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LOWER KARROO (PERMIAN) ACANTHOMORPHITAE ACRITARCHS FROM SOUTH AFRICA

by George F. Hart

Abstract

Eight populations of fifty individuals of Acritarchs from the Permian marine horizons of South Africa are statistically analysed and assigned to two species of *Micrhystridium*. The use of the multivariate discriminant function and Mahalanobis- D^2 as a taxonomic tool in distinguishing populations and species that have but few measurable variables is briefly discussed and the possibility of using such techniques to determine stratigraphic position in lineage studies noted.

Introduction

During recent years evidence has accumulated that the Lower Karroo succession of the Great Karroo Basin of South Africa, in part, is marine (Hart 1963, 1964, in press a; Rilett 1963). The major evidence is the presence of glauconitic horizons and of Acanthomorphitae Acritarchs, occasionally in association. The acritarchs, particularly, occur in specific positions, corresponding to the pro-delta clay and presumed distal bar sand environments, in those sedimentary sequences that have been documented. The *combination* of these factors is strong evidence that the environment is marine. In fact, even in isolation, glauconite or acritarchs would be strong indicators of a marine environment because glauconite and acritarchs are virtually always of marine origin. The best documented exception to this rule among Acanthomorphitae Acritarch studies is that of Churchill and Sarjeant (1962, 1963). However Sarjeant, at the Louisiana State University First Palynology Short Course, on Dinoflagellates and Acritarchs (1968), noted that he considered that such exceptions really represent dinoflagellate cysts, or alternatively, are reworked marine acritarchs (Sarjeant personal communication 1968). Some other evidence for marine conditions existing in the Karroo Basin is provided by Rilett's documentation of a nautiloid cephalopod from Natal. There is no evidence to suggest that this was erroneous, or even doubtful, documentation and, as Rilett points out, the position in the stratigraphic sequence of the cephalopod is such that one could anticipate marine conditions nearby. Conodont occurrence has been mentioned by Van Eeden, Director of South African Geological Survey, as occurring in the south western outcrops of the Karroo and in the Sambokkraal borehole (private communication 1964) but this has never been documented.

Although frequently mentioned by Hart (loc. cit.) the acritarchs have never been fully documented, and the aim of this report is to do this and, at the same time, consider the value of the acritarchs for distinguishing the various marine beds that are believed to occur at different stratigraphic levels in the Lower Karroo succession.

The samples forming the basis of the report are all from cored boreholes from the south-western Transvaal and northern Orange Free State, South Africa. Their geographic position is given in text-figure 1 and their stratigraphic position in text-figure 2. Those boreholes lying in the western sector of the region (boreholes 1, 2, 12) have presumed marine sediments occurring as distinct, thin members (see possible standard on figure 2). All of the eastern samples analyzed palynologically (boreholes 22, 23, 24) contained acritarchs and the entire rock column cored is presumed essentially to be of marine origin. The whole of this marine succession and the three marine members in the eastern area are assigned to either the Cavati or the Cingulati Biozone of Hart (in press).

The percentage abundances of acritarchs, disacciatrileti miospores, and other miospores, in the eight samples studied, are shown in text-figure 3. As is well known to palynologists the residual preparatory concentrate of organic particles obtained from non-marine sediments has a dominance of plant tissues and miospores, but from marine sediments there may be a dominance of phytoplankton (Downie, 1958). With the exception of assemblages 204 and 614 the dominance of phytoplankton in the samples studied is clear and is taken as additional evidence for the marine origin of the sediments. In the presumed non-marine samples studied from the Karroo succession phytoplankton are absent. Although the bulk of the phytoplankton noted were Acanthomorphitae Acritarchs a few specimens of Tasmanitids (order Praeinophyceae) were noted.

Description and Variation Study of the Acritarchs

The specimens described herein are all assigned to the genus *Micrhystridium* Deflandre 1937 and the group Acanthomorphitae Downie, Evitt, and Sarjeant, 1963. *Micrhystridium* is a genus of extremely simple morphology and thus is difficult to divide into taxa of species rank. The variables most frequently used are: diameter of body; number of processes seen around the outline; and length of processes. Length of process is taken as the average of the three longest processes observed around the outline. In the present study, the three variables were measured on 50 individuals from each of the eight assemblages and the data used for statistical analysis of the taxa. Two species are recognised: *Michrystridium A* and *Micrhystridium B*.

MICRHYSTRIDIUM sp. A

Typical Specimens

Plate 1, figures 1-7, 10; plate 2, figures 1, 2 from assemblage 948. Text-figure 5A.*

Description

Simple acritarchs belonging to the Group Acanthomorphitae of Downie, Evitt, and Sarjeant, 1963. The outline of the body is more or less circular, with a diameter of 10 to 19 microns. No phylome or operculum was observed but the

*Text-figures lie between pp 64-68

body wall was often folded. With the scanning electron microscope these folds are determined as compression folds and not due to any underlying structural weakness.

The processes are parallel sided or slightly tapering and have truncated apices. The process lengths are three or four times their basal diameter and their distance apart is generally greater than their height. Both the body and the processes are seen to be covered by extremely small grana when the specimens are examined with the scanning electron microscope.

As determined by the light microscope the mean sizes of the body diameter, and process length, and the number of processes around the outline, are given in Table 1 for assemblage 2479, 2496, 2507, 948, 2519, 614 and 1203. Assemblage 948 is taken as representing a typical population and the fifty individual measurements taken on it are given in Table II. For this population the average values of the variables are:

Diameter: 15.5μ
Process length: 2.2μ
Process number: 15

MICRHYSTRIDIUM sp. B

Typical Specimens

Plate 1, figures 8 and 9 from assemblage 204. Text-figure 5B.

Description

Simple acritarchs belonging to the Group Acanthomorphitae Downie, Evitt, and Sarjeant, 1963. The outline of the body is circular to roundly triangular and of diameter varying from 5 to 18 microns. No phylome or operculum was observed. This species was examined using only the light microscope. The processes are slightly tapering and occasionally truncated, and are six or more times as long as their basal diameter. Their distances apart are less than their length. All specimens have a smooth background when seen under the light microscope.

The mean body diameter, process length, and the number of processes around the outline, as determined by the light microscope are given in Table I under assemblage 204. The fifty individual measurements taken on this population are given in Table III. The average values of the variables are:

Diameter: 10.8μ
Process length: 4.4μ
Process number: 31

Comparison Between the Two Species

The obvious visual difference between the two species is seen, on statistical analysis, to be due to the larger diameter, shorter process length, and fewer processes seen around the outline of *Micrhystridium A* compared with *Micrhy-*

stridium B. Table I shows these differences in terms of the means of each variable for each population. The differences are apparent not only by examination of the sample means but also by the population means at the 95% confidence interval. These differences (and the intra-specific similarities) are emphasized by the discriminant functions and Mahalanobis' D^2 for comparison between each pair of populations (Tables IV, V and VI).

The discriminant function and Mahalanobis' D^2 is discussed by Snedecor and Cochran (1967: 414) and Miller and Kahn (1962: 276), and its geological potential by Klovan and Billings (1967).

Stratigraphic Analysis of the Micrhystridium A Samples

The purpose of the discriminant function is to determine by using multivariate techniques the extent to which different populations overlap or diverge from one another. It is particularly useful in studying the relationship between two populations and may be used as a multivariate generalization of the t-test for testing the null hypothesis that two populations have the same means with respect to all variables. An adjunct to this facility is the ability of the discriminant function to perform a classificationary task whereby it is possible to distinguish which variables are most effective in separating two populations. Obviously such a technique has great power as a tool for the systematic paleontologist particularly in situations where a quantitative analysis of the material provides the only means of analysing the patterns of variability. However, the potential of the technique for determining stratigraphic position in an evolving species-complex has not yet been investigated. Its potential value lies in the fact that discriminant function coefficients are a measure of the importance of each variable in distinguishing two populations thus, the equation for the differences between composite values represents a mathematical model for separating the two populations. Obviously, if this model is sensitive enough to be of use the individuals making up the two populations should be placed in their correct population when their individual discriminant function value is calculated. The number of successful placements of individuals in their correct population is thus a good measure of the value of the particular model actually to discriminate. In a real taxonomic situation, it is very much a measure of the soundness of taxonomic groupings. Table IV illustrates this point applied to the present data. It shows the distinct separation of assemblage 204; and, also, the tendency of the other assemblages to form two clusters, viz:

(2496, 2507, 2479) and (614, 1203, 2519).

These groupings are indicated, also, by the other statistics calculated for the data. The important point is that there is a slight tendency for the clusters to be stratigraphically orientated; and thus a possibility that this type of analysis may be able to distinguish individual marine members. Examination of the Mahalanobis' D^2 and the discriminant coefficient values, of Table V, shows

that assemblages 2479, 2496, and 2507 are correctly grouped as the Vierfontein Marine Member; assemblage 614 to the Lazy Marine Member; and assemblage 1203, probably correctly so, to the Lazy Marine Member. Assemblage 2519 is completely misplaced. However, if the taxonomic distance apart of the assemblages is plotted using Mahalanobis' D^2 statistic, as is common practice, and assemblage 204 is taken as reference point a distinct temporal relationship is evident. This is illustrated in text-figure 4 which although showing the clustering of assemblages 2519, 614 and 1203 also shows their temporal arrangement when the individual marine members are superimposed on to the pattern. The reason in using 204 as a reference point is that it is independent of the other assemblages (because it is a different species). At this stage in the development of the technique this is believed to be a valid way of stratigraphically interpreting the D^2 statistic.

In conclusion we may note that discriminant function analysis can be used to distinguish species and may also prove useful in separating variants within a lineage. The technique should certainly be further investigated on some better documented lineages.

Acknowledgements

The samples forming the basis of this investigation were made available by Union Corporation of South Africa (boreholes 1 and 2); Federal Mynbou Beperk, Johannesburg (boreholes 22, 23 and 24); and the Anglo American Corporation of South Africa (borehole 12). To these companies the writer expresses his appreciation for cooperation.

P. Liebrandt and R. N. Pienaar who were my research assistants during 1965 at the University of the Witwatersrand undertook the measurements on each assemblage. Dr. Frank Rossi, of Engis Instruments, took the three steroscan photographs during a demonstration of the machine in Chicago, 1967; and Professor W. A. van den Bold and Associate Professors Gale Billings and Bob F. Perkins, of Louisiana State University, read the manuscript. To all these associates I wish to express my sincerest thanks.

The computor program used to determine the statistics was "Discriminant Analysis of Two Groups", originated by the Health Science Computing Facility at U.C.L.A., California. It was run on the I.B.M. 7040 (16-32k) at the Computor Center of Louisiana State University.

I would like to thank my colleagues in the Department of Experimental Statistics at Louisiana State University for their kindness in allowing me to sit-in on their graduate courses on elementary statistics and advanced statistics during the past two years.

TABLE I

	2479	2496	2507	948	2519	614	1203	204
DIAMETER $\bar{X}$	14.24	14.28	14.16	15.58	13.26	14.46	14.40	10.80
(90%)	13.79 to 14.69	13.78 to 14.78	13.81 to 14.51	15.12 to 16.04	12.93 to 13.59	14.04 to 14.88	14.05 to 14.74	10.14 to 11.46
(95%)	13.70 to 14.78	13.68 to 14.88	13.74 to 14.58	15.02 to 16.14	12.86 to 13.66	13.96 to 14.96	13.99 to 14.81	10.00 to 11.60
(99%)	13.52 to 14.96	13.48 to 15.08	13.60 to 14.72	14.84 to 16.32	12.73 to 13.79	13.79 to 15.13	13.85 to 14.95	9.74 to 11.86
PROCESS LENGTH $\bar{X}$	2.29	1.69	1.93	2.18	0.93	0.81	0.63	4.41
(90%)	2.13 to 2.46	1.56 to 1.83	1.68 to 2.18	2.01 to 2.34	0.79 to 1.06	0.74 to 0.88	0.55 to 0.71	4.17 to 4.64
(95%)	2.10 to 2.49	1.53 to 1.86	1.63 to 2.24	1.98 to 2.30	0.76 to 1.09	0.72 to 0.90	0.54 to 0.72	4.13 to 4.69
(99%)	2.03 to 2.56	1.48 to 1.91	1.53 to 2.34	1.91 to 2.44	0.71 to 1.14	0.69 to 0.93	0.51 to 0.75	4.03 to 4.78
No. PROCESSES $\bar{X}$	10.98	9.86	10.72	14.16	8.64	9.20	9.26	31.48
(90%)	10.19 to 11.77	9.32 to 10.40	9.85 to 11.59	13.28 to 15.04	7.93 to 9.35	8.48 to 9.92	8.53 to 9.99	29.51 to 33.45
(95%)	10.03 to 11.93	9.21 to 10.51	9.67 to 11.77	13.11 to 15.21	7.79 to 9.49	8.34 to 10.06	8.39 to 10.13	29.12 to 33.84
(99%)	9.72 to 12.24	9.00 to 10.72	9.33 to 12.11	12.76 to 15.56	7.51 to 9.77	8.05 to 10.35	8.10 to 10.42	28.33 to 34.62
N	50	50	50	50	50	50	50	50

ARITHMETIC MEANS OF VARIABLES FOR EACH SAMPLE: SAMPLE MEAN ($\bar{X}$) AND POPULATION MEAN (μ) AT THE 90%, 95% AND 99% C.L.

TABLE II

MEASUREMENTS ON 50 INDIVIDUALS FROM ASSEMBLAGE 948

Diam.	Length	No.	Diam.	Length	No.
18	2.7	16	13	2.0	15
18	1.0	7	13	1.0	10
17	2.0	8	18	3.0	13
10	1.3	6	17	2.7	16
14	2.0	15	17	2.3	16
17	3.0	17	15	1.0	10
17	3.0	14	15	2.0	14
17	2.0	15	18	2.7	15
18	3.0	14	14	1.7	19
17	2.7	24	14	1.0	13
15	1.0	12	15	3.0	12
15	3.0	10	15	2.1	16
15	2.3	10	13	2.3	12
18	2.0	11	15	2.0	16
14	3.0	12	15	2.3	14
15	3.0	22	14	1.1	12
14	3.0	20	15	2.3	15
15	2.8	19	14	2.0	18
15	3.0	14	18	1.0	15
14	2.0	13	15	2.0	12
13	2.7	15	13	1.3	10
19	2.0	19	19	2.3	13
18	2.0	16	15	1.0	9
19	2.3	20	15	2.0	12
17	2.3	17	15	3.7	15

TABLE III

MEASUREMENTS ON 50 INDIVIDUALS FROM ASSEMBLAGE 204

Diam.	Length	No.	Diam.	Length	No.
9	3.0	24	9	5.0	39
9	5.3	39	10	4.0	31
11	5.3	26	12	5.0	40
11	5.0	35	9	5 0	31
11	5.0	27	1?	5.0	49
10	4.7	28	17	2.0	22
8	5.0	30	8	4.0	22
13	5.0	46	6	4.0	24
15	3.0	45	5	5.0	28
10	4.7	23	8	4.0	30
7	4.0	18	10	7.7	25
18	3.0	39	9	3.7	20
10	4.0	45	13	4.0	45
12	4.3	33	12	3.5	20
10	4.0	33	14	4.0	15
12	7.0	34	13	5.0	39
11	4.7	25	10	5.0	42
7	3.0	24	17	4.5	43
11	4.0	32	17	4.3	41
10	5.0	26	13	5.0	31
13	5.0	30	10	4.3	31
10	4.0	28	11	3.0	25
12	4.0	31	10	5.0	42
8	3.0	24	11	5.0	35
8	3.3	23	8	5.0	36

TABLE IV

	2479	2496	2507	948	2519	614	1203	204
2479		34	36	24	14	6	4	4
2496			44	22	24	12	10	2
2507				22	24	20	16	4
948					16	12	12	4
2519						38	28	2
614							38	0
1203								0
204								

Areas blocked show inability to distinguish in 25% or more of cases. (N = 100)

TABLE V

MAHALANOBIS D^2

	2479	2496	2507	948	2519	614	1203	204
2479		0.96588	0.20625	1.68460	4.75135	8.79719	12.39935	19.37068
2496	—0.00151 +0.01617 +0.00009		0.12548	2.13977	1.89653	3.96374	6.09107	25.75128
2507	—0.00020 +0.00643 —0.00076	—0.00081 +0.00261 +0.00065		1.37972	1.56633	2.36091	3.56432	19.17238
948	+0.00316 —0.01380 +0.00357	+0.00152 +0.00427 +0.00414	+0.00402 —0.00464 +0.00276		5.57839	6.73114	8.42406	19.29378
2519	+0.00106 +0.03674 —0.00121	—0.00166 —0.02208 —0.00058	—0.00297 —0.01316 —0.00002	+0.00558 +0.02302 +0.00274		0.75827	13.10153	29.38855
614	+0.00400 —0.06335 +0.00288	+0.00297 +0.04523 +0.00010	+0.00285 —0.02214 +0.00108	—0.00047 —0.04318 —0.00183	—0.00511 +0.00928 —0.00095		0.56366	34.77547
1203	+0.00499 —0.07918 +0.00535	—0.00372 +0.05685 —0.00176	—0.00370 +0.02891 —0.00231	—0.00081 —0.05195 —0.00051	—0.00658 +0.02269 —0.00201	+0.00049 —0.02598 +0.00111		36.07326
204	—0.01160 —0.01588 —0.00606	+0.01071 —0.03213 —0.00640	—0.01261 +0.01184 +0.00597	+0.01306 —0.01970 —0.00523	+0.00930 —0.04204 —0.00572	—0.00974 +0.05550 +0.00537	—0.00998 +0.05776 +0.00503	

DISCRIMINANT FUNCTION COEFFICIENT [1 2 3]

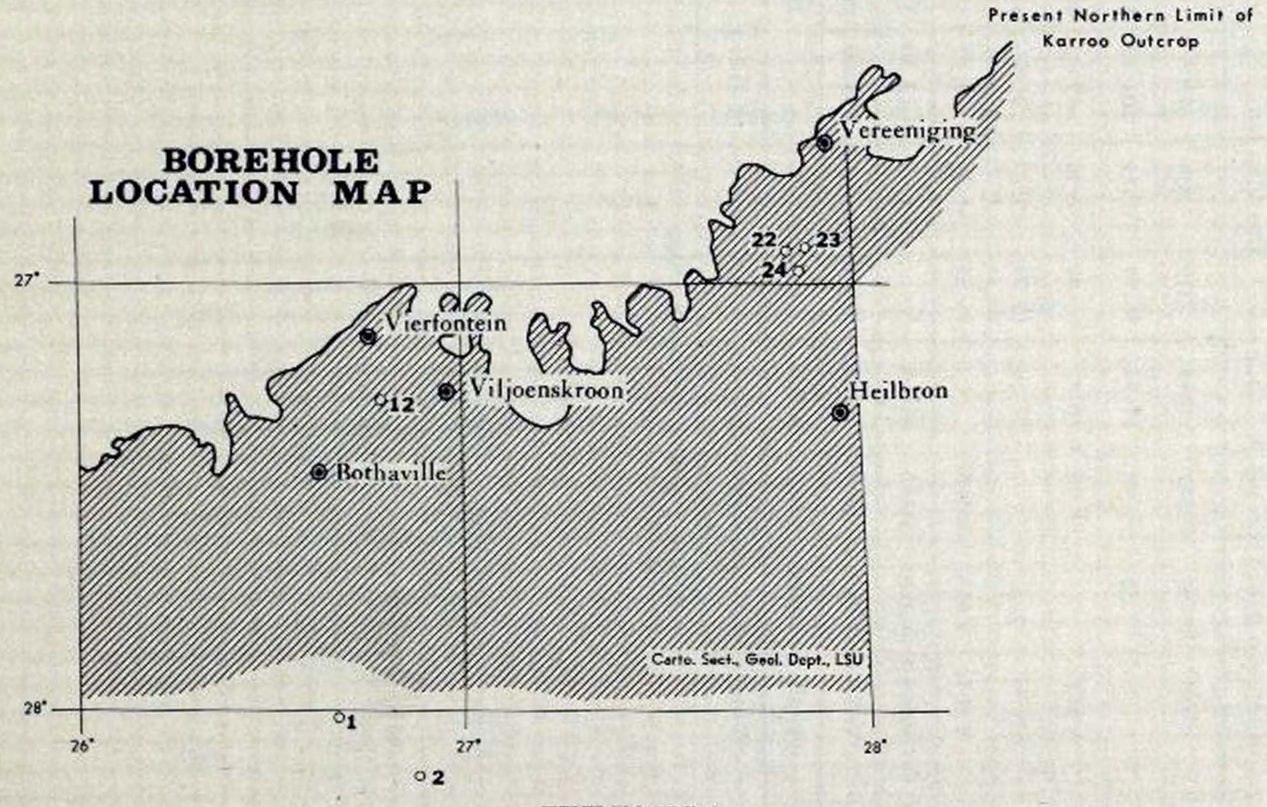
TABLE VI

F VALUE (3,96)

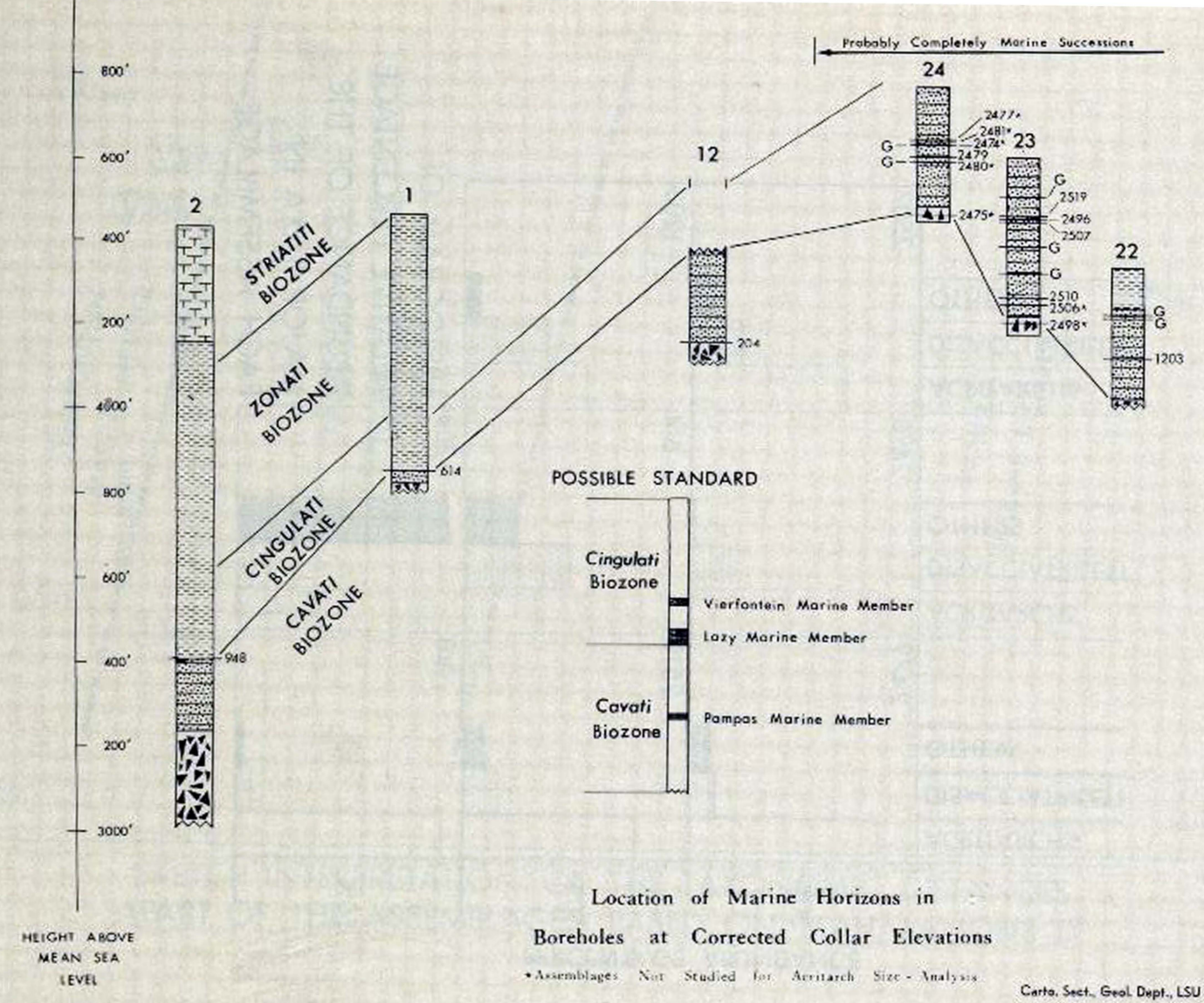
Discriminant Analysis: F values and significance of comparisons between all assemblages studied.
V.H.S. p = .001 H.S. p = .01 S. p = .05 One tailed test

	2479	2496	2507	948	2519	614	1203	204
2479		7.88	1.68	13.75	38.79	71.81	101.22	158.13
2496	V.H.S.		1.02	17.47	15.48	32.36	49.72	210.21
2507	N.S.	N.S.		11.26	12.79	19.27	29.10	156.51
948	V.H.S.	V.H.S.	V.H.S.		45.54	54.95	68.77	157.50
2519	V.H.S.	V.H.S.	V.H.S.	V.H.S.		6.19	13.10	239.91
614	V.H.S.	V.H.S.	V.H.S.	V.H.S.	V.H.S.		4.60	283.88
1203	V.H.S.	V.H.S.	V.H.S.	V.H.S.	V.H.S.	H.S.		294.48
204	V.H.S.	V.H.S.	V.H.S.	V.H.S.	V.H.S.	V.H.S.	V.H.S.	

SIGNIFICANCE OF COMPARISONS

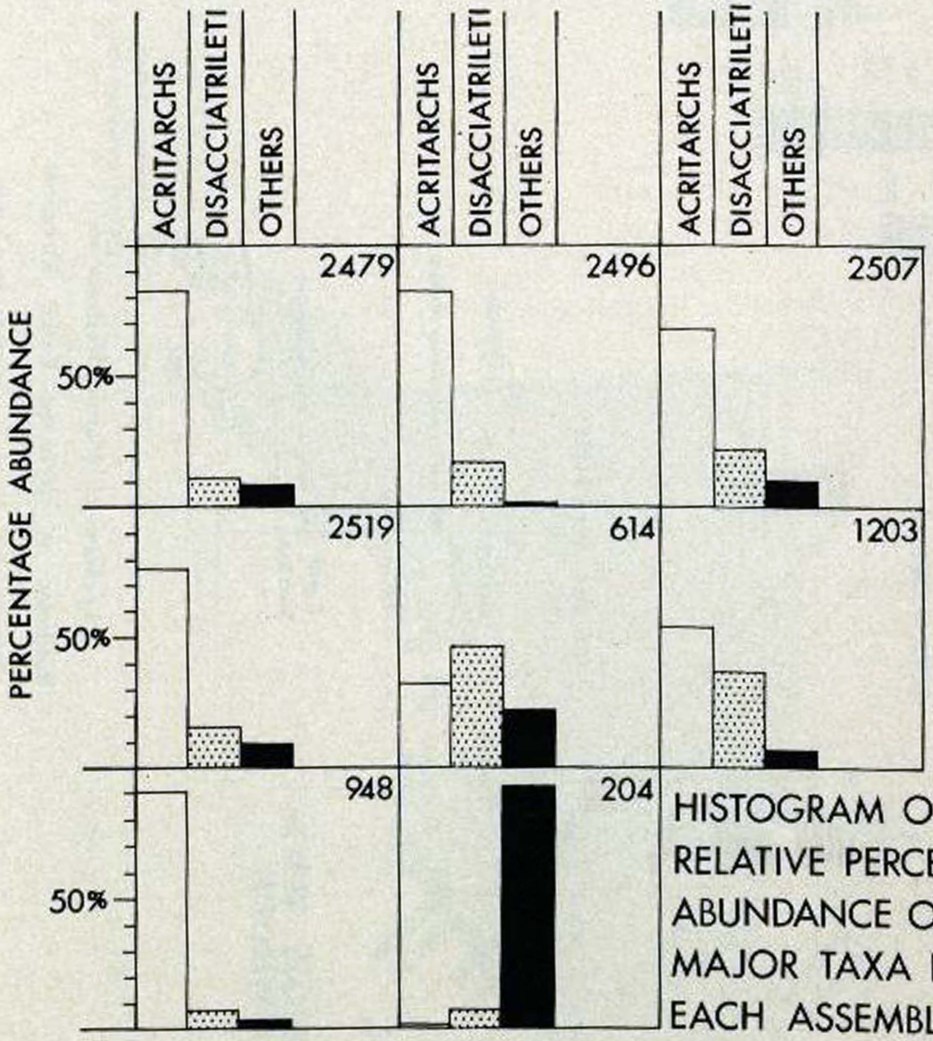


TEXT-FIGURE 1
Location of boreholes studies.

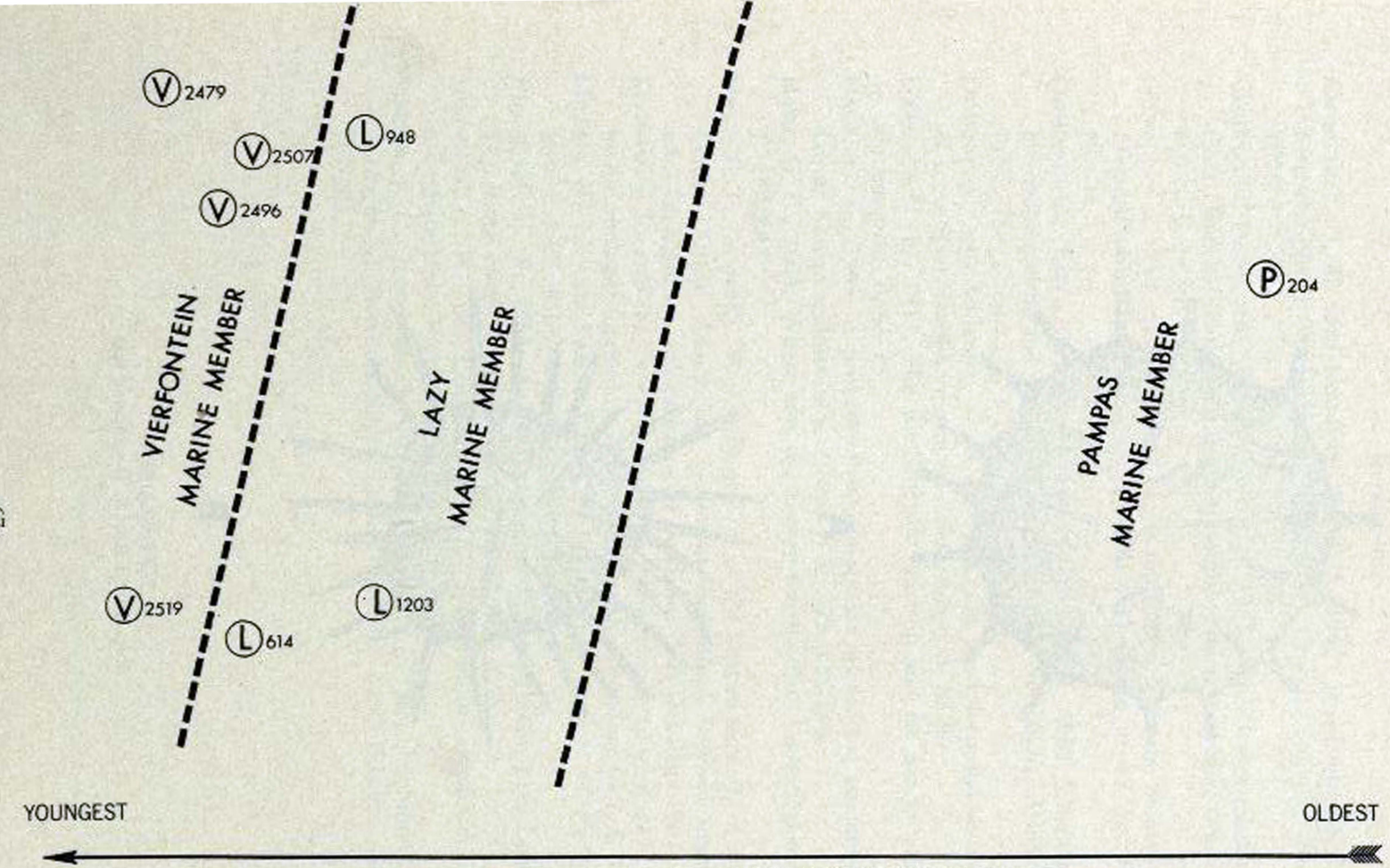


TEXT-FIGURE 2

Location of samples studied in boreholes. (Names of marine members after McKinney—unpublished.)



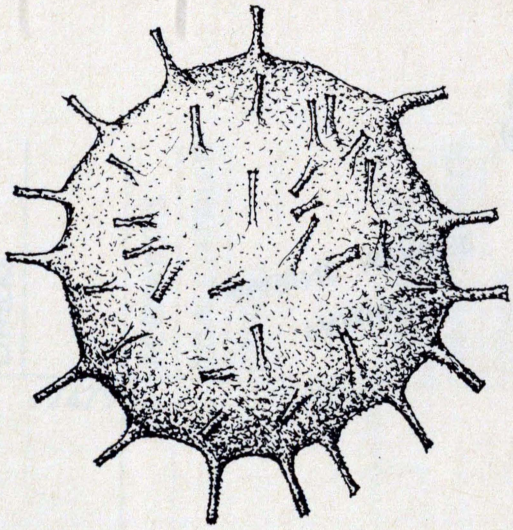
TEXT-FIGURE 3



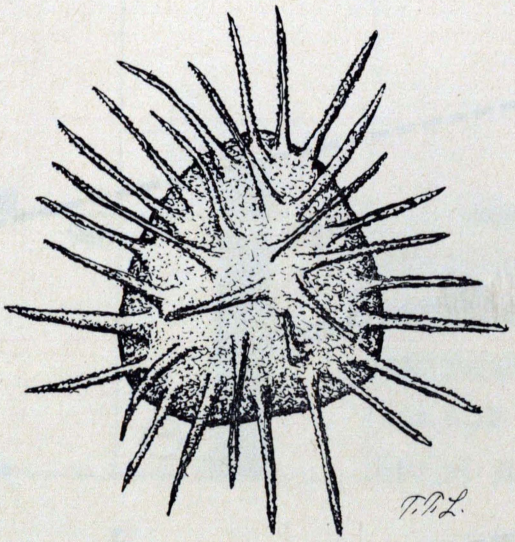
SKETCH INTERPRETATION OF THE TAXONOMIC DISTANCES APART OF THE ASSEMBLAGES BASED ON MAHALANOBIS' D^2

TEXT-FIGURE 4

Carto. Sect., Geol. Dept., LSU



A



B

TEXT-FIGURE 5
M.sp.A. and *M*.sp.B. Diagrams of taxa.

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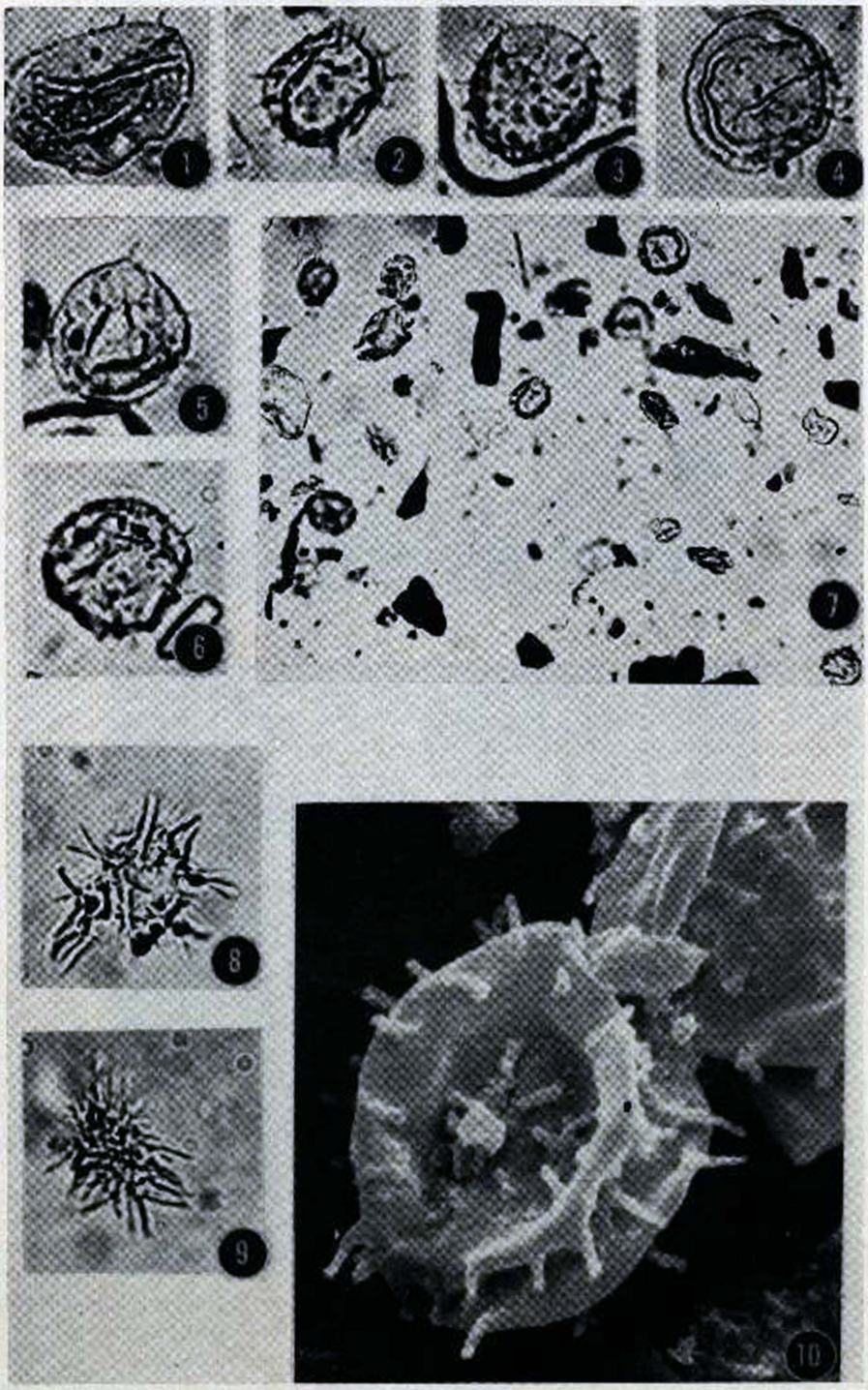
KEY TO PLATE ONE

Fig. 1 Micrhystridium sp. A; assemblage 948; x 750.
Fig. 2 Micrhystridium sp. A; assemblage 948; x 750.
Fig. 3 Micrhystridium sp. A; assemblage 948; x 750.
Fig. 4 Micrhystridium sp. A; assemblage 948; x 750.
Fig. 5 Micrhystridium sp. A; assemblage 948; x 750.
Fig. 6 Micrhystridium sp. A; assemblage 948; x 750.
Fig. 7 Micrhystridium sp. A; assemblage 948; general view of assemblage.
Fig. 8 Micrhystridium sp. B; assemblage 204; x 750.
Fig. 9 Micrhystridium sp. B; assemblage 204; x 750.
Fig. 10 Micrhystridium sp. A; assemblage 948; stereoscan photograph x 3,400.

PLATE I



B.P.—F

KEY TO PLATE TWO

Fig. 11. Micrhystridium sp. A; assemblage 948 stereoscan photograph x 3,500.

Fig. 12. Micrhystridium sp. A; assemblage 948 stereoscan photography, enlargement of figure 11; x 12,000.

PLATE 2

