFACT(4)=C
    NFACT(5)=D
    NFACT(6)=A+B
    NFACT(7)=C+D
    NFACT(8)=A+C
    NFACT(9)=B+D
    DO 800 L=1,9
800 FACT(L)=1.0
    DO 801 L=1,9
    NEND=NFACT(L)-1
    IF (NEND) 801,801,803
803 DO 802 LL=1,NEND
    LLL=LL+1
802 FACT(L)=FACT(L)*LLL
801 CONTINUE
    FNUM=1.0
    FDEN=1.0
    DO 804 MM=1,5
804 FDEN=FDEN*FACT(MM)
    DO 805 MM=6,9
805 FNUM=FNUM*FACT(MM)
```

```
      DIST(I,K)=FNUM/FDEN
      GO TO 37
   37 DIST(K,I)=DIST(I,K)
      IF(NFM)702,702,701
  701 DIST(I,I)=1.0
      GO TO 40
  702 DIST(I,I)=0.0
   40 CONTINUE
      DIST(I,I)=0.0
   39 DIST(I,I)=0.0
C   SCAN DIST FOR MAX AND DIVIDE INTO ALL VALUES AND SUBTRACT EACH FROM 1.0
      IF (NFM)160,160,161
  160 CONTINUE
      DMAX=0.0
      NT=NF-1
      DO45I=1,NT
      M=I+1
      DO45K=M,NF
      IF(DMAX-DIST(I,K))43,45,45
   43 DMAX=DIST(I,K)
   45 CONTINUE
C   DIVIDE DMAX INTO EACH VALUE AND SUBTRACT FROM 1.0
      DO50I=1,NT
      M=I+1
      DO50K=M,NF
      DIST(I,K)=1.0-(DIST(I,K)/DMAX)
      DIST(I,K)=DIST(I,K)/DMAX
   50 DIST(K,I)=DIST(I,K)
  161 DO55J=1,NF
      PRINT 611,(DIST(I,J),I=J,NF)
   55 PUNCH60,(DIST(I,J),I=J,NF)
    5 FORMAT(4I4/10A8/10A8)
  611 FORMAT(* *, 16F5.3)
   60 FORMAT(16F5.3)
C
```

APPENDIX II

Listing of program FOURIER.

```
      PROGRAM FOURIER (INPUT,OUTPUT,PUNCH)
C     EXPLANATION OF METHOD GIVEN BY EHRLICH + WEINBERG, 1970, JOUR.
C     SED. PETROLOGY, V. 40, P. 205-212.
C     REVISIONS TO ORIGINAL PROGRAM BY ROBERT L. ANSTEY, NOV. 20, 1972
C     DECK STRUCTURE...
C          1. CONTROL CARD - NUMBER OF HARMONIC COEFFICIENTS DESIRED,
C          COLS. 1-2. IF DATA IS FROM AN OPEN CURVE, PUNCH 1 IN COL. 4.
C          2. TITLE CARD (FOR SAMPLE GROUP) - ANY ALPHANUMERIC SYMBOLS,
C          LIMITED TO ONE CARD
C          3. DATA CARDS
C          ALL VALUES MUST BE RECORDED AS 4 DIGIT INTEGER NUMBERS, 20 TO
C          A CARD. VALUES FROM A CLOSED SHAPE MUST BE RECORDED AS X, Y
C          IN A COUNTERCLOCKWISE SEQUENCE STARTING FROM THE POINT
C          X=XMAX. VALUES FROM AN OPEN CURVE MUST BE RECORDED AS X, Y IN
C          ORDER OF DECEASING X STARTING FROM THE POINT X=XMAX.
C          Y AT X=XMAX MUST EQUAL Y AT X=XMIN.
C          IN A CLOSED SHAPE, NO VALUE OF THETA SHOULD HAVE MORE THAN
C          ONE VALUE OF R. IN AN OPEN CURVE, NO VALUE OF X SHOULD HAVE
C          MORE THAN ONE VALUE OF Y.
C          (ALL VALUES MUST BE LESS THAN 9999)
C          LAST 8 COLUMNS OF LAST CARD FOR EACH SAMPLE MUST BE BLANK OR
C          ZERO-FILLED (OTHERWISE A BLANK CARD MUST BE INSERTED)
C          4. FLAG CARD - 9999 IN COLS. 1-4 (SIGNALS END OF EACH SAMPLE
C          GROUP)
C          5. CONTINUATION CARD - CONT OR FINI IN COLS. 1-4
C          IF CONT, NEXT SAMPLE GROUP IS EXECUTED
C          IF FINI, PROGRAM TERMINATES
C          6. REPEAT DECK STRUCTURE, STEPS 2-5, FOR EACH SAMPLE GROUP
C     SIZE LIMITATIONS AND RESTRICTIONS...
C          1. LESS THAN 150 POINTS PER SAMPLE
C          2. LESS THAN 400 SAMPLES PER SAMPLE GROUP
C          3. NUMBER OF SAMPLE GROUPS IS UNLIMITED
C          4. ONLY THE FIRST 20 HARMONICS CAN BE CALCULATED.
C          ALL HARMONICS ARE DIVIDED BY THE VALUE OF THE ZEROTH
C          HARMONIC, MAKING ITS VALUE UNITY. AMPLITUDES OF THE FIRST
C          HARMONIC ARE NEITHER PRINTED NOR PUNCHED, BECAUSE THE
C          FOURIER SERIES IS GENERATED FROM THE CALCULATED CENTER OF
C          GRAVITY OF EACH SHAPE. TO OBTAIN MORE THAN 20 HARMONICS,
C          INCREASE THE DIMENSIONS OF A, B, C, AMP, AND ARRAY.
C          5. PHASE ANGLES ARE NOT PRINTED
C          6. STATISTICAL ESTIMATES WILL NOT BE CALCULATED, NOR WILL
C          DATA BE NORMALIZED FOR SAMPLE SIZES SMALLER THAN 20.
C          NORMALIZED VALUES ARE THOSE DIVIDED BY THE MEAN OF THE SAMPLE
C          GROUP.
C          7. NORMALITY IS TESTED ONLY FOR SAMPLE SIZES GREATER THAN 35
C          8. PROGRAM REQUIRES 100000 OCTAL WORDS OF CENTRAL MEMORY
C          9. PROGRAM REQUIRES 1.3 SECONDS (CDC 6500) PER SAMPLE
C         10. PROGRAM PUNCHES 2N + 7 CARDS FOR N SAMPLES IN EACH SAMPLE
C          GROUP, AND PRINTS APPROXIMATELY 20 PAGES PER SAMPLE GROUP.
      COMMON NUM(2000),NN,KV,FVAR,FMED,FMEAN,FKS
      DIMENSION X(150), Y(150), RAD(150), THETA(150)
      DIMENSION A(20), B(20), C(20), AMP(20), NAME(10)
      DIMENSION ARRAY(400,20), ARAD(400)
      DIMENSION IX(150), IY(150)
      EQUIVALENCE (X,IX), (Y,IY)
```

```
      LOGICAL TRBL
      BETA=4HCONT
      NTEST1=1000
      NTEST2=2000
      NTEST3=3000
      IFLAG=9999
      READ 1030, NHARM, NOPEN
   20 READ 1000, NAME
      DO 1060 N=1,NHARM
 1060 AMP(N) = 0.
      AMPSUM=0.
      NOGOOD=0
      ISEQ=0
      LTOTAL=0
      NN=0
      PRINT 940, NAME
   30 JL=1
      JU=10
      TRBL=.FALSE.
   40 READ 950, (IX(J),IY(J),J=JL,JU)
      IF (IX(JL)-IFLAG) 50,810,860
   50 DO 60 K=JL,JU
      KWIT=IX(K)+IY(K)
      IF (KWIT) 60,70,60
   60 CONTINUE
      JL=JL+10
      JU=JU+10
      GO TO 40
   70 L=K-1
      IF(NOPEN) 71,71,72
   72 IXMAX=IX(1)
      DO 73 I=2,L
      IF(IXMAX-IX(I)) 74,73,73
   74 IXMAX=IX(I)
   73 CONTINUE
      IXMIN=IX(1)
      DO 75 I=2,L
      IF(IXMIN-IX(I)) 75,75,76
   76 IXMIN=IX(I)
   75 CONTINUE
      IXMAX=IXMAX-IXMIN
      DO 77 I=1,L
      X(I)=((IX(I)-IXMIN)*6.2832)/IXMAX
   77 Y(I)=IY(I)
      IYMAX=IY(1)
      DO 78 I=2,L
      IF(IYMAX-IY(I)) 79,78,78
   79 IYMAX=IY(I)
   78 CONTINUE
      DO 81 I=1,L
      IX(I)=(Y(I)*COS(X(I)))+IYMAX
   81 IY(I)=(Y(I)*SIN(X(I)))+IYMAX
      L=L-1
   71 ISEQ=ISEQ+1
      LTOTAL=LTOTAL+L
```

```
      DO 560 J=1,L
      INT=2
      LHI=J+1
      LLO=J-1
      IF (LHI-L) 90,90,80
   80 LHI=1
   90 IF (LLO) 110,100,110
  100 LLO=L
  110 LLOO=LLO-1
      IF (LLOO) 130,120,130
  120 LLOO=L
  130 IF (J-2) 140,220,300
  140 IF (IY(L-1)) 860,310,150
  150 IF (IY(L-1)-NTEST1) 180,310,160
  160 IF (IY(L-1)-NTEST2) 180,310,170
  170 IF (IY(L-1)-NTEST3) 180,310,180
  180 IF (IX(L-1)) 860,310,190
  190 IF (IX(L-1)-NTEST1) 220,310,200
  200 IF (IX(L-1)-NTEST2) 220,310,210
  210 IF (IX(L-1)-NTEST3) 220,310,220
  220 IF (IY(L)) 860,310,230
  230 IF (IY(L)-NTEST1) 260,310,240
  240 IF (IY(L)-NTEST2) 260,310,250
  250 IF (IY(L)-NTEST3) 260,310,260
  260 IF (IX(L)) 860,310,270
  270 IF (IX(L)-NTEST1) 300,310,280
  280 IF (IX(L)-NTEST2) 300,310,290
  290 IF (IX(L)-NTEST3) 300,310,300
  300 LOINTY=IABS(IY(LLO)-IY(LLOO))
      LOINTX=IABS(IX(LLO)-IX(LLOO))
      JUMPLY=IABS(IY(LLO)-IY(J))
      JUMPLX=IABS(IX(LLO)-IX(J))
      KICKLY=IABS(JUMPLY-LOINTY)
      KICKLX=IABS(JUMPLX-LOINTX)
      LEAP=200
      GO TO 320
  310 KICKLX=50
      KICKLY=KICKLX
  320 IF (IY(J)) 860,370,330
  330 IF (IY(J)-NTEST1) 360,370,340
  340 IF (IY(J)-NTEST2) 360,370,350
  350 IF (IY(J)-NTEST3) 360,370,360
  360 IF (KICKLY-LEAP) 440,440,370
  370 IF (IY(LHI)) 860,420,380
  380 IF (IY(LHI)-NTEST1) 410,420,390
  390 IF (IY(LHI)-NTEST2) 410,420,400
  400 IF (IY(LHI)-NTEST3) 410,420,410
  410 IF (IY(LHI)-IY(J)) 430,420,430
  420 LHI=LHI+1
      INT=INT+1
      IF (LHI.GT.L) LHI=1
      GO TO 370
  430 IY(J)=IY(LLO)+((IY(LHI)-IY(LLO))/INT)
      INT=2
      LHI=J+1
```

```
      IF (LHI.GT.L) LHI=1
440   IF (IX(J)) 860,490,450
450   IF (IX(J)-NTEST1) 480,490,460
460   IF (IX(J)-NTEST2) 480,490,470
470   IF (IX(J)-NTEST3) 480,490,480
480   IF (KICKLX-LEAP) 560,560,490
490   IF (IX(LHI)) 860,540,500
500   IF (IX(LHI)-NTEST1) 530,540,510
510   IF (IX(LHI)-NTEST2) 530,540,520
520   IF (IX(LHI)-NTEST3) 530,540,530
530   IF (IX(LHI)-IX(J)) 550,540,550
540   LHI=LHI+1
      INT=INT+1
      IF (LHI.GT.L) LHI=1
      GO TO 490
550   IX(J)=IX(LLO)+((IX(LHI)-IX(LLO))/INT)
560   CONTINUE
      DO 570 J=1,L
      X(J)=IX(J)
570   Y(J)=IY(J)
      MX=0
      MY=MX
      MMY=1
      MMX=MMY
      YMOM=0.
      XMOM=YMOM
      YAREA=XMOM
      XAREA=YAREA
580   MMX=MMX+1
      MX=MX+1
      IF (MX-L) 600,590,600
590   MMX=1
600   YAREA=YAREA+(X(MMX)-X(MX))*(Y(MMX)+Y(MX))
      YMOM=YMOM+(X(MMX)-X(MX))*((Y(MMX)+Y(MX))**2-Y(MMX)*Y(MX))
      IF (MX-L) 580,610,580
610   MMY=MMY+1
      MY=MY+1
      IF (MY-L) 630,620,630
620   MMY=1
630   XAREA=XAREA+(Y(MMY)-Y(MY))*(X(MMY)+X(MY))
      XMOM=XMOM+(Y(MMY)-Y(MY))*((X(MMY)+X(MY))**2-X(MMY)*X(MY))
      IF (MY-L) 610,640,610
640   YCEN=YMOM/(YAREA*3.)
      XCEN=XMOM/(XAREA*3.)
      DO 660 I=1,L
      THETA(I)=ATAN((Y(I)-YCEN)/(X(I)-XCEN))
      IF (X(I)-XCEN) 650,660,660
650   THETA(I)=THETA(I)+3.14159
660   RAD(I)=SQRT((Y(I)-YCEN)**2+(X(I)-XCEN)**2)
      DO 670 I=1,NHARM
670   A(I)=B(I)=0.
      A0=0.
      FL=L
      AJ=25./FL
      DO 760 I=1,L
```

```
      II=I+1
      IF (I-L) 690,680,690
  680 II=1
  690 ANGLE=THETA(II)-THETA(I)
      IF (ANGLE) 700,760,710
  700 ANGLE=ANGLE+6.28138
  710 IF (ANGLE-AJ) 730,720,720
  720 TRBL=.TRUE.
      GO TO 760
  730 IF(TRBL) 760,740
  740 AO=AO+ANGLE*(RAD(II)+RAD(I))
      DO 750 N=1,NHARM
      FN=N
      COS2=COS(FN*THETA(II))
      COS1=COS(FN*THETA(I))
      SIN2=SIN(FN*THETA(II))
      SIN1=SIN(FN*THETA(I))
      A(N)=A(N)+((RAD(II)-RAD(I))*(COS2-COS1))/(ANGLE*FN*FN)+(RAD(II)*SI
     1N2-RAD(I)*SIN1)/FN
  750 B(N)=B(N)+((RAD(II)-RAD(I))*(SIN2-SIN1))/(ANGLE*FN*FN)-(RAD(II)*CO
     1S2-RAD(I)*COS1)/FN
  760 CONTINUE
      IF(TRBL) 770,780
  770 NOGOOD=NOGOOD+1
      PRINT 1050, ISEQ
      GO TO 30
  780 DO 790 N=1,NHARM
  790 A(N)=(SQRT(A(N)**2+B(N)**2))*4./AO
      NN=NN+1
      DO 800 N=1,NHARM
  800 ARRAY(NN,N)=A(N)
      ARAD(NN)=AO/125.663
      GO TO 30
  810 PRINT 900, NN
      IF(NN-10) 841,829,829
  829 DO 840 I=2,NHARM
      DO 830 J=1,NN
      F=ARRAY(J,I)*10000.
  830 NUM(J)=F+1
      PRINT 1040, I,NAME
      CALL STAT
      A(I)=(KV/100.)**2
      B(I)=FVAR
      C(I)=FMED
      AMP(I)=FMEAN
      RAD(I)=FKS
      IX(I)=KV
  840 CONTINUE
      PUNCH 1000, NAME
      PUNCH 995, (AMP(N),N=2,NHARM)
      PUNCH 990,(RAD(N),N=2,NHARM)
      PRINT 1003
      DO 1004 I=2,NHARM
 1004 PRINT 1005,I,AMP(I),C(I),RAD(I),IX(I)
  841 PRINT 970
```

```
      PRINT 980, (N,N=2,NHARM)
      DO 853 M=1,NN
      ARAD(M)=ARAD(M)/362.6
      PRINT 960, M,(ARRAY(M,N),N=2,NHARM),ARAD(M)
850   CONTINUE
      DO  858 N=1,NN
      F=ARAD(N)*10000.
858   NUM(N)=F+1
      CALL STAT
      PRINT 878, FMEAN,FKS
      PUNCH 990, FMEAN,FKS
      IF(NN-10) 855,856,856
856   BVAR=0.0
      VAR=0.0
      DO 851 I=2,NHARM
      VAR=VAR+A(I)
851   BVAR=BVAR+B(I)
      DO 852 I=2,NHARM
      IY(I)=(B(I)/BVAR)*100.
852   IX(I)=(A(I)/VAR)*100.
      PRINT 871, BVAR
      PRINT 872, (N,N=2,NHARM)
      PRINT 873, (IY(N), N=2,NHARM)
      PRINT 876, VAR
      PRINT 872, (N,N=2,NHARM)
      PRINT 873, (IX(N), N=2,NHARM)
      PRINT 874
      PRINT 980, (N, N=2,NHARM)
      DO 853 M=1,NN
      ARAD(M)=0.0
      DO 854 N=2,NHARM
      ARRAY(M,N)=ARRAY(M,N)/AMP(N)
854   ARAD(M)=ARAD(M)+(ARRAY(M,N)**2)
      ARAD(M)=SQRT(ARAD(M)/2.)
      PRINT 960, M, (ARRAY(M,N), N=2,NHARM), ARAD(M)
      PUNCH 991, ARAD(M)
853   CONTINUE
      DO 857 N=1,NN
      F=ARAD(N)*1000.
857   NUM(N)=F+1
      CALL STAT
      FMEAN=FMEAN*10.
      FKS=FKS*10.
      PRINT 875, FMEAN
      PRINT 877, FKS
      PUNCH 990, FMEAN,FKS
855   READ 1010, ALPHA
      IF (ALPHA-BETA) 860,20,860
860   CONTINUE
871   FORMAT(1H0,2X,17HTOTAL VARIANCE IS, F9.5)
872   FORMAT(1H0,42X,25HPERCENT OF TOTAL VARIANCE/3X,19(I2,4X))
873   FORMAT(1X,19(I4,2X))
874   FORMAT(1H0,42X,30HNORMALIZED HARMONIC AMPLITUDES,44X,15HNORMALIZED
     + R.C.)
875   FORMAT(1H0,2X,40HMEAN NORMALIZED ROUGHNESS COEFFICIENT IS,F9.5)
```

```
876 FORMAT(1H0,2X,28HTOTAL NORMALIZED VARIANCE IS,F9.5)
877 FORMAT(1H0,2X,7HS.D. IS,F9.5)
878 FORMAT(1H0,2X,7HMEAN IS,F9.5,2X,7HS.D. IS,F9.5)
900 FORMAT(22H USABLE SAMPLE SIZE IS,I4)
940 FORMAT(1H1,10(1H+),10A8,10(1H+)/37H THE FOLLOWING SAMPLES CANNOT B
   +E USED)
950 FORMAT (20I4)
960 FORMAT(1H ,I3,19F6.4,F8.4/)
970 FORMAT(1H0,53X,19HHARMONIC AMPLITUDES,45X,10HRADIUS(MM))
980 FORMAT(6X,19(I2,4X)/)
990 FORMAT (10F7.4)
991 FORMAT (F8.4)
1000 FORMAT(10A8)
1001 FORMAT(16HMEDIAN HARMONICS)
1002 FORMAT(14HMEAN HARMONICS)
1003 FORMAT(9H0HARMONIC,4X,4HMEAN,4X,6HMEDIAN,4X,8HSTD.DEV.,4X,10HCOEFF
   +. VAR.)
1005 FORMAT(1H0,2X,I2,7X,F6.4,3X,F6.4,5X,F6.4,8X,I4)
1010 FORMAT (A4)
1030 FORMAT(2I2)
1040 FORMAT(1X,3(1H*),15HHARMONIC NUMBER,I3,3(1H*),10A8)
1050 FORMAT (21X,6HNUMBER,I5)
     END
```

```
      SUBROUTINE STAT
C     CALCULATICNS ARE VALID FOR 4 SIGNIFICANT FIGURES
C     NORMALITY IS TESTED BY THE KOLMOGOROV-SMIRNOV VALUE OF D AT THE
C     .05 LEVEL OF SIGNIFICANCE. FOR OTHER PROBABILITY LEVELS OF D,
C     CONSULT TABLE E OF SIEGEL, 1956, NONPARAMETRIC STATISTICS FOR THE
C     BEHAVIORAL SCIENCES, MCGRAW-HILL.
      COMMON NUM(2000),NN,KV,FVAR,FMED,FMEAN,FKS
      DIMENSION NBR(10000),NHIST(20),KHIST(20,100),ID(20)
      EQUIVALENCE (NUM,KHIST)
      DO 10 I=1,10000
   10 NBR(I)=0
      DO 20 I=1,NN
   20 NBR(NUM(I))=NBR(NUM(I))+1
      DO 30 I=1,10000
      IF (NBR(I)) 30,30,40
   30 CONTINUE
   40 MIN=I
      DO 50 I=1,10000
      J=10001-I
      IF (NBR(J)) 50,50,60
   50 CONTINUE
   60 MAX=J
      KR=MAX-MIN
      MM=0
      DO 65 I=MIN,MAX
      M=(NN/2)+1
      MM=MM+(NBR(I))
      IF(MM-M) 65,66,66
   65 CONTINUE
   66 MED=I
      INT=(KR/20)+1
      MF=MIN+(INT*19)
      DO 67 M=MIN,MF,INT
      I=((M-MIN)/INT)+1
      NHIST(I)=0
      L=M+INT
      ID(I)=M
      DO 68 J=M,L
   68 NHIST(I)=NHIST(I)+NBR(J)
   67 CONTINUE
      NSUM=0
      DO 70 I=MIN,MAX
   70 NSUM=NSUM+(I*NBR(I))
      MEAN=NSUM/NN
      MM=NN-1
      KVAR=0
      DO 90 I=1,NN
   90 KVAR=KVAR+((MEAN-NUM(I))**2)
      KVAR=KVAR/MM
      FVAR=KVAR
      KS=SQRT(FVAR)
      IF (MEAN) 110,110,100
  100 KV=(KS*100)/MEAN
      FMEAN=MEAN/10000.
      FMED=MED/10000.
```

```
      FMIN=MIN/10000.
      FMAX=MAX/10000.
      FKR=KR/10000.
      FKS=KS/10000.
      FVAR=FKS**2
      DO 101 I=1,20
      DO 101 J=1,100
  101 KHIST(I,J)=1H
      DO 102 I=1,20
      IF(NHIST(I)) 102,102,103
  103 K=NHIST(I)
      IF(K-100) 104,104,105
  105 K=99
      KHIST(I,100)=1H+
  104 DO 106 J=1,K
  106 KHIST(I,J)=1H*
  102 CONTINUE
      FINT=INT/10000.
      PRINT 140,FINT
      DO 107 I=1,20
      FID=ID(I)/10000.
  107 PRINT 150, FID,NHIST(I),(KHIST(I,J),J=1,100)
      IF(NN-35) 110,110,5
    5 DO 1 I=1,20
      J=(INT/2)+1
      NUM(I)=MIN+(I*INT)-J
      NBR(I)=(INT*100)/(KS*SQRT(6.2832))
      F=-(((NUM(I)-MEAN)/KS)**2)/2.
    1 NBR(I)=NBR(I)*(2.7183**F)
      ID(1)=IABS(NBR(1)-((NHIST(1)*100)/NN))
      DO 2 I=2,20
      J=I-1
      NBR(I)=NBR(I)+NBR(J)
      NHIST(I)=NHIST(I)+NHIST(J)
    2 ID(I)=IABS(NBR(I)-((NHIST(I)*100)/NN))
      IDMAX=ID(1)
      DO 3 I=2,20
      IF(IDMAX-ID(I)) 4,3,3
    4 IDMAX=ID(I)
    3 CONTINUE
      DMAX=IDMAX/100.
      FNN=NN
      DTEST=1.36/SQRT(FNN)
      IF(DMAX-DTEST) 6,7,7
    6 PRINT 8, DMAX
      GO TO 110
    7 PRINT 9, DMAX
  110 PRINT 160
      RETURN
    8 FORMAT(32H DATA FIT A NORMAL DISTRIBUTION.,24H KOLMOGOROV-SMIRNOV
     +D IS,F5.3)
    9 FORMAT(39H DATA DO NOT FIT A NORMAL DISTRIBUTION.,24H KOLMOGOROV-S
     +MIRNOV D IS,F5.3)
  140 FORMAT(101H HISTOGRAM OF DATA FREQUENCIES IN 20 EQUAL SIZE CLASSES
     + RANGING FROM THE MINIMUM TO THE MAXIMUM VALUE/25H   SIZE CLASS IN
```

```
   +TERVAL IS,F6.4)
150 FORMAT(3X,F6.4,I5,2X,100A1)
160 FORMAT(1X,100(1H+))
    END
```

APPENDIX III

Listing of means and standard deviations of the 20 repetitive measures for each character on a single specimen. 150 binary characters coded 0 for negative response, 1 for positive, and 2 for unable to determine, characters taken from Eftaxiadis (1973). Data listed in the following format;

Title of specimen

Harmonic Means 2-11

Harmonic Means 12-20

Harmonic Standard deviations 2-11

Harmonic Standard deviations 12-20

Mean radius and its standard deviation

Roughness coefficient and its standard deviation

ZRM, ZRS, ZWTM, ZWTS, APZM, APZS, TMRM, TMRS, DARM, DARS, ANM, ANS, NDPRM, NDPRS, NDARM, NDARS

DLCM, DLCS, DAM, DAS, MDM, MDS, AREAM, AREAS, NNS

150 binary characters listed in order in last two rows.

```
TITLE 6100-8
  .1556   .0522   .0578   .0325   .0201   .0149   .0115   .0091   .0070   .0041
  .0026   .0026   .0022   .0018   .0020   .0015   .0014   .0012   .0011
  .0732   .0319   .0279   .0206   .0138   .0079   .0062   .0043   .0036   .0023
  .0021   .0014   .0018   .0008   .0009   .0008   .0006   .00 5   .0005
  .1567   .0122
 3.4280   .2712
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PLATES

Explanation of Plate 1
For location information, see Table 1.

Figs. 1-7 Nicklesopora renzettiae n. sp. 1, External view showing weak longitudinal and diagonal alignment of zooecia. Loc. 1, 7.5X. 2, Longitudinal section showing budding pattern typical of the genus. No. 6105-R, paratype, Loc. 4, 9X. 3, Transverse section. No. 6103-19, Loc. 1, paratype, 9X. 4. External view showing faintly visible monticules. No. 6104-1, Loc. 1, 3X. 5. Tangential section showing clustering of B acanthopores and replacement giving the impression that the specimen has megacanthopores at zooecial triple junctions. No. 6104-1, Loc. 1, 25X. 6. Tangential section. No. 6103-19, Loc. 1, 9X. 7. Longitudinal section showing thickened amalgamate walls, numerous diaphragms in the outer endozone, and infilled endozonal axis caused by burrowing organism. No. 6102-1, Loc. 1, paratype, 9X.

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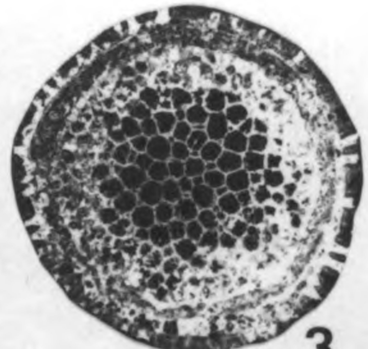

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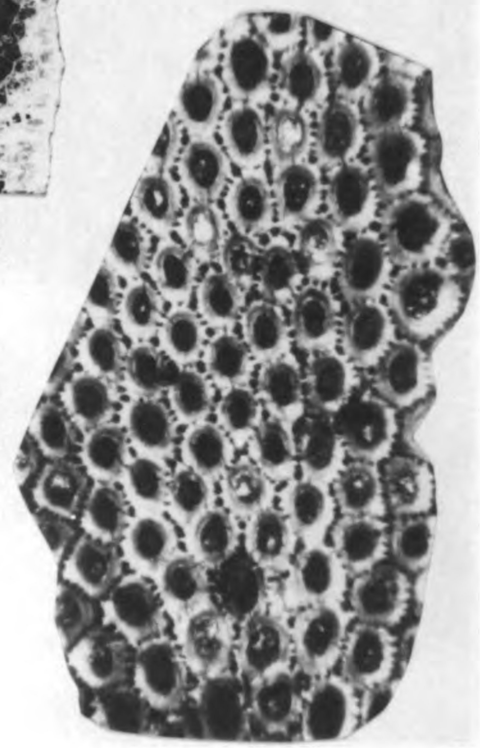

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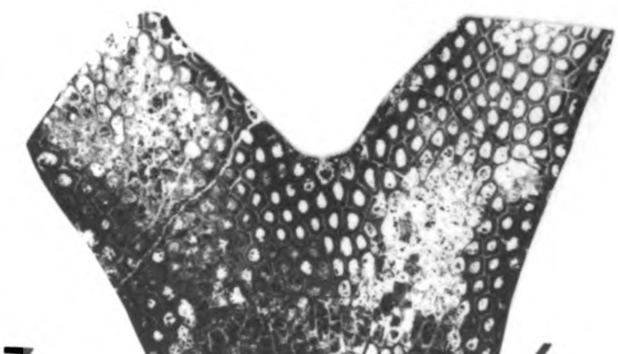

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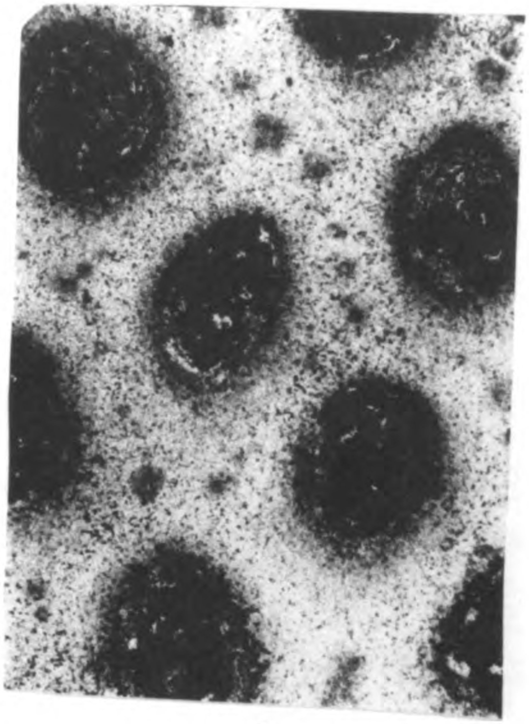
Explanation of Plate 2
For location information, see Table 1.

Figs. 1-5 Nicklesopora renzettiae n. sp. 1. Deep tangential section showing lack of numerous B acanthopores, No. 6102-2, paratype, Loc. 1, 125X. 2. Tangential section showing zooecial openings surrounded by a ring of B acanthopores, No. 6107-1, Holotype, Loc. 2, 125X. 3. Tangential section. No. 6103-24, paratype, Loc. 1, 9X. 4. Longitudinal section showing amalgamate wall structure of exozone. No. 6107-1, Holotype, Loc. 2, 75X. 5. Longitudinal section showing amalgamate wall and side wall projections of B acanthopores in center of thickened walls. No. 6107-1, Holotype, Loc. 2, 75X.



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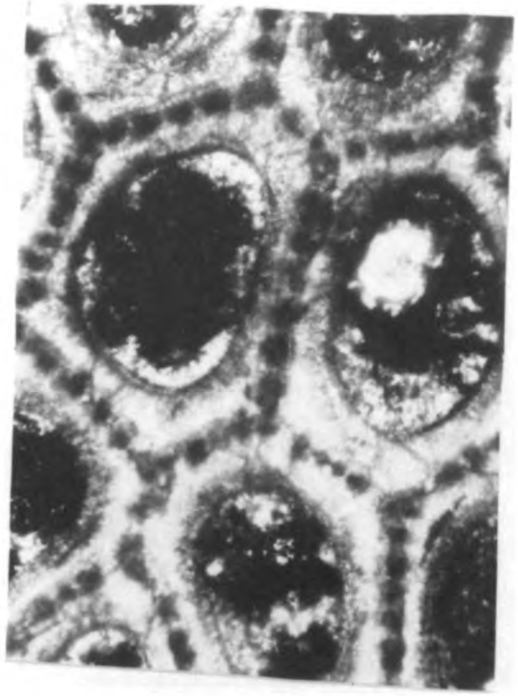

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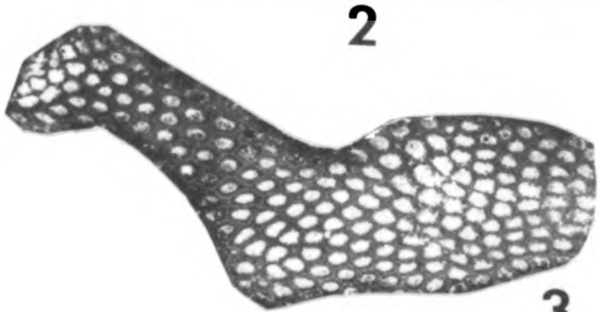

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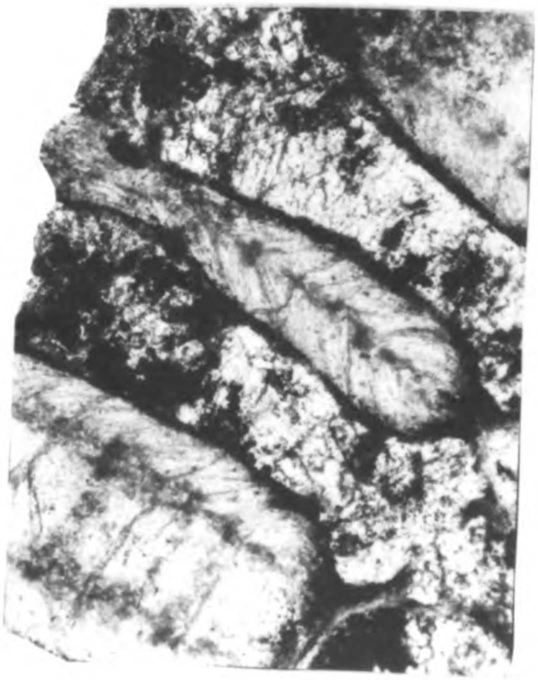


Explanation of Plate 3
For location information, see Table 1.

Figs. 1-2 and 4-6 *Fistulipora* sp. 1. Tangential section No. 6110-7, Loc. 7, 29X.

2. Transverse section No. 6110-7, Loc. 7, 29X.

4. Tangential section. No. 6110-7, Loc. 7, 8.5X.

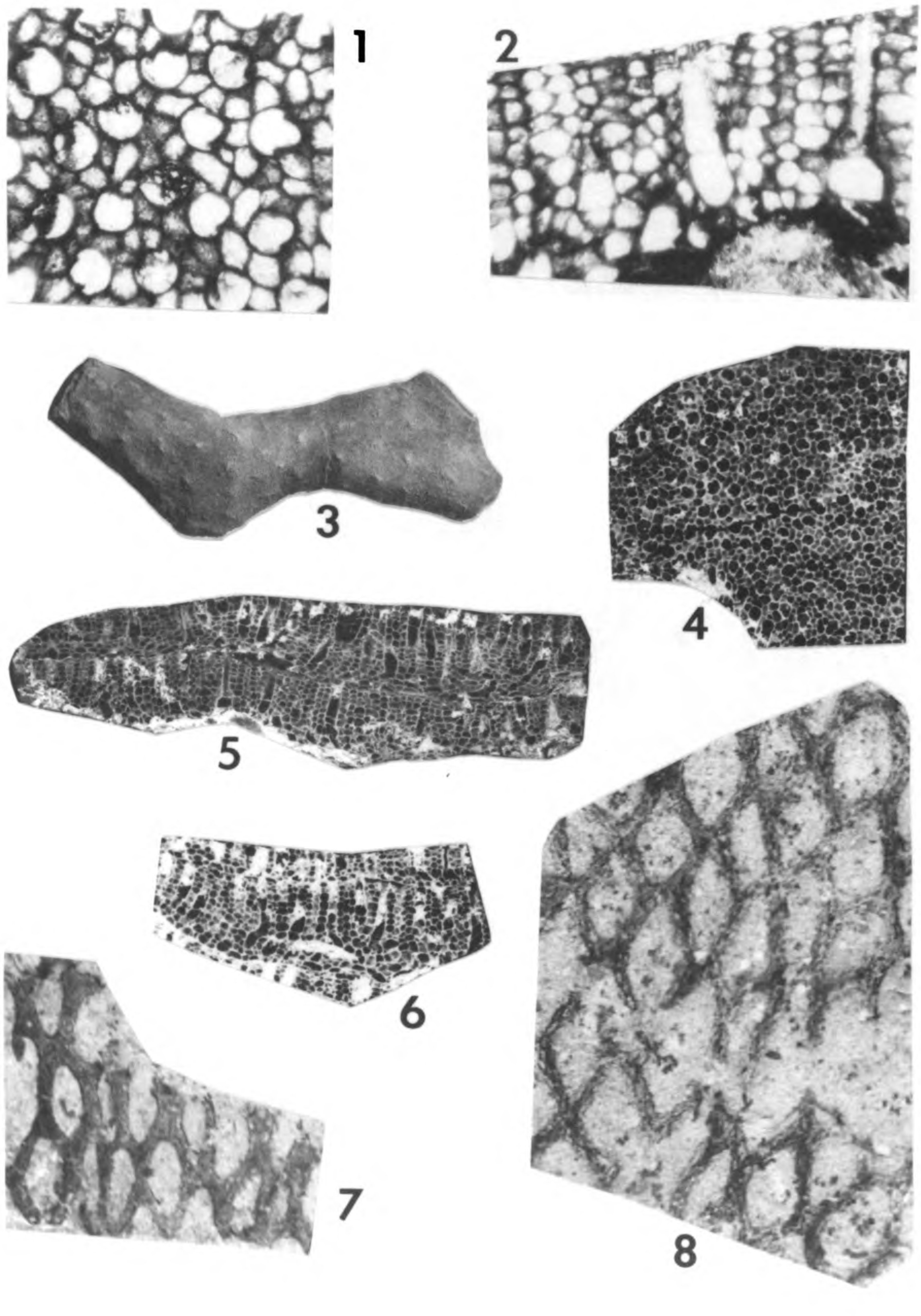
5. Longitudinal section. No. 6110-7, Loc. 7, 7.5X.

6. Transverse section. No. 6110-7, Loc. 7, 8.5X.

Fig. 3 *Leptotrypella pellucida* Duncan, External view showing prominent monticules. No. 6103-23, hypotype, Loc. 1, 3X.

Figs. 7-8 Phyloporinid. 7. Obverse view of fragment, may be part of specimen seen in figure 8, found within several centimeters of specimen figured in Fig. 8. No. 6107-5, Loc. 4, 5X.

8. Specimen poorly preserved and abraded, showing elongate zooecial apertures. No. 6107-5, Loc. 4, 9X.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Explanation of Plate 4
For location information see Table 1.

Figs. 1-5 Leptotrypella pellucida Duncan. 1. External view showing presence of prominent monticules, surface slightly abraided. No. unsectioned specimen, Hypotype, Loc. 1, 3.5X.
2. Tangential section showing typical thin walls and numerous newly budded zooecia. No. 6103-22R, Hypotype, Loc. 1, 9X.
3. Longitudinal section showing amalgamate wall of exozone and the diaphragm laminae forming linings inside zooecial walls and passing upward. No. 6100-R, Hypotype, Loc. 1, 280X. 4. Tangential section, thick walled with faint evidence of A acanthopores at the junctions of the zooecia. No. 6100-R, Hypotype, Loc. 1, 54.5X. 5. Enlargment of Fig. 4 showing presence of A acanthopores at junction of zooecia. No. 6100-R, Loc. 1, 320X.
6. Longitudinal section enlargment of A-acanthopore. No. 6100-R, Hypotype, Loc. 1, 160X.

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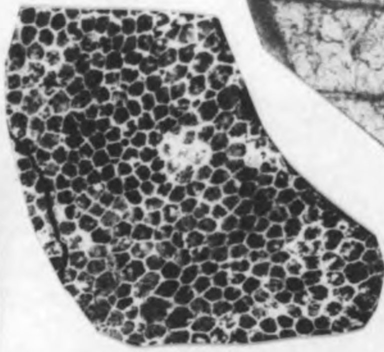

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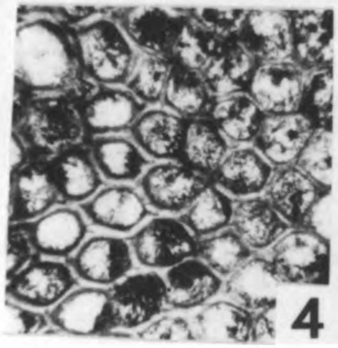

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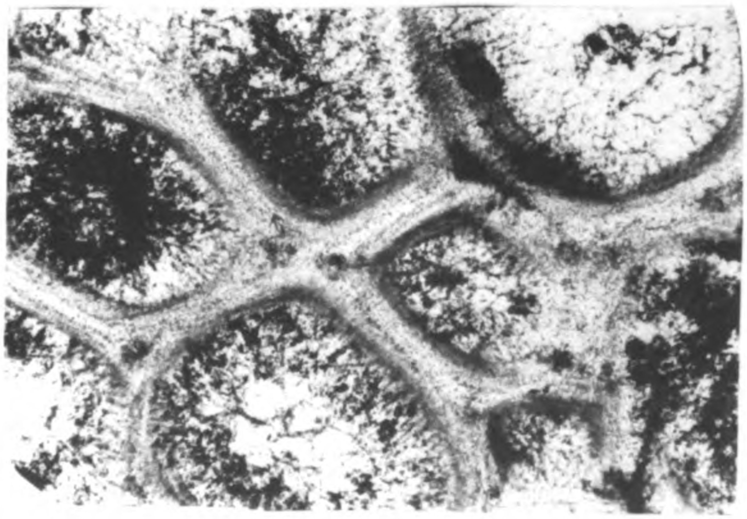

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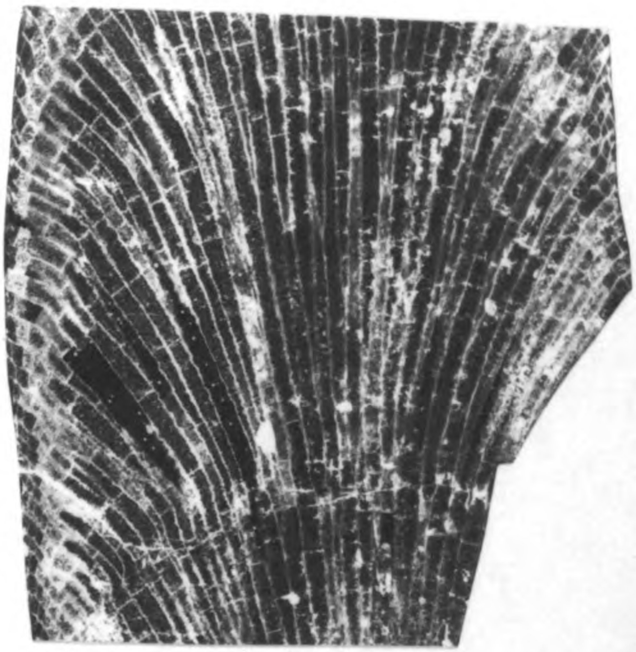
Explanation of Plate 5
For location information see Table 1.

Figs. 1-5 Leptotrypella pellucida Duncan. 1. Longitudinal section, NO. 6103-20, Hypotype, Loc. 1, 9X.

2. Longitudinal section, 6110-9, Hypotype, Loc. 1, 9X.

3. Tangential section showing typical thin walls and numerous newly budded zooecia. No. 6110-9, Hypotype, Loc. 1, 9X.

4. Longitudinal section showing overgrowth and development of shortly spaced diaphragms in upper right of specimen, No. 6103-43, Loc. 1, Hypotype, 7X.



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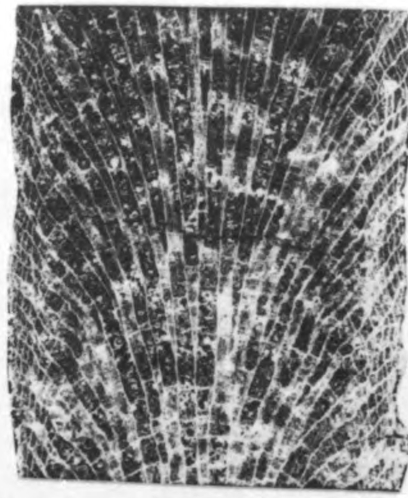

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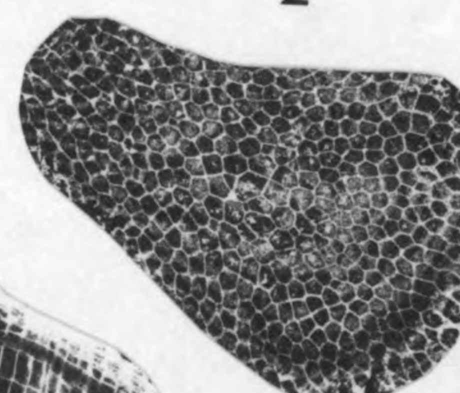

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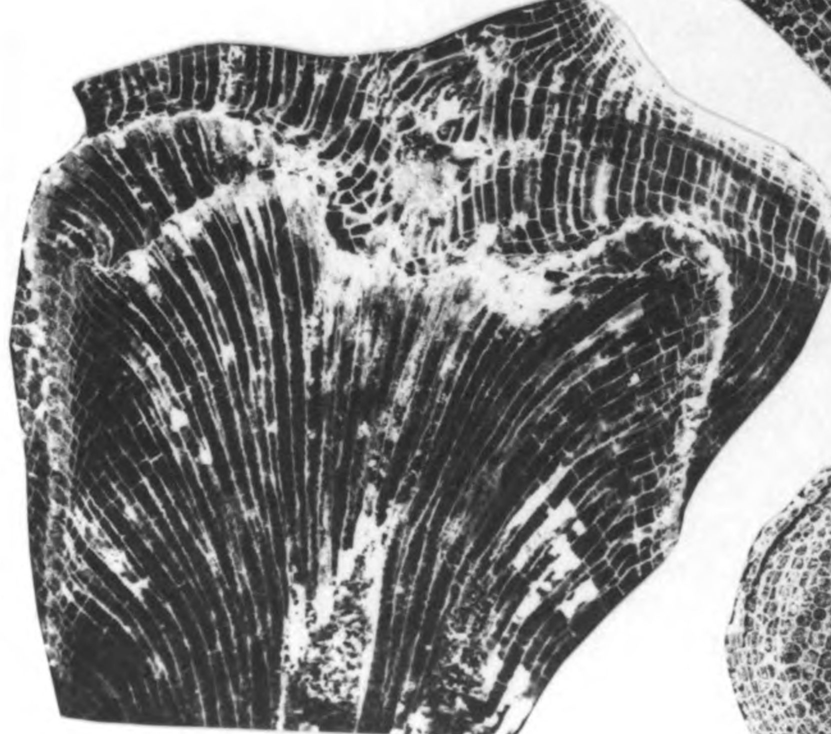

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