PALAEOBIOLOGY AND CARBONATE PETROLOGY OF PART OF THE HUGHES CREEK SHALE IN NORTHEASTERN KANSAS

by

WINFRIED SCHMIDT

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KANSAS STATE UNIVERSITY
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Approved by:

Ronald R. West

Major Professor

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INTRODUCTION

Purpose of Investigation

Lower Permian rocks in Kansas are characterized by limestone/shale sequences with an abundance of well preserved fossils. The palaeoecology of four limestone beds in the Hughes Creek Shale Member of the Foraker Limestone (lower Permian) in northeastern Kansas was investigated. In my opinion, a comprehensive palaeoecologic study should involve an integration of nearly every aspect of geology from structural features and basement relief to geochemistry and carbonate petrology.

Within this framework four objectives were defined: 1) identify and determine the ecological significance of the fossil records, 2) study the petrology and determine the depositional environments, 3) determine lateral and vertical differences in the benthic fossil assemblages, and 4) determine the effects of the Nemaha Anticline on the biota and petrology as suggested by West (1972) for the Crouse Limestone.

The Hughes Creek Shale was selected because of its distinct lithologic boundaries and abundance of well preserved fossil assemblages.

The investigation was carried out in cooperation with Gale Yarrow (Yarrow, 1974), who examined the mudstones separating the four limestones in the Hughes Creek Shale at the same localities using similar techniques.

Location

Five localities (fig. 1) of the Hughes Creek Shale (fig. 2) were chosen based on their position relative to the Nemaha Anticline. The Blue River (BR) and Westmoreland (W) localities are on the west flank of the Nemaha Anticline, and Deep Creek (DC) and Louisville (L) sites are near its axis, and locality P (Paxico) is on the east flank of the anticline. The study area includes the southeastern part of Riley County, Pottawatomie County, and north central part of Wabaunsee County, and extend over 40 square miles.

Previous Investigations

The Hughes Creek Shale Member of the Foraker Limestone was named by Condra (1927) for an exposure at Hughes Creek, Nemaha County, Nebraska.

Zeller (1968, p. 45) gives the following description:

> In northeastern Kansas this part of the Foraker comprises light-gray to nearly black shale and thin limestone beds containing a profusion of fusulinids and abundant brachiopods....The thickness ranges from about 20 to 56 feet.

Garber (1956) investigated the stratigraphy of the Hughes Creek Shale in Chase, Lyon, and Wabaunsee Counties. Mudge and Yochelson (1962) described the stratigraphy and palaeontology of the lowermost Permian rocks in Kansas, including the Hughes Creek Shale. Palaeontologic investigations of the Hughes Creek Shale include a study of conodonts in Wabaunsee and Riley Counties by Little (1962), and a study of fusulinids in the upper beds of this member by Fisher (1971). Earlier this year Yarrow (1974) completed a palaeoecological study of some mudstones in the Hughes Creek Shale.

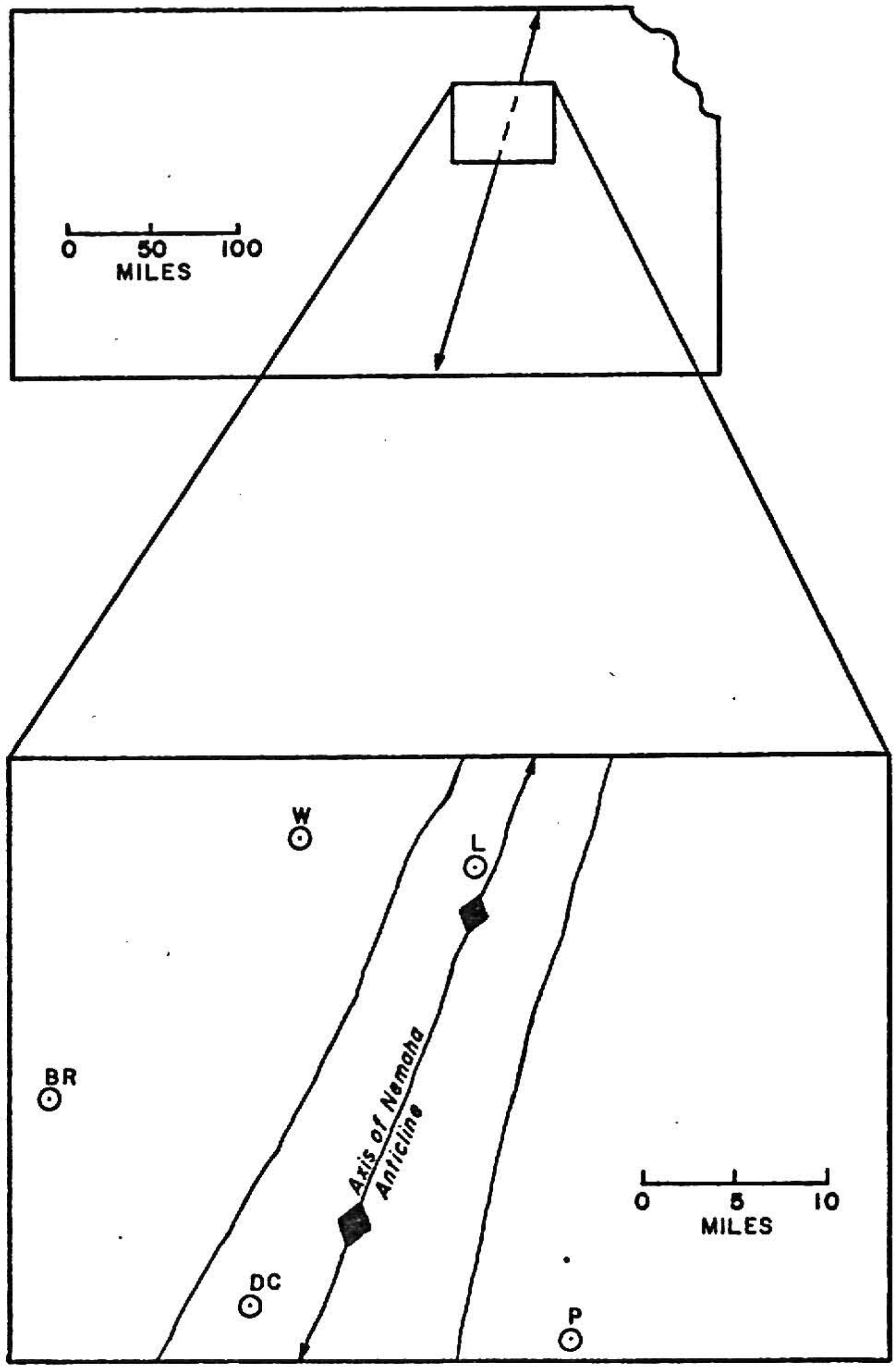


Fig.1. Geographic Location of Study Area

member studied

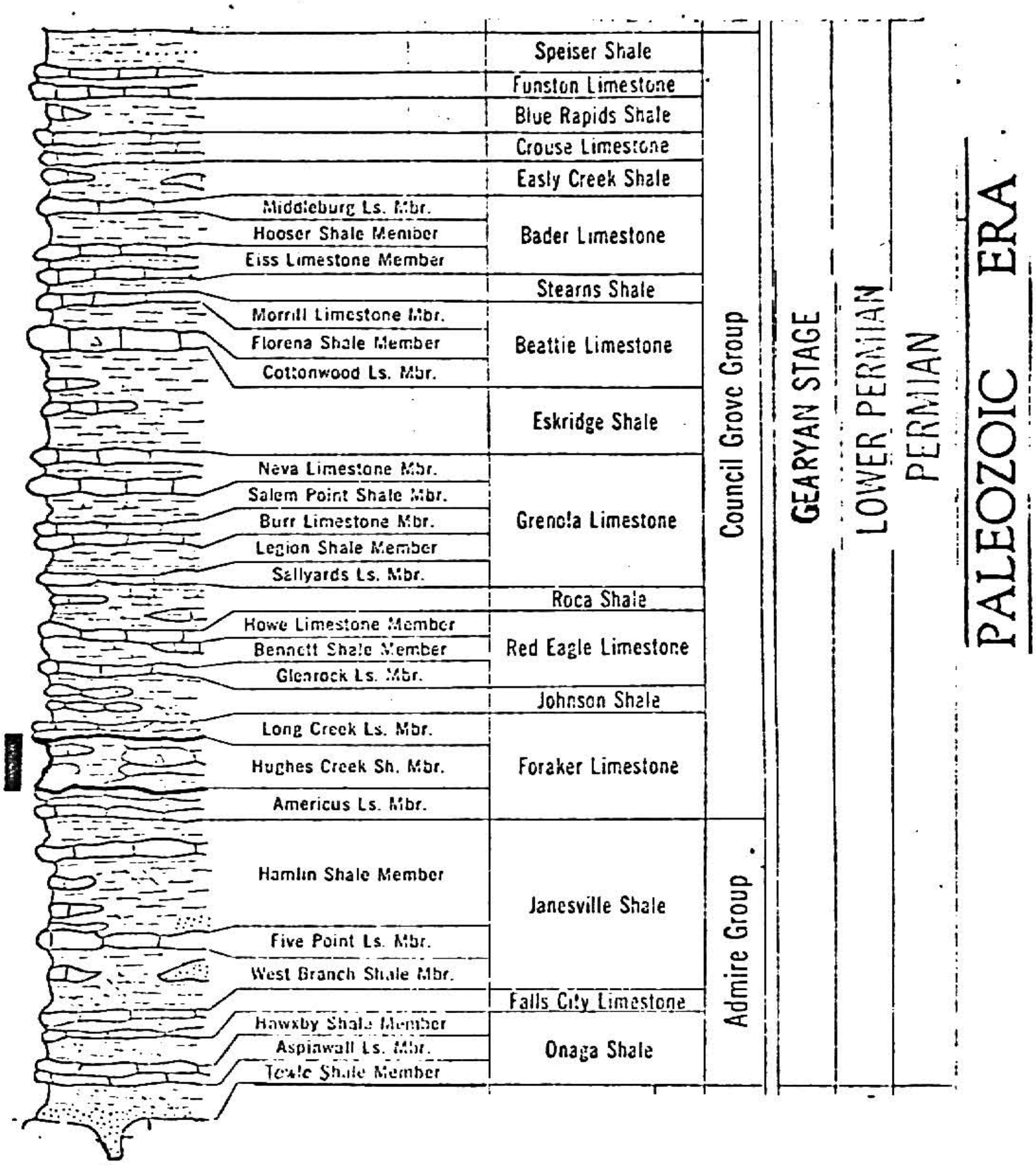


Fig.2. Generalized Stratigraphic Sequence (from Zeller, 1968)

METHODS OF INVESTIGATION

Field Procedure

General Statement.--Geologic maps (Mudge and Burton, 1959; Scott, Forster and Crumpton, 1959; and Jewett, 1941) of Wabaunsee, Riley and Pottawatomie counties were studied to locate usable outcrops. Only outcrops in the proximity of the Nemaha Anticline were considered, because one objective was to determine whether relief, if any, along the Nemaha affected depositional environments and fossil assemblages during Hughes Creek deposition.

Five study sites were selected using the following criteria: 1) a complete section of the Foraker Formation had to be exposed, 2) preference was given to unweathered and well-exposed outcrops (i.e., road cuts, stream cuts) which were not covered by vegetation and, 3) outcrops had to be accessible for adequate sampling. Localities were named with first letter designations as follows: (W) = Westmoreland, (BR) = Blue River, (L) = Louisville, (DC) = Deep Creek, and (P) = Paxico.

Tacheometric Surveying.--Surveying to establish the elevation at the top of the Americus Limestone was done with Yarrow and a detailed description of the technique is given by Yarrow (1974, p. 5 and 6).

Several sources of errors limit the accuracy of tacheometer instruments (Mussetter, 1966, p. 155): 1) errors in reading the rod; 2) errors because of adverse observing conditions, such as wind, refraction, etc.; and 3) errors in adjusting the instrument.

Sampling.--Before looking for suitable outcrops in the field, the following general requirements for samples were postulated: 1) only fresh, unweathered material should be collected, and 2) only samples of the complete units being studied should be used.

Before a specific sampling plan was adopted, the degree of homogeneity between and within beds at the five selected localities was determined to prevent sample bias.

Examination of field notes (Yarrow, 1974, Appendix I) indicated that lithologies between and within localities ranged from micritic limestones to argillaceous mudstones and limestones. Because of this heterogeneity a block of each bed at each locality was collected to assure unbiased sampling. It is essential that samples are collected at the predetermined interval, regardless of any outstanding and extravagant features which may occur at the prefixed sampling point.

Collection of the field samples was done in cooperation with Yarrow (1974). Because mudstones crumble, the whole section, including the limestones, had to be collected "en bloc". Sample size was limited to a horizontal area of 15 cm. by 15 cm., because the maximum width of the available diamond saw vise was 18 cm. Sample blocks were cut from the exposure using a chain saw and the whole block wrapped with burlap strips soaked in molding plaster. Compass orientation and up direction were marked and the block allowed to dry. Wedges were driven under the block's base to break it loose from underlying strata and the blocks removed to the laboratory. Additional samples were collected for petrologic and geochemical analysis (fig. 3). Insoluble residue and thin section samples were collected as follows:

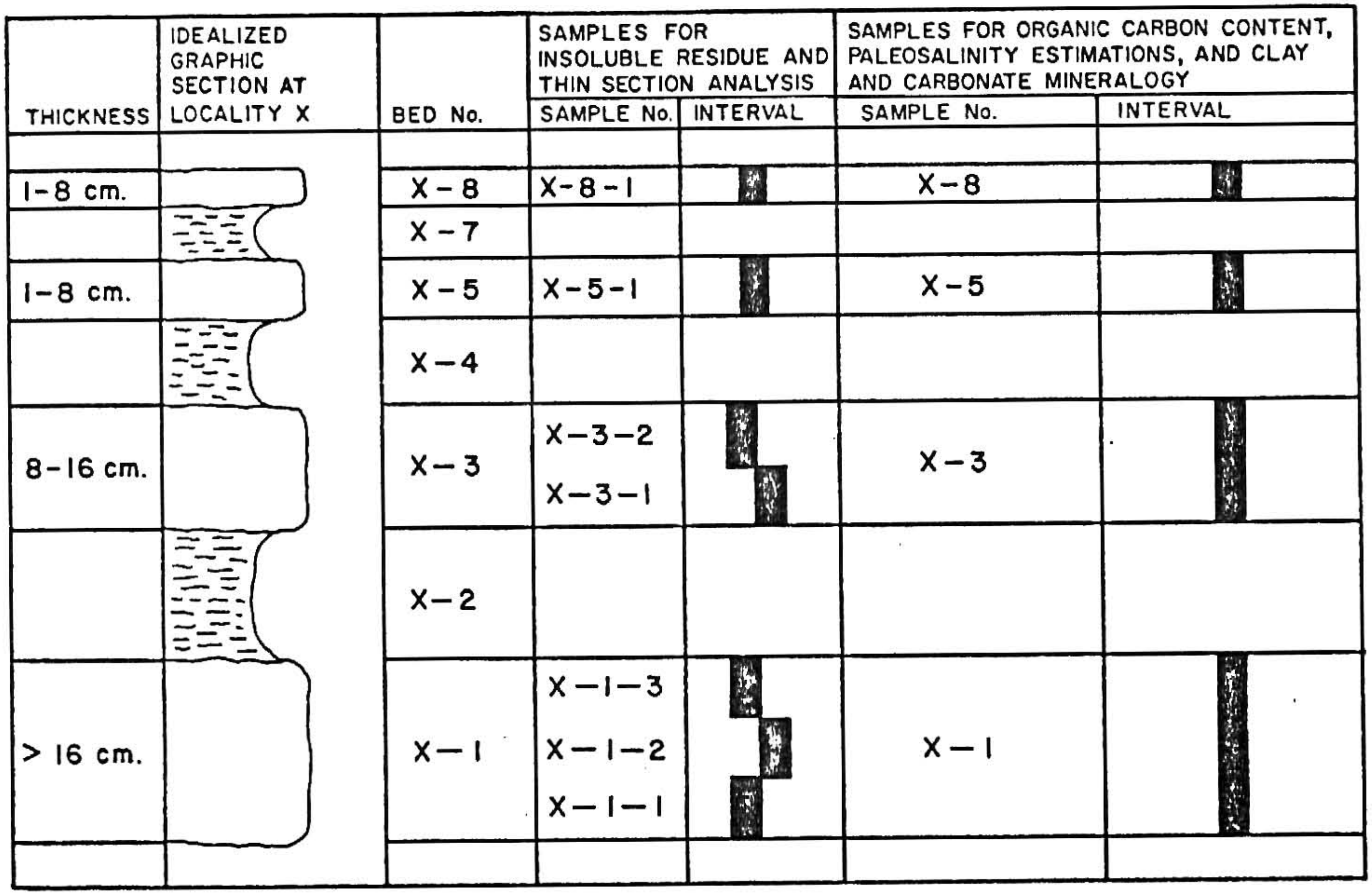


Fig.3. Idealized Grahpic Section Showing Sampling Procedure for Petrologic and Geochemical Samples (modified from Yarrow, 1974)

1) one composite sample for a bed up to 8 cm. thick; 2) from beds between 8 and 16 centimeters thick, two composite samples, one from the lower half and one from the upper half; and 3) if the bed was greater than 16 centimeters thick, three composite samples, one each from the top, middle and bottom were collected. Samples for clay and carbonate mineralogy, organic carbon content and palaeosalinity estimations were composites for the entire bed irrespective of thickness. Sampling the entire section was a compromise to cut down the number of samples requiring time-consuming geochemical analysis.

Data from samples can be biased and, therefore, misleading if sampling specifications are not followed closely (Compton, 1962, p. 184). To prevent sample bias a sample splitter was used to subdivide the original sample when specific analysis required a smaller sample.

Correlation

The term "correlation" is used in a lithologic and palaeontologic sense, applying rock stratigraphic and biostratigraphic principles. Field notes were consulted for information on bedding, thickness and color of the limestone beds and these correlations are shown in Figure 4. Subsequent analysis of clay mineralogy, carbonate petrology, palaeosalinity estimations and organic carbon content substantiated these correlations. However, the most useful information came from the fossil record.

Vertical mapped surfaces (Appendix II) indicate a uniquely developed *Isogramma* zone (Beds W-L, DC-L, BR-L, P-L, and L-L; Appendix II, surface P-8, Appendix III, Plate IV, figs. 1 and 2) which is recognizable in the lower part of the lower limestone at all five outcrops. The middle part of the lower unit is bioturbated (Beds P-L, L-L, W-L, and BR-L; Appendix II, Plate II, Fig. 1), whereas the upper part contains an accumulation of *Crurithyris* and crinoid debris (Beds DC-L, W-L, L-L; Appendix II). There is only a slight

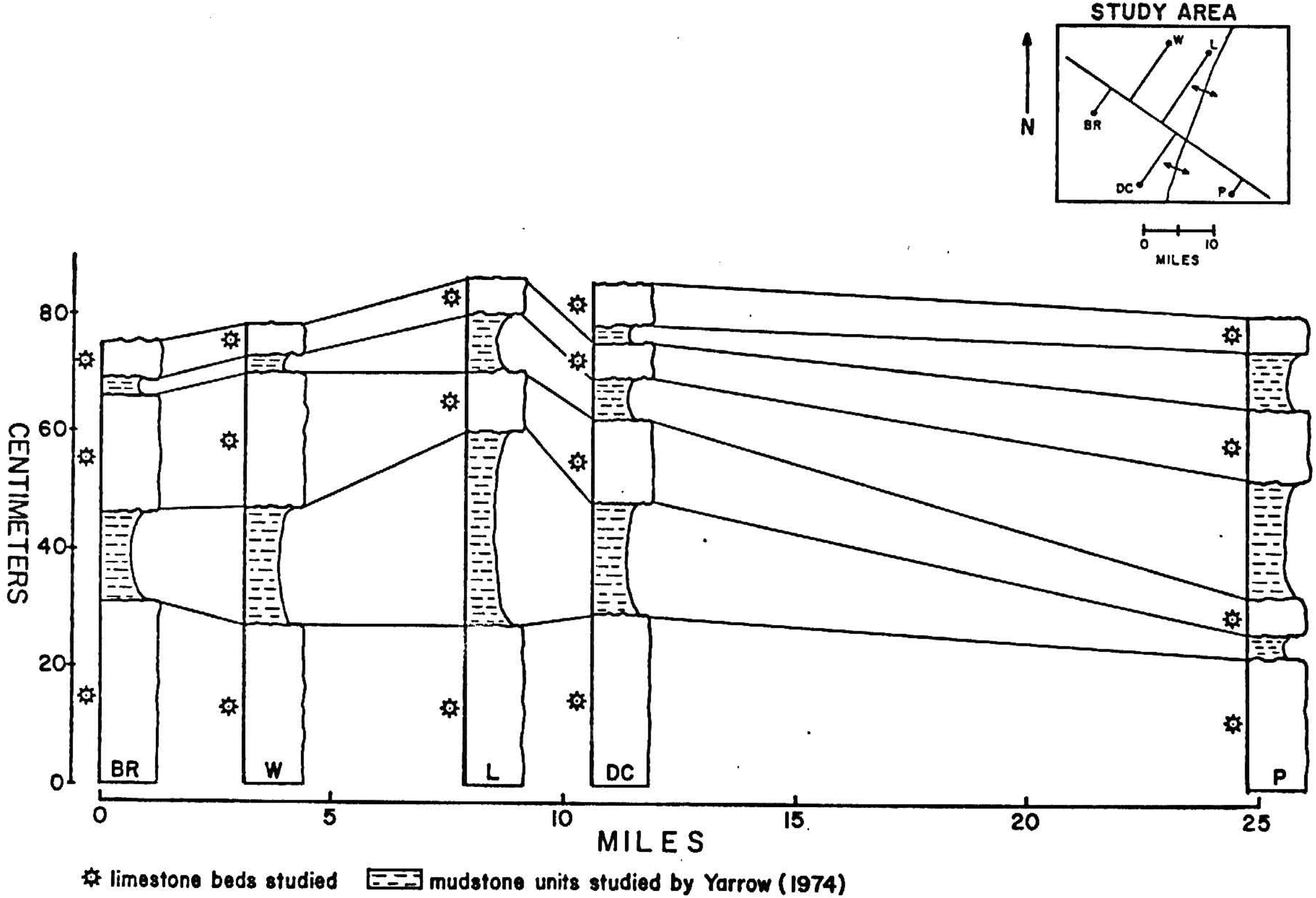


Fig.4. Correlation of Limestone Beds in Part of the Hughes Creek Shale

difference in the thickness of the lower micritic limestone (L-L, P-L).

The middle limestone can be recognized at all five localities by a distinctive fusulinid zone in its lower part (Beds W-M, DC-M, L-M, BR-M; Appendix II).

The upper bed contains a zone of tightly packed Crurithyris (Beds L-U, P-U, DC-U, W-U, BR-U; Appendix II; Plate IV, fig. 3).

The lower bed of the interval is uniformly thick (fig. 4). Limestones and mudstones differ in thickness and color from locality to locality and at Localities DC and P, a fourth limestone bed is correlated as an independent unit and included in the study interval.

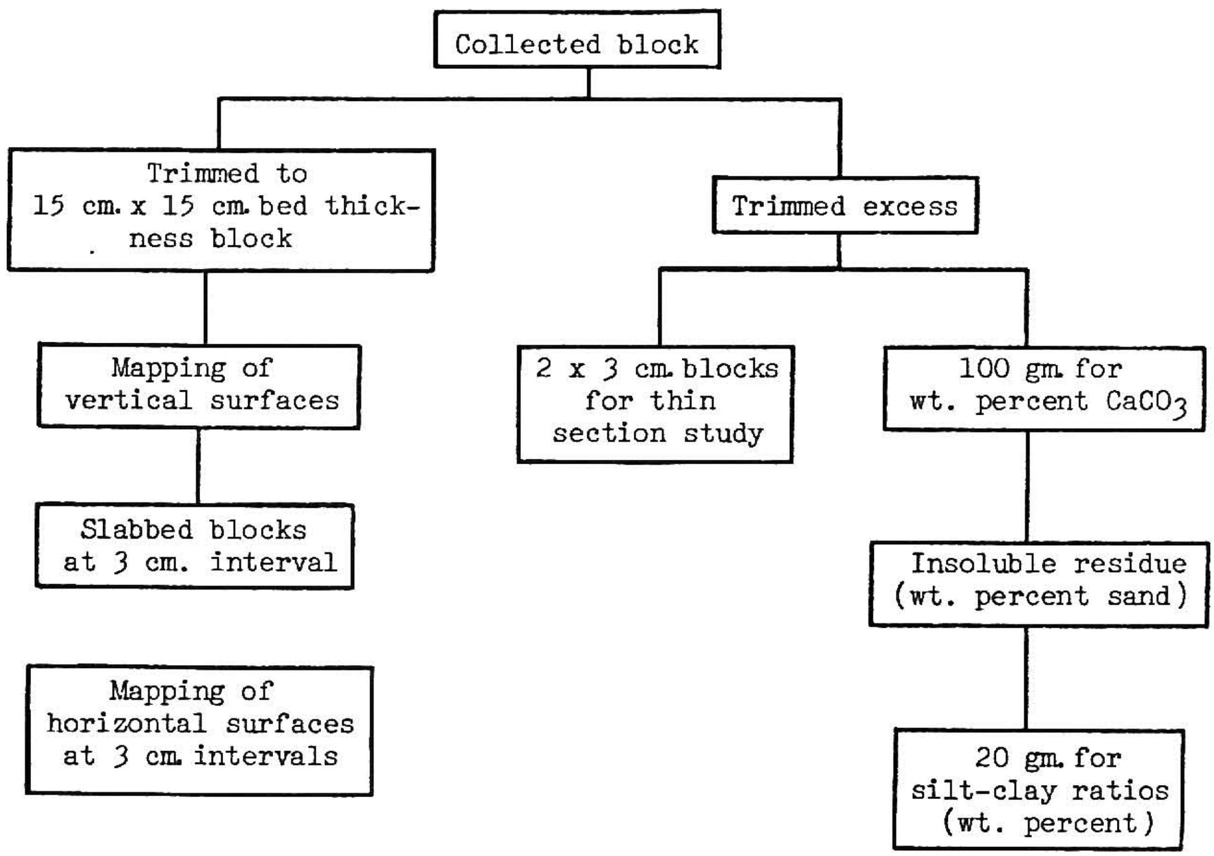
Laboratory Procedure

General Statement.--General laboratory procedure (fig. 5) consisted of: 1) cutting the blocks to be mapped to the proper dimensions, 2) crushing to pea size or pulverizing all other samples, and 3) weighing aliquots for specific analysis.

Biotic Analysis.--Limestone samples were cut into 15 cm. by 15 cm. bed thickness blocks using a kerosene cooled diamond saw. After removal of the burlap plaster cast, the vertical surfaces were cleaned and marked for mapping.

Mapping Vertical Surfaces.--A piece of thin plexiglas was placed over one vertical side of the limestone block and the shapes of the fossils traced on it with multicolored grease pencils. Using a light table the fossil record was transferred from the plexiglas to a measured section log (Appendix II). Only conspicuous fossils were mapped and relative abundances visually estimated (i.e. rare, abundant, locally abundant). The quantification of these abundance terms is in the introduction to Appendix II. Ratios of broken to unbroken valves and articulated to disarticulated valves were recorded. Biogenic sedimentary structures were classified as small horizontal, small vertical, U-shape, and large 'spreite' burrows.

A.



B.

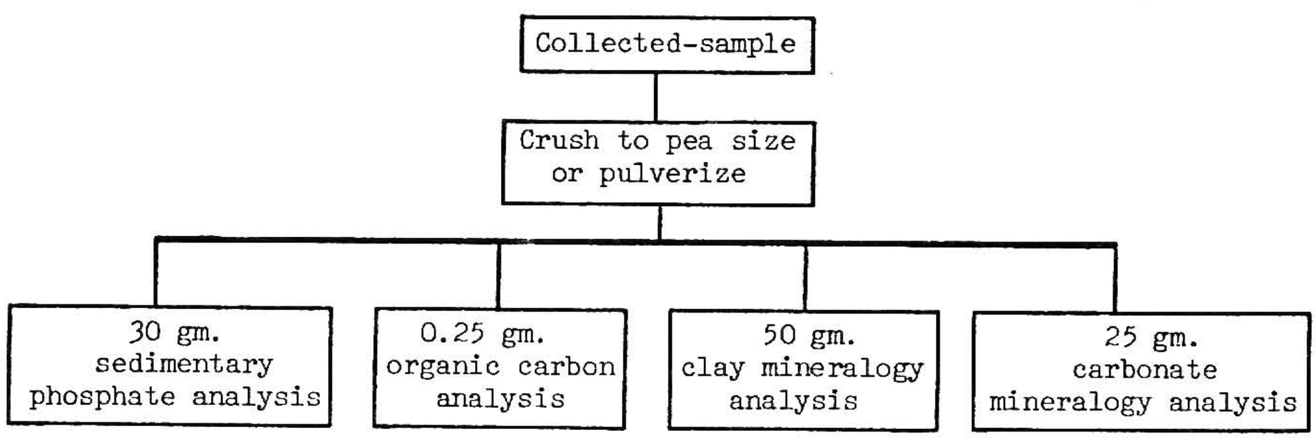


Fig.5. Flow Diagram for General Laboratory Procedure.

Mapping of Horizontal Surfaces.--The quadrat is the most useful technique for mapping macrofossils; however, the method is limited. The procedure is based only on the assumption that the bedding plane assemblage is reasonably contemporaneous (Ager, 1963, p. 221). A halt in sedimentation on a bedding plane will be indicated by large fossil accumulations, thus, preventing the danger of sampling error.

Diameter of the slabbing saw blade limited the size of the horizontal surface that could be mapped. The Bayer Stone Company, Manhattan, Kansas, provided facilities to slice the limestone blocks at approximately 3 cm. intervals which were thin enough to reveal vertical changes in the fossil assemblage, and yet thick enough to include most larger fossil invertebrates. A 15 x 15 cm. area was marked on the plexiglas and all the fossils were transferred to separate data sheets applying the above technique. Approximately 15,000 individual measurements were recorded.

Data for each mapped horizontal surface are defined and listed in Appendix III.

Statistical Analysis.--Q-mode cluster analysis using the Dice correlation coefficient was applied to compare biotic data between localities and within individual beds at specific locations. Q-mode cluster analysis tests the degree of similarity between samples. A data matrix, composed of taxa versus locality, bed and surface was constructed with each individual taxon recorded as present or absent from each of the five localities, three or four beds per locality and surfaces per locality. Figure 6 is an example of the data matrix of taxa versus locality.

Dice's coefficient of association as given by West (1970, p. 32) was used in calculating the matrix of correlation coefficients. Positive matches were weighed twice as heavy as mismatches for the reason stated by West (1970, p. 34). Negative matches were not considered. Values obtained were clustered by the

Taxonomic Entities	Localities				
	BR	DC	P	L	W
Fusulinids	X	X	X	X	X
Ramose type I		X			X
II		X		X	X
III	X	X	X		X
IV		X			X
Fenestrate type I		X	X		
II		X	X	X	X
Cancrinella		X			
Composita	X	X	X	X	X
Crurithyris	X	X	X	X	X
Derbyia				X	X
Hustedia	X	X		X	X
Hystriculia			X		
Juresania				X	
Isogramma	X	X	X	X*	X
Lingula	X	X			X
Linoproductus	X	X	X	X	X
Meekella					X
Neochonetes	X	X	X		X
Neospirifer	X	X	X	X	X
Orbiculoidea	X	X	X	X	X
Petrocrania	X		X	X	
Retaria	X		X	X	X
Reticularia	X				
Rhipidomella		X	X	X	X
Wellerella	X	X	X	X	X
Astartella	X				
Aviculopecten sp.		X		X	
Myalina	X		X		
Schizodus	X				
Septimyalina					X
Wilkingia				X	
Bellerophon sp.		X			X
Crinoids	X	X	X	X	X
Echinoid Spines	X	X*	X	X*	X*
Ostracods*	X	X	X	X	X
Fish Debris	X				
Algae*	X	X	X	X	X

*only observed in thin sections

Fig.6. Data Matrix of Taxonomic Entities

weighed pair method with simple arithmetic averages (Mello and Buzas, 1968, p. 750, Table 4).

A computer program for these calculations was written in WATFIV by Harris (Appendix V) for an IBM 370 computer. Highest degree of similarity is indicated by a correlation coefficient value of 1.0, and lowest degree of similarity by 0.0.

Petrologic Analysis.--Major objectives of petrologic study are to aid in 1) interpreting the environment of deposition, and 2) determining and understanding animal-substrate relationships.

Rhoads and Young (1970, p. 174) found that the physical instability of mud bottom sediments created by deposit-feeding organisms tend to: 1) clog the filtering structures of suspension feeding organisms, 2) bury newly settled larvae or discourage settling of other organisms, and 3) prevent sessile epifauna from attaching to the unstable mud bottom. Sand, silt, clay ratios were determined to clarify the influence of the benthos on sediment stability and to aid in understanding trophic structure. An insoluble residue analysis described by Muller (1967, p. 36) and pipette analysis (Folk, 1974, p. 37 and Royse, 1970, p. 21) were used to separate these three size classes.

Insoluble Residue Analysis.--To determine the amount of insolubles, the carbonates have to be completely removed from the sample (Royse, 1970, p. 27 and Folk, 1974, p. 17). Twiss's modification of the Wentworth size class (silt-clay border at the 2 micron, 9Ø level) was used for all grain size measurements. Figure 7 is a flow diagram of the procedure followed to obtain insoluble residues in weight percent. The sand fraction was stored in paper bags for visual examination of pyrite, chert, and heavy minerals.

Grain Size Analysis.--Figure 8 shows the procedure followed in grain size analysis using the pipette method. The weight of the dried aliquot subtracted from the amount of the sodium hexametaphosphate (brand name of Calgon) dispersant

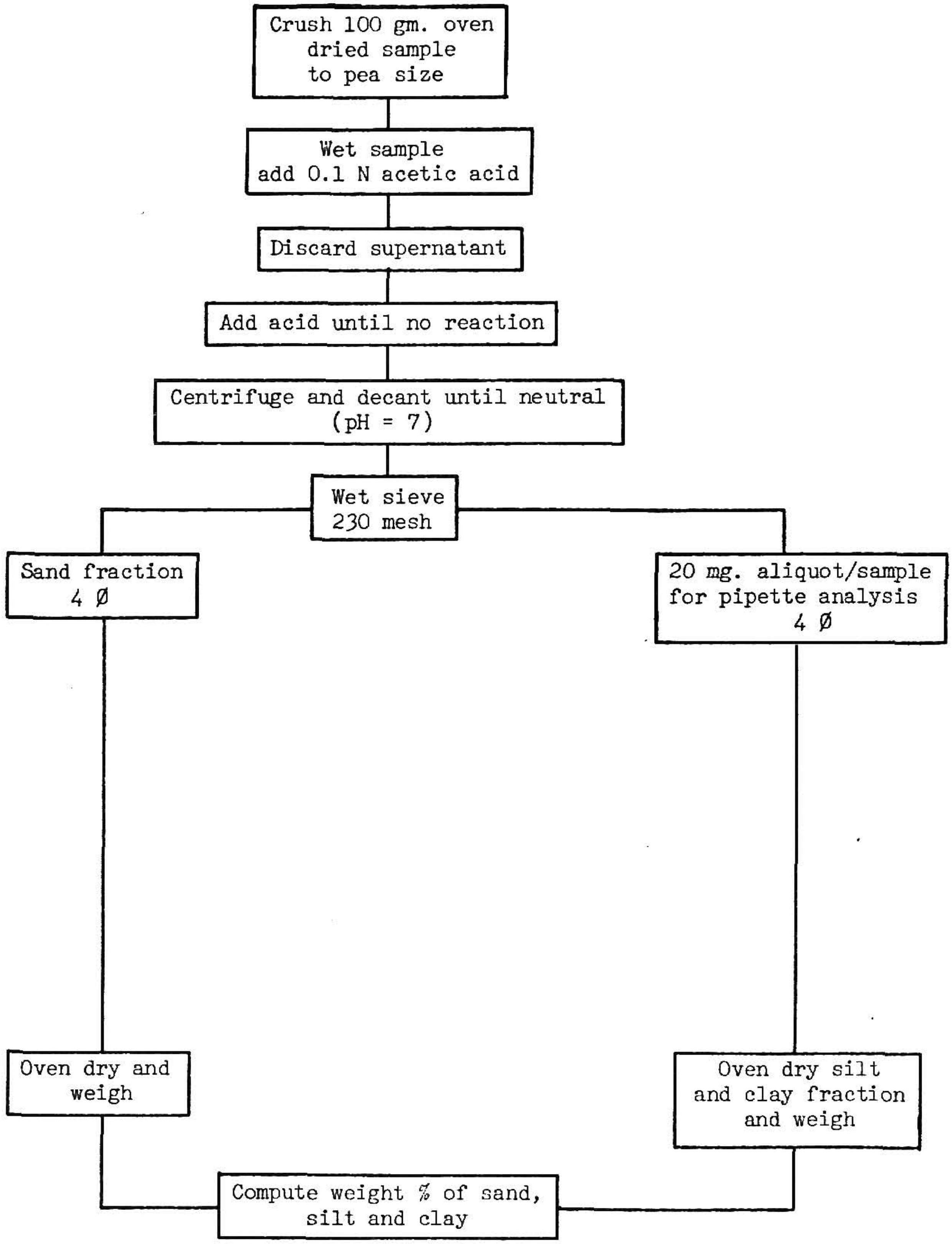


Fig.7. Flow Diagram of Insoluble Residue Analysis

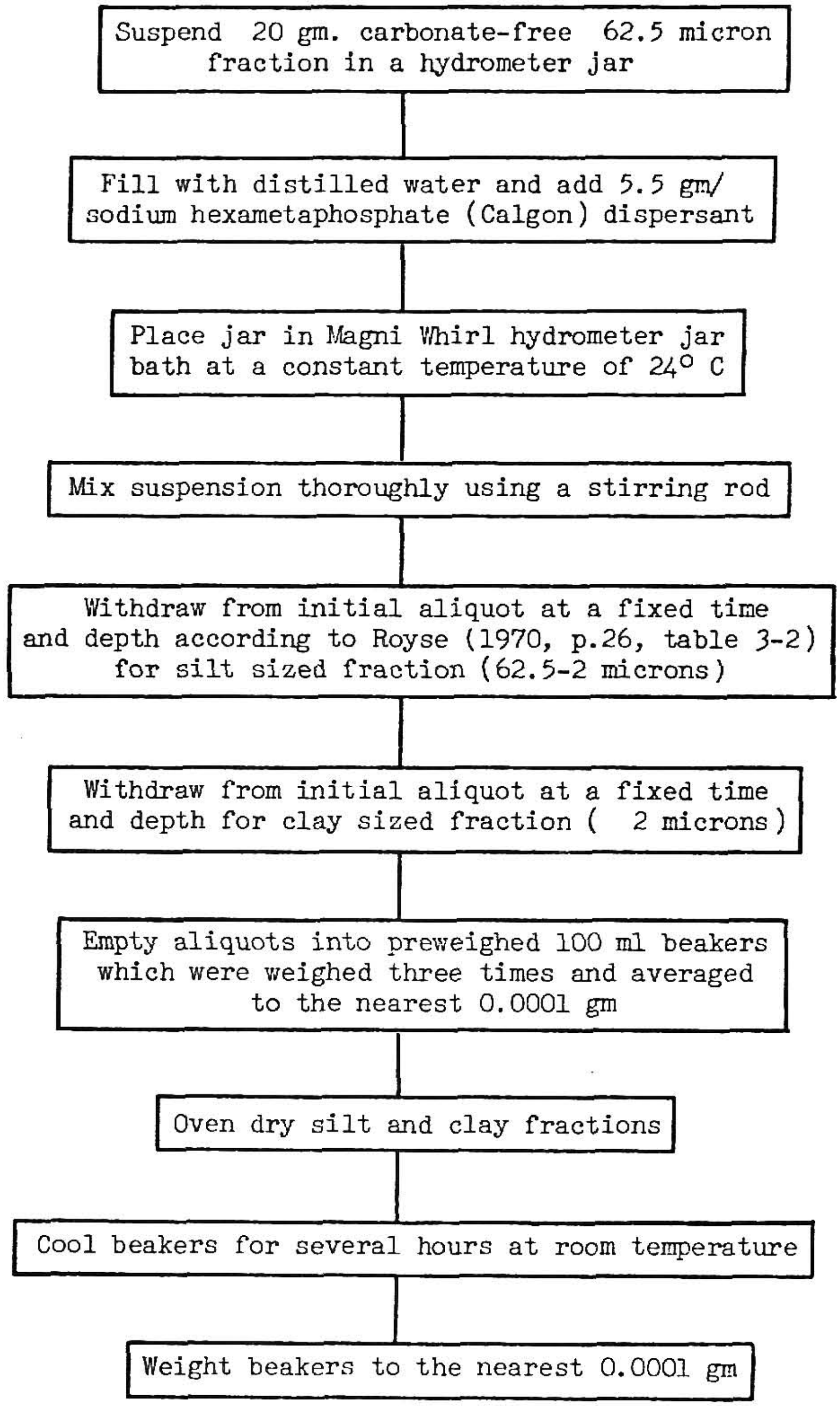


Fig. 8. Flow Diagram of Grain Size Analysis.

equals 1/50 of the weight of the sediment present, at a fixed depth, at a fixed time. The silt and clay fractions are obtained by multiplication of the difference between the weights of the initial and the two micron withdrawal times fifty.

X-Ray Diffraction.--Clay mineral analysis was performed on less than two micron fractions from a 50 gm. sample (fig. 5). The samples were centrifuged and contained no carbonate.

All slides were prepared by the "drop on glass method". Treatments, as described by Jeppesen (1972, p. 18) were applied: 1) untreated slides were scanned from 1½ - 60 degrees two theta, 2) samples treated with ethylene glycol were run from 1½ - 32 degrees two theta, 3) samples heated for 7 hours to 450° C and 600° C were run at ½ degrees two theta, and 4) 6 N HCl treatment was applied to samples for 12 hours and samples were run from 1½ - 15 degrees two theta. Instrument settings were identical with those used by Jeppesen (1972, p. 21) and Scott (1973, p. 15) and identification of clay minerals was based on data obtained on a Norelco Wide Range Diffractometer. Quantitative peak area measurements were made using planimeter as described by Lee (1972, p. 49).

Diffraction patterns of random samples of carbonates were run primarily to detect dolomite, but all other carbonate minerals were identified and the mole percentage of magnesium carbonate in calcium carbonate was determined.

Because X-rays penetrate the analyzed surface only a few hundred A.U. and do not detect coarser minerals, all samples were ground in a Spex Mixer Mill. Specially designed aluminum sample holders, closed on the underside by a cover glass, were lightly packed with the powdered limestone.

A few samples were scanned from 0-90 degrees for major peak positions. Analyzing runs were made from 0-60 degrees. Instrument settings were the same as given by Scott (1973, p.14).

Mole percentages of $MgCO_3$ in $CaCO_3$ were determined by a relationship between the magnesium carbonate content and the position of the strongest calcite reflection (d = 3.03 A.U., [104]) (Goldschmidt, et al., 1955, 1958).

Thin Section Analysis.--Thirty-six thin sections were prepared using a Hillquist Thin Section Machine and I had to decide whether to do a detailed analysis of a few slides or a less sophisticated analysis on all thin sections. All thin sections were scanned using a Bausch and Lomb stereozoom microscope and four general carbonate rock types were recognized. Four slides, one of each of these four general rock types were selected and a point count (1,400 points) performed on each slide. Only three hundred points were counted on each of the remaining thirty-two slides.

A 1" x 3/4" area was marked on each slide which assures, according to Chayes (1949), 1,400 points counted if the mechanical stage is set at 0.3 mm for the horizontal interval and 0.5 mm for the vertical interval. Because the vertical traverse on the mechanical stage used could only be moved in 0.4 mm increments slightly more than 1,400 points were included in the 1" x 3/4" area. I was particularly interested in microfossil content, mineralogical composition and grain parameters. A total of 15,000 points were counted. Allochems and orthochems were classified listing the major constituents of each (Appendix IV). Small unidentifiable clay particles were recorded as matrix. Average sizes of all constituents were recorded and the degree of recrystallization, packing and porosity noted. Finally, each slide was named according to Folk's compositional classification of limestones (Folk, 1959 and 1962) (i.e. silty brachiopod biomicrosparite) and Folk's grain size scale for carbonate rocks (Folk, 1974, p. 167) (i.e. unsorted fine calcirudite, immature).

Geochemical Analysis.--Laboratory work included highly sensitive geochemical experiments. To avoid possible contamination of these samples with kerosene during slabbing individual samples for organic carbon content and sedimentary phosphate determinations were collected separately in the field.

Palaeosalinity Estimations.--Phosphorus occurs in many organic and inorganic forms in our environment. It is one of the basic nutrient elements and essential to all forms of life. Occurrence of sedimentary phosphate in sediments and sedimentary rocks provides the basis for a method of palaeosalinity estimation. Nelson (1967, p. 917) described the sedimentary phosphate method (SPM) as:

> .....based on the discovery that both recent and ancient argillaceous sediments contain small quantities of sedimentary phosphate that are distributed widely in sediments from different environments. The sedimentary phosphate can be extracted selectively from the sediment and differentiated into fractions whose relative proportions are sensitive to the salinity of the water at the site of deposition. The phosphate fractions are interdependent variables affected by salinity. The ratio between them is independent of their absolute abundance in the sediment......

While I relied heavily on Jeppesen's study, new procedures had to be developed because to my knowledge no one had applied this method (SPM) to carbonate rocks. Phosphate fractionation analysis involved various kinds of problems: 1) storage of organic phosphate in chitinosphosphatic brachiopods, inorganic compounds of rooted and encrusting plants of the sea bottom, and in nektonic animals (Hooper, 1973) are most likely to affect the total phosphate content of carbonate rocks, 2) objection might be raised that diagenetic processes would not allow tracing the actual inorganic phosphorus content of ancient seas, and 3) leaching and reprecipitation of phosphorus caused by migrating waters could interfere with determination of orthophosphates. Sedimentary orthophosphates are used to estimate palaeosalinity. General sample preparation is as follows: 1) crush limestone into pea size; 2) pick out $CaPO_4$ fossil fragments; 3) dissolve 30 gm. sample in 0.3 N acetic acid; 4) decant supernatant, add distilled water; 5) centrifuge slurry to obtain the less-than-two micron fraction; 6) dry residue at 35° C; 7) disaggregate sample in Spex Mixer Mill;

8) weigh out 0.5 gm. sample; and 9) proceed with analysis described by Jeppesen (1972, p. 22) (figs. 9 and 10). Phosphorous determinations were made on a Coleman Model 14 Universal Spectrophotometer set at a wavelength of 660 mu. A calibration curve was obtained by determining percent transmittance on six standard phosphorous solutions with a concentration ranging from 0.05 to 0.50 ppm phosphorous (fig. 11).

Because of the intimate relationship between grain size and phosphate content in carbonate rocks, painstaking experimentation with different size fractions of acid treated and untreated carbonate samples was necessary to establish a usable technique. Results of test runs and replication analysis are given in Appendix VIII.

Organic Carbon Analysis.--Soils and lithified rock contain different forms of carbon: 1) the carbonate minerals (calcite, dolomite, aragonite) and also HCO_3^- and $CO_3^=$ ions of soluble salts and small amounts of active CO_2; 2) elemental organic carbon in the form of coal, paraffin, etc.; and 3) fossil plant, animal and micro-organism remains and their immediate decomposition products.

The modified weight loss hydrogen peroxide analysis as described by Jackson (1965) was applied to determine weight percent organic matter (fig. 12). The method is only an estimator of oxidizable carbon and not a substitute for a total organic analysis. Jackson (1965) reported that elemental carbon and some paraffin-like organic compounds are not destroyed by hydrogen peroxide.

GEOLOGIC SETTING

General Statement

The Nemaha Anticline, one of the major positive structures in Kansas, trends northeast-southwest across the east central part of the state. Subsurface geology of the Permian System in Pottawatomie, Riley, and Wabaunsee Counties, Kansas, is affected by this structure.

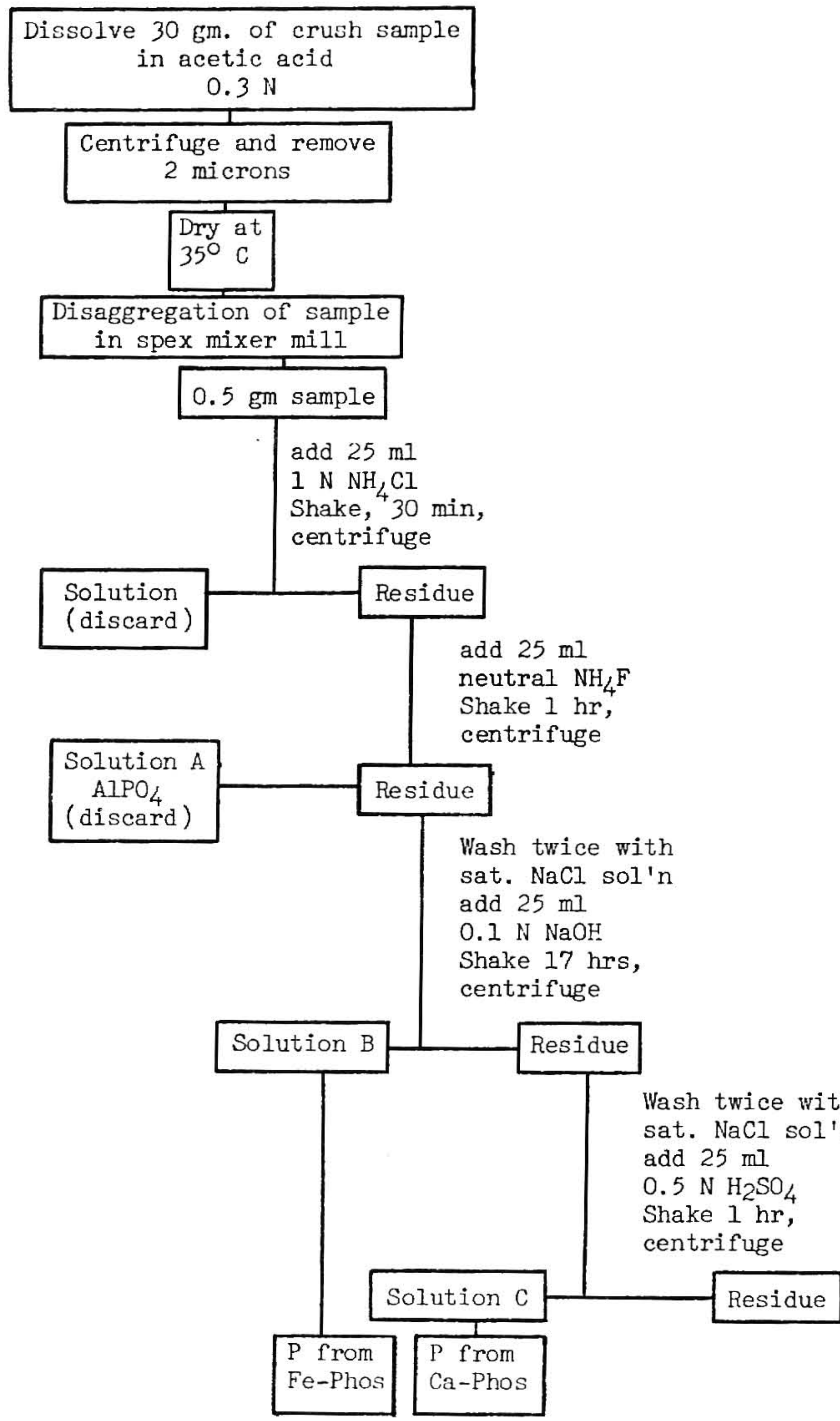


Fig. 9. Flow Diagram of Sedimentary Phosphate Fractionation Procedure (modified from Jeppesen, 1972).

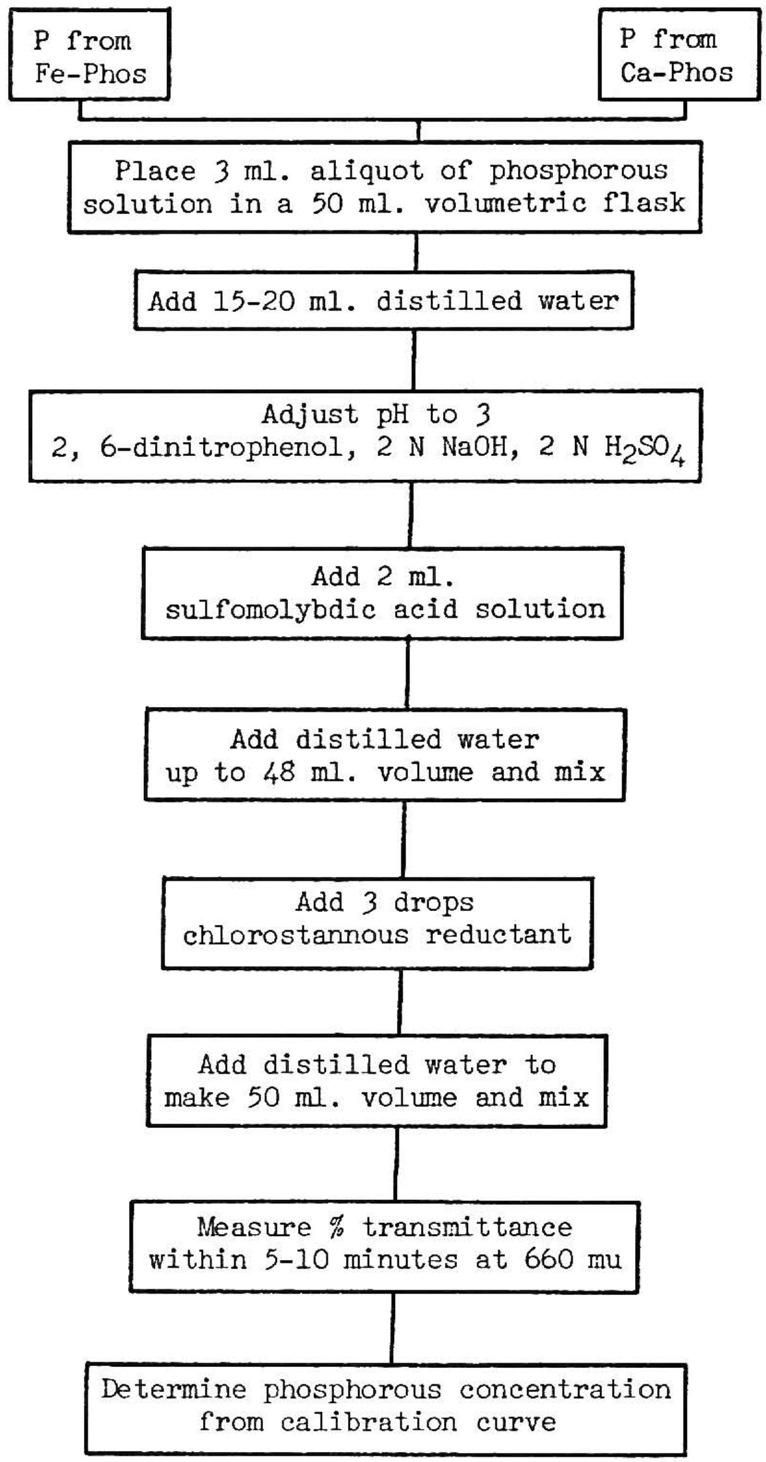


Fig. 10. Flow Diagram of Procedure Used in Spectrophotometric Determinations of Phosphorous (from Jeppesen, 1972).

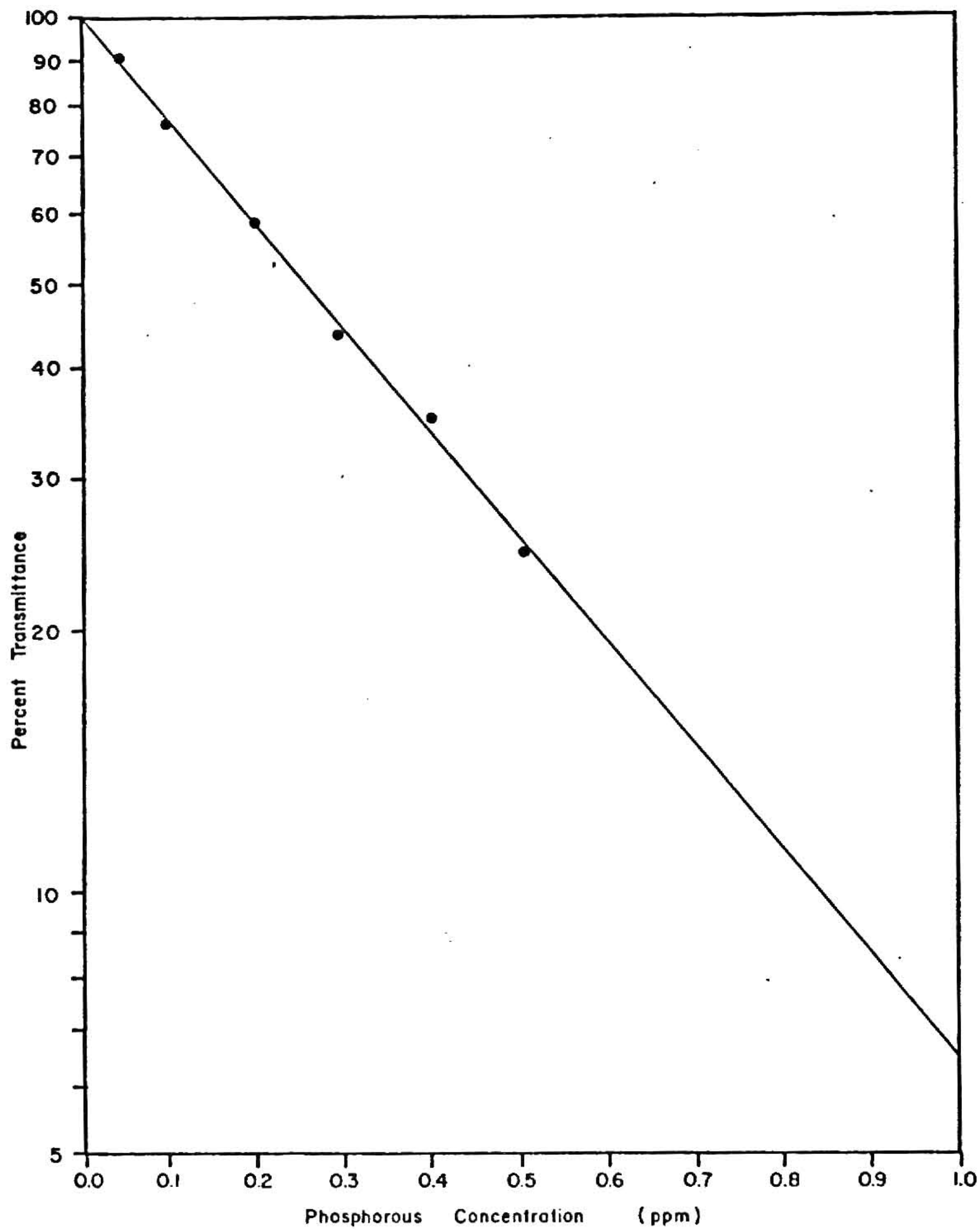


Fig. 11. Concentration-Transmittance Calibration Curve

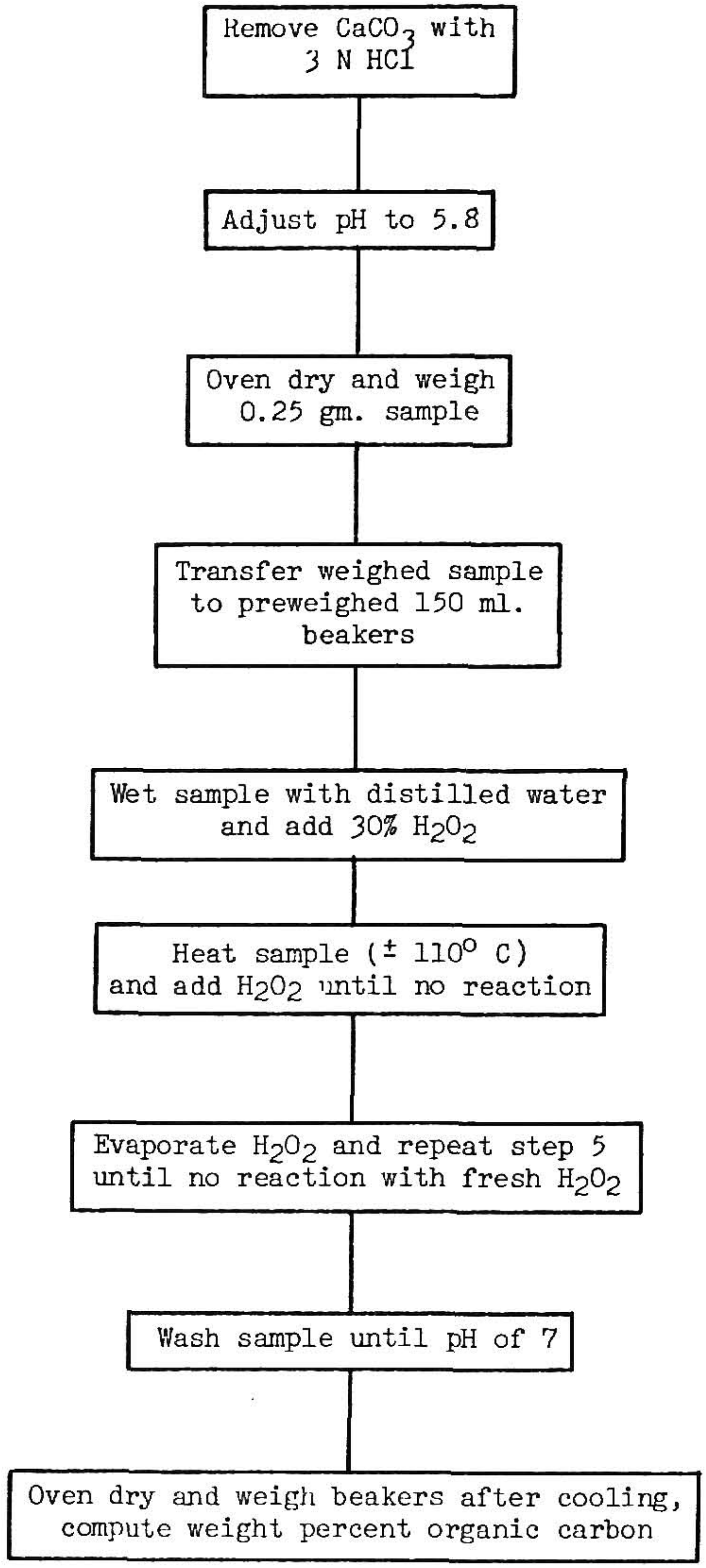


Fig. 12. Flow Diagram of Organic Carbon Analysis.

Structure

The Nemaha is a truncated anticline plunging southward. It is asymetrical with steeper dips on its eastern flank. Faulting along the eastern flank has been suggested by Rieb (1954, p. 13), Koons (1955, p. 9), Ratcliff (1957, p. 28), and Koenig (1971, p. 76, pl. III). Swett (1959, p. 46) described the Zeandale Dome as a local high on the Nemaha axis. A conformity between magnetic and structural anomalies for the Nemaha was shown by Baysinger (1963, p. 22).

Localities studied were selected on either side and near the center of the Nemaha Anticline. A structure contour map on top of the Americus Limestone Member of the Foraker Limestone was prepared (fig. 13) to locate the measured sections more accurately with respect to the anticline. Localities L and DC are near the center of the uplift, P is east, and W and BR are west of the Nemaha.

Stratigraphy

The Hughes Creek Shale Member of the Foraker Limestone of the Council Grove Group is part of the Lower Permian Series. It was named for a type locality at Hughes Creek, Nemaha County, Nebraska (Condra, 1927). The unit is underlain by the Americus Limestone Member and overlain by the Long Creek Limestone Member.

Lithologically the Hughes Creek Shale is composed of alternating beds of black (N1) or greyish-brown (5YR 3/2) argillaceous shales and black (N1) to light brown (5YR 6/4) micritic limestones. Mudge and Yochelson (1962, p. 33) and Zeller (1968, p. 45) confirmed the same lithologic characteristics for the Hughes Creek in northeastern Kansas, whereas in the southeastern part of the

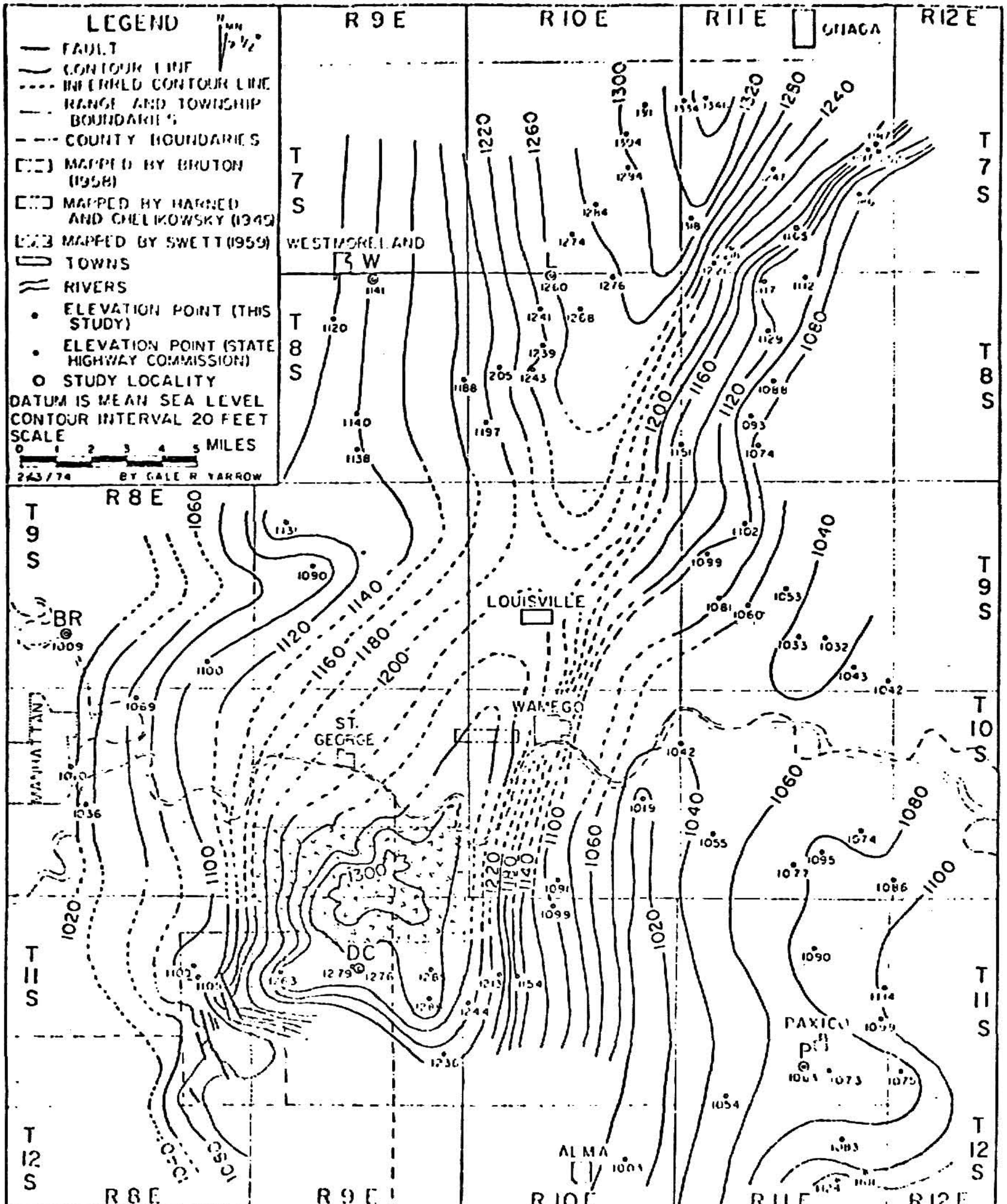


Fig. 13. Structure Contour Map on Top of Americus Limestone Member of the Foraker Limestone (from Yarrow, 1974)

state the member is a massive chert-bearing limestone (fig 14). The interval studied consists of three (at localities BR, L, and W) to four (at localities DC and P) limestone beds separated by dark mudstones and corresponds to Unit 2 of Mudge and Yochelson (1962, p. 34, fig. 17).

INTERPRETATION OF DATA

Biotic Data

General Statement.--How valid are data recorded on those 97 mapped surfaces, and what do they mean? An essential problem involved in the mapping of benthic fossil assemblages is that post-mortem events alter original composition. A careful study of articulation, fragmentation, opposite valve ratios and abrasion helped to distinguish between organisms transported to the burial site from those which actually lived and died at a specific spot on the sea floor.

For a long time palaeoecologists were tempted to associate fluctuations in animal numbers in benthic communities with physical not biological factors. Most shallow water communities comprise many species and individuals, but only thirty percent of these species have resistant hard parts enhancing their chances of preservation (Johnson, 1964, p. 107).

Yarrow (1974, p. 20) referring to Dennison and Hay (1967), calculated the probability of observing a species, if present, in a fossil assemblage on a 225 square centimeter surface. He reported that even large specimens with a shell area of twenty square centimeters, and making up five percent of a population, would only have a probability of 0.76 of being seen on the slabbed surfaces. Therefore, size of the surface area mapped is a disturbing bias in the biotic analysis.

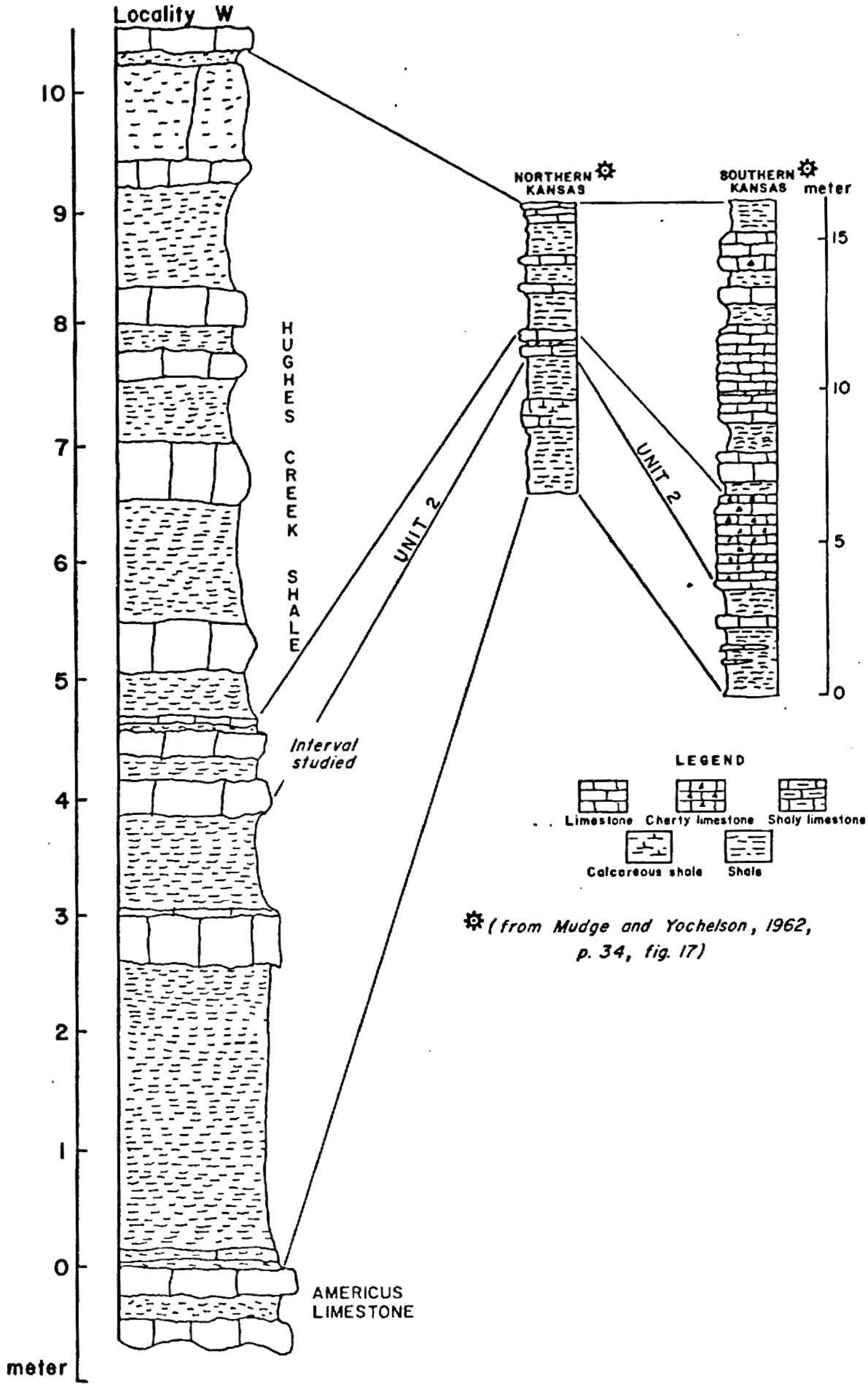


Fig. 14. Range of Thickness of the Investigated Interval

Diversity.--One major characteristic of communities is their diversity, either thought of as the number of species or the relationship between numbers of species and numbers of individuals.

In a community only a small percentage of the total number of species are usually abundant and a large percent are rare. While the few dominant species largely account for the energy flow of biomass or productivity, the large number of rare species largely determines the species diversity in trophic groups or in communities (Odum, 1971, p. 148).

Diversity values were calculated using the Shannon-Wiener function as described by Margalef, 1957 and MacArthur and MacArthur, 1961) and are listed in Table 1. For mapped surfaces with only one species no value was calculated.

A comparison of average diversity values for mudstones and limestones with weight percent $CaCO_3$ of these beds is in Table 2 and shows higher diversities in mudstones than in limestones. Reyment (1971, p. 164) found a similar pattern in ostracode samples from western Nigeria, where a lower diversity index was observed for calcareous environments than in argillaceous environments. Yarrow (1974, p. 23, Table 2), working predominantly with mudstones and shales in the same interval of the Hughes Creek Shale, also obtained slightly higher diversity values for non-carbonate rocks.

Table 2

Relationship Between Weight Percent $CaCO_3$ and Diversity in Part of the Hughes Creek Shale

Section	Mudstones		Limestones	
	Wt. % $CaCO_3$	Diversity	Wt. % $CaCO_3$	Diversity
BR	43.41	1.24	64.85	1.22
DC	45.25	2.11	57.15	0.96
W	41.27	2.18	56.28	1.45
L	--	--	68.10	1.12
P	--	--	70.61	1.43

Table 1

Diversity and Equitability of Fossil Assemblages in Part of the Hughes Creek Shale Member of the Foraker Limestone

Bedding Surface Number	Diversity	Equitability
BR-U- 1	.831	1.000
BR-U- 2	.525	1.000
BR-U- 3	.419	.667
BR-M- 1	.282	.333
BR-M- 2	1.299	1.000
BR-M- 3	1.585	1.333
BR-M- 4	2.257	1.200
BR-M- 5	1.003	1.375
BR-M- 6	1.764	1.333
BR-L- 1	2.923	1.000
BR-L- 2	1.585	1.000
BR-L- 3	1.003	1.000
BR-L- 4	1.897	1.250
*BR-L- 5	---	---
BR-L- 6	.551	1.000
BR-L- 7	1.923	1.250
BR-L- 8	3.033	1.667
DC-T- 1	2.724	1.286
DC-T- 2	2.408	1.167
DC-T- 3	1.993	1.250
DC-T- 4	1.585	1.333
DC-U- 1	1.571	1.000
DC-U- 2	1.149	1.000
DC-U- 3	1.521	1.333
DC-M- 1	.777	.667
DC-M- 2	.651	1.000
DC-M- 3	.392	.500
DC-L- 1	.621	.500
DC-L- 2	1.658	1.000
DC-L- 3	2.528	1.333
*DC-L- 4	---	---
DC-L- 5	.811	1.000
DC-L- 6	1.585	1.333
DC-L- 7	1.498	1.333
DC-L- 8	1.003	1.000
DC-L- 9	1.003	1.000
DC-L-10	1.498	1.333
DC-L-11	.857	1.000
DC-L-12	.718	.500

Table 1 Cont.

Bedding Surface Number	Diversity	Equitability
P -T- 1	1.874	1.000
P -T- 2	2.123	1.200
P -T- 3	1.286	2.333
P -U- 1	.684	1.000
P -U- 2	1.212	.750
P -U- 3	1.329	1.000
P -U- 4	1.688	1.000
P -M- 1	1.498	1.333
P -L- 1	.724	1.000
P -L- 2	1.993	1.250
P -L- 3	2.325	1.400
P -L- 4	1.923	1.250
P -L- 5	2.521	1.600
P -L- 6	.917	1.000
P -L- 7	.462	.667
P -L- 8	1.661	1.000
L -U- 1	1.880	1.000
L -U- 2	2.256	1.400
L -M- 1	.591	1.000
L -M- 2	.674	.667
L -M- 3	1.418	.750
L -M- 4	1.046	.500
L -L- 1	1.937	.714
L -L- 2	1.252	1.000
L -L- 3	1.751	1.000
L -L- 4	1.585	1.333
*L -L- 5	---	---
L -L- 6	1.003	1.000
*L -L- 7	---	---
L -L- 8	1.003	1.000
W -U- 1	1.884	1.000
W -U- 2	1.382	1.000
W -U- 3	1.445	1.000
W -U- 4	.947	1.000
W -M- 1	.764	1.000
W -M- 2	.651	1.000
W -M- 3	1.820	.833
W -M- 4	1.920	1.250
W -M- 5	2.156	1.000
W -M- 6	2.807	.909
W -M- 7	2.923	1.375
W -M- 8	2.588	1.143
W -L- 1	2.073	1.000
W -L- 2	2.322	1.167
W -L- 3	.724	1.000

Table 1 Cont.

Bedding Surface Number	Diversity	Equitability
W -L- 4	1.920	1.250
W -L- 5	1.239	1.000
W -L- 6	1.923	1.250
W -L- 7	1.159	1.000
W -L- 8	.917	1.000
W -L- 9	1.372	1.000
W -L-10	2.724	1.286
W -L-11	.724	1.000

*No calculation only one species present

Equitability.--A numerical value of evenness of individuals among species (equitability) was given by Lloyd and Ghelardi (1964). Equitability is the ratio of the hypothetical number of species with an equal number of individuals in each species needed to produce the Shannon-Wiener diversity equivalent of the observed diversity to the actual number of species observed.

A surprisingly large number of values show perfect equitability (1.0) or values greater than one (Table 1).

Deevey (1969) said that equitability values greater than one could indicate post mortem transportation of the fossils, however, the surface area of 225 square centimeters was probably not adequate for a representative unbiased sample as stated on page 27. Even though the surface area may affect the calculations, equitability values should still be comparable because each mapped surface has the same bias (i.e. all are the same area).

Autecology.--Autecology is the study of the relationships between individual organisms or species and their environment.

Autecological parameters (mode of life, feeding behaviour, etc.) for fossils are determined by studies of functional morphology of their skeletons and by comparison with morphologically similar and/or taxonomically related modern organisms. Autecological data permits 1) a better understanding of the relationship between species in an assemblage, and 2) a basis for comparing fossil assemblages in terms of their inferring ecological structure.

The significance of the type and mobility of the substratum as a critical environmental factor in the distribution of fossil invertebrates has been discussed by Ager (1965 and 1967), Bretsky (1968), Rhoads and Young (1970) and others. Minute particles, including fine detritus, bacteria and plankton are the sole food of many invertebrates. Grain size and mobility of the nutrient-bearing substrate play an important role in the mode of life and feeding behaviour of most organisms inhabiting a soft substrate.

The categories of mode of life, feeding behaviour, and trophic level of taxa as defined by Scott (1973, p. 44, Table 5) and used by Yarrow (1974, p. 26, Table 4) were applied and are listed in Table 3.

Foraminiferids.--Only larger foraminiferids of the family Fusulinidae were observed on the mapped surfaces. Pseudofusulina and Triticites (Plate III, figs. 4 and 5) were the most abundant and could be identified with a binocular microscope in all five measured sections. Thin section study revealed Pseudoschwagerina and a variety of unidentified calcified pyritized and Osagia-coated smaller opthalmids (Plate III, figs. 6 and 7).

Kahler and Kahler (1942, p. 754) reported abundant fusulinid assemblages from pure and argillaceous limestones. Fusulinids were described to be rare where pelecypods, brachiopods and crinoids abound, but were plentiful in association with certain algae and scattered benthic organisms. Fusulinids probably avoided areas that were strongly colonized by larger organisms which preyed on them. The increased uptake of calcium carbonate of larger organisms for their shells could be another reason for the scarcity of these larger foraminiferids. Fusulinids in the Hughes Creek Shale show the same distribution pattern. Examination of mapped horizontal surfaces (W-M-7, P-L-5, P-L-6) shows that fusulinids are abundant while other invertebrates are scarce.

Benthic foraminiferids, like the extinct fusulinids, are believed to be deposit or suspension feeders, which fed either on particulate organic matter or extracted their nutrients from sea water (West, 1970, p. 80, 116).

Fusulinids occurring as fossils are more abundant in limestones or calcareous shales than in sandstones; they seem to have been restricted to offshore shallow water environments. Pennsylvanian and Permian rocks of the midcontinent are characterized by cyclic occurrence of fusulinids. In these cyclothems, the fusulinaceans are found in and near the central part of the marine phase of the sedimentary cycle (Thompson, 1964, p.C387).

Table 3

Autecology of Fossils

Trophic Level	Modes of Life	Feeding Behaviour
P-Primary Consumer	I-Infaunal	LS-Low level susp.
S-Secondary Consumer	E-Epifaunal	HS-High level susp.
T-Tertiary Consumer	Q-Quasi-infaunal	C -Collector
PR-Producer	S-Semi-infaunal	CA-Carnivore
	N-Nektonic	S -Scavenger

TAXA	TROPHIC LEVEL	MODE OF LIFE	FEEDING BEHAVIOUR
Protozoa			
Foraminifera			
Pseudofusulina	P	E	C
Triticites	P	E	C
Ectoprocts			
ramose type I	P	E	HS
II	P	E	HS
III	P	E	HS
IV	P	E	HS
fenestrate type I	P	E	HS
II	P	E	HS
Brachiopoda			
Inarticulata			
Lingula cf. carbonaria	P	I	LS
Orbiculoidea cf. missouriensis	P	E	LS
Petrocrania cf. modesta	P	E	LS
Articulata			
Cancrinella cf. boonensis	P	Q	LS
Composita cf. subtilita	P	E	HS
Crurithyris cf. expansa	P	E	HS
Derbyia cf. crassa	P	E	HS
Hustedia cf. mormoni	P	E	HS
Hystriculia cf. histricula	P	Q	LS
Juresania cf. nebrascensis	P	Q	LS
Isogramma cf. renfrarum	P	E	HS
Linoproductus cf. magnispinus	P	Q	LS
Meekella cf. straitocostata	P	E	HS
Neochonetes cf. granulifer	P	E	HS
Neospirifer cf. dunbari	P	E	HS
Retaria cf. lasallensis	P	Q	LS
Reticulatia cf. huecoensis	P	Q	LS

Table 3 Cont.

TAXA	TROPHIC LEVEL	MODE OF LIFE	FEEDING BEHAVIOUR
Brachiopoda			
Articulata			
Rhipidomella cf. *carbonaria*	P	E	HS
Wellerella cf. *osagensis*	P	E	HS
Mollusca			
Bivalvia			
Astartella	P	E	HS
Aviculopecten cf. *arctisulcatus*	P	E	HS
Myalina	P	E	HS
Schizodus	P	I	LS
Septimyalina	P	E	HS
Wilkingia cf. *terminale*	P	S	LS
Gastropoda			
Bellerophon	P	E	S
Echinodermata			
Crinoid Debris	P	E	HS
Echiniod Debris	S	E	CA
Arthropoda			
Ostracodes	P	N-E-I	C
Vertebrata			
Fish Debris	T	N	CA
Algae			
Osagia	PR		

Limestone beds of the Hughes Creek Shale, especially the lower part of the lower beds contain accumulations of fusulinids. The Ca^{++} saturated waters during early stages of limestone deposition must have offered more favorable conditions for taking up calcium carbonate to use in test formation than in later argillaceous environments. Small and large tests showing no abrasion indicate a lack of bottom currents for sorting.

Ectoprocts.--Fragmented ectoprocts observed on the bedding planes were classified into ramose and fenestrate types. Ramose ectoprocts were subdivided into four growth forms and fenestrates into two growth forms following Yarrow (1974, Plate I). Ramose forms were generally better preserved. Some individual pieces (ramose types 3 and 4) could be glued together extending to 4 cm. in length and 3 cm. in width.

Fairly large pieces (3 cm. in diameter) of fenestrate forms were recovered from some surfaces, but were broken during ultrasonic cleaning.

The fairly large ectoproct fragments (average size = 1.5 cm.) are, according to Chave (1964), indicative of a low energy environment. Chave proved in laboratory experiments, using a tumble barrel to simulate the effect of waves, and particle-against-particle abrasion, that physical durability is controlled by the micro-architecture of the skeletons and ectoproct fragments (originally greater than 4 mm. in size) were reduced to less than 4 mm. (in size) in less than one hour.

Individual ectoproct fragments encountered on the surfaces and having the same growth form were recorded as one colony, because post-mortem transportation of 15 cm. in either direction from the living site is assumed even in a quiet water environment.

Ectoprocts seem to prefer clear water which is constantly agitated by waves or strong currents to assure a maximum food supply. Turbid, muddy water or moving sand are less favorable as Bretsky (1968) suggested for Upper

Ordovician trepostomes. Ectoprocts more likely prefer a rocky habitat or a hard ground for settlement and shells of bivalves and brachiopods could provide a hard substrate for attachment in areas of soft substrate such as the Hughes Creek Shale. All ectoprocts are classified as primary high level suspension feeders.

Brachiopods.--Inarticulate and articulate brachiopods are the most diverse group of fossils encountered. With few exceptions, almost all recent living brachiopods are marine, benthonic, epifaunal, sessile suspension feeders. Studies on fossil forms generally assume that this mode of life has been characteristic for the phylum throughout its evolutionary history.

Brachiopods, like other sessile invertebrates, filter the water and extract suspended particles of food. McCammon (1969) studied gut contents of seven articulate brachiopods from different depths and areas of the world ocean. She found that inorganic matter in the gut was higher than organic particulate matter. She argued that brachiopods may utilize dissolved organic nutrients as a major food source. In the laboratory, brachiopods have survived in artificial seawater for more than two years while being fed organic nutrients, indicating their ability to use dissolved food. However, Suchanek and Levinton (1974) have maintained bivalves in a aquarium for over a year without addition of any substances and noted no adverse effects and suggest that perhaps many bivalves and brachiopods subsist for long periods of time without direct nutrient input.

Walker and Bambach (1974) in classifying the feeding behaviour of benthic invertebrates showed that the location of food resources is a restricting parameter in animal ecology. Food resources are not scattered randomly throughout the water, but concentrated mainly at the sediment-water interface. Also the sediment down to a depth of 5 cm. and water immediately above the sediment-water interface are enriched by either organic nutrients or suspended particulate matter. Location of the maximum food supply is characterized by a rich benthic epifauna, which consists for the Palaeozoic to a large extent of epifaunal brachiopods.

Lingula is the only species with an infaunal mode of life among brachiopods living in deep vertical burrows. When disturbed, the shell is withdrawn by contraction of the pedicle anchored in the sediment. Thayer and Steele-Petrovic (1971) described the burrowing mechanism on the lingulid *Glottidia pyramidata*. The stiffened pedicle positioned the anterior end of the shell in contact with the sediment. In this position a U-shape burrow is produced using a scissoring valve movement. In feeding position the anterior end of the organism is at the sediment-water interface and the pedicle extends down into the burrow.

Lingula, oriented parallel to bedding, is classified as an infaunal low level suspension feeder. *Petrocrania* and *Orbiculoidea*, are low level suspension feeders, but where attached to other organisms may be high level suspension feeders. *Reticulatia*, *Linoproductus*, *Juresania*, and *Hystriculia* are classified as quasi-infaunal, low level suspension feeders (Rudwick, 1970, p. 93). All other brachiopods are considered epifaunal, high level suspension feeders.

As sessile benthos, the relationship of fossil brachiopods to the substrate is of great ecological importance, and reflected in their shell morphology (Rudwick, 1965, p. H199). Many epifaunal species (*Composita*, *Orbiculoidea*) were attached to the substrate by a pedicle, others were cemented on hard ground (*i.e.* *Petrocrania*). Organisms which were just lying on the bottom of the sea had to develop stabilizing mechanisms to hold their position on the sea floor. Extended hinge lines of *Neospirifer* probably aided in stabilization on a soft substrate. Wallace and Ager (1966) demonstrated that spiriferid brachiopods were probably oriented normal to prevailing currents with the dorsal valve facing into the current. Flume experiments on paired spiriferid valve replicas oriented in this way showed that the current entered the gape made by the fold and left along the lateral margins and could decrease the energy expenditure necessary for feeding (i.e. less movement of lophophore tentacles and cilia).

Reticulatia, Cancrinella, Juresania, Retaria, Linoproductus and many others with a concavo-convex shell were probably balanced by their strongly curved and heavier pedicle valves. Long anchoring spines rooted these organisms to the soft substrate for a quasi-infuanal life habit (Rudwick, 1970, p. 93). There are some unusual modes of attachment, Linoproductus angustus attaches itself by cardinal (grasping) spines to a cylindrical object, usually a crinoid stem, and remains there, suspended above the sea floor throughout life (Grant, 1963).

Swimming habits, already known for pectinid molluscs, may have been used by some brachiopods (chonetids) to escape predators (Rudwick, 1970, p. 91). Ager (1963, p. 133) suggested that small, thin-shelled rhynchonellids like Leiorhynchus may have been attached to floating sea weeds, thus being classified as nektobenthonic. Wellerella in the Hughes Creek may have had this habit.

Lamont (1934) suggested that brachiopods in a muddy habitat tend to be flattened, with wide hinge lines. Ager (1963, p. 133) found in the European Mesozoic that different brachiopod families produced forms with widely expanded anterior margins. Because muddy bottoms often lack oxygen, forms with a larger mantle area would have an adaptive advantage. Genera in the Hughes Creek possessive of these characteristics are Derbyia, Neochonetes, and Isogramma.

Fragmented valves of Isogramma occur in the lower part of the lower limestone. The morphology and geologic distribution of Isogramma are poorly known (Cooper and Grant, 1974, p. 251). Isogramma was described by Meek and Worthen (1870) as Chonetes ?? millepunctata, but it is now classified as follows:

Class Articulata
Order uncertain
Suborder Dictyonellidina
Superfamily Eichwaldiacea
Family Isogrammidae
Genus Isogramma

Isogramma is concavo-convex with a semielliptical outline. The width is much greater (7.1 cm. in Isogramma renfrarum) than the length (4.0 cm.) of the shell. The surface is marked by fine concentric lines (Plate IV, fig. 2). Complete specimens were not encountered because the shells are unusually large and the valves are relatively thin. Specimens found on bedding plane P-L-8 (Plate IV, figs. 1 and 2) lacked beak areas and cardinal processes and were broken into fragments averaging 4 cm. (one nearly complete specimen was 6-7 cm. wide). No distinction between pedicle and brachial valves could be made. Fragments observed in thin sections showed closely packed punctae (Plate III, figs. 1, 2, and 3) filled with matrix and with thin walls separating the neighboring punctae. The punctae, moreover, were not uniform in size and shape.

The shell form closely resembles that of a large transverse Chonetes. However, Cooper (1952), found no relationship between the location and arrangement of pedicle muscles of Isogramma as compared to Chonetes and Strophomena. Association of the punctate Isogramma with Strophomena is ruled out because strophomenid brachiopods are all pseudopunctate. The "spongy" interior of Isogramma shells suggests a relationship with punctate orthid or terebratulid brachiopods.

The broadly-flattened and thin-shelled organisms with a very narrow field of attachment for muscles (Cooper, 1952) were probably not active swimmers. Lack of anchoring and/or supporting spines rules out a quasi-infaunal life habit. It is most likely that Isogramma was a epifaunal high suspension feeder resembling strophomenid (Derbyia) brachiopods.

Bivalves.--Most bivalves are shallow-water, bottom-dwelling invertebrates that feed on particulate matter which is filtered by ciliary mechanisms on their gills. Posterior siphons regulate the incoming and outgoing water. A muscular foot aids in locomotion, burrowing and attachment to the substrate.

Habits and modes of feeding of lamellibranchs are many. Aviculopecten, Septimyalina, and Myalina lived on the sea floor as epifaunal high suspension feeders. Schizodus is an example of an infaunal, low level suspension feeding burrower (Yarrow, 1974, p. 27, Table 4). Wilkingia is considered a semi-infaunal, high level suspension feeder (Pearce, 1973, p. 29-45). Astartella is classified as an epifaunal high level suspension feeder.

Gastropods.--Most marine gastropods are benthic, inhabiting most areas of the sea floor. Some are infaunal burrowers, others live on seaweeds, in a rocky habitat or on a soft substrate. Herbiverous and carnivorous gastropods feed by means of mouth and radula (Cox, 1960, p. I 87).

Only Bellerophon was encountered in this study. It is considered a vagrant browser and deposit feeder with an epifaunal mode of life (West, 1970, p. 117, Table 12). In this study Bellerophon is classified as a scavenger.

Echinoderms.--Only crinoid stems and echinoid spines were encountered. Both organisms are easily disarticulated and it is unlikely that a completely preserved specimen will be observed on a small surface (225 cm^2). Crinoid morphology suggests classification as epifaunal high level suspension feeders. Echinoids are epifaunal (Yarrow, 1974, p. 27, Table 4), most species being predators, but they may belong to different trophic groups and are, therefore, classified as epifaunal to infaunal vagrant browsers, deposit feeders or scavengers (West, 1970, p. 129, Table 16).

Arthropods.--Arthropods are represented by ostracodes, which were only observed in thin sections. The same ostrocode species has been observed to be epifaunal, infaunal, and nektonic. I have followed Walker (1972) and classify ostrocodes as collectors.

Chordates.--Although no fish remains were observed on horizontal surfaces, possible fish remains (teeth?) were encountered in thin sections. Fish are considered nektonic secondary carnivores.

Algae.--Thin section study indicates that Osagia-coated grains and skeletal fragments are a major rock constituent. My observations (Plate III, figs. 2 and 7) support Henbest (1963) who showed that Osagia was an algal foraminiferid consortium of the algal genus Girvanella and the opthalmid foraminiferid Hedraites. Algae usually dominate the foraminiferids in the colony type association. Because true symbiosis cannot be positively demonstrated in fossils, it is not advisable to use the term symbiont in this association. Henbest (1963) favors the term colony in the sense of an isolated or segregated association of organisms. The algae in the colony are primary producers.

Petrologic Data

General Statement.--Determination of sedimentary parameters (insoluble residues, grain size, clay minerals, and carbonate minerals) and geochemical analysis (palaeosalinity estimates and percent organic carbon) were used to illuminate the pre-diagenetic depositional environment of the Hughes Creek Shale.

Insoluble Residue.--Along with organic remains, pyritized or silicified fossils, insoluble residues consisted of clay minerals, quartz, and feldspar*. Total percent insolubles were used to classify the beds lithologically. Surprisingly, several beds which according to field descriptions were reported as limestones, are actually mudstones (BR-M-1, BR-M-3; DC-U-1, DC-L-3, and W-L-3) with insoluble residues ranging from 50.38 to 58.14 weight percent (Appendix VI). Average weight percentages of insoluble residues were calculated and are given in Table 4.

*Plagioclase was only observed through a petrographic microscope (W-L-3).

Table 4

Average Weight Percentages of Insoluble Residues for Each Bed in Part of the Hughes Creek Shale

Locality	Lower Limestone	Middle Limestone	Upper Limestone	Top Limestone
BR	30.60	49.42	36.94**	---
DC	44.86	38.89**	51.56**	48.52**
P	26.89	27.36**	22.11	20.90**
L	30.62	32.53	25.35	---
W	40.51	36.72	36.97	---

** only one value obtained
--- Top limestones were only at localities DC and P

All four beds at locality P have the lowest average value of insolubles which may indicate a remote location from the source area (shore line) compared to localities DC and BR (highest insoluble values in all four beds). Authigenic minerals like pyrite, most chert fragments and limonite were observed in small quantities (less than 0.5 gm. per sample) in nearly all limestone beds and are included with the insoluble residue values. Larger quantities of authigenic minerals would affect insoluble residue values if used in an environmental interpretation, because these minerals may have formed authigenically within the site of deposition and do not reflect any evidence of transportation.

A t-test of means of insoluble residues between upper, middle, and lower beds at all localities indicates no significant difference between them (Table 5). Unfortunately an f-test could not be performed because the variances of the mean are not homogenous (Table 9, based on Bartlett's test of homogeneity). In some cases (Appendix VI; BR-L, L-L, W-U) the insoluble residue and carbonate content, within the individual bed remained fairly constant throughout. This suggests, especially in the lower limestone, that beds at each locality represent

Table 5

Statistical Comparison of Insoluble Residues between Beds in Part of the Hughes Creek Shale

Bed*	Min	Max	Mean	Var	Stdv	Ster
Upper Lst	22.11	51.56	34.59	135.07	11.62	5.20
Middle Lst	27.36	49.42	36.99	67.70	8.23	3.68
Lower Lst	26.89	44.86	34.70	57.86	7.61	3.40

*Top Limestone bed excluded, present only at two localities

Comparison of Insoluble Residue Mean using t-Test

				d.f.
Upper Lst. / Middle Lst.	t-test	0.3774	*	8
Upper Lst. / Lower Lst.	t-test	0.0177	*	8
Middle Lst. / Lower Lst.	t-test	0.4578	*	8

t values must be greater than 2.306 for a significant difference to exist at the 0.05 alpha level.

*no significant difference at the 0.05 alpha level.

Bartlett's test of homogeneity of variances X^2 = 8.20, table value (2d.f.) = 5.99, value $^{M}/_{C}$ is > than 5.99, F-test can not be performed because variances of the mean are not homogenous.

a genetic unit, which formed under homogeneous conditions of sedimentation and diagenesis.

Locality DC has the highest average value of insolubles (45.96 weight percent), whereas localities P (24.31 percent) and L (29.50 percent) have the lowest average values. Both the Louisville and Deep Creek localities are along the axis of the Nemaha. The discrepancy in their insoluble residues indicates the possibility that the Nemaha Anticline during this part of Hughes Creek deposition may have been a "high" at DC and a "low" at P. Locality DC also contains an average of 19.80 weight percent (highest) terrigenous clays, which would be unrealistic for a spot situated on top of a morphological high on the ancient sea floor. Possibly the source of these terrigenous clays resulted from erosion and deposition at DC because of a fluctuating wave base that periodically intersected the sea floor "high". Furthermore authigenic formation of clay minerals has to be taken into consideration. The shore line of the embayment as a contributor of terrigenous material is believed to be of minor influence during Lower Permian time.

Grain Size of Insoluble Residue.--This section is a discussion of the grain size of the insoluble residue. Grain size of the carbonate fraction will be discussed in a later section. Grain size reflects the energy of the transporting medium as well as the energy at the immediate site of deposition. In a fluid medium, grain size generally decreases in the direction of transport. Coarser sediments occur in high-energy environments and fine sediments in low-energy environments.

Analysis of means performed on the clay, silt, and sand sized fractions of the lower, middle, and upper limestones at all localities indicated no significant difference in sand, silt, and clay fraction between the lower three limestone beds (Table 6).

Table 6

Statistical Comparison of Grain Size (Variance of Means)

Beds Compared	Size Fraction	F-computed	F-table	95 % CI
Lower - Middle	Clay	2.26	9.60	no significant difference between L, M, and U limestone clay sized fractions
Lower - Upper	Clay	1.93	9.60	
Middle - Upper	Clay	1.17	9.60	
Lower - Middle	Silt	4.12	9.60	no significant difference between L, M, and U limestone silt sized fractions
Lower - Upper	Silt	8.39	9.60	
Middle - Upper	Silt	2.03	9.60	
Lower - Middle	Sand	3.00	9.60	no significant difference between L, M, and U limestone sand sized fractions
Lower - Upper	Sand	1.25	9.60	
Middle - Upper	Sand	3.75	9.60	

*Bartlett's test of homogeneity of variances showed that the variances of the mean for the sand, silt, and clay-sized fractions were homogenous and allowed the performance of a F-test.

Using values listed in Appendix VII, average weight percentages of sand, silt, and clay were calculated for each bed at each locality (Table 7).

Physical conditions, like water currents, distance from source areas, wave base, etc. at the site of deposition may have been slightly different with respect to the relative position of the five localities. For example silts and clays of the lower limestone at locality BR could have been deposited in decreasing water depths. During deposition exposure may have converted the spot into a source area for the deposition of the middle and upper limestones and mudstones. Grain size decreases away from the source area. It is a function of source and energy available for transportation. The high percentages of silts and clays compared to the sand fraction indicate a low energy environment, knowing that the shore line of the Permian "Basin" was relatively close.

Large quantities of clays were observed at the W (20.82 average wt. percent), L (19.98 average wt. percent), and DC (19.08 average wt. percent) localities. Yarrow (1974, p. 38) believed that the dispersant (sodium hexametaphosphate, Calgon) being in contact with the clay sample for a long time (pipette analysis withdrawal for the 11 Ø fraction at 20° C after 106 hours and 50 minutes, Royse, 1970, p. 26, Table 3-2) dissolves the clay producing weights of these smaller sizes larger than actual values. This effect may have its greatest importance in the smaller (less than 11 Ø) clay fractions. In this case, however, where only a 9 Ø withdrawal was required to calculate the clay fraction, the dissolution could have some effect, if a significant quantity of very small clay sized particles remain in colloidal suspension (Chaudhuri, 1974). Opposite electrical charges on particle surfaces create repulsive forces which would keep the smaller sized grains in collodial dispersion.

Marschner (1968, p. 56) described a relationship between early diagenetic carbonate minerals and clay mineral content in micritic limestones. Envelopes

Table 7

Average Weight Percentages of Sand, Silt, and Clay for Each Bed in Part of the Hughes Creek Shale

Locality	Lower Limestone			Middle Limestone			Upper Limestone			Top Limestone		
	Sand 4Ø	Silt 4-9Ø	Clay 9Ø	Sand 4Ø	Silt 4-9Ø	Clay 9Ø	Sand 4Ø	Silt 4-9Ø	Clay 9Ø	Sand 4Ø	Silt 4-9Ø	Clay 9Ø
BR	.19	19.20	11.16	.34	28.93	19.96	.10*	24.92*	11.92*	-	-	-
DC	.59	26.83	17.46	.44*	21.53*	16.92*	.37*	32.67*	18.52*	.82*	21.05*	26.65*
P	.36	21.86	15.63	.64*	10.79*	15.93*	.56	7.40	14.10	.30*	.50*	20.10*
L	.24	21.60	19.60	.44	10.65	21.45	.21*	6.93*	18.21*	-	-	-
W	.38	18.33	21.86	.37	14.53	21.90	.29	18.95	17.70	-	-	-

* only one value obtained
- Top limestones were only present at localities DC and P

of clay minerals around carbonate grains prevent formation of larger carbonate crystals during recrystallization. With a similar composition of clay to carbonate grains in most samples and the same recrystallization pattern, Marschner's results may also hold true for grain size/carbonate relationships in the Hughes Creek.

Carbonate and Clay Mineralogy.--There has been a controversy about the origin of carbonate sediments, organic versus inorganic. Matthews (1966, p. 428) in a study of recent lime muds in southern British Honduras stated:

> Physical breakage and abrasion in agitated environments are considered the dominant processes of lime mud production on carbonate shoals; whereas the major factors in the *in situ* production of lagoonal lime mud appear to be: (1) the inherently fragile nature of the shells of molluscs and tests of hyaline foraminifera of the lagoonal environment, (2) the removal of binding organic matter from mollusc shells, (3) the weakening of larger skeletal particles by the activity of boring micro-organisms, and (4) the mastication, ingestion, and perhaps even simple movement of sediment by the vagrant benthos.

Logan *et al.*, (1970) demonstrated that algae and bacteria in a tidal flat to shallow water environment at Shark Bay, Australia, control the Eh-pH system and hence carbonate precipitation. *Goniolithon*, *Penicillus*, or *Halimeda* are known to produce large amounts of skeletal carbonate relative to their biomass. Therefore, with direct inorganic precipitation of carbonates in a minor role, the effects of bio-chemical and organic precipitation are responsible for carbonate sediments. Many marine invertebrates, as well as calcium-secreting algae, are known to contain large quantities of magnesium in their skeletons (Müller, 1967, p. 190). Magnesium carbonate in some organisms may be as high as 20 mole percent.

Because Mg-calcite plays an important role in the carbonate system, its exact determination is important. Goldsmith, *et al.*, (1955) described a relationship between $MgCO_3$ content and the position of the strongest calcite X-ray diffraction peak (d = 3.03 A.U., [104]). From this relationship (fig. 15)

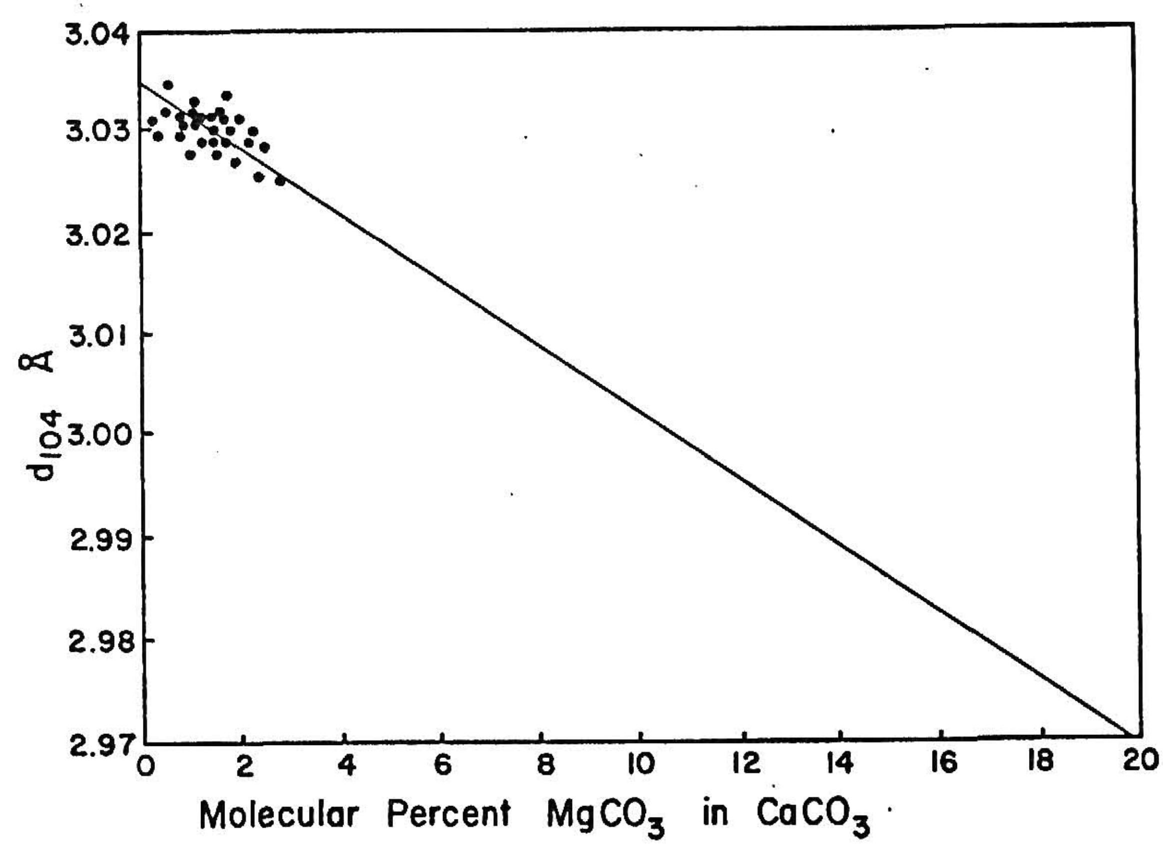


Fig. 15. Relation between the Amount $MgCO_3$ in High-Magnesium Calcite and the Position of the (104) Reflection (after Goldsmith et al., in Müller, 1967, p. 190)

the $MgCO_3$ content in $CaCO_3$ can be determined and was applied to detect magnesium carbonate in Hughes Creek limestones.

Random power X-ray diffraction indicated that calcite was the only carbonate mineral (Table 8). X-ray patterns also show a "d" spacing of quartz with a major peak at 3.34 A.U.

Some bedding surfaces with abundant ectoproct fragments have a higher concentration of $MgCO_3$ (Table 9). Ectoproct skeletons are composed of both types of calcite. Minimum values of magnesium carbonate, however, do not always correspond with mapped surfaces containing fossils with low magnesium skeletons.

Table 9

Percent High Magnesium Calcite in $CaCO_3$ for Bedding Planes Containing Abundant Ectoproct Fragments

Section	Mapped Surface	Mole Percent $MgCO_3$	No. of Fragments
BR	U-3	2.08	4
DC	L-12	2.65	7
P	L-8	2.08	5

X-ray identification of clay minerals was made from air dried, glycolated, heated and acid treated samples. Illite, chlorite, and mixed-layered chlorite clays were identified from their basal X-ray diffraction peaks (Table 10).

A semiquantitative technique described by Biscaye (1964, p. 1284; 1965, p. 809) and John, Grim, and Bradley (1954, p. 250) was used for comparative purposes. Different quantitative estimation methods based on peak height intensity or peak area measurements are commonly used. Results are semiquantitative, that is, capable of being measured, but always remain approximations of real quantities. The 7 A.U. [002] chlorite peak area from the glycolated

Table 8

X-Ray Diffraction Data of Carbonate Minerals and Mole Percentages of $MgCO_3$ in $CaCO_3$ of Part of the Hughes Creek Shale

Sample #	Carbonate Mineral(s)	Other Identified	Mol % $MgCO_3$ in $CaCO_3$*
BR-L-1	Calcite	Quartz	1.72
BR-L-2	Calcite	Quartz	1.46
BR-L-3	Calcite	Quartz	.82
BR-M-1	Calcite	Quartz	.51
BR-M-2	Calcite	Quartz	.21
BR-M-3	Calcite	Quartz	.82
BR-U-1	Calcite	Quartz	2.08
DC-L-1	Calcite	Quartz	1.46
DC-L-2	Calcite	Quartz	2.65
DC-L-3	Calcite	Quartz	1.46
DC-M-1	Calcite	Quartz	1.13
DC-U-1	Calcite	Quartz	1.13
DC-T-1	Calcite	Quartz	---
P -L-1	Calcite	Quartz	2.65
P -L-2	Calcite	Quartz	1.46
P -L-3	Calcite	Quartz	2.08
P -M-1	Calcite	Quartz	1.15
P -U-1	Calcite	Quartz	.82
P -U-2	Calcite	Quartz	.82
P -T-1	Calcite	Quartz	---
L -L-1	Calcite	Quartz	2.33
L -L-2	Calcite	Quartz	2.08
L -L-3	Calcite	Quartz	.82
L -M-1	Calcite	Quartz	.82
L -M-2	Calcite	Quartz	2.08
L -U-1	Calcite	Quartz	2.08
W -L-1	Calcite	Quartz	1.72
W -L-2	Calcite	Quartz	1.72
W -L-3	Calcite	Quartz	.82
W -M-1	Calcite	Quartz	---
W -M-2	Calcite	Quartz	.21
W -M-3	Calcite	Quartz	1.13
W -U-1	Calcite	Quartz	---
W -U-2	Calcite	Quartz	.82

*Determined from graph (fig. 15).

Table 10

Clay Minerals in Part of the Hughes Creek Shale

Locality	[hkl]	dA.U.	Io/I	Clay Mineral
BR	001	10.06	100	Illite
	002	5.01	20	
	003	3.34	40	
	001	14.06	50	Chlorite
	002	7.12	30	
	003	4.77	10	
	004	3.53	20	
DC	001	10.04	100	Illite
	002	5.00	20	
	003	3.34	30	
	001	14.24	50	Chlorite
	002	7.09	40	
	003	4.74	10	
	004	3.54	10	
P	001	10.04	100	Illite
	002	4.99	20	
	003	3.34	30	
	001	14.24	50	Chlorite
	002	7.09	40	
	003	4.74	10	
	004	3.54	20	
L	001	10.13	100	Illite
	002	4.98	10	
	003	3.33	30	
	001	13.63	40	14 A.U. exp. Clay
W	001	10.06	100	Illite
	002	4.98	20	
	003	3.34	30	
	001	14.15	40	Chlorite
	002	7.12	30	
	003	4.73	10	
	004	3.53	20	

*Samples were collected for each bed at each locality, but only one composite sample of all beds at each locality was analyzed pattern, multiplied by two, was preferred for the quantitative measurements, because the 14 A.U. [001] chlorite reflection usually interferes with a possible glycolated montmorillonite peak. The 10 A.U. [001] illite peak area from the glycolated pattern, multiplied by two, was used to determine the relative amounts of illite.

Illite, a mica group constituent of argillaceous sediments is the dominant clay mineral at all five localities (fig. 16). The basal peak sequence showed 10 A.U., 4.7 A.U. and 3.3 A.U. reflections with variable peak intensities. Heat treatment and glycolation did not affect the basal peaks.

Biscaye (1965, p. 816) found that illite is the dominant clay mineral in the less than 2 micron fraction of Atlantic deep-sea sediments. Illite is reported as being associated with mica-rich rock types and is relatively resistant to chemical weathering. Illite comprised 80 percent of the total mineral assemblage at all five localities. The source for illite cannot be clearly defined, because midwestern basins were relatively far from primary source area during Permian time. Most of it is recycled sediment originally derived from the Ozark Mountains, the Wichita Mountains or the Ancestral Rockies, however, diagenetic changes after deposition could also lead to the formation of illite.

Chlorite is the second most abundant clay mineral in all but the Louisville locality. The 14 A.U., 7.1 A.U., 4.7 A.U. and 3.5 A.U. reflections were observed. Chlorite is one of the most easily weathered silicates. Its main source is basic igneous rocks but it also forms on marine diagenesis in near-shore environments (Folk, 1974, p. 95) and in marine sediments which receive an influx of iron-rich terrigenous sediment.

Mixed layered clays are interstratifications of different clay mineral species. A mixed layer chlorite with expandable layers was observed as the second most abundant clay mineral at locality L. A 13.6 A.U. peak was recorded,

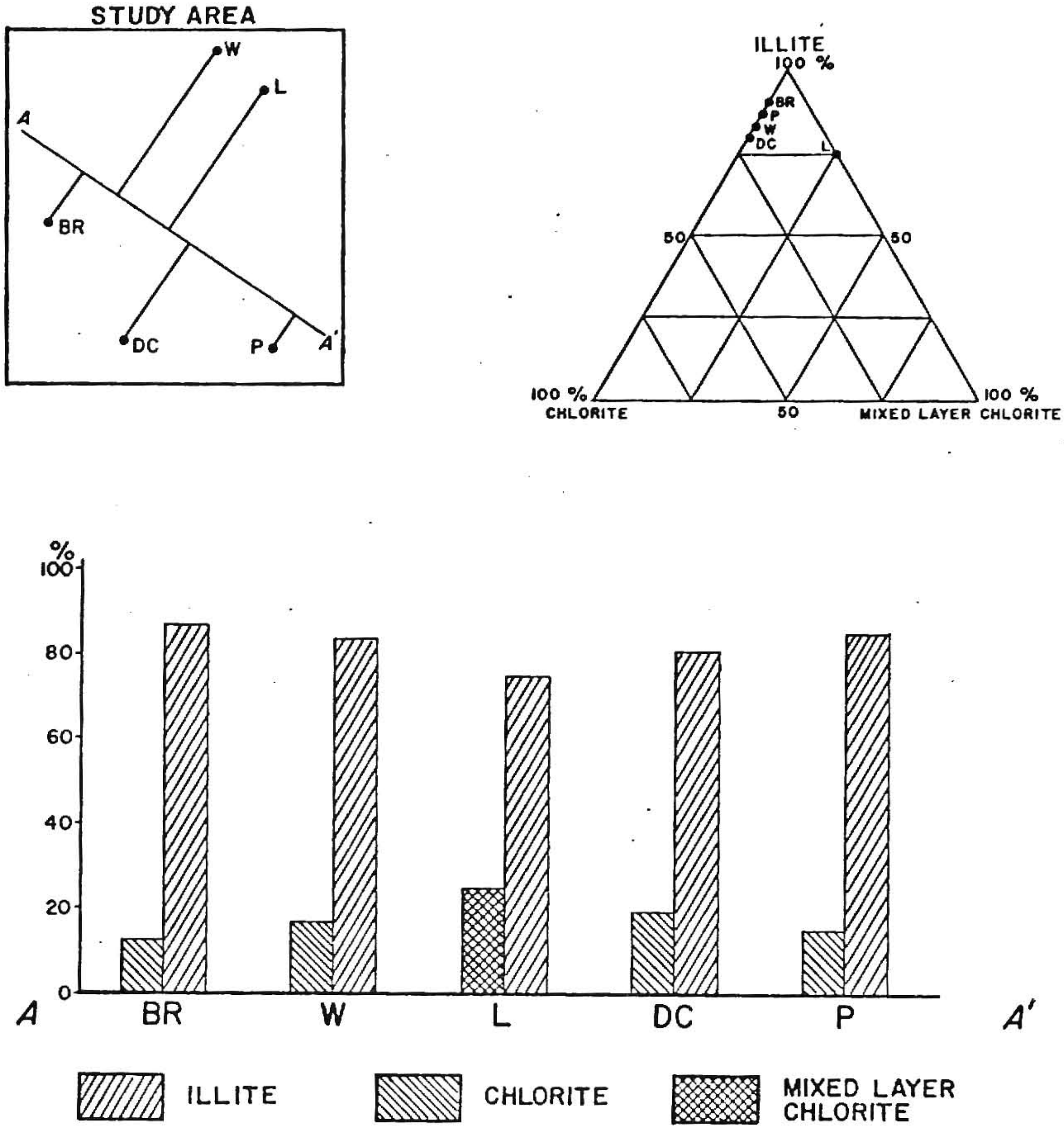


Fig. 16. Clay Mineral Distribution in Part of the Hughes Creek Shale

which moved upon glycolation to 15 A.U. The interlayered clays confirm field observation that locality L has been deeply weathered. Generally, a leaching-weathering process causes a degradation of micas, and mixed layer clays are developed by the partial removal of inter-layer potassium from the micas and magnesium from the brucite layers in chlorites (Grim, 1958, p. 247).

Thin Section Data.--Limestones are perhaps the most difficult group of sediments to study petrographically, because of the variety of conditions under which they may have formed, and differences in diagenetic history. Folk's (1959) textural classification of limestones, was used in assigning rock names. A detailed point count of four slides most representative of the limestones indicated that all thin sections were recrystallized fossiliferous micrites (Appendix IV). Average weight percentages of allochemical, orthochemical, and terrigenous components for each bed at five localities are listed in Table 11.

Chemically precipitated microcrystalline ooze or micrite, forming grains from 1-4 microns, microspar 4-10 microns, and clear, coarse-grained sparry calcite or spar with grains over 10 microns in diameter are considered orthochemical.

Micrite is faint greyish-brown under plane polarized light and is hard to distinguish from clay matrix. In some slides (Plate III, figs. 5, 6), microcrystalline calcite occurred as test fillings of foraminiferids. Dismicrite features were observed in a few samples and occurred in connection with burrow type structures (burrows filled with clear sparry calcite). Micrite forms by chemical (evaporation, agitation), and biochemical (algae, bacteria) precipitation and settles on the seafloor in a "snow flake effect" being drifted by weak currents and finally settling on the bottom of the ocean. Even though freshly precipitated micrite particles undergo some transportation during the settling process, microcrystalline ooze is still considered to be orthochemical.

Table 11

Average Weight Percentages of Allochemical, Orthochemical and Terrigenous Constituents for Each Bed in Part of the Hughes Creek Shale

		Orthochemical Constituents			Allochemical Constituents	
Locality	Bed	Micrite 1-4 microns	Microspar 4-10 microns	Sparry Calcite 10 microns	Skeletal Fragments	Terrigenous Constituents
BR	U	37.2	23.2	1.6	14.2	21.6
	M	40.3	15.6	0.5	20.3	18.6
	L	39.5	9.5	1.3	20.0	25.7
DC	T**	--	--	--	--	--
	U*	34.1	26.7	--	15.9	21.7
	M	35.8	24.7	1.0	19.5	16.4
	L	47.4	15.4	0.6	16.6	17.3
P	T	29.3	14.5	2.7	18.0	33.1
	U	27.8	19.0	8.8	22.2	13.9
	M*	29.5	33.5	0.3	9.2	26.2
	L	54.5	7.3	1.5	20.6	13.9
L	U	--	--	--	--	--
	M	45.3	17.1	0.9	15.5	16.0
	L	55.2	6.7	0.7	13.6	21.7
W	U*	35.8	28.7	--	11.7	19.5
	M	46.4	14.0	0.8	18.5	18.4
	L	46.0	18.0	2.9	24.0	18.2

* only one value obtained
**no thin section

Microspar in all slides is due to recrystallization. Section L shows low microspar but extremely high micrite percentages (11.9 and 50.0 percent). Consequently, the Louisville section is the least affected by recrystallization. In all slides, microspar occurred as recrystallized micrite, although spar can undergo the same phenomena. A distinction between microspar and sparry calcite can be difficult especially in a "dirty" slide with a high percentage of clays and silt. Spar and microspar were, therefore, clearly defined by size.

Sparry calcite, rare and mostly restricted to cavity fillings, occurred in recrystallized pelecypod and crinoid fragments or as replacement of skeletons (Appendix IV; W-L-3, W-L-2, P-T-1, P-U-1). Spar characteristically occurred in connection with vertical and horizontal burrows which were filled with clear crystals held together by limonite cement (Appendix IV: L-L-2, DC-U-1).

Fossils and intraclasts are the only allochems encountered with the later occurring in only one slide (BR-M-3). Most common skeletal grains are laminated, punctate or pseudopunctate brachiopod shell fragments, recrystallized pelecypod shells and crinoid debris, matrix-filled ostracodes, spar and matrix filled foraminiferids and ectoproct debris. Penecontemporaneous fragments of consolidated rounded grey limestone 2.5 mm. in diameter were found in one slide BR-M-3 and defined as intraclasts.

Algal-foraminiferid colonies (Osagia) encrust some skeletal fragments and burrow walls (Plate III, fig. 2). Detrital quartz, feldspars and clays are the most common terrigenous components. Some rounded quartz grains and authigenic quartz occurred in samples W-M-2, W-M-3, P-L-3, and W-L-3 indicating a detrital origin for the rounded grains. A few plagioclase grains smaller than 0.03 mm. and small mica flakes were observed, but are of minor importance (L-L-1 and W-L-3).

Pyrite is well known to form exclusively authigenically. Chert and limonite aggregates are also believed to be products of in situ chemical and biochemical action. Both minerals were observed in thin sections replacing mollusc shells or in burrow structures (L-M-2, W-L-3, DC-M-3, and BR-U-3). Clay was observed in all limestones. Illite was identified petrographically by a color change from yellow over red to blue with crossed nicols and inserted gypsum plate and its high interference color. Chlorite is pale green to deep green.

Silt and clay sized grains are common terrigenous components. Samples contained an average of 19.5 percent clay and silt with a minimum of 10.4 percent and a maximum of 43.7 percent. Terrigenous matrix estimations show a good correlation with the obtained insoluble residue data (Appendix VI), which ranges from 17.5 to 58.1 percent total rock constituents.

Glauconite was observed in many samples and is not included in the percent terrigenous sediment, but recorded separately (Appendix IV). It was encountered as altered rounded grains or as fresh replacement filling in fenestrate ectoprocts and foraminiferid tests. Bathurst (1971, p. 411) stated:

> Glauconite, though requiring reducing conditions for its development, is found in well-oxygenated environments where there is a rich supply of organic matter. Thus, it is found on open sea floors today, but inside the tests of foraminiferids where the microenvironment had at one time a negative redox potential.

Chalcedony or chert occur as partial replacement of mollusc fragments. X-ray diffraction failed to reveal dolomite, yet dedolomitization and inversion to calcite on a 2 mm. dolomite grain was noted on slide BR-M-4. Grain size of skeletal fragments ranged from 0.4 mm. to 20 mm. with an average of 1.5 mm. Average grain size of microspar was 6 microns and sparry calcite grains averaged approximately 40 microns. Diagenetic change or cementation of carbonate rocks may start during or soon after deposition. Solution, precipitation, recrystallization and compaction are considered the primary processes.

Cementation features are rare, occurring only on dismicritic dissolution patches, where the spar crystals and skeletal fragments are bound together by reprecipitated clear calcite cement. Iron cementation occurs in connection with biogenic sedimentary structures or in iron-stained patches. Detailed diagenesis of a carbonate sediment is complex and beyond the scope of this report.

Geochemical Data

Palaeosalinity estimations and organic carbon analysis proved to be useful interpretive tools in this study. A combination of geochemistry, carbonate petrography and palaeobiology can be used effectively to support each other in an alternating mudstone and limestone sequence.

Palaeosalinity Estimations.--Concentrations of $CaPO_4$ and $FePO_4$ in ppm, the ratio of Ca to Fe aliquot quantities used, and the calcium phosphate ratio (Ca/Ca + Fe) were calculated and tabulated in Table 12.

Palaeosalinity values were determined from Figure 17. Nelson's SPM experiments have been severely criticized by co-workers in the field. Müller (1969) examined Recent sediments, Pleistocene, Tertiary, Permian, and Carboniferous sedimentary rocks from the North Sea to the German Alps ranging from fresh-water sediments to hypersaline salt clays. SPM results obtained did not match the directly observed salinities for Recent sample or the known salinity values derived from geologic and/or palaeontologic evidence. Müller argued that some of the phosphorous must have been derived from older, mostly marine sediments or rocks containing apatite. Calcium phosphate could, therefore, be of detrital origin and may not indicate salinity of the depositional environment.

Table 12

Palaeosalinity Determinations Based on Sedimentary Phosphates in Limestones and Mudstones in Part of the Hughes Creek Shale

		Ca-PO4 Conc.(ppm)	Fe-PO4 Conc. (ppm)	Amount Aliquot Fe^+/Ca^+(ml)	Ca / Ca+Fe	Salinity* (%)
LIMESTONES	BR-U	1.213	.022	9 / 1	.982	33.01**
	BR-M	1.662	.011	9 / 1	.993	33.40
	BR-L	.315	.007	9 / 1	.978	32.90
	DC-T	.378	.023	9 / 1	.943	31.57
	DC-U	.735	.025	9 / 1	.967	32.50
	DC-M	.654	.021	9 / 1	.969	32.60
	DC-L	1.470	.010	12 / 1	.993	33.40
	P -T	.849	.011	9 / 1	.987	33.25
	P -U	2.700	.013	9 / 1	.995	33.50
	P -M	1.242	.015	9 / 1	.998	33.29
	P -L	.714	.012	9 / 1	.983	33.18
	L -U	.927	.019	9 / 1	.980	32.96
	L -M	..549	.025	9 / 1	.956	32.08
	L -L	.756	.019	9 / 1	.975	32.79
	W -U	.444	.012	9 / 1	.974	32.72
	W -M	1.521	.025	9 / 1	.984	33.10
	W -L	.519	.020	9 / 1	.963	32.30
MUDSTONES	P -6	.460	.018	12 / 3	.962	32.30***
	L -8	.733	.021	12 / 3	.974	32.58***
	W -8	.341	.033	12 / 3	.913	30.42***
	W-8-2	.430	.011	12 / 3	.975	32.80
	W-8-3	.552	.021	12 / 3	.963	32.40
	W-9-b	.883	.015	12 / 3	.983	33.07***

* Palaeosalinities estimated from Figure 17.
** Average of two values
*** Average of three values

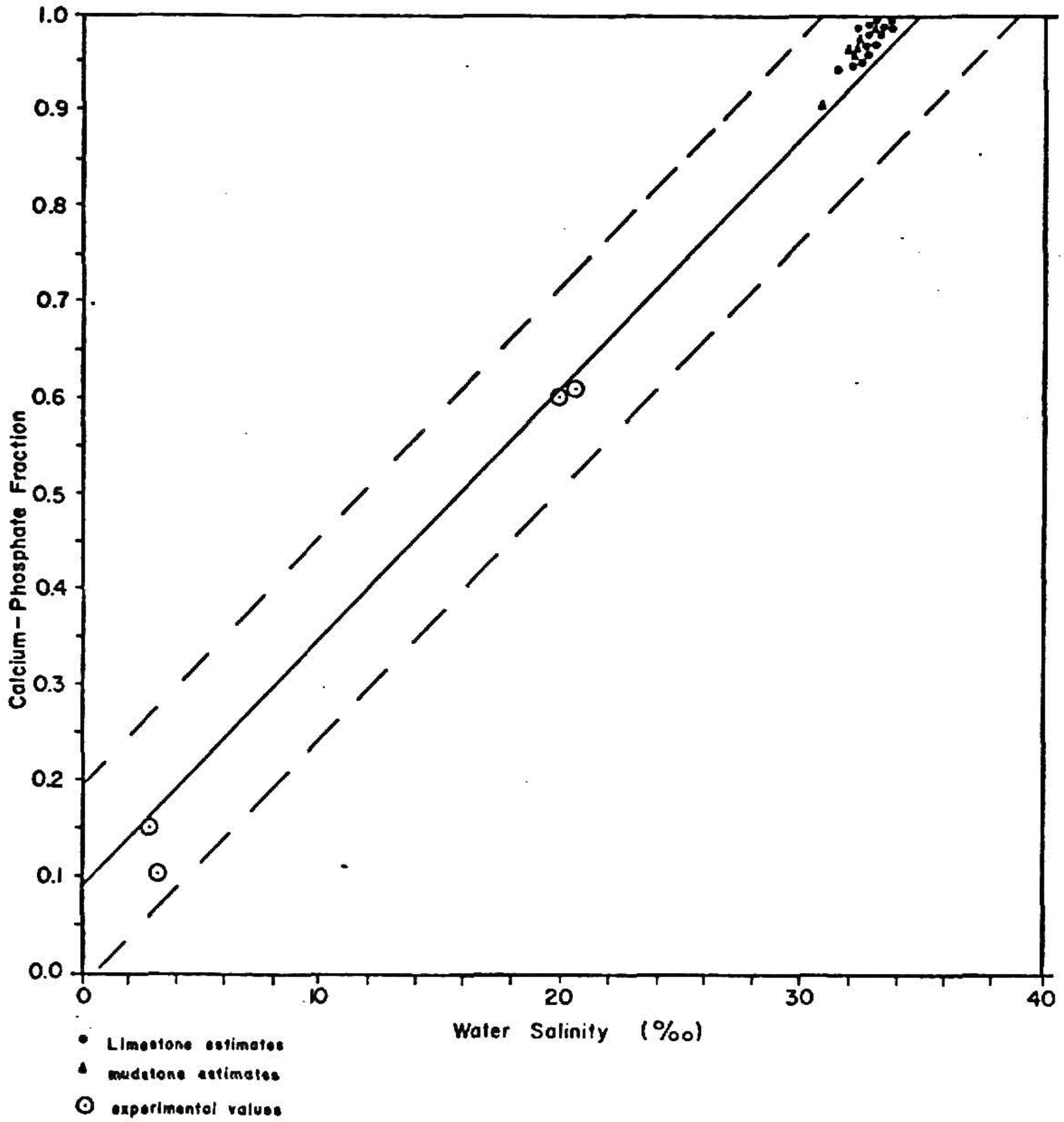


Fig. 17. Relation between Calcium-Phosphate Fraction and Bottom Water Salinity (after Nelson, 1967)

Guber (1969) compared SPM salinities with inferred estimations based on trace element distribution, carbon isotope ratios, and fossil evidence. The brackish environment of a Pennsylvanian Lingula-bearing shale showed nearly marine conditions.

Accurate estimates of palaeosalinity using Nelson's technique require: 1) removal of all detrital phosphatic minerals, 2) the assumption that all phosphate in the sample is of "in situ" inorganic orgin, and 3) the assumption that there has been no diagenetic alteration of the phosphate or that diagenetic effects were essentially the same for all samples.

The sedimentary phosphate method is a highly sensitive analytical method with some limiting factors which are hard to control. It is, therefore, advisable not to use the SPM exclusively but to integrate it with palaeobiological and geological evidence.

Organic Carbon Data.--Samples treated with 30 percent hydrogen peroxide contained up to 14 percent of the weight of the total sample in organic carbon (Appendix VII). Analysis of variance of the mean performed on the upper, middle, and lower beds revealed no significant difference between the upper, middle, and lower limestone beds at the 0.05 level (Table 13). The amount of organic carbon in the sediment is believed to be an indicator for the food supply available to benthic organisms.

Biogenic Sedimentary Structures

Biogenic sedimentary structures represent the activity of organisms rather than part of the animal itself; their presence is evidence that organisms which lack preservable hardparts existed during deposition (Howard, 1968).

In recent years, growing emphasis has been placed on the study of trace fossils (Richter, 1920, 1926, 1927, 1937; Seilacher, 1954, 1964, 1967; Schäfer, 1952, 1956, 1972; and Reineck, 1958, 1963, and Reineck and Singh, 1973). Tracks,

Table 13

Statistical Comparison of Organic Carbon
between Beds in Part of the Hughes Creek Shale

			d.f.
Upper Lst. Middle Lst.	F-test	1.3524	2
Upper Lst. Lower Lst.	F-test	2.4558	2
Middle Lst. Lower Lst.	F-test	1.8155	2

F-Values must be greater than 6.39 for a significant difference to exist at the 0.05 level

Bartlett's test of homogeneity of variances:

$X^2 = 0.706$, table value (2 d.f.) = 5.99

value $^M/C$ is $<$ than 5.99, variances of the mean are homogenous, perform F-test.

trails, and burrows always leave a considerable uncertainty as to their origin and are, therefore, hard to interpret. Trace fossil morphology is more strongly controlled by the behaviour and response of the organism to its substrate than by anatomical and morphologic characteristics. Seemingly identical traces found on a bedding plane may well be the result of completely different genera of animals.

Burrowing can be used to interpret and determine sedimentation rates. Animals living in the substrate are sensitive to erosion and sediment accumulation, and will respond to it by moving downward or upward in the substrate.

Seilacher (1967, p. 418) and Rhoads (1967, p. 475) noted that trace fossils are mainly depth controlled. Deep vertical burrows are generally characteristic of intertidal and shallow subtidal environments, whereas shallow horizontal burrows are more indicative of deeper offshore areas. A general rule for bathymetric zonation of fossil lebensspuren exemplifies that suspension feeders are common in shallow and highly agitated waters with loose coarse grained or firm substrates and sediment feeders settle in deeper more quiet waters of finer grained loose substrates. This explanation seems logical if one considers a behavioral response to the available food supply at different depth levels. Food particles will remain suspended in agitated water and settle in a low energy environment.

Laminated biostratification structures (Frey, 1973) on the vertical mapped surfaces probably reflect slow sedimentation (Appendix II; Beds BR-U, BR-M, and P-L) which leads to extensive reworking of the substrate (Frey, 1970). U-shaped burrows up to 5 centimeters high were observed on some vertical surfaces (Appendix II; BR-U, BR-M, and DC-M). Infaunal deposit feeders like some gastropods, arthropods, and annelids are known to form U-shaped bioturbation structures (Howard, 1968). Burrows are generally formed by a digging process of the inhabiting animal. The walls of bioturbated holes are often made stable by secretions of the organism which bind sediment particles together. U-shaped burrows and smaller vertical tube-like or cylindrical structures are here interpreted as being formed by suspension feeders (Appendix II; Beds DC-M, W-M, BR-M, and L-M) and are classified as dwelling structures or domichnia.

Small single horizontal burrows and branching burrows are classified as Chondrites, feeding structures or fodinichnia (Plate II, fig. 2). Patterns classified as Chondrites are designed by deposit feeders to use a maximum possible area for their food supply.

Large blade-like, patchy structures are defined as 'spreite' burrows (Appendix II; Beds W-L, DC-1, BR-L, P-L, L-L, and L-M). These are the biggest burrows encountered, ranging from 5 to 10 cm. in height and width respectively. Dark rounded spots within the spreiten were first believed to be fecal pellets, but because most of these 1 to 3 mm. large particles are neither well rounded nor well sorted, I believe they represent mottling of the burrow filling. 'Spreite' burrows are also considered as deposit-feeding fodinichnia structures.

Grain size analysis comparing the rock inside and outside burrowed structures were not made, but visual estimates suggest a smaller mean grain size inside the burrows. Sediment ingesting organisms probably cause a reduction of grain size during digestion. Furthermore, burrow color is either darker or lighter than the surrounding matrix. Oxidation and other biochemical changes during the feeding and digestive process are probably responsible initially for color differences which could be accentuated by diagenesis.

Classification of bioturbation features proposed by Reineck and Singh (1973, p. 149) was applied in this study (Table 14). They give each mapped surface a grade from 0 to 6 according to the degree of bioturbation, 0 percent = no bioturbation to 6 = 100 percent bioturbation (fig. 18).

Table 14

Classification of Bioturbation Features
(from Reineck and Singh, 1973)

Grade	Degree of Bioturbation (%)	Classification of Bioturbation
0	0%	no bioturbation
1	1-5%	sporadic bioturbation traces
2	5-30%	weakly bioturbated
3	30-60%	medium bioturbated
4	60-90%	strongly bioturbated
5	90-99%	very strongly bioturbated, but rest of inorganic bedding still recognizable
6	100%	completely bioturbated

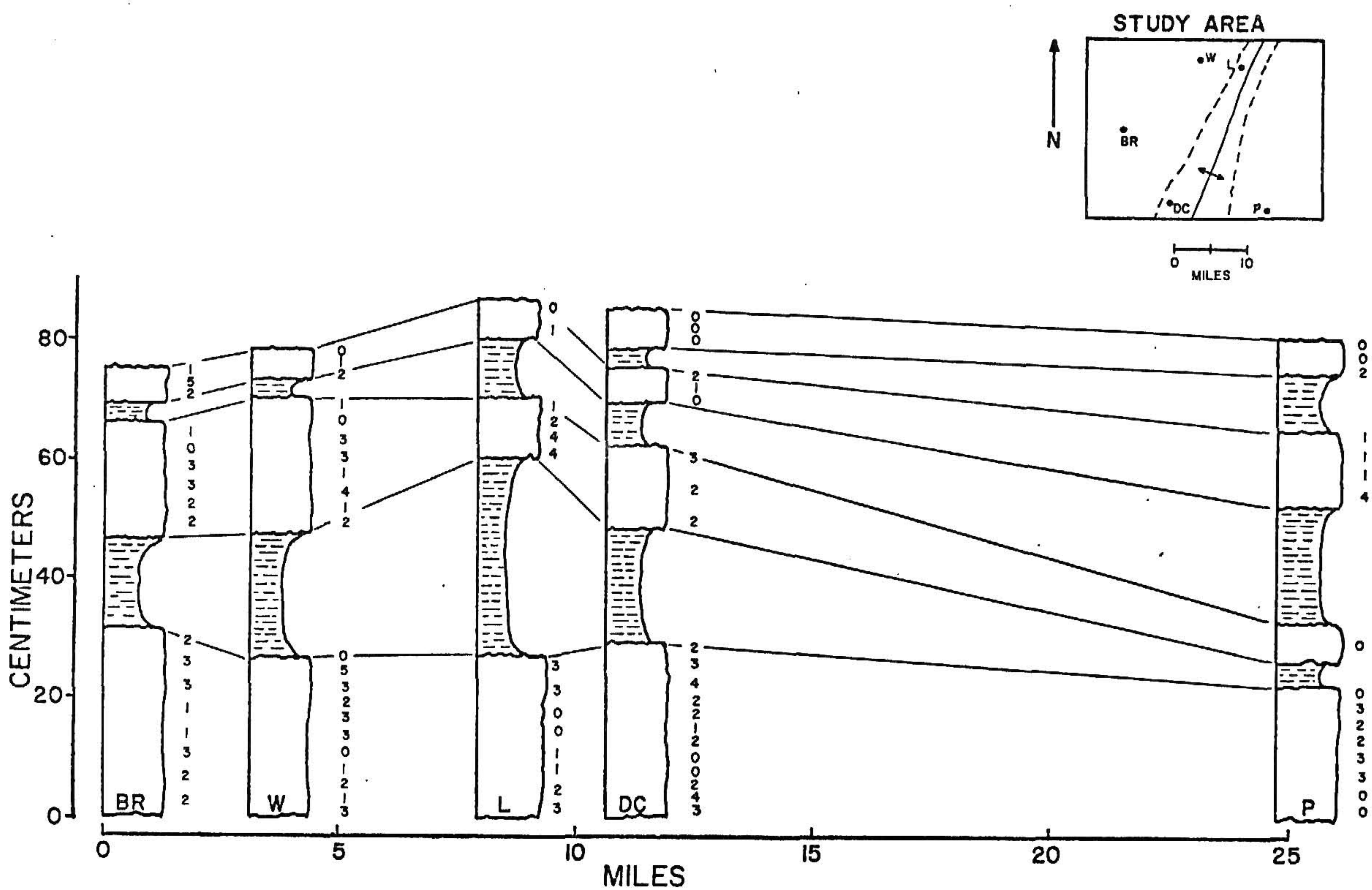


Fig. 18. Grade of Bioturbation for All Limestone Beds in Part of the Hughes Creek Shale

INTEGRATION OF DATA

Vertical Integration

Limestone beds studied are interpreted to have been deposited in a normal marine low-energy but agitated carbonate environment with terrigenous influx. Glauconite, supports a marine origin of the Hughes Creek Shale limestones, which can form under mildly oxidizing conditions in agitated water (Bathurst, 1971, p. 411). Osagia-coated skeletal fragments and specific trace fossils suggest shallow, well lit, agitated waters of the subtidal zone.

Thin section study clarified the environmental interpretation of all carbonate beds. Relative proportions of calcite cement to micrite are good indicators of current strength. Calcareous ooze, as the major constituent in most thin sections, signifies a lack of vigorous currents, comparable to immature sandstone containing an excess of clay matrix.

Most limestones are calcarenites (0.062 mm. to 1 mm.) or calcirudites (1 to 64 mm.). Genetically micritic calcirudites or calcarenites are indicative of shallow quiet water environments.

Biotic, petrologic and geochemical data are integrated in figures 19-23. Dendograms for each locality indicate degree of similarity between fossil assemblages on each horizontal surface. There is no clear pattern of similarities between horizontal surface assemblages. However, using coefficient values of 0.5 or larger a general trend in similarities was noted at each locality marked with heavy lines in figures 19-23. For all localities this involves the three highest levels of similarity. General trends noted in the vertical succession are: 1) localities BR, L, and W show similarity (0.8) between fossil assemblages of the upper part of the lower limestone with the upper part of the middle limestone and the upper part of the upper limestone unit (figs. 19, 22, 23); 2) at locality P the three highest correlation levels are within

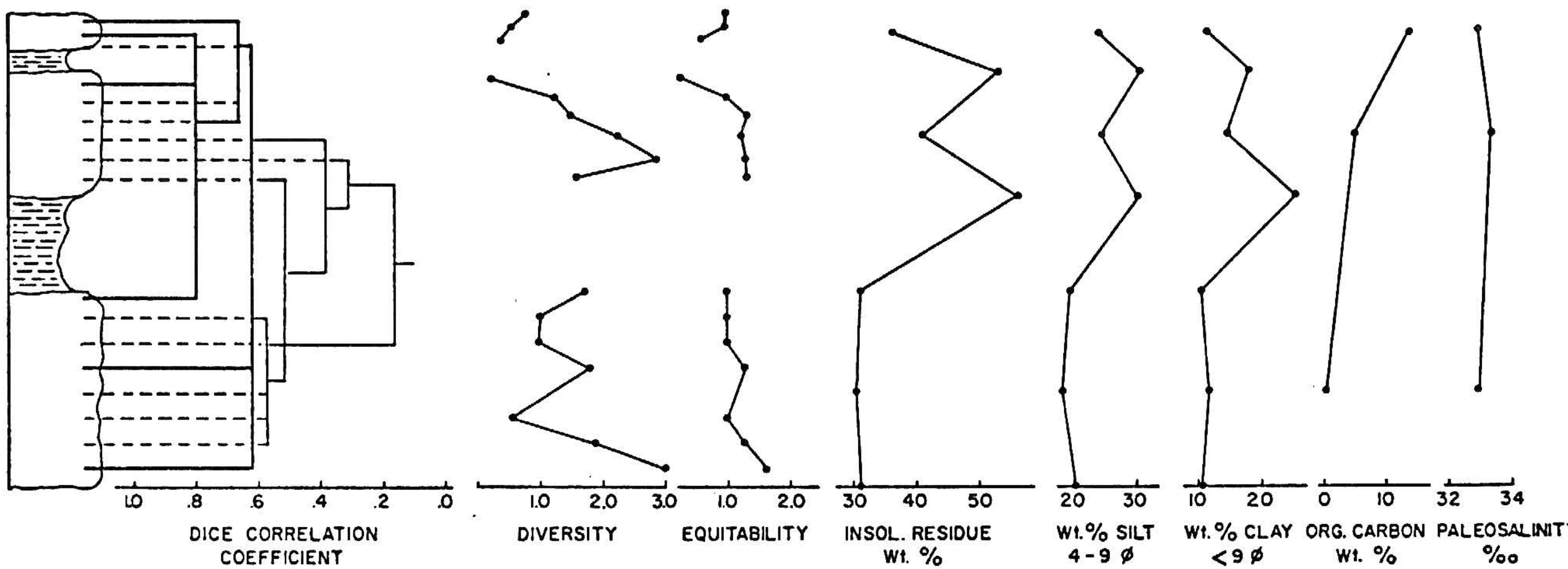


Fig. 19. Integration of Data from Location BR in Part of the Hughes Creek Shale

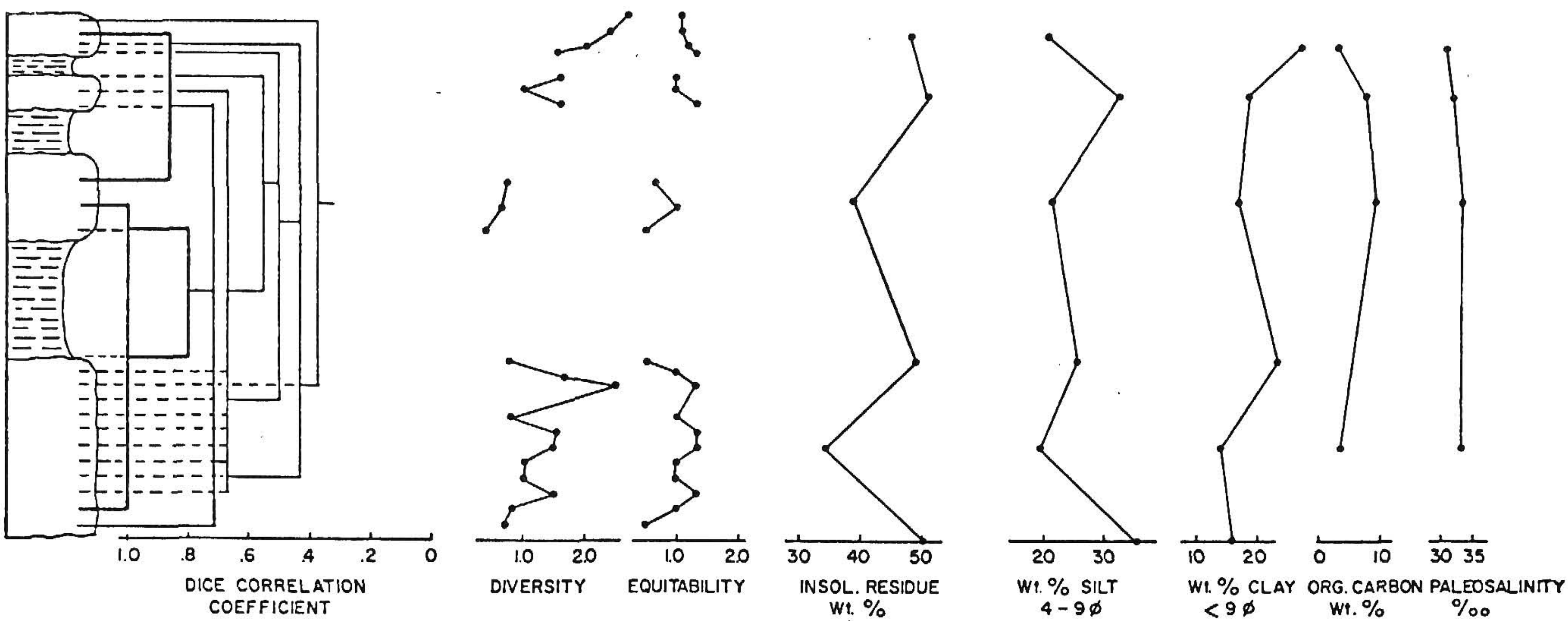


Fig. 20. Integration of Data from Location DC in Part of the Hughes Creek Shale

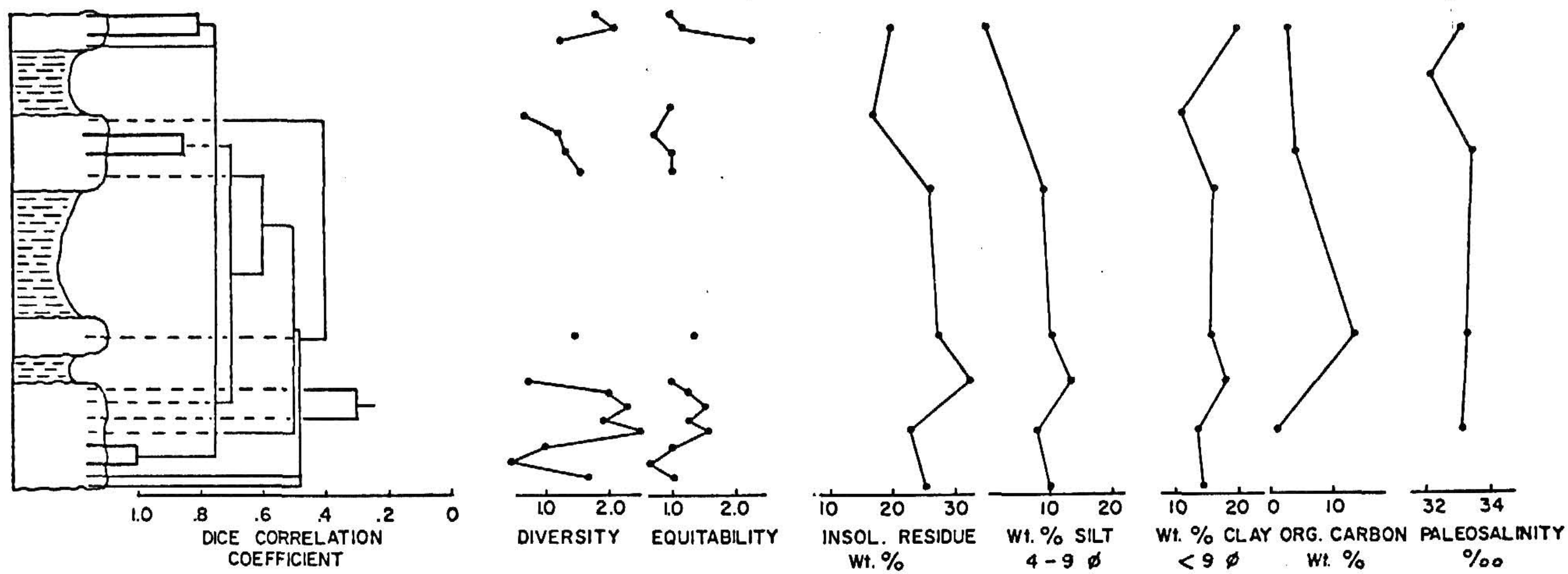


Fig. 21. Integration of Data from Location P in Part of the Hughes Creek Shale

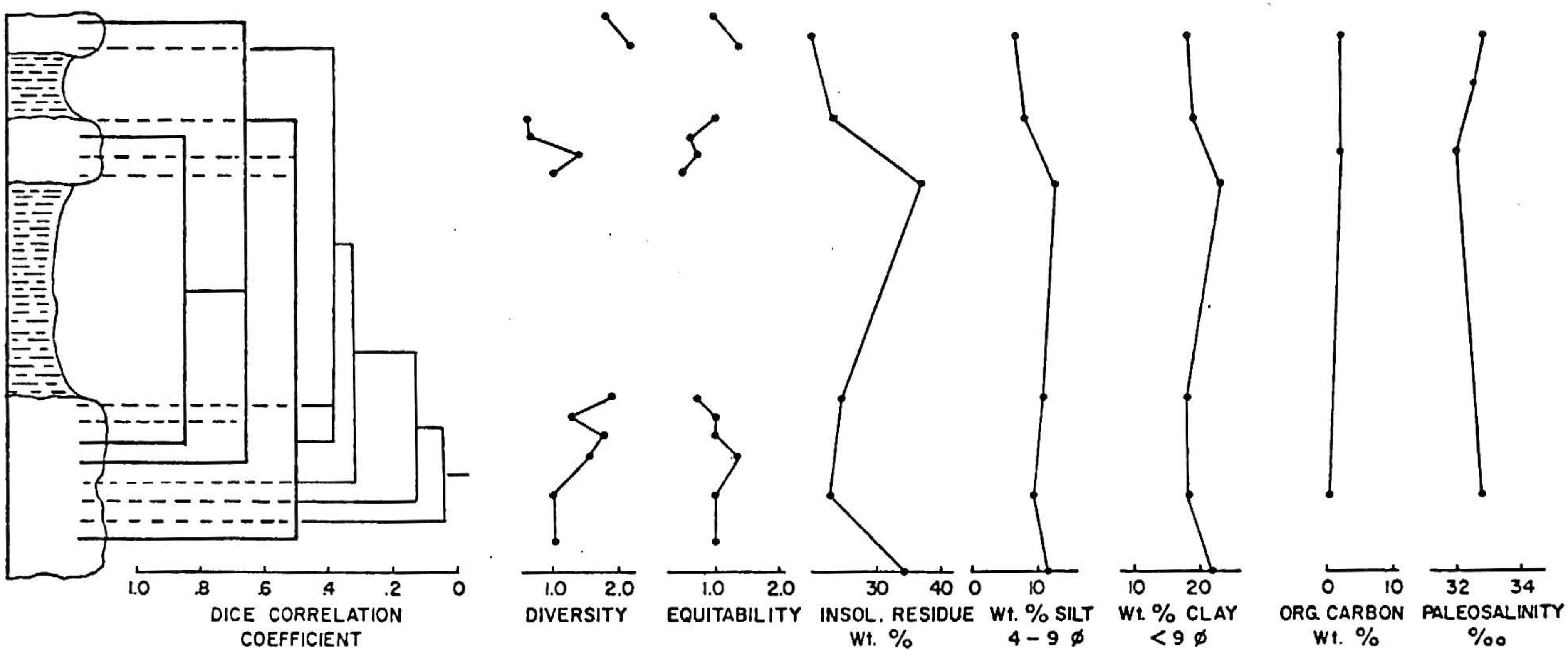


Fig. 22. Integration of Data from Location L in Part of the Hughes Creek Shale

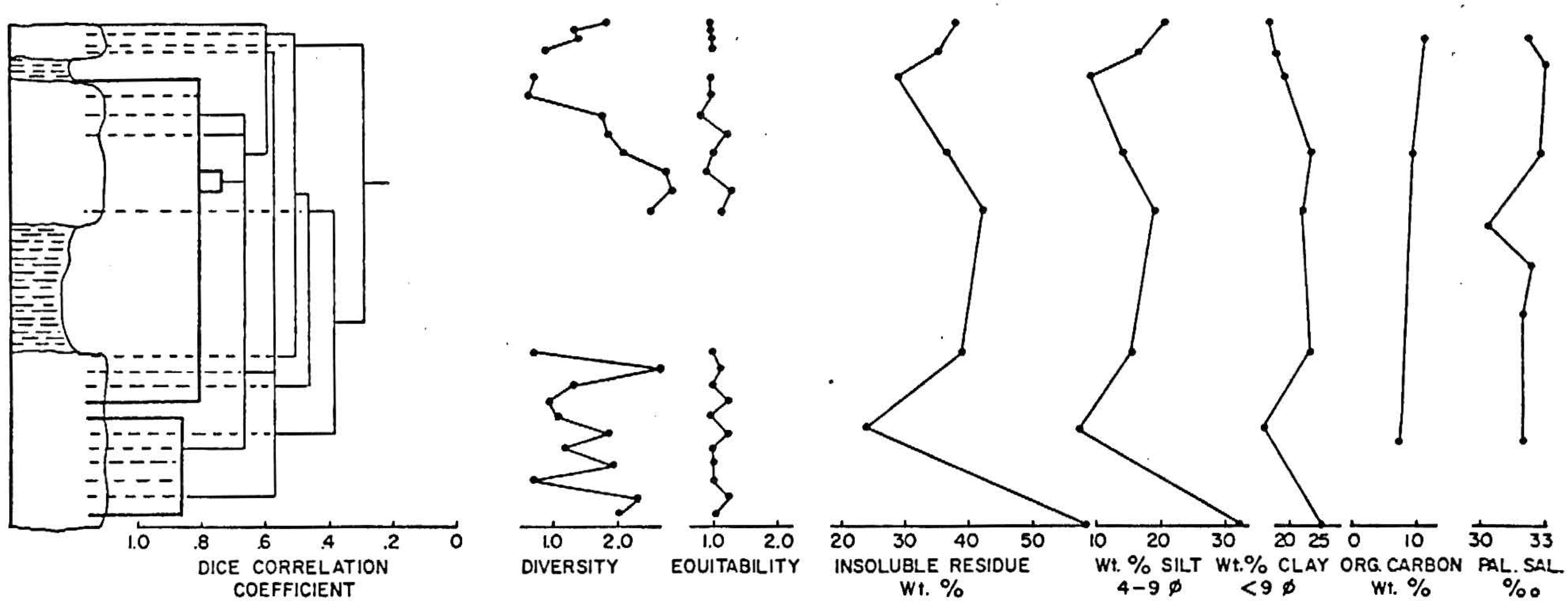


Fig. 23. Integration of Data from Location W in Part of the Hughes Creek Shale

the lower, middle and top beds respectively (fig. 21); and 3) greatest similarity of locality DC, is between the lower parts of the lower and middle limestones, and the upper parts of the middle and top limestone beds (fig. 20).

Lower Limestone.--The lower limestone is the thickest bed at all localities. Diversity in the lower limestone generally increases upward but shows a sharp decline in the uppermost part of the bed. Equitability values range from 0.5 to 1.6 and are fairly constant throughout the bed with a slight decrease at the top of the bed.

Somewhat contradictory to Yarrow (1974), who found good correlations of fossil assemblages on successive surfaces in the lower mudstones, adjacent bedding surfaces in the lower limestone do not correlate with the exception of two surfaces at locality P (fig. 21). If good similarity in fossil assemblages is obtained from successive surfaces within the same bed, these assemblages may represent the same developmental stage, either reflecting a colonizing, stabilizing, diversifying, or dominating fossil community. The lack of correlation in the lower bed then may indicate a non-gradational change from one developmental stage to another, with different fossil assemblages, thus not showing any similarity in the fossil record. A close look at the percent insolubles supports this idea. Insoluble residues drop sharply to a minimum in the middle part of the bed and simultaneously the fossil assemblages, except for Locality BR, get more diverse before dropping to a low point at the upper contact to the mudstones. The occurrence of Isogramma in the lowermost part of the lower bed (Appendix II) may represent the colonization stage of such a cycle. Decreasing terrigenous influx towards the middle part of the bed is associated with different species of brachiopods and ectoprocts, crinoids, pelecypods, and fusulinids, and bioturbation (feeding tracks). This middle part of the bed may represent the diversifying stage with a rich benthic life on the sea floor.

Organisms quickly respond to the increase in insolubles in the upper part of the bed as indicated by a sharp drop in diversity suggesting a halt or a reversing of any community development.

Middle Limestone.--Fossil assemblages of the middle limestones are similar (coefficient values) to those of the upper and/or lower part of the lower limestone beds. The consistent occurrence of fusulinids in the basal part of the middle limestone may have the same significance as Isogramma in the lower bed and Yarrow (1974) found an accumulation of fusulinids in the upper part of the mudstone immediately below this middle limestone. Insolubles and weight percent silt and clay decrease considerably from the base to the top of the middle bed (figs. 19, 20, 21, 22, and 23). The general diversity trend also decreases upward showing a reverse trend compared to the lower bed.

Fusulinid accumulations with well preserved tests lacking abrasion effects in the lower part of the bed represent "in situ" assemblage. Local abundance of fusulinids (W-M, BR-M, and P-L) has a "stability effect" on benthic fossil assemblages (Table 15). Surface BR-M-6 is a bedding plane immediately below the local abundance of fusulinids (BR-M-5) and surface BR-M-4 is above the accumulation zone. At the beginning of carbonate deposition the sea bottom must have been an unstable carbonate mud bottom that held particles in suspension above the water-sediment interface. This is clearly expressed in the mode of feeding. Abundant crinoids, ectoprocts, epifaunal brachiopods, and infaunal lingulids characterize the benthic fossil assemblage. Organisms encountered were either able to feed high above (> 3 cm.) the unstable mud bottom (crinoids, ectoprocts, or some of the larger brachiopods, for example Neospirifer), or were infaunal (Lingula). Chonetids were probably attached to crinoids or seaweed. High level suspension feeders are predominant with over 70 percent of all species and individuals encountered (Table 15).

Table 15

Feeding Behaviour of Benthic Invertebrates on Three Bedding Surfaces in Part of the Hughes Creek Shale

	BR-M-6 7 species		BR-M-5 4 species		BR-M-4 7 species	
	% species	% ind.	% species	% ind.	% species	% ind.
High level susp.	71.43	78.26	50.00	2.00	57.14	84.21
Low level susp.	14.28	4.35	25.00	3.00	42.86	15.79
Collectors	14.28	17.39	25.00	95.00	-	-

Surface BR-M-5 represents a completely different picture. Fusulinids are abundantly clustered over the entire bedding surface. Also encountered were three lingulids, one crinoid stem and one Crurithyris. High level suspension feeders still dominate with 50 percent of all species observed. Fusulinids as collectors make up 95 percent of all individuals. A trend towards substrate stabilization and diversification are indicated by low level suspension feeders. Fusulinids caused a stable substrate, as expressed on surface BR-M-4. Diversity is high (2.26, Table 2), and nearly half of all species encountered were low level suspension feeders (Table 15).

Fusulinids from bedding plane BR-M-5, being larger than the clay-sized carbonate mud formed a substrate which supported a more diverse assemblage in terms of mode of life and feeding behaviour.

Fenstrate and ramose ectoprocts on bedding plane BR-M-8 and BR-M-4 provide a clue to the energy level during deposition of the middle limestone bed. Because ectoprocts require somewhat turbulent water, slight bottom currents are predicted for this interval.

An increase in current velocity in the upper part of the unit is indicated by intraclasts at locality BR (thin section BR-M-3).

Upper Limestone.--Fossil assemblages of the upper limestone bed are similar with the lower and/or upper part of the lower limestone at localities P, DC, BR, and L. Diversity decreases at localities L and P, and increases or stays constant at BR, DC, and W. Equitability is constant at P and W, at localities L and DC it decreases upward and at BR it increases upward.

Feeding strategies of the lowermost bedding surface of the upper limestone were calculated in (Table 16).

High level suspension feeders dominate the assemblages at the base of the upper limestone, however, the picture is somewhat distorted, because the bed is composed almost entirely of Crurithyris, the only high level suspension

Table 16

Percent High Level and Low Level Suspension Feeders for One Bedding Surface in Upper Limestone at All Localities in Part of the Hughes Creek Shale

		High Level Susp.	Low Level Susp.
BR-U-3 (4 species)	% species	50.0	50.0
	% ind.	73.3	26.7
W-U-3 (4 species)	% species	75.0	25.0
	% ind.	97.8	2.2
L-U-2 (5 species)	% species	50.0	50.0
	% ind.	60.0	40.0
DC-U-3 (3 species)	% species	33.3	66.7
	% ind.	33.3	66.7
P-U-3 (3 species)	% species	75.0	25.0
	% ind.	91.7	8.3

feeder (horizontal surfaces BR-U-2 and U-3; vertical surfaces BR-U and W-U; Plate IV, fig. 3). Low level suspension feeders are commonly represented by two or three species.

Caldwell (1967) reported that ambocoeliid (Crurithyris) brachiopods from northern Canada occur in calcareous shales and muddy limestones. Crurithyris in the Hughes Creek Shale appears to prefer exactly the same type of sedimentary environment. The lower and upper part of the upper limestone contain accumulations of packed, partly broken pedicle valves of Crurithyris and extensive burrows and other bioturbation features. Slow sedimentation or no sedimentation favored shell accumulation. Organisms either became attached to the shells of dead members of their own species or they could have used organisms which, although not preserved as fossils, were fashioned in such a way as to offer sufficient anchorage for their pedicle valves. Nearly 20 percent of all fossils, predominantly Crurithyris shells are broken contradicting a low energy environment. However, shells may be broken by predator organisms which crush them in obtaining access to soft parts (Folk, 1974, p. 173). West (1970, p. 127) suggested predation by asteroids on Crurithyris.

Top Limestone.--A fourth limestone bed occurs at the top of the interval investigated at localities DC and P. A fossil assemblage in the top limestone (DC-T-2) shows a high degree of similarity (0.86) with one in the middle limestone (DC-M-1) at locality DC. At locality P assemblages in the top limestone (P-T-1 and T-2) are similar at the 0.75 level to assemblages in the lower limestone (P-L-5, L-6).

In conformity with Yarrow's (1974, p. 49) results obtained from the mudstones, lithologic units correlate with each other (limestones with limestones and mudstones with mudstones). However, no sharp contacts between the mudstones and limestones exist, indicating gradational changes in the depositional environments and fossil assemblages (percent $CaCO_3$, Appendix VI).

Lateral Integration

If the Nemaha Anticline was a topographic, "submarine" high during Hughes Creek deposition, then it is reasonable to assume that differences in fossil assemblages might occur between localities in a pattern relating to their proximity to the anticline. To test the influence of the Nemaha Anticline on these assemblages, a Q-mode cluster analysis applying the Dice correlation coefficient was used to compare bedding surface L-4 at all localities (fig. 24) and in a second run, all bedding surfaces at all localities (fig. 25).

Bedding surface L-4 in the lower limestone was selected, because environmental conditions were believed to be more stable in the middle part of the unit compared to conditions near the upper and lower contacts. Closest correlation

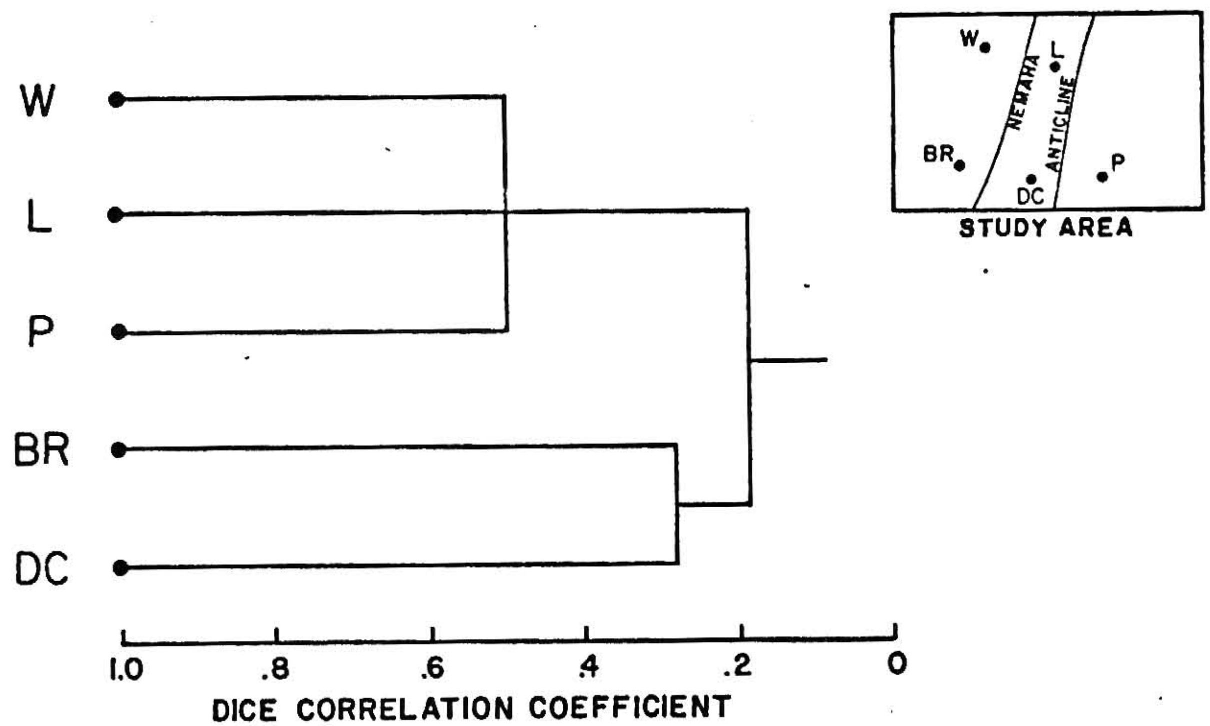


Fig. 24. Dendogram Indicating Similarity between One Bedding Surface at All Localities in Part of the Hughes Creek Shale

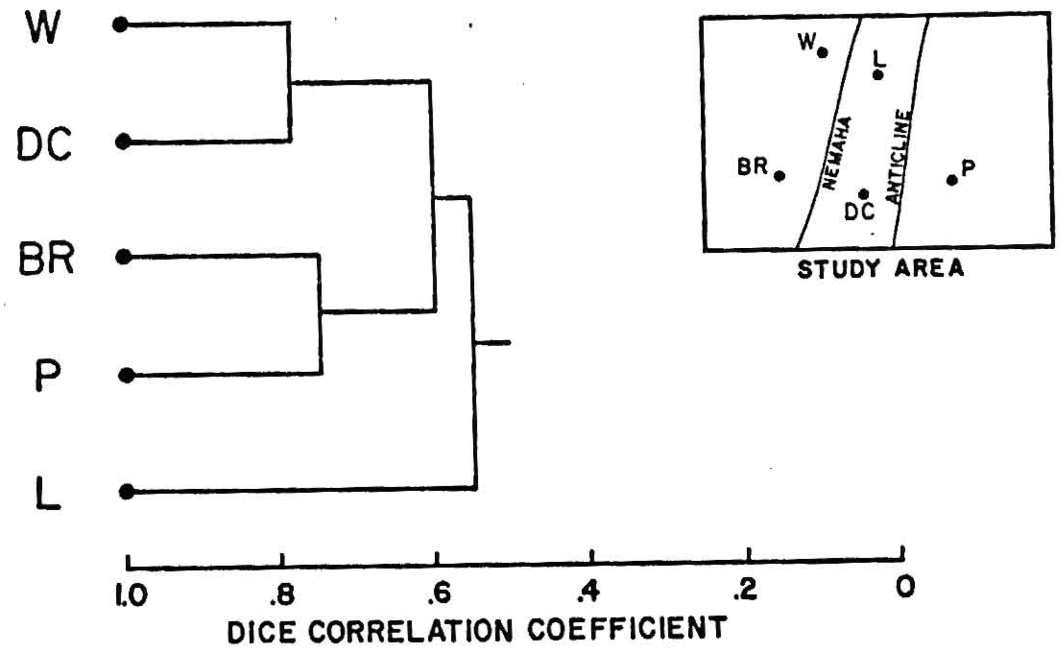


Fig. 25. Dendogram Indicating Similarity between All Bedding Surfaces at All Localities in Part of the Hughes Creek Shale

of fossil assemblages (0.5) is illustrated between localities W, L, and P, indicating that localities on either side and on top of the presumed structure show the same correlation values (fig. 24). However, at the 0.28 level (fig. 24), the locality on the west flank (BR) of the Nemaha has a closer relationship with localities on top of the structure DC and L than with the one on the Nemaha's eastern flank (P). Closest similarities were between localities L, W, and P and their relationship to the presumed structure is sketched in figure 26.

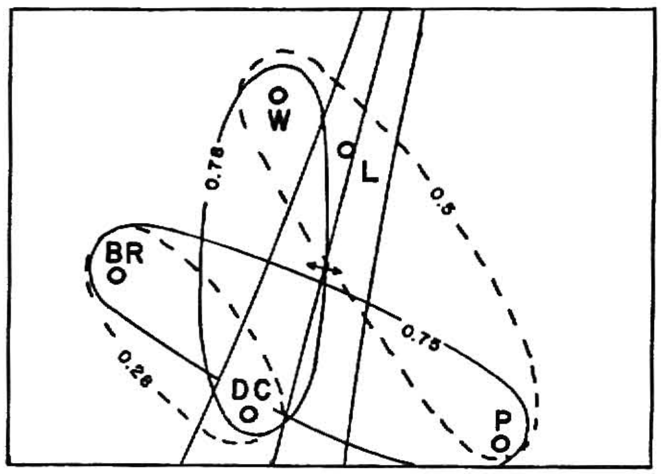


Fig. 26. Degree of Similarity Between Five Hughes Creek Shale Localities with Respect to the Proposed Structural Setting.

- - - similarity between one bedding surface at all localities

____ similarity between all bedding surfaces at all localities

Good correlation of fossil assemblages between localities on the west flank (W), east flank (P) and locality L on top of the presumed structure allow the following conclusions: 1) the depositional environment is uniform throughout the study area during deposition of the middle part of the lower limestone, 2) fossil assemblages are not affected by the Nemaha Anticline within this interval of carbonate deposition, and 3) localities P, L, and W probably belonged to the same cyclic phase at this interval of limestone deposition.

Comparing all bedding surfaces at all localities shows a different picture (fig. 25). The BR and P sections correlate with a value of 0.75 (fig. 26) similar to Yarrow's (1974, p. 61, fig. 19) results. Yarrow reported a correlation coefficient of 0.8 for the same sites located on opposite sides of the Nemaha Anticline. Fossil assemblages showed slight differences possible resulting from a structural high on the ancient sea floor.

Yet, locations W and DC on the west flank and on top of the structure respectively show an even better correlation with a value of 0.78 (fig. 25 and 26) indicating little effect of structure on fossil assemblages.

A reasonable explanation may be that highs and "saddles" along the ridge occurred in locally restricted areas, thus creating a specific relationship between these features and the fossil assemblages. For example the Zeandale Dome which represents a slight east-west broadening of the Nemaha may have served as a "cross road" for settling larvae from the west (BR) to the east (P) of the submarine structure (fig. 26).

Generally speaking, however, Hughes Creek fossil assemblages on both sides of the Nemaha Anticline do not bear the bathymetric significance of the Crouse Limestone assemblages in respect to submarine topography (West, et al., 1972). I can only assume that this discrepancy is the result of a slight uplift of the Nemaha Anticline in post Hughes Creek pre Crouse time.

SUMMARY

General vertical trends are: (1) fossil assemblages on successive bedding planes are not highly similar (approaching 1.0) with the exception of locality P; (2) fossil assemblages in parts of the lower and middle limestone beds are more alike (highest Dice correlation values) than those in the remaining limestone beds; (3) diversity generally increases to a peak in the upper half of the lower limestone, declines in the middle beds and increases upward in the upper and top limestone beds; (4) equitability stays fairly constant with fluctuations around a value of one; (5) insoluble residues, weight percent silt, and weight percent clay decline from a maximum in the lower limestone to a minimum in the upper and top beds; (6) organic carbon content slightly increases from the bottom to the top of the section, but the differences are not statistically significant; and (7) the palaeosalinity estimates are fairly constant with values around 33.5^{o}/oo for the limestone beds, but drop to low values for mudstones.

General lateral trends are: (1) the middle part of the lower limestone was deposited under the same environmental conditions at localities W, L, and P, (2) fossil assemblages of the middle part of the lower limestone are not affected by the Nemaha Anticline, and (3) comparison of fossil assemblages from all bedding planes at all localities provide evidence to believe that the submarine topography of the Nemaha Anticline had no significant influence on the nature and structure of Hughes Creek fossil assemblages.

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REFERENCES

Ager, D. V., 1960, Brachiopod distributions in the European Mesozoic: Rept. XXIst Internat. Geol. Cong., Copenhagen, part 22, p. 20-25.

__________ 1963, Principles of paleoecology, New York, McGraw-Hill Book Company, 371 p.

__________ 1965, The adaption of Mesozoic brachiopods to different environments: Palaeogeog., Palaeoclim., Palaeoecol., v. 1, p. 143-172.

__________ 1967, Brachiopod paleoecology, Earth Science Review, v. 3, p. 157-179.

Bathurst, R. G. C., 1971, Carbonate sediments and their diagenesis: Amsterdam, Elsevier Publishing Company, 620 p.

Baysinger, B. L., 1963, A magnetic investigation of the Nemaha Anticline in Wabaunsee, Geary and Riley counties, Kansas: Kansas State Univ., M.S. Thesis, 47 p.

Biscaye, P. E., 1964, Distinction between kaolinite and chlorite in recent sediments by x-ray diffraction: Am. Mineralogist, v. 49, p. 1281-1289.

__________ 1965, Mineralogy and sedimentation of recent deep sea clay in the Atlantic Ocean and adjacent seas and oceans: Geol. Soc. America Bull., v. 76, p. 803-832.

Bretsky, P. W., 1968, Bryozoan ecology and sedimentary environment, central Appalachian upper Ordovician: Am. Assoc. Petroleum Geologists Bull., v. 52, p. 521.

__________ 1969, Central Appalachian - late Ordovician communities: Geol. Soc. America Bull. v. 80, p. 193-212.

Caldwell, W. G. E., 1967, Ambocoeliid brachiopods from the middle Devonian rocks of northern Canada: in Oswald, D. N. (editor), International symposium of the Devonian system, v. 2, p. 601-616.

Chang, S. C., and Jackson, M. L., 1956, Fractionation of soils phosphorous: Soil Science, v. 84, p. 133-143.

Chaudhuri, S., 1974, personal communication.

Chave, K. E., 1952, A solid solution between calcite and dolomite: Jour. Geol. v. 60, p. 190-192.

__________ 1964, Skeletal durability and preservation: in Imbrie, J., and N. D. Newell (editors), Approaches to paleoecology, New York, John Wiley and Sons, p. 377-387.

Chayes, F., 1949, A simple point counter for thin section analysis: Am. Mineralogist, v. 34, p. 1-11.

Christiansen, B. O., 1964, Spiculosiphon radiata, a new foraminifera from Northern Norway: Astarte, v. 25, p. 1-8.

Compton, R. R., 1962, Manual of field ecology: New York, John Wiley and Sons, 378p.

Condra, G. E., 1927, The Stratigraphy of the Pennsylvanian system in Nebraska: Nebraska Geol. Survey Bull. 1, 82p.

Connell, J. H., and Orias, E., 1964, The ecological regulation of species diversity: Am. Naturalist, v. 98, p. 399-414.

Cooper, G. A., 1952, Unusual specimens of the brachiopod family Isogrammidae; Jour. Paleontology, v. 26, p. 113-119.

__________ and Grant, R. E., 1974, Permian brachiopods of West Texas, II: Smithsonian Contributions to Paleobiology, No. 15, 793p.

Cox, L. R., 1960, General characteristics of gastropoda: in Moore, R. C., et al., (editor): Treatise on invertebrate paleontology, Part I, Mollusca 1, 351p., Geol. Soc. America and Univ. Kansas Press.

Davies, G. R., 1970, Algal-laminated sediments Gladstone embayment, Shark Bay, Western Australia: in Logan, B. W., et al., (editor) Carbonate sedimentation and environments, Shark Bay, Western Australia: Am. Assoc. Petroleum Geologists, Memoir 13, Tulsa, Oklahoma, 223p.

Dayton, P. K., and Hessler, R. R., 1972, Role of biological disturbance in maintaining diversity in the deep sea: Deep Sea Research, v. 19, p. 199-208.

Deevey, E. S., 1969, Specific diversity in fossil assemblages: Brookhaven Symposium in Biology, No. 22, Diversity and stability in ecological systems, p. 224-241.

Dennison, J. M., and Hay, H. W., 1967, Estimating the needed sampling area for sub-aquatic ecological studies: Jour. Paleontology, v. 41, p. 706-708.

Dice, L. R., 1945, Measures of the amount of ecologic association between species: Ecology, v. 26, p. 297-302.

Dunbar, M. J., 1960, The evolution of stability in marine environments, natural selection at the level of the ecosystem: Am. Naturalist v. 94, p. 129-136.

Elias, M. K., 1937, Depth of deposition of the big blue (Late Palaeozoic) sediments in Kansas: Geol. Soc. America Bull., v. 48, p. 403-432.

Fischer, A. G., 1960, Latitudinal variations in organic diversity: Evolution, v. 14, p. 64-81.

Fisher, W. L., 1971, Stratigraphic and geologic variation of population characteristics of fusulinids from the upper Hughes Creek Shale (Permian) of Wabaunsee County, Kansas: Kansas Univ., M. S. Thesis, p. 77.

Folk, R. L., 1959, Practical petrographic classification of limestones: Am. Assoc. Petroleum Geologists Bull., v. 43, p. 1-38.

____________ 1962, Spectral subdivision of limestone types: in Ham, W. E. (editor), Classification of carbonate rocks: Am. Assoc. Petroleum Geologists Memoir 1, Tulsa, Okla., p. 62-84.

____________ 1968, Petrology of sedimentary rocks: Austin, Texas, Hemphill's, 170p.

____________ 1974, Petrology of Sedimentary rocks: Austin, Texas, Hemphill Publishing Company, 182p.

Frey, R. W., 1970, The lebensspuren of some common marine invertebrates near Beaufort, N. C.: Jour. Paleontology, v. 44, p. 308-311.

____________ 1973, Concepts in the study of biogenic sedimentary structures: Jour. Sed. Petrology, v. 43, p. 6-19.

Garber, M. S., 1956, Stratigraphy of the Foraker Limestone in East-Central Kansas: Kansas Univ. M. S. Thesis, 86p.

Goddard, E. N. et al., 1963, Rock color chart: New York, Geol. Soc. America,

Goldsmith, J. R., Graf, D. L., and Joensuu, O. I., 1955, The occurrence of Magnesian calcites in nature: Geochim. et Cosmochim. Acta, v. 7, p. 212-230.

____________ and Graf, D. L., 1958, Relation between lattice constants and composition of the Ca-Mg carbonates: Am. Mineralogist, v. 43, p. 84-101.

Grant, R. E., 1963, Unusual attachment of a Permian linoproductid brachiopod: Jour. Paleontology, v. 37, p. 134-140.

Griffiths, J. C., 1967, Scientific method in analysis of sediments: New York, McGraw-Hill, 508p.

Grim, R. E., 1958, Concept of diagenesis in argillaceous sediments: Am. Assoc. Petroleum Geologists Bull., v. 42, p. 246-253.

____________ and Johns, W. D., 1954, Clay mineral investigations of sediments from the northern Gulf of Mexico: Nat. Acad. Science Pub. 327, p. 81-103.

Guber, A. L., 1969, Sedimentary phosphate method for estimation of paleosalinities: Science, v. 166, p. 744-746.

Harris, R. J., 1974, personal communication.

Henbest, L. G., 1963, Biology, mineralogy and diagenesis of some typical late Paleozoic sedentary foraminifera and algal-foraminiferal colonies: Cushman Foundation of Foraminiferal Research, Special Publication No. 6, 44p.

Hesse, P. R., 1971, A textbook of soil chemical analysis: New York Chemical Publication Company, Inc., 520p.

Hofker, J., 1931, De foraminiferen in den omstrek van Amsterdam. De Biologie van der Zuidersee tijdens harr droogelegging: Afl. 3, p. 61-66.

Hooper, F. F., 1973, Origin and fate of organic phosphorous compounds in aquatic systems: in Griffith, E. J., et al. (editor) Environmental phosphorous handbook, New York, John Wiley and Sons, 718p.

Howard, J. D., 1968, X-ray radiography for examination of burrowing in sediments by marine invertebrate organisms: Sedimentology, v. 11, p. 249-258.

Jackson, M. L., 1956, Soil chemical analysis: A Manual of Methods, Univ. Wisconsin, 991p.

__________ 1965, Soil chemical analysis: Englewood Cliffs, N. Y., Prentice-Hall, 498p.

Jeppesen, J. A., 1972, Petrology of part of the Wewoka Formation (Pennsylvanian) in Hughes County, Oklahoma: Kansas State Univ. M. S. Thesis, 88p.

Jewett, J. M., 1941, The geology of Riley and Geary Counties, Kansas: Kansas Geol. Survey Bull. 39, 164p.

Johns, W. D., Grim, R. E., and Bradley, W. F., 1954, Quantitative estimations of clay minerals by diffraction methods: Jour. Sed. Petrology, v. 24, p. 242-251.

Johnson, R. G., 1960, Variations in diversity within benthic marine communities: Am. Naturalist v. 104, p. 285-300.

__________ 1964, The community approach to palecology: New York, John Wiley and Sons, p. 107-134.

Kahler, F., and Kahler, G., 1942, Lebensraum und Lebensweise der Fusuliniden: Palaeontographica, Bd. 94, Pt. A, p. 1-29.

Klopfer, P. H., 1959, Environmental determinants of faunal diversity: Am. Naturalist, v. 93, p. 337-342.

Koenig, M., 1971, A magnetic profile across the Nemaha Anticline in Pottawatomie and western Jackson Counties, Kansas: Kansas State Univ. M. S. Thesis, 86p.

Koons, D. L., 1955, Faulting as a possible origin for the formation of the Nemaha Anticline: Kansas State Univ. M. S. Thesis, 37p.

Lamont, A., 1934, Lower Palaeozoic brachiopods of the Girvan district: Suggestions on morphology in relation to environment: Annals Mag. Nat. Hist., Ser. 10, v. 14, p. 161-184.

Land, L. S., 1967, Diagenesis of skeletal carbonates: Jour. Sed. Petrology, v. 37, p. 914-930.

Lawrence, D. R., 1971, The nature and structure of paleoecology: Jour. Palaeontology, v. 45, p. 593-607.

Lee, M., 1972, Clay mineralogy of the Havensville Shale: Kansas State Univ. M. S. Thesis, 109p.

Little, J. M., 1962, Conodont faunas in the Hughes Creek Shale and Bennett Shale of Riley and Wabaunsee Counties, Kansas: Kansas State Univ. M. S. Thesis, 79p.

Lloyd, M. and Ghelardi, R. J., 1964, a table for calculating the equitability component of species diversity: Jour. Animal Ecology, v. 33, p. 217-225.

Longbottom, M. R., 1968, Nutritional factors affecting the distribution of Arenicola marina L.: Univ. of London, Doctoral Dissertation.

MacArthur, R. and MacArthur, J., 1961, On bird species diversity: Ecology, v. 42, p. 594-598.

Margalef, R., 1957, La theoria de la informacion en ecologia: Memorias de la Real Academia de Ciencias y Artes, Barcelona, v. 33, p. 373-449.

__________ 1968, Perspectives in ecological theory: Chicago, Univ. Chicago Press, 112p.

Marschner, H., 1968, Relationship between carbonate grain size and non-carbonate content in carbonate sedimentary rocks: in Müller, G., and G. H. Friedman (editors), Recent developments in carbonate sedimentology in central Europe, New York, Springer Verlag, 255p.

Matthews, R. K., 1966, Genesis of recent lime mud in southern British Honduras: Jour. Sed. Petrology, v. 36, p. 428-454.

McCammon, H. M., 1969, The food of articulate brachiopods: Jour. Paleontology, v. 43, p. 976-985.

Meek, F. B. and Worthen, A. H., 1870, Description of new species and genera of fossils from the Paleozoic Rocks of the Western States: Proc. Philadelphia Acad. Sci., v. 22, 36p.

Mello, J. F., and Buzas, M. A., 1968, An application of cluster analysis as a method of determining biofacies: Jour. Paleontology, v. 42, p. 747-758.

Moore, R. C. Lalicker, C. G., and Fischer, A. G., 1952, Invertebrate fossils: McGraw-Hill, New York, 766p.

Mudge, M. R. and Burton, R. H., 1959, Geology of Wabaunsee County, Kansas: U. S. Geol. Survey Bull. 1068, 210p.

__________ and Yochelson, E. L., 1962, Stratigraphy and palaeontology of the uppermost Pennsylvanian and lowermost Permian rocks in Kansas: U. S. Geol. Survey Prof. Paper 323, 213p.

Müller, G., 1967, Methods of sedimentary petrology, Part I, 283p.

__________ 1969, Sedimentary phosphate method for estimating paleosalinities: limited applicability: Science, v. 163, p. 812-813.

Murray, J. W., 1973, Distribution and ecology of living benthic foraminiferids: New York, Crane, Russa and Company Inc., 274p.

Musseter, W., 1966, Tacheometric surveying: Surveying and Mapping v. 16, p. 137-156.

Nairn, A. E. M., 1965, Uniformitarianism and environment: Palaeogeog., Palaeoclim., Palaeoecol., v. 1, p. 5-11.

Nelson, B. W., 1967, Sedimentary phosphate method for estimating paleosalinities: Science, v. 158, p. 917-919.

Odum, E. P., 1971, Fundamentals of ecology, Philadelphia, W. B. Saunders Company, 574p.

Ostrom, M. E., 1961, Separation of clay minerals from carbonate rocks by using acid: Jour. Sed. Petrology, v. 31, p. 123-129.

Paine, R. T., 1966, Food web complexity and species diversity: Am. Naturalist, v. 100, p. 65-75.

Pearce, R. W., 1973, Paleoecology of some upper Pennsylvanian benthic invertebrates: Kansas State Univ. M. S. Thesis, 90p.

Ratcliff, G. A., 1957, Surface structure on the east flank of the Nemaha Anticline in northeast Pottawatomie County: Kansas State Univ. M. S. Thesis, 32p.

Rieb, S. L., 1954, Structural geology of the Nemaha ridge in Kansas: Kansas State Univ. M. S. Thesis, 36p.

Reineck, H. E., 1958, Wühlbau Gefüge in Abhängigkeit von Sediment Umlagerungen: Senckenbergiana Lethaea, v. 39, p. 1-24.

__________ 1963, Sedimentgefüge im Bereich der Südlichen Nordsee: Abh. Senckenbergische Nat. Ges., v. 505, 138p.

__________ and Singh, I. B., 1973, Depositional sedimentary environments, New York, Springer Verlag, New York, 439p.

Reyment, R. A., 1971, Introduction to quantitative paleoecology, Amsterdam, Elsevier Pub. Company, 226p.

Richter, R., 1920, Vom Bau und Leben der Trilobiten II, Der Aufenthalt am Boden., Der Schutz. Die Ernährung: Senckenbergiana, v. 2, p. 23-43.

___________ 1926, Flachseebeobachtungen zur Paläeontologie und Geologie XII-XIV, Abdrücke lebendiger Tiere (Fische und Würmer): Senckenbergiana, v. 8, p. 221-224.

___________ 1927, Die fossilen Fährten und Bauten der Würmer, ein Überblick über ihre biologischen Grundformen und deren geologische Bedeutung: Palaeont. Zeit., v. 9, p. 193-240.

___________ 1937, Marken und Spuren aus allen Zeiten: Senckenbergiana, v. 19, p. 150-169.

Richter, G., 1964a, Zur Ökologie der Foraminiferen II. Lebensraum und Lebensweise von Nonion depressulum, Elphidium selsyense: Natur Mus., Frankfurt, v. 95, p. 421-430.

___________ 1964b, Zur Ökologie der Foraminiferen I. Die Foraminiferengesellschaften des Jadegebietes: Natur. Mus., Frankfurt, v. 94, p. 343-353.

Rhoads, D. C., 1967, Biogenic reworking of intertidal and subtidal sediments in Barnstable harbor and Buzzards Bay, Massachusetts: Jour. Geology, v. 75, p. 461-476.

___________ and Young, D. K., 1970, The influence of deposit feeding organisms on sediment stability and community trophic structure: J. Mar. Research, v. 28, p. 150-178.

Rothwell, W. T., 1966, Stratigraphic facies prediction and recognition in young offshore basins from studies of fossil environments: Am. Assoc. Petroleum Geologists, v. 1, no. 3, pt. 1, 650p.

Royse, Jr., C. F., 1970, An introduction to sediment analysis: Arizona State Univ., Tempe, Arizona, 177p.

Rudwick, J. M. S., 1965, Brachiopod ecology and paleoecology: in Moore, R. C., et al., (editor): Treatise of invertebrate paleontology, Part H. Brachiopoda, 521p., Geol. Soc. America and Univ. Kansas Press.

___________ 1970, Living and fossil brachiopods. London, Hutchinson Univ. Lib., 199p.

Sanders, H. L., 1968, Marine benthic diversity: a comparative study: Am. Naturalist, v. 102, p. 243-282.

Schäfer, W., 1952, Biogene Sedimentation im Gefolge von Bioturbation: Senckenbergiana, v. 33, p. 1-12.

___________ 1956, Wirkungen der Benthos Organismen auf den Jungen Schichtverband: Senckenbergiana Lethaea, v. 37, p. 183-263.

___________ 1972, Ecology and paleoecology of marine environments, Chicago, Univ. of Chicago Press, 538p.

Scott, D. R., 1963, Marine benthic communities of the Reading Limestone (Upper Pennsylvanian), Atchinson County, Kansas: Kansas State Univ. M. S. Thesis, 135p.

__________ Forster, F. W., and Crumpton, C. F., 1959, Geology and construction material resources of Pottawatomie County, Kansas: U. S. Geol. Survey Bull. 1060-C, 183p.

Seilacher, A., 1954, Die Geologische Bedeutung Fossiler Lebensspuren: Z. Deut. Geol. Ges., v. 105, p. 214-227.

__________ 1964, Biogenic sedimentary structures: in Imbrie, J., and N. D. Newell (editors), Approaches to paleoecology, New York, John Wiley and Sons, p. 296-316.

__________ 1967, Bathymetry of trace fossils: Marine Geology, v. 5, p. 413-428.

Stebbing, A. R. D., 1972, Observations on colony overgrowths and spatial competition: in Larwood, G. (editor), Living and fossil bryozoa, London, Academic Press, p. 173-183.

Suchanek, T. H., and Levinton, J., 1974, Articulate brachiopod food: Jour. Paleontology, v. 48, p. 1-5.

Sverdrup, H. U., Johnson, M. W., and Fleming, R. H., 1942, The oceans, their physics, chemistry, and general biology: New York, Prentice Hall Inc., 1087p.

Thayer, C. W., and Steele-Petrovic, H. M., The burrow mechanism of the lingulid brachiopod Glottidia pyramidata: in press.

Thompson, M. L., 1964, Fusulinacea: in Moore, R. C., (editor) Treatise on invertebrate paleontology: Part C, Protista 2, p.C358-C436, Geol. Soc. America and Univ. of Kansas Press.

Terry, R. D., and Chilingar, G. V., 1955, Charts for estimating percentage composition of rocks and sediments: Jour. Sed. Petrology, v. 25, p. 229-234.

Turpaeva, E. P., 1957, Food interrelationships of dominant species in marine benthic biocoenoses: in Nikitin, B. M. (editor), Transactions of the Institute of Oceanology, Vol. XX, Marine Biology, U.S.S.R. Acad. Science Press, p. 137-148 (published in U.S.A. by Am. Inst. Biological Science, Washington, D. C.).

Twiss, P. C., 1974, personal communication.

Wadell, H., 1936, Some practical sedimentation formulas: Geol. Foren Forhandl, v. 58, p. 397-407.

Wallace, P., and Ager, D. V., 1966, Flume experiments to test the hydrodynamic properties of certain spiriferid brachiopods with reference to their supposed life orientation and mode of feeding: Geol. Soc. London, Proc., v. 1635, p. 160-162.

Walker, K. R., 1972, Trophic Analysis: A method for studying the function of ancient communities: Jour. Paleontology, v. 46, p. 87-93.

__________ and Bambach, R. K., 1974, Feeding by benthic invertebrates: Classification and terminology for paleoecologic analysis: Lethaia, v. 7, p. 67-79.

__________ and Laporte, L. F., 1970, Congruent fossil communities from Ordovician and Devonian carbonates of New York: Jour. Paleontology, v. 44, p. 928-944.

West, R. R., 1970, Marine communities of a portion of the Wewoka Formation (Pennsylvanian) in Hughes County, Oklahoma: Oklahoma Univ. Ph.D. Dissert., Univ. Microfilm, Ann Arbor, Michigan, 310p.

__________ and McMahon, E. C., 1972, Significance of lower Crouse fossil assemblages: in West, R. R. (editor), Stratigraphy and depositional environments of the Crouse Limestone (permian) in north-central Kansas: South-Central Section Geol. Soc. America, Manhattan, Kansas, 109p.

Whittaker, R. H., 1970, Communities and ecosystems: London, The Macmillan Company, 158p.

Yarrow, G. R., 1974, Paleoecologic study of part of the Hughes Creek Shale (Lower Permian) in north-central Kansas: Kansas State Univ. M. S. Thesis, 247p.

Zeller, D. E., 1968, The stratigraphic succession in Kansas: Kansas Geol. Survey Bull., 189, 81p.

APPENDIX I

This appendix contains field descriptions made by Yarrow (1974) of the interval studied. The limestone units are numbered according to the system used in the present study, all other units and those in parenthesis are Yarrow's designations. The numbering system used proceeds from the lower limestone to the top limestone bed, the lower part of each unit always designated with the highest number. For example the lower part of the lower limestone unit at the Westmorland locality is referred to as W-L-3. With these exceptions the remainder of this appendix is taken directly from Yarrow, 1974, p. 69-92.

> Color designations are those of Goddard, et al., 1963. Recorded hardness is a relative value using the following scale: the upper bed of the Americus Limestone was defined as very hard and the softest mudstone encountered was defined as soft. Mud percentages were estimated in the field using a 10 X hand lens and the visual percentage charts of Terry and Chilingar (1955). Fossils are listed in order of abundance based on field observations. Strike and dip of joints are recorded to the nearest degree and when more than one attitude was observed the values are separated by a semicolon (strike and dip are separated by a comma).

BLUE RIVER (BR) SECTION

Date measured: 22 Jan., 1972

Measured by: G. R. Yarrow
J. V. Miesse
K. A. Shewell
D. L. Pearson

Locality: NE¼, SW¼, SE¼, NE¼, Sec. 30, T9S, R8E, Pottawatomie County, Kansas road cut on north side of road. The lower part of this unit appears to be weathered at the outcrop. Total thickness of Hughes Creek Shale was obtained by measuring the lower part at a nearby locality and is 7.25+ meters.

Bed No.	Description	Thickness
BR-L (BR-B2a)	Argillaceous micritic limestone, gradational contact below and above.	20 cm.
	Color: Unweathered, light gray (N7) to light olive gray (5YR5/6) stained grayish orange (10YR7/4) to light brown (5YR5/6).	
	Bedding: One bed. Distinguished from beds above and below by being more resistant to weathering.	
	Composition: Micritic calcite cement, argillaceous.	
	Fossils: Small fossil fragments with some algal coated grains.	
	Joints: No information taken.	
(BR-B2b)	Argillaceous micritic limestone, gradational contact above and below.	6 cm.
	Color: Unweathered, light gray (N7) mottled grayish orange (10YR7/4).	
	Bedding: Distinguished from beds above and below by being slightly less resistant to weathering.	

Composition: Micritic calcite cement, more argillaceous than beds above and below. Iron oxide staining.

Fossils: Composita, Hustedia, Derbyia (fragments), productids (non-life position i.e. pedical valve up), fossils more broken than in unit above.

(BR-B2c) Micritic limestone, gradational contact above and below. 5 cm.

Color: Unweathered, medium dark gray (N4) to light olive gray (5YR6/1) mottled areas grayish orange (10YR7/4) to dark yellowish orange (10YR6/6).

Bedding: Distinguished from beds below and above by being more resistant to weathering.

Composition: Micritic calcite cement.

Fossils: More than units below and above, most are complete specimens, Derbyia, Neochonetes, few Crurithyris, chitinophosphatic fragments, and echinoid spines.

Joints: No information taken.

(BR-B3) Calcareous mudstone, gradational contact above and below. 15 cm.

Color: Unweathered olive gray (5Y4/1) to dark greenish gray (5GY4/1) mottled gray orange (10YR7/4) to light brown (5YR5/6).

Bedding: Distinguished from beds below and above by being less resistant to weathering, blocky.

Composition: Silt and clay grains, calcareous, iron stained zone in middle.

Fossils: 4 cm. from top is a zone of Neochonetes 2 to 3 valves thick, 9 cm. from top is a zone of productids, Reticulatia, Myalinid clams, Neospirifer, unbroken fenestrate Ectoprocts, Crurithyris, Linoproductus, and Derbyia, thin zone is iron stained; other fossils in the unit are Hustedia, Hystriculina, Rhipidomella, crinoid debris, echinoid spines, and ramose Ectoprocts.

Joints: No information taken.

BR-M (BR-B4a) Micritic limestone, gradational contacts below and above. 20 cm.

Color: Unweathered, medium gray (N5) to light olive gray (5Y6/1) stained dark yellow orange (10YR6/6).

Bedding: Distinguished from bed above and below by being more resistant to weathering.

Composition: Micritic calcite cement.

Fossils: Fusulinids abundant in lower 6 cm., other fossils observed are: Hustedia, Composita, Neospirifer, Hystriculina, Reticulia (inferred life position i.e. pedicle valve down), Rhipidomella, Derbyia, and Orbiculoidea fragments.

(BR-B4b) Calcareous carbonaceous shale, gradational contact below and above. 3 cm.

Color: Unweathered medium gray (N5) to dark gray (N3) mottled light olive gray (5Y6/1), some iron stains dark yellow orange (10YR6/6).

Bedding: Distinguished from unit above and below by being less resistant to weathering, fissle.

Composition: Carbonaceous, calcareous, with some iron stains.

Fossils: *Crurithyris* (pedicle valve down and/or up), *Hystriculina*, and *Rhipidomella*.

BR-U
(BR-B4c) Micritic limestone, gradational contact below and above. 6 cm.

Color: Weathered, grayish orange (10YR5/4) to moderate yellowish brown (10YR5/4), unweathered, mottled pale yellow brown (10YR6/2) to medium gray (N5) to grayish black (N2).

Bedding: Distinguished from unit above and below by being more resistant to weathering.

Composition: Micritic calcite cement.

Fossils: Fish bone fragment, *Lingula*, Myalinid clams, *Hustedia*, and evidence of burrowing and reworking.

DEEP CREEK (DC) SECTION

Date measured: 28-30 July, 1974 Measured by: G. R. Yarrow

Locality: NE¼, SE¼, NW¼, Sec, 14, R8E, T11S, Riley County, Kansas; stream cut where Deep Creek changes direction from east to north eroding the bank into the lowermost mudstone of the Hughes Creek Shale. This outcrop shows slight weathering characteristics (i.e. some roots in the mudstone) but contains no vegetation cover. Total Hughes Creek Shale thickness was obtained by measuring the non-exposed interval down stream (about 150 M.) where Deep Creek cuts through the Americus Limestone. Total thickness of the Hughes Creek Shale is 9.87+ meters.

Bed No.	Description	Thickness
DC-L (DC-B5)	Medium hard micritic limestone, sharp contact below, gradational above, persistant throughout outcrop.	29 cm.
	Color: Weathers grayish orange (5YR7/12), stained dark yellowish orange (10YR6/6), unweathered medium dark gray (N4).	
	Bedding: Massive, uneven fracture, distinguished from units above and below by being more resistant to weathering.	
	Composition: Micritic calcite cement with 10-20% mud, iron oxide filled vugs and cracks, and sparry calcite filled fossils.	
	Fossils: Crinoid debris, bivalve fragments, <u>Meekella</u> (non-life position i.e. pedicle valve	

up, disarticulated), Pteronities (25 cm. long parallel to bedding, algae?.

Joints: N 46°E, 81°W; S 41°E, 80°W.

(DC-B6) Soft calcareous mudstone, gradational contacts below and above, persistent throughout outcrop. 19 cm.

Color: Weathers pale brown (5YR5/2), unweathered dark gray (N3).

Bedding: Crumbly to blocky with numerous fossils weathered in relief, upper part more yellowish than lower part, distinguished from beds above and below by being less resistant to weathering.

Composition: Silt and clay grains, silt dominant, calcareous, some iron oxide staining on bedding surfaces.

Fossils: Reticulatia (brachial valve in hydrodynamically stable position, 5 cm. across), Neochonetes (disarticulated and articulated), Derbyia (disarticulated in hydrodynamically stable position), Hustedia (life position i.e. pedicle valve up), Crurithyris (pedicle valve up and/or down, articulated and disarticulated), Linoproductus (hydrodynamically stable position), ramose Ectoprocts, crinoid debris, and fusulinids.

Joints: None observed.

DC-M (DC-B7a) Medium hard micritic argillaceous limestone, gradational contact above and below, persistent throughout outcrop. 14 cm.

Color: Weathers light brown (5YR6/6), unweathered medium dark gray (N4).

Bedding: One bed, distinguished from units above and below by change in color and resistance to weathering, uneven fracture, fossil fragments weather in slight relief on vertical face.

Composition: Micritic calcite cement, estimate 30-40% mud, iron oxide stained vugs.

Fossils: Orbiculoidea fragments (most abundant fossil in lower part), Compositia (3 cm. in width), Hystriculina, crinoid debris, fusulinids, Derbyia (disarticulated), and indications of burrowing (mottled texture). Orbiculoidea fragments decrease upwards.

Joints: N 54°E, 82°N; S 24°E, 86°W

(DC-B7b) Medium soft argillaceous micritic limestone, gradational contacts above and below, persistent throughout outcrop. 7 cm.

Color: Weathers light gray (N7), unweathered grayish black (N2).

Bedding: Blocky, breaks into pieces 0.3-0.7 cm. thick and 8-14 cm. long, distinguished from beds above and below by being less resistant to weathering.

Composition: Silt and clay grains with an abundance of silt, micritic calcite cement, carbonaceous.

Fossils: 80-90% of fossils are Crurithyris (pedicle valve up and/or down, most articulated, 0.3-1.2 cm. in width), Lingula (maximum length 3.0 cm. oriented

parallel to bedding), Edmondia?, crinoid debris
and horizontal burrows.

Joints: As in bed DC-B7a.

DC-U (DC-B7c) Medium hard argillaceous micritic limestone, gradational contact above and below, persistent throughout outcrop. 6 cm.

Color: Weathers grayish orange pink (5YR7/2), unweathered dark gray (N3).

Bedding: One bed, uneven fracture, brachiopod valves observed on weathered surface, distinguished from beds above and below by being more resistant to weathering.

Composition: 30-40% mud, micritic calcite cement, carbonaceous.

Fossils: 95% of fossils are Crurithyris (pedicle valve down, decrease in abundance upward), horizontal and vertical burrows filled with "pellets", unidentifiable nuculid bivalves (some with splayed valves).

Joints: As in bed DC-B7a.

(DC-B7d) Soft argillaceous micritic limestone, gradational contact above and below, persistent throughout outcrop. 3 cm.

Color: Weathers pale yellowish brown (10YR6/2), unweathered medium dark gray (N4), mottled light brown (5YR6/4).

Bedding: Flaky partings 0.1-0.3 cm., distinguished from beds above and below by being less resistant to weathering, consists mostly of shells and fragments separated by thin mud layers 0.2-0.3 cm.

Composition: Silt and clay (mostly silt) with micritic calcite cement, some shell fragments iron oxide stained.

Fossils: Crurithyris (most with pedicle valve up), brachiopod fragments, algae?, and appears burrowed (mottled).

Jointing: As in bed DC-B7a.

DC-T (DC-B7e) Medium soft argillaceous micritic limestone, gradational contact above and below, persistent throughout outcrop. 7 cm.

Color: Weathers grayish orange pink (5YR7/2), unweathered pale brown (5YR4/2)

Bedding: Wavy, 1-2 cm. thick, distinguished from beds above and below by being slightly more resistant to weathering, uneven fracture and weathers crumbly.

Composition: 40-50% mud, micritic calcite cement, and some iron oxide staining.

Fossils: 60%+ algae coated grains, 10% fusulinids, crinoid debris, brachiopod fragments, Crurithyris (pedicle valve up), and Linoproductus (pedicle valve up).

Joints: As in bed DC-B7a.

PAXICO (P) SECTION

Date measured: 3 Aug., 1974 Measured by: G. R. Yarrow

Locality: SE¼, NE¼, SW¼, Sec. 27, R11E, T11S, Wabaunsee County, Kansas; road cut on northeast side of I-70 near the bridge over Mill Creek. The stratigraphic interval was measured on the road cut 10 meters southeast of the east guard rail end post. Although this outcrop has been exposed several years, little weathering is apparent. Total thickness of the Hughes Creek Shale is 11.37 meters.

Bed No.	Description	Thickness
P-L (P-B5a)	Hard micritic limestone, sharp contact below, gradational above, persistent throughout outcrop.	22 cm.
	Color: Weathers light gray (N5), unweathered medium gray (N5).	
	Bedding: Massive, weathers nearly smooth, uneven fracture, distinguished from unit above and below by being more resistant to weathering (ledge former), some fossils weather in relief, upper surface slightly undulating, fracture in upper part wavy.	
	Composition: Micritic calcite cement, estimate mud fraction less than 10%, pyrite burrow fillings.	
	Fossils: Bivalve fragments parallel, inclined, and perpendicular to bedding, Neospirifer (disarticulated, concave up), Hystriculina (near top of bed in inferred life position i.e. pedicle valve down), crinoid debris and fusulinids occur throughout the unit with less than	

one specimen per square decimeter of vertical surface, bottom surface appears burrowed.

Joints: Well defined 5-20 cm. apart, N 72°E, 80°E; S 20°E, 88°S.

(P-B5b) Medium soft calcareous mudstone, variable thickness, gradational contact below and above, persistent throughout outcrop. 1-3 cm.

Color: Weathers medium gray (N5), unweathered medium dark gray (N4).

Bedding: Platy weathers flaky, distinguished from unit above and below by being less resistant to weathering, unweathered very hard to distinguish from units above and below.

Composition: Clay and silt grains with clay dominant, calcareous cement and carbonaceous.

Fossils: Burrows, brachiopod fragments, Crurithyris (patchy distribution), fossil assemblage similar to that of overlying bed (P-B5a).

Joints: Not observed in this unit.

P-M (P-B5c) Medium hard carbonaceous argillaceous micritic limestone, gradational contact below, sharp above, persistent throughout outcrop, variable in thickness. 3-6 cm.

Color: Weathers medium gray (N5), unweathered dark gray (N3).

Bedding: One bed splitting into two in places, bedding surfaces are grayish black (N2) mottled pale yellowish brown

(10YR6/2), distinguished from unit above and below by being less resistant to weathering, uneven fracture upper surface uneven, fossils weather in relief.

Composition: Micritic calcite cement, carbonaceous, 5-15% mud estimated, selenite crystals (less than 0.1 cm. long) on bedding surfaces, some pyritized fossils.

Fossils: 10-20% of weathered surface appears to be fossil fragments, on a broken surface less than 5% of area is fossils, Crurithyris (60-80%, generally with pedicle valve down), unidentifiable brachiopod fragments (second in abundance greater than 10% of fossils), Neochonetes, Hystriculina, Derbyia, ramose Ectoprocts and productid spines.

Joints: N 71°E, 75°N, S 17°E, 47°W.

(P-B6) Soft calcareous mudstone, sharp contact below and above, persistent throughout outcrop. 20 cm.

Color: Weathers medium light gray, unweathered dark gray (N3).

Bedding: Unweathered, blocky to flaky, weathers fissle to crumbly, distinguished from unit below and above by being less resistant to weathering (forms slope), lower 4 cm. more blocky with upper part more fissle.

Composition: Clay and silt grains with silt dominant, calcareous, selenite crystals between bedding planes and in fractures, iron oxide staining in possible burrow fillings.

Fossils: Fossils weather out easily, most are well preserved, upper part of bed appears as carbonate filled burrows, Crurithyris most abundant fossil concentrated in the lower 5 cm. decreasing upwards (pedicle valve up and/or down and most are articulated); Neochonetes most abundant fossil above lower 5 cm. (all observed were disarticulated oriented parallel to bedding and ranged in size from less than 1 cm. to 3 cm. in width); crinoid calyx plates, crinoid columnals, Reticulatia (non-life position i.e. pedicle valve up) and productid spines were also observed.

Joints: None observed.

P-U (P-B7a) Hard micritic limestone, sharp lower contact, gradational upper one, persistent throughout outcrop. 12 cm.

Color: Weathers pale grayish orange pink (5YR7/1), unweathered medium gray (N5).

Bedding: One massive bed, distinguished from unit above and below by being more resistant to weathering (ledge former), weathered surface is hummocky, fracture is uneven with sharp edges, fossils weather in slight relief, parting plane 3 cm. from top.

Composition: Micritic calcite cement with patches of sparry calcite, sparry calcite fillings of some fossils, selenite crystals on joint and parting surfaces giving them a glazed appearance.

Fossils: Less than 5% of surface is fossil debris, fish debris and fragments of Orbiculoidea in lower part, fish debris disappears upward and Orbiculoidea fragments decrease, Hystriculina, next in abundance, (most in a hydrodynamically stable position i.e. pedicle valve up) crinoid debris present throughout the unit with a few fusulinids, a trilobite pygidium (Ditomopyge?), a Rhipidomella and burrows up to 3-4 cm. in diameter in the lower part.

Joints: Well defined N 72°E, 90°; S 22°E, 88°W.

(P-B7b) Soft argillaceous micritic limestone, gradational contacts below and above, persistent throughout outcrop. 10 cm.

Color: Weather dark gray (N3), unweathered grayish black (N2).

Bedding: Flaky to fissle, weathers fissle, distinguished from unit below and above by being less resistant to weathering.

Composition: Silt and clay size grains with more clay, carbonaceous, selenite crystals on bedding surfaces, some fossils pyritized and filled with iron oxide.

Fossils: Crurithyris (pedicle valve up and/or down, mostly articulated 95% of all fossils, most abundant in middle of unit), Lingula (oriented parallel to bedding), Hystriculina (non-life position i.e. pedicle valve up), and Wellerella (disarticulated and in hydrodynamically stable position i.e. convex up)

Joints: None observed.

P-T (P-B7c) Medium soft argillaceous carbonaceous micritic limestone, contact gradational below and sharp above, persistent throughout outcrop. 5 cm.

Color: Weathers medium light gray (N6), unweathered dark gray (N3) mottled grayish orange pink (5YR7/2).

Bedding: One bed, blocky, uneven fracture, distinguished from unit above and below by being more resistant to weathering, more well cemented than underlying unit, weathers with uneven surface along joints, some upper bedding surfaces mottled suggesting burrowing, fossils weather in moderate relief.

Composition: Micritic calcite cement with 15+% clay and silt, carbonaceous, glaze of gypsum covering joint and bedding surfaces.

Fossils: 5% of rock, Crurithyris (pedicle valve up and/or down, most abundant fossil), Hystriculina (in lower part), Orbiculoidea, Wellerella (disarticulated), Derbyia (disarticulated), Reticulatia, Linoproductus (hydrodynamically stable position i.e. pedicle valve up), and algae coated grains (1-2 cm. across on the top surface).

Joints: 8-10 cm. apart, N 75°E, 86°W; S 40°E, 74°S.

LOUISVILLE (L) SECTION

Date Measured: 9 Aug., 1974 Measured by G. R. Yarrow

Locality: NW¼, NW¼, NW¼, Sec. 9, R10E, T8S, Pottawatomie County Kansas; Starts in a road ditch 40 meters east of intersection with a north-south county road and ends near the top of a hill east of intersection. This section appears more weathered than the other four sections. Total thickness of Hughes Creek Shale is 10.69 meters.

Bed No.	Description	Thickness
L-L (L-B7)	Medium hard micritic limestone, sharp contact above and below, persistent throughout outcrop.	27 cm.

Color: Weathers grayish orange (10YR7/4), unweathered medium gray (N5) mottled moderate yellow orange (10YR6/4).

Bedding: Wavy bedded, splits into beds 6-9 cm. thick, distinguished from units above and below by being more resistant to weathering (ledge former), bedding surfaces are uneven but rounded, upper 8-10 cm. is more argillaceous than lowerpart and weathers in less relief, fossils weather in slight relief, mottled and appears burrowed.

Composition: Micritic calcite cement, 10-20% mud with some iron oxide fracture filling, dendrites on bedding surfaces.

Fossils: Fragmented fossil debris (30-40% brachiopods) crinoid debris, _Pteronites_ (parallel to bedding), Neospirifer (hydrodynamically stable, both disarticulated and articulated), in upper 5 cm. Punctospirifer, branching vertical and/or horizontal burrows 0.2 - 0.3 cm. in diameter and in the upper part of the bed carbonized plant fragments.

Joints: S25°E, 88°W; N28°E, 75°N.

(L-B8) Soft calcareous mudstone, sharp contact below, gradational above, persistent throughout outcrop. 33 cm.

Color: Covered by slump, unweathered light brown (5YR5/4) mottled dark gray (N3).

Bedding: Blocky to flaky, weathers crumbly, distinguished from unit above by being less resistant to weathering. Lower and upper portion (5-10 cm). more calcareous than middle.

Composition: Silt and clay grains with silt being most abundant, calcareous, iron oxide stains between bedding surfaces and throughout lower 5 cm.

Fossils: Crurithyris (pedicle valve up and/or down) most abundant fossil in lower part decreasing upward, absent in middle and upper part, Hystriculina associated with Crurithyris in lower part, crinoid columnals are associated with Crurithyris and increase upwards, Neochonetes, Neospirifer (disarticulated and articulated), and Aviculopecten molds occur in the middle and upper part. Other fossils on the weathered outcrop are corals Reticulatia, Composita, and Hustedia.

Joints: None observed.

L-M (L-B9) Medium to medium hard argillaceous micritic limestone gradational contact below and above, persistent throughout outcrop but variable in thickness. 8-10 cm.

Color: Weathers moderate orange (5YR8/4), unweathered dark gray (N3) mottled grayish orange pink (5YR7/2).

Bedding: One bed, distinguished from units above and below by being more resistant to weathering, surface is uneven because of weathering along joints, uneven fracture, appears burrowed (mottled).

Composition: 30-40% mud, micritic calcite cement, iron oxide stains of burrow fillings.

Fossils: 10% of rock, Orbiculoidea fragments most abundant in lower half of bed, Hystriculina (non-life i.e. pedicle valve up), Rhipidomella (non-life i.e. pedicle valve down) and burrows.

Joints: 8-12 cm. apart, S 69°E, 77°E; N 56°E, 80°N.

(L-B10) Soft argillaceous micritic limestone, gradational contact below and above, persistent throughout outcrop. 10 cm.

Color: Covered by slump, unweathered moderate yellowish brown (10YR5/2).

Bedding: Blocky to flaky weathers crumbly, distinguished from unit above and below by being less resistant to weathering (slope former), upper and lower part more calcareous than middle.

Composition: Silt and clay with dominance of clay, micritic calcite cement, iron oxide staining between parting planes.

Fossils: Crurithyris (pedicle valve up and/or down) consisted of 80-90% of fossils, other fossils were Orbiculoidea, crinoid debris and unidentifiable fragments.

Joints: None observed.

L-U (L-B11) Medium hard argillaceous micritic limestone, gradational contacts below and above, persistent throughout outcrop. 6 cm.

Color: Covered by slump, unweathered grayish black (N2) mottled moderate brown (5YR4/4).

Bedding: One bed, distinguished from units below and above by being more resistant to weathering, parting planes 1-2 cm. apart, fractures around fossils parallel to bedding, uneven fracture across bedding, forms part of covered slope.

Composition: 30-40% mud, micritic calcite cement, iron oxide staining along joints; iron oxide staining of burrows.

Fossils: Crurithyris (pedicle valve up and/or down) 70-80% of fossils, other fossils are Orbiculoidea, Wellerella (disarticulated), Acanthopecten, and burrows.

Joints: S 29°E, 82°W; N 64°E, 74°N.

WESTMORELAND (W) SECTION

Date measured: 16 July, 1974 Measured by: G. R. Yarrow

Locality: NE¼, NE¼, SW¼, Sec. 3, R9E, T8S, Pottawatomie County, Kansas; a "fresh" stream bank cut (nearly vertical) with Rock Creek flowing on the upper bed of the Americus Limestone and the top of the bank is in the Eskridge Shale. Total thickness of the Hughes Creek Shale is 10.32 meters.

Bed No.	Description	Thickness
W-L (W-B7)	Micritic limestone, gradational contacts above and persistent throughout outcrop.	27 cm.
	Color: Weathers grayish orange pink (5YR7/2), unweathered grayish orange pink (5YR7/2).	
	Bedding: Distinguished from beds above and below by being more resistant to weathering, top 7 cm. separated from lower massive 20 cm. by a parting plane, bedding surfaces nearly flat.	
	Composition: Micritic calcite cement, less than 10% mud, smells of sulfur when struck with rock hammer (pyrite?).	
	Fossils: Crinoid debris, echinoid spines, unidentifiable brachiopods, Hustedia (non-life position i.e. pedicle valve down) and fish debris.	
	Joints: None observed.	
(W-B8)	Calcareous mudstone, gradational contact above and below, persistent throughout outcrop.	20 cm.

Color: Weathers medium light gray (N6), unweathered dark gray (N3).

Bedding: Distinguished from units above and below by being less resistant to weathering, blocky fracture, parting of mudstone at 0.5 cm. intervals.

Composition: Calcareous clay and silt size grains, pyrite infillings of burrows, lower 3-5 cm. iron oxide stained.

Fossils: Neochonetes (articulated, cast of fenestrate Ectroproct, Crurithyris, Neospirifer, Derbyia, Linoproductus (generally in hydrodynamically stable position), ramose ectoprocts, crinoid debris.

Joints: None observed.

W-M (W-B9a) Soft argillaceous micritic limestone, gradational contacts above and below, persistent throughout outcrop. 23 cm.

Color: Weathers pale yellowish brown (10YR6/2), unweathered medium gray (N5).

Bedding: One massive bed, distinguished from beds above and below by being more resistant to weather and color change, upper contact very gradational, surface rough with few fossils weathering in relief throughout the unit.

Composition: Micritic calcite cement, 20-30% mud.

Fossils: Criniod debris, fusulinids (randomly oriented), fish debris, fenestrate and ramose Ectoprocts, Wilkingia (life position i.e. inclined to bedding) 3.5 cm. long, fusulinids and crinoid debris in lower part, overlain by middle part containing fish debris and upper part containing few fossils.

Joints: N19°E, 89°E.

(W-B9b) Argillaceous micritic limestone, gradational contact above and below, appears thicker where more weathered. 3 cm.

Color: Weathers medium dark gray (N4), unweathered medium dark gray (N4).

Bedding: Distinguished from beds above and below by being less resistant to weathering, fissle.

Composition: Micritic calcite cement with nearly 50% mud.

Fossils: Large numbers of Crurithyris (Pedicle up and/or down, majority oriented with pedicle valve down).

Joints: Oriented as in bed W-B9a.

W-U (W-B9c) Argillaceous micritic limestone, gradational contact above and below, appears persistent throughout outcrop. 5 cm.

Color: Weathers medium dark gray (N4), unweathered grayish black (N2).

Bedding: Distinguished from units above and below by being more resistant to weathering.

Composition: Micritic calcite cement, estimate 10-20% mud, carbonaceous.

Fossils: Lower part dominated by *Crurithyris* (pedical valve down) and *Lingula* (parallel to bedding), upper part horizontally burrowed with star shaped burrows, a few crinoid columnals and *Hystriculina*.

Joints: Oriented as in bed W-9a.

APPENDIX II

Major genera of fossils were listed on the vertical mapped surfaces and relative abundances estimated with the following quantifications:

rare = less than 50 specimens of the same genus in a 225 cm^2 area

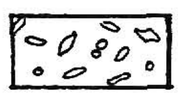
abundant = more than 50 fossils of the same genus in a 225 cm^2 area

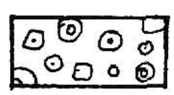
locally abundant = clustered occurrence of fossils of the same genus

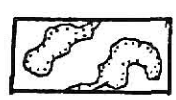
Ratios of broken to unbroken shells and articulation were recorded. Additionally biogenic sedimentary structures and gross carbonate lithological differences were noted.

Symbols used on mapped vertical surfaces
(bottom or left of page)


brachiopods and other shell debris


fusulinids


crinoids

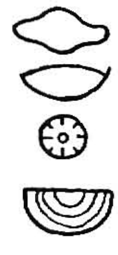

biogenically reworked area

Example for numbering system

DC-L (1) = lower limestone at the Deep Creek locality, the number in parenthesis (1) indicates the first (lower) part of the lower limestone, with the second part (2) following on the next page.

Symbols used in columns (top or right of page)

Fossils



fusulinids

brachiopods

crinoids

Isogramma sp.

Biogenic sedimentary structures

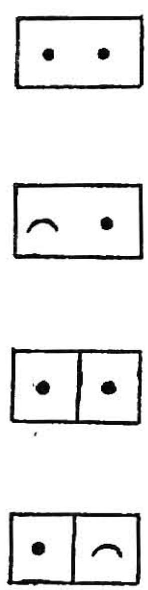
large burrow

small vertical burrow

small horizontal burrow

U-shape burrow

Lithology



micrite
(0 - 1% allochems)

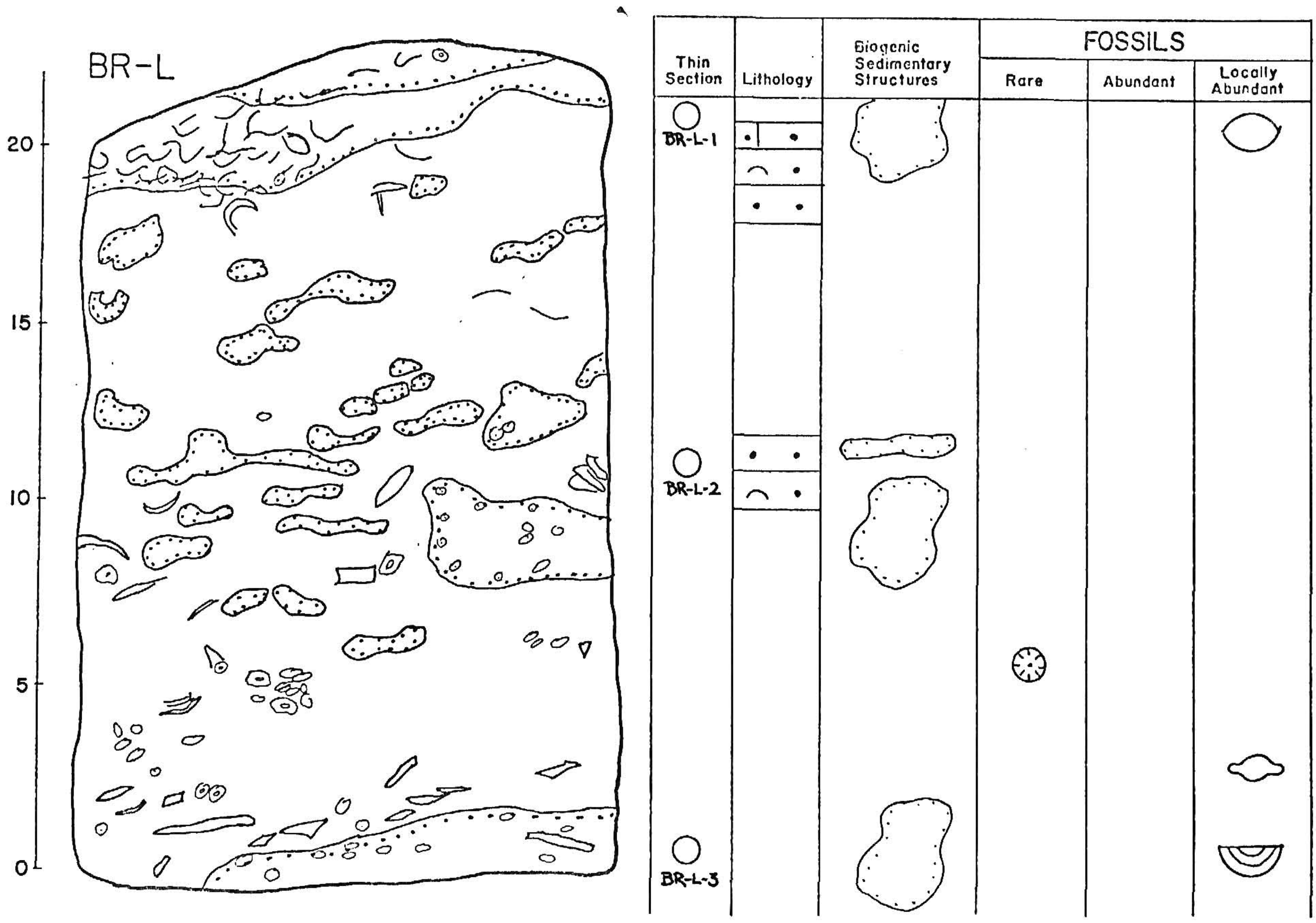
fossiliferous micrite
(1 - 10% allochems)

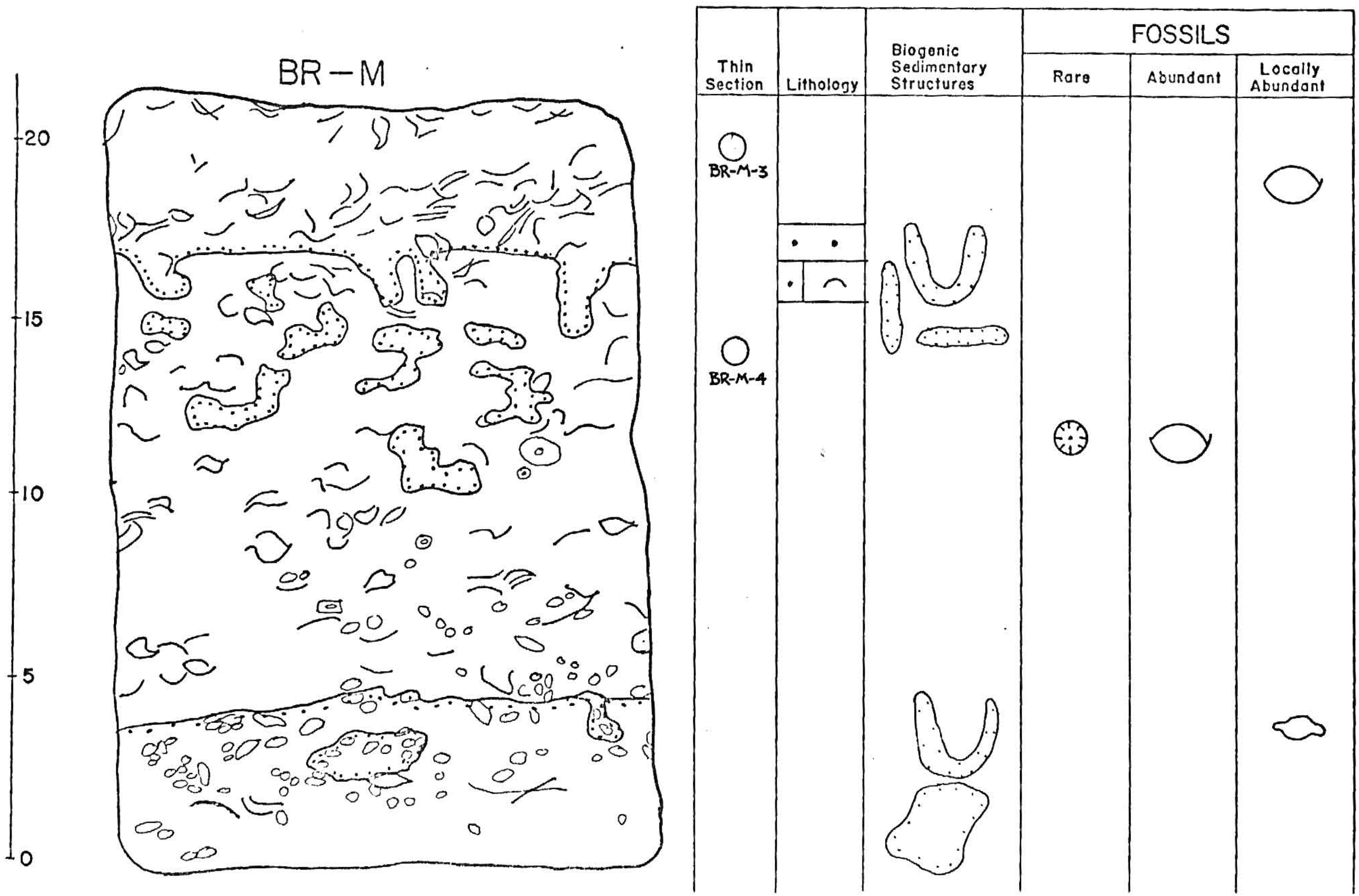
biomicrite
(10 - 50% allochems)

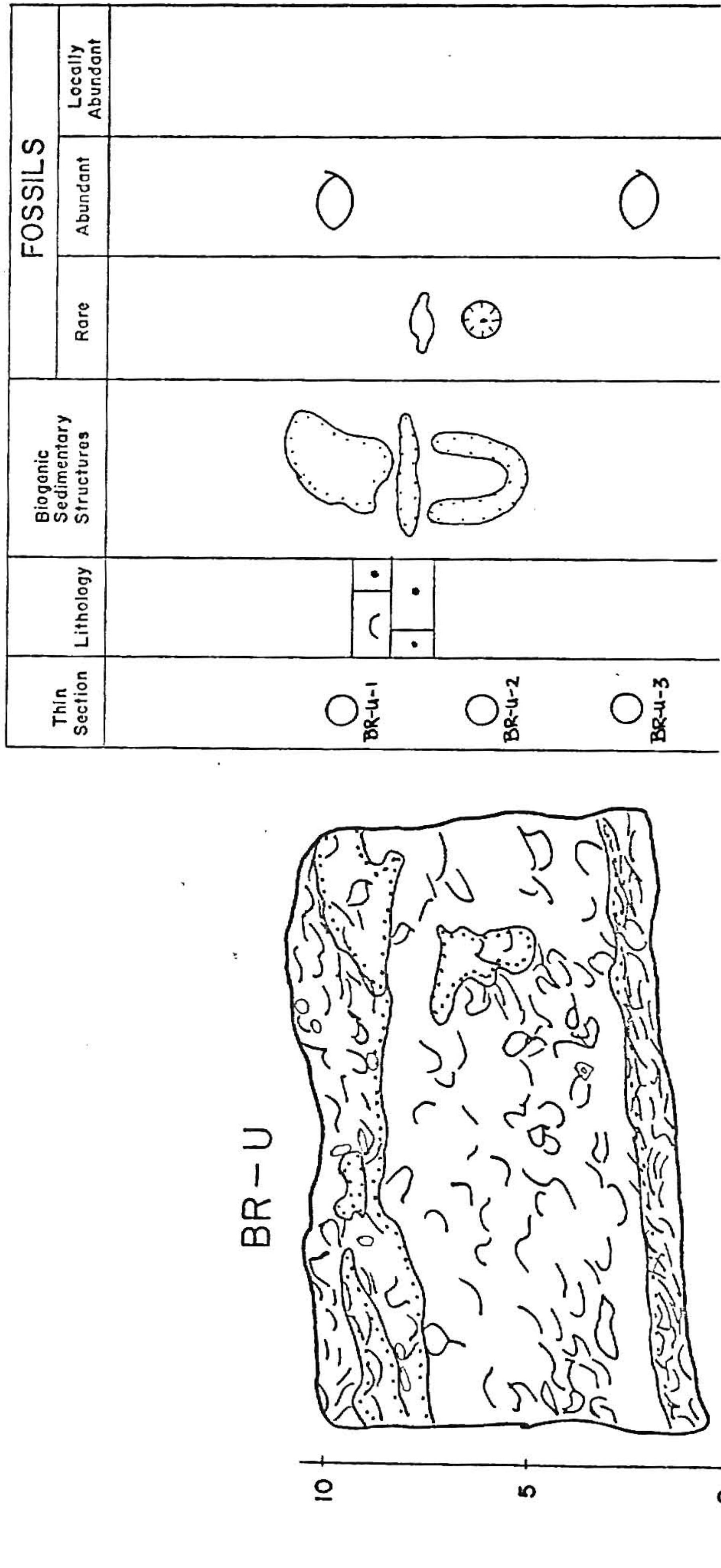
packed biomicrite
(> 50% allochems)

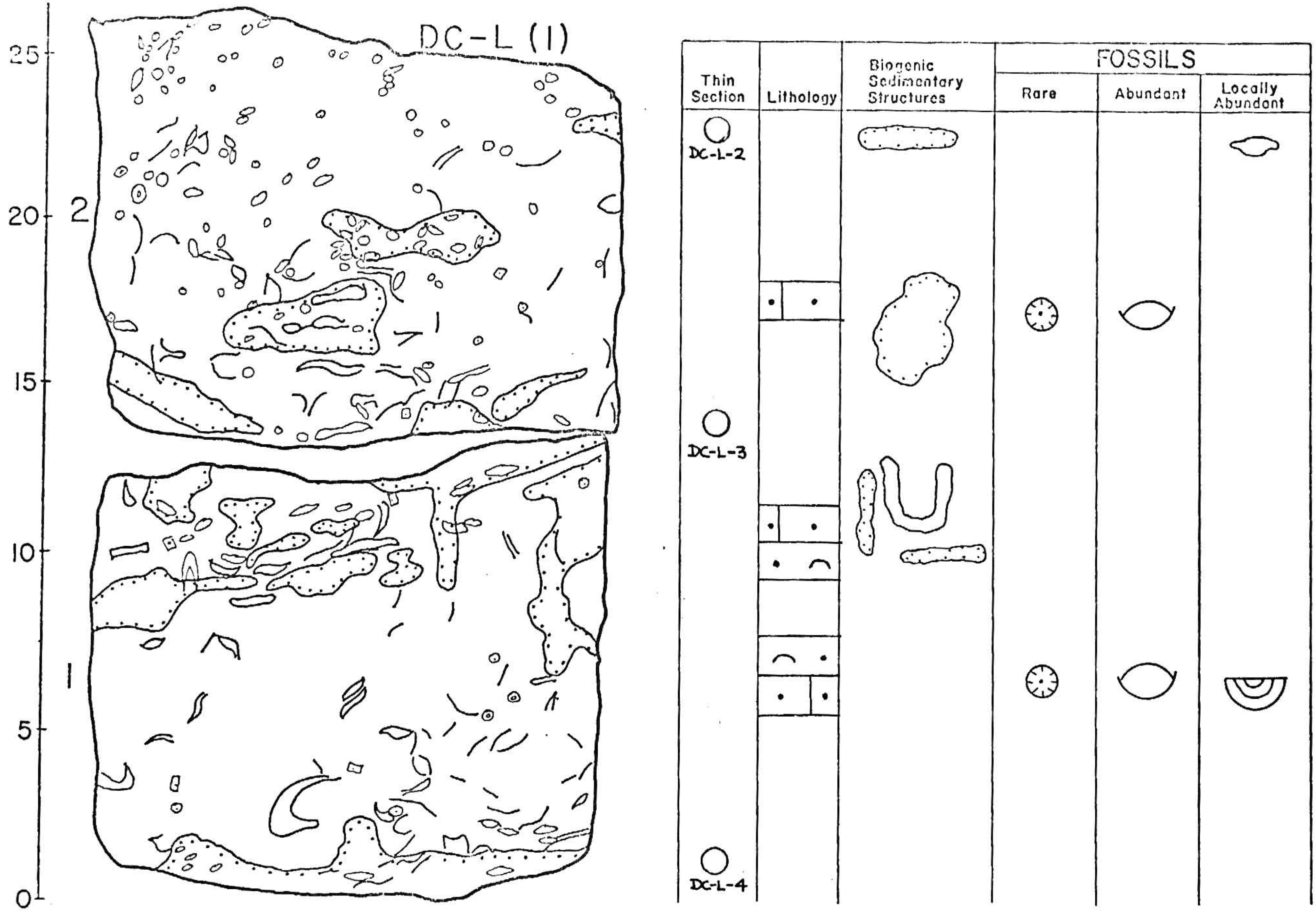
Symbols in this column are used to mark boundaries of different lithologies.

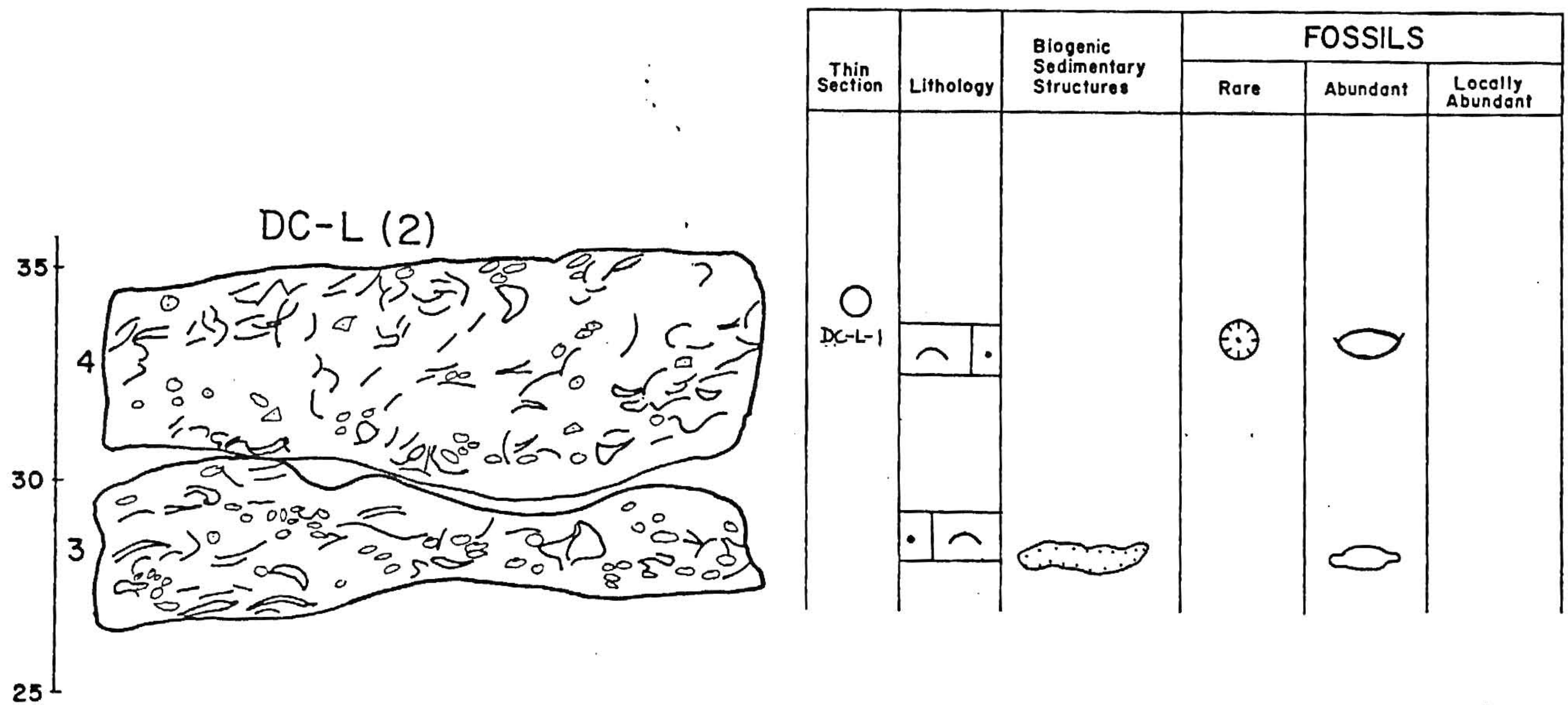
Each symbol is valid from the bottom of the column to the point of change.


BR-L
20
15
10
5
0
Thin Section
Lithology
Biogenic Sedimentary Structures
FOSSILS
Rare
Abundant
Locally Abundant
BR-L-1
BR-L-2
BR-L-3

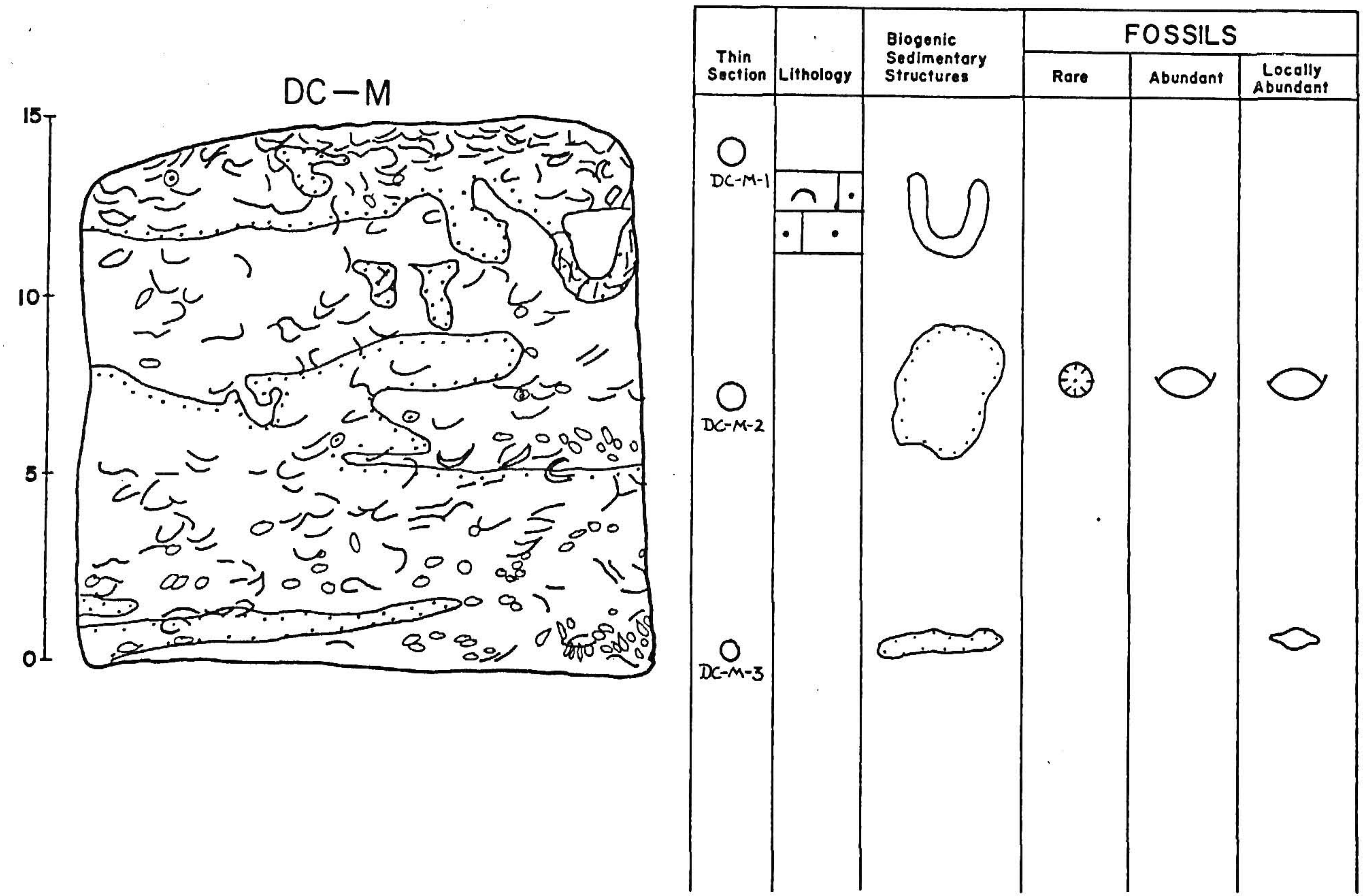

BR – M
20
15
10
5
0
Thin Section
Lithology
Biogenic Sedimentary Structures
FOSSILS
Rare
Abundant
Locally Abundant
BR-M-3
BR-M-4

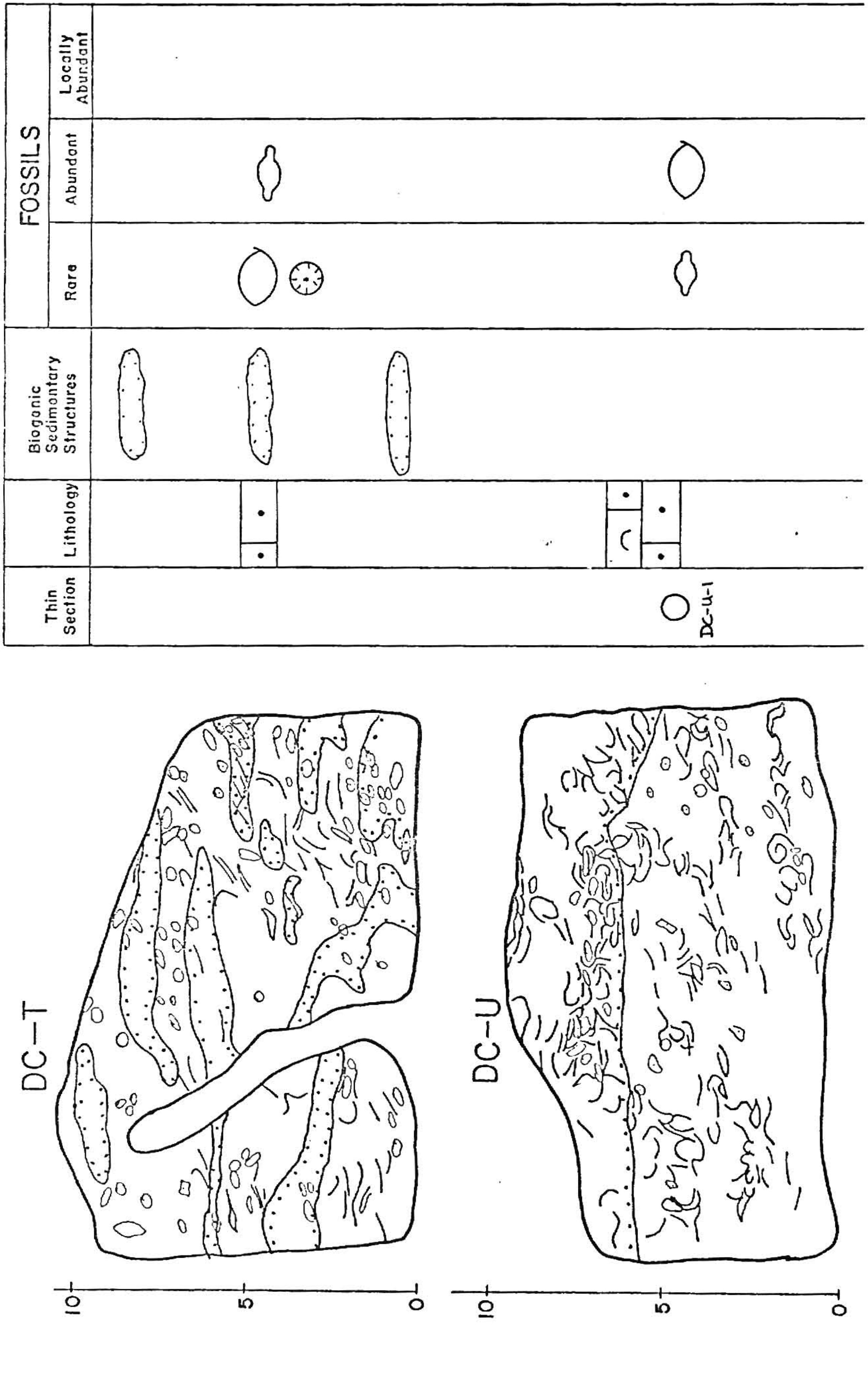

BR – U
10
5
0
Thin Section
BR-U-1
BR-U-2
BR-U-3
Lithology
Biogenic Sedimentary Structures
FOSSILS
Rare
Abundant
Locally Abundant

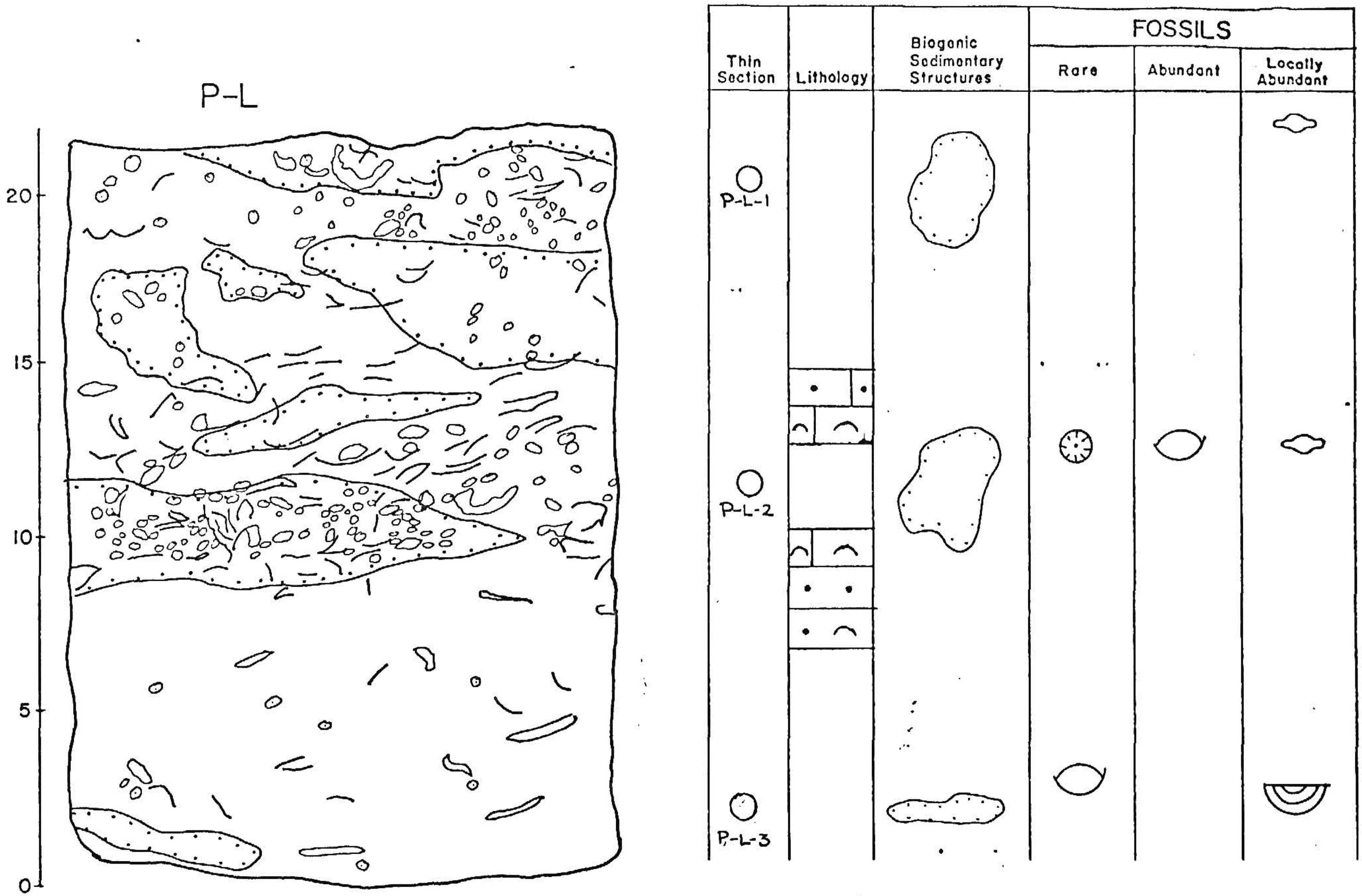

DC-L (1)
25
20
15
10
5
0
2
1
Thin Section
Lithology
Biogenic Sedimentary Structures
FOSSILS
Rare
Abundant
Locally Abundant
DC-L-2
DC-L-3
DC-L-4

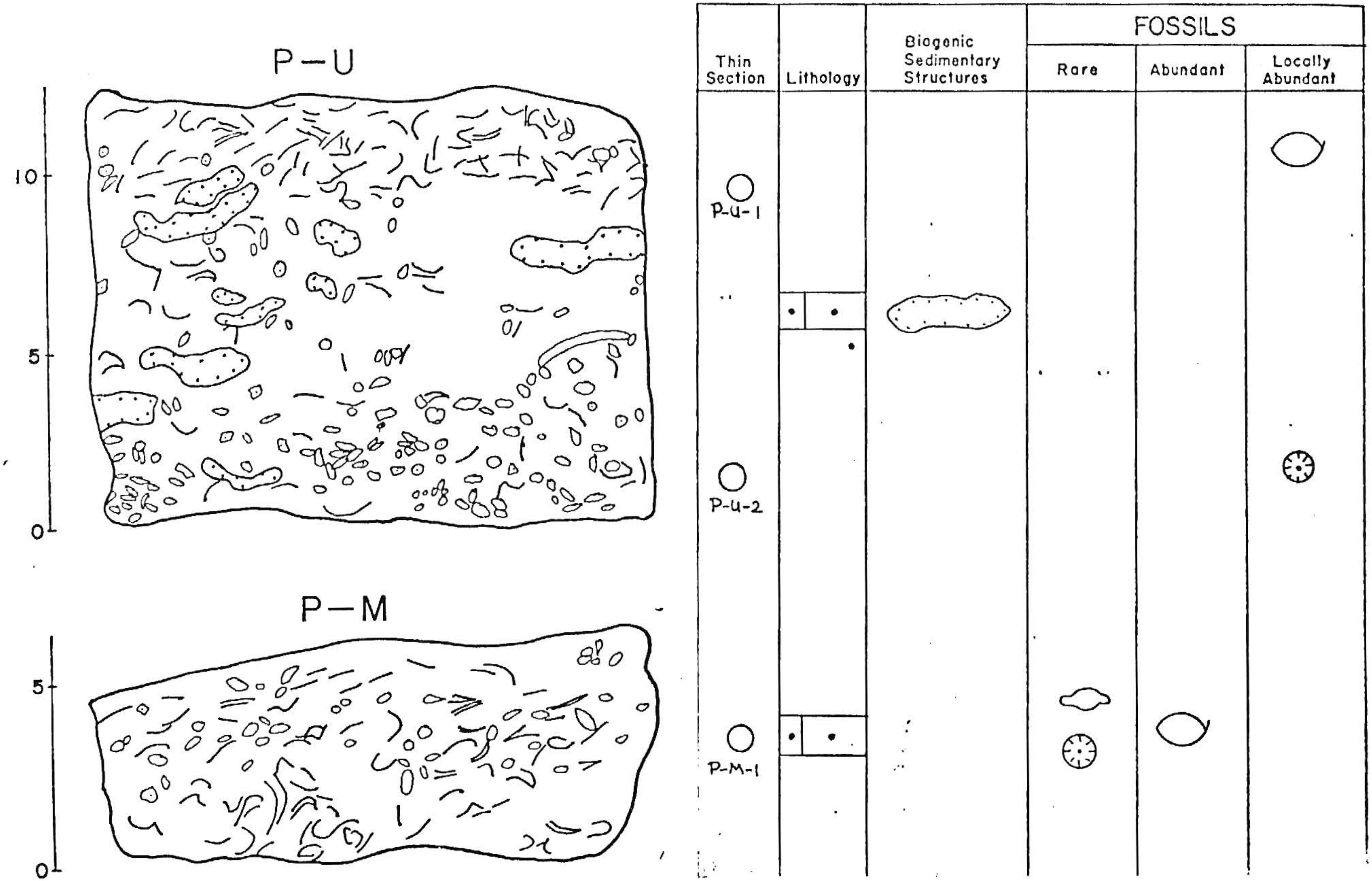


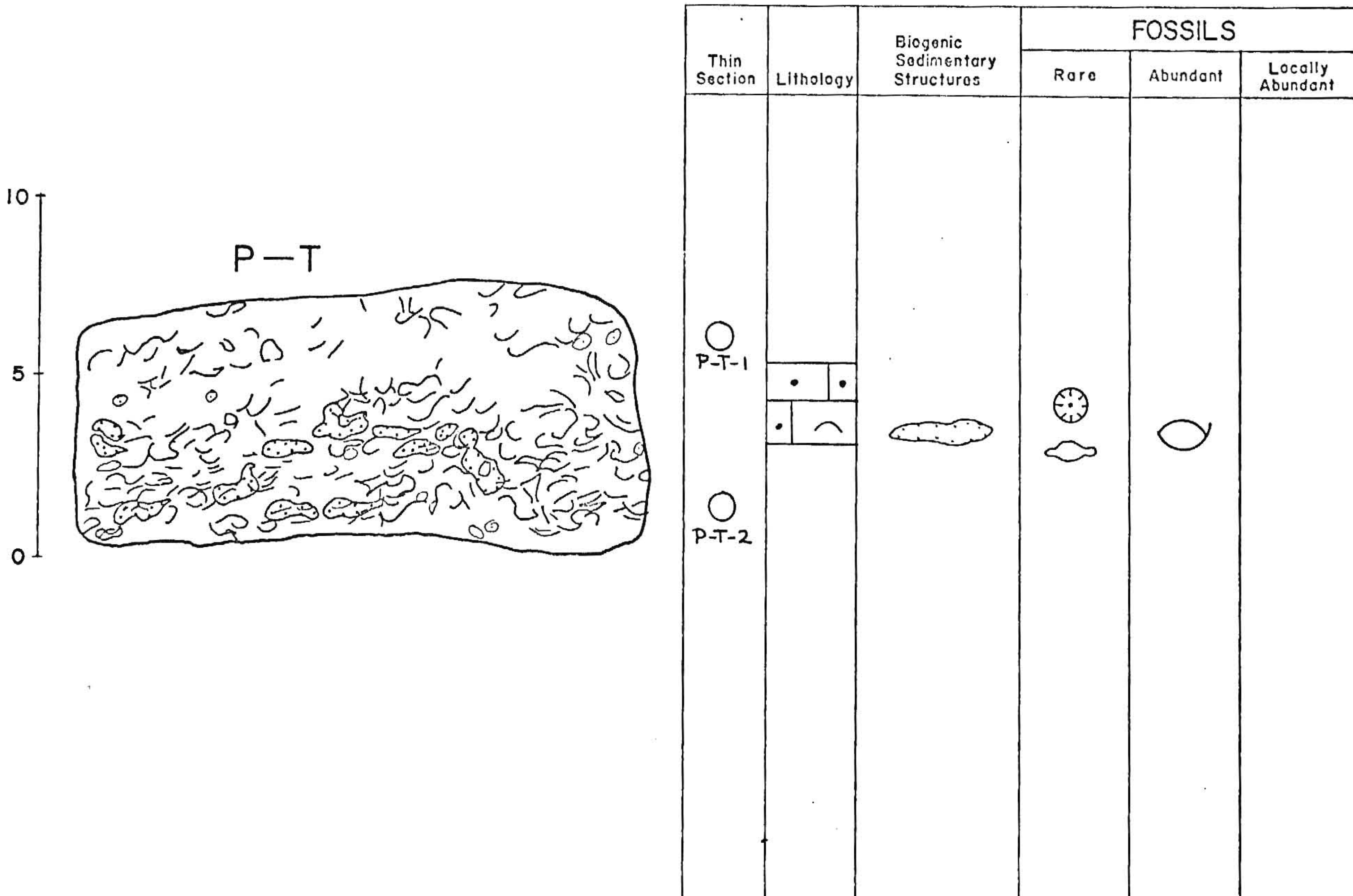
DC-L (2)
35
30
25
4
3
Thin Section
Lithology
Biogenic Sedimentary Structures
FOSSILS
Rare
Abundant
Locally Abundant
DC-L-1

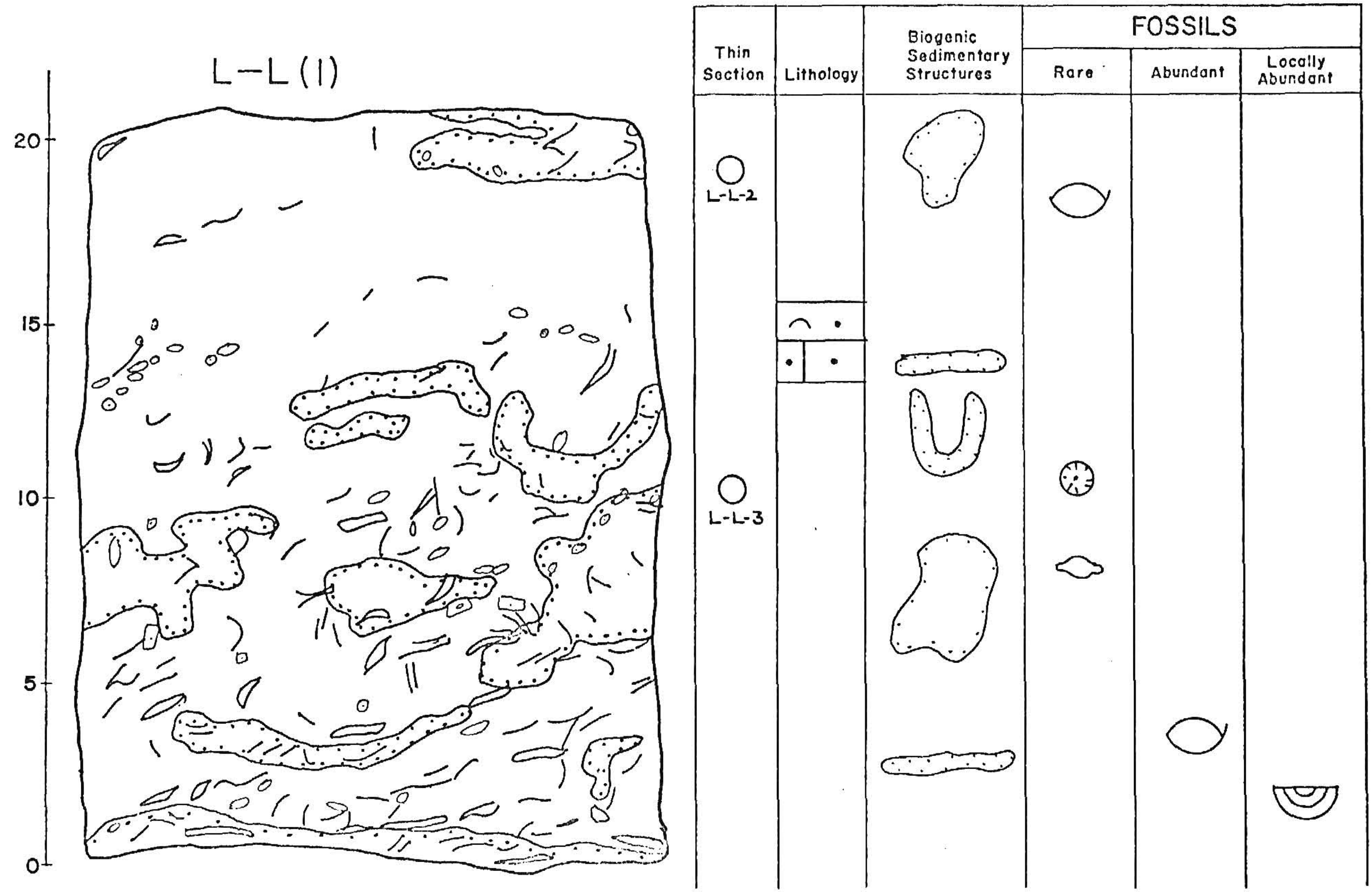

DC—M
15
10
5
0
Thin Section
Lithology
Biogenic Sedimentary Structures
FOSSILS
Rare
Abundant
Locally Abundant
DC-M-1
DC-M-2
DC-M-3


FOSSILS
Locally Abundant
Abundant
Rare
Biogenic Sedimentary Structures
Lithology
Thin Section
DC-U-1
DC—T
DC—U
10
5
0
10
5
0

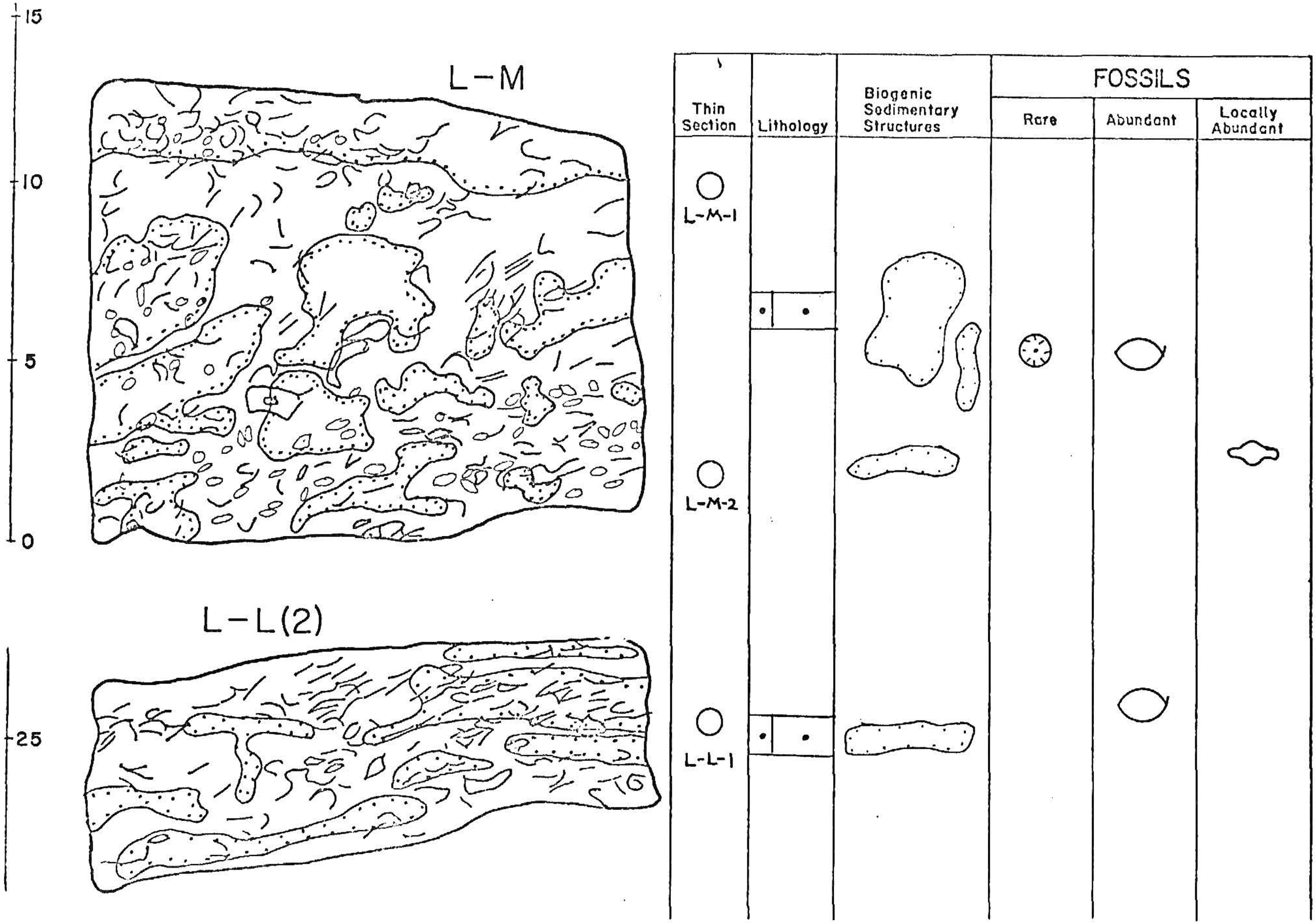

P-L
20
15
10
5
0
Thin Section
Lithology
Biogenic Sedimentary Structures
FOSSILS
Rare
Abundant
Locally Abundant
P-L-1
P-L-2
P-L-3

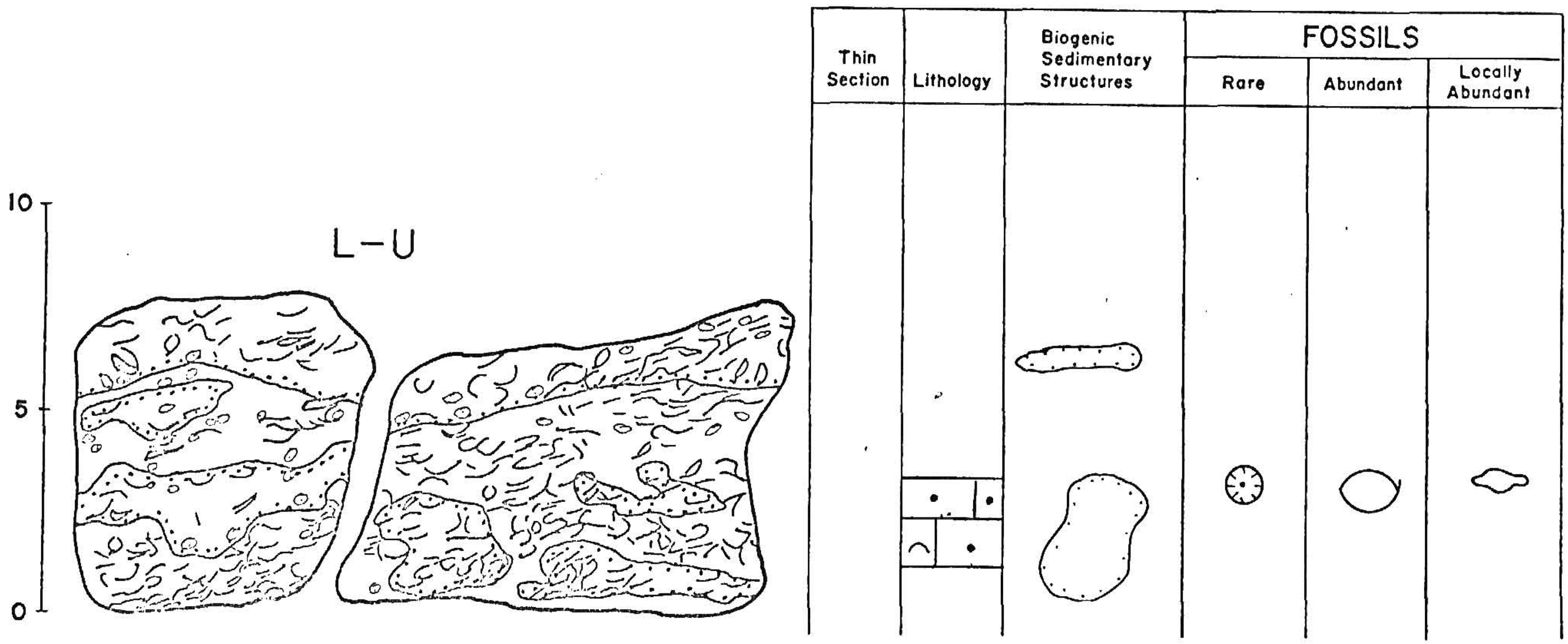

P—U
P—M
10
5
0
5
0
Thin Section
Lithology
Biogenic Sedimentary Structures
FOSSILS
Rare
Abundant
Locally Abundant
P-U-1
P-U-2
P-M-1

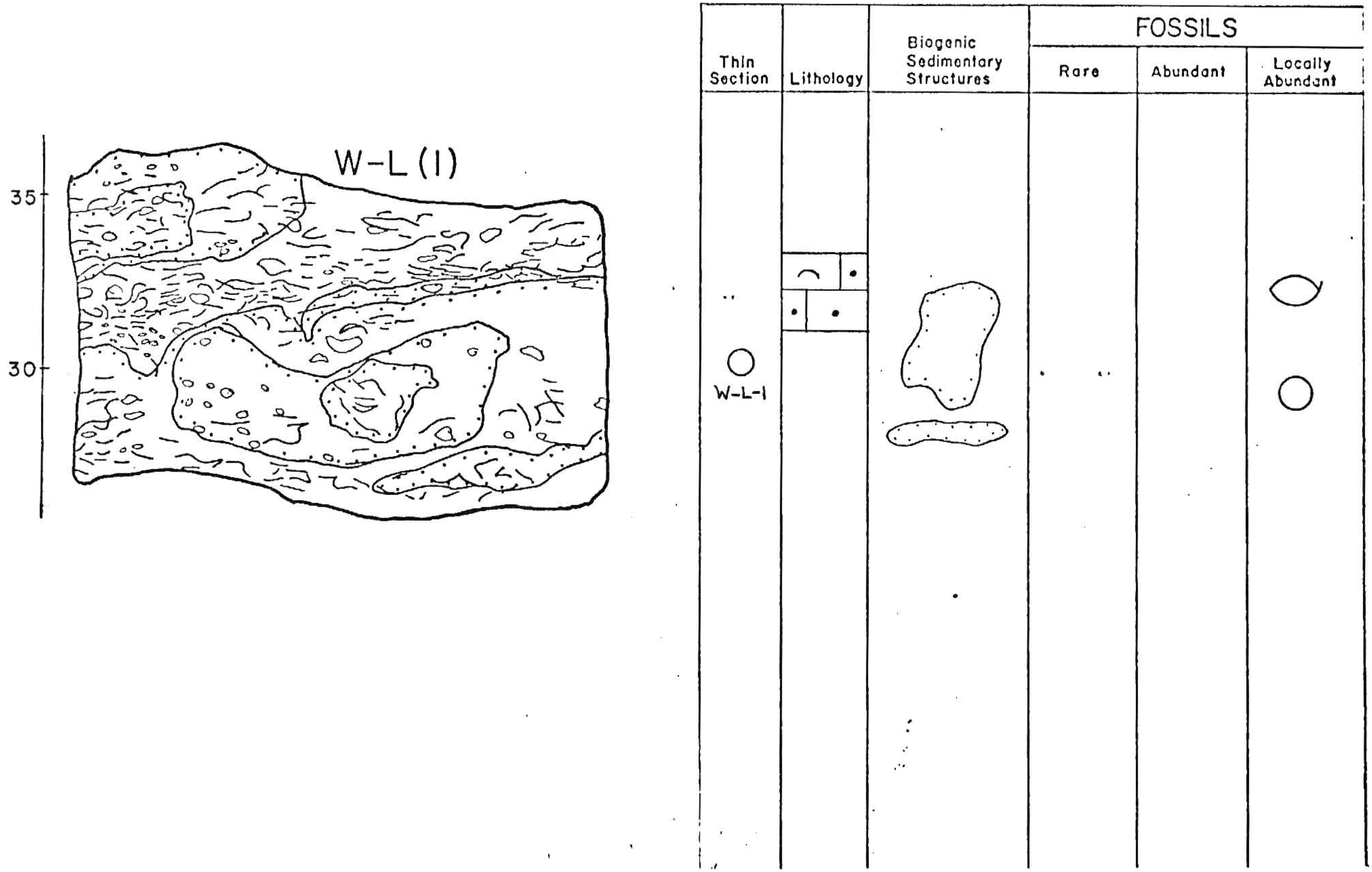

P—T
10
5
0
Thin Section
Lithology
Biogenic Sedimentary Structures
FOSSILS
Rare
Abundant
Locally Abundant
P-T-1
P-T-2

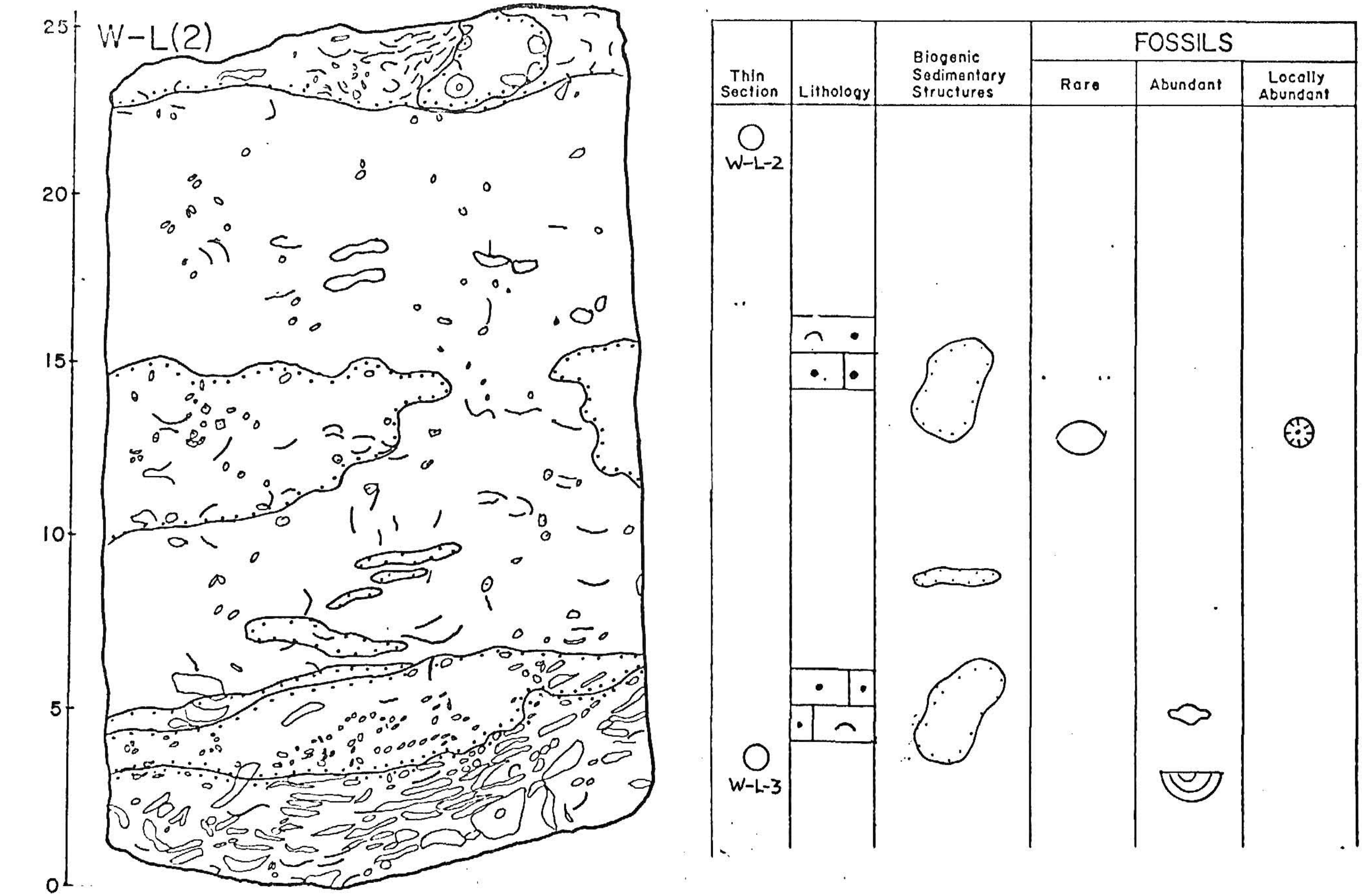


L-L(1)
20
15
10
5
0
Thin Section
Lithology
Biogenic Sedimentary Structures
FOSSILS
Rare
Abundant
Locally Abundant
L-L-2
L-L-3

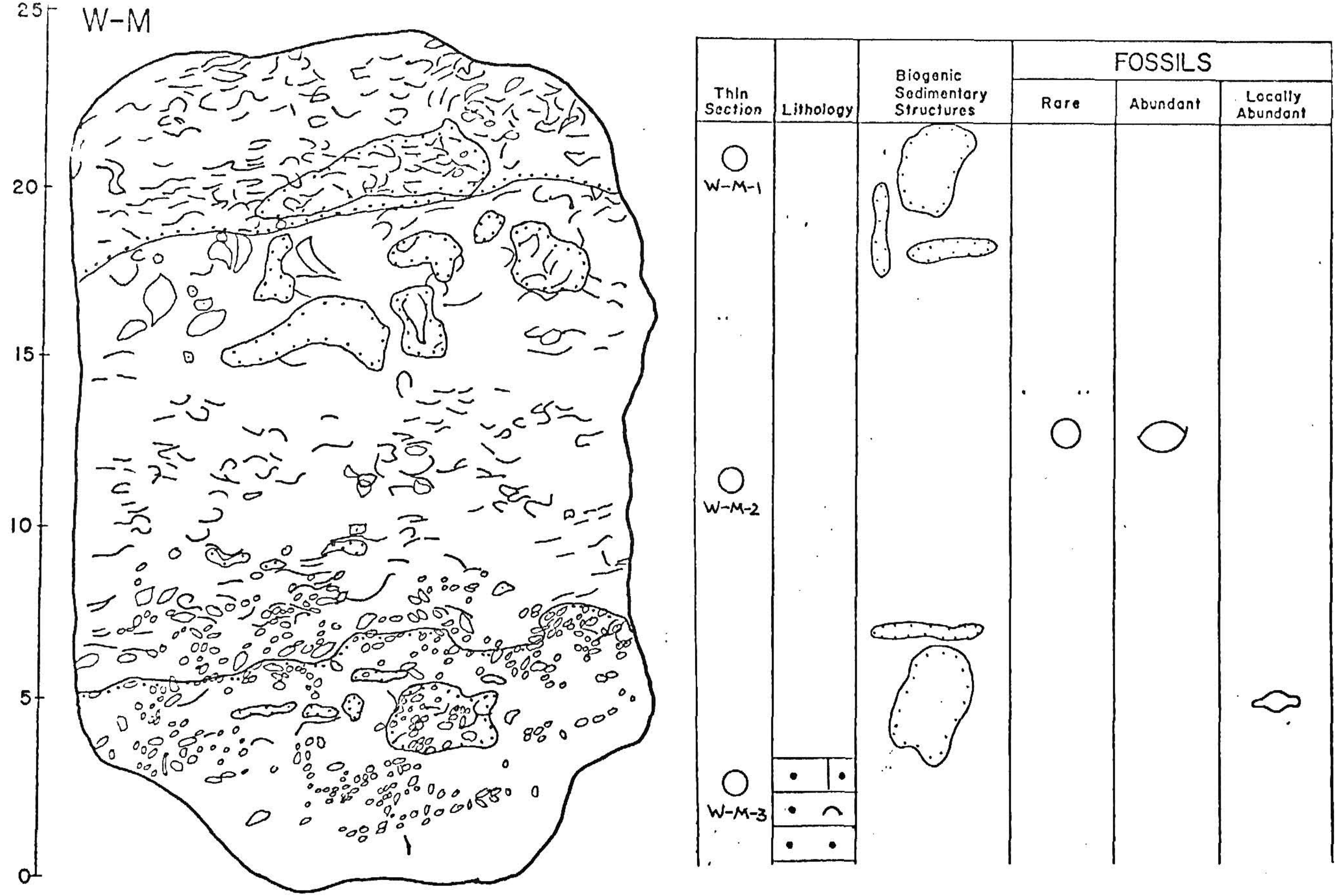

15
10
5
0
25
L-M
L-L(2)
Thin Section
Lithology
Biogenic Sedimentary Structures
FOSSILS
Rare
Abundant
Locally Abundant
L-M-1
L-M-2
L-L-1

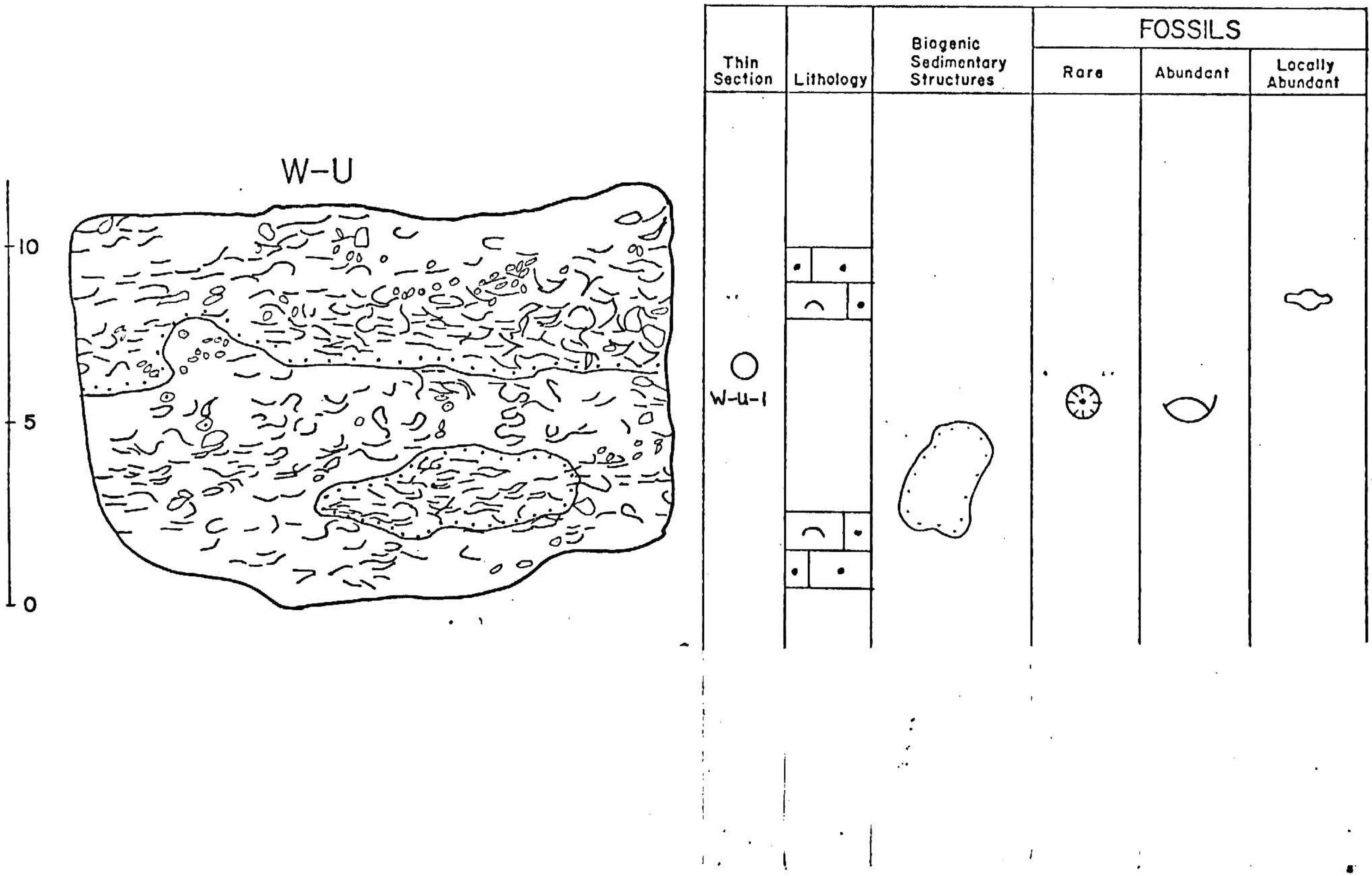

10
5
0
L–U
Thin Section
Lithology
Biogenic Sedimentary Structures
FOSSILS
Rare
Abundant
Locally Abundant


W-L (I)
35
30
Thin Section
Lithology
Biogenic Sedimentary Structures
FOSSILS
Rare
Abundant
Locally Abundant
W-L-I



W-L(2)
25
20
15
10
5
0
Thin Section
Lithology
Biogenic Sedimentary Structures
FOSSILS
Rare
Abundant
Locally Abundant
W-L-2
W-L-3

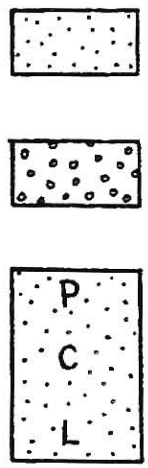

W-M
25
20
15
10
5
0
Thin Section
Lithology
Biogenic Sedimentary Structures
FOSSILS
Rare
Abundant
Locally Abundant
W-M-1
W-M-2
W-M-3


W–U
10
5
0
Thin Section
Lithology
Biogenic Sedimentary Structures
FOSSILS
Rare
Abundant
Locally Abundant
W-U-1

APPENDIX III

Horizontal mapped surfaces contain: 1) maps of the "bedding surfaces" showing location of the fossils relative to each other, and 2) descriptions of the fossils observed on these surfaces.

The following lithologic differences were distinguished on the maps:



burrow filled matrix

shell debris

pyrite

calcite

limonite

Each mapped surface contains diversity (D) and equitability (E) values and grade bioturbation (GB).

Size of Fossils

Size of Fossils in centimeters was recorded in longest (long dim.) and shortest (short dim.) dimensions looking at the bedding surface in plan view.

Orientation = orient

p = parallel to bedding (= longitudinal section)
i = inclined to bedding (= cross section)
- ccu = concave up
- cvu = convex up
- zeu = zooecia up
- zed = zooecia down

Articulation = art

oval = open valves
cval = closed valves

Valves = val

r = right valve
l = left valve
b = brachial valve
p = pedicle valve
? = valve indeterminate

Fragmentation = frag

x = fragmented fossil

Episymbionts = epis

The specimen number from the mapped surface was placed in this column if an episymbiontic relationship was observed.

Type of Preservation = type pres

o = original or altered shell
m = molds
o&m = original or altered shell or molds
cal = more calcareous than surrounding matrix
lim = iron oxide
pyr = pyrite

Abbreviations

Foraminiferida

Fus = Fusulinids

Ectoprocts

r I = Ramose type 1
r II = Ramose type 2
r III = Ramose type 3
r IV = Ramose type 4

f I = Fenestrate type 1
f II = Fenestrate type 2

Brachiopoda

Lg = *Lingula* cf. *carbonaria*
Orb = *Orbiculoidea* cf. *missouriensis*
Pet = *Petrocrania* cf. *modesta*
Canc = *Cancrinella* cf. *boonensis*
Comp = *Composita* cf. *subtilita*
Cru = *Crurithyris* cf. *expansa*
Derb = *Derbyia* cf. *crassa*
Hust = *Hustedia* cf. *mormoni*
Hyst = *Hystriculia* cf. *histricula*
Jur = *Juresania* cf. *nebrascensis*
Iso = *Isogramma* cf. *renfrarum*
Lino = *Linoproductus* cf. *magnispinus*
Meek = *Meekella* cf. *striatocostata*
Nech = *Neochonetes* cf. *granulifer*
Nesp = *Neospirifer* cf. *dunbari*
Pet = *Petrocrania* cf. *modesta*
Rea = *Retaria* cf. *lasallensis*
Ret = *Reticulatia* cf. *huecoensis*
Rhip = *Rhipidomella* cf. *carbonaria*
Well = *Wellerella* cf. *osagensis*
brac = unidentified brachiopod

Mollusca

Bivalvia

Ast = *Astartella*? sp.
Apec = *Aviculopecten* cf. *artisulcatus*
Myl = *Myalina* sp.
Sch = *Schizodus* sp.
Smyl = *Septimyalina* sp.
Wilk = *Wilkingia* cf. *terminale*

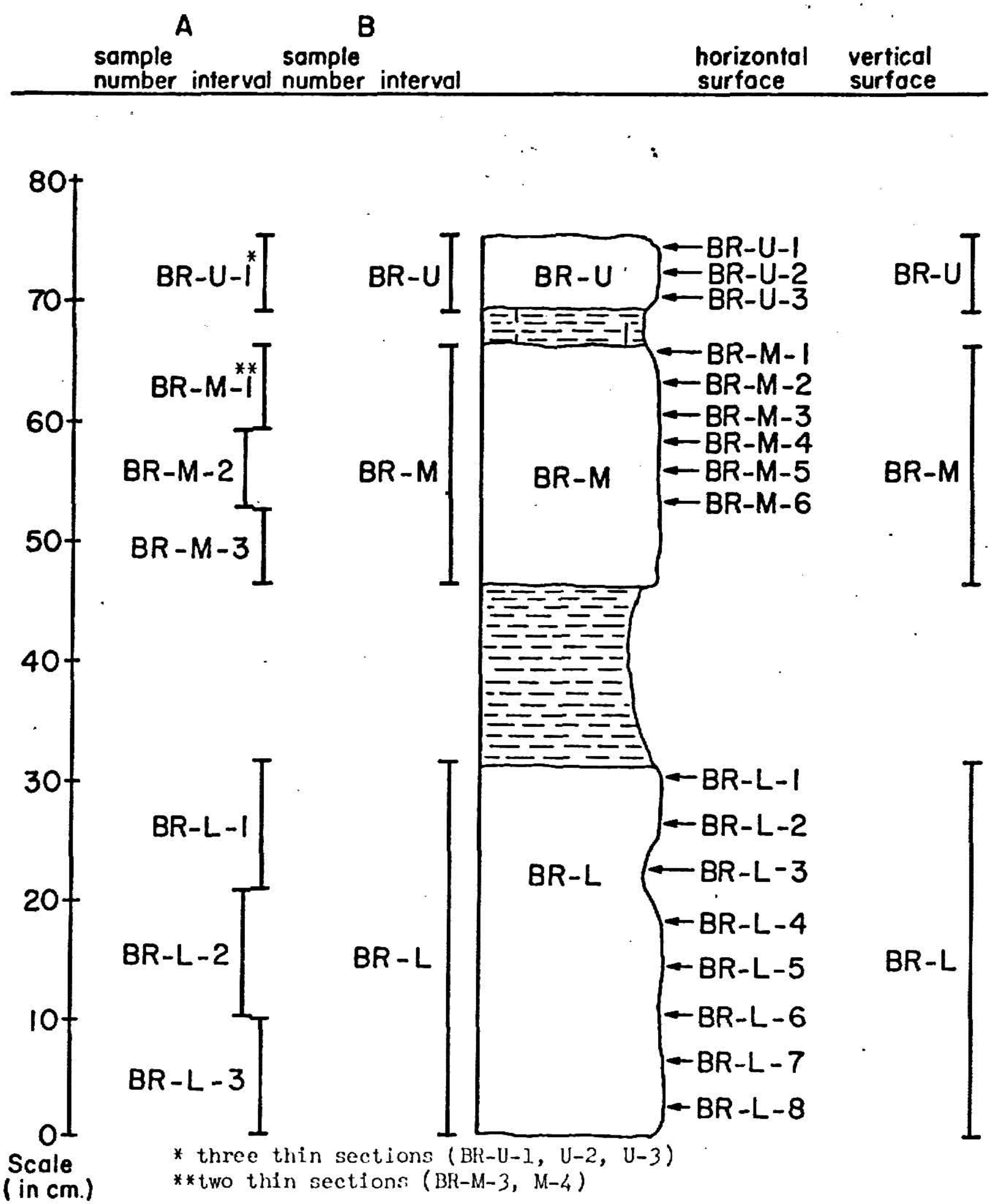
Gastropoda

Bell = *Bellerophon* sp.

Abbreviations Cont.

Echinodermata Crin = crinoid debris Ech = echinoid debris
Arthropoda ost = ostracodes
Vertebrata fi de = fish debris
Algae Osa = <u>Osagia</u> sp.
Bioturbation Features bur = burrow (for degree of bioturbation see p. 68 , Table 14)

BLUE RIVER (BR) SECTION

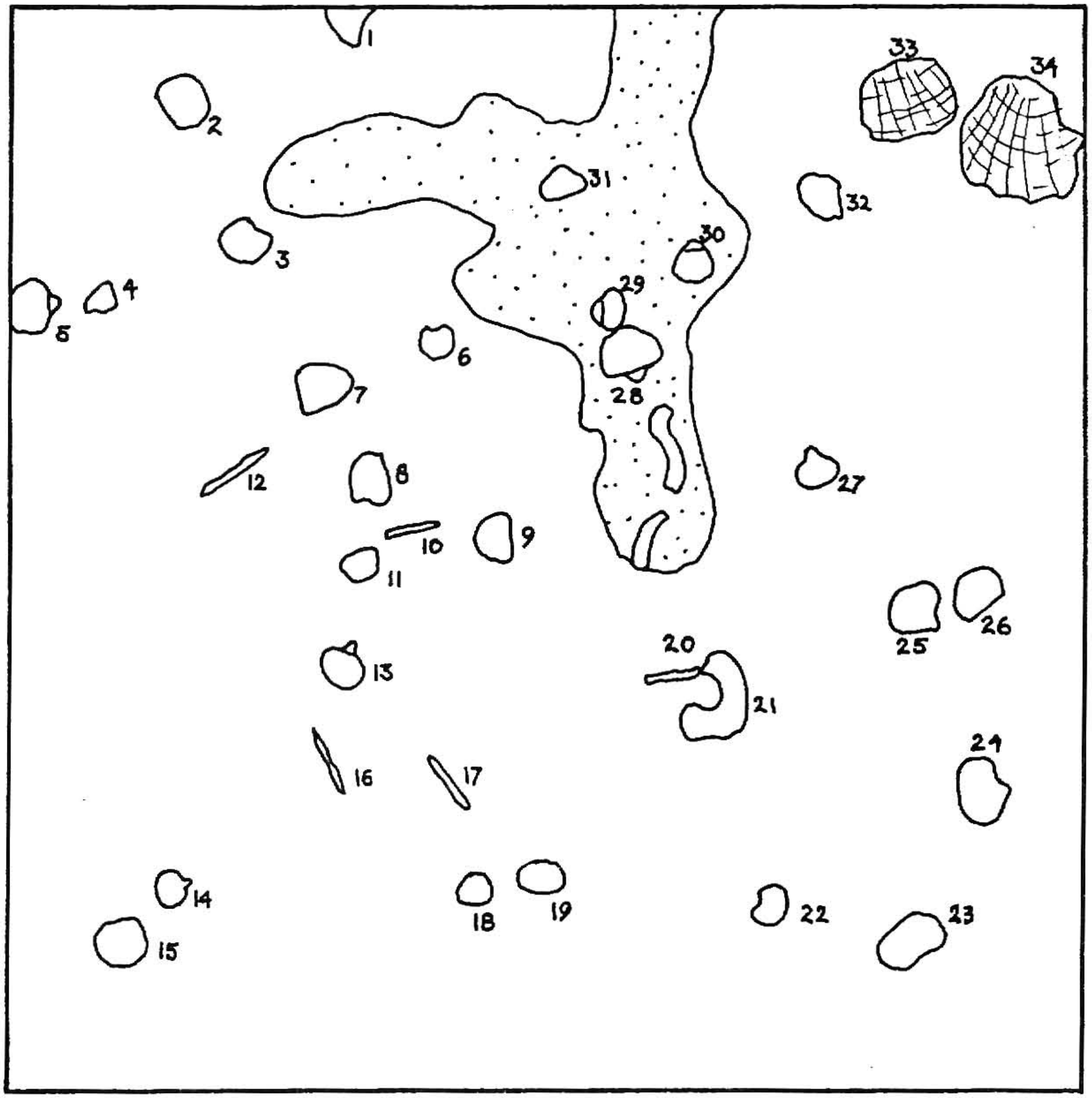


* three thin sections (BR-U-1, U-2, U-3)
**two thin sections (BR-M-3, M-4)

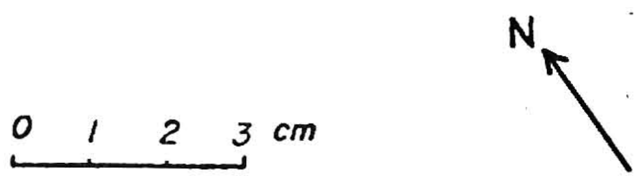
A = samples for insolubles, thin sections and carbonate mineralogy
B = samples for organic content, palaeosalinity estimations and clay mineralogy

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru			cvu		b			o&m	
2	Cru	.7	.5	ccu		p	x		o&m	
3	Cru	.7	.6	cvu		b			o&m	
4	Cru	.4	.4	cvu		b	x		o	
5	Cru	.8	.7	dfu		b			o	
6	Cru	.5	.5	cvu		b			o	
7	Cru	.8	.7	ccu		p	x		o	
8	Cru	.8	.6	cvu		p	x		o	
9	Cru	.6	.7	cvu		b			o	
10	brac								o&m	
11	Cru	.5	.3	cvu		b			o	
12	brac								o	
13	Cru	.5	.4	cvu		b			o	
14	Cru	.4	.4	cvu		b			o	
15	Cru	.7	.6	cvu		p			o	
16	brac									
17	brac									
18	Cru	.4	.4	cu		b	x		o	
19	Cru	.6	.4	ccu		b	x		o&m	
20	brac								o&m	
21	Comp	1.3	.5	i			x		o&m	
22	Cru	.4	.4	cvu		b	x		o	
23	Cru	.8	.5	ccu		p	x		o	
24	Cru	.8	.6	cvu		b			o&m	
25	Cru	.7	.7	cvu		b			o	
26	Cru	.7	.8	cvu	cval		x		o	
27	Cru	.5	.4	cvu		b			o	
28	Cru	.8	.9	ccu	cval				o&m	
29	Cru	.5	.4	ccu	cval				o&m	
30	Cru	.6	.5	cvu		b			o&m	
31	Cru	.5	.4	ccu		b			o	
32	Cru	.6	.6	ccu		p	x		o	
33	Rea	1.3	1.1	ccu		b	x		o&m	
34	Rea	1.6	1.6	cvu		p	x		o&m	

BR-U-1

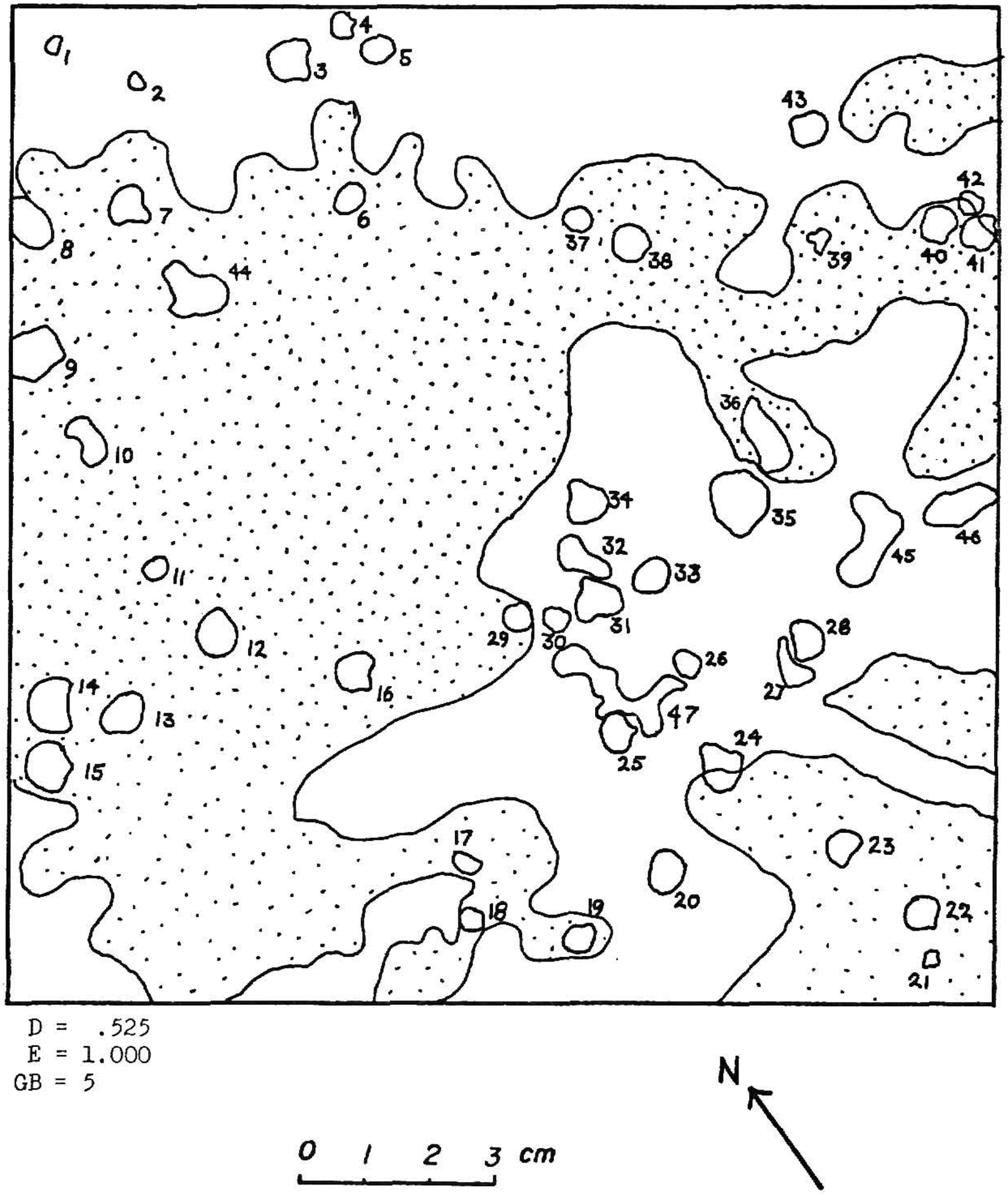


D = .831
E = 1.000
GR = 1



#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru			cvu					o&m	
2	Cru			cvu					o&m	
3	Cru	.6	.5	cvu		b			o	
4	Cru	.4	.3	cvu		b			o&m	
5	Cru	.3	.4	cvu		b	x		o	
6	Cru	.4	.4	cvu		b	x		o	
7	Cru	.5	.5	cvu		b	x		o	x
8	brac									
9	Cru	.9	.7	ccu		b			o	
10	brac									
11	Cru	.3	.2	ccu		p			o	
12	Cru	.9	.7	i					o	
13	Cru	.7	.4	cvu		b	x		o	
14	Cru	.8	.6	ccu		p			o	
15	Cru	.7	.7	ccu		p			o	
16	Cru	.5	.5				x			
17	Cru	.4	.3	cvu		b			o	
18	Cru	.4	.4	cvu		b			o	
19	Cru	.4	.3	cvu		b			o&m	
20	Cru	.7	.4	i					o&m	
21	Cru								o&m	
22	Cru	.4	.5	cvu		b			o	
23	Cru	.5	.6	cvu		b	x		o	
24	Cru	.7	.6	ccu		b			o	
25	Cru	.6	.4	i	cval				o	
26	Cru	.3	.2	cvu		b			o	
27	Cru	.9	.5	i	cval				o	
28	Cru	.7	.5	ccu		p			o	
29	Cru	.6	.4	ccu		b			o	
30	Cru	.4	.4	ccu		p			o	
31	Cru	.7	.7	cvu		b	x		o	
32	Cru	.9	.5	i	cval				o	
33	Cru	.5	.4	cvu		b			o	
34	Cru	.7	.5	cvu		b	x		o	
35	Cru	1.2	1.0	ccu		b			o	
36	Cru	1.0	.6	i	cval				o	
37	Cru	.4	.4						o	
38	Cru	.5	.5	cvu		b			o	
39	Cru								o	
40	Cru	.6	.5	cvu		b			o	
41	Cru	.5	.4	cvu		b			o&m	
42	Cru	.4	.3	cvu		b	x		o&m	
43	Cru	.5	.4	cvu		b	x		o&m	
44	rIII	1.1	.7	i			x			
45	rIII	1.4	.5	i			x			
46	rIII	1.2	.4	i			x			
47	rIII	1.9	.4	i			x			

BR-U-2



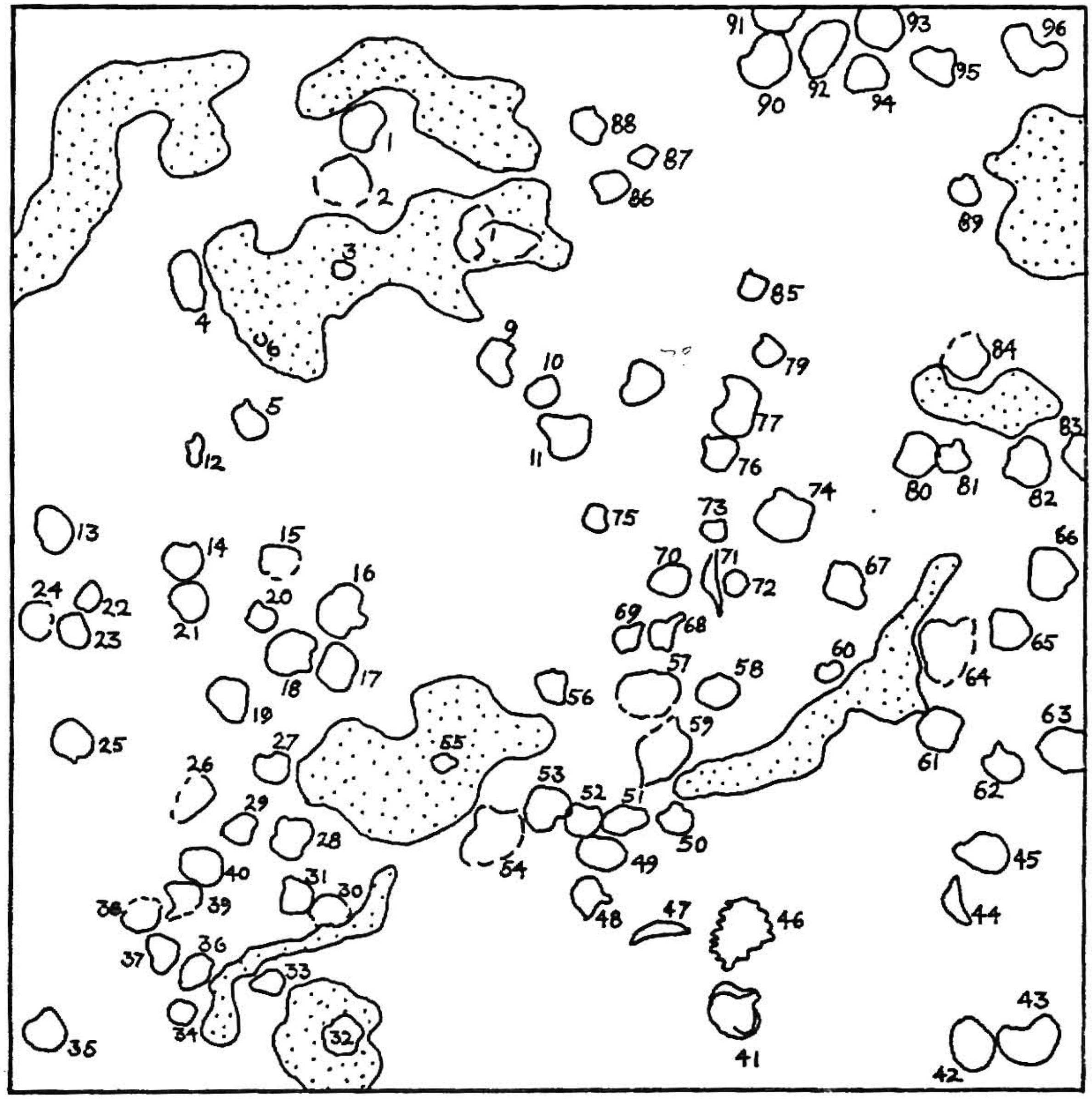
D = .525
E = 1.000
GB = 5

BR-U-3

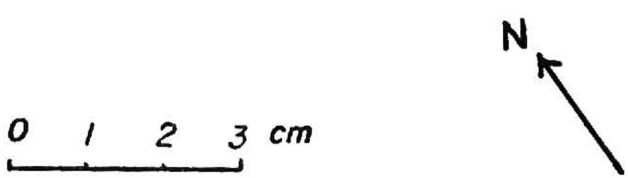
#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.7	.5	ccu		b	x		o	
2	Cru	.6	.7	ccu		b	x		o	
3	Cru		1	i					o	
4	Cru	.9	.6	cvu		b	x		o	
5	Cru	.4	.3	cvu		b			o	
6	Cru			i					o	
7	Cru	.7	.6	ccu		p	x		o	
8	Cru	.7	.7						m	
9	Cru	.6	.4	ccu		p			m	
10	Cru	.4	.5	cvu		b			o	
11	Cru	.6	.6	cvu	cval	b			o	
12	Cru			p					o	
13	Cru	.6	.4	cvu		b			o&m	
14	Cru	.6	.4	cvu		b			o	
15	Cru	.6	.5	cvu		b			o	
16	Cru	.6	.5	cvu		b			o	
17	Cru	.5	.5	cvu		b			o	
18	Cru	.7	.5	ccu		b			o	
19	Cru	.6	.4	i		?			o	
20	Cru	.3	.2	cvu		b			o	
21	Cru	.5	.4	ccu		p			o	
22	Cru	.3	.3	cvu		b			o	
23	Cru	.3	.2	cvu		b	x		o	
24	Cru	.5	.3			?	x		o	
25	Cru	.4	.5	cvu		b			o	
26	Cru	.5	.3	i	cval		x		o	
27	Cru	.4	.4	cvu		b			o	
28	Cru	.5	.4	cvu		b			o	
29	Cru	.4	.3	cvu		b	x		o	
30	Cru	.5	.3	i	cval				o	
31	Cru	.6	.5	cvu		b			o	
32	Cru	.4	.5	cvu		b			o	
33	Cru	.3	.3	cvu		p	x		o	
34	Cru	.3	.2	cvu		b			o	
35	Cru	.5	.6	ccu		b			o	
36	Cru	.7	.5	ccu		p	x		o	
37	Cru	.5	.6	ccu		p	x		o	
38	Cru	.5	.5	ccu		p	x		o	
39	Cru	.4	.4	ccu		b	x		o	
40	Cru	.5	.4	cvu		b			o	
41	Cru	.8	.7	cvu		b				
42	Cru	.7	.6	cvu		b	x			
43	Cru	1.0	.8	ccu		p	x		o	
44	Ch	.6	.2	i	cval				o	
45	Cru	.7	.5						o	
46	Hust	1.0	.8	i	cval				m	
47	brac	.9	.2	i	cval				o	
48	Cru	.8	.7	ccu		b			o	
49	Cru	1.1	.9	ccu		b			o	
50	Cru	.6	.5	cvu		p			o	

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
51	Cru	.7	.6	ccu		p			m	
52	Cru	.6	.5	ccu		p			o	
53	Cru	.7	.6	ccu		p			o	
54	Cru	1.2	.9	cvu		b	x		o	
55	Cru	.3	.3	cvu		p			o&m	
56	Cru	.5	.3	ccu		b	x		o&m	
57	Cru	1.0	.8	ccu		p	x		o	
58	Cru	.6	.5	ccu		b			o	
59	Cru	1.0	1.3	i	cval		x		o&m	
60	Cru	.3	.3	ccu		p			o	
61	Cru	.6	.5	cvu		p			o	
62	Cru	.6	.6	cvu		b			o	
63	Cru	1.2	.8	ccu		p			o&m	
64	Cru	1.3	1.0	i	cval		x		o&m	
65	Cru	.5	.4	ccu		p			o	
66	Cru	1.2	.8	ccu		p			o	
67	Cru	1.0	.8			?			o	
68	Cru	.5	.4	ccu		?	x		o	
69	Cru	.4	.3				x		o	
70	Cru	.6	.5	cvu		p				
71	Cru	1.0	.3	i	cval				m	
72	Cru	.3	.3	i					o	
73	Cru	.3	.2	ccu		b			o	
74	Cru	.9	.7	ccu		b			o	
75	Cru	.3	.2	cvu			x		o	
76	Cru	.4	.3	ccu		b			o	
77	brac	.5	1.0			?			o	
78	Cru	.5	.4	ccu		p			o	
79	Cru	.3	.2	cvu		b			o	
80	Cru	.6	.5	ccu		p			o&m	
81	Cru	.4	.3	cvu		b			o	
82	Cru	.6	.5	ccu		p			o	
83	Cru	.5	.4	ccu		p			o	
84	Cru	.5	.5			p	x		o	
85	Cru	.3	.2	cvu		b			o	
86	Cru	.4	.3	ccu		b			o	
87	Cru	.2	.2			?	x		o	
88	Cru	.4	.3			?	x		o	
89	Cru	.4	.3	ccu		b			o	
90	Cru	.8	.6	cvu		p			o	
91	Cru	.7	.5	cvu		p			o	
92	Cru	.9	.6	cvu		p			o	
93	Cru	.7	.5	cvu		p			o	
94	Cru	.5	.4	cvu		p			o	
95	Cru	.5	.4	cvu		p	x		o	
96	Cru	1.0	.5			?	x		o	

BR-U-3



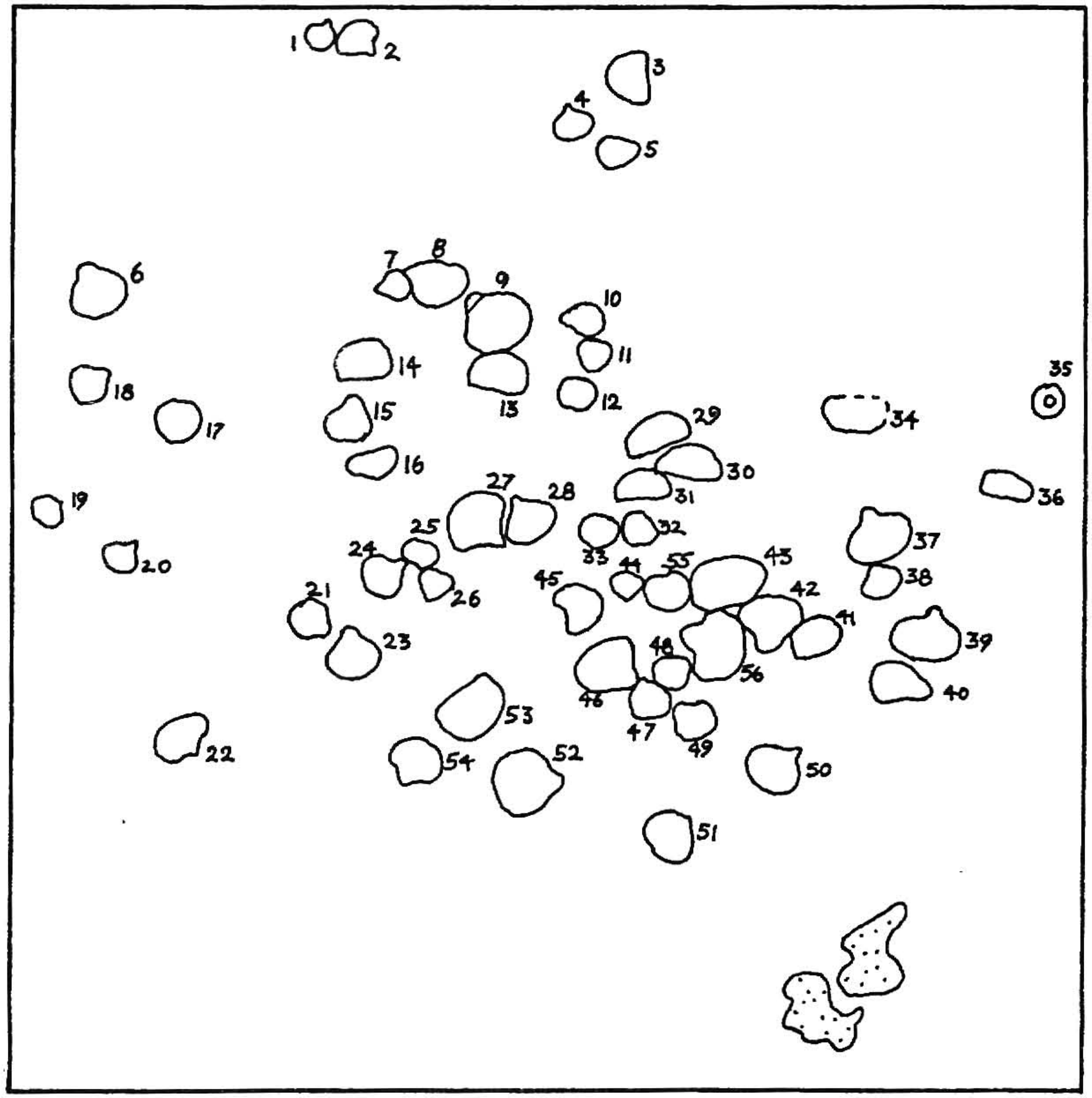
D = .419
E = .667
GB = 2



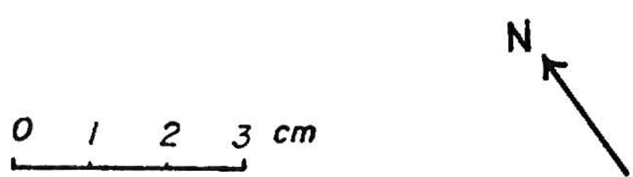
#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.4	.4	cvu		b			o	
2	Cru	.6	.5	cvu		b			o	
3	Cru	.7	.6	cvu		b	x		o	
4	Cru	.5	.5	cvu		b			o	
5	Cru	.4	.4	cvu		b			o	
6	Cru	.9	.8	cvu		b			o	
7	Cru	.4	.4	cvu		b			o	
8	Cru	.9	.9	cvu		b	x		o	
9	Comp	.9	.9	cvu		b			o	
10	Cru	.4	.4	cvu		b			o	
11	Cru	.5	.5	cvu		b			o	
12	Cru	.5	.5	cvu		b	x		o	
13	Cru	.8	.5	ccu		p			m	
14	Cru	.9	.6	ccu		b			m	
15	Cru	.7	.8	cvu		b			o	
16	Cru	.7	.5	cvu		p	x		o	
17	Cru	.6	.6	cvu		b			o	
18	Cru	.7	.6	cvu		b			o	
19	Cru	.5	.3	cvu		b	x		o	
20	Cru	.6	.5	cvu		b			o	
21	Cru	.6	.6	cvu		b			o	
22	Cru	.8	.6	cvu		b			o	
23	Cru	.7	.7	cvu		b			o	
24	Cru	.6	.7	cvu		b			o	
25	Cru	.4	.3	cvu	cval				o	
26	Cru	.5	.5	cvu	cval				o	
27	Cru	.9	1.0	cvu		b			o	
28	Cru	.8	.7	cvu		b			o	
29	Cru	.9	.6	ccu		b			m	
30	Cru	1.0	.5	ccu		b			m	
31	Cru	.8	.5	ccu		b			m	
32	Cru	.4	.5	cvu		b			o	
33	Cru	.5	.5	cvu		b			o	
34	Cru	.9	.7	ccu		b			m	
35	Crin	.4	.4	i						
36	Cru	.6	.3	cvu		b	x			
37	Cru	1.0	.8	cvu		p			o	
38	Cru	.6	.6	cvu		b			o	
39	Cru	1.0	.8	cvu		b			o	
40	Cru	1.0	.7	cvu		b			o	
41	Cru	.6	.7	cvu		b	x		o	
42	Cru	.9	1.0	cvu		b	x		o	
43	Cru	1.0	.8	cvu		b	x		o	
44	Cru	.4	.3	cvu		b			o	
45	Cru	.8	.6	cvu		b			o	
46	Cru	.9	.8	cvu		p			o	
47	Cru	.5	.6	cvu		b			o	
48	Cru	.4	.4	cvu		b	x		o	
49	Cru	.6	.6	cvu		b	x		o	
50	Cru	.8	.8	cvu		b			o	
51	Cru	.8	.6	cvu		b			o	
52	Cru	1.0	1.0	cvu		b			o	
53	Cru	.9	.7	ccu		p			m	

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
54	Cru	.7	.6	cvu		b			o	
55	Cru	.5	.4	ccu		b			o&m	
56	Cru	1.2	.9	ccu		b			o	

BR-M-1

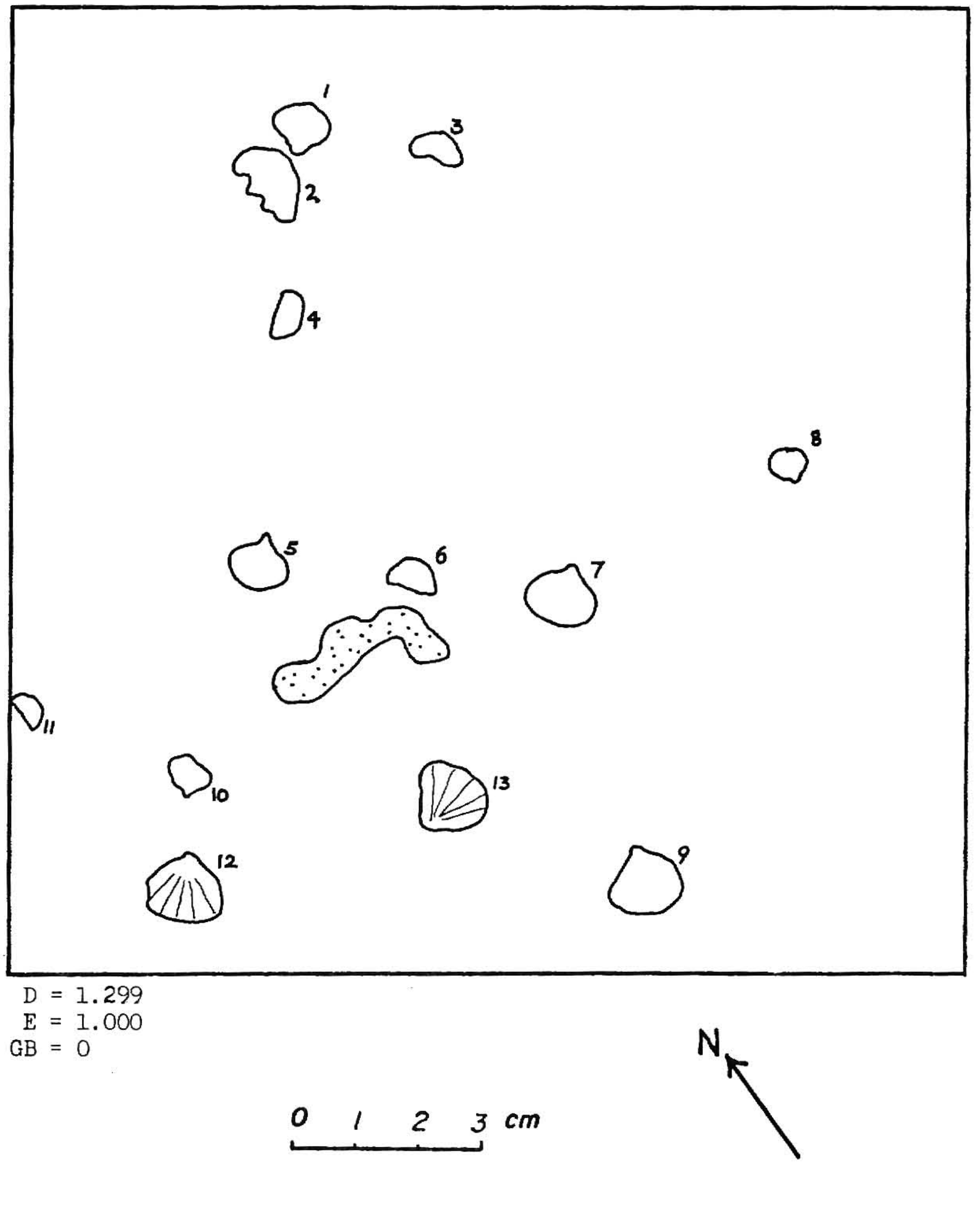


D = .282
E = .333
GB = 0



#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.8	.8	ccu		p			m	
2	Lg	.7	1.4	ccu		p			m	
3	Lg	.4	.9			?	x		o	
4	Cru	.7	.5	ccu		p			m	
5	Cru	1.0	.9	cvu		b			o	
6	Cru	.8	.4	ccu		p			m	
7	Cru	1.2	.9	cvu		b			o	
8	Cru	.5	.5	cvu		b	x		o	
9	Cru	1.2	1.0	cvu		b			o&m	
10	Cru	.6	.5	cvu		b			o	
11	Cru	.7	.3	ccu		p			m	
12	Well	1.2	1.0	ccu	cval				o	
13	Well	1.1	1.1	ccu	cval				m	

BR-M-2

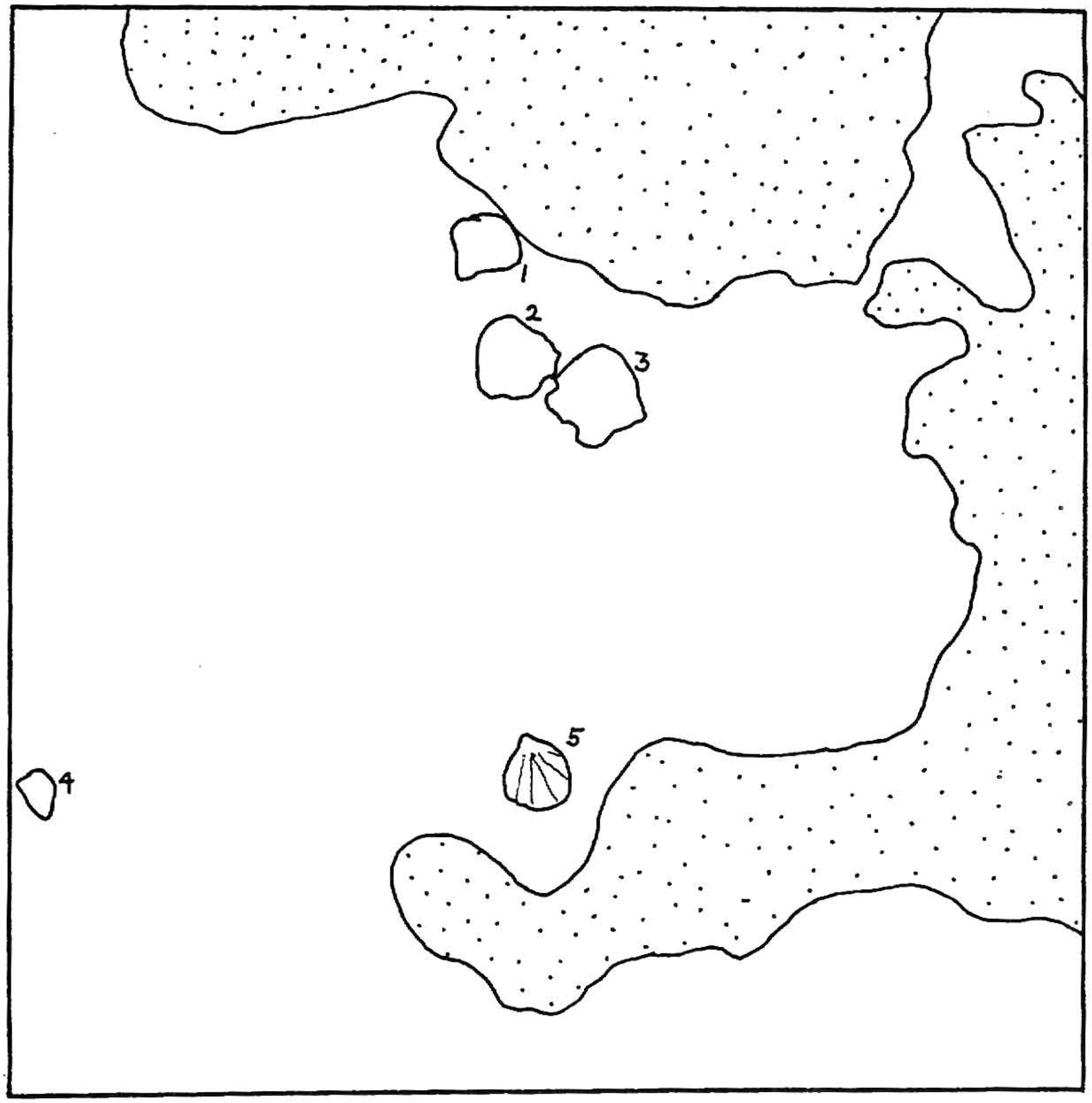


D = 1.299
E = 1.000
GB = 0

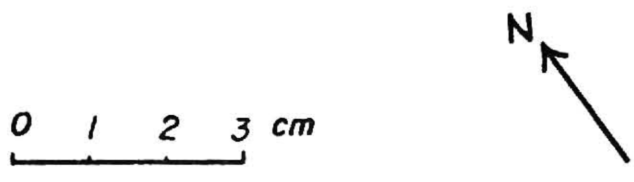
BR-M-3

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	1.0	.9	cvu		b			o	
2	Comp	1.2	1.1	cvu		b	x		m	
3	Comp	1.3	1.4	cvu		p	x		o	
4	Cru	.6	.4	ccu		p			m	
5	Well	.2	1.2	cvu		b			o	

BR-M-3

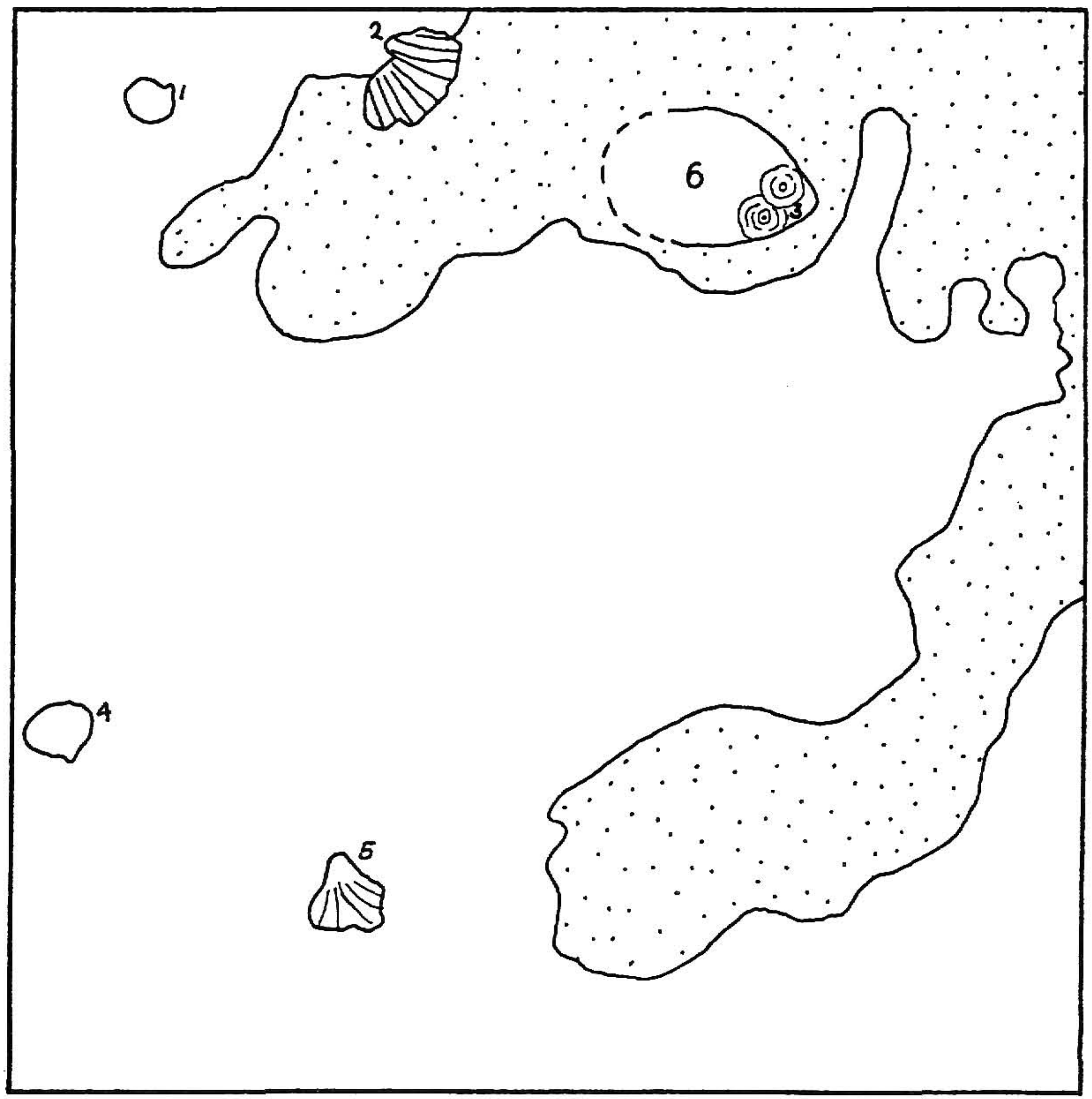


D = 1.585
E = 1.333
GB = 3

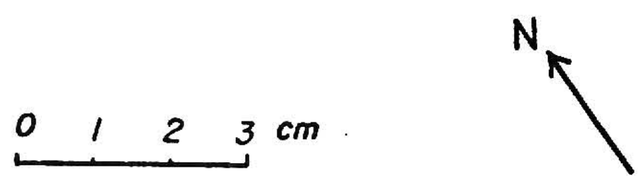


#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.7	.6	cvu		p			o	
2	Lino	1.7	1.1	cvu		p	x		o	
3	Myl	2.0	3.2	ccu		r		6	m	
4	Cru	.9	.8	cvu		b			o	
5	Well	1.0	1.2	cvu	cval		x		o	
6	Pet	.4	.4	cvu		b	x			

BR-M-4



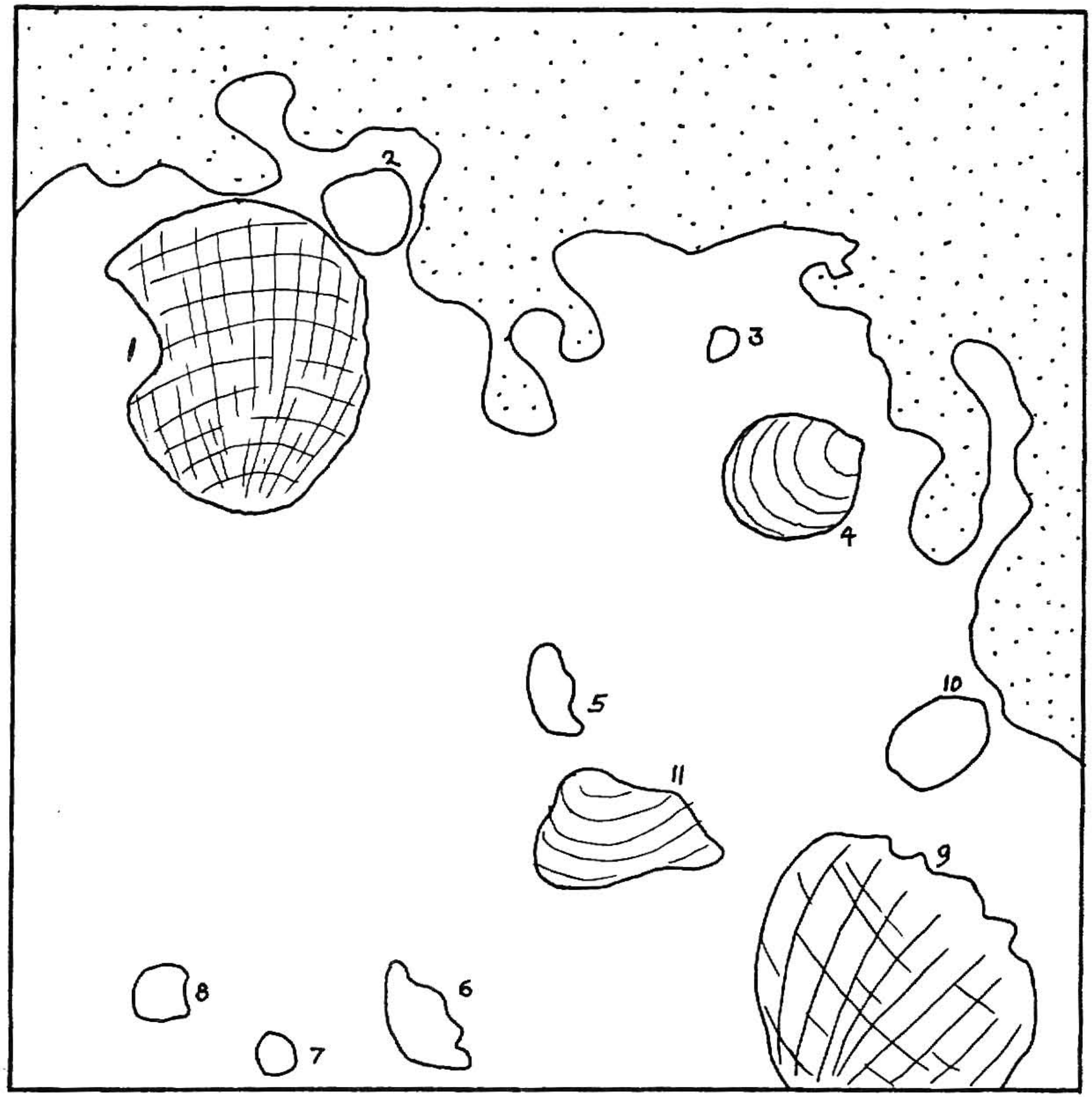
D = 2.257
E = 1.200
GB = 3



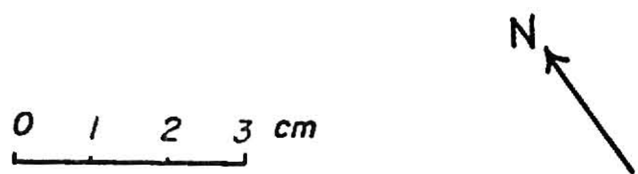
BR-M-5

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Ret	3.4	4.9	cvu	cval		x		o	
2	Lino	1.2	1.2	cvu	cval				o	
3	Lg	.3	.5				x		o	
4	Ast	1.8	2.1	cvu	oval	r/l				
5	Lg	.6	1.3	ccu		b	x		o	
6	Lg	.8	1.8	ccu		b	x		o	
7	Cru	.5	.6	ccu		p			m	
8	Cru	1.0	1.0	ccu		p			m	
9	Rhip	4.2	3.8	cvu		p	x		o	
10	Rea	1.5	1.0	cvu		p	x		o	
11	Sch	2.4	1.6	cvu	oval	r/l				

BR-M-5

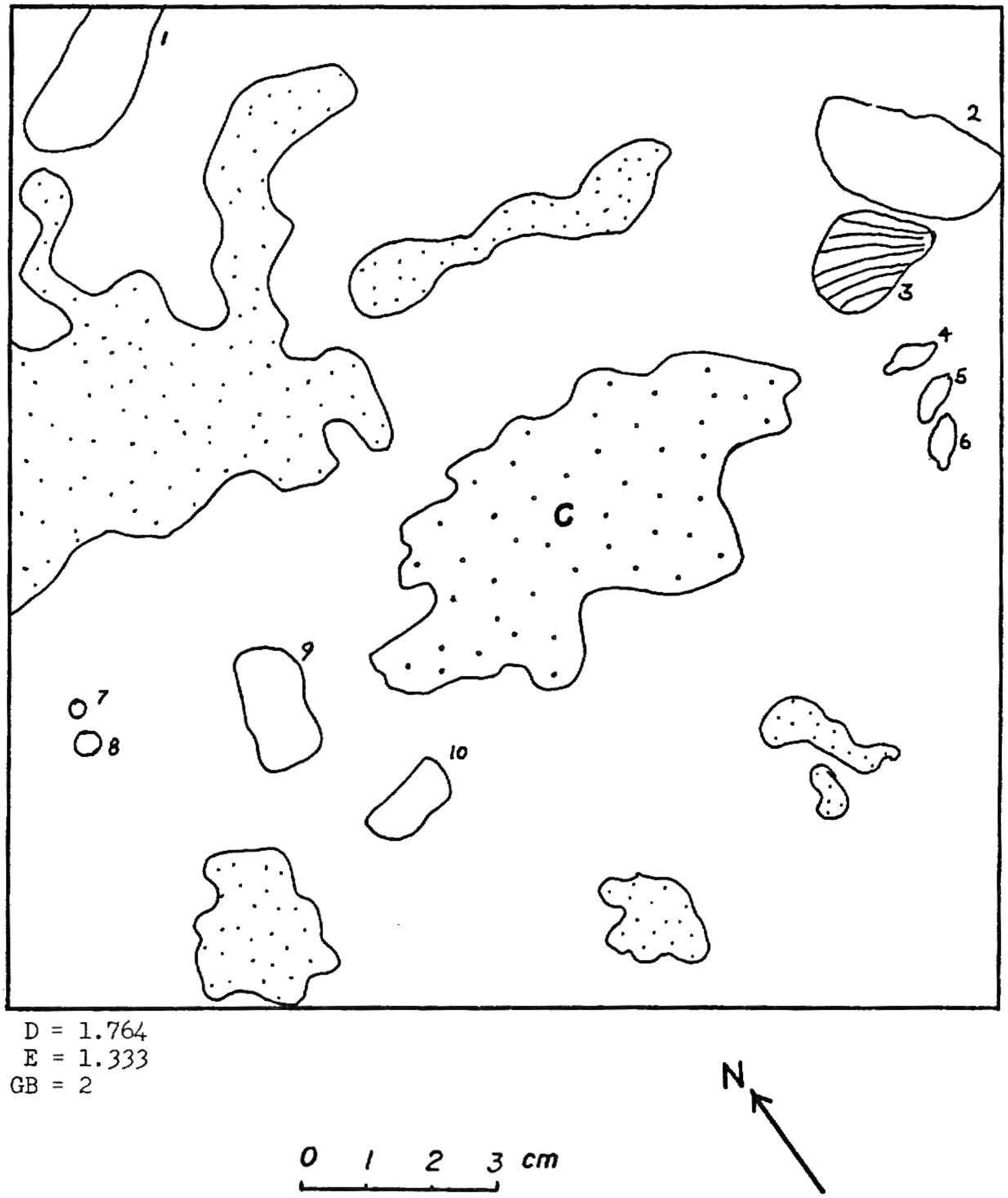


D = 1.003
E = 1.375
GB = 2



#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	brac	2.5	1.1	ccu			x		m	
2	Nesp	3.1	1.5	ccu					m	
3	Lino	7.6	1.5	ccu		P	x		m	
4	Fus	.7	.3	p					o	
5	Fus	.7	.3	p					o	
6	Fus	.6	.4	p					o	
7	Fus	.3	.8	i					o	
8	Fus	3	3	i					o	
9	Nech	1.8	.9	cd		p			o	
10	Nech	1.4	.6	cd		b			o	

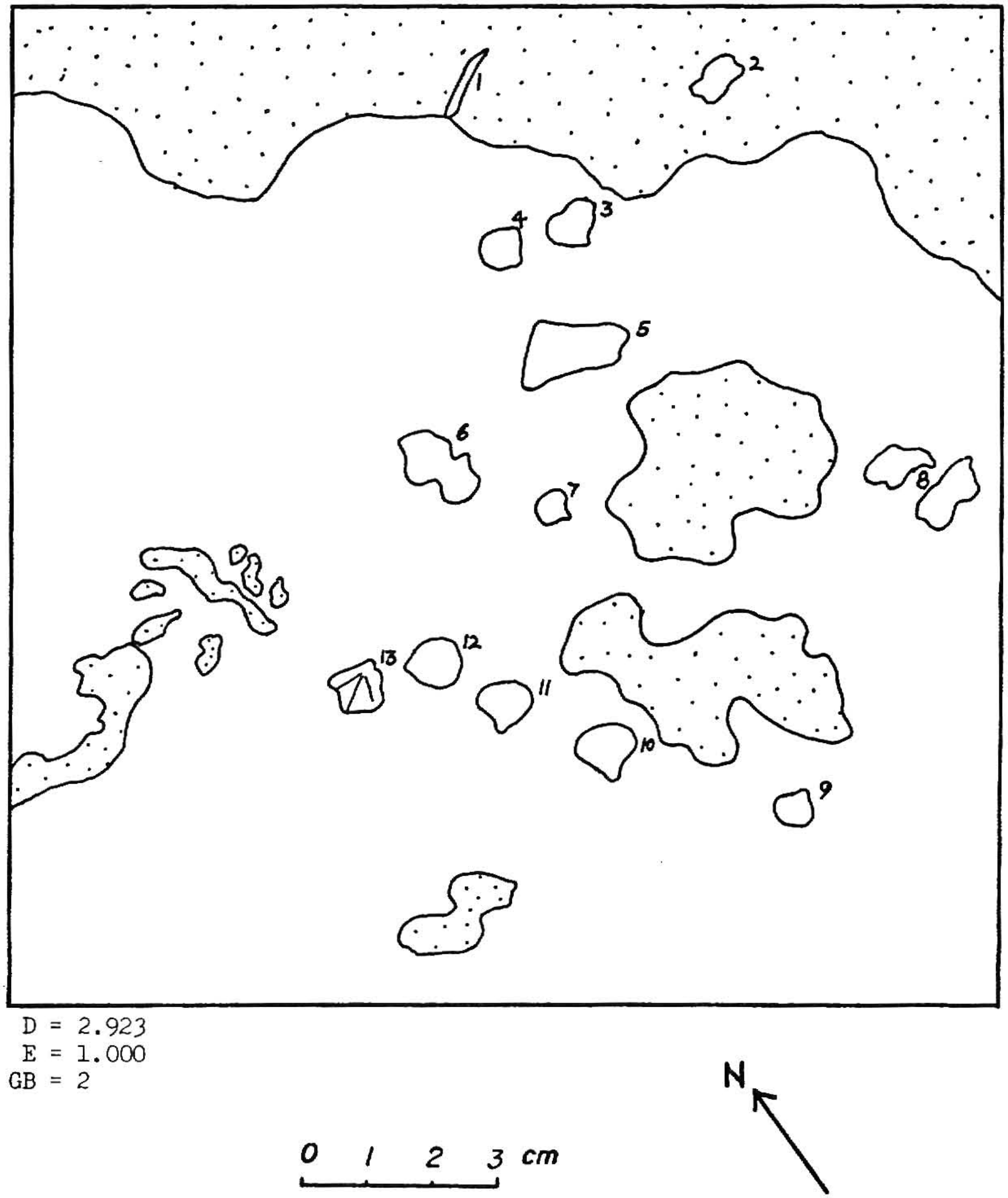
BR-M-6



D = 1.764
E = 1.333
GB = 2

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	brac	.2	1.2				x		o	
2	Crin	.5	1.0	p			x		cal	
3	Well					b			o	
4	Cru	.6	.6	cvu		b			o	
5	brac	.7	1.6	p			x		o	
6	?	.8	1.4				x		o	
7	Cru	.6	.5	cvu	cval				o	
8	brac	1.5	1.1	p			x		o	
9	Cru	.6	.5	cvu	cval				o	
10	Cru	.9	.9	cvu		b			o	
11	Cru	.8	.9	cvu		b			o	
12	Cru	.8	.8	ccu					o	
13	Well	.9	.9	ccu		b			o	

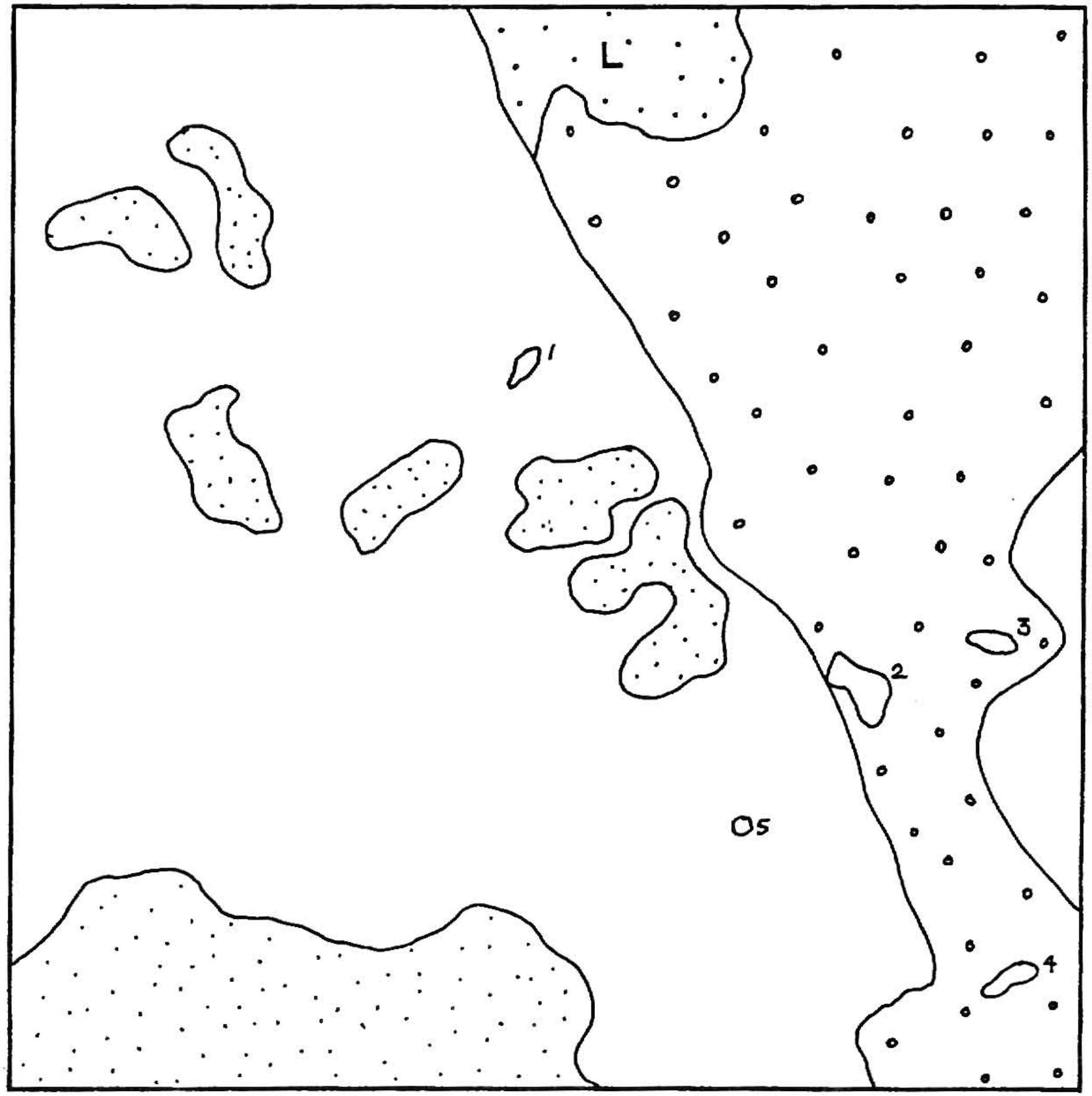
BR-L-1



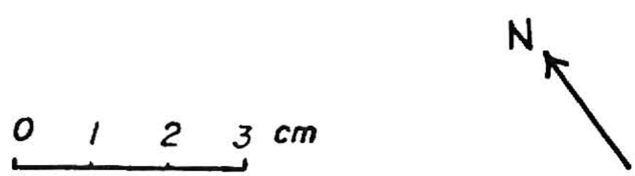
D = 2.923
E = 1.000
GB = 2

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Ech	.2	.2				x		o	
2	Crin	.9	.4	i					o	
3	Fus	.4	.2	p					o	
4	Fus	.6	.2	p					o	
5	Fus	.3	.3	i					o	

BR-L-2

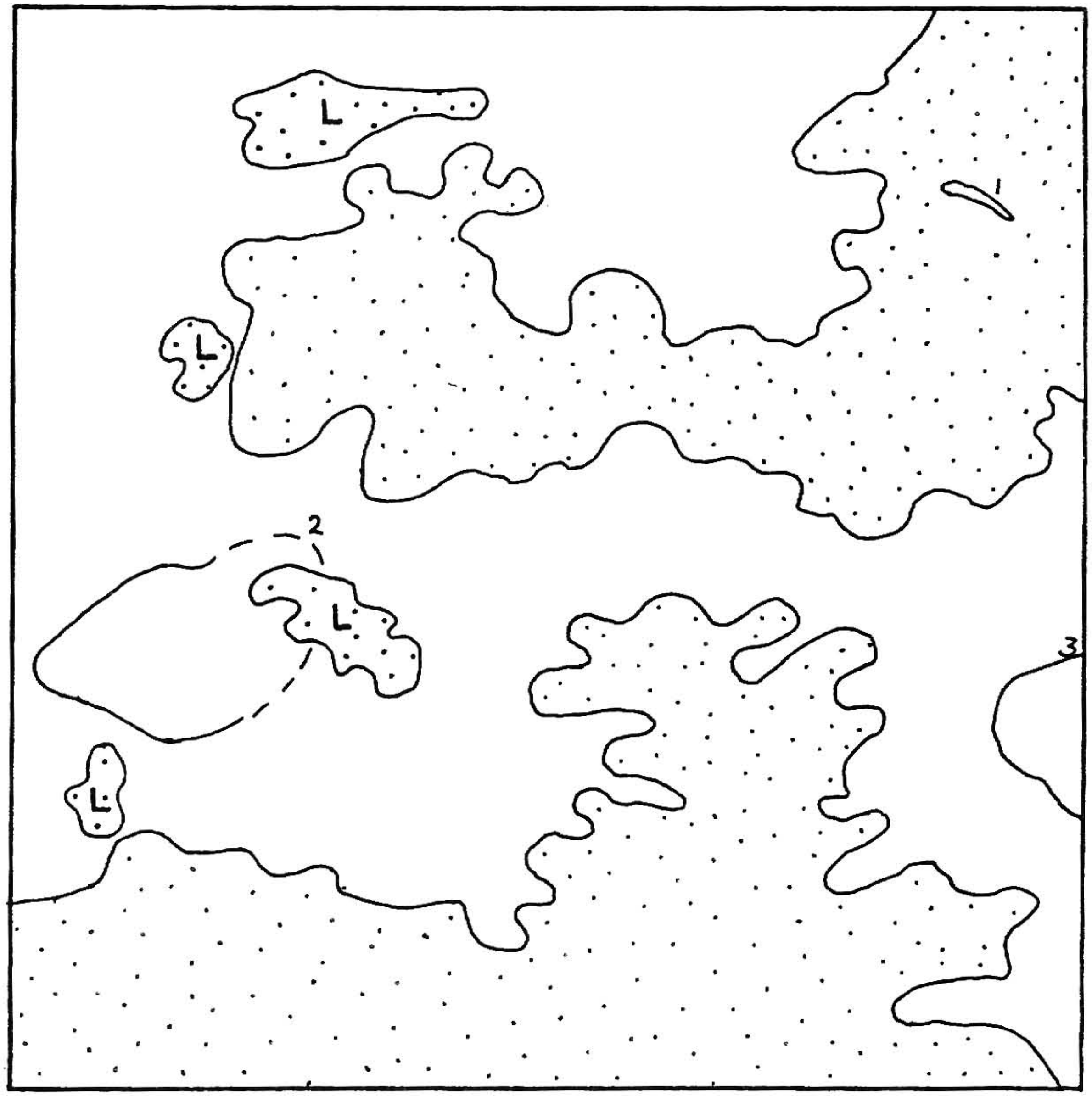


D = 1.585
E = 1.000
GB = 3

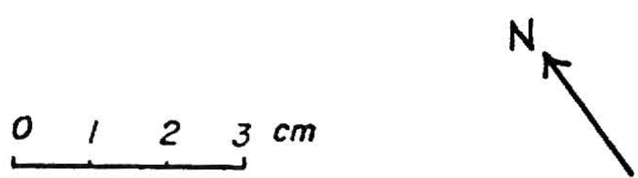


#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	brac	.8	.2						o	
2	Ret	4.0	1.5	ccu	p				o	
3	Comp	1.5	.9	cvu	cval				m	

BR-L-3



D = 1.003
E = 1.000
GB = 3

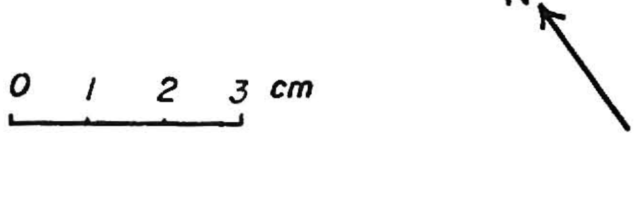


BR-L-4

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Crin	.4	1.1	p			x			
2	Comp	1.5	1.7	ccu		p			o	
3	Comp	2.7	2.4	ccu		p	x		o	
4	Lino	3.4	3.0	ccu		?			m	
5	Comp	1.7	1.7	cvu		b			o	
6	Well	.9	1.0		cval				m	

BR-L-4

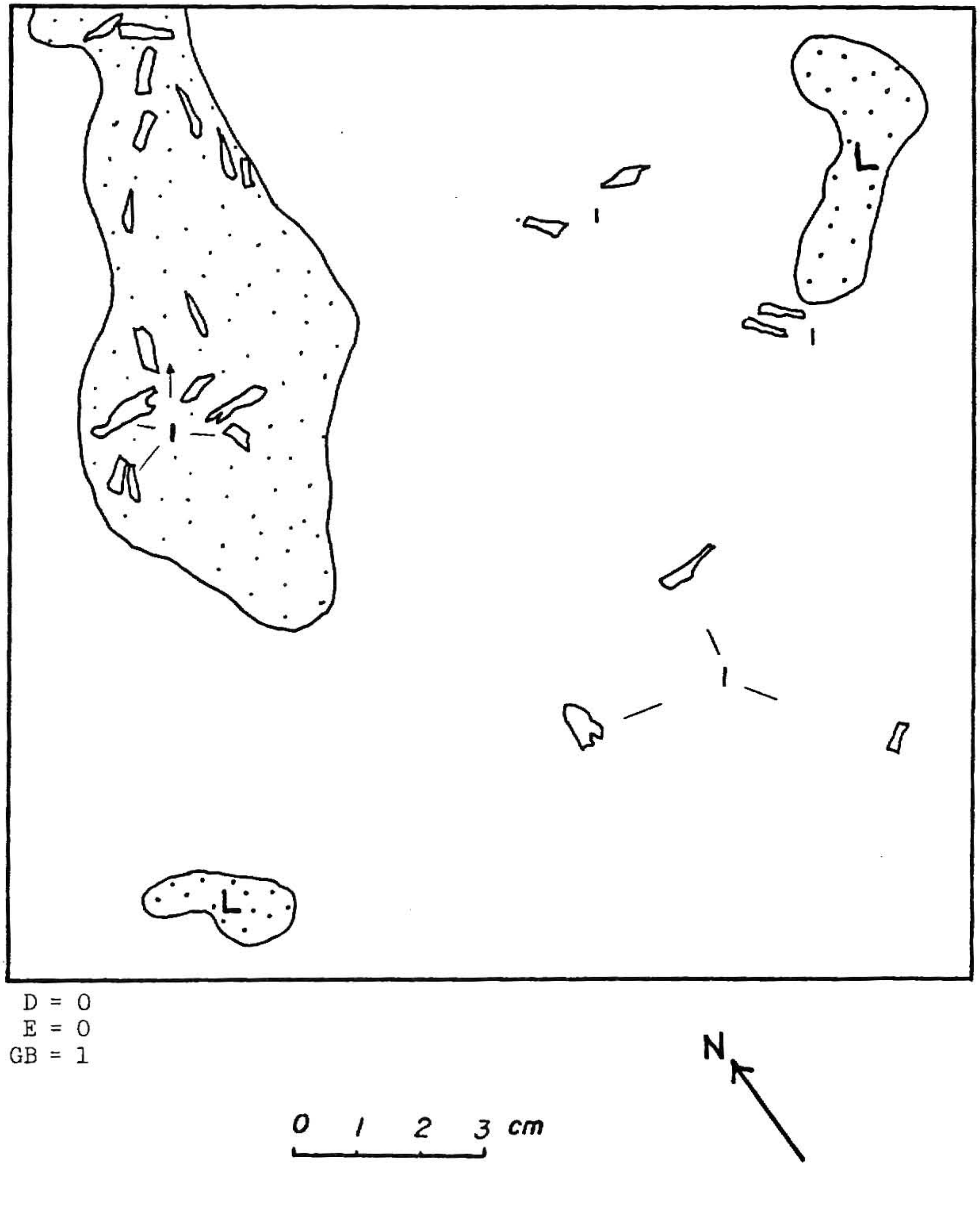
D = 1.897
E = 1.250
GB = 1



BR-L-5

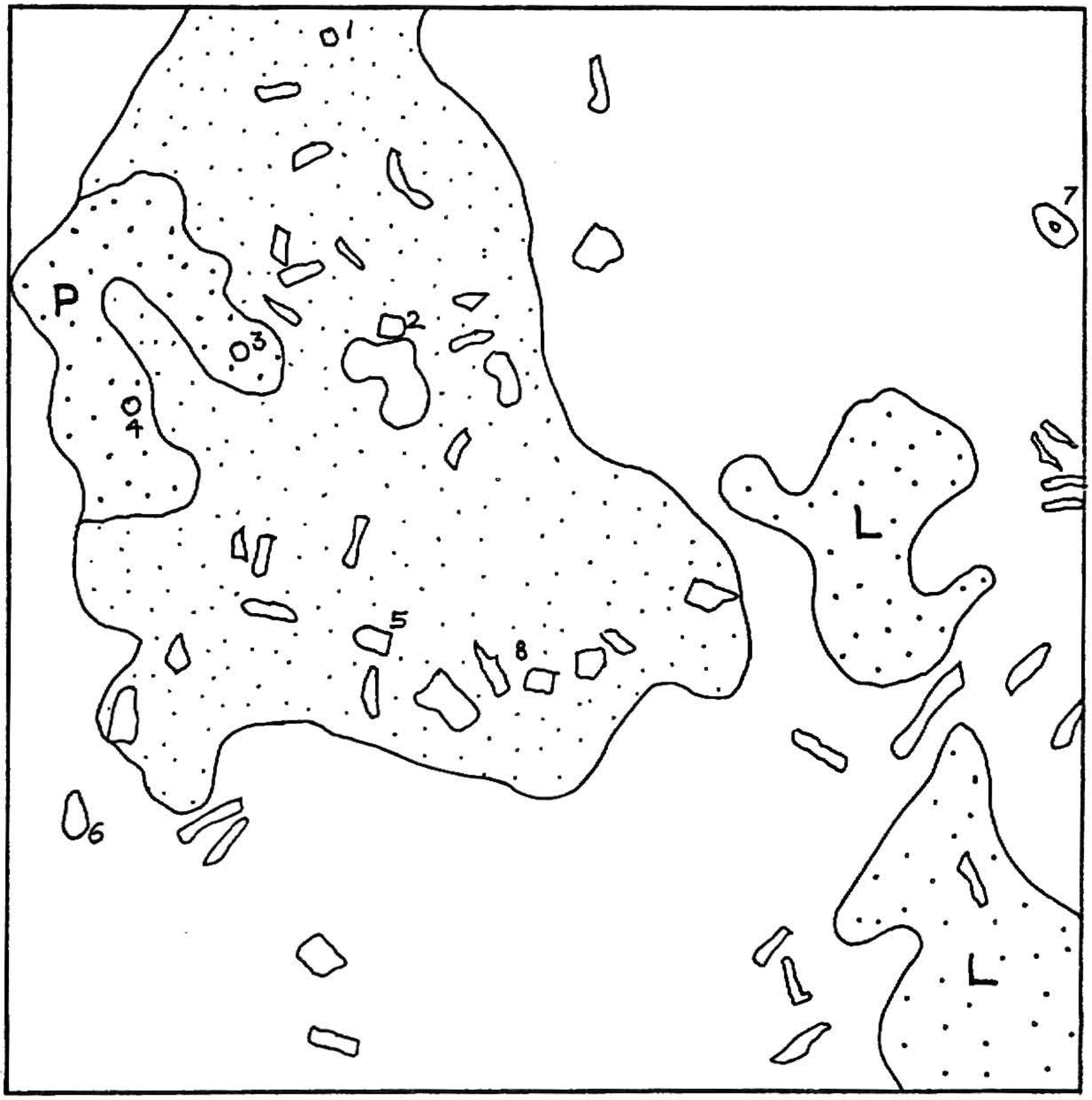
#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
	Iso						x		o	

BR-L-5

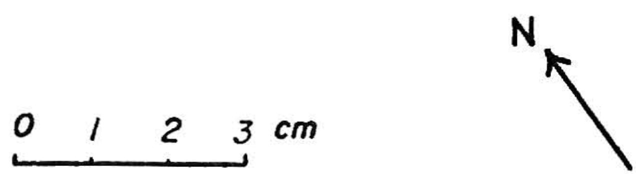


#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Crin	.2	.2	i						
2	Crin	.2	.3	i						
3	Crin	.2	.2	i						
4	Crin	.2	.2	i						
5	Crin	.4	.2	p						
6	Crin	.3	.2	i						
7	Crin	.5	.3	i						
8	Iso						x		o	

BR-L-6



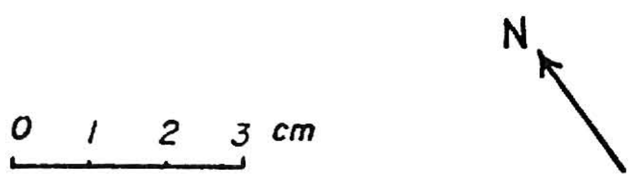
D = .551
E = 1.000
GB = 3



#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Crin	.1	.1	i					o	
2	Crin	.2	.2	i					o	
3	Crin	.5	.3	ccu	cval				o	
4	Lino	1.4	.8			?	x		o	
5	Iso						x		o	

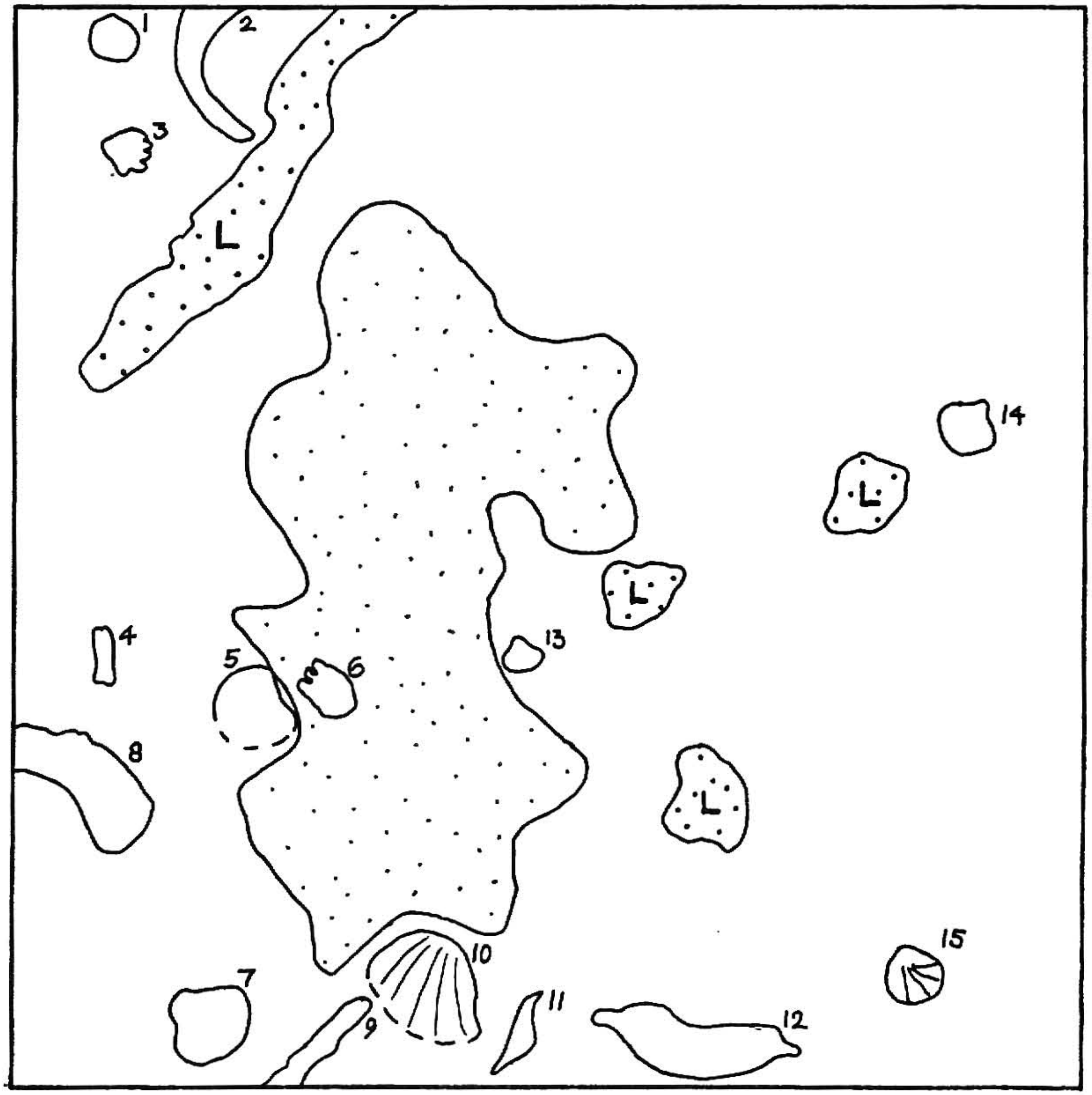
BR-L-7

D = 1.923
E = 1.250
GB = 2

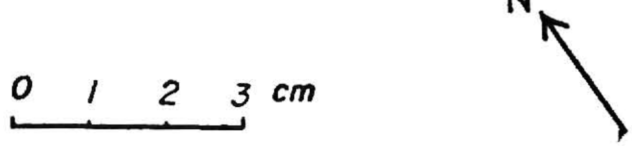


#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.6	.6	cvu		b			o	
2	?	2.4	.8							
3	Hust	.6	.7	p	cval				m	
4	Crin	.5	.2	i					o	
5	Comp	1.3	1.1	cvu		p			o	
6	Hust	.6	.8	p	cval				o	
7	Comp	1.3	1.1	cvu		p			o	
8	Ret	2.6	1.2	ccu	cval		x		o	
9	Lino	1.9	.6			?	x		o	
10	Lino	1.7	1.5	ccu		b	x		o	
11	Nech	1.2	.4	i	cval		x		o	
12	Nesp	3.0	1.0	i	cval		x		o	
13	Cru	.6	.5	cvu		b			o	
14	Cru	.7	.8	cvu		b			o	
15	Well	.8	.7	ccu		p			o	

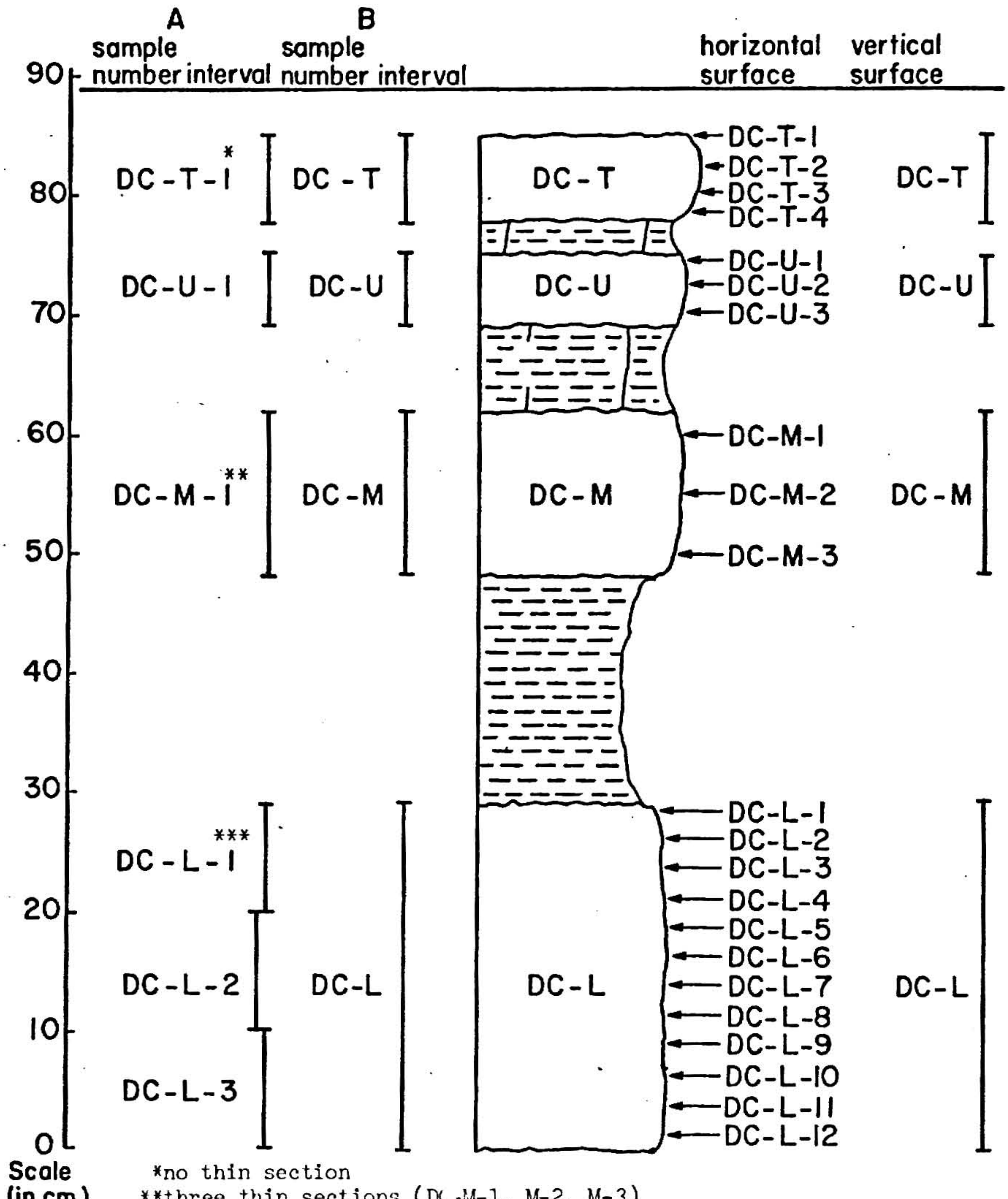
BR-L-8



D = 3.033
E = 1.667
GB = 2



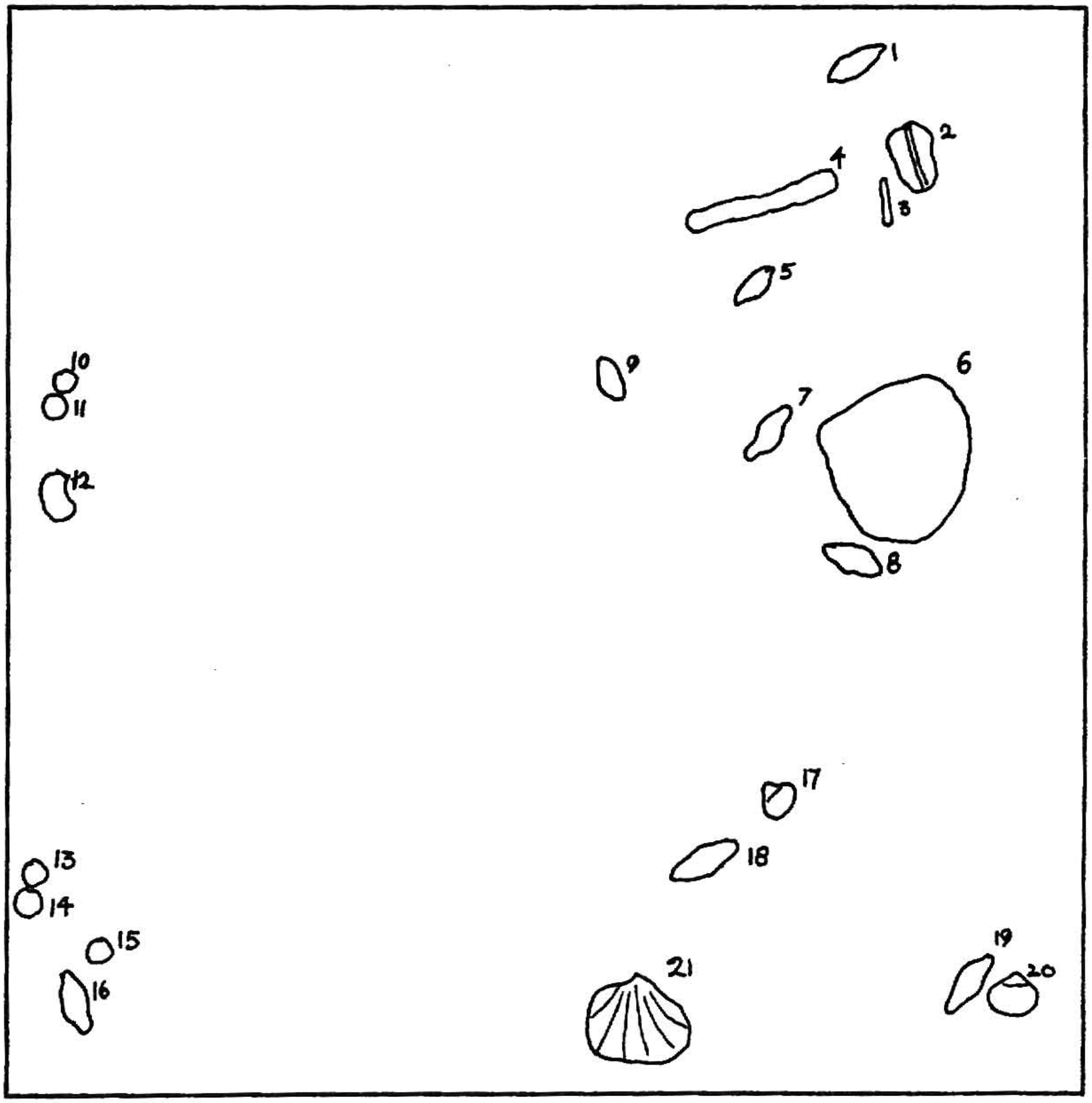
DEEP CREEK (DC) SECTION



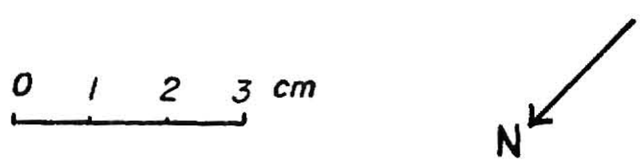
*no thin section
**three thin sections (DC-M-1, M-2, M-3)
***four thin sections (DC-L-1, L-2, L-3, L-4)

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Fus			p					o	
2	Bell	.9	.6	i					o	
3	rI	.6	.1				x		o	
4	rII	2.2	.4				x		o	
5	Fus			p					o	
6	Comp	2.4	2.2	ccu		p			o	
7	Fus					p			o	
8	Fus					p			o	
9	Fus					p			o	
10	Fus					i			o	
11	Fus					i			o	
12	Bell	.6	.4	i					o	
13	Fus					i			o	
14	Fus					i			o	
15	Fus					i			o	
16	Fus					p			o	
17	Cru	.5	.5	ccu		b			o	
18	Fus			p					o	
19	Fus			p					o	
20	Cru	.6	.5	cvu		b			o	
21	Rhip	1.5	1.2	ccu		p			o	

DC-T-1

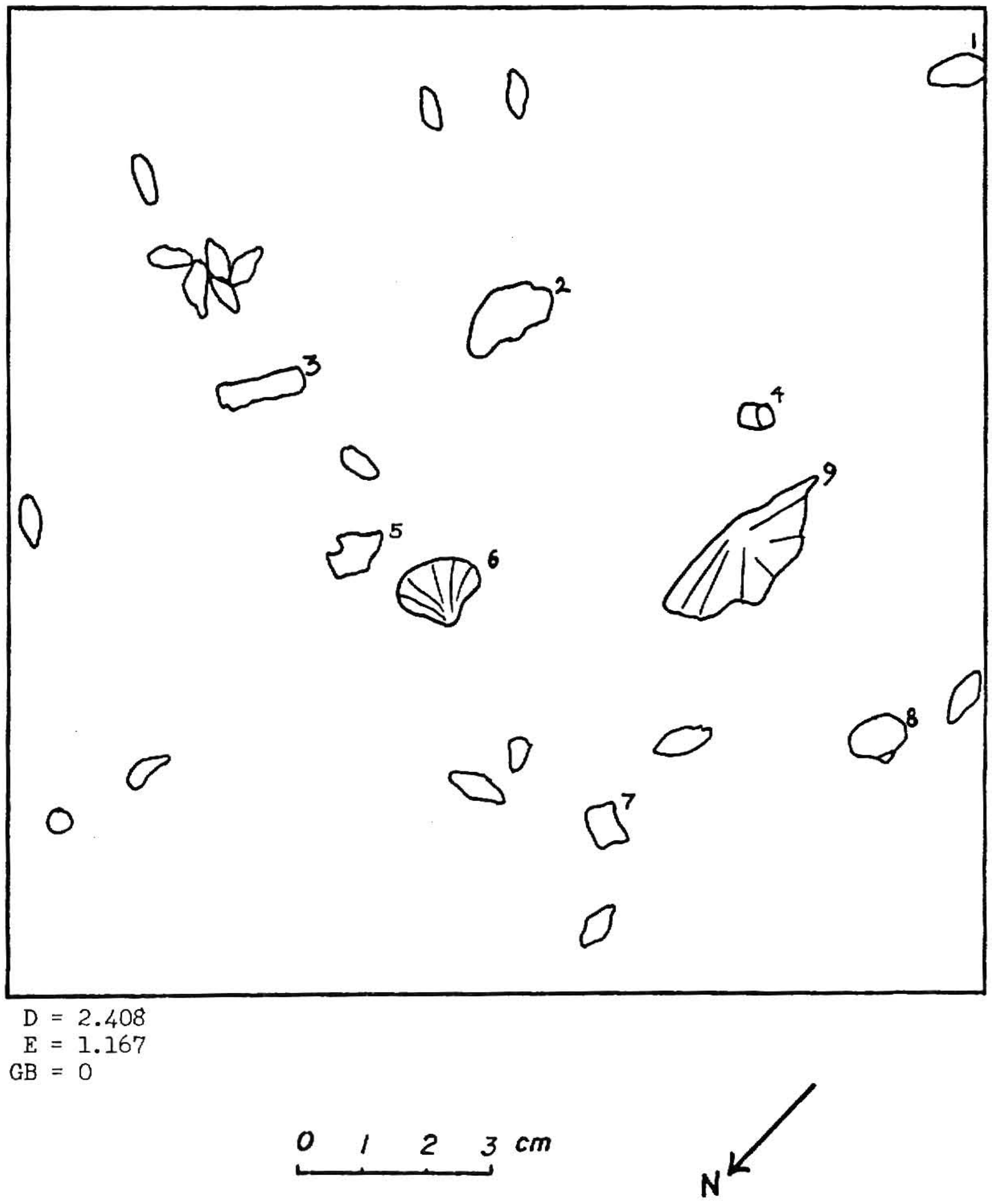


D = 2.724
E = 1.286
GB = 0



#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Fus			p					o	
2	rIII	1.2	.6	p			x		o	
3	rIV	1.9	.5	p			x		o	
4	rIII	.9	.5	p			x		o	
5	rIII	1.5	.6	p			x		o	
6	Rhip	1.3	.4	ccu		p			o	
7	rIII	.5	.4	p			x		o	
8	Cru	1.2	.9	cvu		b			o	
9	Nesp	3.1	1.3	ccu		b	x		o	

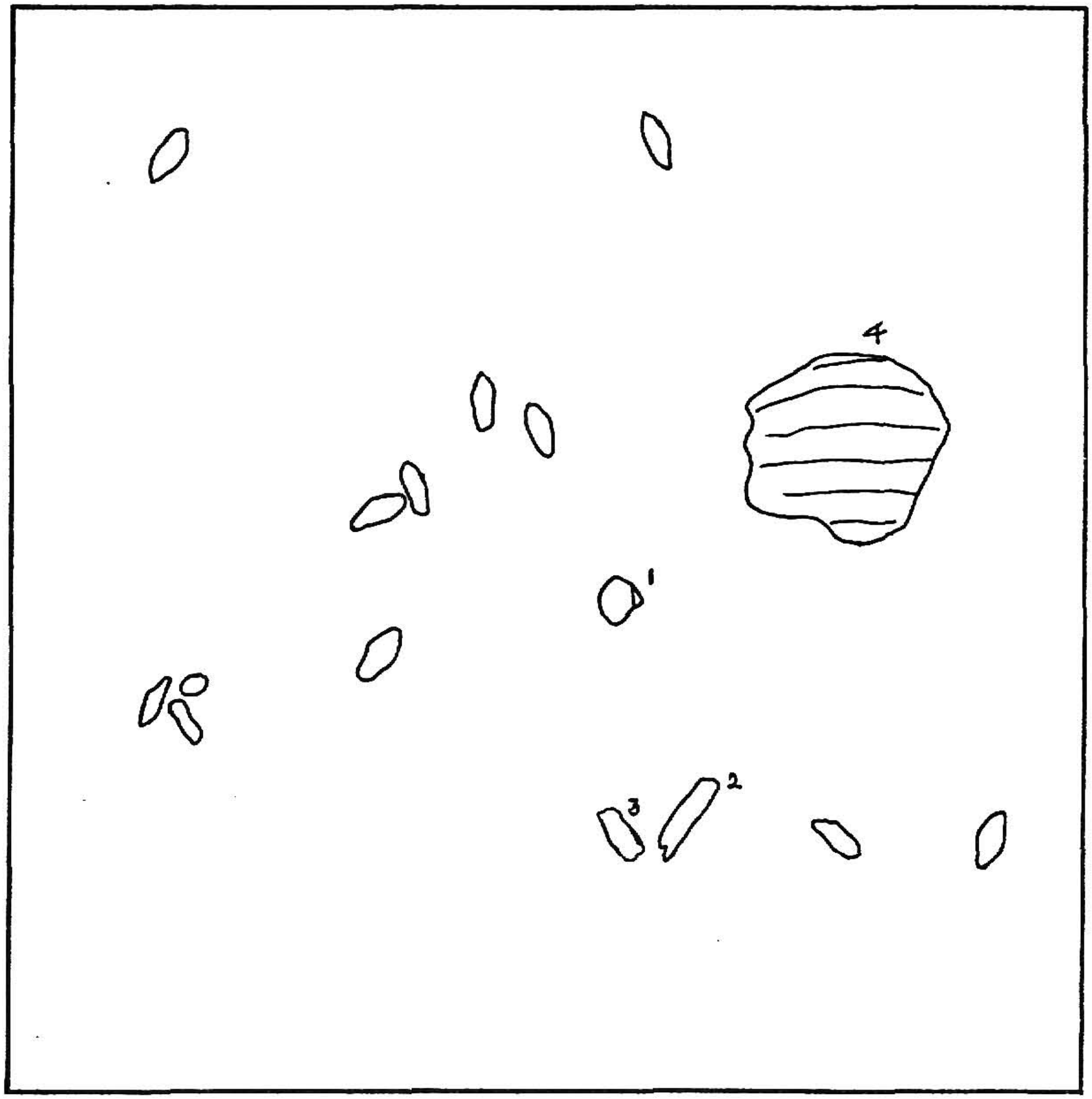
DC-T-2



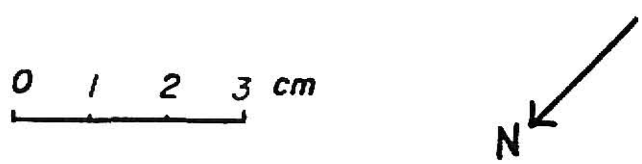
DC-T-3

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.5	.6	ccu		p			o	
2	Crin	.8	.3	p			x		o	
3	rII	1.3	.3	p			x		o	
4	Lino	2.7	2.6	ccu		p	x		o	

DC-T-3



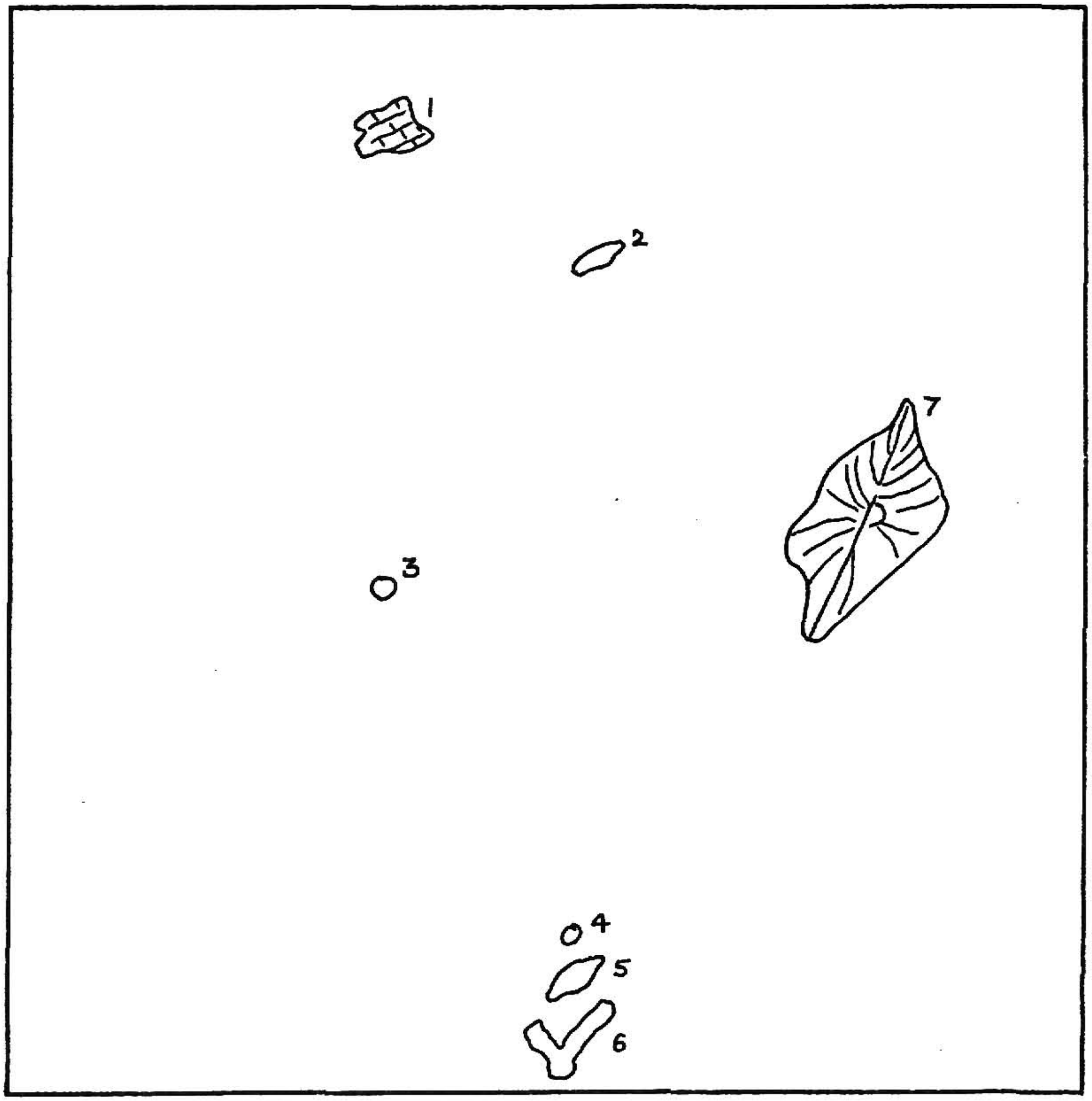
D = 1.993
E = 1.250
GB = 0



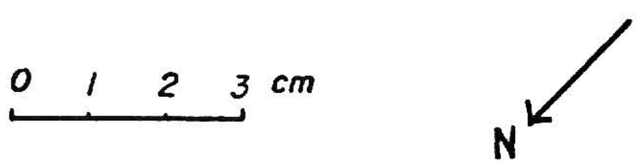
DC-T-4

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	fII	.9	1.0	p			x		o	
2	Fus	.5	.3	p					o	
3	Fus	.3	.3	i					o	
4	Fus	.2	.2	i					o	
5	Fus	1.0	.6	p					o	
6	rII	1.0	1.0	p			x		o	
7	Nesp	3.5	2.0		cval		x		o	

DC-T-4

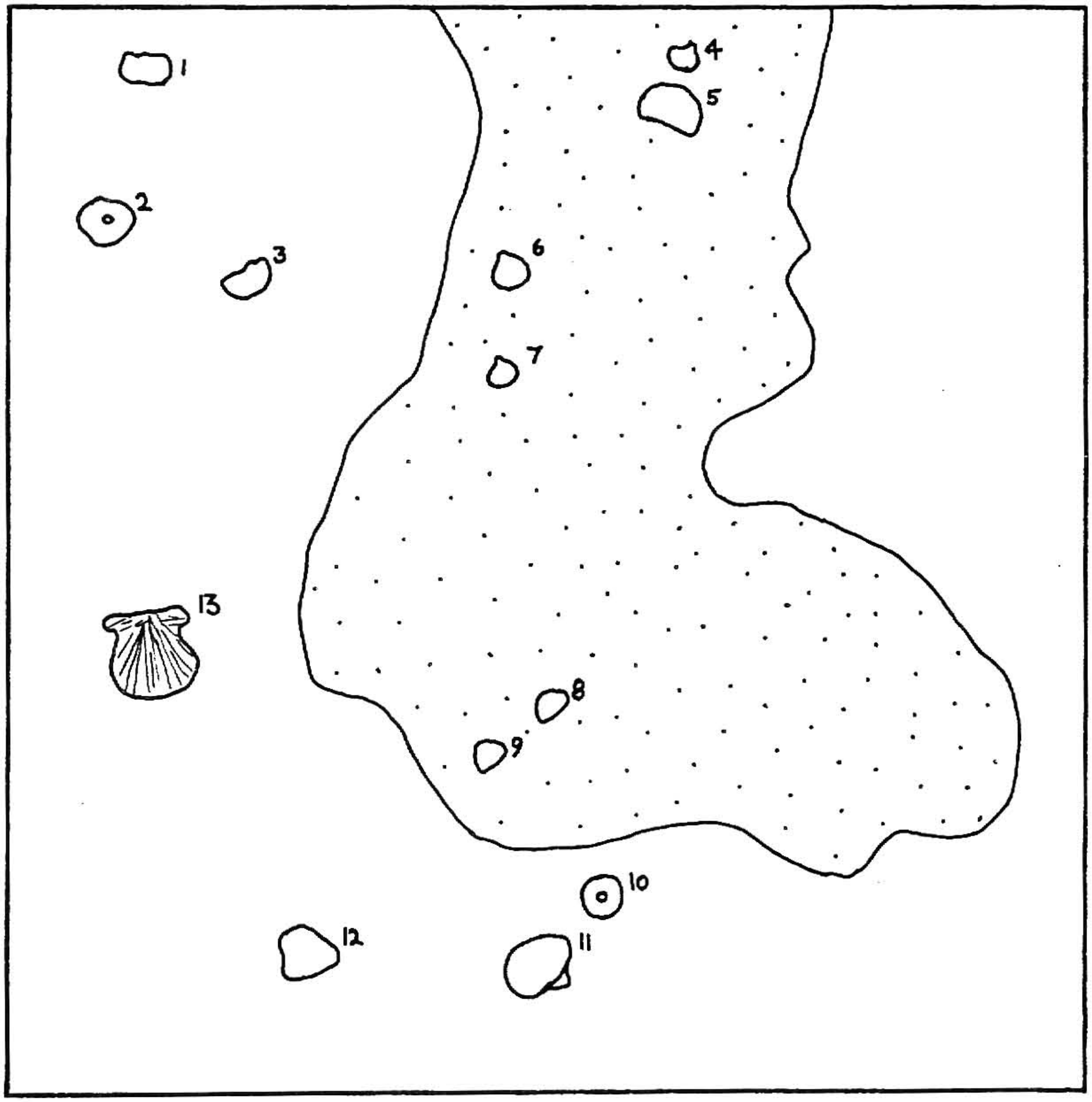


D = 1.585
E = 1.333
GB = 0

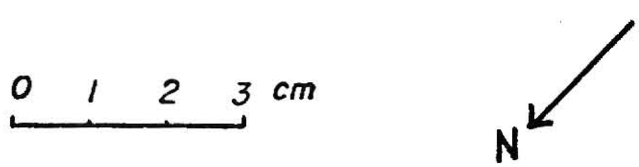


#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.7	.4	ccu		b			m	
2	Crin	.7	.7	i						
3	Cru	.7	.4	ccu		b			m	
4	Cru	.4	.4	cvu		p	x		o	
5	Nech	.9	.5	ccu		p			m	
6	Cru	.6	.5	ccu		p			o	
7	Cru	.5	.4	cvu		p			o	
8	Cru	.6	.4	ccu		b			m	
9	Cru	.5	.4	cvu		p			o	
10	Crin	.6	.6	i					o	
11	Cru	1.1	1.0	cvu		p			o	
12	Cru	.6	.8	cvu		p	x		o	
13	Apec	1.1	1.2	cvu		r			o	

DC-U-1

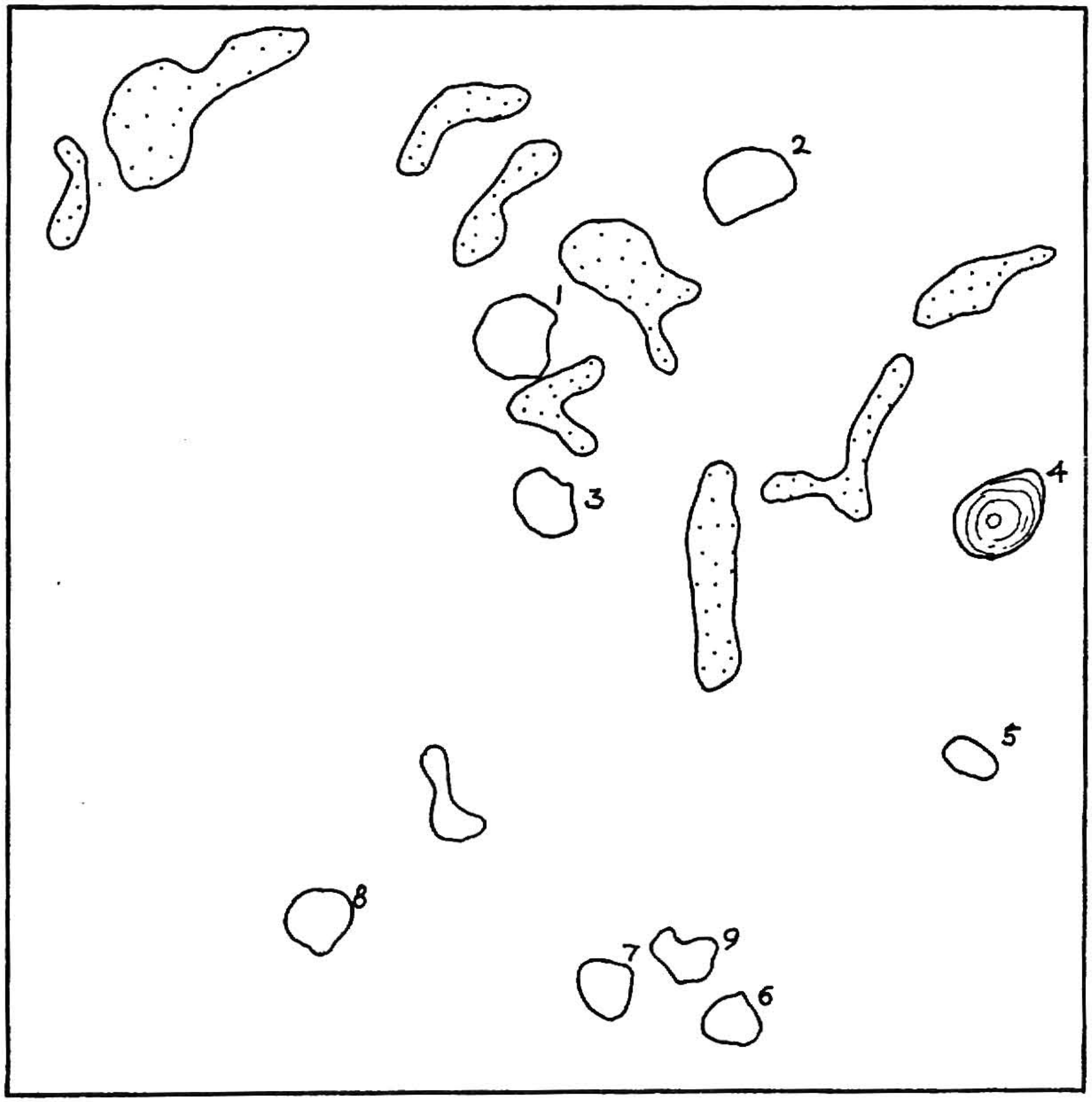


D = 1.571
E = 1.000
GB = 2

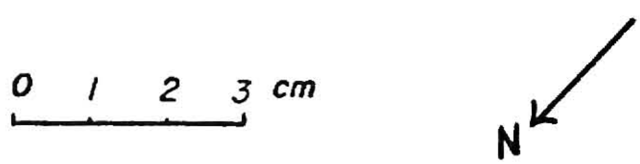


#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	1.2	1.0	cvu		p	x		o	
2	Cru	1.2	1.0	ccu		b			m	
3	Cru	1.0	.8	cvu		p			o	
4	Cru	1.5	1.1	cvu		b	x		o	
5	Cru	.8	.4	ccu		b			o	
6	Cru	.8	.7	cvu		p			o	
7	Cru	1.0	.9	cvu		p			o	
8	Cru	.9	1.0	cvu		p			o	
9	Lg	.9	.7	cvu		?	x		o	

DC-U-2

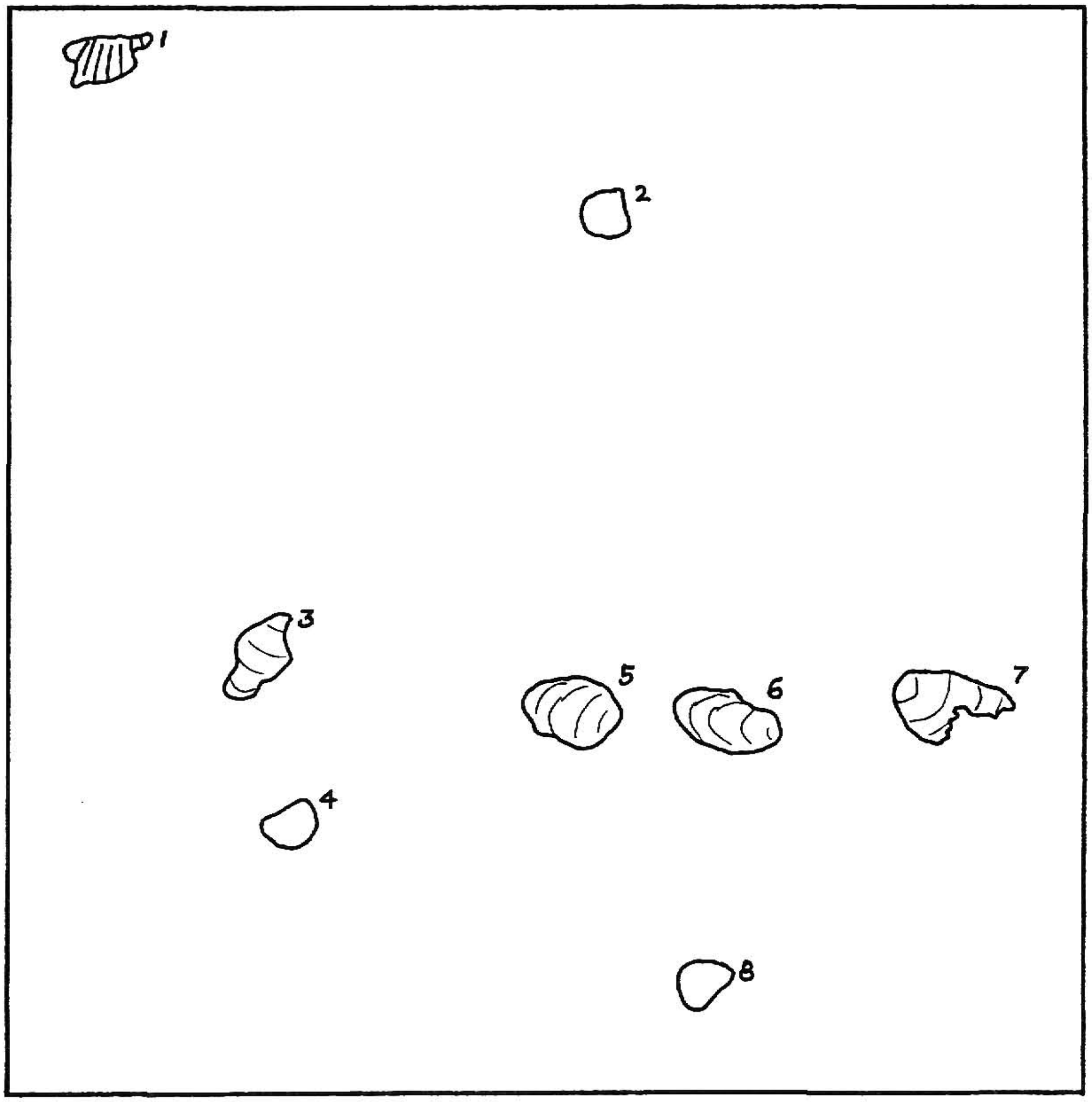


D = 1.149
E = 1.000
GB = 1

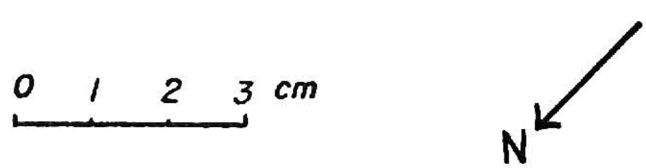


#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Lino	1.2	.6	cvu		p	x		o	
2	Cru	.8	.7	cvu		p			o	
3	Lg	.8	1.4	ccu		b			m	
4	Cru	.8	.6	cvu		p			o	
5	Lg	.9	1.4	ccu		b			o	
6	Lg	.8	1.7	ccu			x		o	
7	Lg	1.0	1.6	ccu		p	x		o	
8	Cru	.8	.5	ccu		b			o&m	

DC-U-3



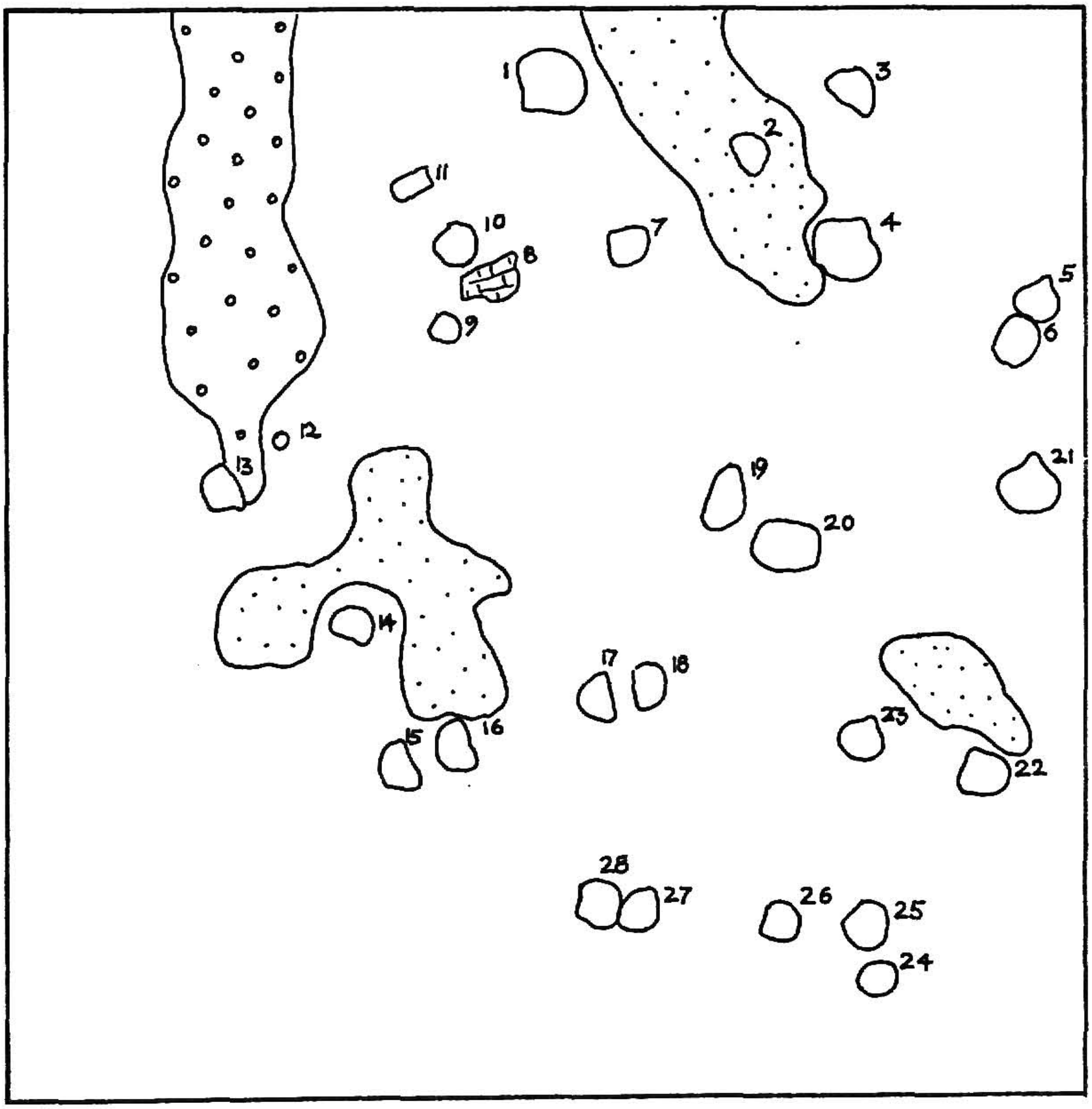
D = 1.521
E = 1.333
GB = 0



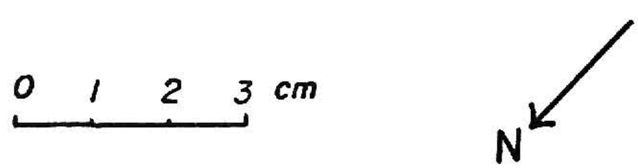
DC-M-1

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	1.0	.9	cvu	cval				o	
2	Cru	.6	.4	ccu		p			o	
3	Cru	.7	.5	ccu		p	x		o	
4	Cru	1.0	.9	cvu		b			o	
5	Cru	.7	.6	cvu		b	x		o	
6	Cru	.6	.7	cvu		b	x		o	
7	Cru	.6	.6	cvu		b			o	
8	rI	.9	.7	p			x			
9	Cru	.3	.4	ccu		b	x		o	
10	Cru	.6	.5	cvu		b	x		o	
11	Crin	.6	.3	p					cal	
12	Crin	.2	.2	i					cal	
13	Cru	.6	.5	ccu		p			o	
14	Cru	.7	.5	ccu		p			o&m	
15	Cru	.7	.5	ccu		p	x		o	
16	Cru	.7	.5	ccu		p			o	
17	Cru	.6	.6	cvu		p			o	
18	Cru	.7	.4	ccu		p			m	
19	Cru	.9	.6	cvu		b	x		m	
20	Cru	1.0	.8	cvu		b	x		o	
21	Cru	.9	.7	cvu		p			o	
22	Cru	.7	.6	cvu		b			o	
23	Cru	.7	.4	cvu		b			o	
24	Crin	.4	.4	p					o	
25	Cru	.7	.6	cvu		b			o	
26	Cru	.5	.4	cvu		b			o	
27	Cru	.6	.5	cvu		b	x		o	
28	Cru	.7	.6	cvu		b	x		o	

DC-M-1

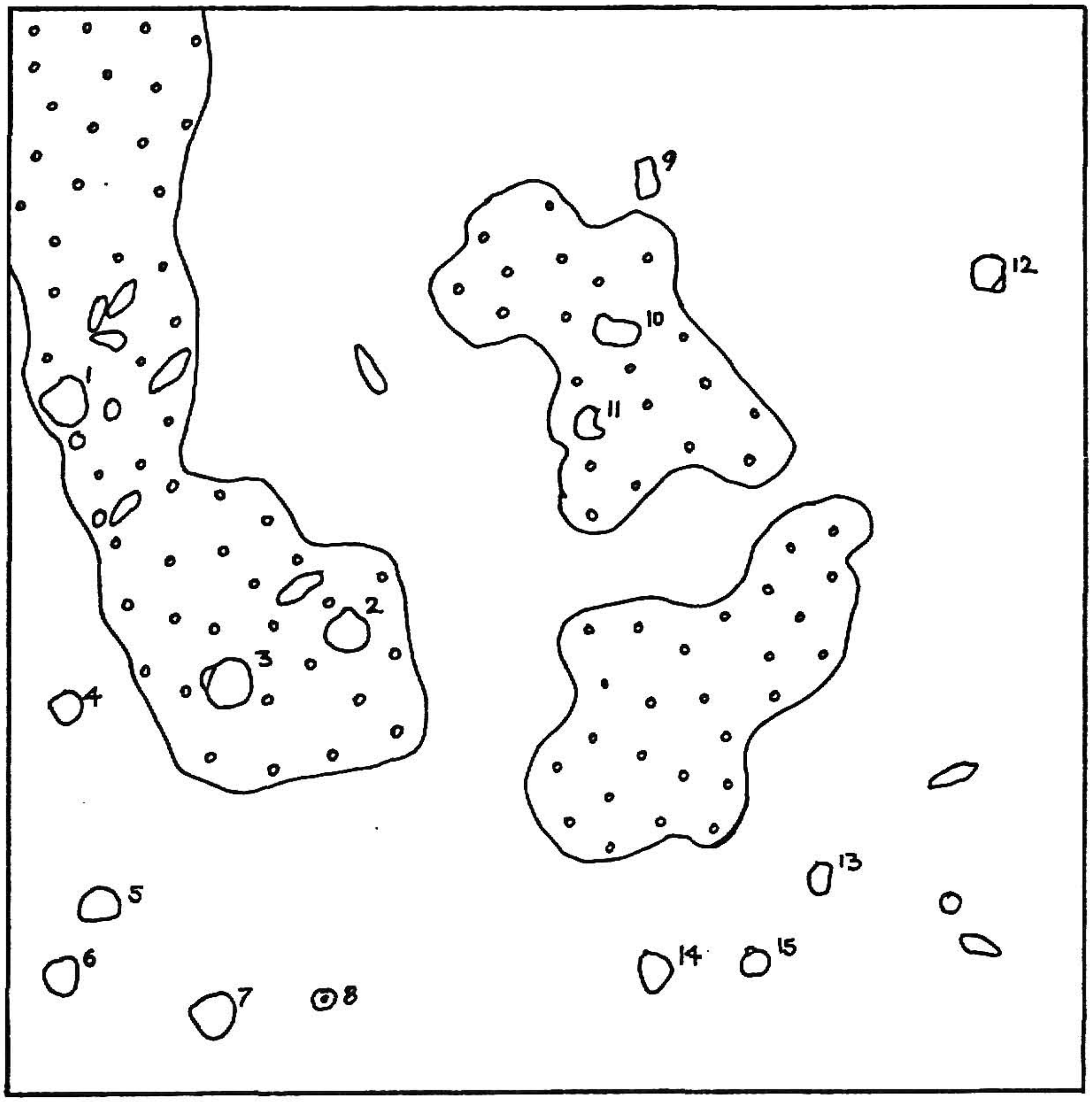


D = .777
E = .667
GB = 1

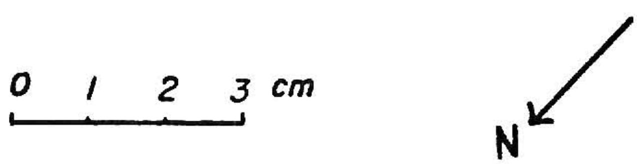


#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.7	.6	cvu		b	x		o	
2	Cru	.6	.6	cvu		b			o	
3	Cru	.7	.7	cvu		b			o	
4	Cru	.4	.4	cvu		b			o	
5	Cru	.4	.5	ccu		p	x		o	
6	Cru	.5	.5	cvu		p	x		o	
7	Cru	.6	.7	cvu		b			o	
8	Crin	.2	.2	i			x		o	
9	Crin	.6	.2	p					o	
10	Cru	.6	.3	ccu		p	x		o	
11	Cru	.5	.4	i	cval				o	
12	Cru	.5	.4		cval				o	
13	Cru	.4	.4	cvu		b	x		m	
14	Cru	.5	.4	cvu	cval				o	
15	Cru	.6	.4	cvu		b	x		o	

DC-M-2

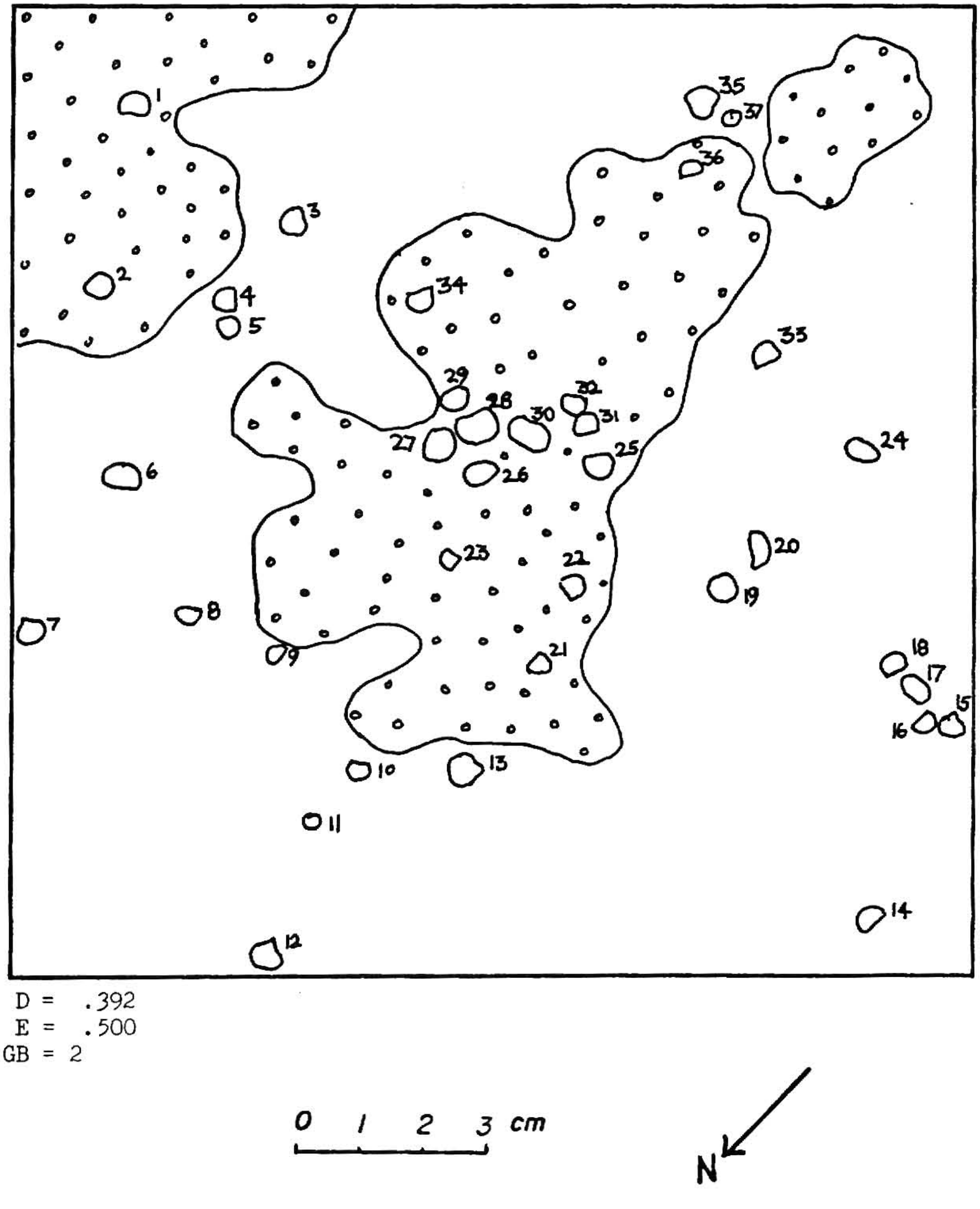


D = .651
E = 1.000
GB = 2



#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.5	.3	cvu		b	x		o	
2	Cru	.3	.2	cvu		b			o	
3	Cru	.6	.3	cvu		b			o	
4	Cru	.4	.4	cvu		b			o	
5	Cru	.4	.4	cvu		b			o	
6	Cru	.6	.4	cvu		p	x		o	
7	Cru	.5	.4	cvu		b			o	
8	Cru	.3	.3	?			x		o	
9	Cru	.3	.2	cvu		b	x		o	
10	Cru	.4	.2	ccu		p			o	
11	Cru	.2	.2	cvu		b			o	
12	Cru	.5	.4	?			x			
13	Cru	.6	.4	ccu		b			o	
14	Cru	.4	.2	ccu		p	x		o	
15	Cru	.4	.3	cvu		b			o	
16	Cru	.3	.3	ccu		b	x		m	
17	Cru	.5	.3	cvu		b	x		o	
18	Cru	.3	.3	cvu		b			o	
19	Cru	.5	.5	cvu		b			o	
20	?	.8	.3	?	cval				m	
21	Cru	.3	.3	cvu		b			o	
22	Cru	.3	.2	cvu		b			o	
23	Cru	.2	.1	cvu		b			o	
24	Crin			i					o	
25	Cru	.6	.4	cvu	cval				o	
26	Cru	.5	.4	cvu	cval				o	
27	Cru	.5	.7	ccu		b			o	
28	Cru	.8	.7	ccu		p			o	
29	Cru	.3	.3	cvu		b			o	
30	Cru	.7	.5	ccu		p			m	
31	Cru	.3	.3	ccu		b			o	
32	Cru	.4	.3	cvu		p			o	
33	Crin			i					cal	
34	Cru	.3	.2	cvu		b			o	
35	Cru	.4	.4	ccu		b			o	
36	Crin								cal	
37	Crin								cal	

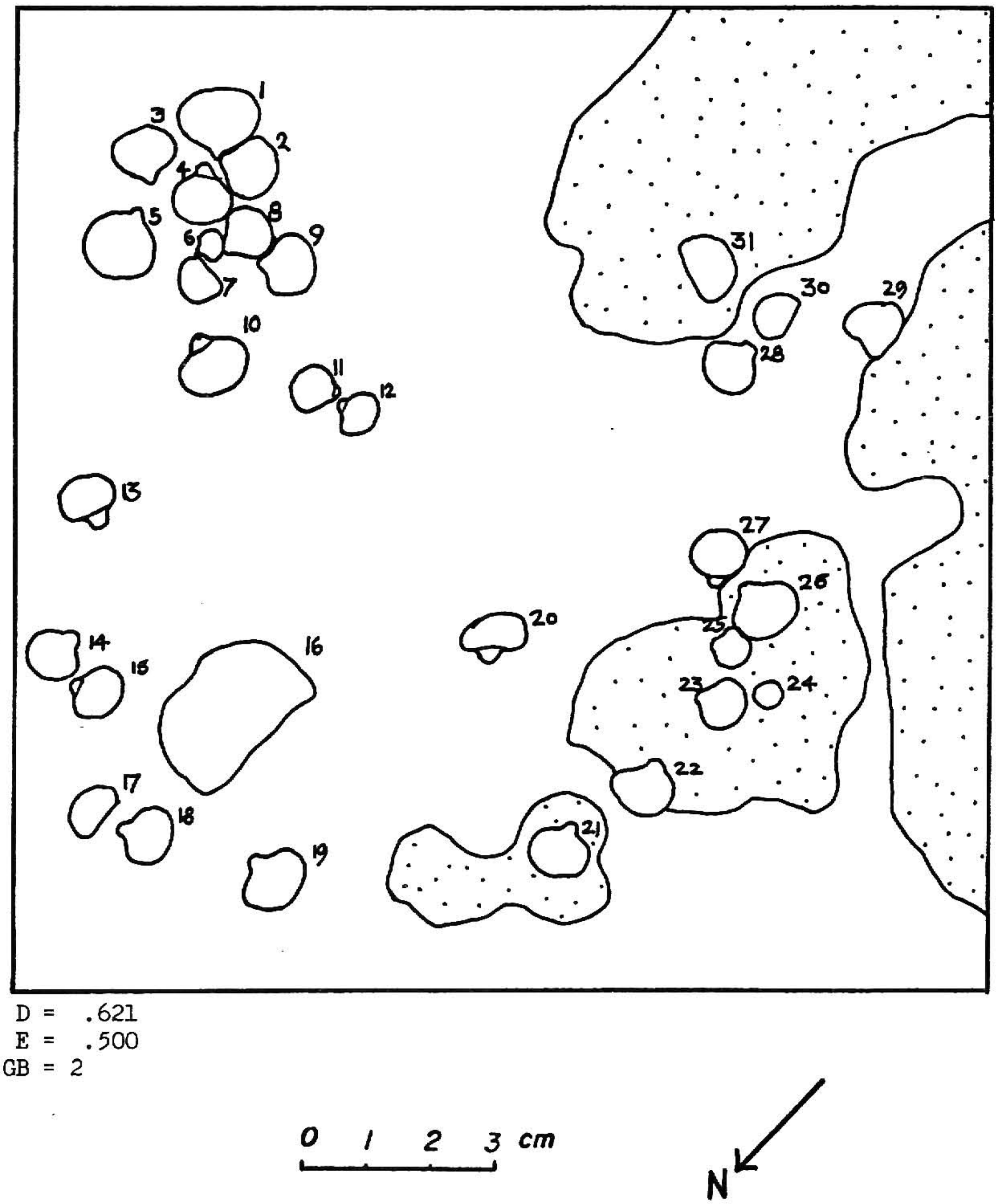
DC-M-3



D = .392
E = .500
GB = 2

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	1.3	.9	ccu		b			o	
2	Cru	.9	.7	ccu		b			o	
3	Cru	1.0	.9	ccu		b			o	
4	Cru	.9	18	ccu		b	x		o	
5	Comp	1.2	1.1	ccu		?			o&m	
6	Cru	.4	.5	cvu		b			o	
7	Cru	.6	.7	ccu		b			o	
8	Cru	.9	.9	ccu		p	x		m	
9	Cru	1.0	1.0	cvu	cval				o	
10	Cru	1.2	1.1	ccu		b			o	
11	Cru	.7	.7	ccu		b			o	
12	Cru	.5	.5	ccu		b				
13	Cru	1.0	1.0	ccu		b			o	
14	Cru	.8	.9	ccu		b	x		o	
15	Cru	.9	1.0	ccu		b	x		o	
16	Nesp	2.5	1.7	ccu					o	
17	Cru	.7	1.1	ccu		p	x		m	
18	Cru	.8	.9	ccu		b			o	
19	Cru	.9	1.2	ccu		b	x		o	
20	Cru	1.1	1.0	ccu		b	x		o	
21	Cru	.9	.9	ccu		b	x		o&m	
22	Cru	1.0	.9	cvu		p			o	
23	Cru	1.0	1.0	cvu		b			o	
24	Cru	.4	.3	ccu		b	x		o	
25	Cru	.6	.5	ccu		b	x		o	
26	Cru	1.4	1.0	ccu		b			o	
27	Cru	1.2	.9	cvu		b			o	
28	Cru	1.0	.8	ccu		b			o	
29	Cru	1.0	1.0	ccu		b	x		o	
30	Cru	.9	.8	ccu		p	x		o	
31	Nech	1.0	.7	cvu		p			o	

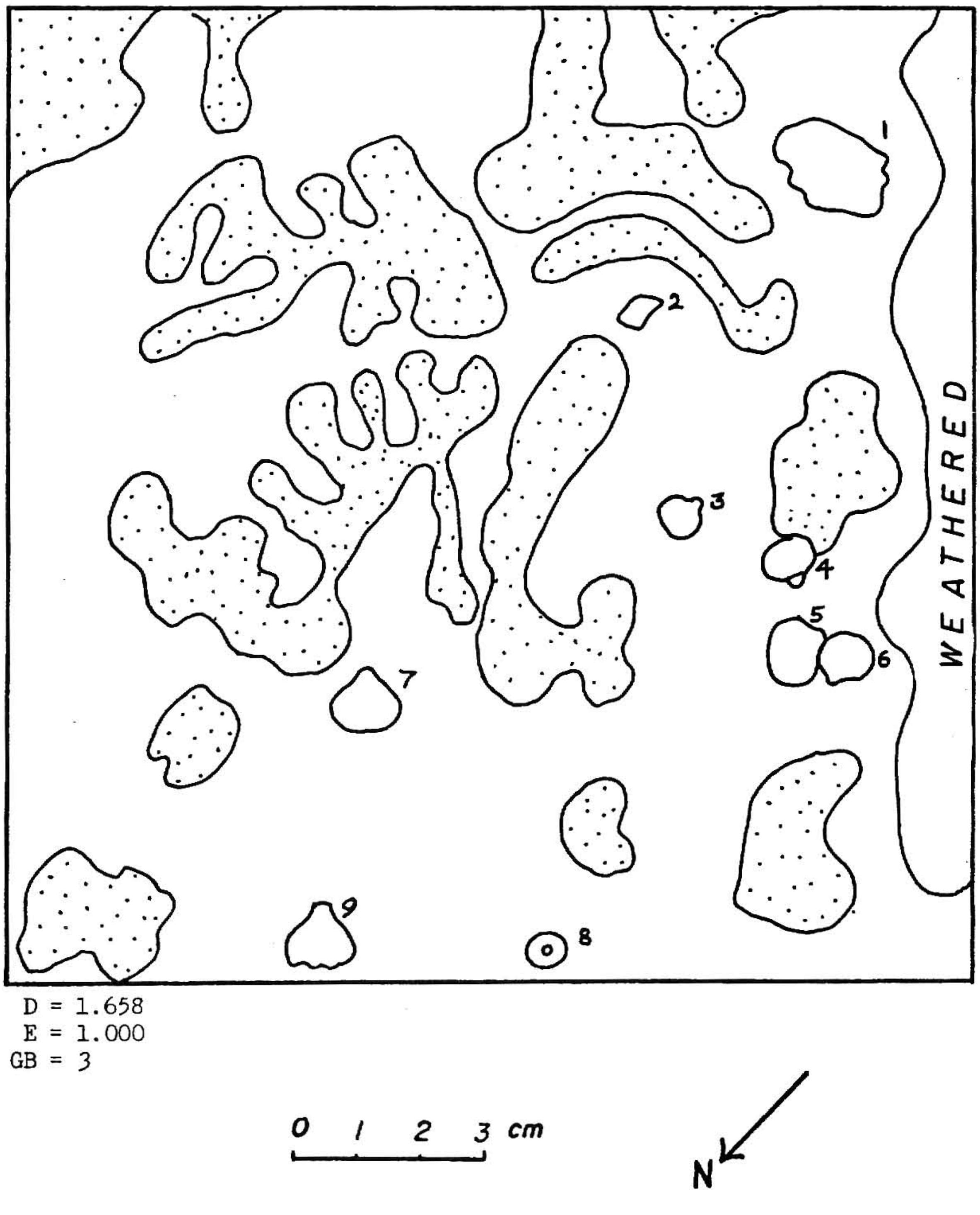
DC-L-1



D = .621
E = .500
GB = 2

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Lino	1.7	1.5	?		?	x		o	
2	Crin	.4	.6	i			x		o	
3	Cru	.6	.6	cvu		b	x		o	
4	Cru	1.2	1.1	cvu		b			o	
5	Cru	1.3	1.2	cvu		b	x		o	
6	Cru	.8	.6	cvu		b	x		o	
7	Cru	1.1	.9	cvu		b			o	
8	Crin	.7	.7	i			x		cal	
9	Hust	1.1	1.1	ccu		p			o	

DC-L-2

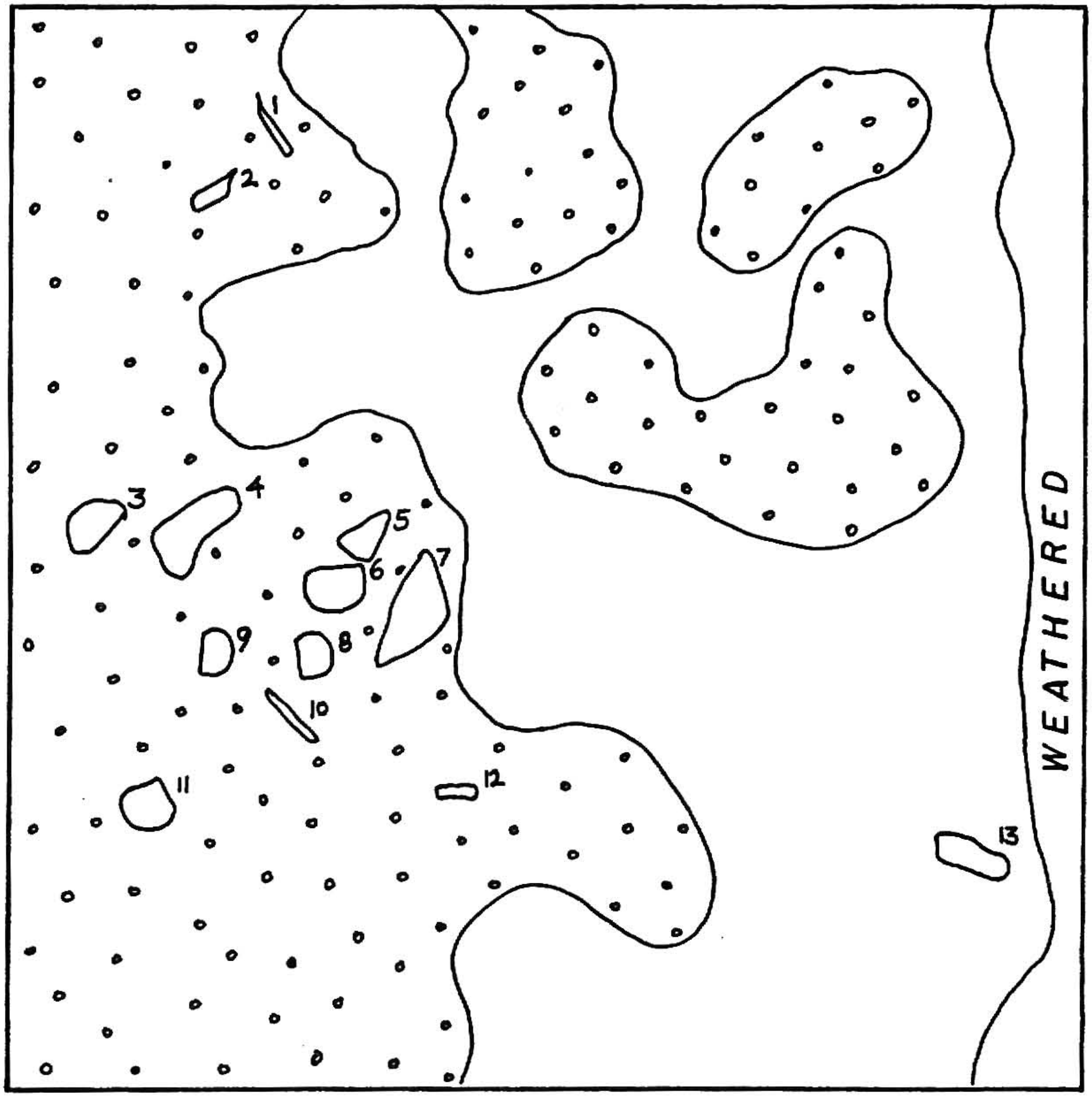


D = 1.658
E = 1.000
GB = 3

DC-L-3

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	brac	1.2	.1	p			x		o	
2	rII	.9	.2	p			x		o	
3	Cru	.7	.5	ccu		p	x		o	
4	rIII	1.4	.6	p			x		o	
5	rIII	.7	.5	p			x		o	
6	rIII	.8	.6	p			x		o	
7	Nesp	1.7	.8	ccu		b			o	
8	Cru	.5	.5	cvu		b	x		o	
9	Hust	.6	.4		cval				o	
10	brac	1.0	.1	p					o	
11	Cru	.8	.8	cvu		b	x		o	
12	brac	.6	.2	p			x		o	

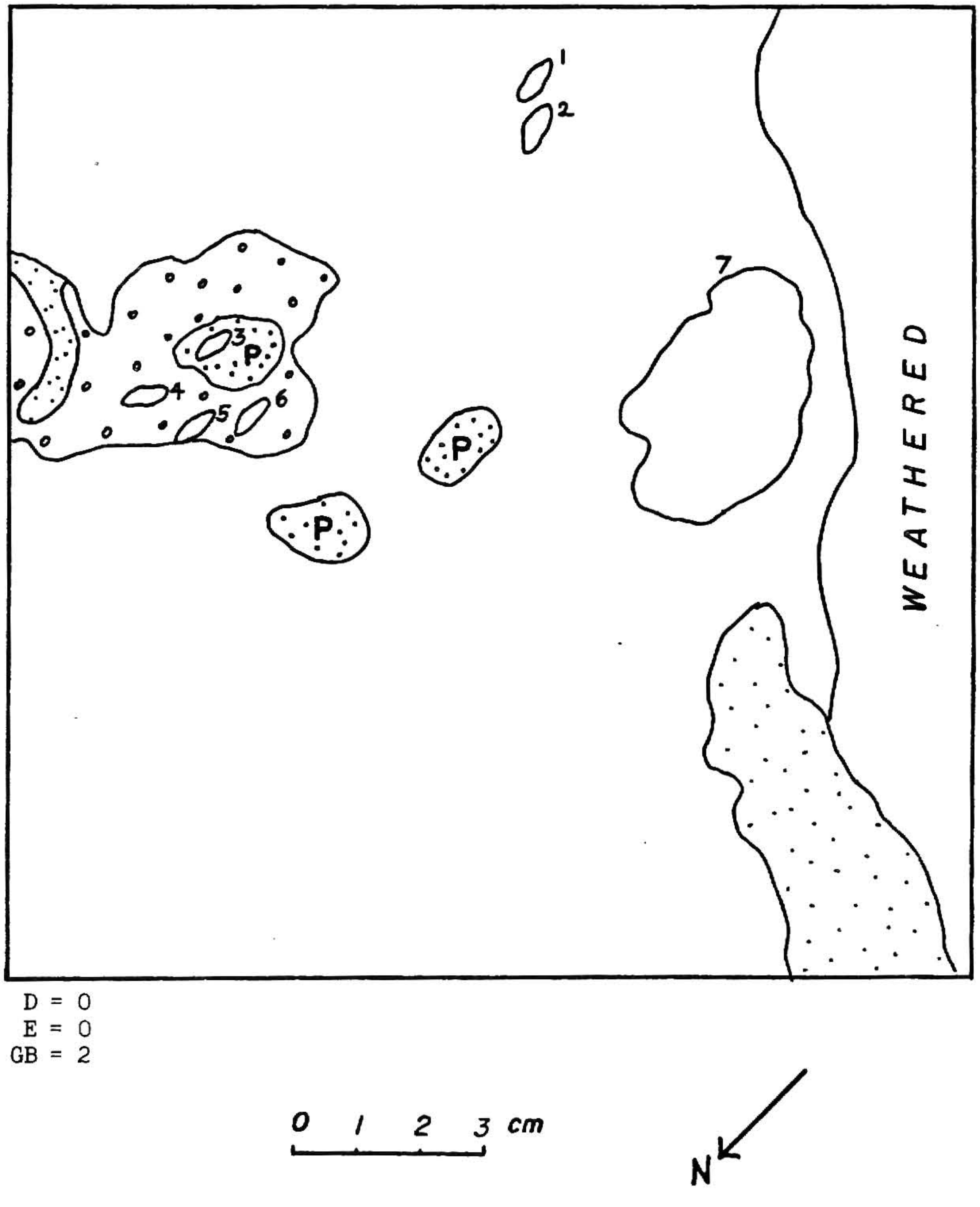
DC-L-3



D = 2.528
E = 1.333
GB = 4

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Fus								o	
2	Fus								o	
3	Fus								o	
4	Fus								o	
5	Fus								o	
6	Fus								o	
7	brac	4.2	2.5				x		o	

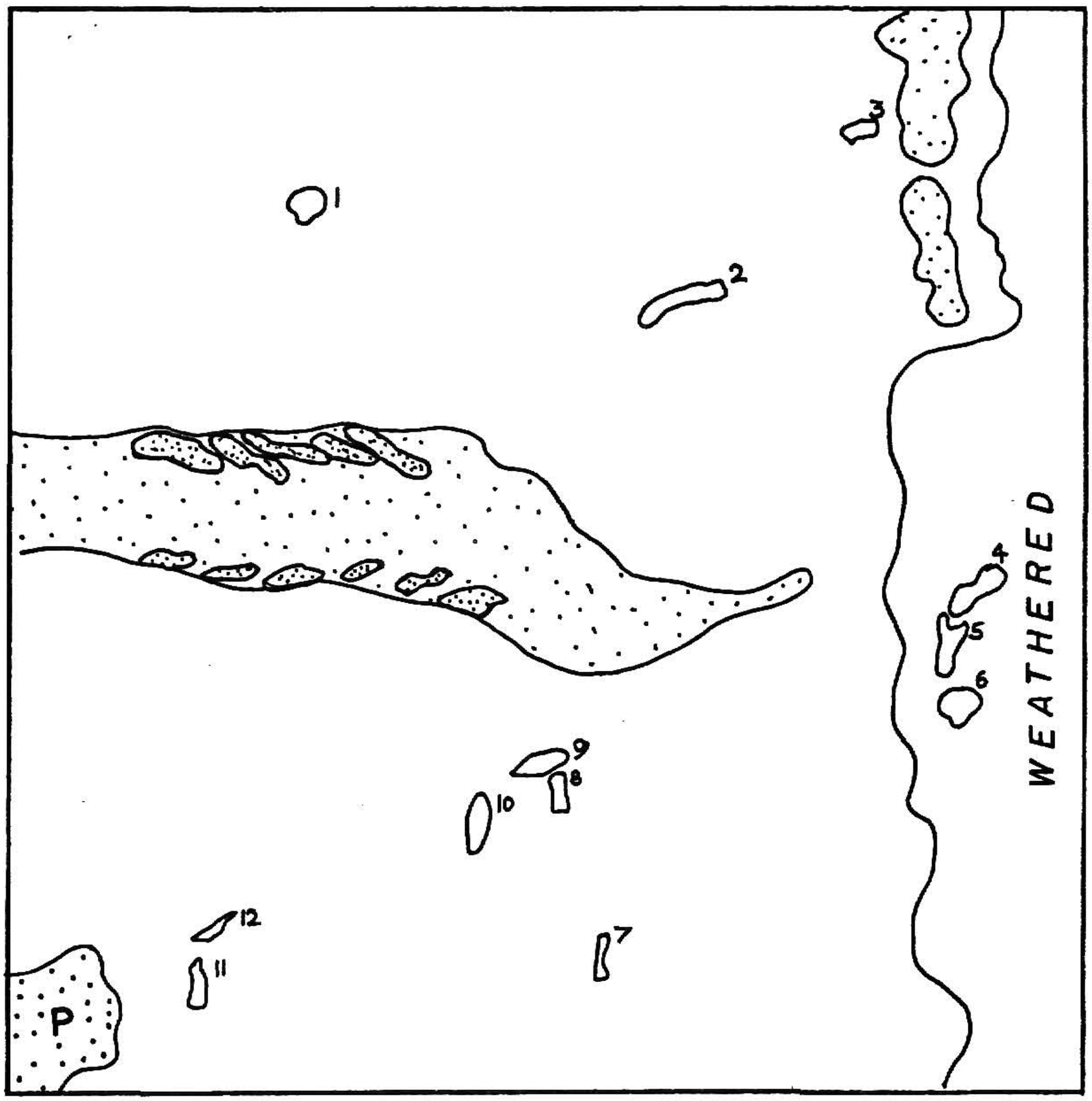
DC-L-4



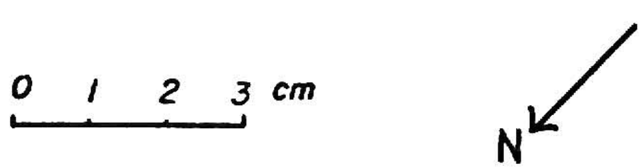
D = 0
E = 0
GB = 2

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.2	.2	ccu		b			o	
2	Iso	1.4	.2			?	x		o	
3	Iso	.3	.2			?	x		o	
4	rII	.6	.2				x		o	
5	rII	.4	.2				x		o	
6	rIII	.4	.4				x		o	
7	Isu	.4	.1			?	x		o&m	
8	Fus								o	
9	Fus								o	
10	Fus								o	
11	Iso	.4	.2			?	x		o	
12	Iso	.3	.1			?	x		o	

DC-L-5

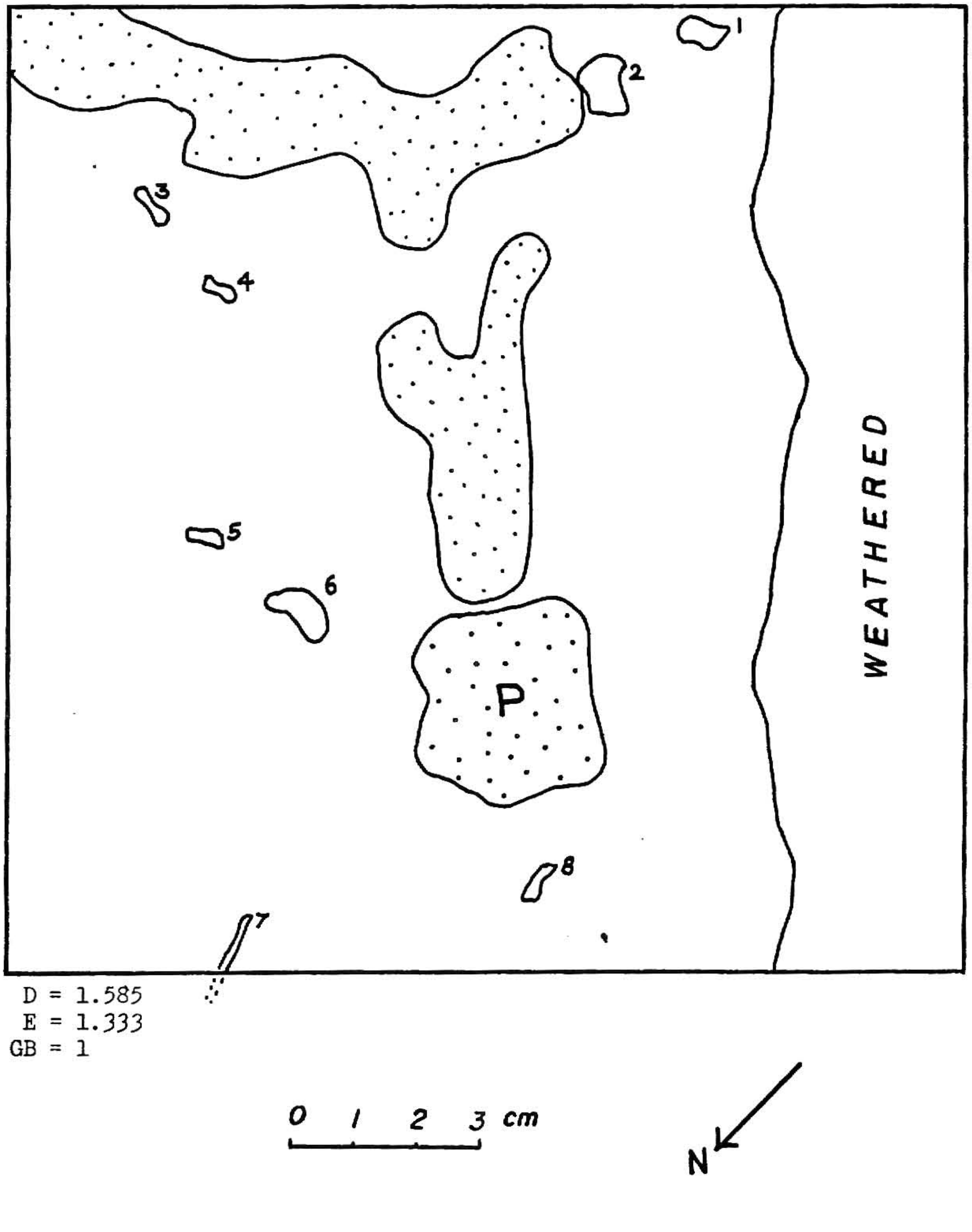


D = .811
E = 1.000
GB = 2



#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Iso	.7	.4	cvu		?	x		o	
2	Comp	1.0	.6	ccu		?	x		o	
3	Iso	.5	.2			?			o	
4	Iso	.4	.2			?			o	
5	Iso	.4	.2			?			o	
6	rIII	1.0	.5	i			x		o	
7	brac	1.8	.2			?			o	
8	Iso	.6	.2			?			o	

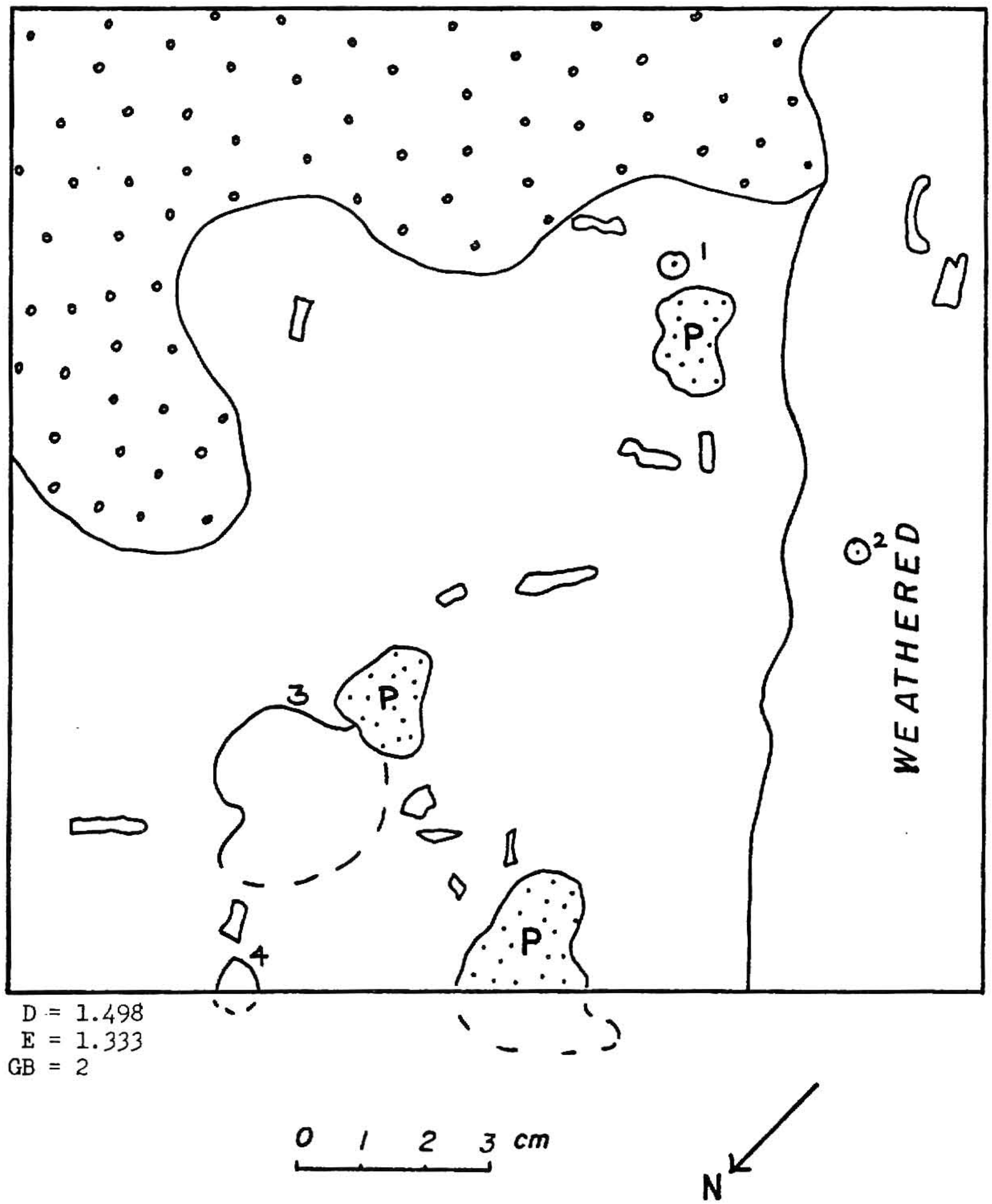
DC-L-6



D = 1.585
E = 1.333
GB = 1

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Crin	.4	.4	i			x		o	
2	Crin	.3	.3	i			x		o	
3	Lino	3.0	2.7	ccu		?	x		o	
4	Lg	.9	.7			?	x		o	
	Iso						x		o	

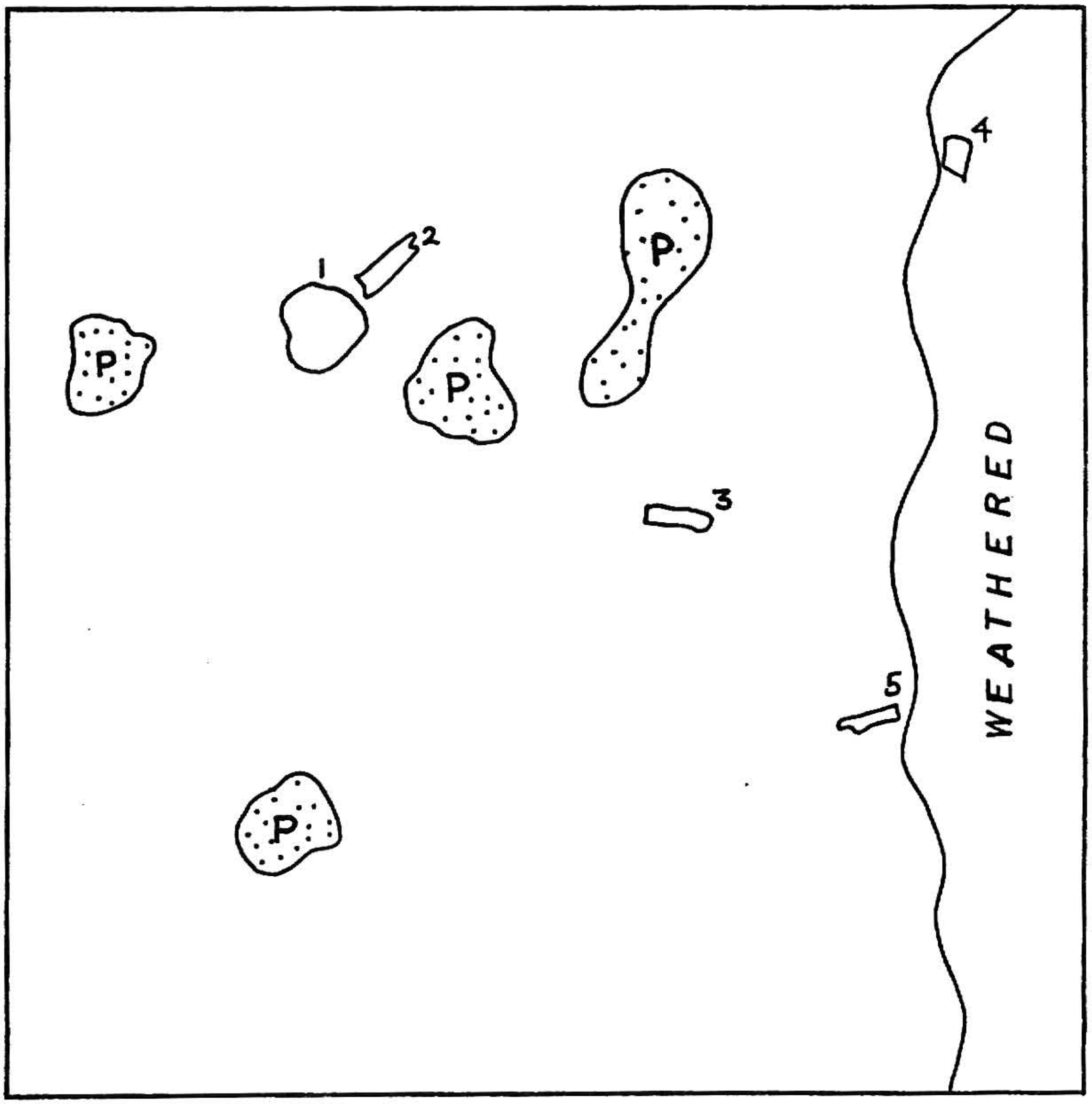
DC-L-7



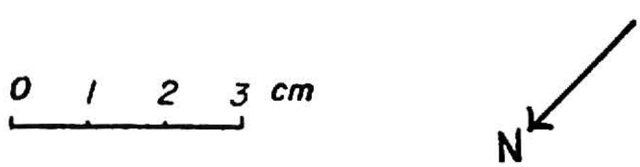
DC-L-8

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Comp	1.2	1.1	ccu		b			o	
2	Iso						x		o	
3	Iso					?	x		o	
4	Iso					?	x		o	
5	Iso					?	x		o	

DC-L-8



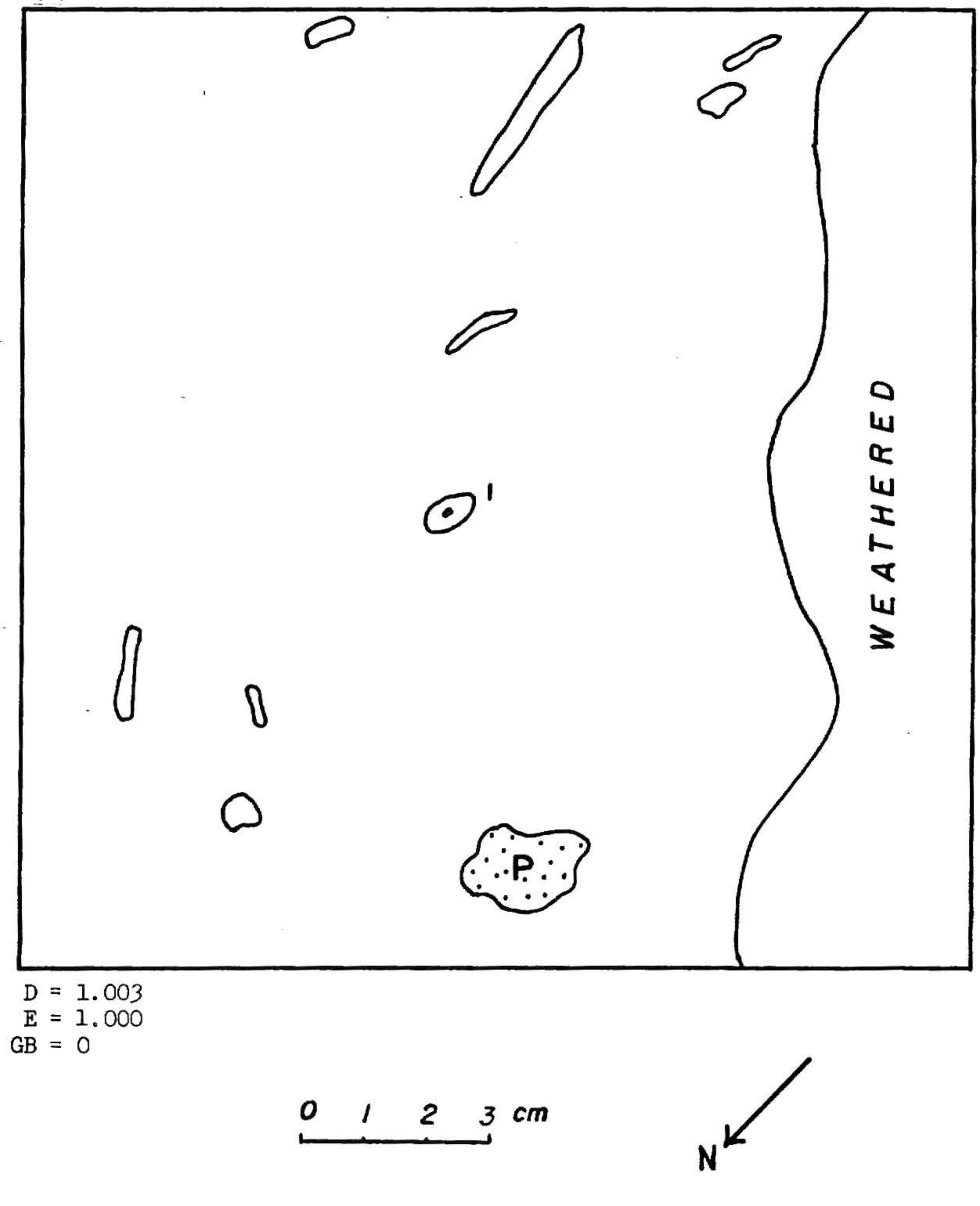
D = 1.003
E = 1.000
GB = 0



DC-L-9

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Crin			i			x		o	
	Iso					?	x		o	

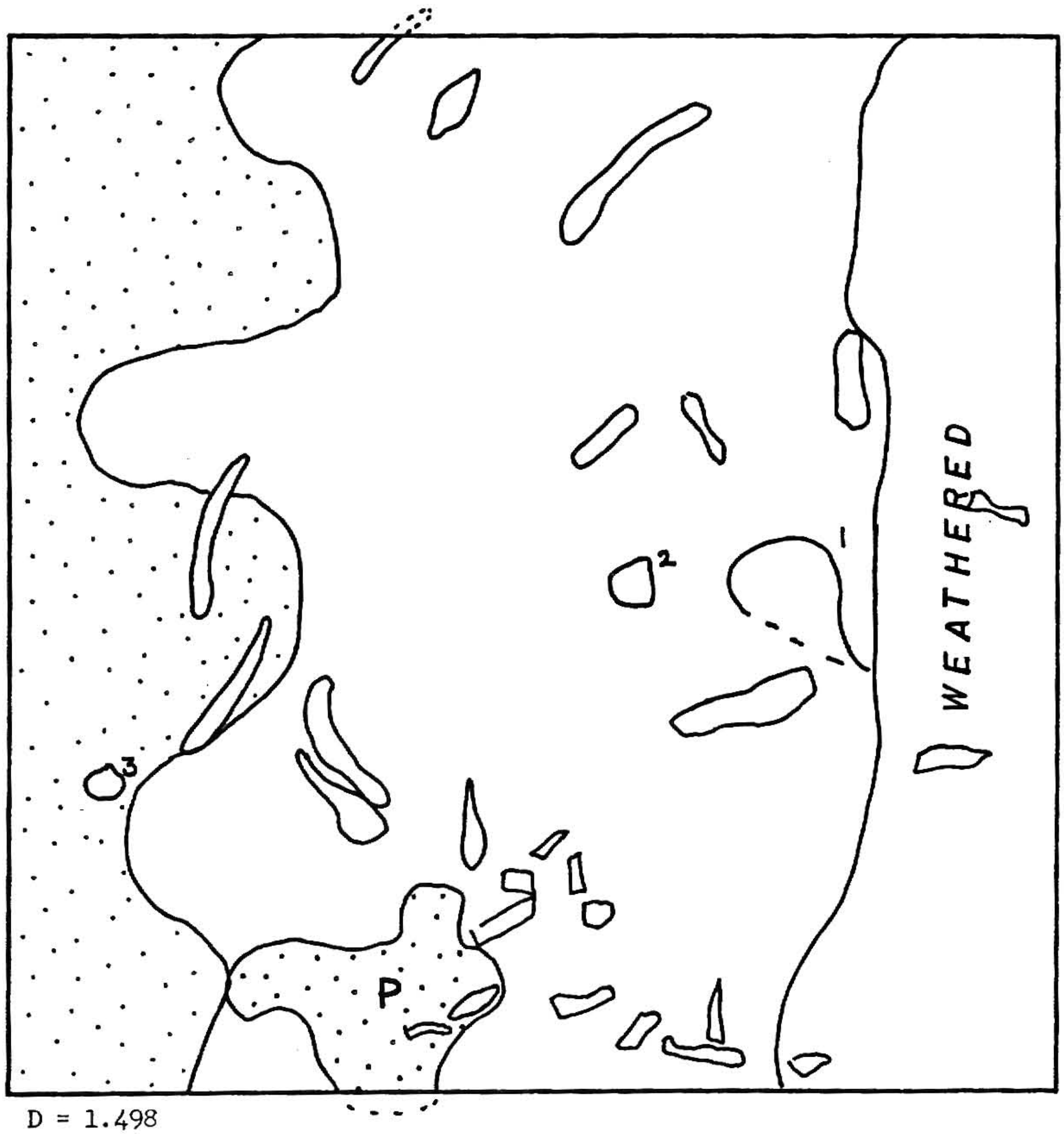
DC-L-9



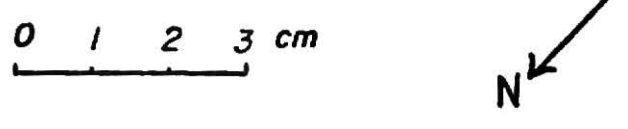
DC-L-10

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Lino	2.2	1.4		cval		x		o	
2	Cru	.6	.5	cvu		b				
3	Cru	.4	.3	cvu		b				
	Iso					?	x		o	

DC-L-10



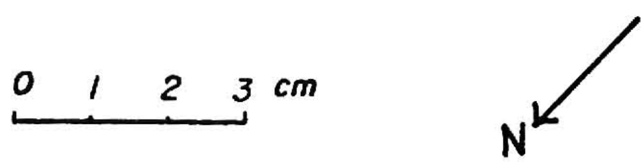
D = 1.498
E = 1.333
GB = 2



#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Crin	.4	.4	i			x		cal	
2	Crin	.3	.3	i			x		cal	
3	Cru	.8	.6	cvu		b	x		o	
4	Cru	.3	.3	cvu		b	x		o	
5	Cru	.2	.9	cvu	cval				o	
6	Crin	.7	.4	p			x		o	
7	Crin	.3	.3	p			x		cal	
8	Cru	.4	.4		cval				o	
9	Crin	.3	.2				x		o	
10	Cru	.6	.5			?	x		o	
11	Cru	.4	.4	ccu		p			o	
12	Cru	1.3	.4	ccu	cval				o&m	
13	Cru	.5	.3	ccu	cval				o	
14	Cru	.6	.3	ccu	cval		x		m	
15	Crin	.3	.2	i			x		o	
16	Cru	.5	.4	cvu		b			m	
17	Cru	.4	.4	ccu		p			m	
18	Cru	.5	.4	ccu		p			m	
19	Cru	.4	.4	ccu		b			m	
20	Cru	.4	.3	cvu		b			o	
21	Cru	.3	.3	ccu		p	x		o	
22	Cru	1.1	1.0	cvu		b			o	
23	Cru	.3	.3	ccu		p	x		o	
24	Cru	.5	.4	cvu		b			o	
25	Cru	.4	.3	ccu		b	x		m	
26	Cru	.4	.5	ccu		p			o	
27	Cru	.2	.3	cvu		b			o	
28	Cru	.7	.5	ccu		?			o	
29	Crin	.2	.2						cal	
30	Cru	.7	.5	ccu	cval				o	
31	Cru	.4	.3	cvu		b			o	
32	Cru	.5	.4	cvu		b			o	
33	Cru	.3	.3	cvu		b			o	

DC-L-11

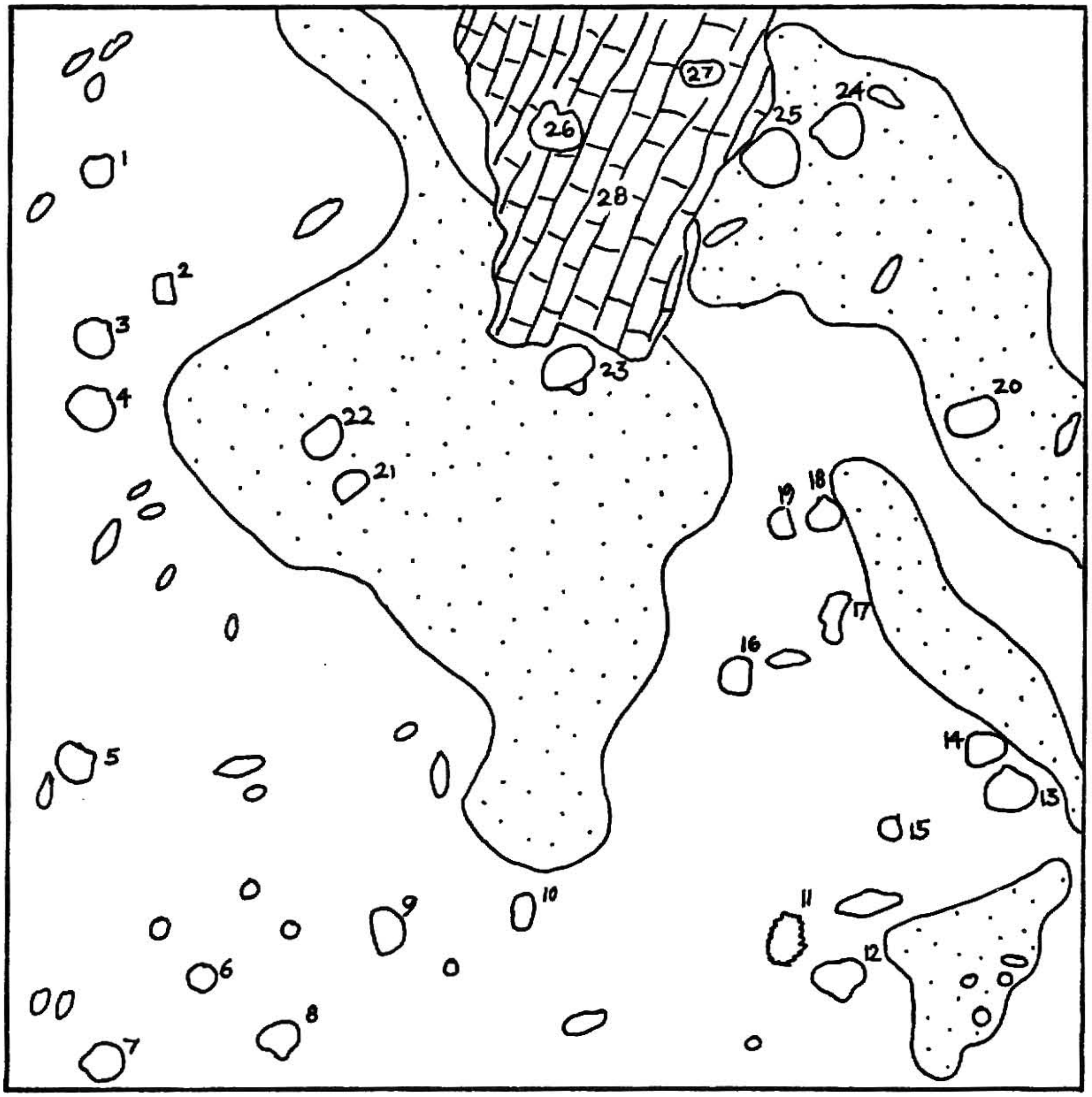
D = .257
E = 1.000
GB = 3



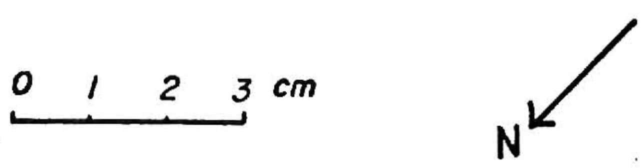
DC-L-12

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.2	.2	cvu		b			o	
2	Crin	.3	.2	i					o	
3	Cru	.6	.4	cvu		b			o	
4	Cru	.7	.5	cvu		b	x		o	
5	Cru	.6	.5	ccu		b			o	
6	Cru	.3	.3	cvu		b	x		o	
7	Cru	.6	.5	ccu		b			m	
8	Cru	.4	.4	cvu		b			m	
9	Cru	.6	.4	ccu		p			o	
10	Cru	.5	.3	ccu	cval				o	
11	Hust	.5	.4	ccu	cval				m	
12	Cru	.7	.5	ccu	cval		x		o	
13	Cru	.6	.7	cvu		b			o	
14	Cru	.5	.4	ccu		b			o	
15	Crin	.2	.2	i		?			cal	
16	Cru	.4	.3	ccu		p			o	
17	Crin	.7	.3	p					o	
18	Cru	.5	.3	ccu		b			o	
19	Cru	.3	.3	cvu		b			o.	
20	Cru	.4	.3	ccu		p			o	
21	Cru	.4	.3	ccu		p			o	
22	Cru	.6	.5	ccu		b				
23	Cru	.7	.6			?	x		o	
24	Cru	.8	.7	cu		b	x		o	
25	Cru	.8	.8	cu		b	x		o	
26	Cru	.7	.6	cd		b	x		o	
27	Cru	.5	.4	cu		p			o	
28	fII	4.0	4.9	p			x		o&m	

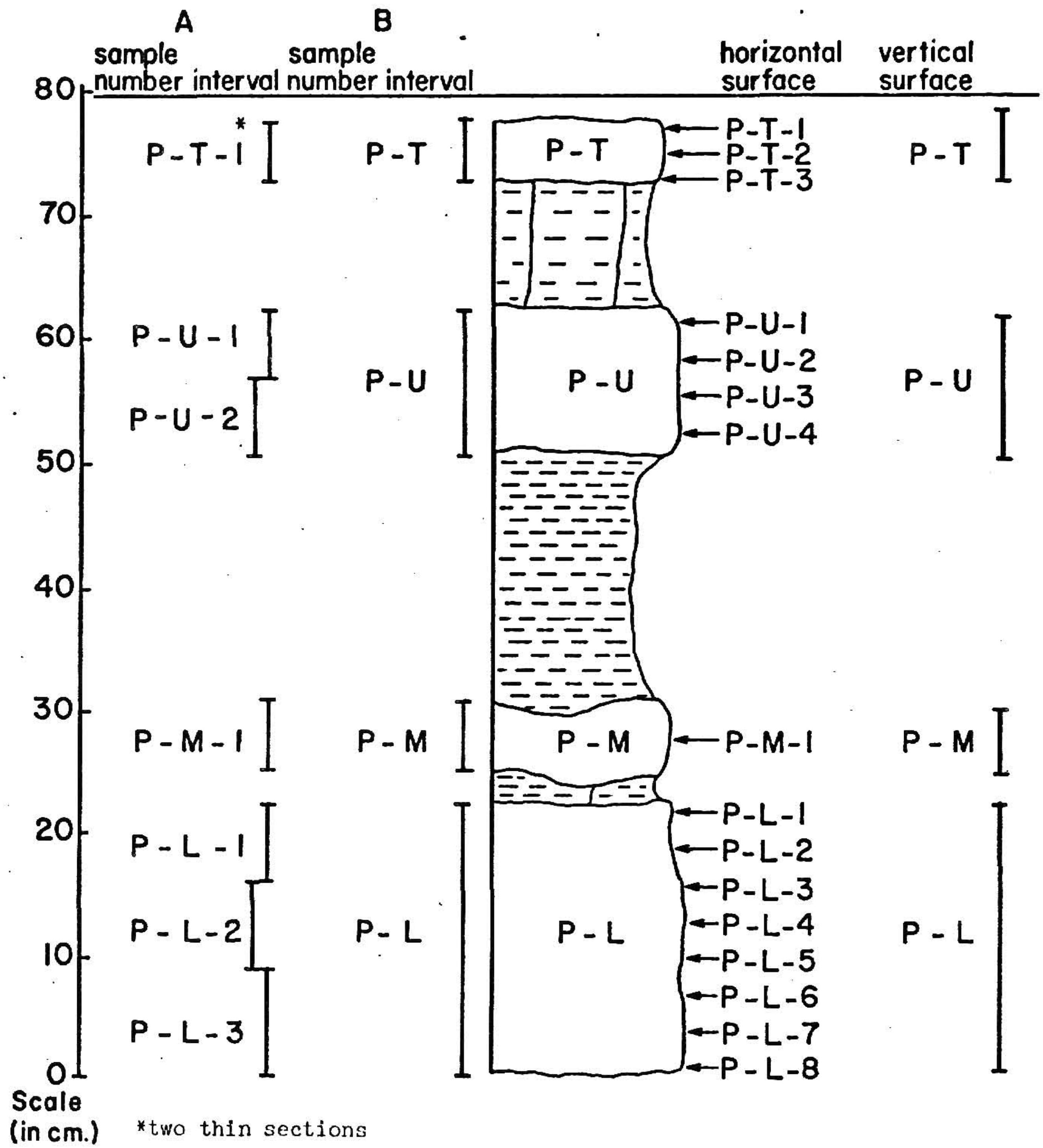
DC-L-12



D = .718
E = .500
GB = 3

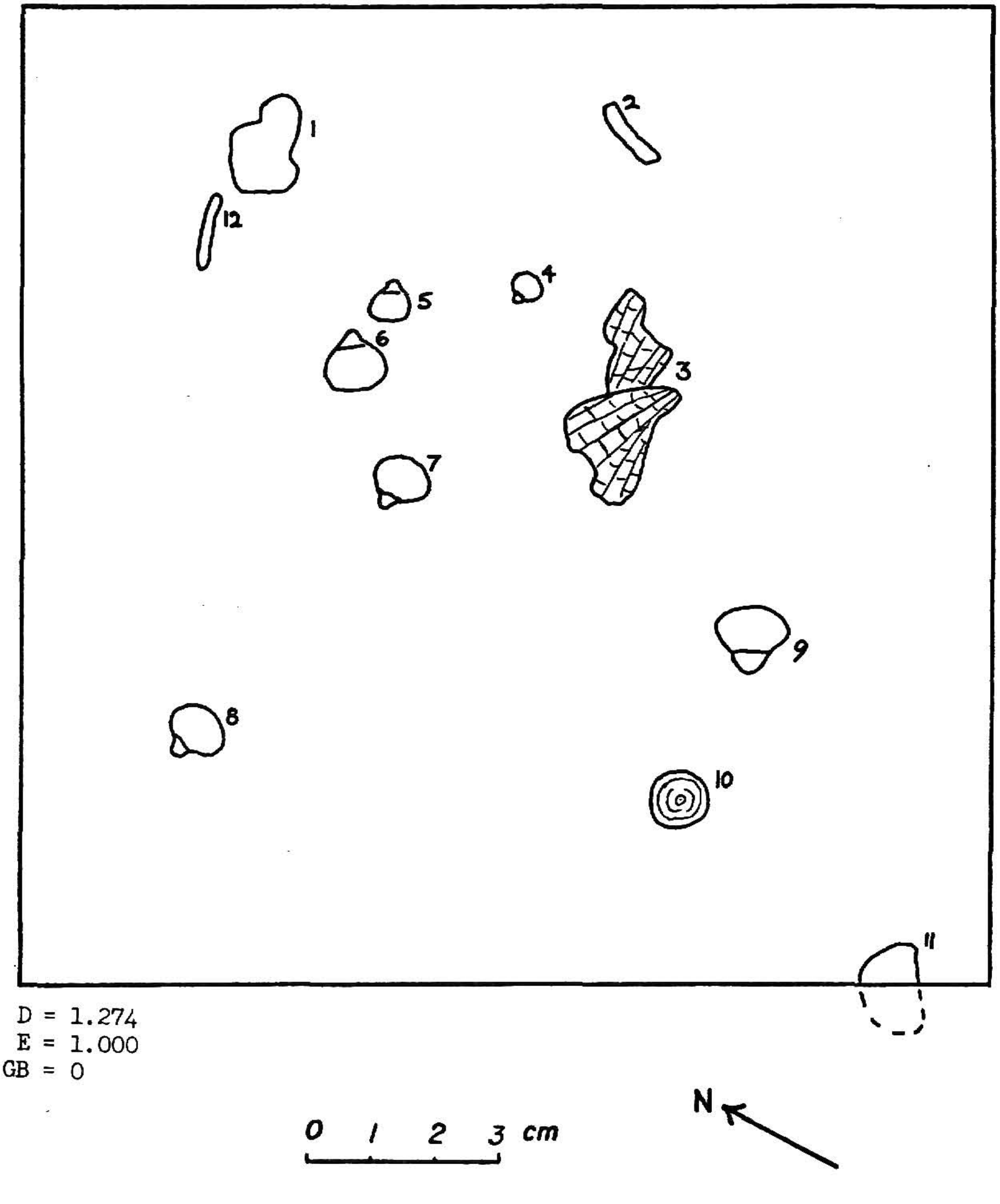


PAXICO (P) SECTION



*two thin sections

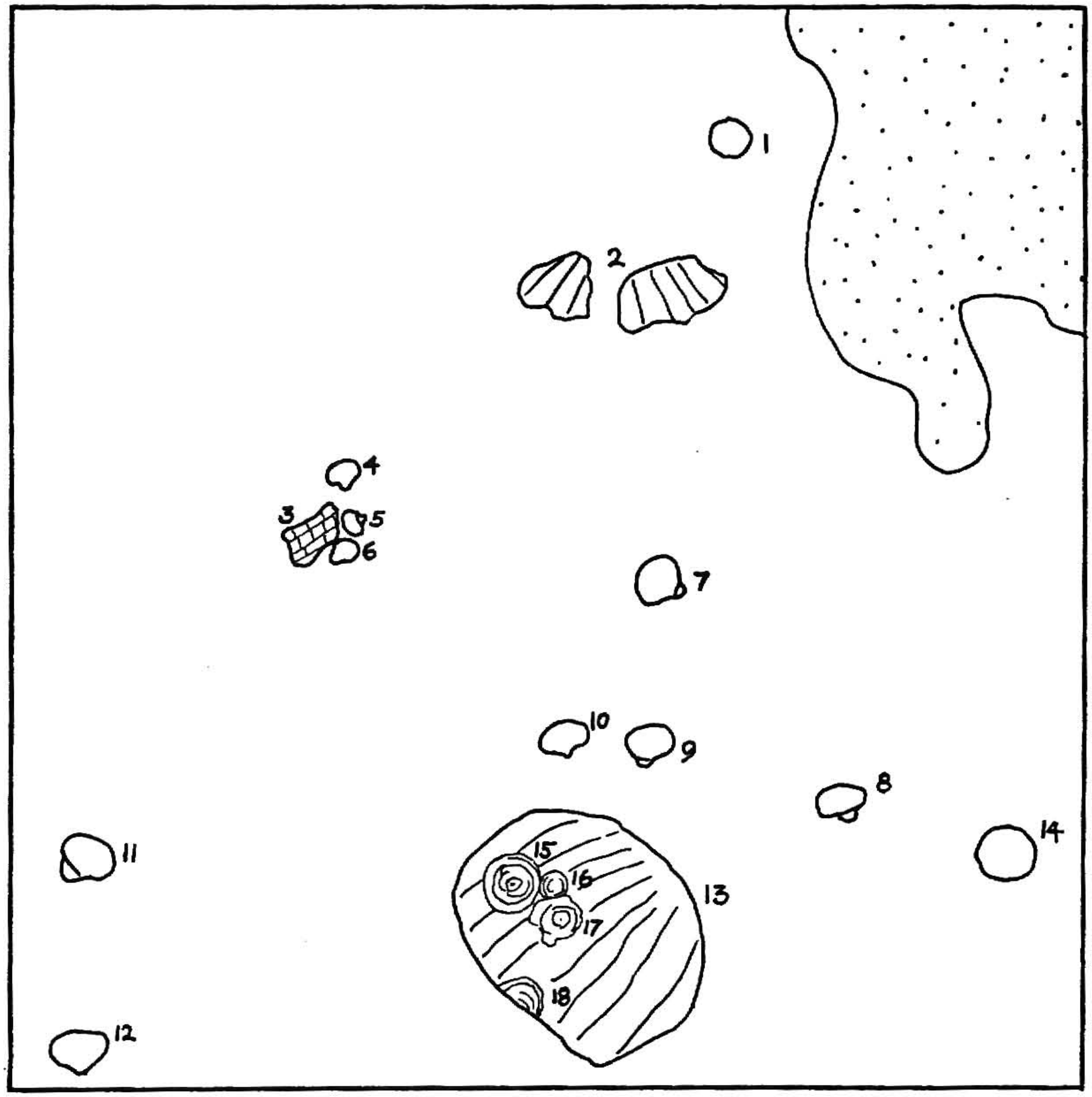
P-T-1



D = 1.274
E = 1.000
GB = 0

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Orb	.5	.5	b		cvu			o	
2	Lino	3.7	3.0	p		cvu			o	
3	fII	.5	.9				x		o&m	
4	Cru	.5	.4	b		cvu			o	
5	Cru	.3	.3	p		ccu			o	
6	Cru	.3	.3	b		cvu			o	
7	Cru	.6	.7	p		ccu			o	
8	Cru	.6	.6	p		ccu			o	
9	Cru	.7	.5	p		ccu			o	
10	Cru	.6	.5	b		cvu			o	
11	Cru	.8	.7	p		ccu			o	
12	Cru	.8	.6	b		ccu			o	
13	Lino	3.6	3.0	p		cvu			o	
14	Orb	.7	.7	b		cvu			o	
15	Pet	.8	.7	b		cvu		13	o	
16	Pet	.4	.4	b		cvu		13	o	
17	Pet	.7	.5	b		cvu	x	13	o	
18	Pet	.6	.3	b		cvu	x	13	o	

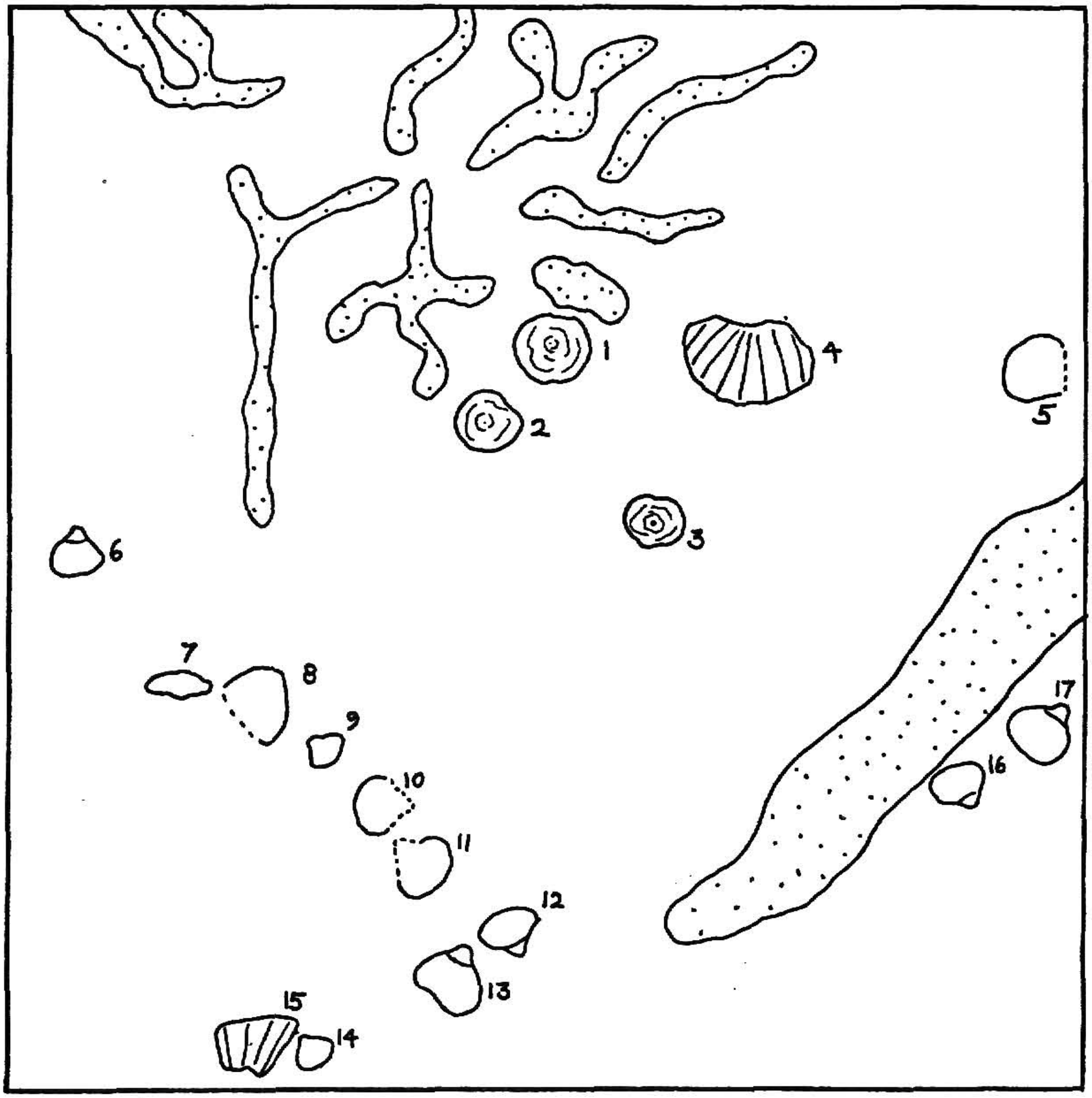
P-T-2



D = 2.123
E = 1.200
GB = 1

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Orb	1.1	1.1	cvu		b				
2	Orb	.8	.8	cvu		b				
3	Orb	.7	.7	cvu		b				
4	Lino	1.9	1.1	cvu		p				
5	Cru	1.0	.9	cvu		b				
6	Cru	.8	.8	ccu		p				
7	?	.9	.3			?	x			
8	Cru	1.3	.9	ccu		p	x			
9	Cru	.5	.4	ccu		b				
10	Cru	.9	.8	cvu		b	x			
11	Cru	.9	.8	ccu		b	x			
12	Cru	.8	.7	ccu		b				
13	Cru	1.0	.9	ccu		b				
14	Cru	.5	.3	ccu		b				
15	Lino	1.2	1.0			?	x			
16	Cru	.7	.6	ccu		b				
17	Cru	1.1	.9	ccu		b				

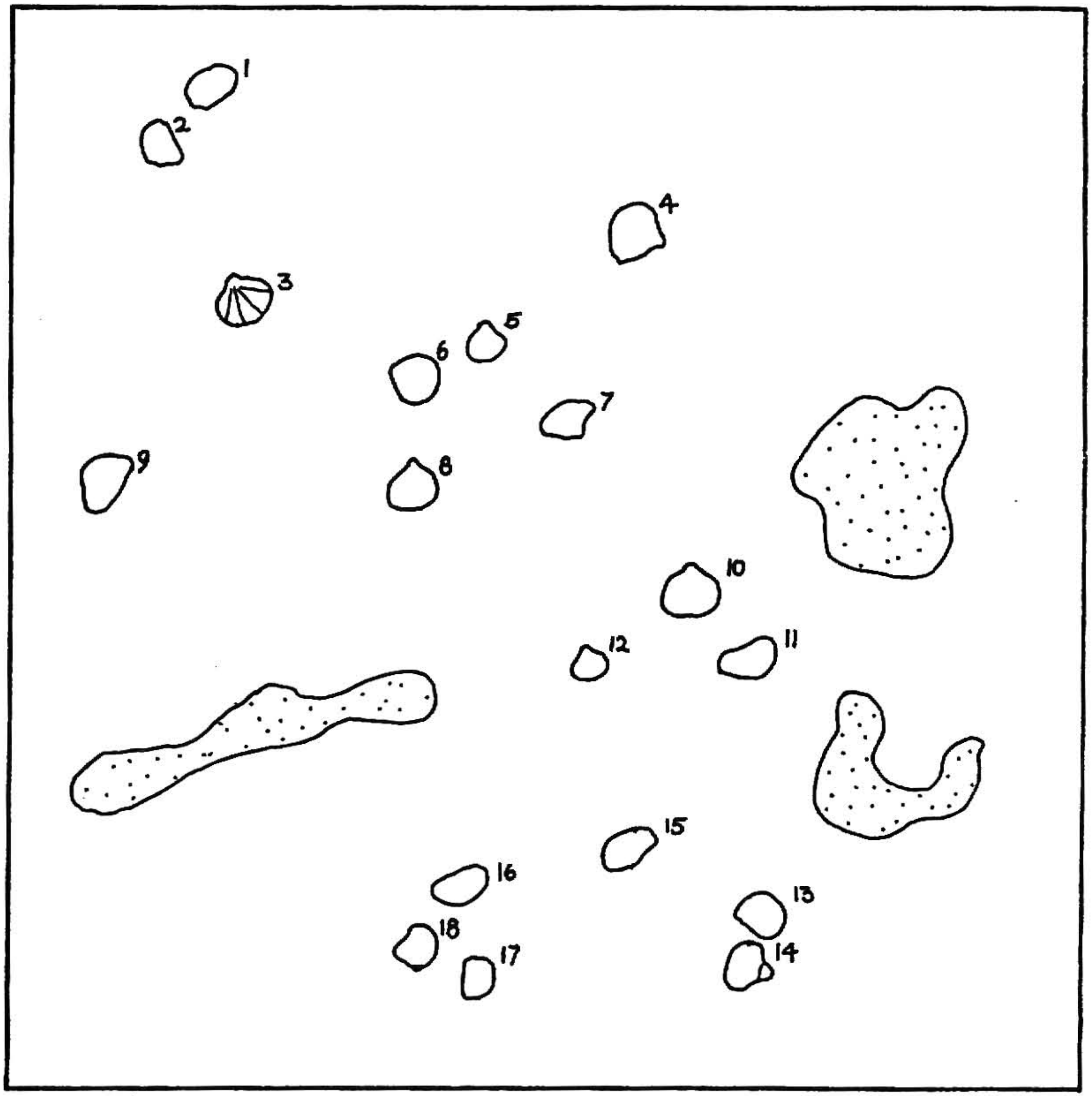
P-T-3



D = 1.286
E = 2.333
GB = 2

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.6	.5	cvu		b	x		o	
2	Cru	.7	.6	ccu		p	x		o	
3	Rhip	.8	.6	cvu		p			o	
4	Cru	.8	.8	cvu		b	x		o	
5	Cru	.5	.4	cvu		b	x		o	
6	Cru	.7	.7	ccu		p	x		m	
7	Cru	.7	.6	cvu		b			o	
8	Cru	.7	.7	cvu		b			o	
9	Rhip	1.0	.8	?		?	x		o	
10	Cru	.8	.7	cvu		b			o	
11	Cru	.9	.7	ccu		p			o	
12	Cru	.3	.3	ccu		b			o	
13	Cru	.6	.4	ccu		p			o&m	
14	Cru	.5	.5	ccu		b			o	
15	Cru	.6	.5	ccu		p	x		o	
16	Cru	.6	.4	ccu		p			o	
17	Cru	.5	.4	ccu		p			o	
18	Cru	.5	.5	cvu		b	x		o	

P-U-1

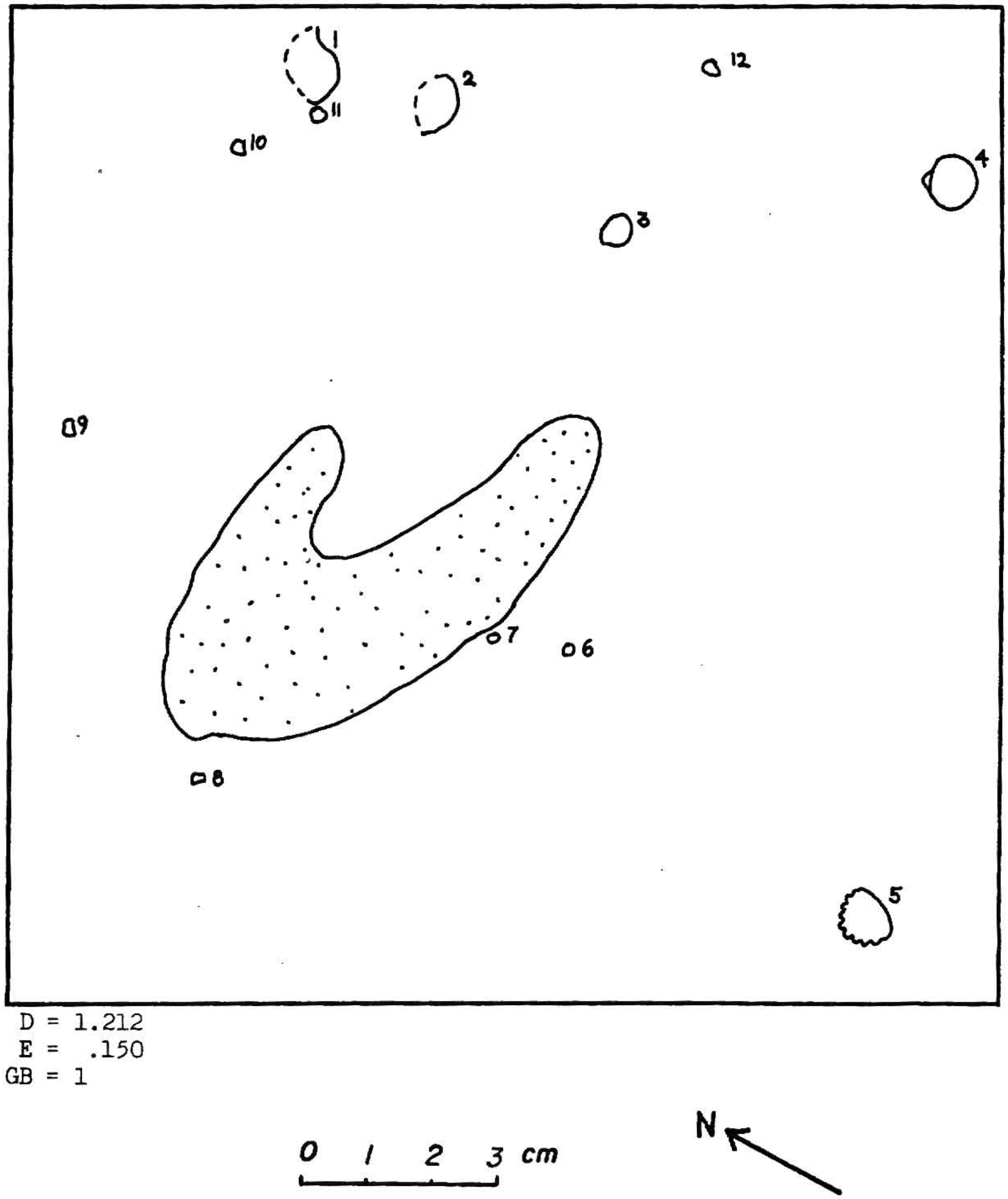


D = .684
E = 1.000
GB = 1

P-U-2

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Rea	1.1	.9	i	cval		x			
2	Rea	.9	.7	i	cval		x			
3	Cru	.5	.3	cvu		b	x			
4	Cru	.8	.7	cvu		b				
5	Well	.9	.7	i	cval		x			
6	Crin	.1	.1	i			x			
7	Crin	.1	.1	i			x			
8	Crin	.2	.1	p			x			
9	Crin	.2	.1	p			x			
10	Crin	.2	.2	i			x			
11	Crin	.2	.2	i			x			
12	Crin	.3	.2	i			x			

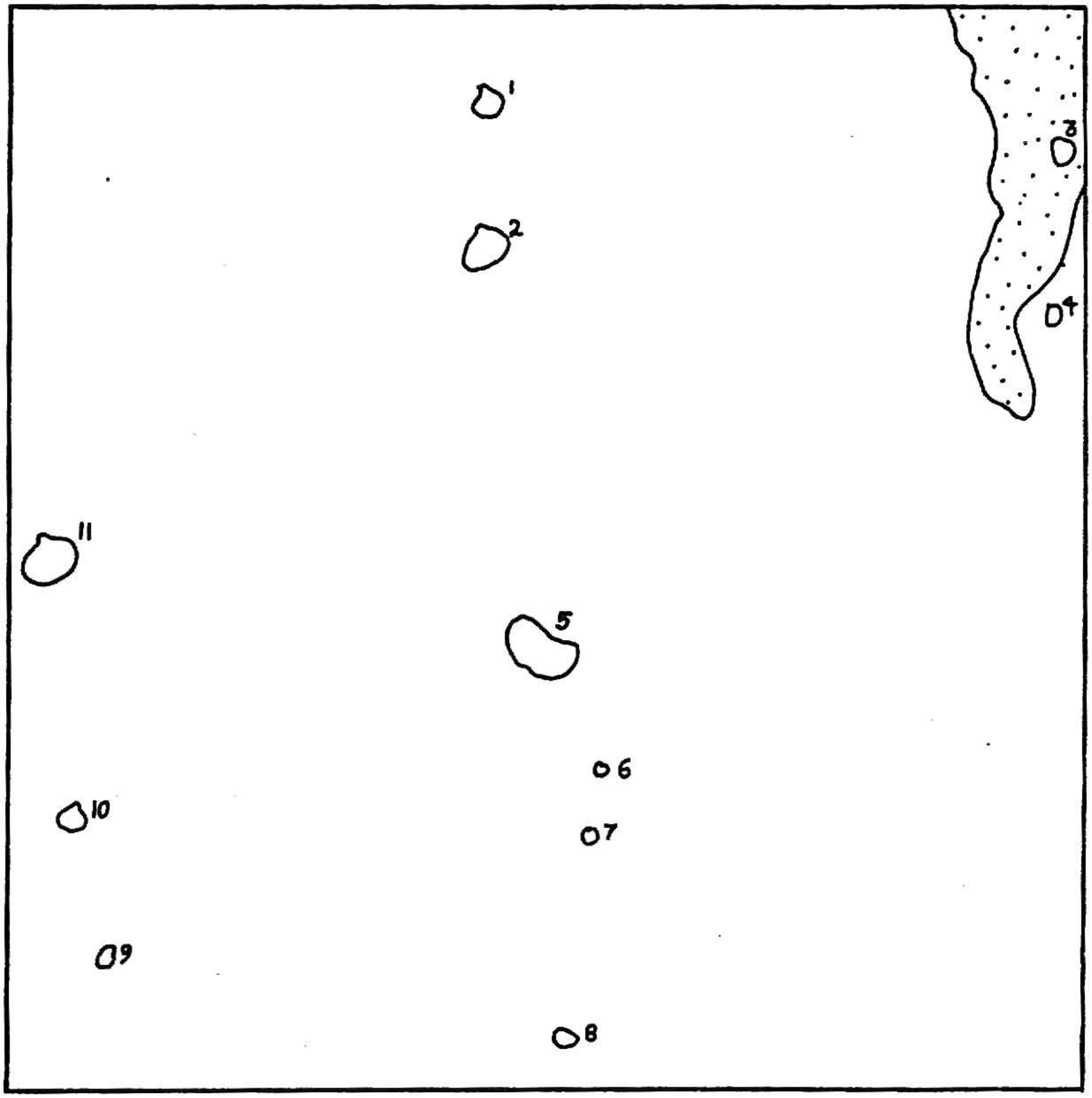
P-U-2



D = 1.212
E = .150
GB = 1

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.3	.3	cvu		b			o	
2	Cru	.5	.4	ccu		b	x		o	
3	Crin	.3	.2	p					o	
4	Crin	.2	.2	p					o	
5	Rea	1.1	.5	i	cval				o	
6	Crin	.1	.1	i					cal	
7	Crin	.1	.2	i					cal	
8	Crin	.2	.2	i					cal	
9	Cru	.2	.2	cvu		b	x		o	
10	Cru	.3	.3	ccu		p	x		o	
11	Cru	.8	.6	cvu		b			o	

P-U-3

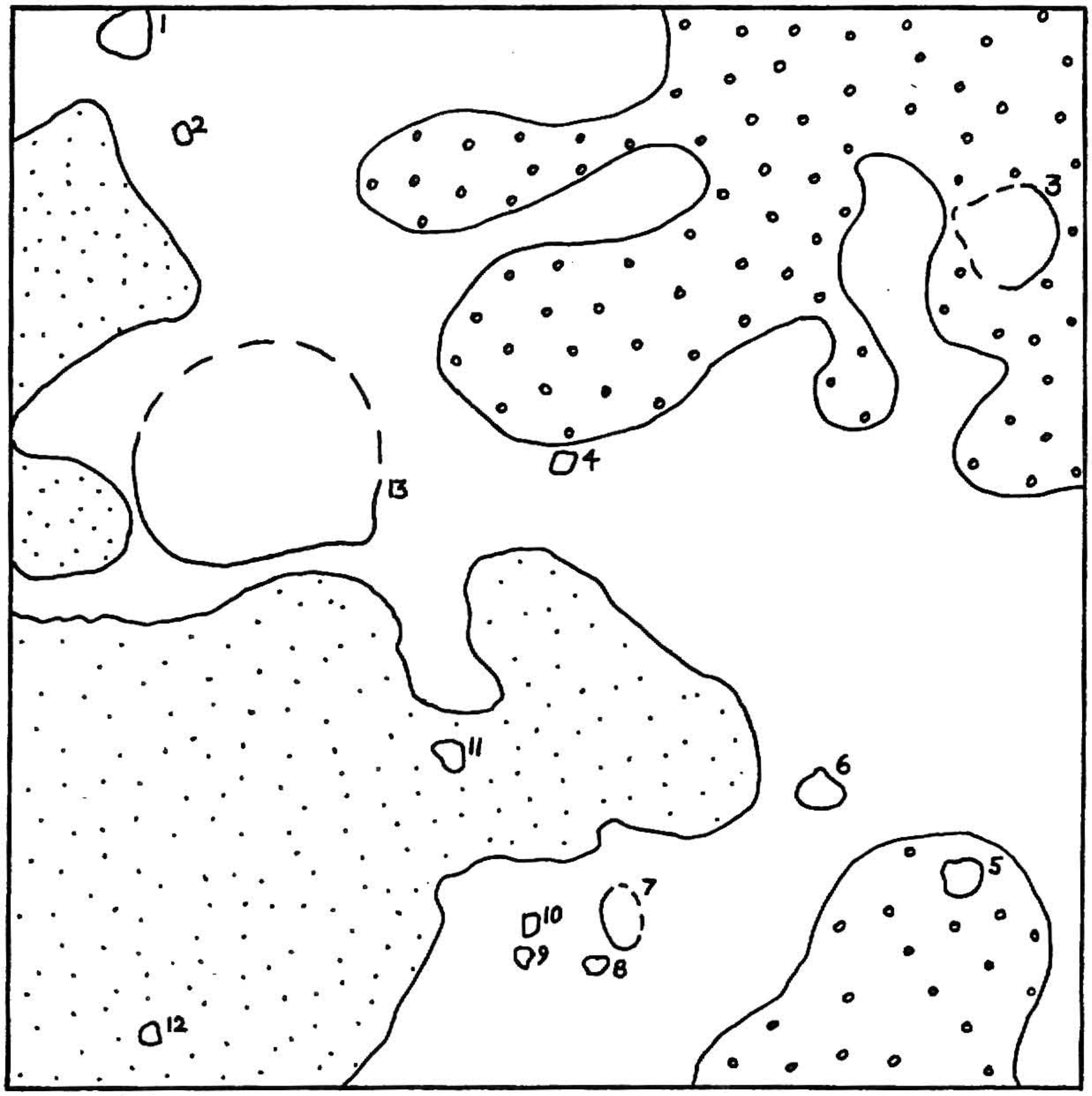


D = 1.329
E = 1.000
GB = 1

P-U-4

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.6	.7	cvu		b	x		o	
2	Crin	.3	.2	p			x		o	
3	Comp	1.7	1.5			?	x		o	
4	Crin	.3	.3	p			x		o	
5	Cru	.6	.5	cvu		b			o	
6	Cru	.7	.6	cvu		b			o	
7	?	.9	.5	i	cval				o	
8	Crin	.3	.2	i			x		cal	
9	Crin	.2	.2	p			x		cal	
10	Crin	.3	.2	p			x		cal	
11	Cru	.5	.3	ccu		p			o	
12	Cru	.3	.2	ccu		p			o	
13	Pet	3.6	3.6	ccu		p			o	

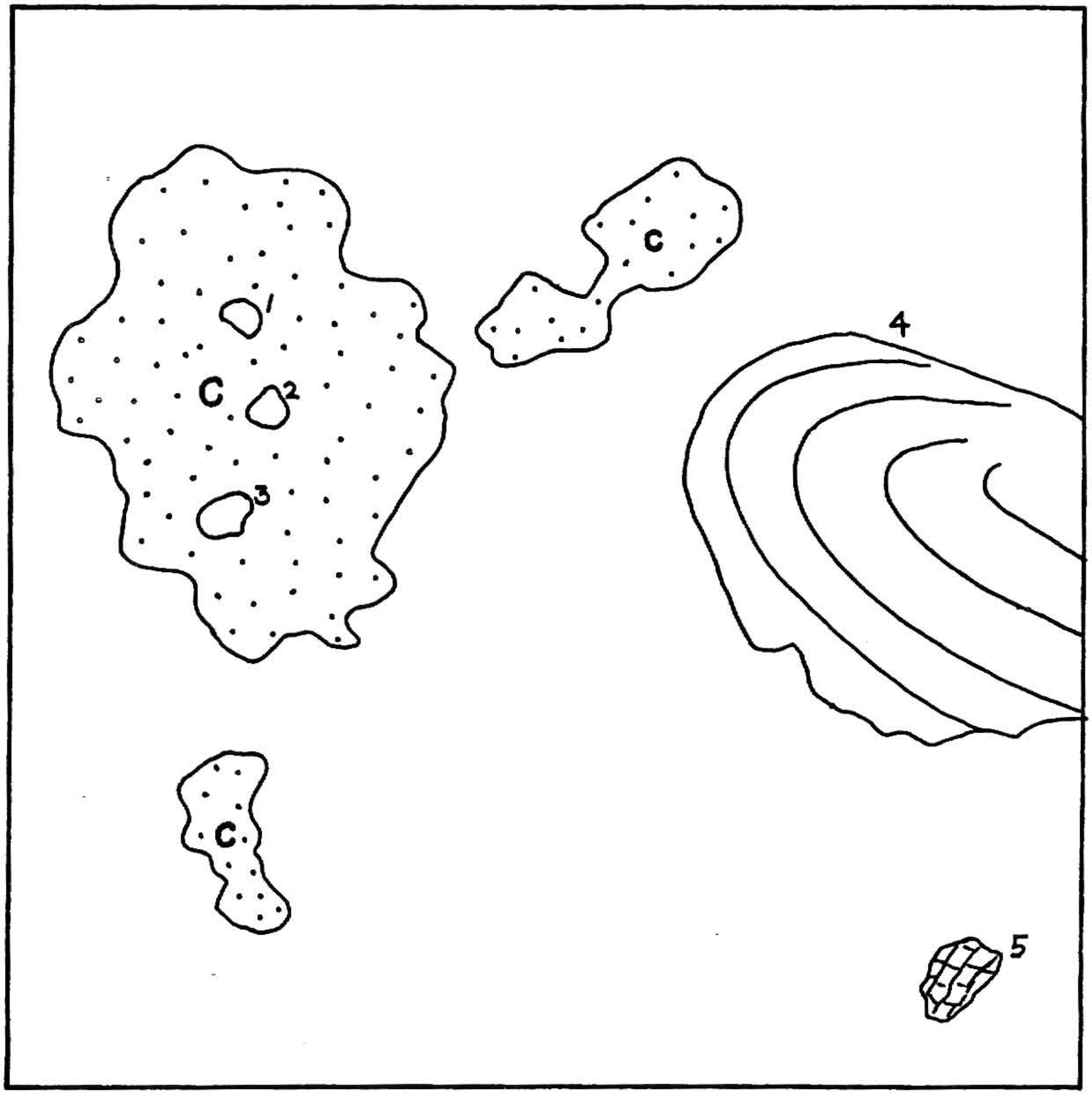
P-U-4



D = 1.688
E = 1.000
GB = 4

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.6	.4	ccu		b			cal	
2	Cru	.6	.5	cvu		p			cal	
3	Cru	.8	.5	cvu		p			cal	
4	Myl	7.0	5.6	cvu		?			o	
5	fII	1.2	.8	zeu			x		o	

P-M-1



D = 1.498
E = 1.333
GB = 0

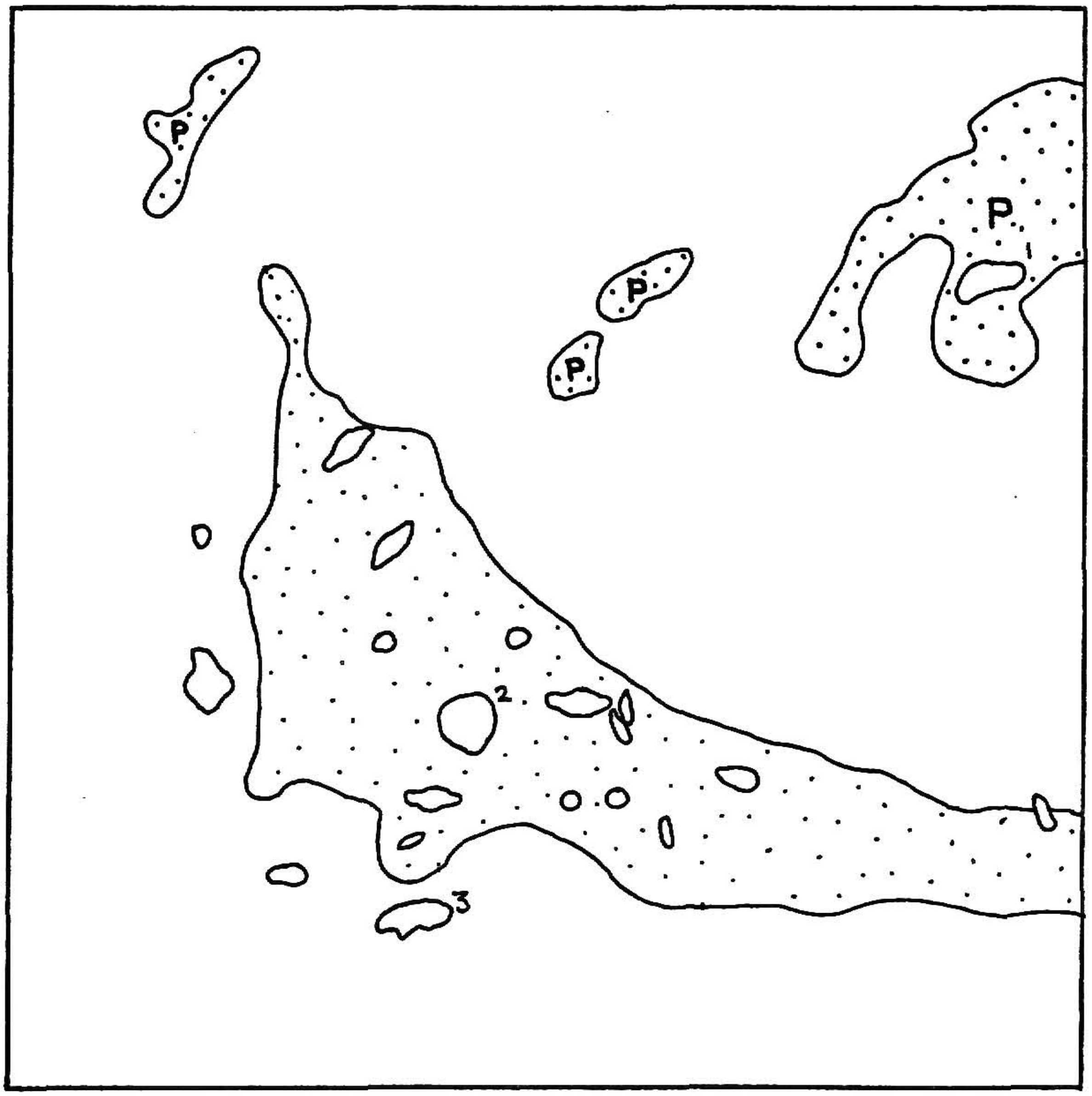
#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.7	.6	cvu		p			o	
2	Cru	.5	.3	ccu		b			m	
3	Cru	.6	.6	cvu		p	x		o	
4	Cru	.6	.6	cvu		p			o	
5	Well	1.3	1.3	cvu	cval				o	
6	Cru	.8	.6	ccu		p			m	

P-L-1

D = .724
E = 1.000
GB = 3

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Hyst	.9	.5	ccu		?	x		o	
2	Cru	.8	.8	cvu	cval				o	
3	rIV	1.0	.3	p		zeu			cal	
	Iso						x		o	

P-L-2



D = 1.993
E = 1.250
GB = 3

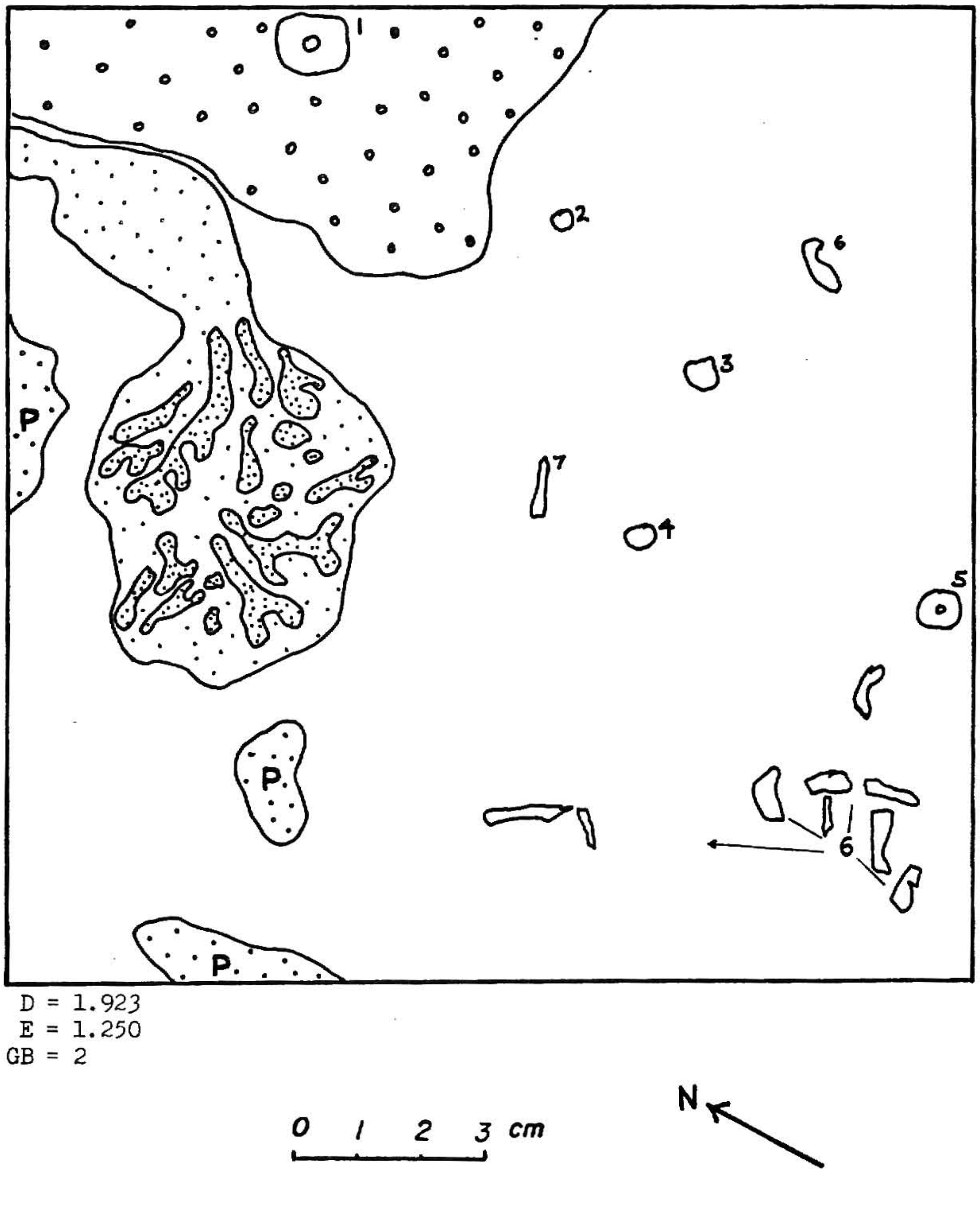
P-L-3

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Crin	.3	.3	i			x		o	
2	Cru	1.0	.8	cvu		b			o	
3	Comp	1.4	.3	ccu		b	x		o	
4	Rea	1.1	.8			?	x		o	

P-L-3

D = 2.235
E = 1.400
GB = 2

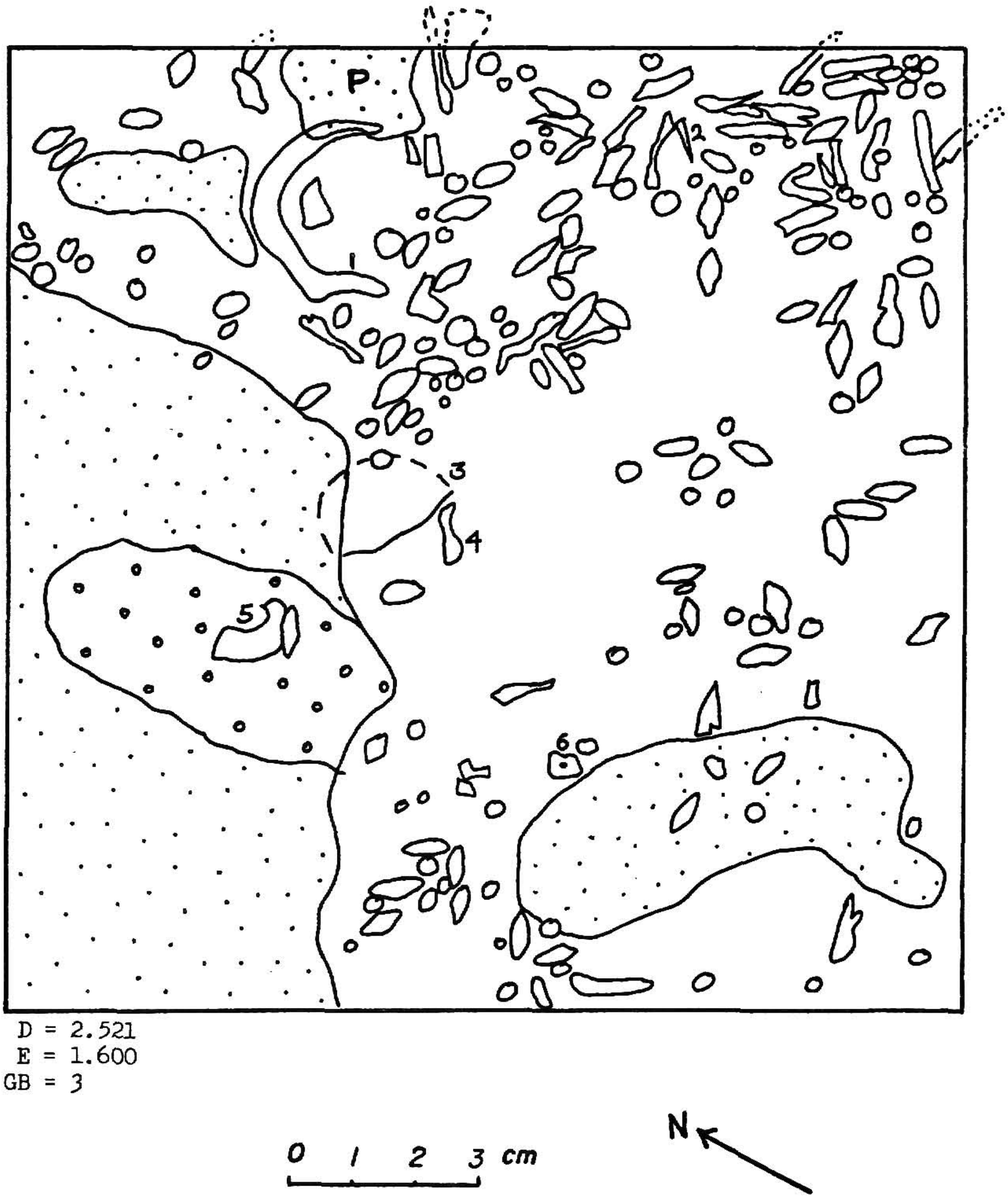
#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Crin	1.1	.9	i			x		pyr	
2	Fus	.3	.3						pyr	
3	rIV	.5	.4	p		zeu	x		o	
4	Fus	.4	.4						pyr	
5	Crin	.6	.6	i			x		pyr	
6	Iso						x		o	



D = 1.923
E = 1.250
GB = 2

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Lino	2.9	3.0	cvu		p	x		pyr	
2	Ech	.1	.6	i			x		cal	
3	Lino	1.4	2.0	cvu		p	x		o	
4	?	.2	.6	i	cval				o	
5	Crin	.8	1.3	i			x		cal	
	Fus								o	
	Iso						x		o	

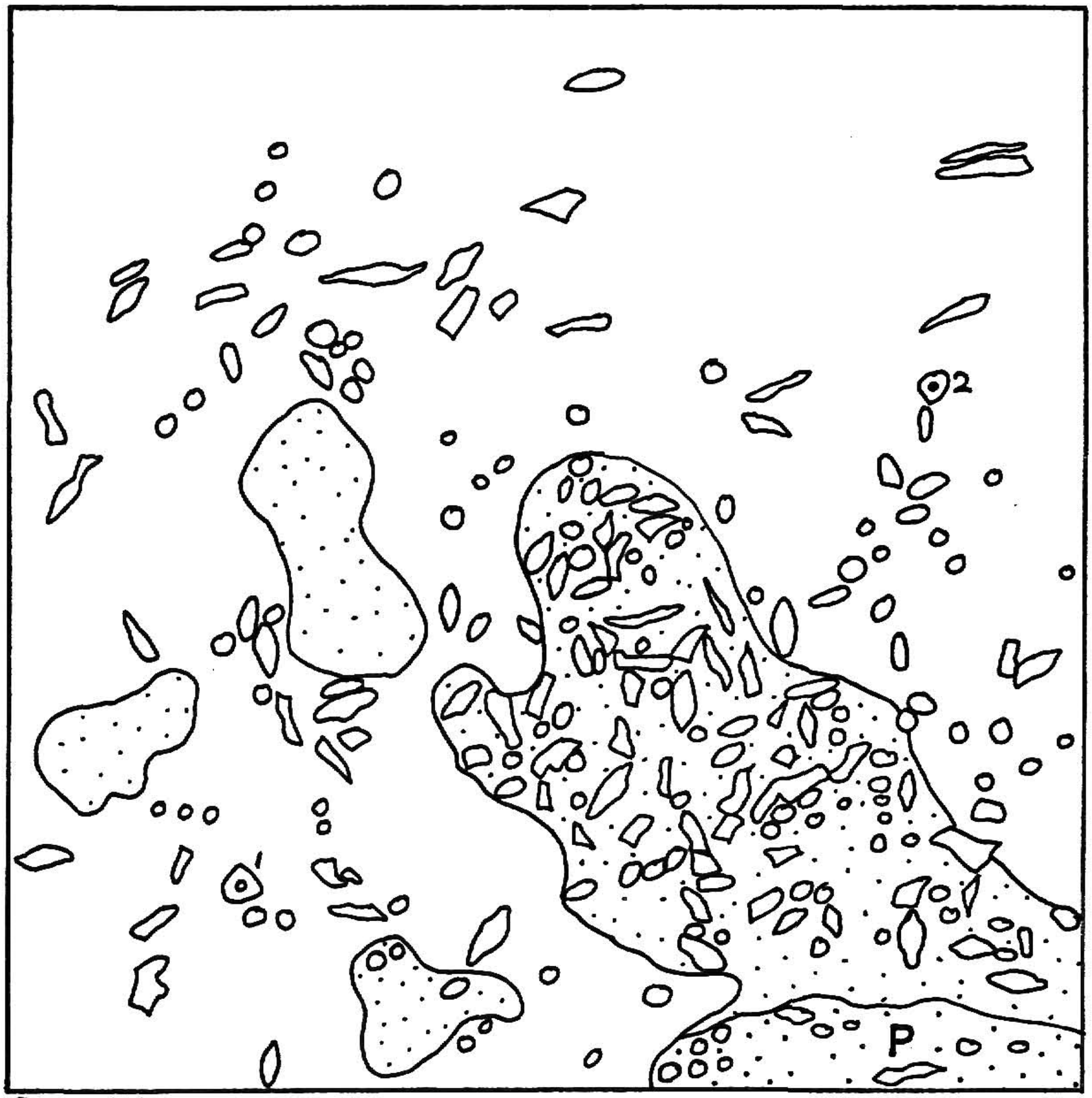
P-L-5



D = 2.521
E = 1.600
GB = 3

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Crin	.4	.3	i			x		o	
2	Crin	.3	.2	i			x		o	

P-L-6

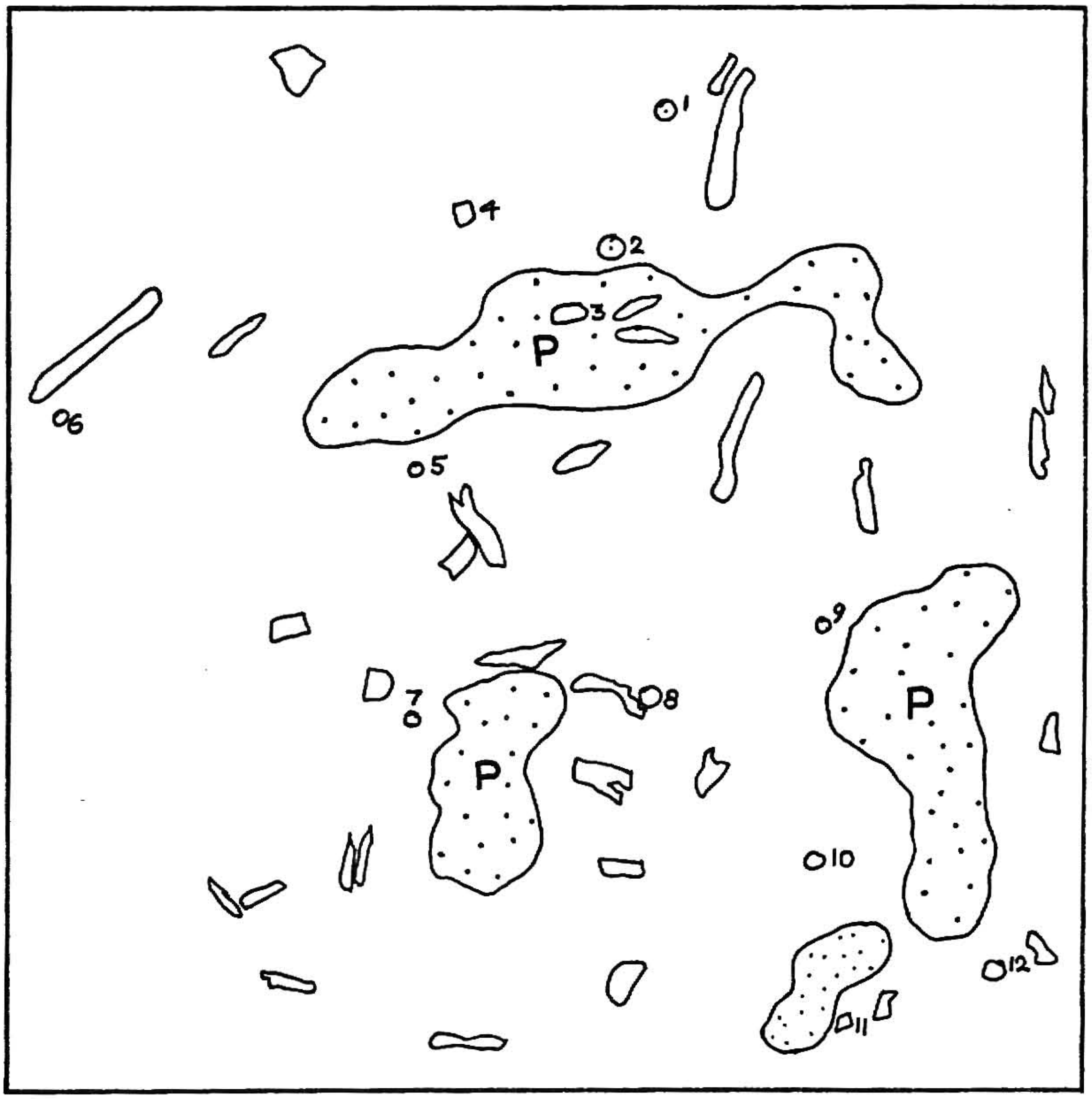


D = .917
E = 1.000
GB = 3

P-L-7

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Crin	.2	.2	i			x		cal	
2	Crin	.3	.3	i			x		cal	
3	Crin	.3	.2	p			x		pyr	
4	Crin	.3	.3	p			x		cal	
5	Crin	.1	.1	i			x		cal	
6	Crin	.1	.1	i			x		cal	
7	Crin	.1	.1	i			x		cal	
8	Crin	.3	.3	i			x		cal	
9	Crin	.2	.2	i			x		cal	
10	Crin	.2	.2	i			x		cal	
11	Crin	.2	.2	p			x		cal	
12	Crin	.3	.3	i			x		cal	

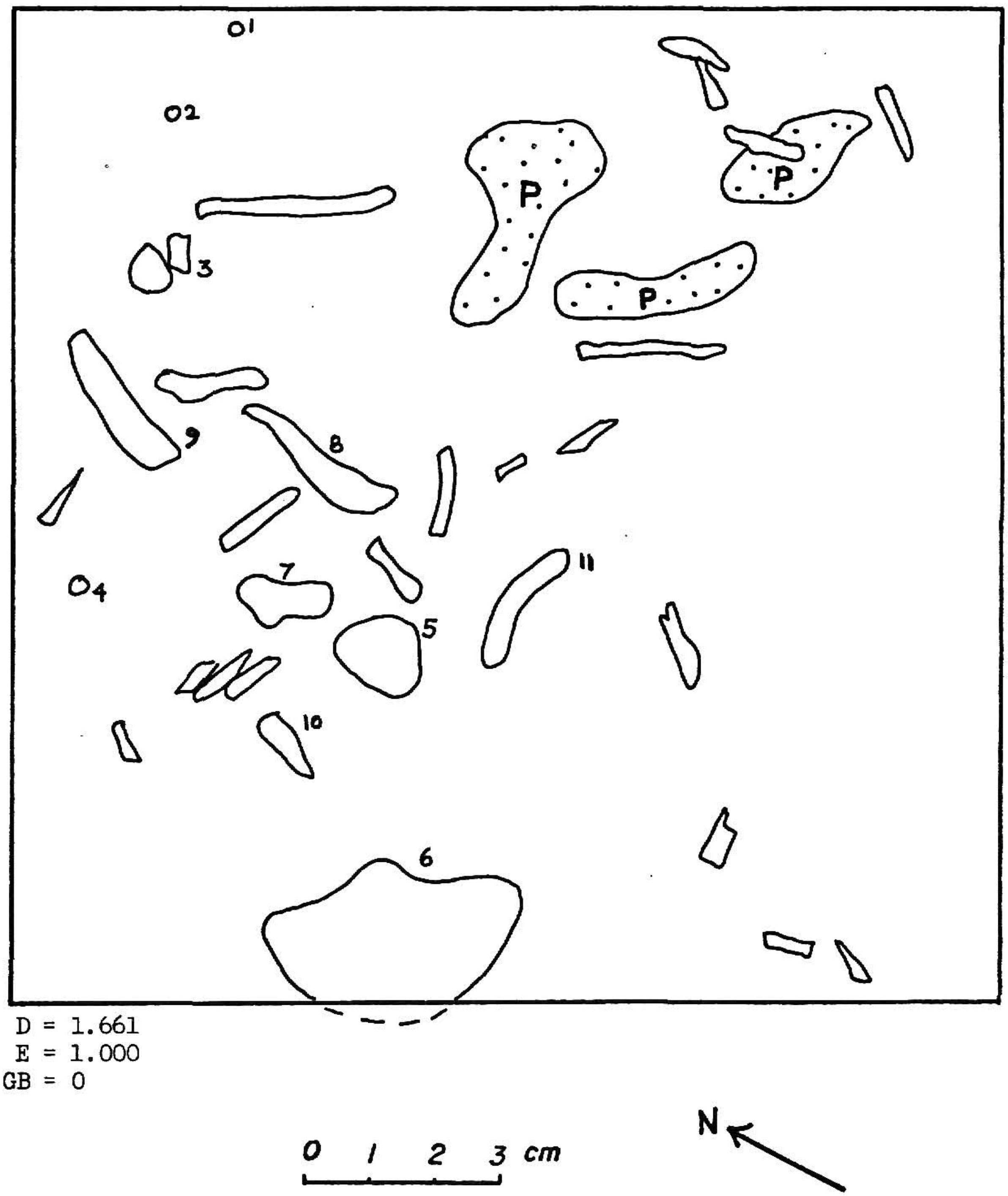
P-L-7



D = .462
E = .667
GB = 0

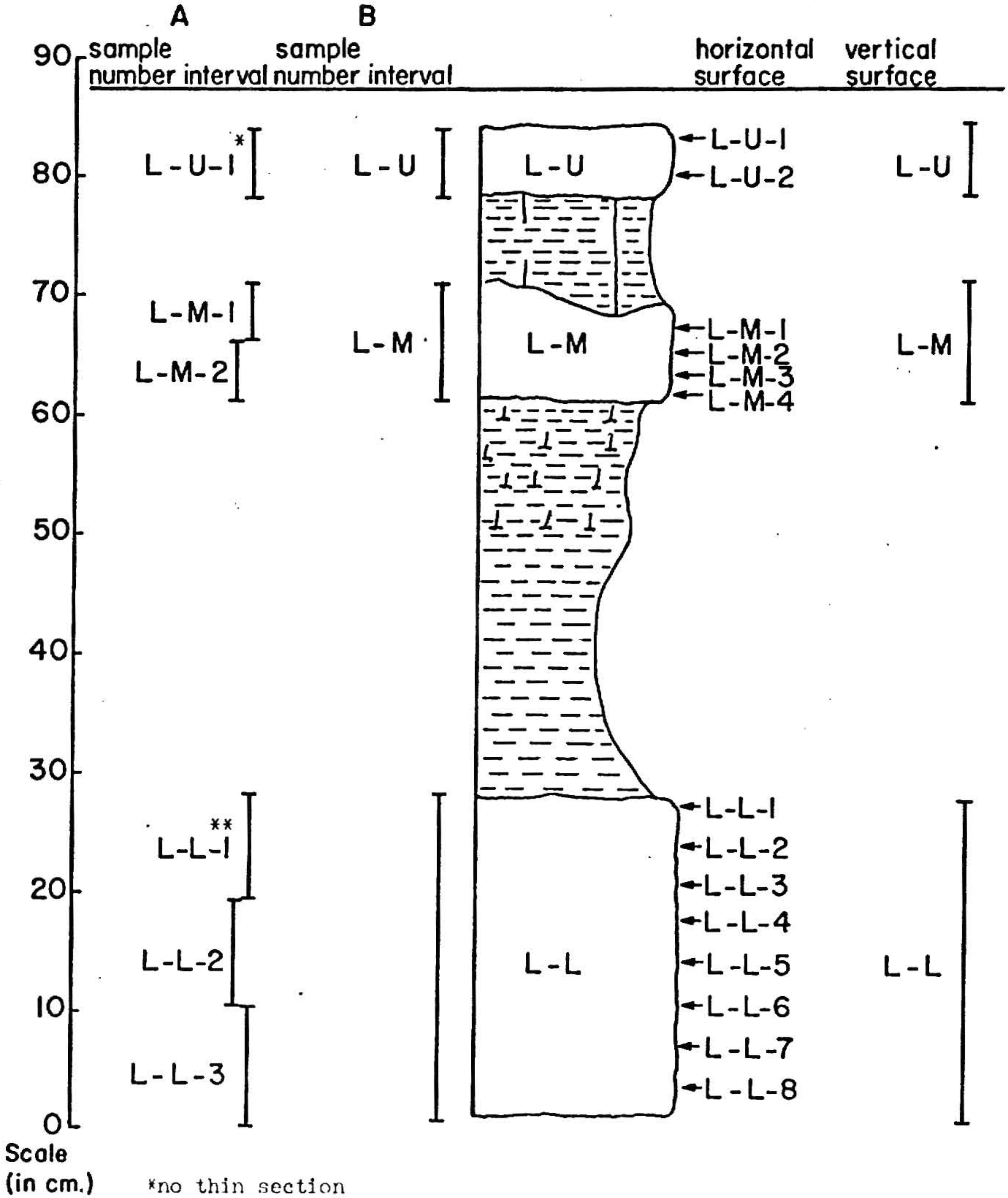
#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Crin	.1	.1	i			x		o	
2	Crin	.1	.1	i			x		o	
3	Crin	.4	.4	i			x		o	
4	Crin	.2	.2	i			x		o	
5	Comp	1.7	1.5	cvu		p			o	
6	Nesp	4.0	2.6	ccu		p			o	
7	rIII	1.5	.7	zeu			x		o&m	
8	rIII	2.6	.6	zeu			x		o&m	
9	rIII	2.4	.6	zeu			x		o	
10	rIII	1.2	.4	zeu			x		o	
11	rIII	2.2	.4	zed			x		o	

P-L-8



D = 1.661
E = 1.000
GB = 0

LOUISVILLE (L) SECTION

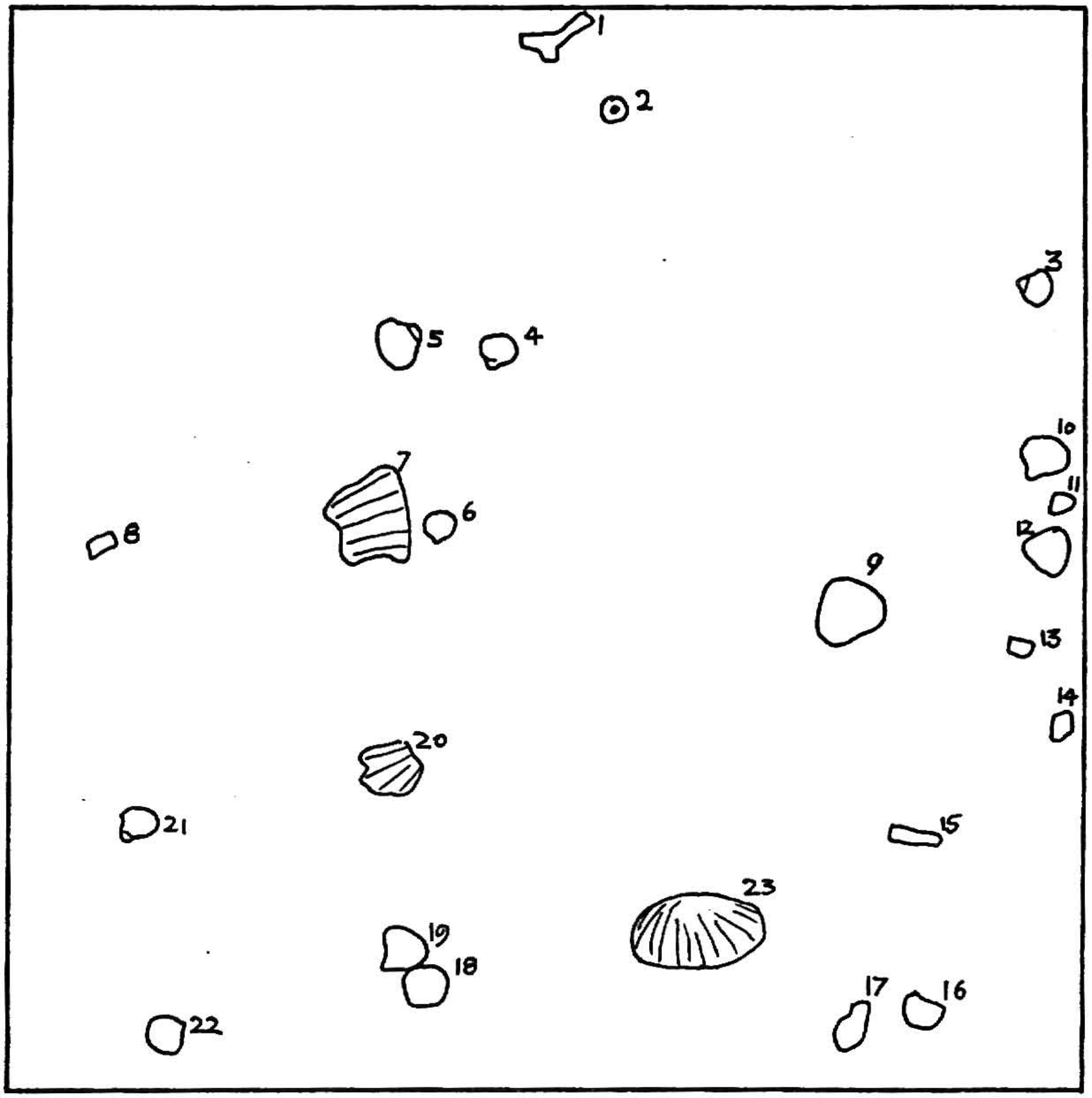


*no thin section
**four thin sections (L-L-1, L-2, L-3)

L-U-1

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	brac	.7	.2	p			x		o	
2	Crin	.2	.2	i			x		o	
3	Cru	.5	.4	ccu		p			o	
4	Cru	.3	.3	cvu		b			o	
5	Cru	.5	.4			b			o	
6	Rhip	.3	.4	ccu			x		o	
7	Lino	1.1	1.1	ccu		p	x		o	
8	Crin	.3	.1	p					o	
9	Comp	1.4	1.1	ccu		?			o	
10	Cru	.5	.7	ccu		p				
11	Cru	.4	.3	ccu		p			o	
12	Cru	.5	.5	ccu		p			o	
13	Crin	.2	.1	p			x		cal	
14	Crin	.2	.2	p			x		cal	
15	Crin	.3	.1	p			x		cal	
16	Cru	.4	.4	ccu		p			o	
17	?	.5	.3			?	x		o	
18	Cru	.3	.4	ccu		p			o	
19	Cru	.6	.6	cvu		p			o	
20	Lino	.7	.6	ccu		p	x		o	
21	Cru	.3	.2	ccu		p	x		o	
22	Rea	.9	.8	ccu					o	

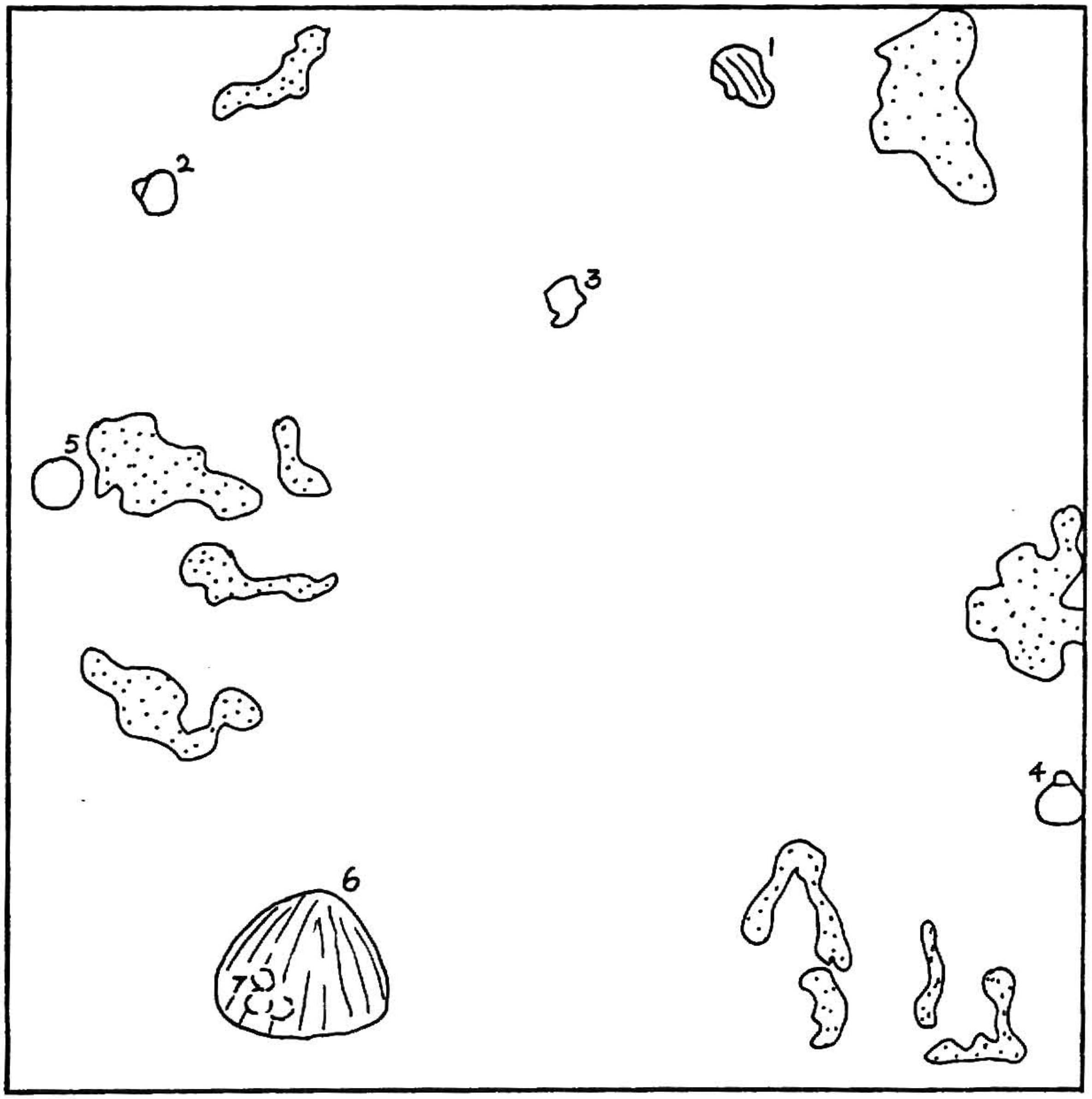
L-U-1



D = 1.880
E = 1.000
GB = 0

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	brac	.4	.3	ccu		?	x		m	
2	Cru	.5	.4	cvu		p			o	
3	Hust	.4	.3			?	x		m	
4	Cru	.7	.4	cvu		b			o	
5	Orb	.6	.6	ccu		b			o	
6	Derb	2.5	2.2	cvu		?				
7	Pet	.3	.3	cvu		b		6		

L-U-2

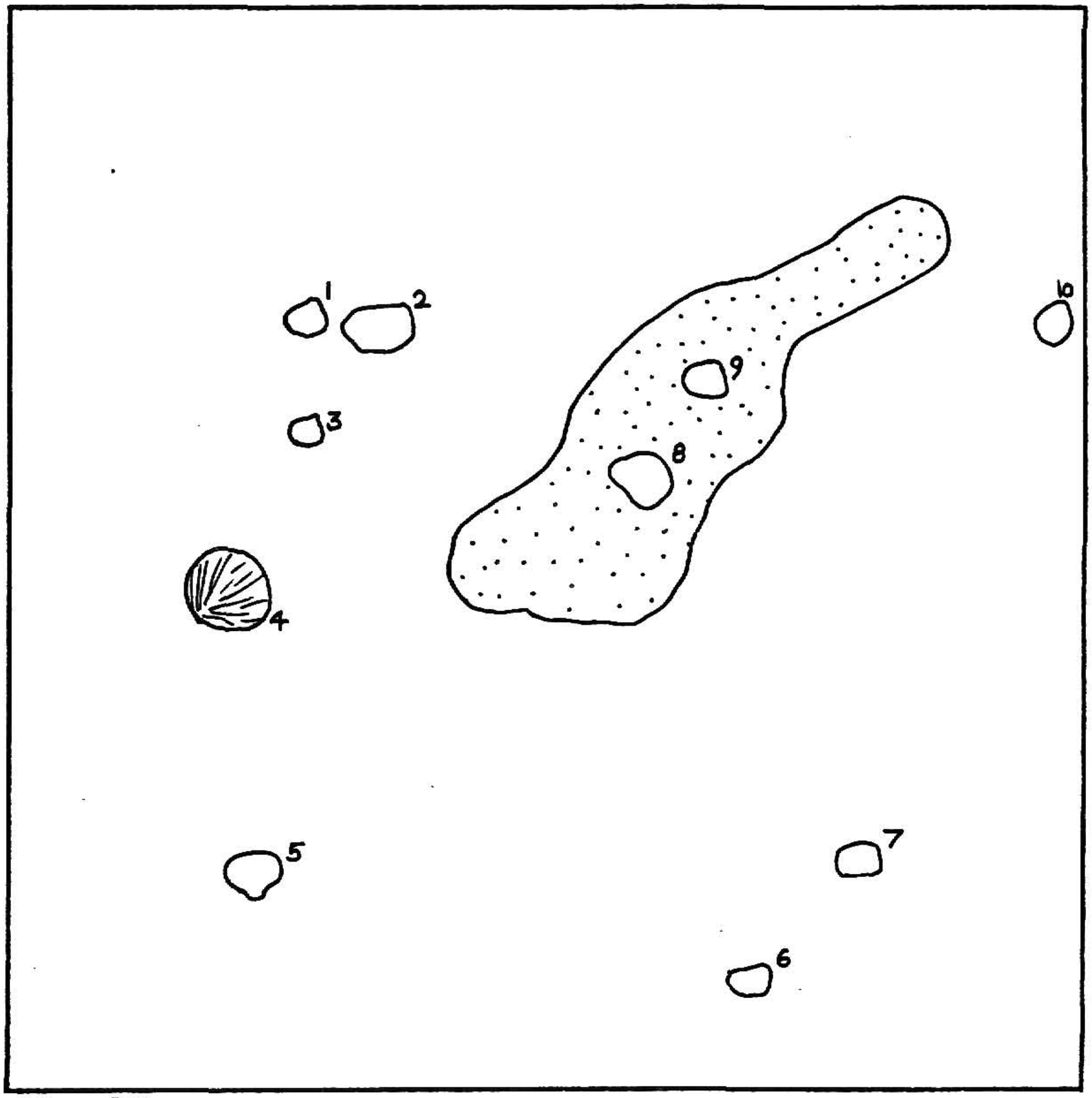


D = 2.256
E = 1.400
GB = 1

L-M-1

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.4	.5	cvu		b			o	
2	Cru	1.0	.7	ccu		p	x		o	
3	Cru	.3	.3	cvu		b			o	
4	Rhip	.2	1.0	cvu		p	x		o	
5	Cru	.5	.4	cvu		b			o	
6	Cru	.4	.3	ccu		b			o	
7	Cru	.5	.4	cvu		p			o	
8	Cru	1.0	.7	ccu		p	x		o	
9	Cru	.6	.4	cvu		b			o	
10	Cru	.6	.5	cvu		b	x		o	

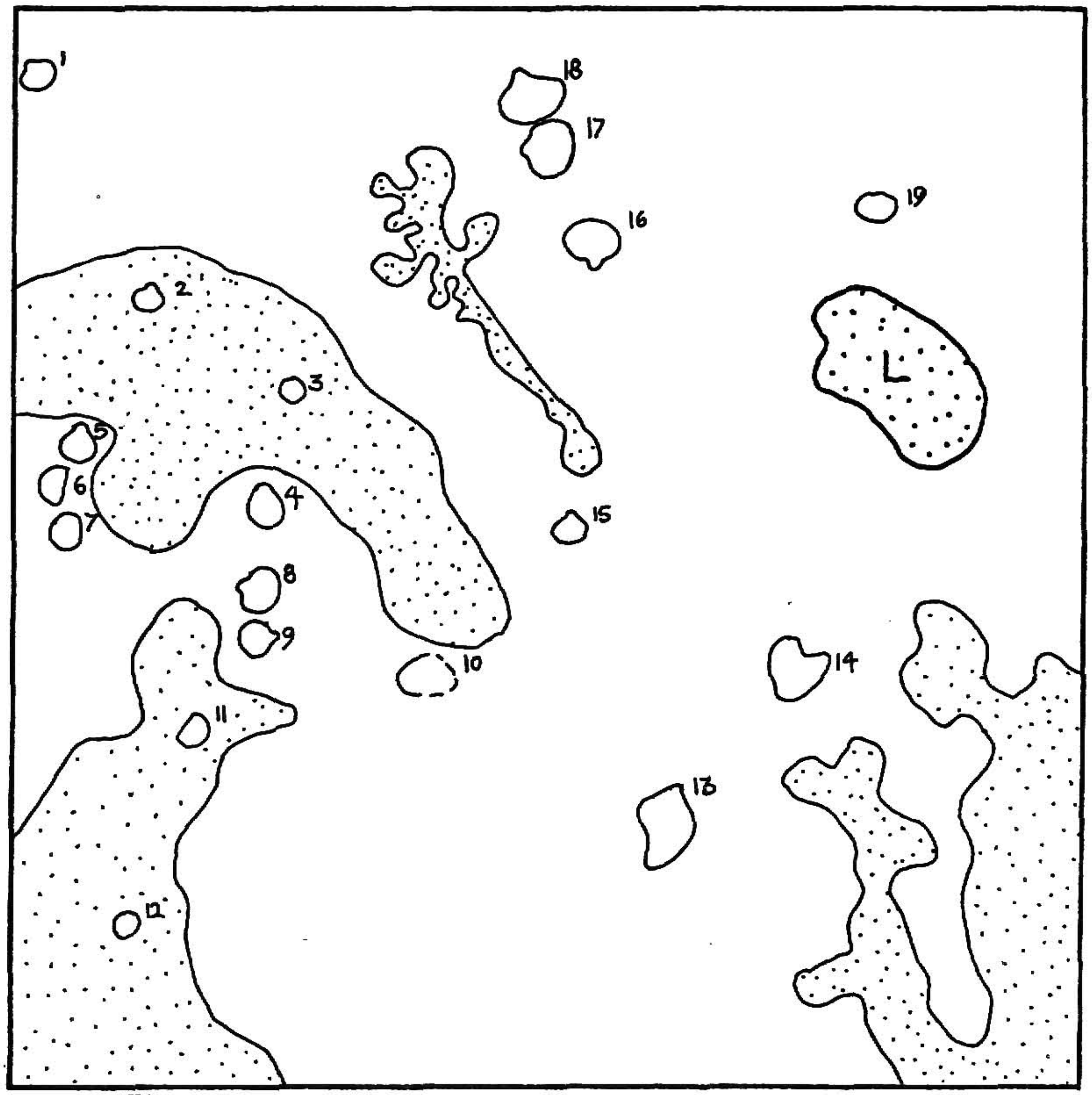
L-M-1



D = .591
E = 1.000
GB = 1

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.3	.3	cvu		b			o	
2	Cru	.3	.2	cvu		b			o	
3	Cru	.3	.3	cvu		b	x		o	
4	Cru	.6	.4	i	cval				o	
5	Cru	.5	.4	cvu		b			o	
6	Cru	.5	.4	ccu		p			o	
7	Cru	.5	.5	ccu		b	x		o	
8	Cru	.5	.6	cvu		b	x		o	
9	Cru	.6	.6		cval				o	
10	Cru	.7	.5	cvu		b	x		o	
11	Cru	.3	.3	cvu		b			o	
12	Cru	.2	.3			?			m	
13	Nesp	1.2	.8		cval				o	
14	Comp	.7	.7		cval				o	
15	Cru	.4	.3	cvu		b			o	
16	Cru	.6	.7	cvu		b			o	
17	Cru	.8	.9	cvu		b			o	
18	Cru	1.0	.9	cvu		b			o	

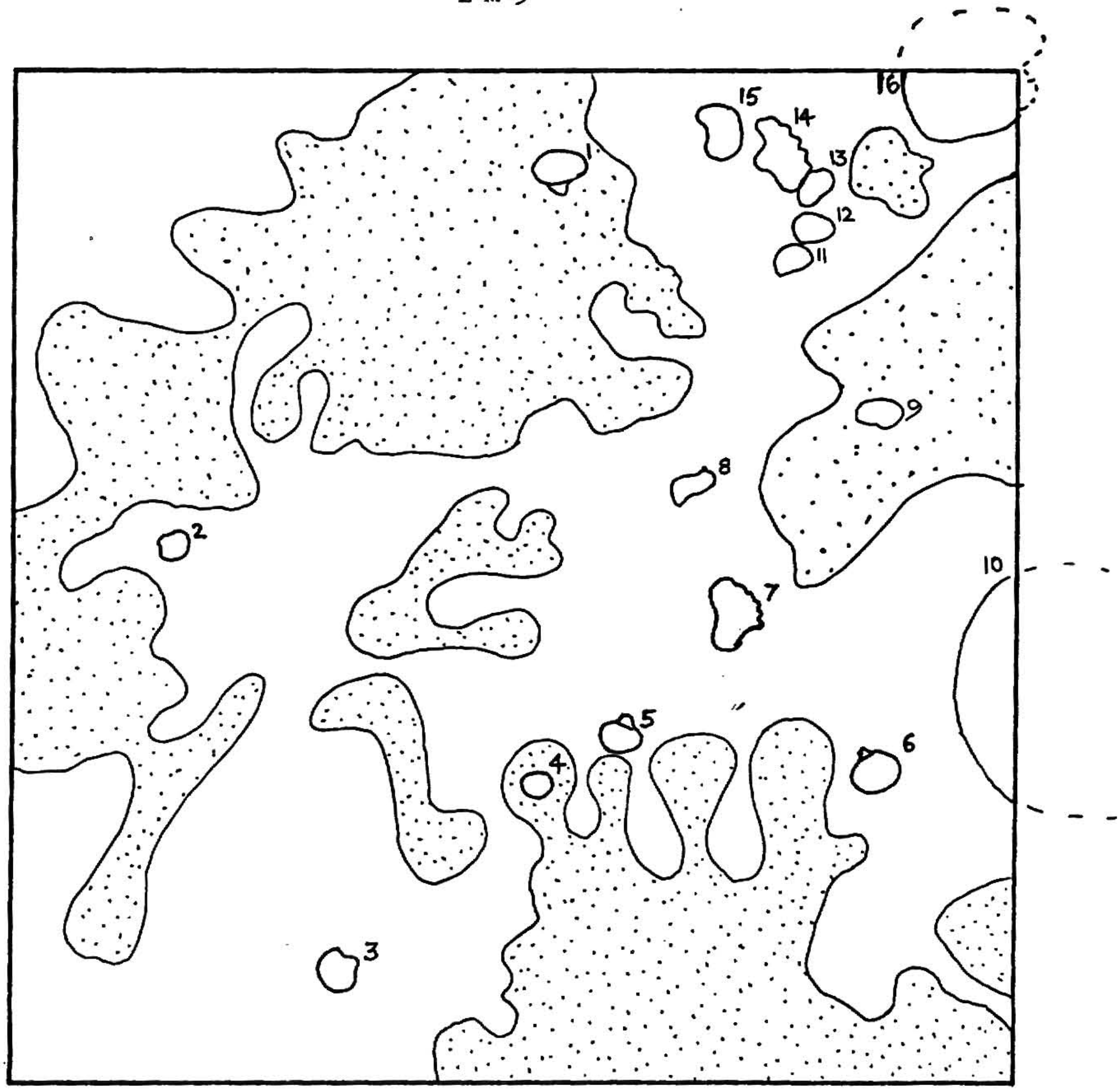
L-M-2



D = .674
E = .667
GB = 3

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.7	.5	cvu		b			o	
2	Cru	.3	.3	cvu		b	x		o	
3	Cru	.6	.4	cvu		b			o	
4	Cru	.3	.3	ccu		p	x		o	
5	Cru	.5	.5	cvu		b			o	
6	Cru	.8	.7	cvu		b			o	
7	Well	1.0	.8		cval				o	
8	Cru	.7	.4		cval				o	
9	Cru	.7	.5	ccu		p	x		o	
10	Jur			cvu		p			o	
11	Cru	.5	.4	ccu		b	x		o	
12	Cru	.6	.5	cvu		b			o	
13	Cru	.7	.6	ccu		p	x		o	
14	Well	1.3	.8		cval				o	
15	Cru	.9	.6	ccu		p	x		o	
16	Rea	2.1	1.9	ccu		?	x		o	

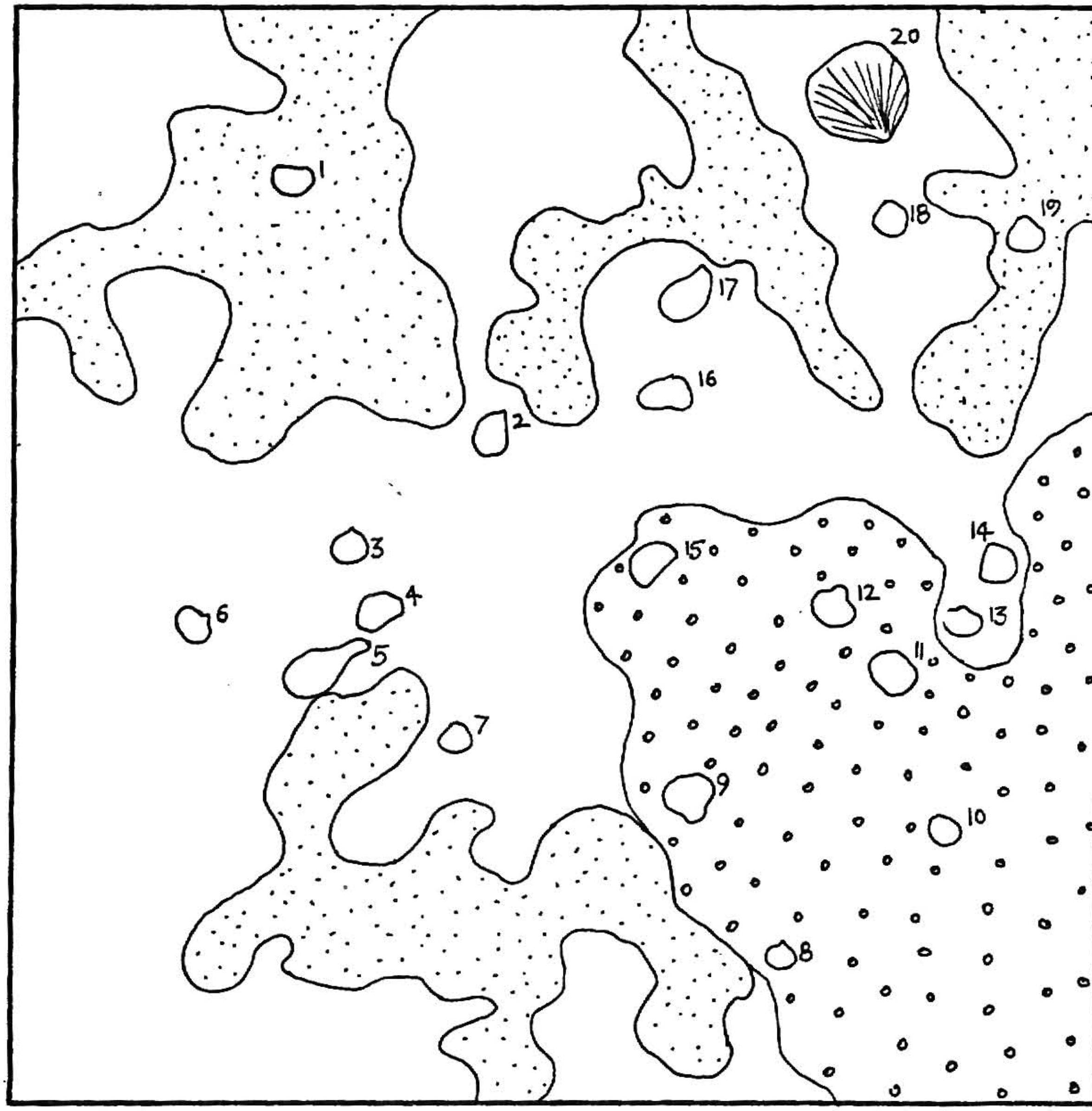
L-M-3



D = 1.418
E = .750
GB = 4

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.4	.3	cvu		b			o	
2	Cru	.6	.4		cval				o	
3	Cru	.4	.4	cvu		b			o	
4	Cru	.6	.5	ccu		p	x		o	
5	Apec	1.2	.7		cval				o	
6	Cru	.3	.3	cvu		b			o	
7	Cru	.3	.4	cvu		b			o	
8	Cru	.3	.3	cvu		b			o	
9	Cru	.6	.6	ccu		p	x		o	
10	Crin	.4	.4	i			x		cal	
11	Cru	.8	.7	ccu		p	x		o	
12	Cru	.6	.6	ccu		p			o	
13	Cru	.4	.5	cvu		b			o	
14	Cru	.5	.5	cvu		b			o	
15	Cru	.7	.6	ccu		p	x		o	
16	Cru	.6	.4		cval				o	
17	Cru	1.0	.7		cval				o	
18	Cru	.5	.4	cvu		b			o	
19	Cru	.5	.5	cvu		b			o	
20	Derb	1.4	1.4	cvu		b			o	

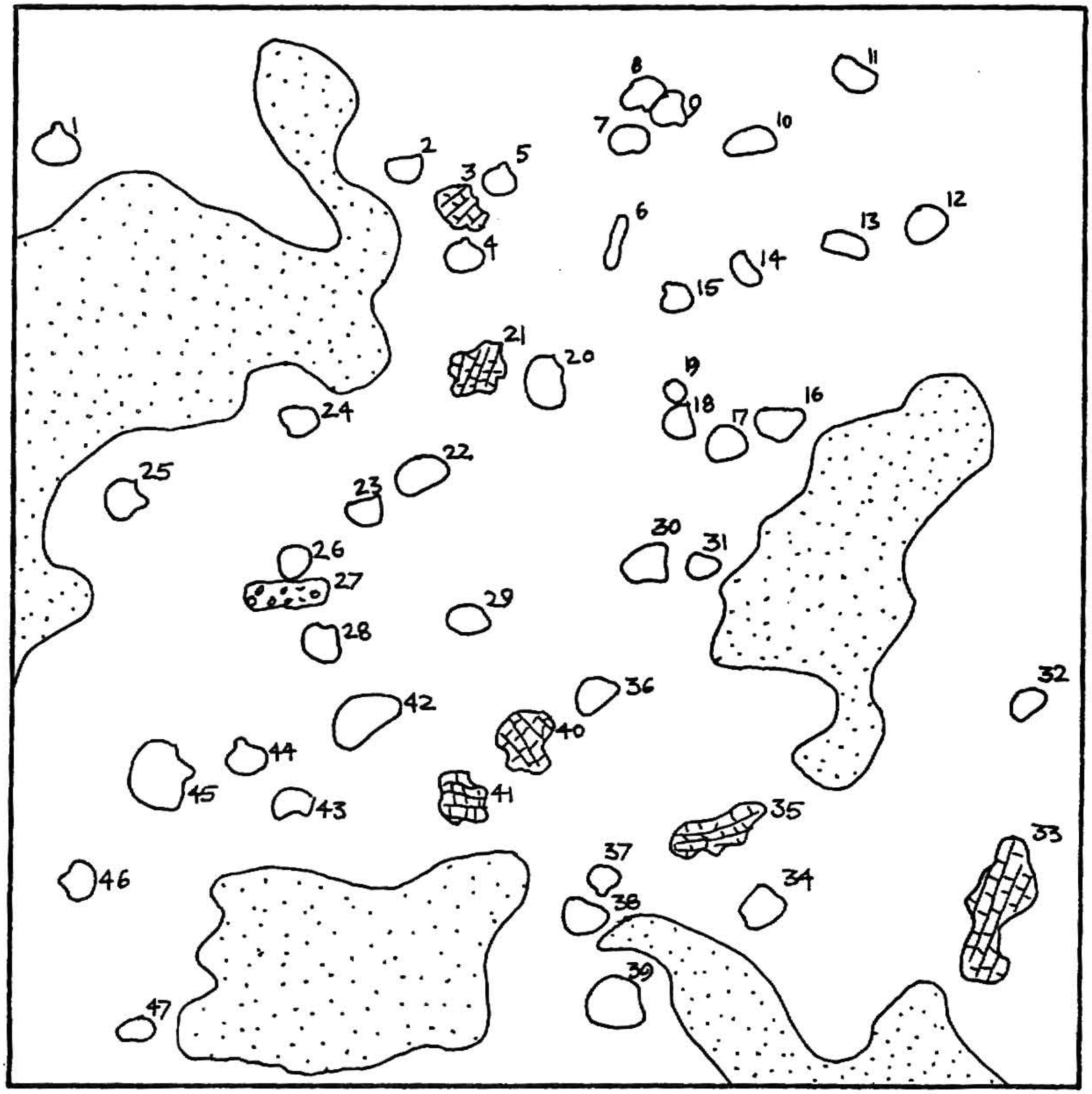
L-M-4



D = 1.046
E = .500
GB = 3

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.6	.4	cvu	cval				o	
2	Cru	.5	.3	ccu		b			m	
3	fII	.8	.6	p			x		o	
4	Rhip	.5	.4	cvu	cval				o	
5	Cru	.5	.5	cvu		p			o	
6	brac	.2	.8	p			x		o	
7	Cru	.6	.5	cvu		p	x		o	
8	Cru	.8	.6	cvu		p	x		o	
9	Cru	.6	.6	ccu		b	x		m	
10	Cru	.7	.4	ccu		b			m	
11	Cru	.7	.5	ccu		b			m	
12	Cru	.5	.4	ccu		b	x		m	
13	Cru	.7	.3	?		?			o	
14	Cru	.6	.3	ccu		b			m	
15	Cru	.3	.3	cvu		p	x		o	
16	Cru	.7	.5	ccu		b			o	
17	Cru	.7	.6	ccu		p			o	
18	Cru	.5	.4	cvu		p	x		o	
19	Cru	.3	.2	?		?	x		o	
20	Cru	.7	.5	cvu		b			m	
21	fII	.8	.9	p			x		o&m	
22	Cru	.7	.5	cd		b			o	
23	Cru	.4	.4	ccu		b	x		o	
24	Cru	.6	.4	ccu					o	
25	Rhip	.6	.6		cval				cal	
26	Cru	.5	.4	ccu		p			o	
27	rII	1.2	.3	p			x		o	
28	Cru	.6	.5	ccu		b			o	
29	Cru	.4	.6	cvu		?	x		o	
30	Cru	.6	.6	cvu		b			o	
31	Cru	.4	.4	cvu		p			o	
32	Cru	.5	.4	ccu		p			m	
33	fII	.8	2.1	p			x		o	
34	Cru	.6	.5	cu		p			m	
35	fII	.5	1.4	p			x		o	
36	Cru	.4	.6	cu		p			m	
37	Cru	.4	.3	cu		p			m	
38	Cru	.7	.5	cu		b			m	
39	Cru	.7	.7	cd		p			m	
40	fII	.7	.8	p			x		o	
41	fII	.6	.7	p			x		o	
42	Cru	1.0	.6	cvu		b			o	
43	?	.6	.3				x		o	
44	Cru	.5	.5	cvu		p	x		o	
45	Comp	1.1	.8	cvu		b	x		o	
46	Hust	.5	.4	ccu		b			o	
47	Cru	.6	.3	ccu		b			m	

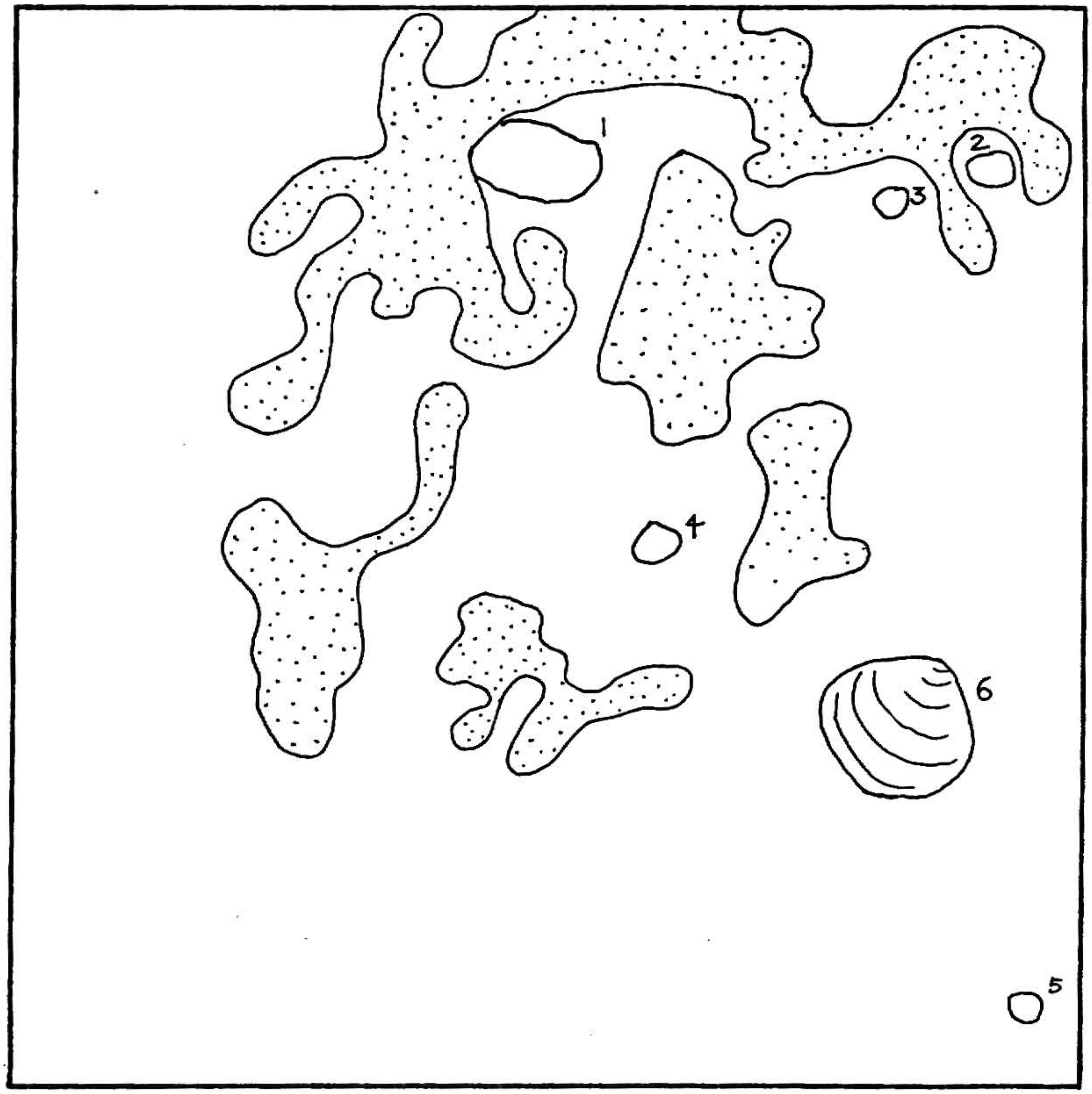
L-L-1



D = 1.937
E = .714
GB = 3

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Rea	1.1	1.7	ccu		?			m	
2	Cru	.6	.5	cvu		p	x		o	
3	Cru	.5	.5	cvu		p			o	
4	Cru	.7	.6	cvu		p			o	
5	Cru	.4	.4	cvu		p	x		o	
6	Comp	2.2	2.2	cvu		p	x		o	

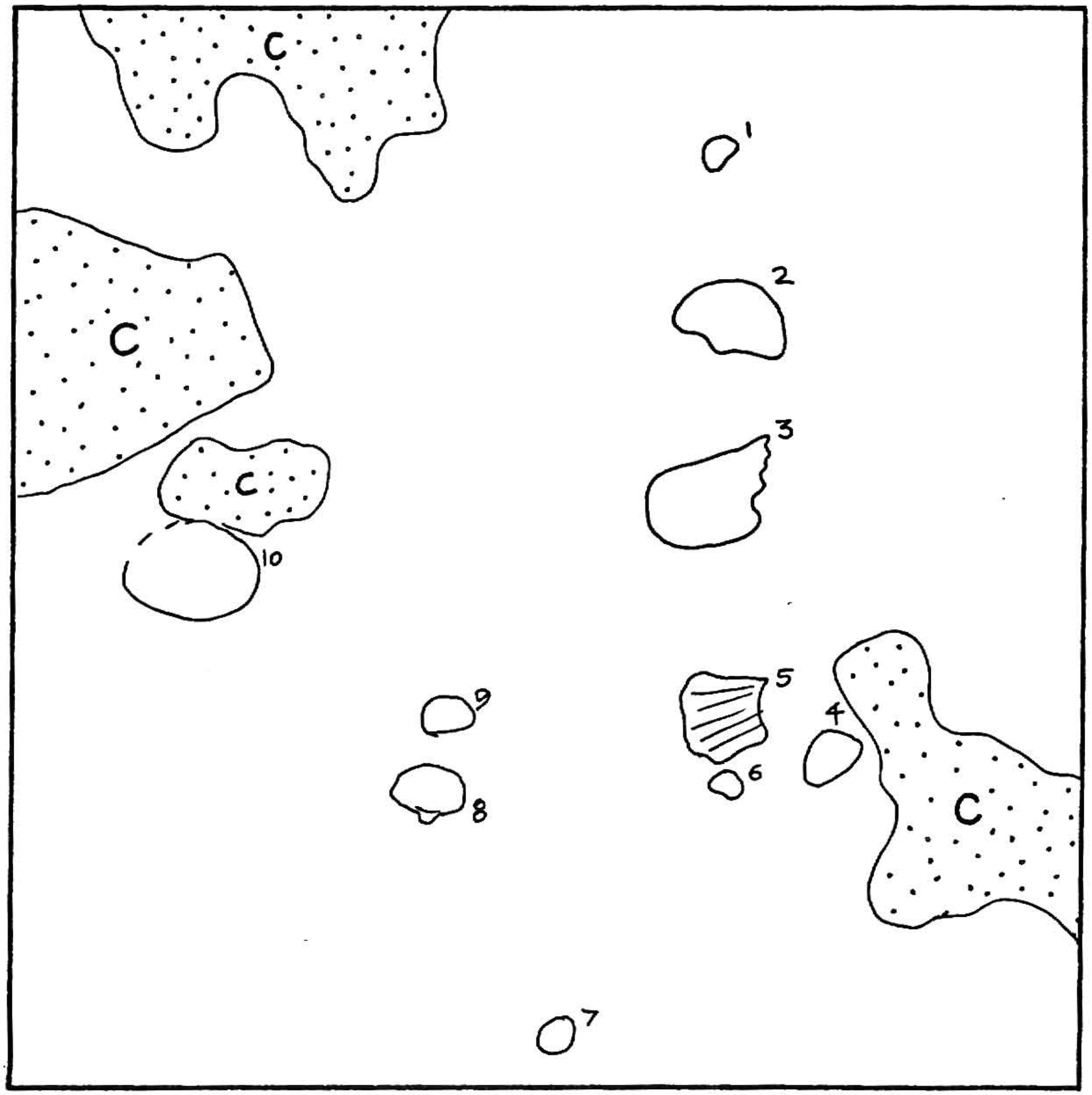
L-L-2



D = 1.252
E = 1.000
GB = 3

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.5	.3	ccu		b	x		o	
2	Nesp	1.6	1.1	cvu					o	
3	Lino	1.2	1.7	cvu			x		o	
4	Cru	.6	.8	cvu		b	x		o	
5	Lino	1.3	1.2	cvu			x		o	
6	Cru	.5	.3	ccu		p			o	
7	Cru	.5	.4	cvu		b			o	
8	Cru	.9	.8	ccu		b			o	
9	Cru	.6	.5	ccu		p			o	
10	Comp	1.0	1.4	cvu		p	x		o	

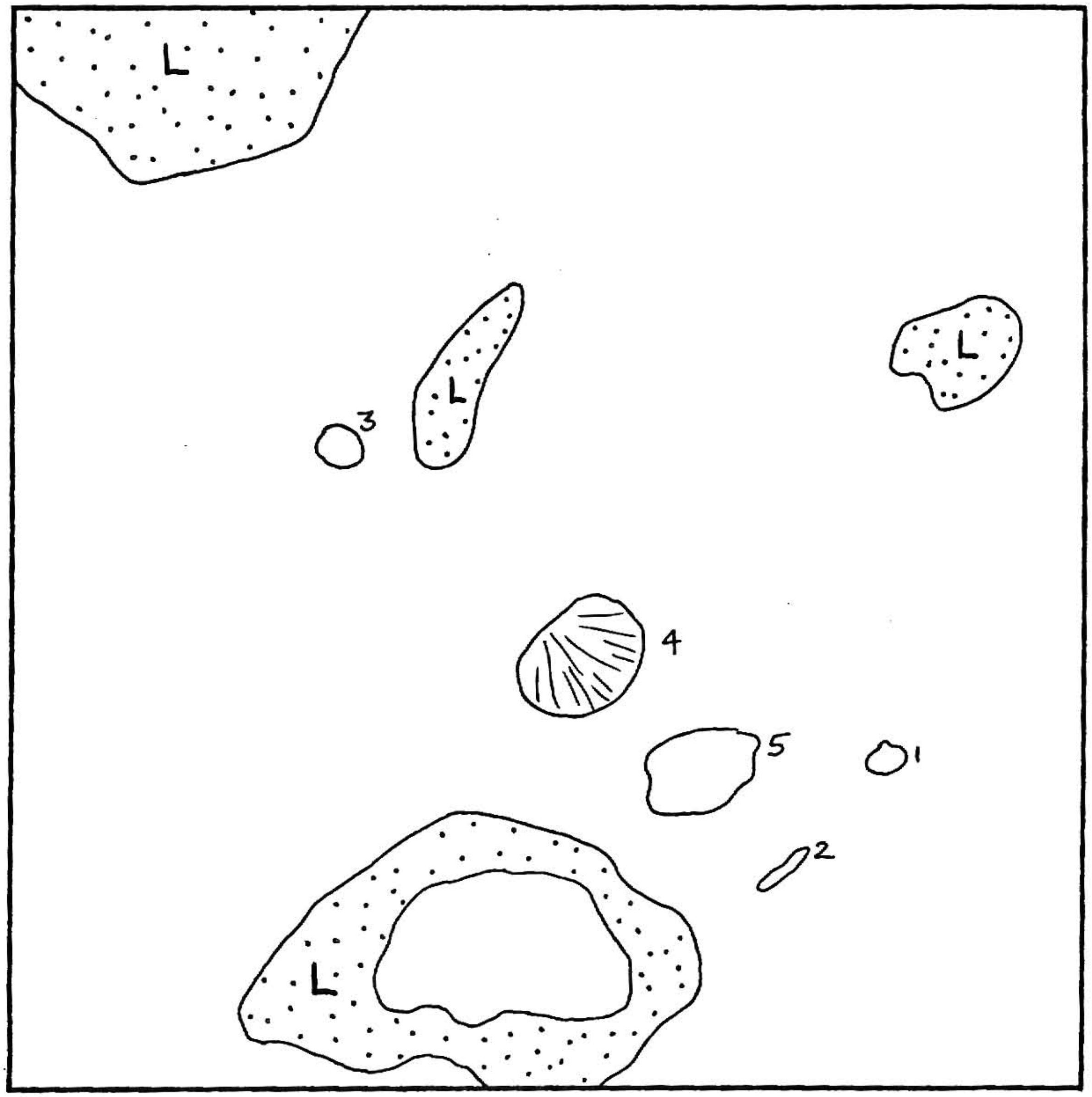
L-L-3



D = 1.751
E = 1.000
GB = 0

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.5	.4	cvu		b			o	
2	brac	.7	.2				x		o	
3	Cru	.6	.5	ccu		p	x		o	
4	Derb	1.9	1.4	cvu		p			o	
5	Rea	1.7	1.2			?	x		o	

L-L-4



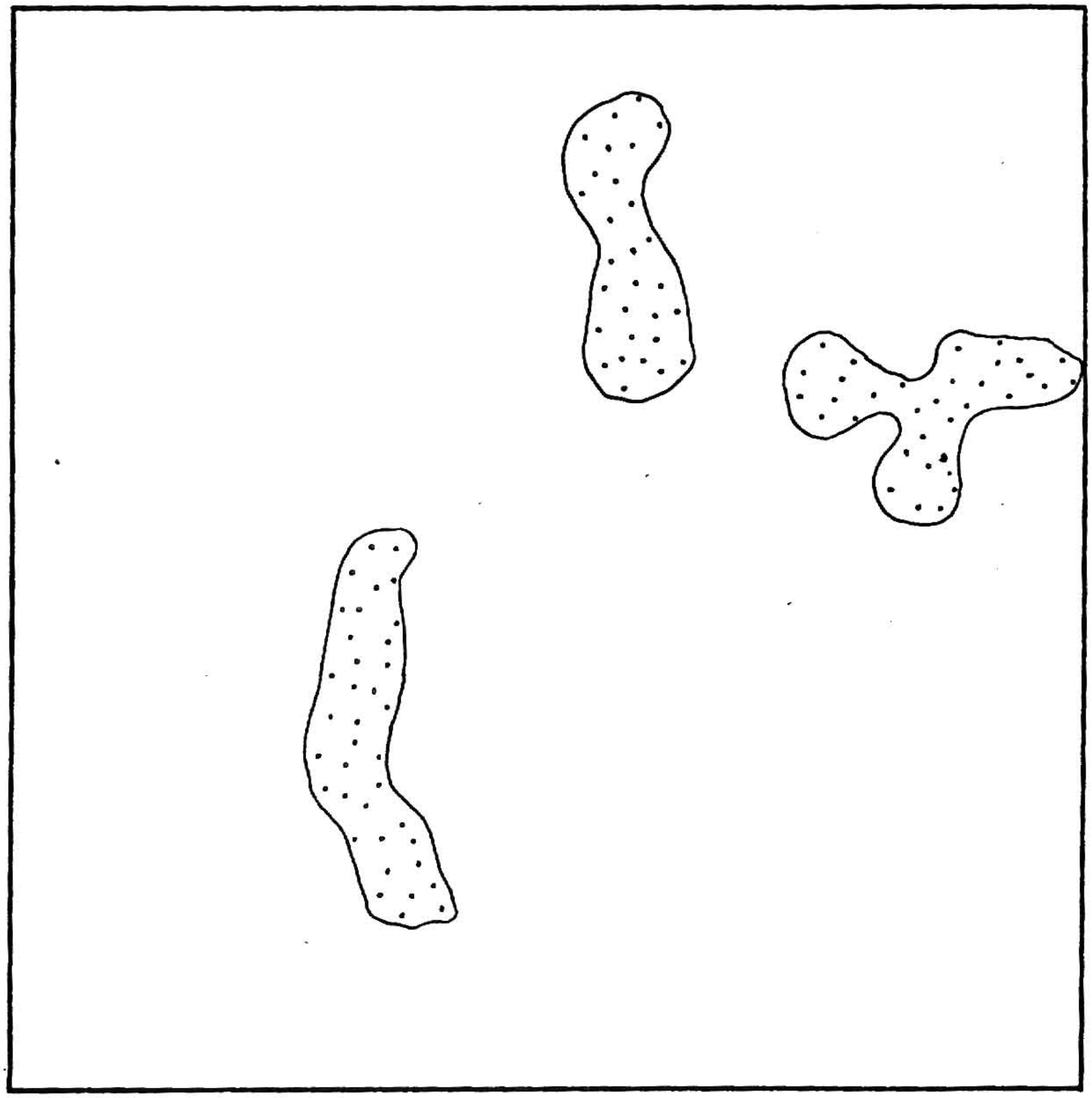
D = 1.585
E = 1.333
GB = 0

L-L-5

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del

no fossils encountered

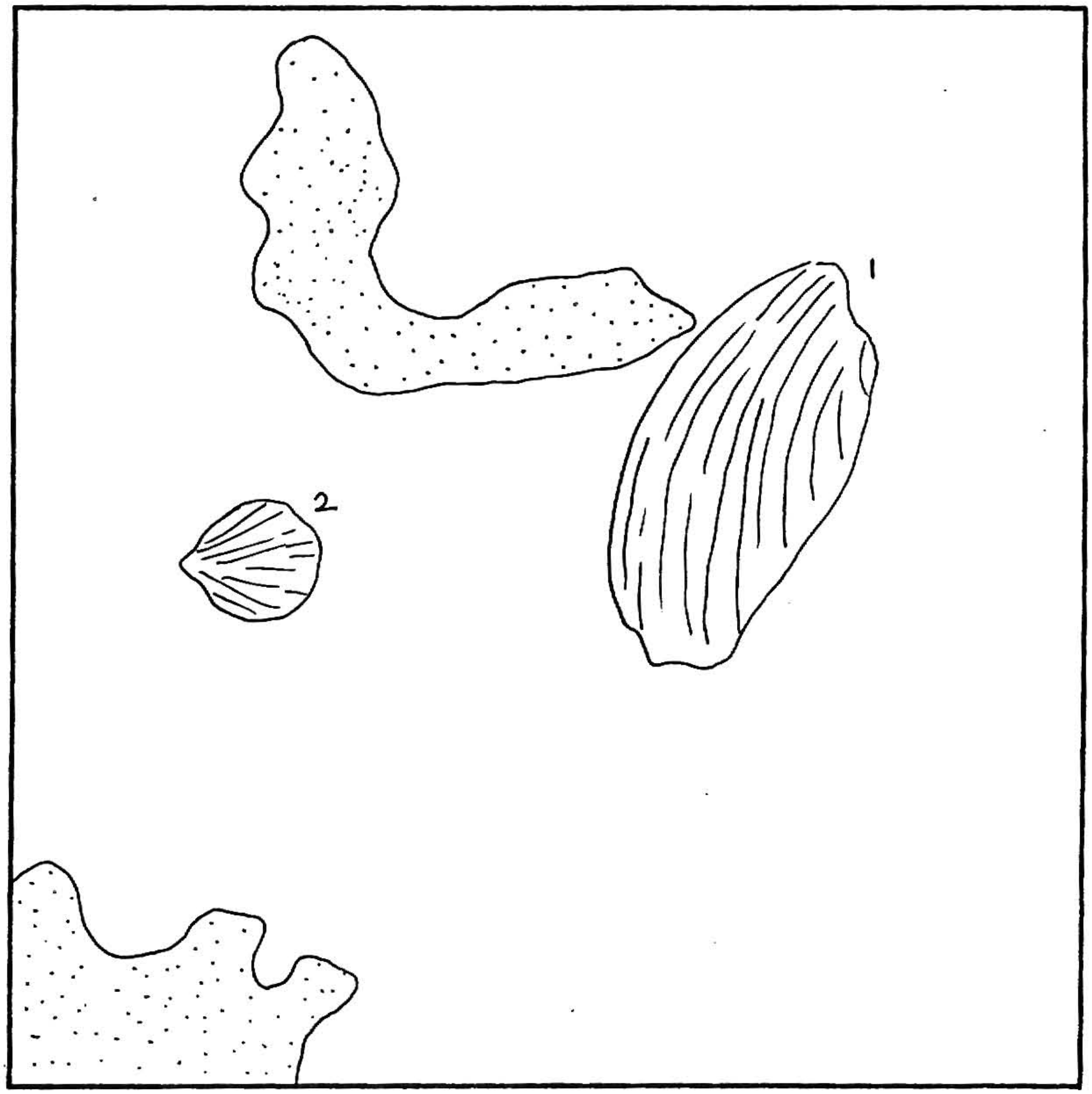
L-L-5



D = 0
E = 0
GB = 1

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Wilk	6.2	2.5	p	cval		x		o	
2	Derb	2.0	1.7	cvu		b			o	

L-L-6

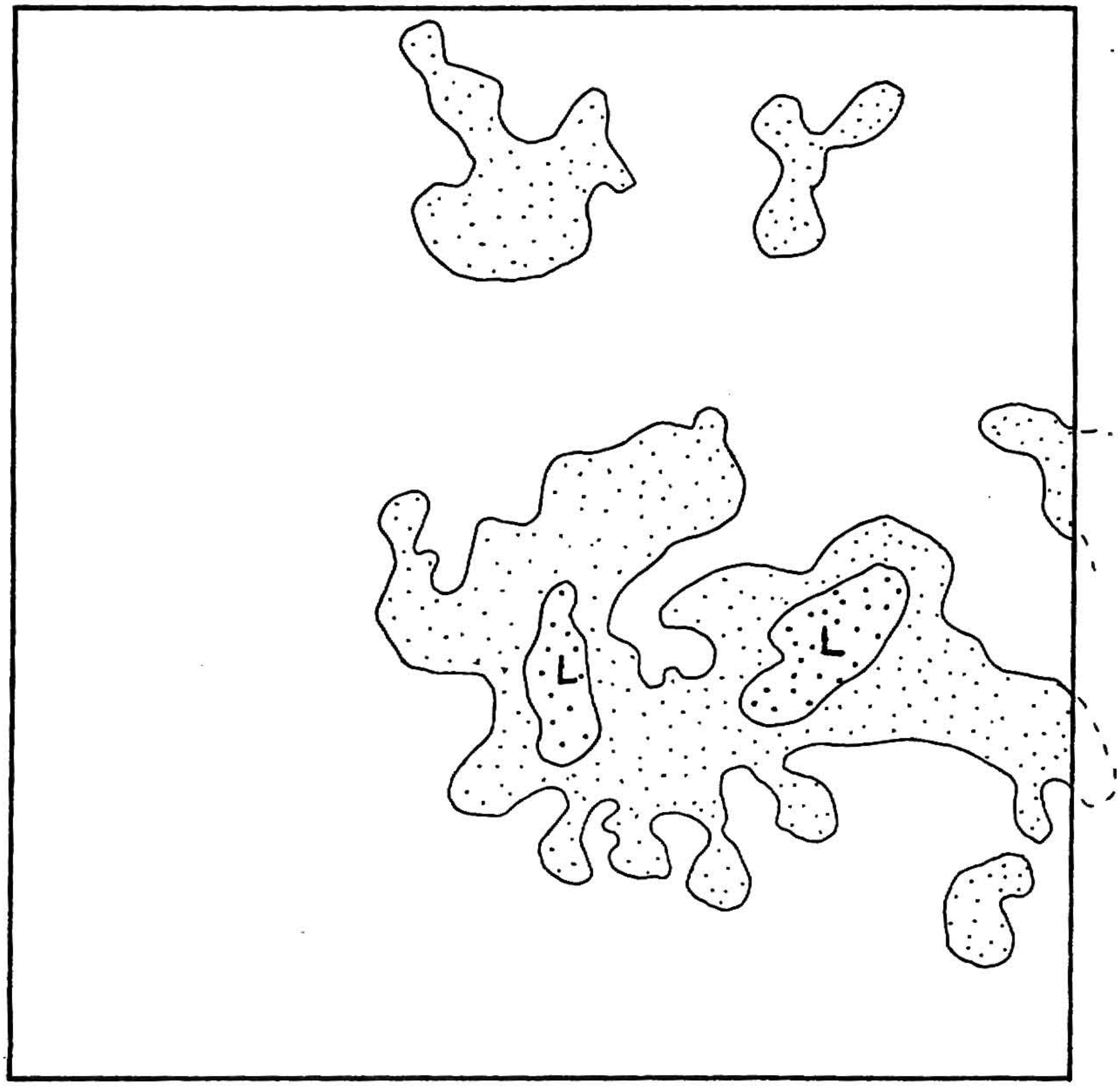


D = 1.003
E = 1.000
GB = 1

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del

no fossils encountered

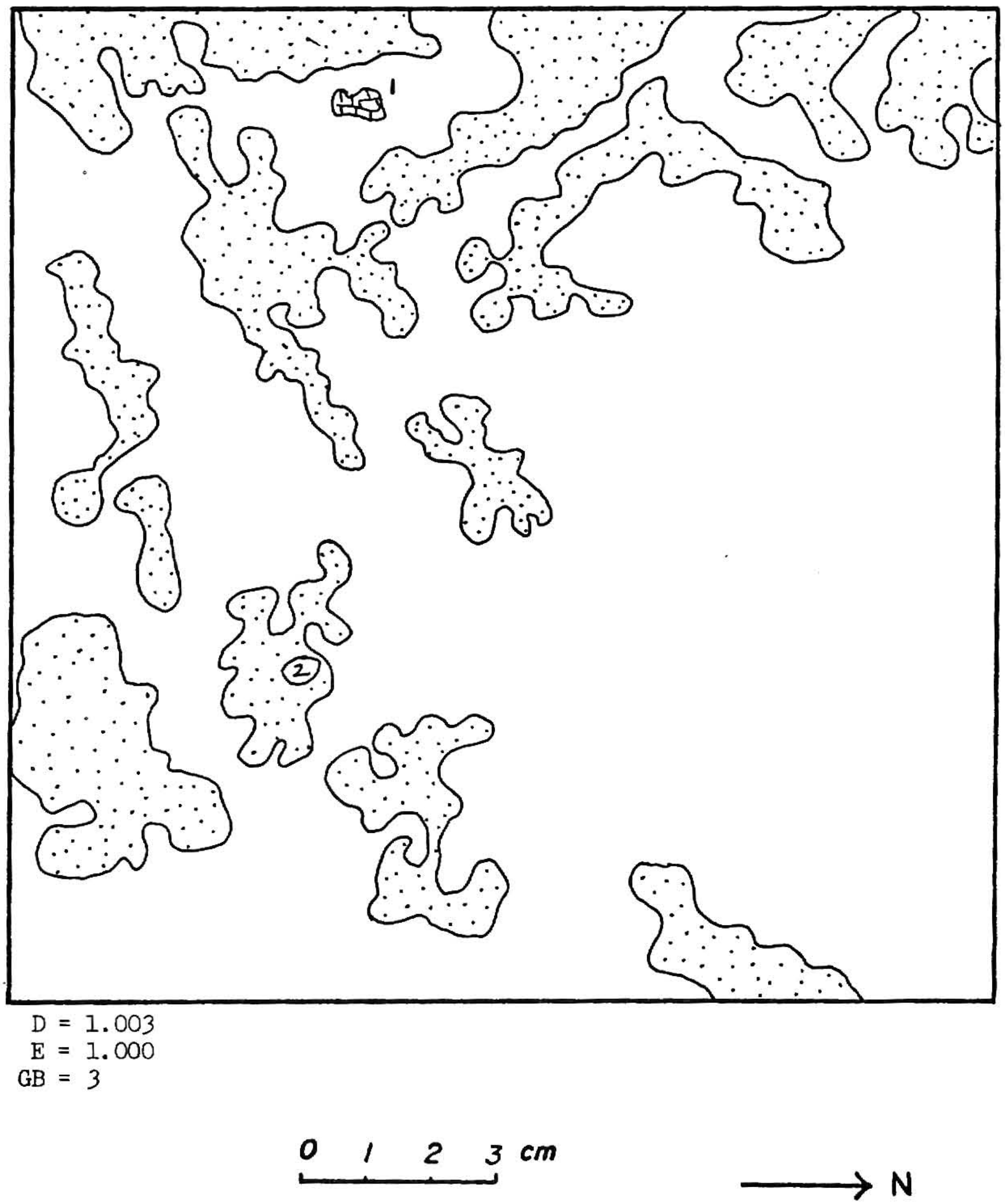
L-L-7



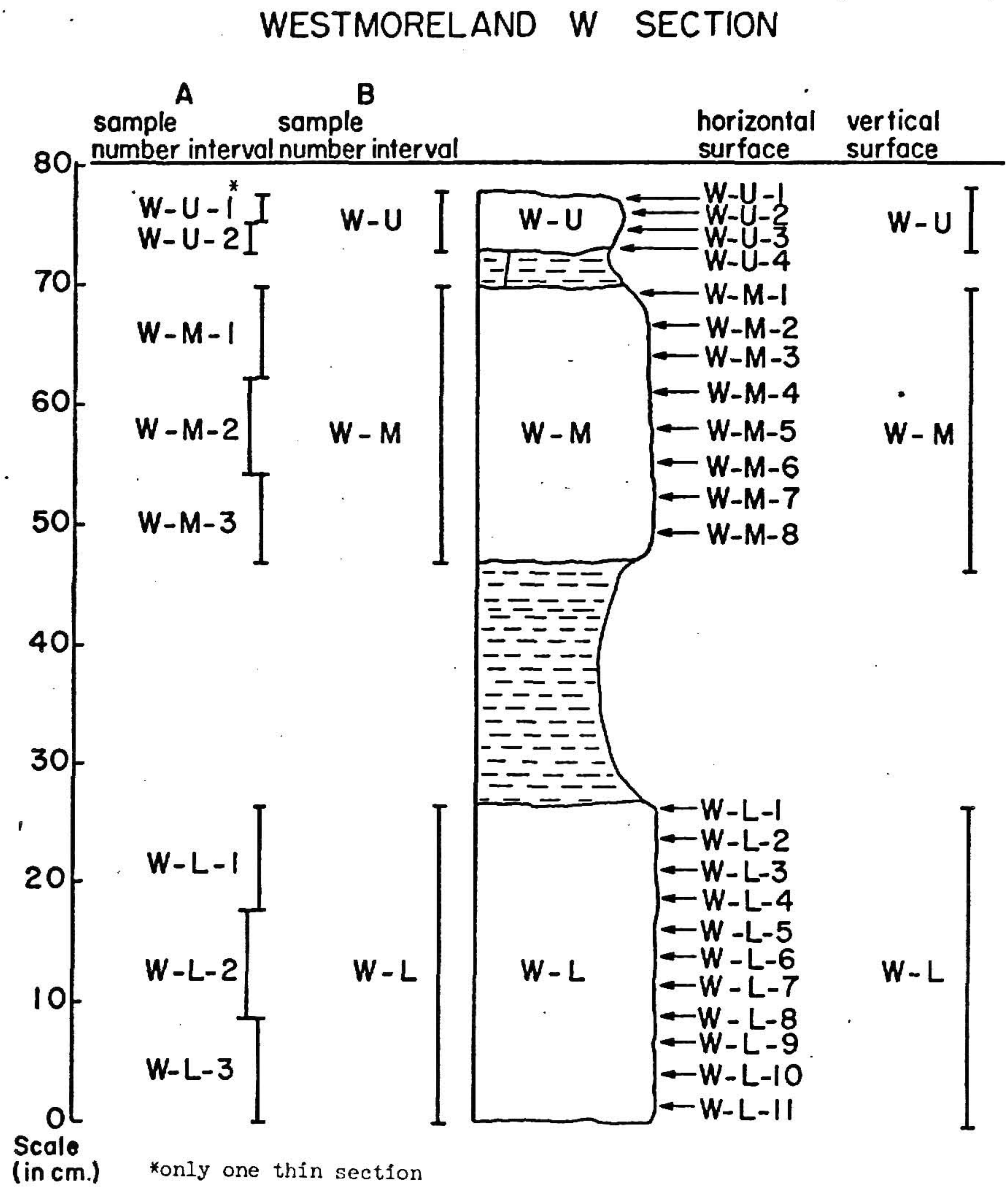
D = 0
E = 0
GB = 2

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	fII	.9	.4	p			x		o	
2	Cru	.5	.4	i	cval				o	

L-L-8



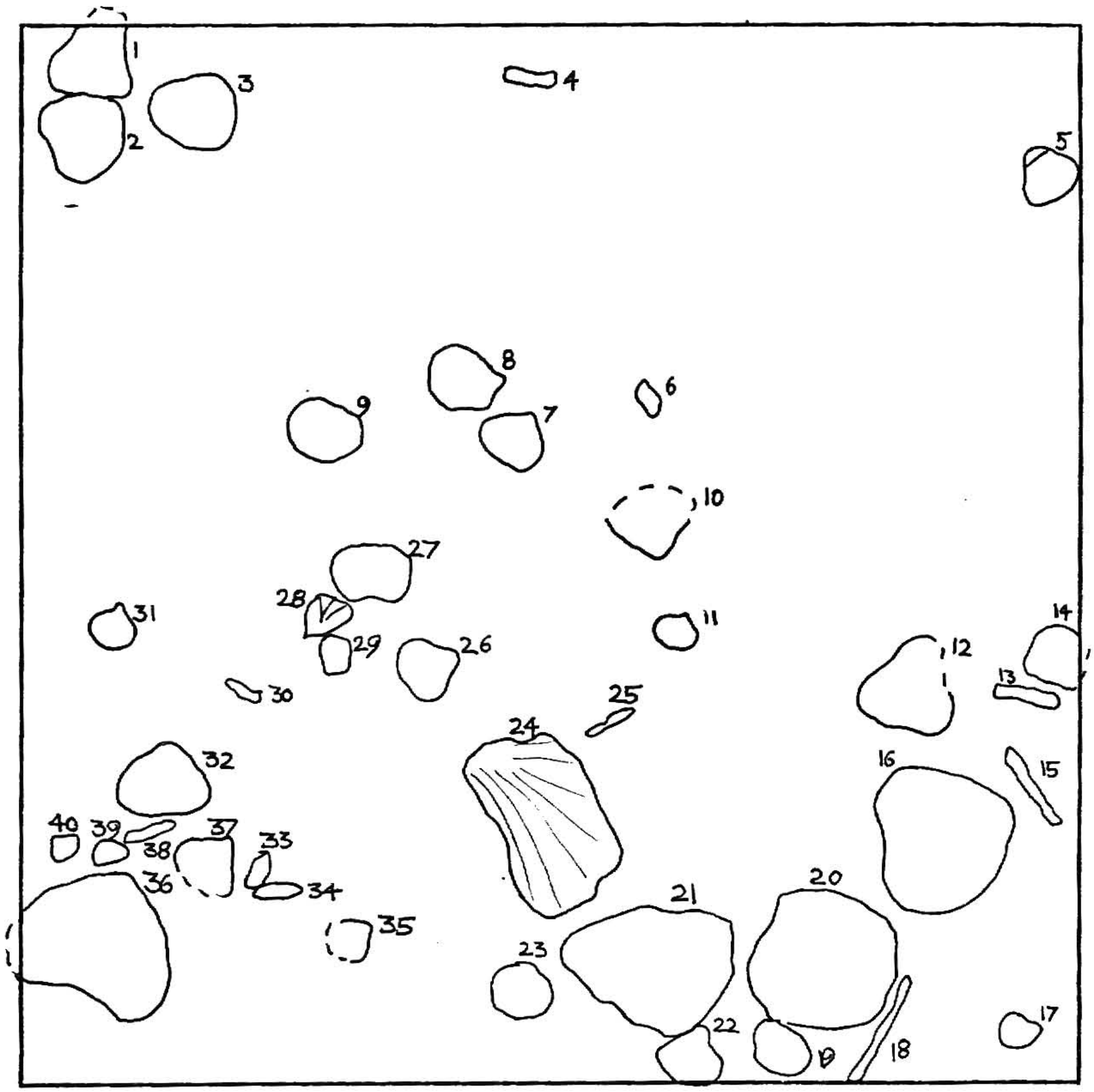
D = 1.003
E = 1.000
GB = 3



*only one thin section

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Comp	1.5	1.2	ccu		?	x		o	
2	Comp	1.2	1.2	cvu		b			o	
3	Comp	1.3	1.1	ccu		p			o	
4	brac	.6	.2						o	
5	Cru	.9	.7	ccu		b	x		o	
6	Crin	.4	.3	p			x		o	
7	Cru	1.0	.8	ccu		b			o	
8	Cru	1.0	1.1	ccu		b			o	
9	Cru	1.1	1.0	cvu		?	x		o	
10	Cru	1.3	1.1	ccu		b	x		o	
11	Cru	.6	.5	ccu		b			o	
12	Comp	1.4	1.3	cvu		b	x		o	
13	brac	.9	.2	p			x		o	
14	Cru	.8	.8			?	x		o	
15	brac	1.4	.2	p			x		o	
16	Comp	2.1	1.9	cvu		b			o	
17	Cru	.5	.4	ccu		p			o	
18	brac	1.7	.2			p	x		o	
19	Cru	1.0	.8	ccu		?	x		o	
20	Comp	2.3	2.2	cvu		b			o	
21	Lino	2.3	1.9	cvu		p	x		o	
22	Cru	1.0	.9	ccu		b	x		o	
23	Cru	1.0	.9	ccu		b			o	
24	Lino	2.5	2.2	cvu		p	x		o	
25	brac	.5	.2	p			x		o	
26	Cru	1.0	.9	ccu		b			o	
27	?	1.1	.7	ccu		?			o	
28	Rhip	.5	.4	cvu		p			o	
29	Crin	.5	.4	i			x		cal	
30	brac	.4	.1	p			x		o	
31	Cru	.5	.3	ccu		b			o	
32	Comp	1.4	1.0	cvu		b			o	
33	Fus			p					o	
34	Fus			p					o	
35	Cru	.5	.4	cvu		?	x		o	
36	Comp	2.4	1.8	ccu		b			o	
37	Cru	.9	.9	ccu		b	x		o	
38	brac	.7	.2	p			x		o	
39	Cru	.4	.3	ccu		b			o	
40	Cru	.5	.4	ccu		b			o	

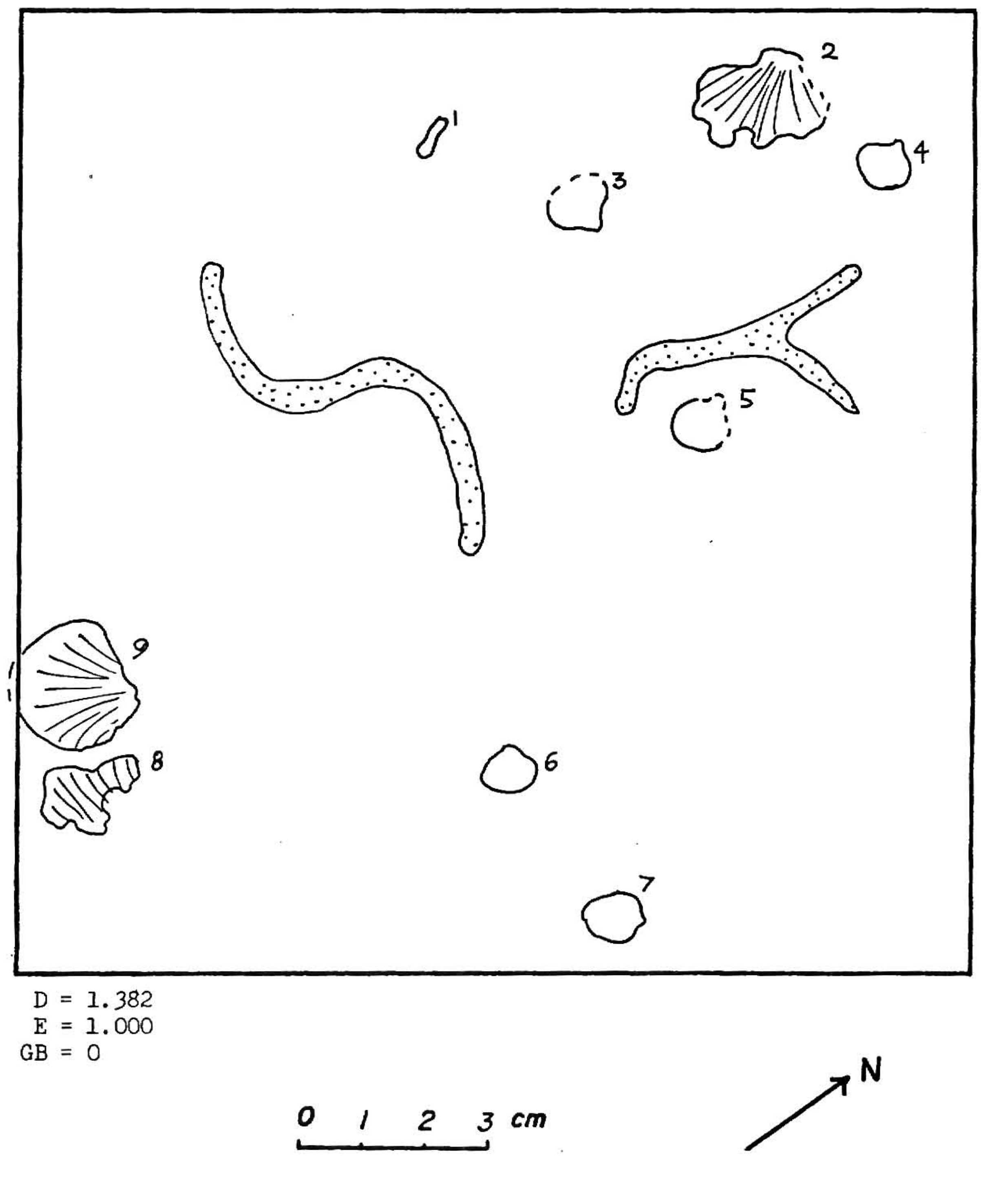
W-U-1



D = 1.884
E = 1.000
GB = 0

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	rI	.5	.2	p			x			
2	Lino	2.0	1.7	ccu		p	x		m	
3	Cru	1.0	.8	cvu		b			o	
4	Cru	.8	.6	cvu		b			o	
5	Cru	.9	.9	cvu		b			o	
6	Cru	.8	.7	cvu		p			o	
7	Cru	.8	.7	cvu		b			o	
8	Lino	1.7	1.3	cvu		b	x		o	
9	Lino	2.1	1.7	cvu		b			o	

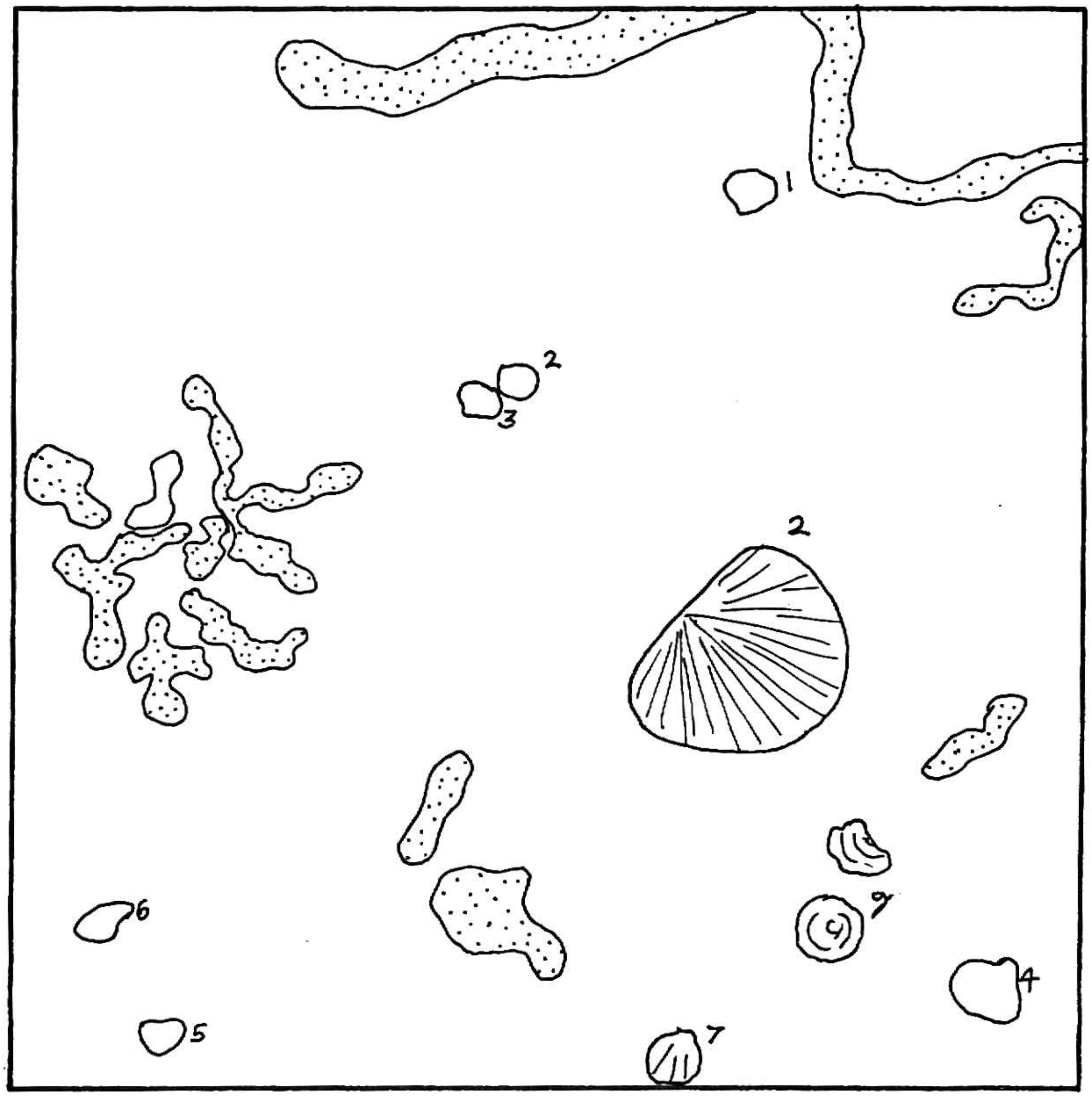
W-U-2



D = 1.382
E = 1.000
GB = 0

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.7	.6	cvu		b			o	
2	Cru	.6	.5	cvu		b			o	
3	Cru	.7	.6	cvu		b			m	
4	Cru	.9	.8	cvu		b			o	
5	Cru	.5	.5	cvu		b			o	
6	Cru	.5	.3	cvu		b	x		o	
7	Well	.8	.6	cvu		p			o	
8	Derb	3.2	2.5	ccu		b			o	
9	Orb	1.0	1.0	cvu		b	x		o	

W-U-3

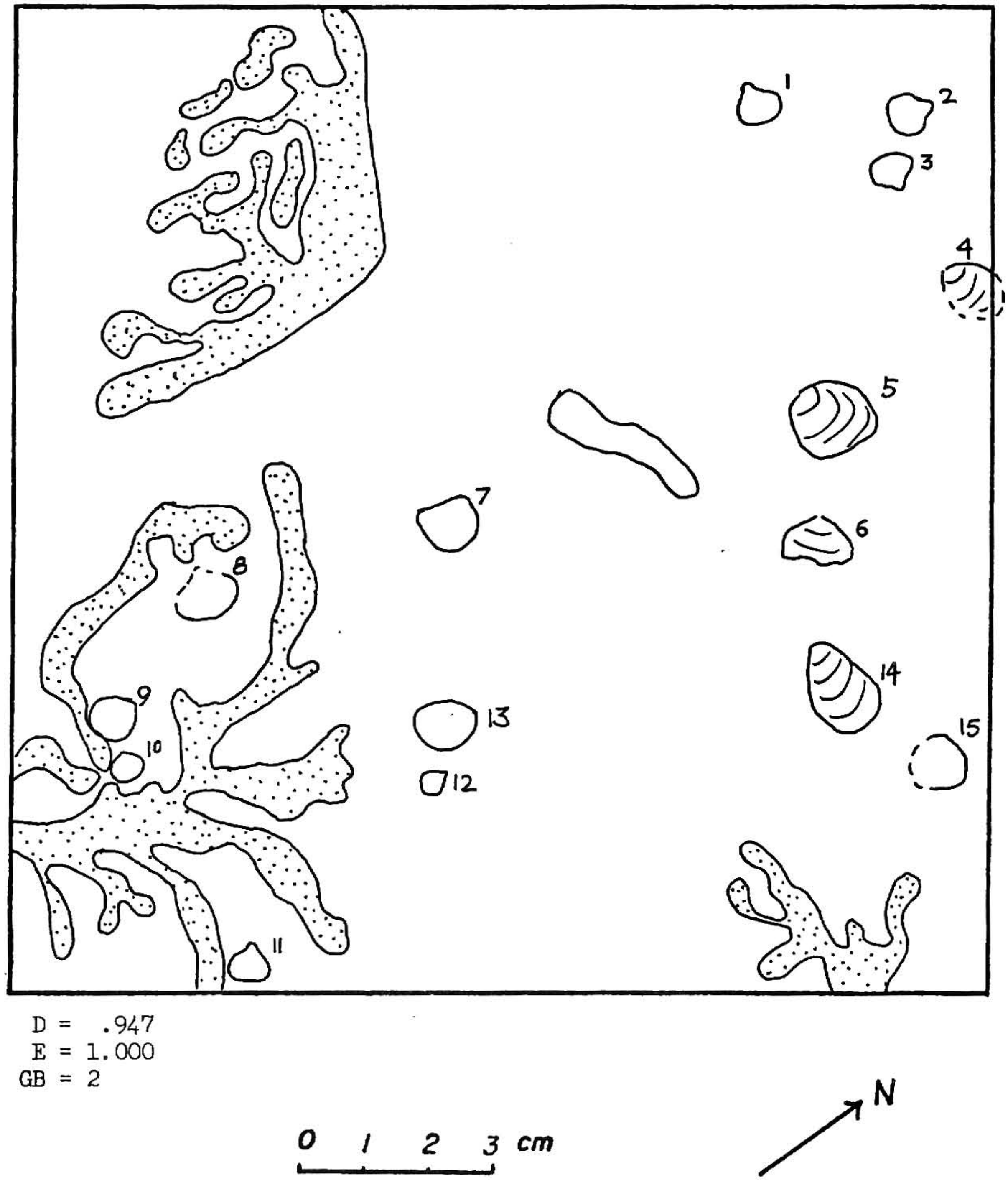


D = 1.445
E = 1.000
GB = 1

W-U-4

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.7	.7	cvu		b			o	
2	Cru	.8	.7	cvu		b			o	
3	Cru	.6	.6	cvu		b			o	
4	Lg	.8	.7		cval				o	
5	Lg	1.4	1.3	cvu		b	x		o	
6	Lg	1.1	.7	cvu		b	x		o	
7	Cru	1.0	.8	cvu		b			o	
8	Cru	.9	.6	ccu		p			m	
9	Cru	.7	.7	ccu		p			m	
10	Cru	.4	.5	ccu	cval				o	
11	Cru	.6	.4	cvu		p			o	
12	Cru	.4	.3	cvu		b			o	
13	Cru	.9	1.0			b			o	
14	Lg	1.0	1.5		cval				o	
15	Cru	.9	.8	cvu		p			o	

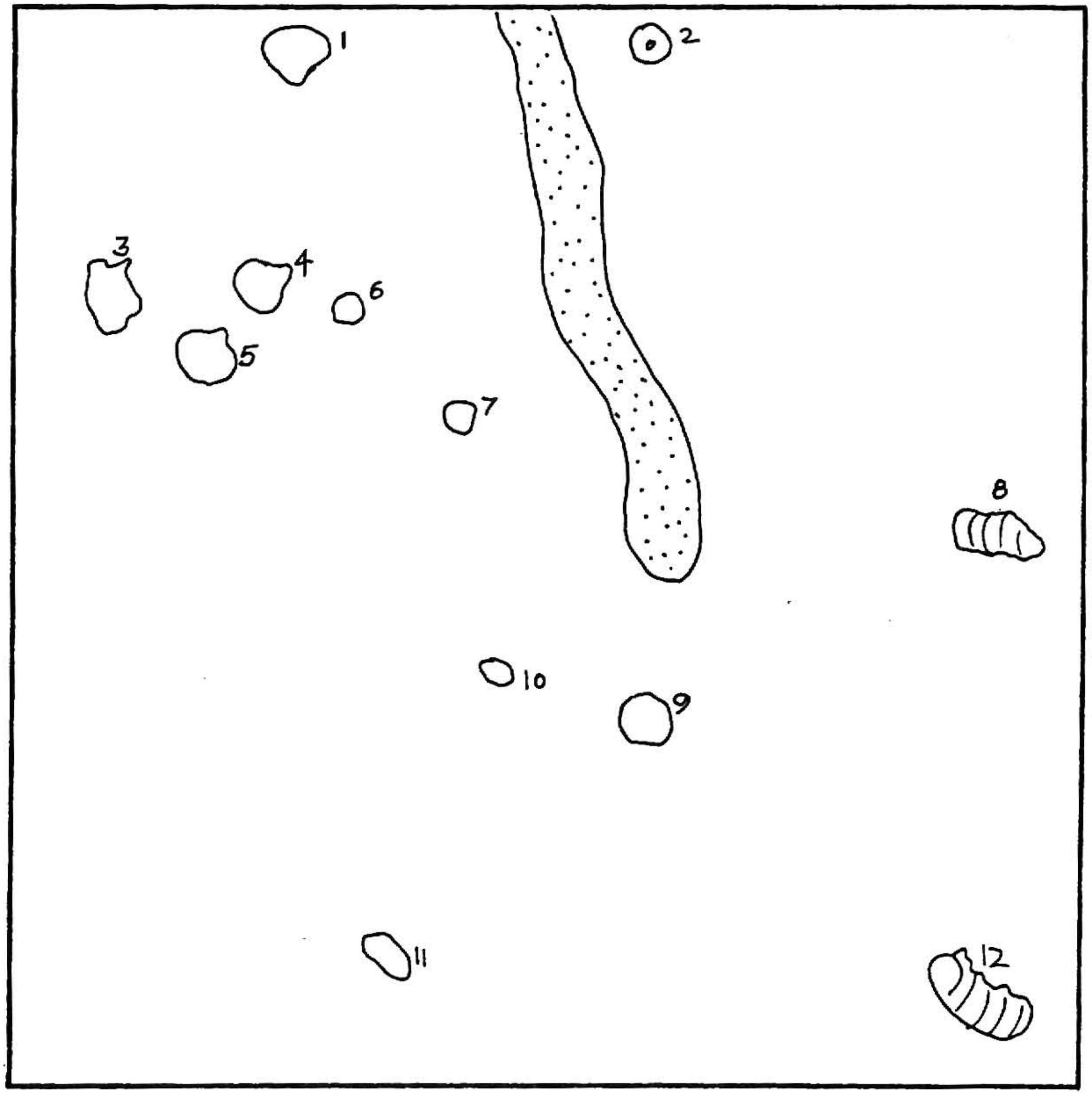
W-U-4



D = .947
E = 1.000
GB = 2

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	1.0	.8	cvu		p			o	
2	Crin	.5	.5	i					cal	
3	Crin	.7	1.0	p					o	
4	Cru	.8	.8	cvu		p			o	
5	Cru	.9	.8	cvu		p			o	
6	Cru	.4	.4	cvu		p			o	
7	Cru	.4	.5	cvu		p	x		o	
8	Lg	.6	1.3	ccu		b	x	x	m	
9	Cru	.8	.7	cvu		p	x		o	
10	Cru	.5	.3	cvu		p			o	
11	Cru	.8	.4	ccu		b	x		m	
12	Lg	.7	1.6	ccu		b	x		m	

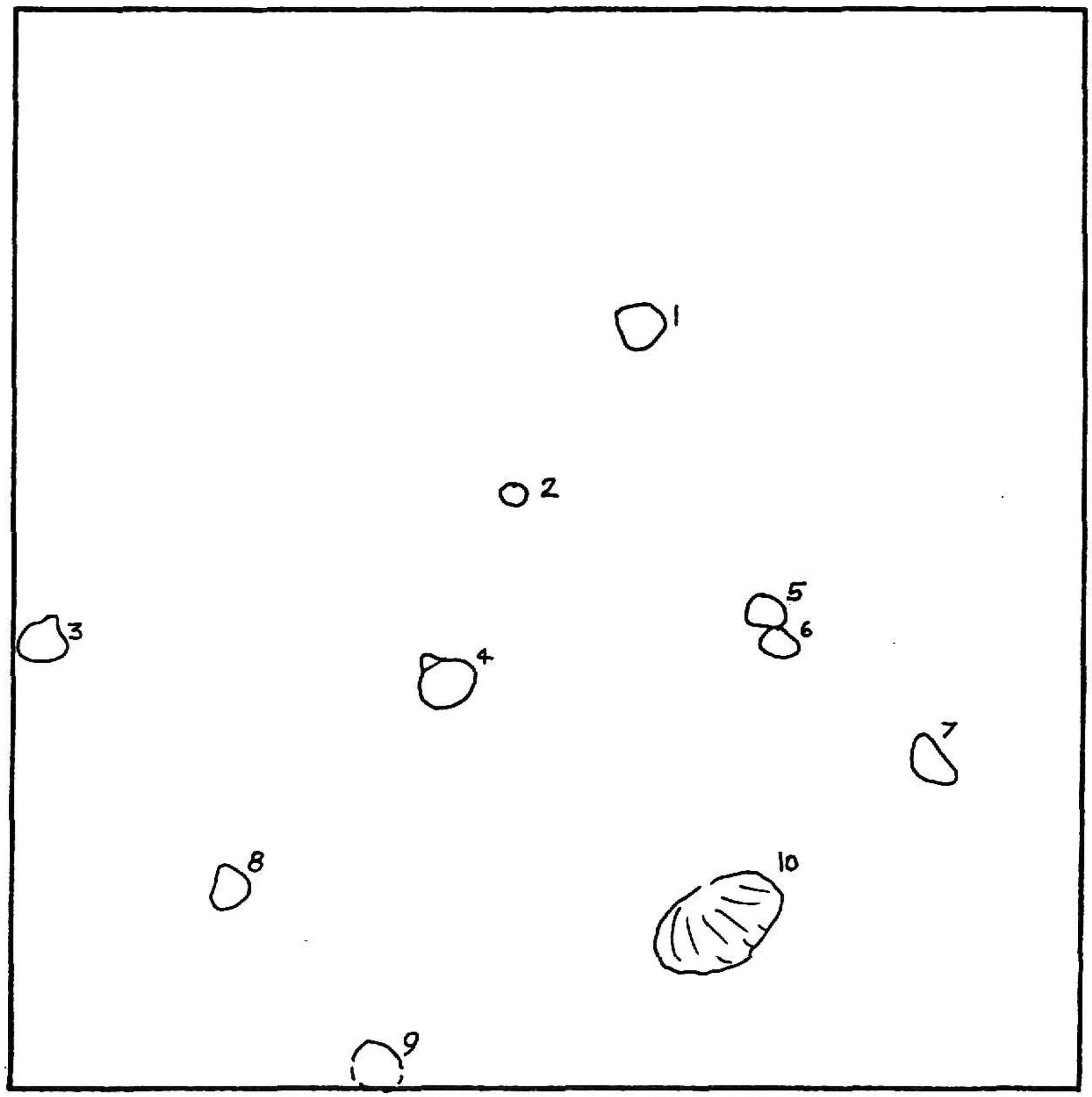
W-M-7



D = .764
E = 1.000
GB = 1

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.6	.6	cvu		p			o	
2	Cru	.3	.2	cvu		p			o	
3	Cru	.8	.6	cvu		b			o	
4	Cru	.8	.7	cvu		p			o	
5	Cru	.5	.5	ccu		b	x		m	
6	Cru	.5	.5	ccu		b	x		m	
7	Cru	.8	.5	ccu		b			m	
8	Cru	.6	.6	cvu		p			o	
9	Cru	.8	.6	cvu		p	x		o	
10	Rea	1.9	1.2	cvu		b	x		o	

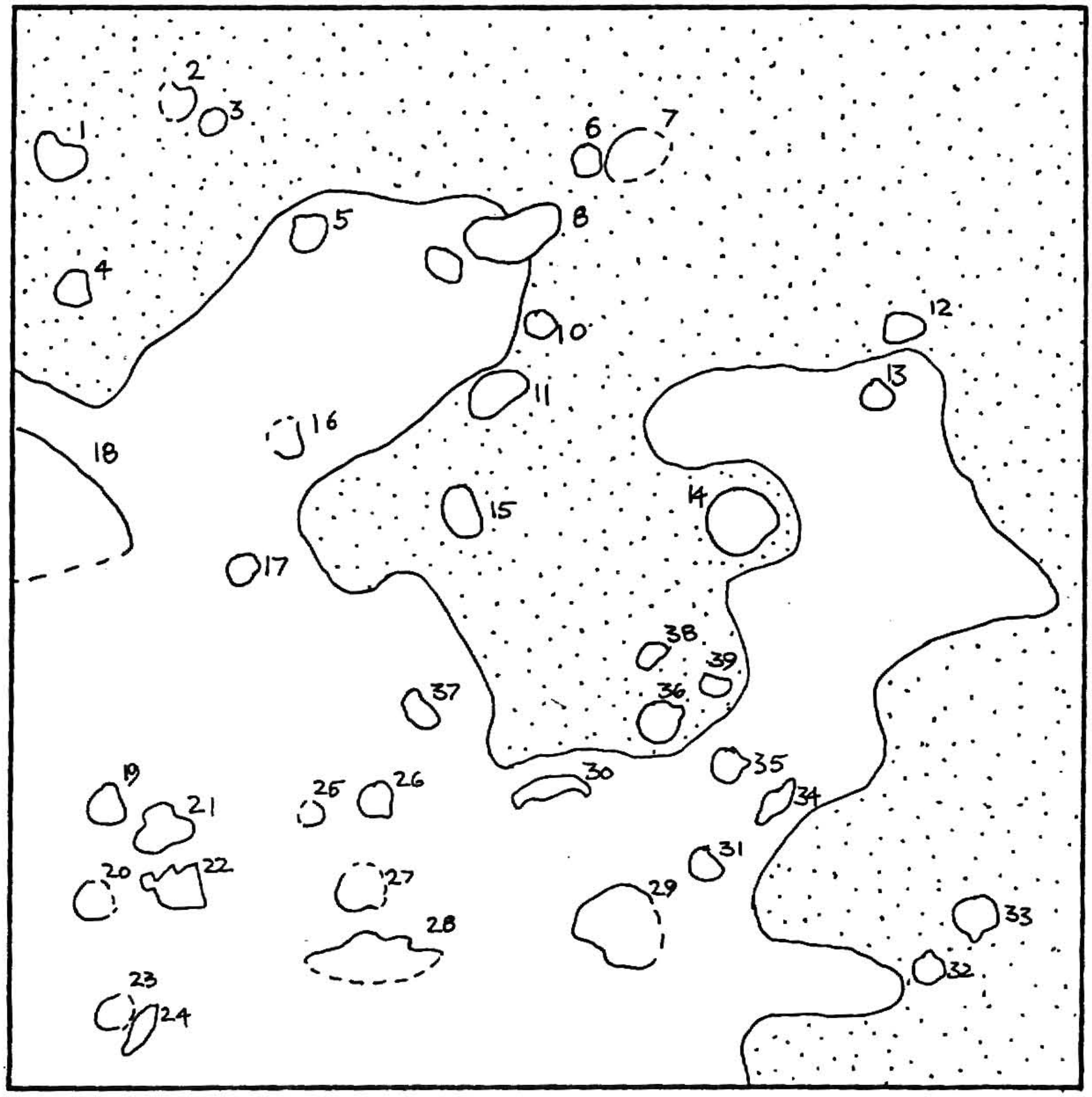
W-M-2



D = .651
E = 1.000
GB = 0

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.5	.4	ccu		p			o	
2	Cru	.4	.4	ccu		?	x		o	
3	Cru	.3	.3	ccu		b			o	
4	Cru	.5	.4	cvu		b			o	
5	Cru	.5	.4	ccu		b			o	
6	Cru	.4	.4	ccu		b			o	
7	Comp	1.0	.6			b	x		o	
8	fII	1.5	.5	p			x		o	
9	Cru	.4	.3	ccu		b			o	
10	Cru	.3	.3	cvu		p			o	
11	Cru	.7	.5	cvu		p			o	
12	Cru	.4	.3	ccu		b			o	
13	Cru	.4	.4	cvu		b			o	
14	Comp	.9	.9	cvu		b			o	
15	Cru	.8	.5	cvu		p			o	
16	Cru	.5	.4	ccu		p			o	
17	Cru	.3	.3	ccu		b			o	
18	Smyl			ccu		r	x		o	
19	Cru	.4	.3	ccu		b			o	
20	Cru	.5	.4	ccu		p	x		o	
21	Rhip	.9	.7		cval		x		o	
22	Well	.9	.7			?	x		o	
23	Cru	.4	.4	ccu		b			o	
24	Fus			p					o	
25	Cru	.5	.3	cvu		b			o	
26	Cru	.3	.3	ccu		b	x		o	
27	Cru	.9	.7	ccu		b	x		o	
28	Well	1.9	.7			?	x		o	
29	Comp	1.2	1.2			b	x		o	
30	?	1.1	.3				x		o	
31	Cru	.4	.3	ccu		b			o	
32	Cru	.4	.4	cvu		b			o	
33	Cru	.5	.4	ccu		b			o	
34	Fus			p					o	
35	Cru	.4	.4	ccu		b			o	
36	Cru	.6	.4	cvu		b			o	
37	Cru	.7	.4	ccu		p			o	
38	Cru	.3	.3	ccu		p			o	

W-M-3



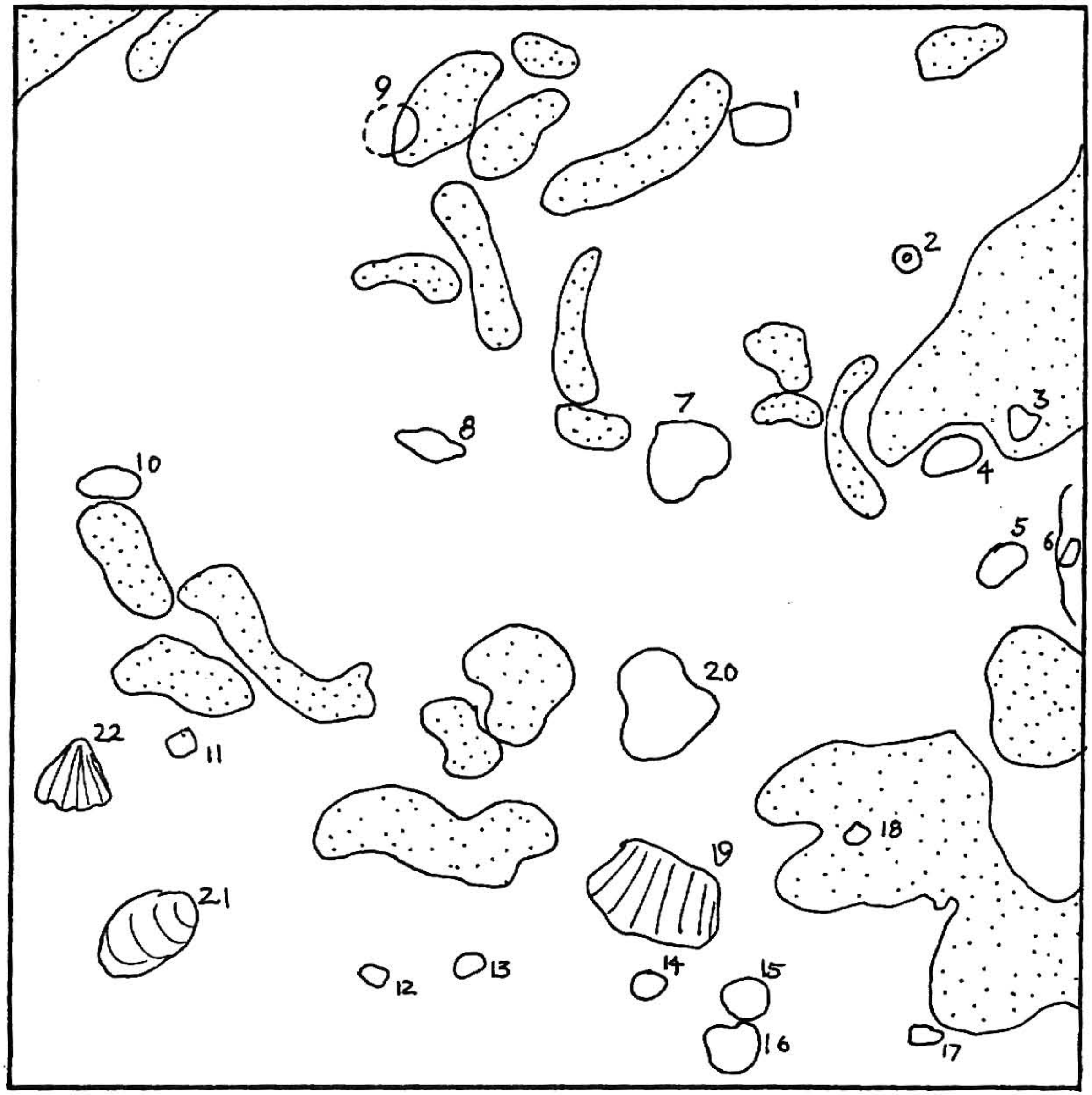
D = 1.820
E = .833
GB = 3

0 1 2 3 cm

N

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	rIII	.8	.6	zeu			x		o	
2	Crin	.3	.3	i			x		o	
3	Cru	.4	.3	ccu		b			o	
4	rIV	.8	.5	zeu			x		o	
5	Cru	.7	.4			p			o	
6	Crin	.3	.2	p			x		o	
7	Comp	1.2	1.1	ccu		b			o	
8	Fus			p					o	
9	Cru	.7	.7	ccu		b	x		o	
10	Cru	.8	.4	cvu		p			o	
11	Crin	.3	.3	p			x		o	
12	Cru	.3	.2	ccu		p			o	
13	Cru	.3	.3	ccu		p			o	
14	Cru	.4	.3	cvu		b			o	
15	Cru	.6	.5	cvu		b			o	
16	Comp	1.0	1.0	cvu		b			o	
17	Crin	.4	.2	p			x		o	
18	Cru	.2	.2	ccu		b			o	

W-M-4

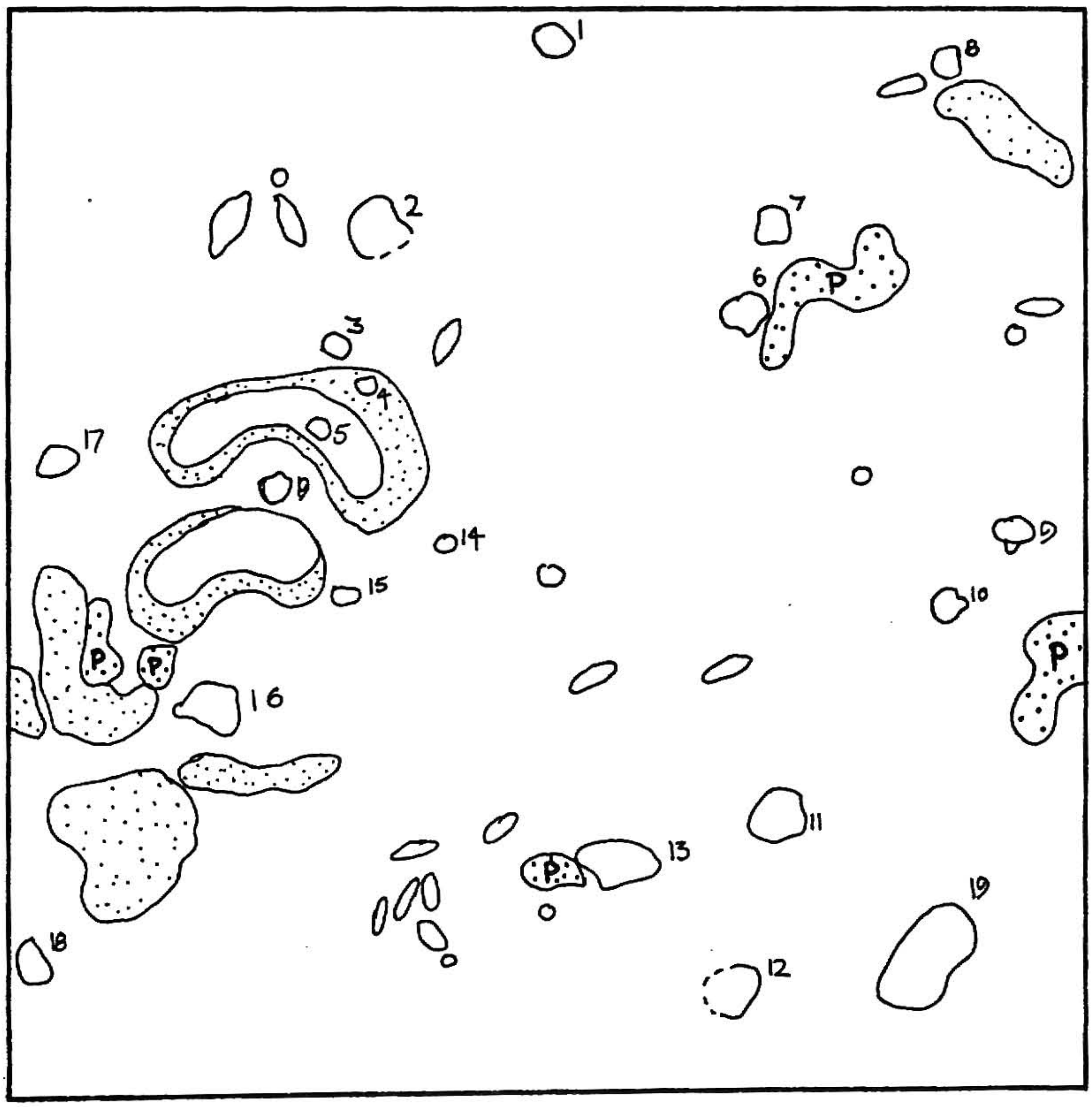


D = 1.920
E = 1.250
GB = 3

W-M-5

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.5	.3	ccu		b			o	
2	Cru	.7	.6	ccu		b			o	
3	Cru	.4	.3	ccu		p			o	
4	Crin	.3	.3	p			x		o	
5	Crin	.4	.3	p			x		o	
6	Cru	.6	.5	ccu		b			o	
7	Cru	.6	.5	ccu		p			o	
8	Crin	.5	.5	p			x		o	
9	Cru	.6	.6	ccu		b			o	
10	Cru	.5	.4	cvu		b	x		o	
11	Comp	1.0	.9			?	x		o	
12	Comp	1.0	.9	ccu		?	x		o	
13	Nesp	1.2	.7	ccu		b	x		o	
14	Crin	.2	.2	i			x		o	
15	Cru	.3	.2	ccu					o	
16	Well	.9	.6	ccu		?	x		o	
17	Cru	.6	.4	cvu		p			o	
18	Cru	.7	.5	ccu		p			o	
19	Nech	1.6	1.1	ccu		?			o	

W-M-5

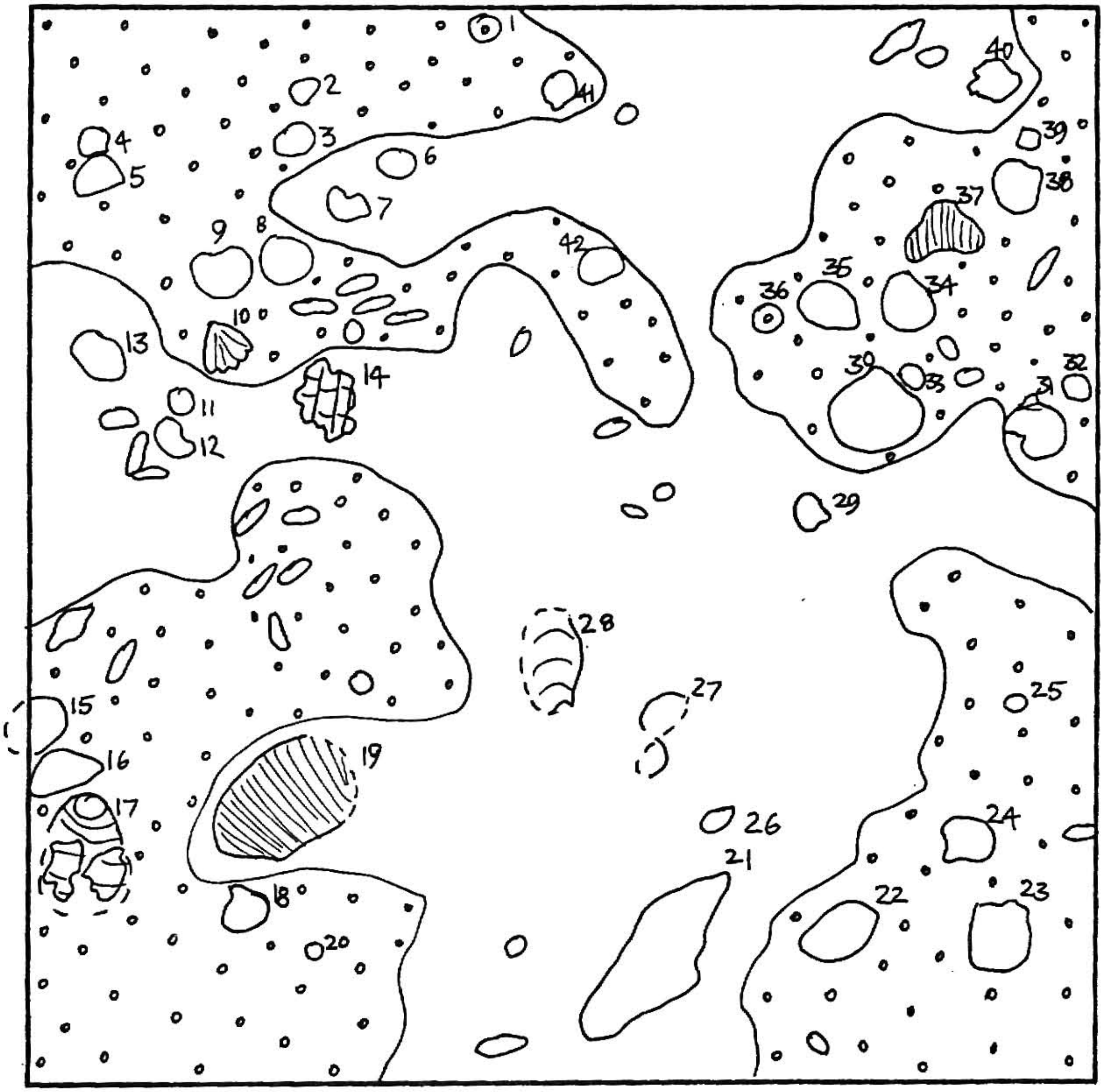


D = 2.156
E = 1.000
GB = 1

W-M-6

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Crin	.4	.3	i			x		o	
2	Cru	.4	.2	ccu		p			o	
3	Cru	.5	.4	ccu		p			o	
4	Cru	.3	.3	ccu		b			o	
5	Cru	.6	.4	ccu		p			o	
6	Cru	.5	.4	cvu		p			o	
7	Well	.6	.4			?	x		o	
8	Cru	.7	.7	ccu		b			o	
9	Comp	.9	.7	ccu		b			o	
10	Rhip	.8	.8		cval				o	
11	Cru	.4	.4	ccu		b			o	
12	Cru	.7	.5	ccu		p			o	
13	Cru	1.0	.8	cvu		p			o	
14	fII	1.2	.9				x		o	
15	Comp	1.0	.8	ccu		b	x		o	
16	Comp	1.1	.7	cvu		p	x		o	
17	Lg	1.8	1.3			?	x		o	
18	Cru	.7	.7	ccu		b			o	
19	Lino	2.2	1.4	cvu		?	x		o	
20	Crin	.2	.2	i			x		o	
21	Nesp	3.0	1.4	ccu		?	x		o	
22	Comp	1.1	.7	cvu			b		o	
23	Nech	.9	.9	ccu		?	x		o	
24	Cru	.7	.7	cvu		b			o	
25	Crin	.2	.2	i			x		o	
26	Crin	.4	.2	p		?	x		o	
27	?	.7	.4	ccu		?	x		o	
28	Lg	1.4	.9	ccu		?	x		o	
29	Cru	.5	.3	cvu		b			o	
30	Comp	1.4	1.2	cvu		p			o	
31	Cru	1.0	.8	ccu		b	x		o	
32	Cru	.4	.3	ccu		b			o	
33	Cru	.3	.3	ccu		p	x		o	
34	Cru	.9	.7	cvu		p			o	
35	Cru	.9	.6	ccu		b	x		o	
36	Crin	.4	.4	i			x		o	
37	Lino	1.1	.8			?	x		o	
38	Comp	.8	.7	cvu		b			o	
39	Crin	.3	.3	i			x		o	
40	Hust	.6	.6		cval		x		o	
41	Crin	.5	.4	i			x		o	

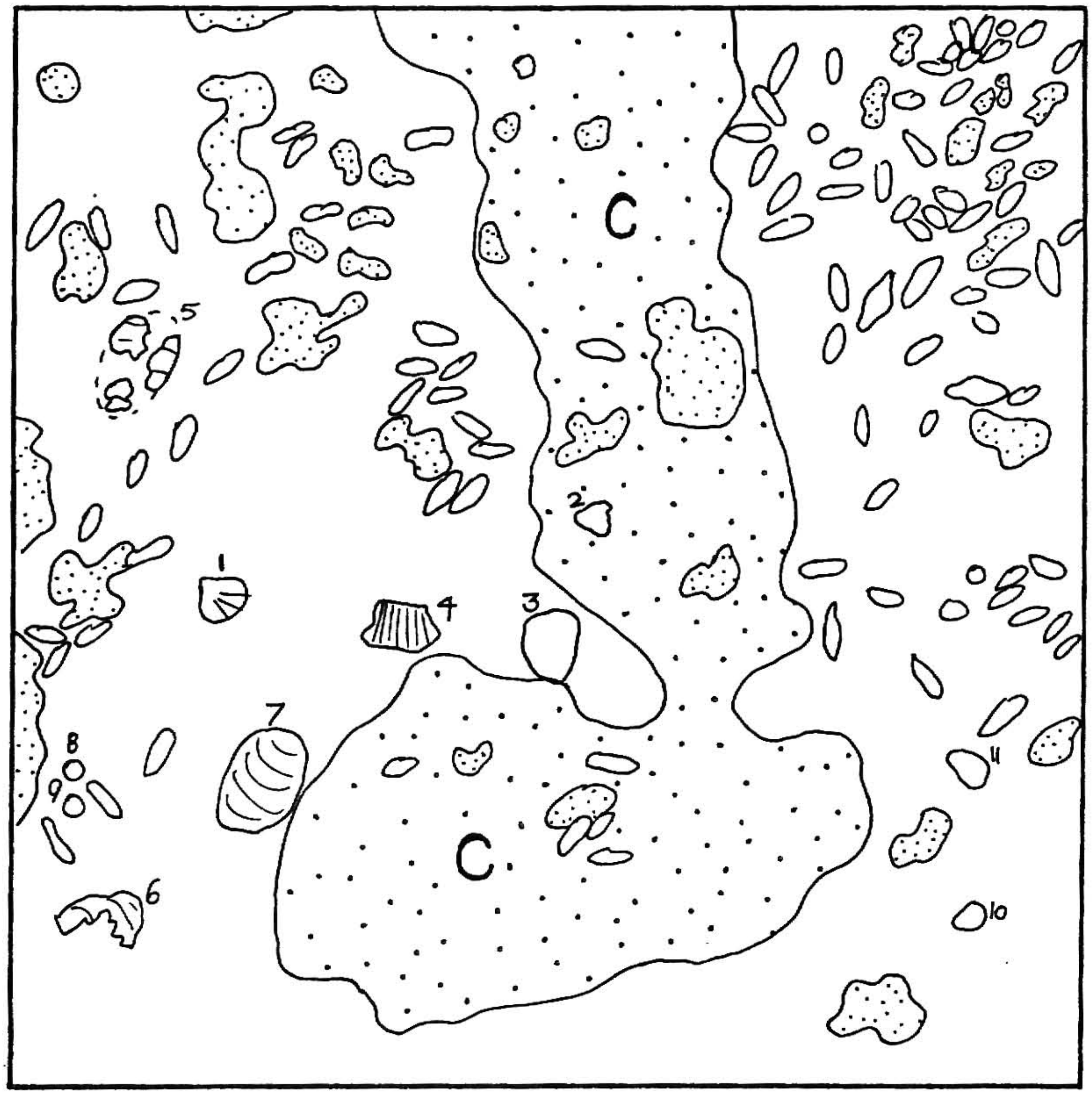
W-M-6



D = 2.807
E = .909
GB = 4

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Well	.6	.5		cval				o	
2	Hust	.5	.4		cval		x		o	
3	Comp	1.0	.8	ccu		b	x		o	
4	Lino	1.1	.7			?	x		o	
5	Lg	1.6	1.1	ccu		?	x		o	
6	Lg	1.3	1.0			?	x		o	
7	Rea	1.7	1.1	cvu		b	x		o	
8	Crin	.3	.3	i			x		o	
9	Crin	.3	.3	i			x		o	
10	Cru	.5	.4	ccu		p			o	
11	Cru	.6	.4	cvu		p			o	

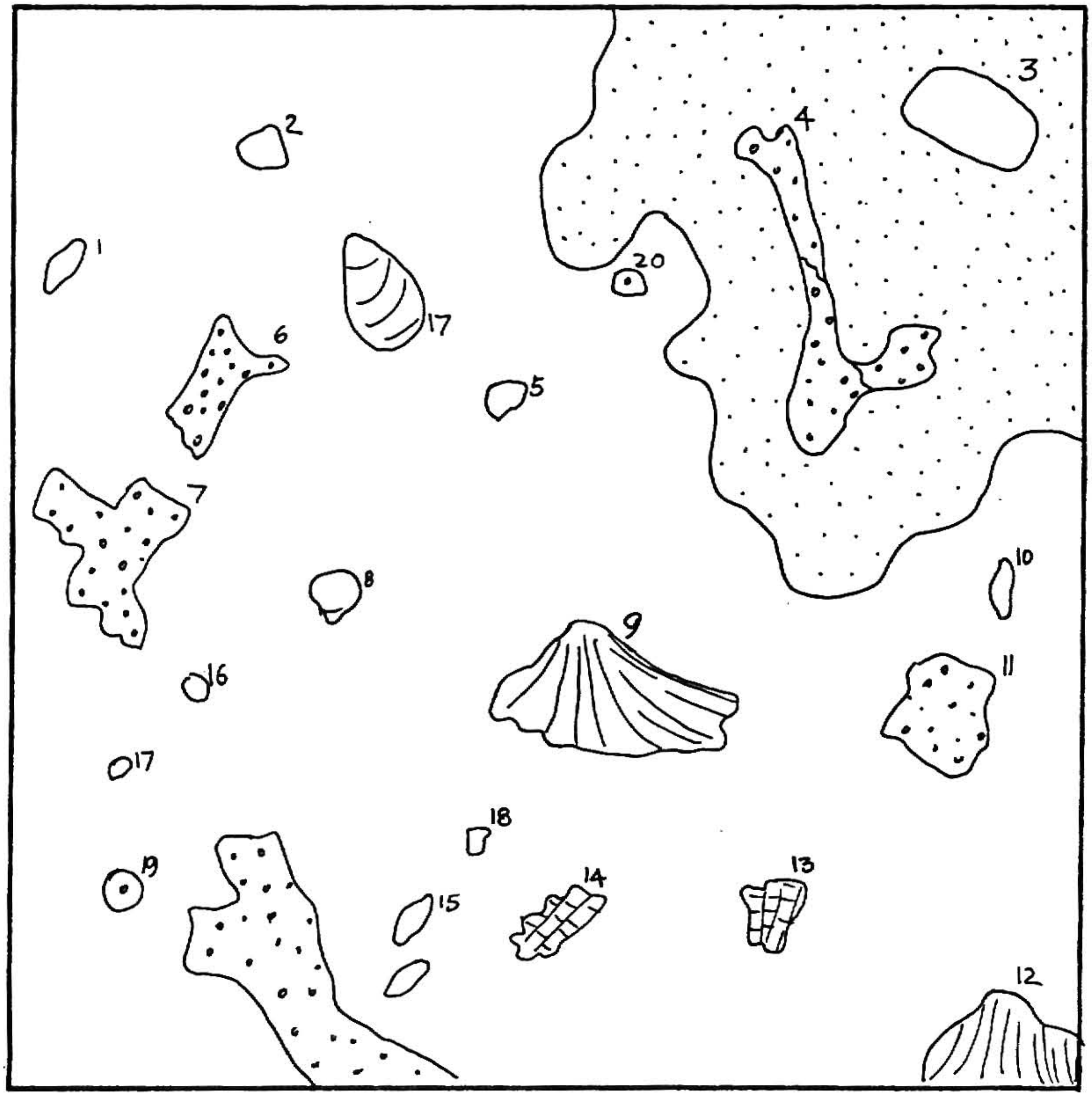
W-M-7



D = 2.923
E = 1.375
GB = 1

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Crin	.9	.3	p			x		o	
2	Cru	.8	.6	ccu		b			o	
3	Nech	1.9	1.2	cvu		?			o	
4	rIII	4.7	2.0	p			x		o	
5	Cru	.6	.4	ccu		p	x		o	
6	rIII	1.7	1.2	p			x		o	
7	rIII	2.5	1.9	p			x		o	
8	Cru	.7	.7	ccu		b			o	
9	Nesp	3.5	1.9	cvu		?	x		o	
10	brac	.9	.4		cval				o	
11	rIII	1.5	1.3	p			x		o	
12	Meek	2.5	2.0	cvu		?	x		o	
13	fII	1.1	.9	p			x		o	
14	fII	1.4	.7	p			x		o	
15	Fus			p					o	
16	Crin	.4	.4	i			x		o	
17	Cru	.3	.2	ccu		b			o	
18	Crin	.4	.2	p			x		o	
19	Crin	.5	.5	i			x		o	
20	Crin	.3	.3	i			x		o	

W-M-8

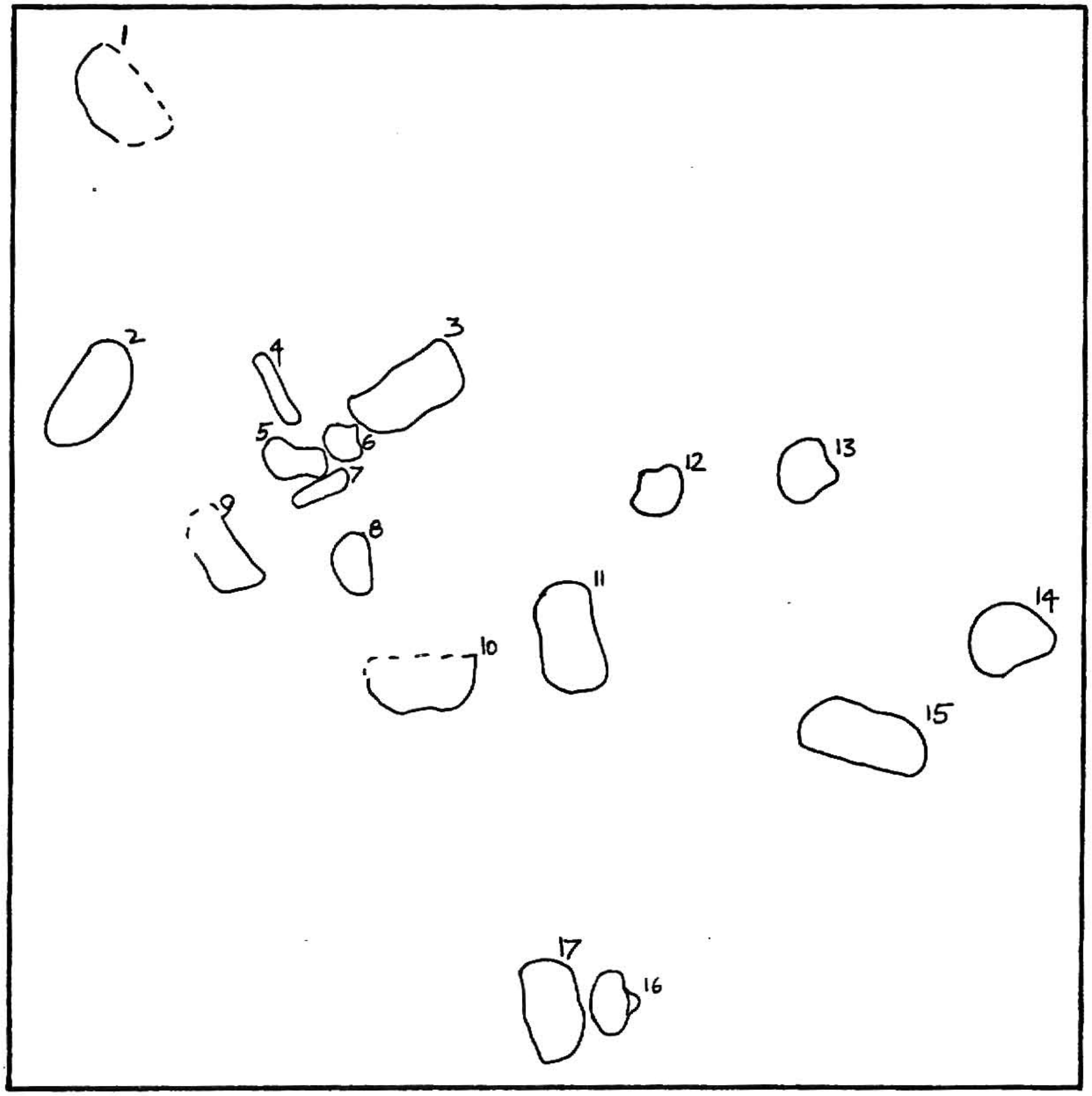


D = 2.588
E = 1.143
GB = 2

W-L-1

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Nech	1.6	.9	cvu		p	x		o	
2	Nech	1.6	.7	cvu		b	x		o	
3	Nech	1.7	.8	ccu		p			o	
4	rII	1.1	.3	p			x		o	
5	rIII	1.0	.5						o	
6	Cru	.5	.5	cvu		b			o	
7	rII	.8	.3	p			x		o	
8	Cru	.9	.5	ccu		p	x		o	
9	Nech	1.3	.6	ccu		p	x		o&m	
10	Nech	1.6	.7	ccu		p			o&m	
11	Nech	1.5	.8	cvu		b			o&m	
12	Cru	.6	.6	cvu		b			o	
13	Cru	.9	.8	cvu		b			o	
14	Com	1.1	.9	ccu		?	x		o	
15	Nech	1.8	.9	ccu		p			o	
16	Cru	.7	.5			?	x		o	
17	Nech	1.9	.8	cvu		b			o	

W-L-1

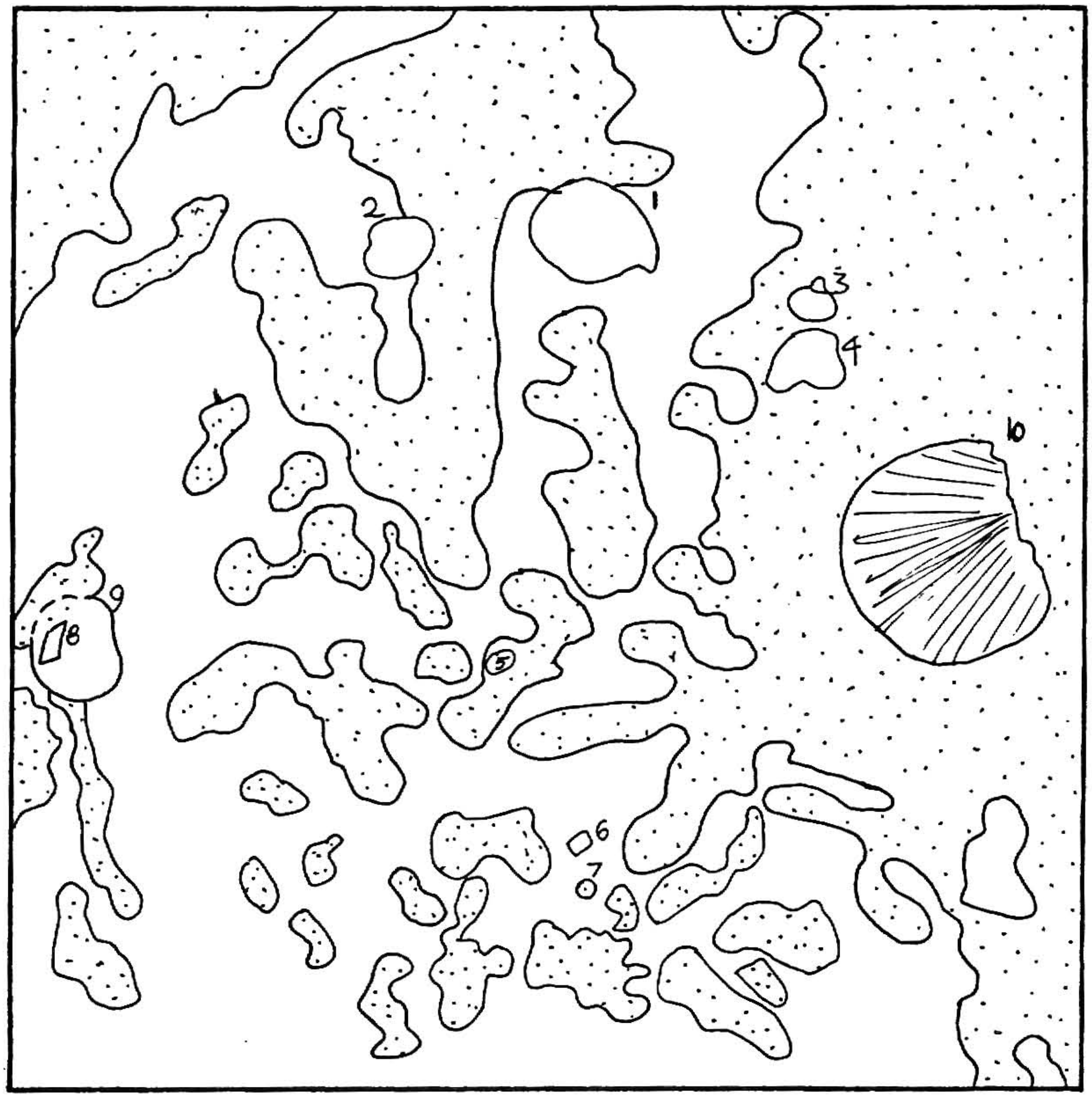


D = 2.073
E = 1.000
GB = 0

W-L-2

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Bell	1.7	2.0	i			x		o	
2	Cru	.9	1.0	cvu		b			o	
3	Cru	.7	.5	cvu		b			o	
4	Comp	.7	1.1		cval				o	
5	Crin			i					o	
6	Crin			i					o	
7	Crin			i					o	
8	Crin			p					o	
9	Rea	1.5	1.2		cval				o	
10	Derb	3.1	2.6	cvu		b	x		o	

W-L-2

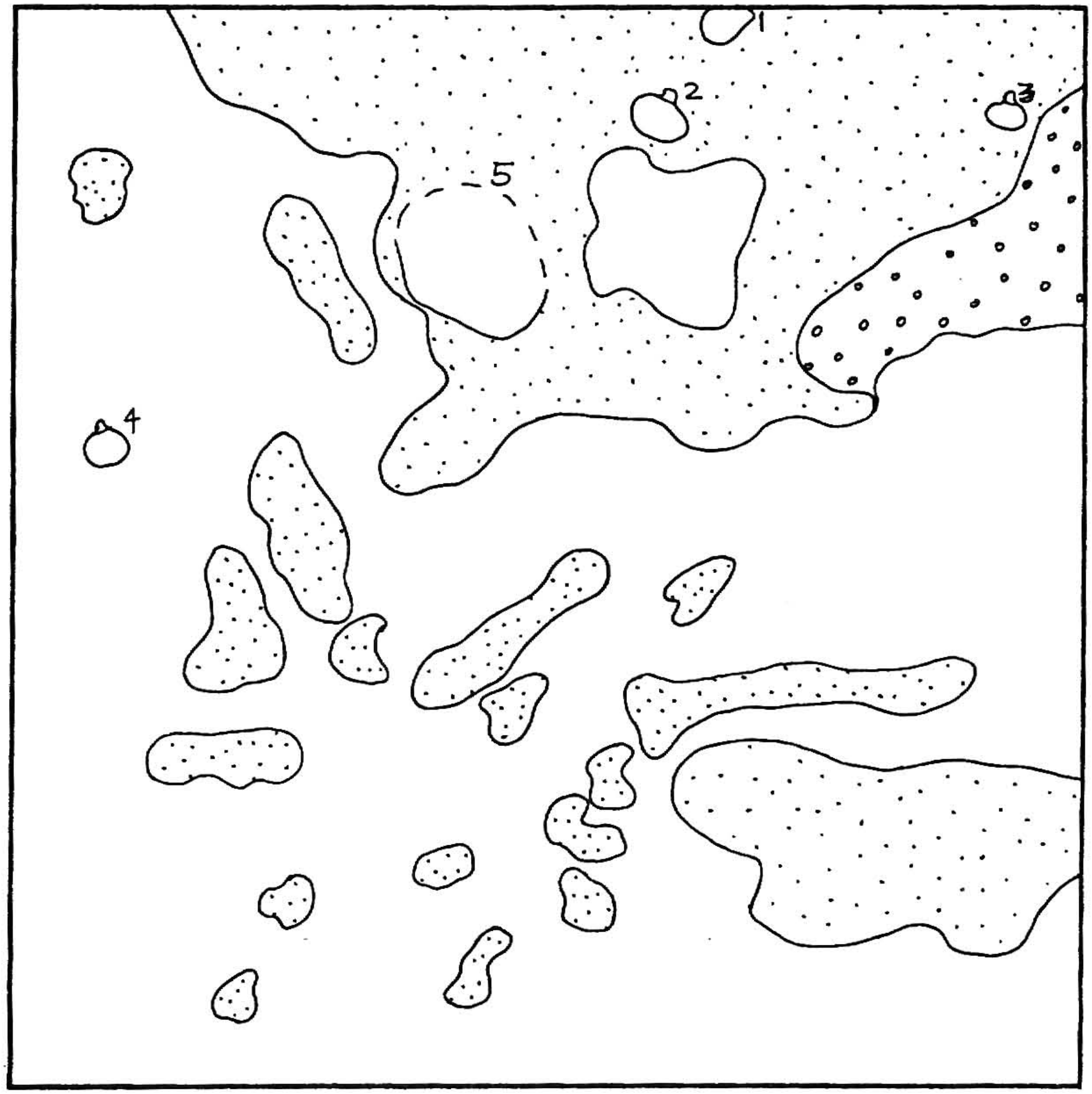


D = 2.322
E = 1.167
GB = 5

W-L-3

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.6	.5	cvu		b	x		o	
2	Cru	.7	.7	cvu		b			o	
3	Cru	.5	.6	cvu		b			o	
4	Cru	.5	.5	cvu		b			o	
5	Smyl	2.5	1.8			?			o	

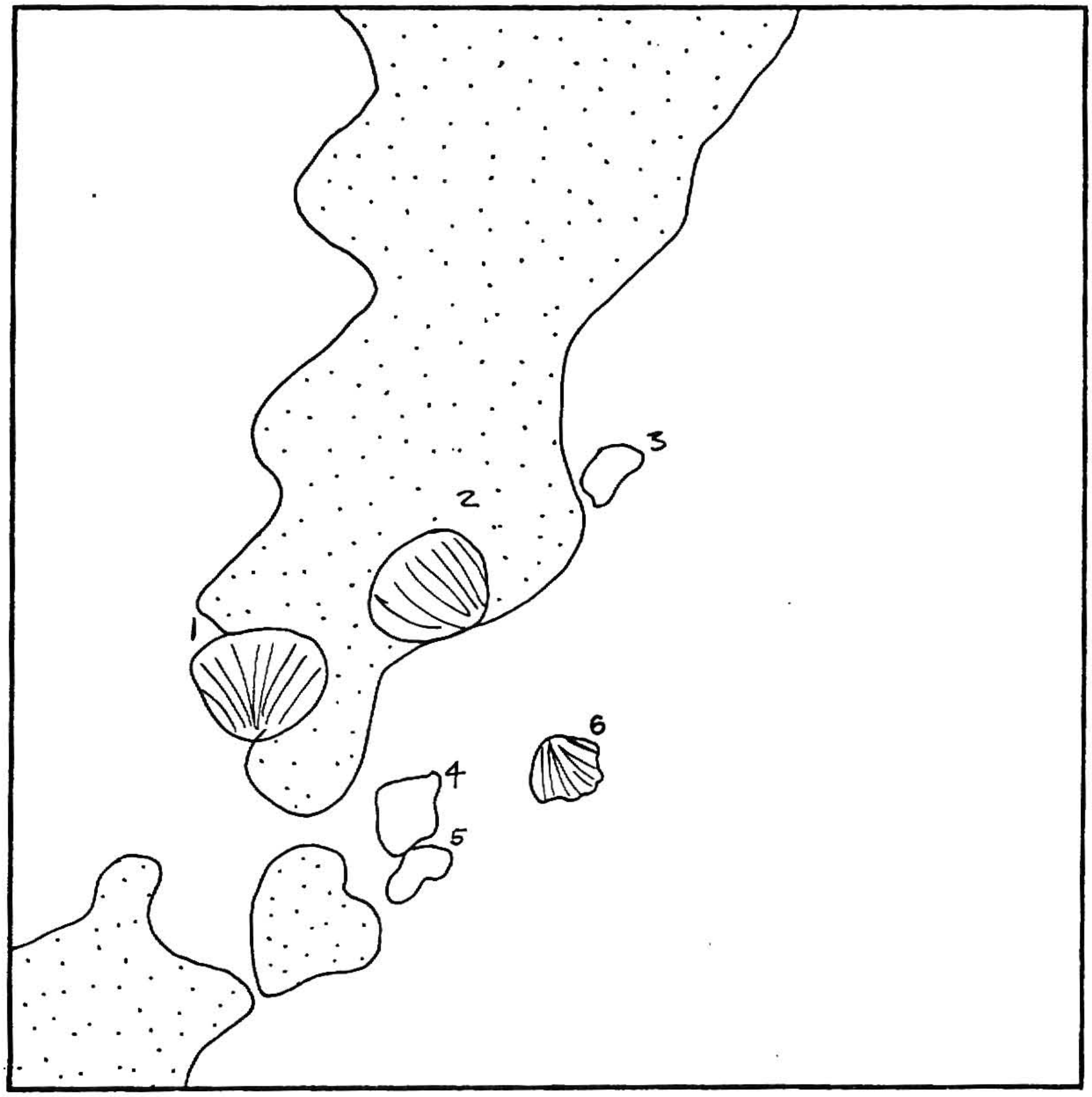
W-L-3



D = .724
E = 1.000
GB = 3

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Rea	2.0	1.4	ccu		p	x		o	
2	Rea	1.8	1.5	ccu		p			o	
3	Crin	1.0	.6	p			x		o	
4	rIII	1.0	.8	p			x		o	
5	rIII	.8	.7	p			x		o	
6	Rhip	1.0	.9	ccu		p			o	

W-L-4

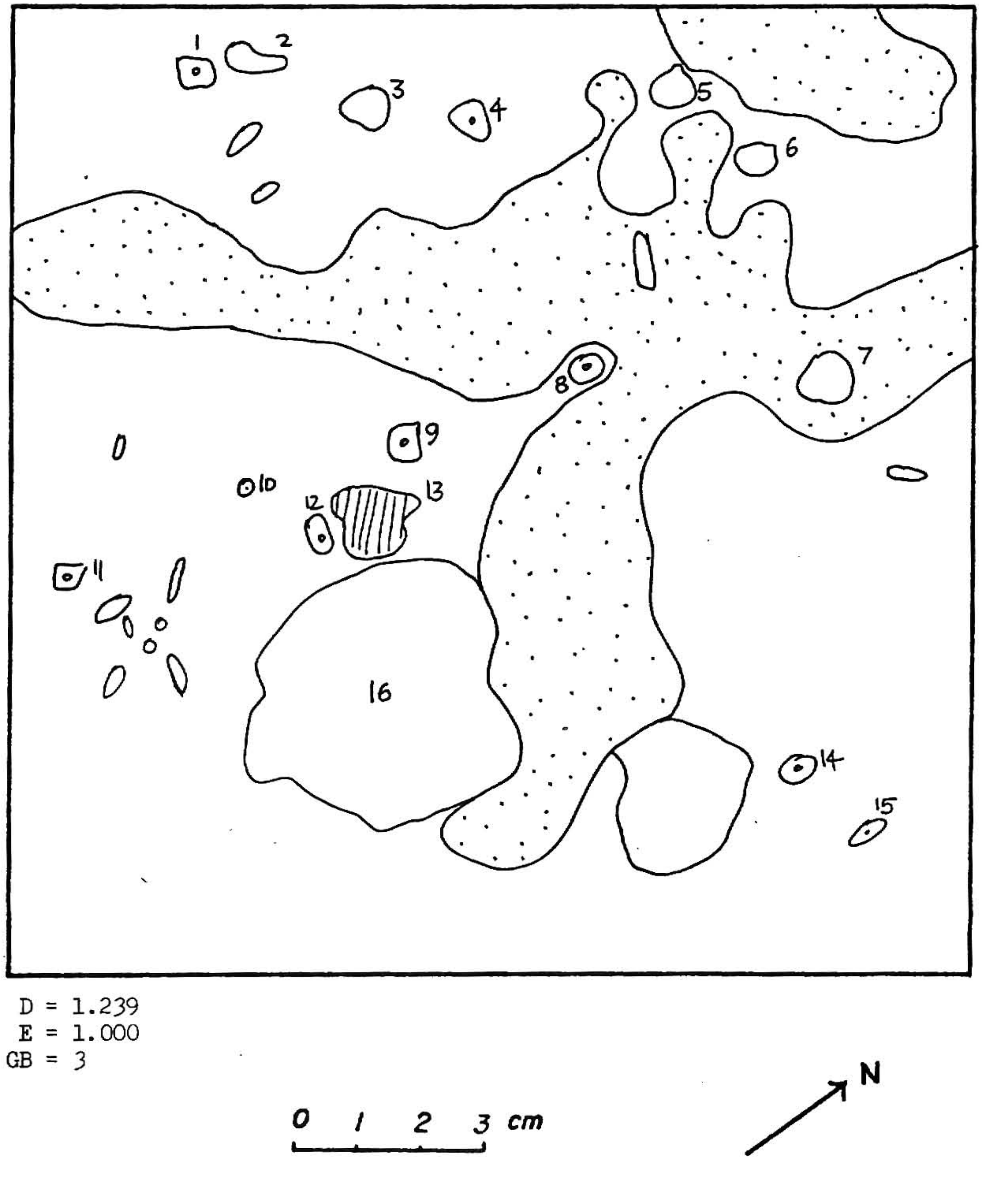


D = 1.920
E = 1.250
GB = 2

W-L-5

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Crin	.5	.5	p			x		o	
2	Cru	1.1	.3	ccu		b			o	
3	Cru	.7	.7						o	
4	Crin	.7	.5	p			x		o	
5	Cru	.6	.5	ccu		b			o	
6	Cru	.5	.5	cvu		b			o	
7	Cru	.9	.8	ccu		b			o	
8	Crin	.4	.4	p			x		o	
9	Crin	.5	.5	i			x		o	
10	Crin	.2	.2	i			x		o	
11	Crin	.4	.3	i			x		o	
12	Crin	.6	.3	i			x		o	
13	Rea	1.3	1.1			?	x		o	
14	Cru	.5	.3	ccu		p			o	
15	Crin	.5	.3	i			x		o	

W-L-5

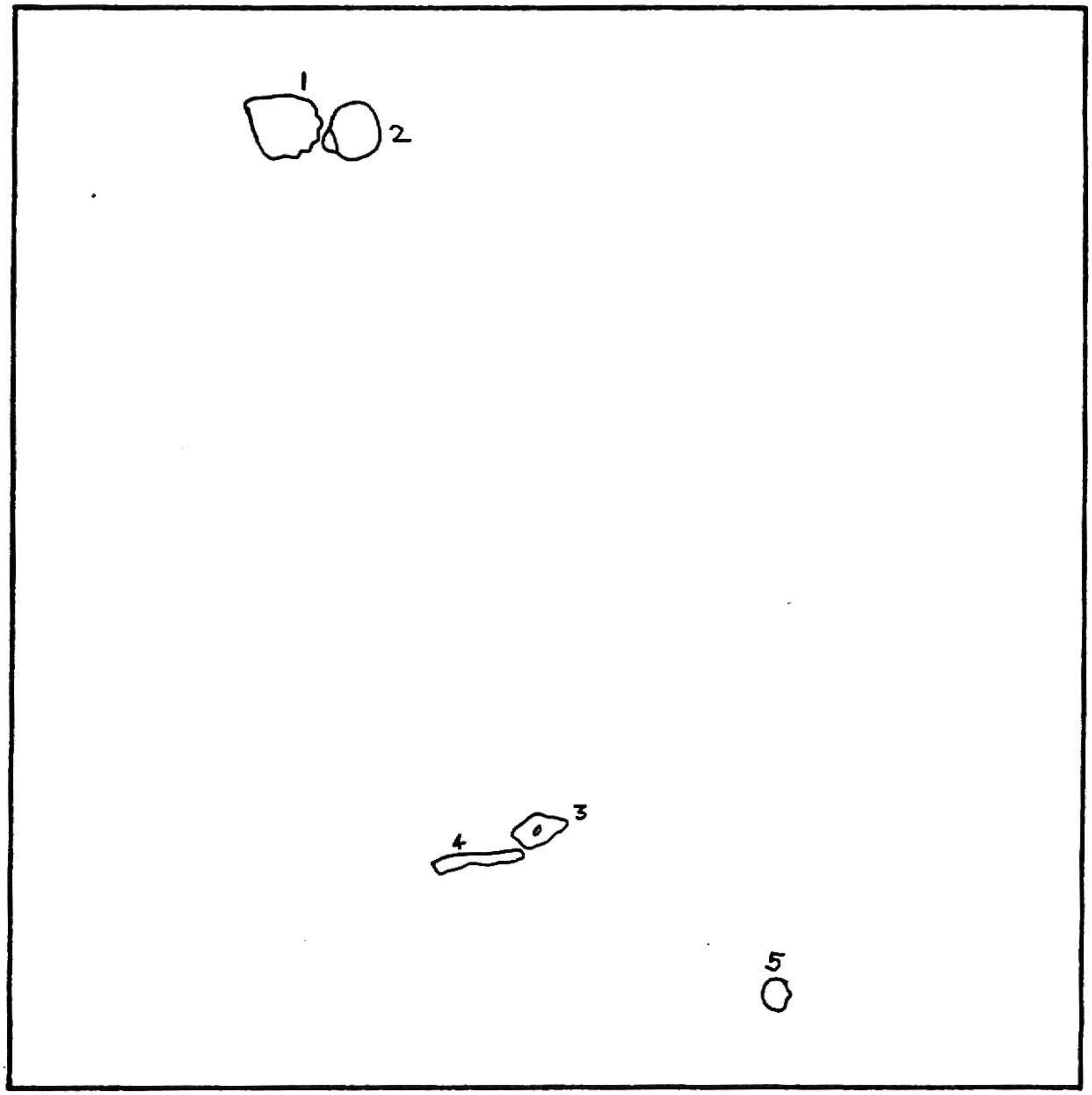


D = 1.239
E = 1.000
GB = 3

W-L-6

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Hust	1.0	.9		cval				o	
2	Cru	.7	.9	ccu		b			o	
3	Crin	.7	.4	i			x		o	
4	rII	1.4	.2	p			x		o	
5	Cru	.4	.3	ccu		b			o	

W-L-6

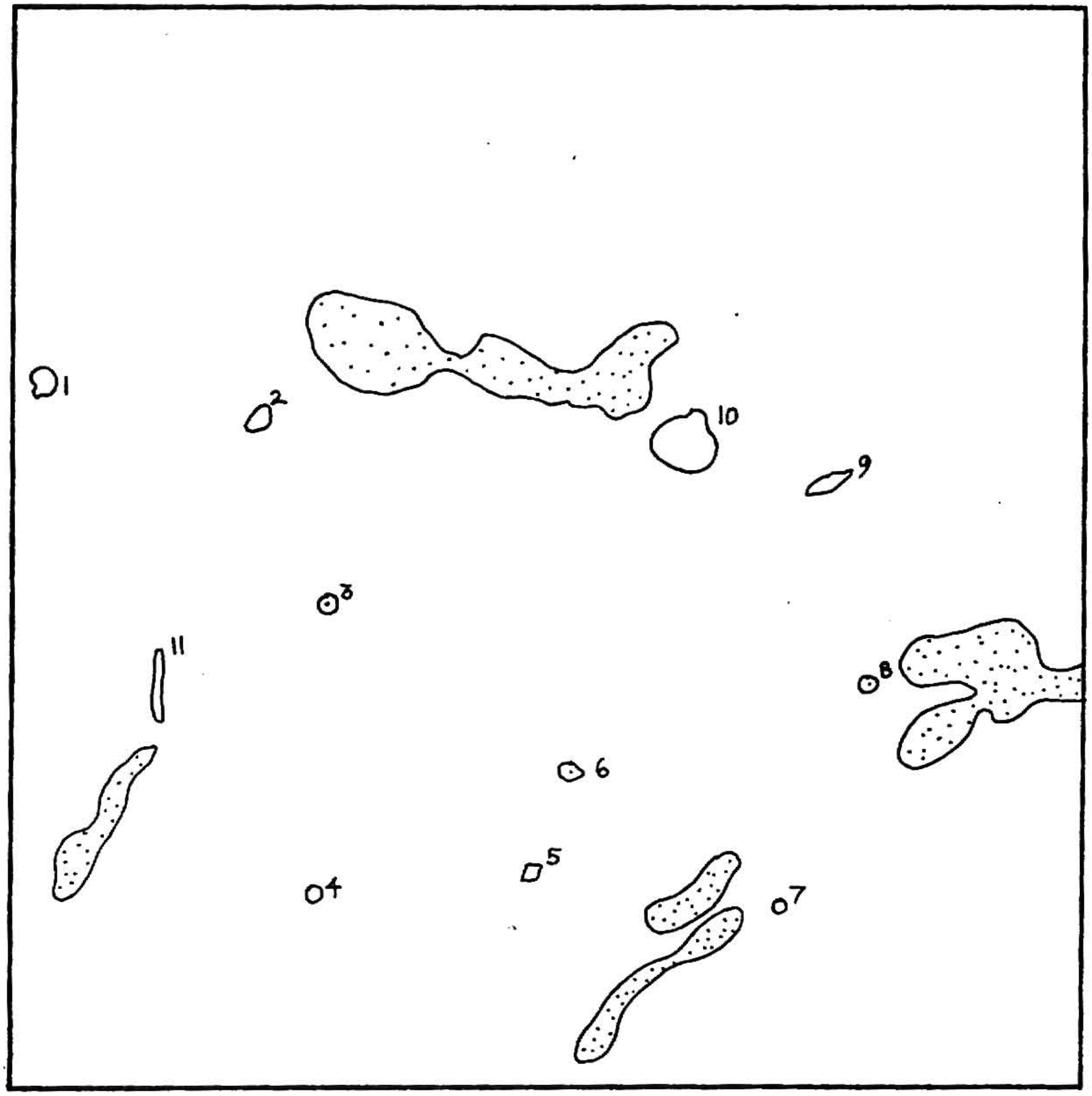


D = 1.923
E = 1.250
GB = 0

W-L-7

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.3	.3	ccu		b	x		cal	
2	Crin	.4	.2	i			x		cal	
3	Crin	.2	.2	i			x		o	
4	Crin	.2	.2	i			x		o	
5	Crin	.2	.3	p			x		o	
6	Crin	.3	.3	p			x		cal	
7	Cru	.2	.2	i			x		cal	
8	Crin	.2	.3	i			x		cal	
9	Fo	.4	.2	p			x		o	
10	Cru	.8	1.0	cvu		p			o	
11	rII	1.0	.2	p			x		o	

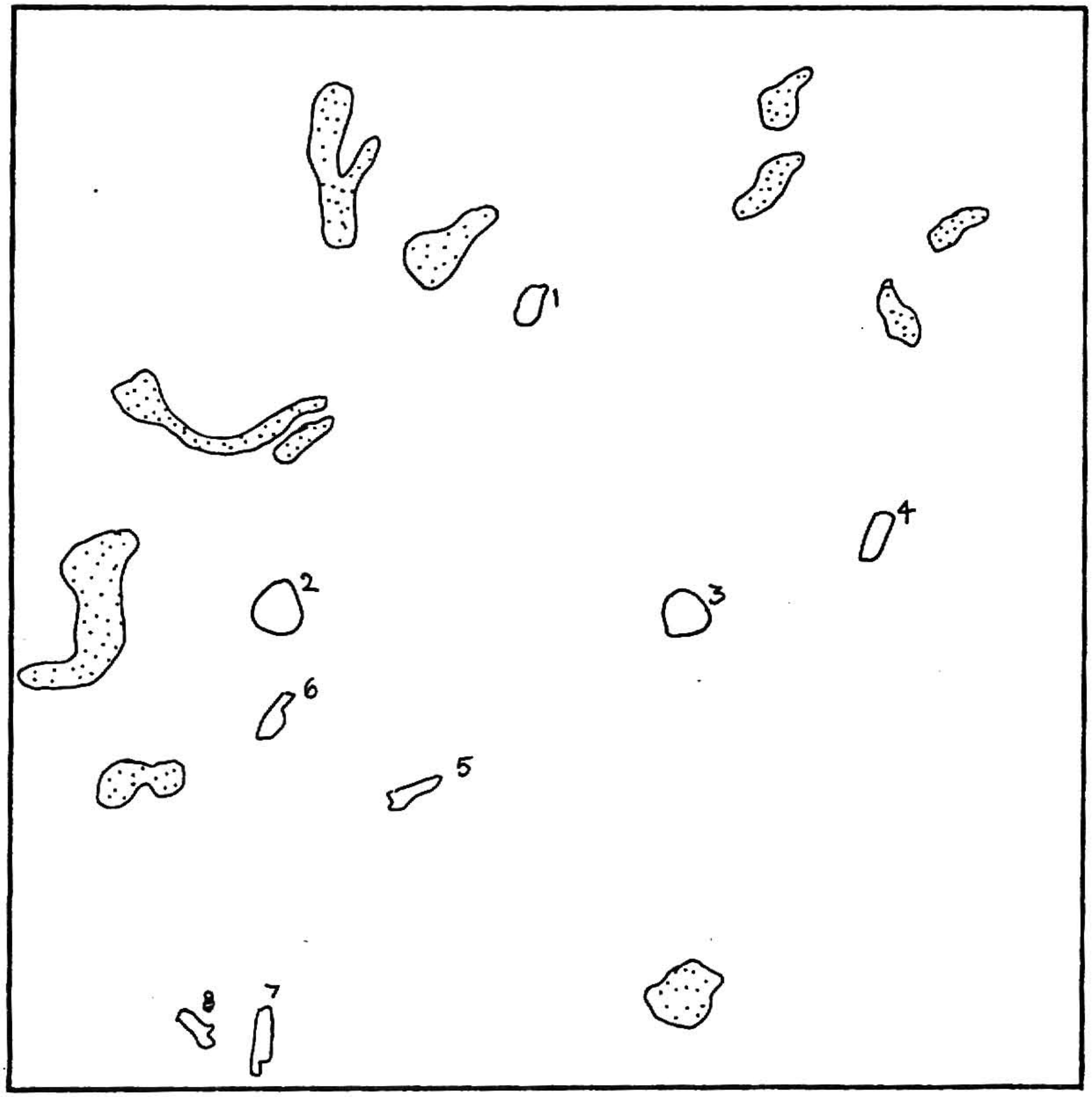
W-L-7



D = 1.159
E = 1.000
GB = 1

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Iso	.3	.5			?	x		cal	
2	Cru	.7	.7	cvu		p			o	
3	Cru	.6	.6	cd		p			o	
4	Iso	.6	.3			?	x		cal	

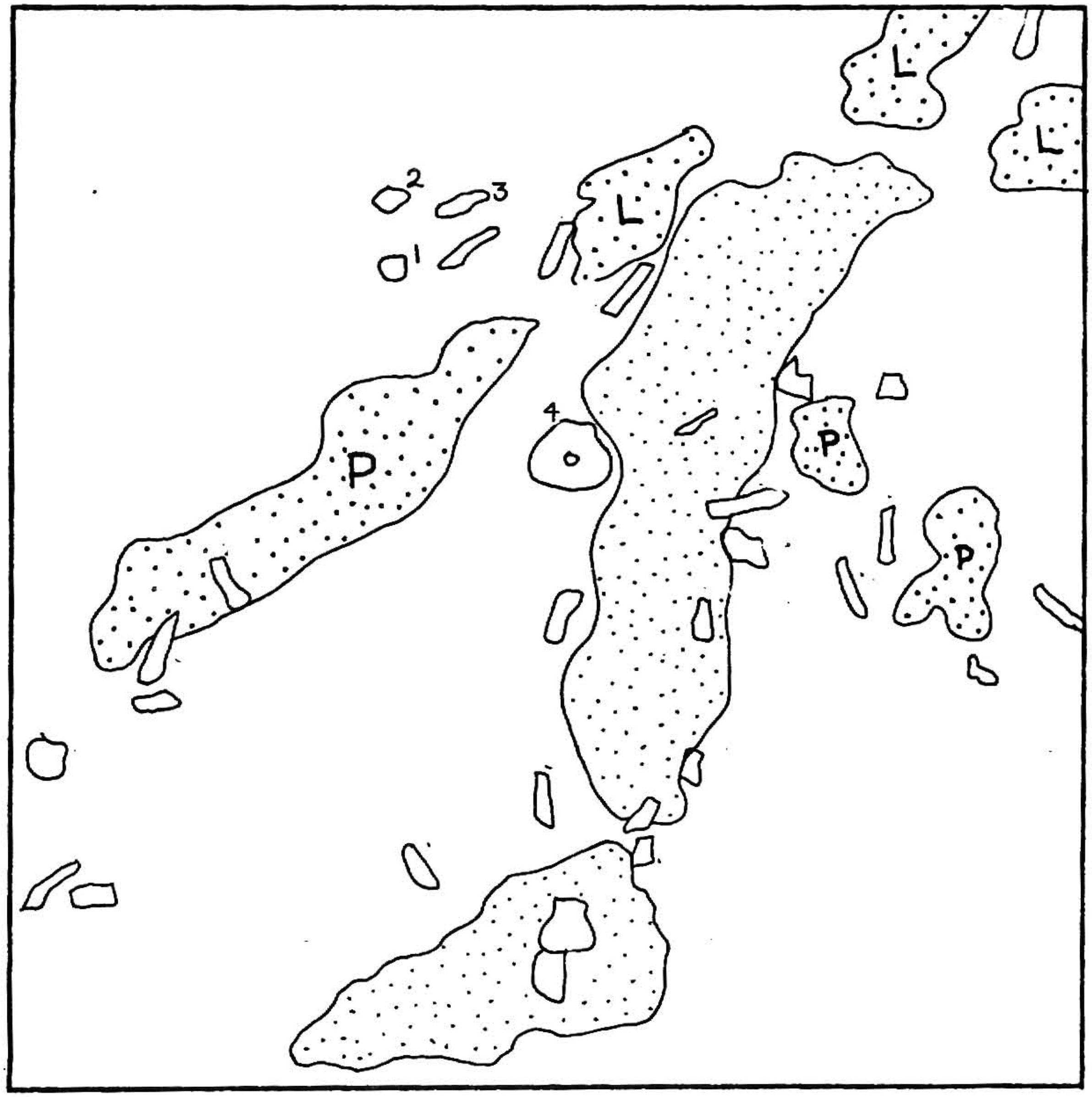
W-L-8



D = .917
E = 1.000
GB = 1

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Cru	.4	.4	cvu		p			o	
2	Cru	.4	.4	p			x		cal	
3	Cru	.6	1.3	i					cal	
4	Cru	1.2	1.0	p					cal	
	Iso						x		o	

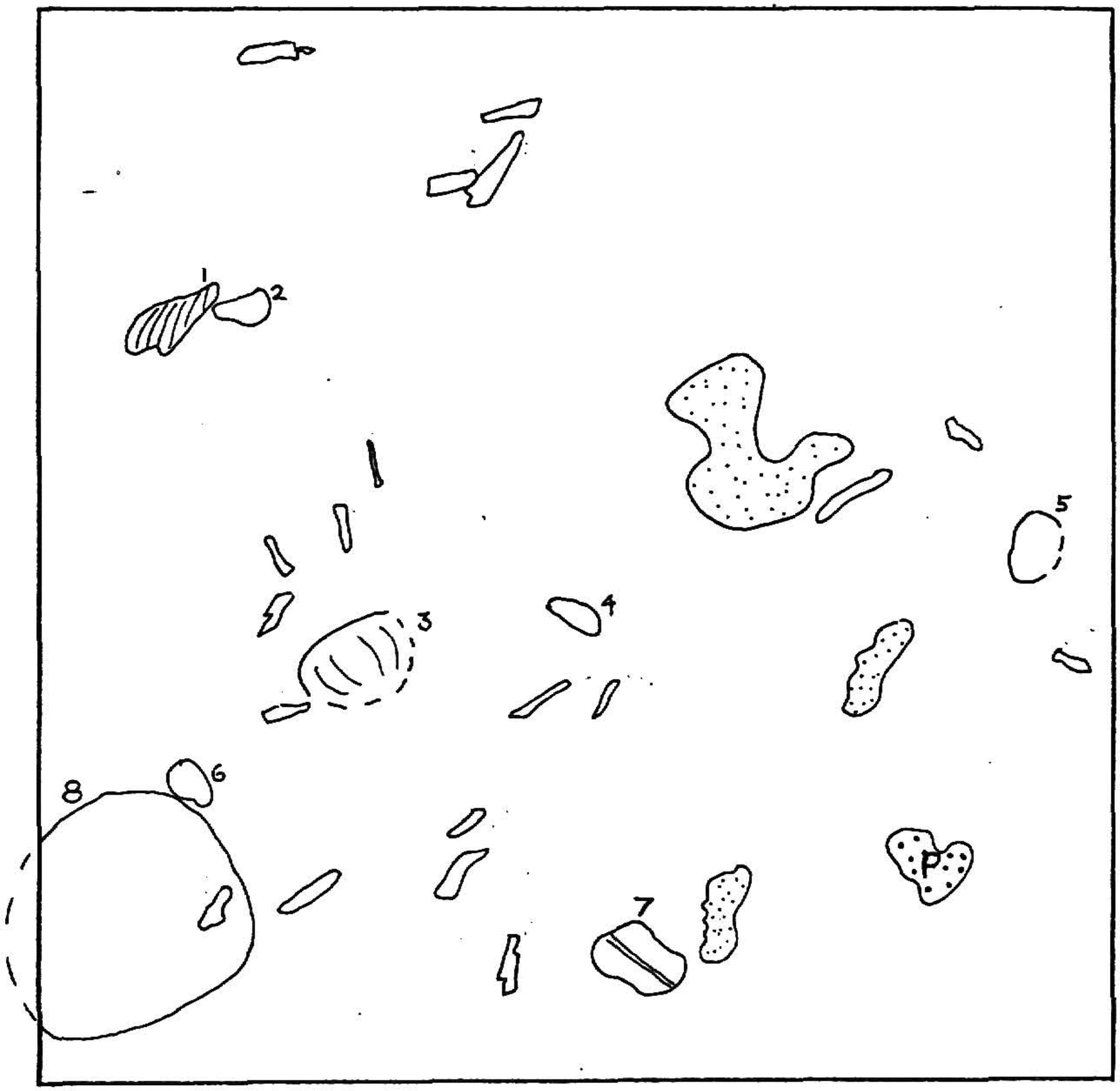
W-L-9



D = 1.372
E = 1.000
GB = 3

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	brac						x		o	
2	brac						x		o	
3	Rea	1.7	1.2			?	x		o	
4	Crin	.8	.4				x		o	
5	?	1.0	.7			?	x		o	
6	Cru	.7	.6	ccu		b	x		o	
7	Bell	1.3	.9	i					o	
8	Lino	3.8	3.5	cvu		b	x		o	

W-L-10

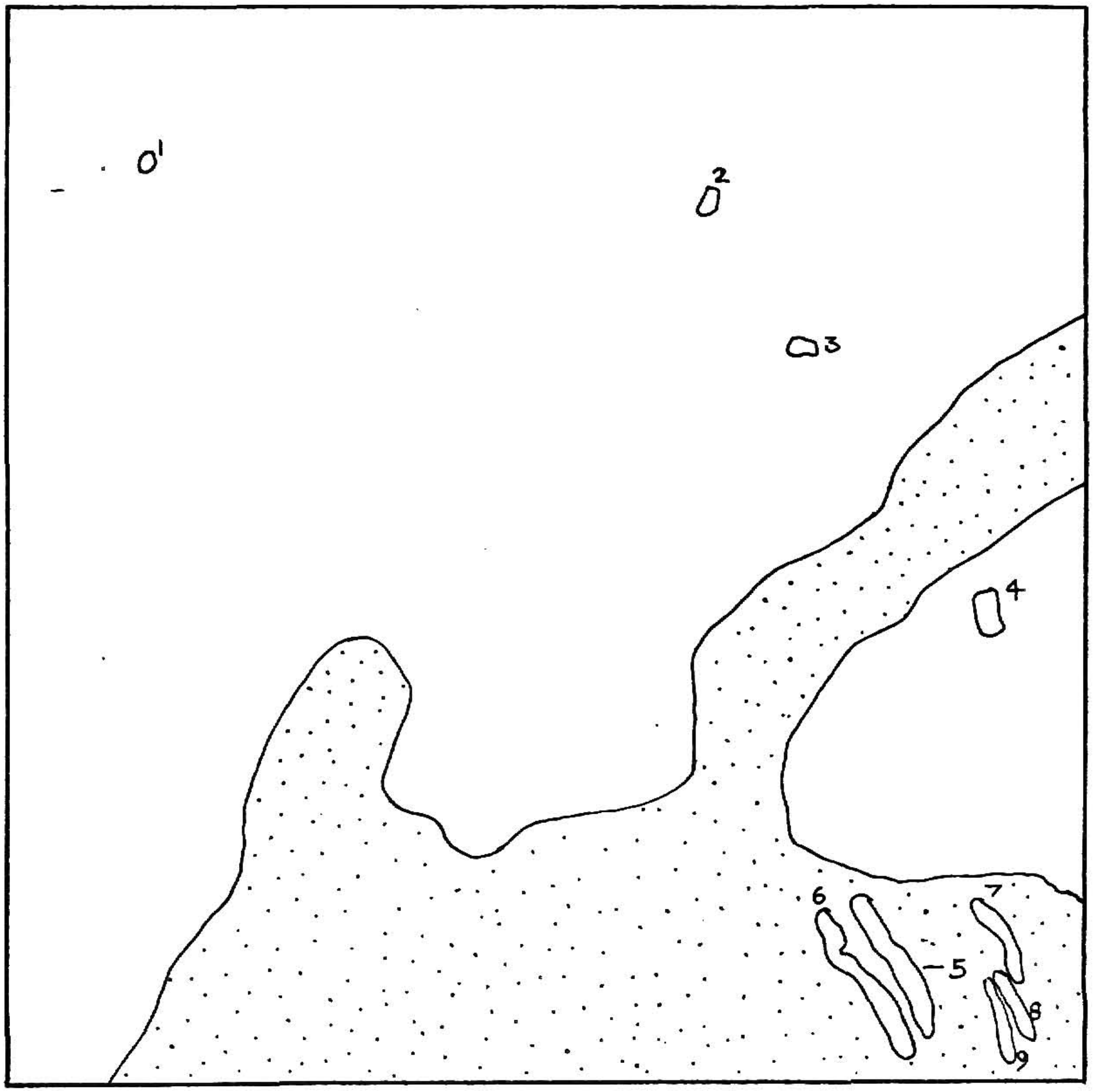


D = 2.724
E = 1.286
GB = 1

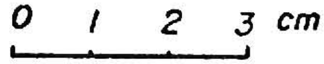
W-L-11

#	genus	long dem.	short dem.	orient.	art	val	frag.	epis	type pres	del
1	Crin	.2	.2	i			x		o	
2	Crin	.4	.2	p			x		o	
3	Crin	.3	.2	p			x		o	
4	Crin	.6	.3	p			x		o	

W-L-11



D = .724
E = 1.000
GB = 3



APPENDIX IV

Thirty-six thin sections were examined. An extensive point count of 1400 points was carried out on samples W-L-3, L-L-2, DC-L-1 and BR-U-1. On all other slides 300 points were counted.

Folk's textural classification of limestones (1959) and Folk's grain size scale for carbonate rocks were applied to name the limestones. A semicolon separates the compositional rock name from the size classification.

Thin Section Data for Locality BR

Bed L-3

Rock Name .... recrystallized brachiopod biomicrite;

Orthochems - 80.9

Mineral	Percentage
Micrite	46.7
Microspar	11.6
Sparry Calcite	1.2
Limonite	1.9
Quartz	
Chert	
Pyrite	
Glauconite	0.4
Clay Matrix	17.9
Unidentified	1.2

Allochems - 19.1

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	2.7
Foraminiferids	1.9
Ectoprocts	2.4
Ostracodes	
Brachiopods	7.0
Bivalves	2.7
Echinoids	
Criniods	2.4

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	

Allochem mean grain size = 0.7 mm

Bed L-2

Rock Name .... brachiopod algal crinoid biomicrite; coarse calcarenite

Orthochems - 80.1

Mineral	Percentage
Micrite	45.6
Microspar	7.7
Sparry Calcite	1.2
Limonite	1.9
Quartz	
Chert	
Pyrite	
Glauconite	
Clay Matrix	22.9
Unidentified	0.8

Allochems - 19.9

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	4.6
Foraminiferids	2.7
Ectoprocts	0.8
Ostracodes	0.4
Brachiopods	5.7
Bivalves	1.1
Echinoids	0.4
Criniods	4.2

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	

Allochem mean grain size = 1 mm

Bed L-1

Rock Name .... limonitic brachiopod biomicrite; coarse calcarenite

Orthochems - 78.6

Mineral	Percentage
Micrite	26.3
Microspar	9.3
Sparry Calcite	1.6
Limonite	3.7
Quartz	0.9
Chert	0.6
Pyrite	
Glauconite	
Clay Matrix	36.2
Unidentified	

Allochems - 21.1

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	3.8
Foraminiferids	1.2
Ectoprocts	1.9
Ostracodes	1.2
Brachiopods	10.2
Bivalves	0.9
Echinoids	0.4
Criniods	1.5

Non Skeletal Frags	Percentage
Intraclasts	0.3
Pellets	
Unidentified	

Allochem mean grain size = 0.7 mm

Bed M-4

Rock Name .... recrystallized brachiopod pelecypod biomicrite; fine calcirudite

Orthochems - 69.5

Mineral	Percentage
Micrite	33.7
Microspar	18.4
Sparry Calcite	1.1
Limonite	0.7
Quartz	1.5
Chert	
Pyrite	
Glauconite	
Clay Matrix	13.7
Unidentified	0.4

Allochems - 30.1

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	
Foraminiferids	
Ectoprocts	0.4
Ostracodes	
Brachiopods	20.4
Bivalves	5.2
Echinoids	
Criniods	4.1

Non Skeletal Frags	Percentage
Intraclasts	0.4
Pellets	
Unidentified	

Allochem mean grain size = 1.8 mm

Bed M-3

Rock Name .... recrystallized limonitic brachiopod biomicrite; coarse calcarenite

Orthochems - 89.0

Mineral	Percentage
Micrite	46.8
Microspar	13.1
Sparry Calcite	0.4
Limonite	4.6
Quartz	
Chert	
Pyrite	
Glauconite	
Clay Matrix	23.5
Unidentified	0.6

Allochems - 10.4

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	
Foraminiferids	0.4
Ectoprocts	0.4
Ostracodes	
Brachiopods	6.8
Bivalves	1.2
Echinoids	0.4
Criniods	1.2

Non Skeletal Frags	Percentage
Intraclasts	0.6
Pellets	
Unidentified	

Allochem mean grain size = 0.9 mm

Bed U-3

Rock Name .... brachiopod biomicrite; coarse calcarenite

Orthochems - 85.8

Mineral	Percentage
Micrite	46.1
Microspar	15.5
Sparry Calcite	3.7
Limonite	0.4
Quartz	
Chert	0.5
Pyrite	0.5
Glauconite	
Clay Matrix	18.6
Unidentified	0.5

Allochems - 13.7

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	
Foraminiferids	0.8
Ectoprocts	
Ostracodes	
Brachiopods	8.5
Bivalves	1.1
Echinoids	0.4
Criniods	2.9

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	0.5

Allochem mean grain size = 0.9 mm

Bed U-2

Rock Name .... recrystallized brachiopod biomicrosparite; coarse calcarenite

Orthochems - 92.5

Mineral	Percentage
Micrite	39.2
Microspar	29.0
Sparry Calcite	
Limonite	0.4
Quartz	
Chert	0.4
Pyrite	
Glauconite	
Clay Matrix	22.4
Unidentified	1.1

Allochems - 7.5

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	
Foraminiferids	0.8
Ectoprocts	0.4
Ostracodes	
Brachiopods	4.3
Bivalves	1.2
Echinoids	
Criniods	0.8

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	

Allochem mean grain size = 0.8 mm

Bed U-1*

Rock Name .... recrystallized brachiopod biomicrosparite; fine calcirudite

Orthochems - 78.3

Mineral	Percentage
Micrite	26.2
Microspar	25.0
Sparry Calcite	1.2
Limonite	0.4
Quartz	0.1
Chert	0.1
Pyrite	
Glauconite	0.6
Clay Matrix	23.9
Unidentified	0.8

Allochems - 21.5

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	0.1
Foraminiferids	0.3
Ectoprocts	0.1
Ostracodes	0.4
Brachiopods	16.8
Bivalves	1.2
Echinoids	0.2
Criniods	2.4

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	0.2

Allochem mean grain size = 2 mm

*1400 points counted

Thin Section Data for Locality DC

Bed L-4

Rock Name .... fossiliferous microsparite; fine calcirudite

Orthochems - 94.3

Mineral	Percentage
Micrite	34.7
Microspar	26.8
Sparry Calcite	
Limonite	1.8
Quartz	
Chert	0.4
Pyrite	
Glauconite	
Clay Matrix	30.2
Unidentified	0.4

Allochems - 5.7

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	0.4
Foraminiferids	0.4
Ectoprocts	0.4
Ostracodes	
Brachiopods	3.0
Bivalves	0.4
Echinoids	
Criniods	1.1

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	

Allochem mean grain size = 1.5 mm

Bed L-3

Rock Name .... biomicrite; coarse calcarenite

Orthochems - 87.1

Mineral	Percentage
Micrite	66.6
Microspar	7.2
Sparry Calcite	
Limonite	0.8
Quartz	
Chert	1.2
Pyrite	
Glauconite	0.4
Clay Matrix	10.9
Unidentified	

Allochems - 12.9

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	1.6
Foraminiferids	2.7
Ectoprocts	1.2
Ostracodes	
Brachiopods	3.9
Bivalves	0.4
Echinoids	
Criniods	3.1

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	

Allochem mean grain size = 0.6 mm

Bed L-2

Rock Name .... recrystallized foram algal biomicrite; fine calcirudite

Orthochems - 69.9

Mineral	Percentage
Micrite	37.7
Microspar	11.4
Sparry Calcite	1.8
Limonite	0.4
Quartz	
Chert	
Pyrite	0.4
Glauconite	0.1
Clay Matrix	17.7
Unidentified	0.4

Allochems - 30.1

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	8.1
Foraminiferids	11.0
Ectoprocts	1.7
Ostracodes	
Brachiopods	6.8
Bivalves	
Echinoids	
Criniods	2.5

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	

Allochem mean grain size = 1.1 mm

Bed L-1*

Rock Name .... limonitic algal brachiopod biomicrite; fine calcirudite

Orthochems - 82.2

Mineral	Percentage
Micrite	50.4
Microspar	16.4
Sparry Calcite	0.7
Limonite	3.3
Quartz	
Chert	
Pyrite	0.7
Glauconite	0.1
Clay Matrix	10.4
Unidentified	0.2

Allochems - 17.8

Skeletal Frags	Percentage
Calc.Algae	0.1
Encrust.Algae	7.3
Foraminiferids	1.9
Ectoprocts	
Ostracodes	0.1
Brachiopods	5.6
Bivalves	0.9
Echinoids	0.7
Criniods	1.2

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	

Allochem mean grain size = 1.1 mm

*1400 points counted

Bed M-3

Rock Name .... recrystallized cherty brachiopod pelecypod biomicrosparite; coarse calcarenite

Orthochems - 77.6

Mineral	Percentage
Micrite	29.0
Microspar	24.0
Sparry Calcite	0.3
Limonite	0.8
Quartz	0.3
Chert	1.9
Pyrite	
Glauconite	0.2
Clay Matrix	20.9
Unidentified	0.2

Allochems - 22.4

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	1.9
Foraminiferids	1.5
Ectoprocts	0.3
Ostracodes	0.8
Brachiopods	10.7
Bivalves	4.2
Echinoids	
Criniods	3.0

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	

Allochem mean grain size = 0.8 mm

Bed M-2

Rock Name .... recrystallized brachiopod biomicrosparite; fine calcirudite

Orthochems - 81.3

Mineral	Percentage
Micrite	39.0
Microspar	26.8
Sparry Calcite	2.8
Limonite	0.8
Quartz	
Chert	1.2
Pyrite	
Glauconite	
Clay Matrix	10.4
Unidentified	0.3

Allochems - 18.7

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	0.4
Foraminiferids	0.4
Ectoprocts	0.8
Ostracodes	
Brachiopods	10.2
Bivalves	2.8
Echinoids	
Criniods	4.1

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	

Allochem mean grain size = 1.4 mm

Bed M-1

Rock Name .... brachiopod biomicrosparite; fine calcirudite

Orthochems - 82.1

Mineral	Percentage
Micrite	39.6
Microspar	23.4
Sparry Calcite	
Limonite	0.4
Quartz	
Chert	
Pyrite	
Glauconite	0.4
Clay Matrix	17.9
Unidentified	0.4

Allochems - 17.5

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	0.8
Foraminiferids	2.4
Ectoprocts	0.8
Ostracodes	
Brachiopods	11.5
Bivalves	1.2
Echinoids	
Criniods	0.8

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	0.4

Allochem mean grain size = 1.7 mm

Bed U-1

Rock Name .... brachiopod biomicrite; fine calcirudite

Orthochems - 84.0

Mineral	Percentage
Micrite	34.1
Microspar	26.7
Sparry Calcite	0.3
Limonite	0.4
Quartz	0.8
Chert	
Pyrite	
Glauconite	
Clay Matrix	21.7
Unidentified	

Allochems - 15.9

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	1.2
Foraminiferids	1.2
Ectoprocts	0.4
Ostracodes	
Brachiopods	8.5
Bivalves	1.5
Echinoids	
Criniods	3.1

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	0.1

Allochem mean grain size = 1.1 mm

Thin Section Data for Locality P

Bed L-3

Rock Name .... brachiopod foram biomicrite; fine

Orthochems - 78.5

Mineral	Percentage
Micrite	58.2
Microspar	4.0
Sparry Calcite	2.8
Limonite	0.8
Quartz	0.2
Chert	0.2
Pyrite	
Glauconite	
Clay Matrix	10.4
Unidentified	1.9

Allochems - 21.4

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	2.3
Foraminiferids	4.4
Ectoprocts	3.9
Ostracodes	
Brachiopods	8.4
Bivalves	0.8
Echinoids	
Criniods	1.6

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	0.1

Allochem mean grain size = 1.2 mm

Bed L-2

Rock Name .... brachiopod biomicrite; coarse calcarenite

Orthochems - 82.6

Mineral	Percentage
Micrite	52.0
Microspar	11.3
Sparry Calcite	0.8
Limonite	0.8
Quartz	
Chert	
Pyrite	
Glauconite	
Clay Matrix	17.7
Unidentified	

Allochems - 17.4

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	2.3
Foraminiferids	3.4
Ectoprocts	1.5
Ostracodes	0.8
Brachiopods	6.3
Bivalves	
Echinoids	0.8
Criniods	2.3

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	

Allochem mean grain size = 0.9 mm

Bed L-1

Rock Name .... brachiopod biomicrite; medium calcirudite

Orthochems - 76.7

Mineral	Percentage
Micrite	53.4
Microspar	6.7
Sparry Calcite	0.8
Limonite	1.1
Quartz	0.4
Chert	0.8
Pyrite	
Glauconite	
Clay Matrix	13.5
Unidentified	

Allochems - 23.0

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	3.2
Foraminiferids	1.5
Ectoprocts	0.8
Ostracodes	0.3
Brachiopods	13.9
Bivalves	0.8
Echinoids	
Criniods	2.5

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	0.3

Allochem mean grain size = 4.2 mm

Bed M-1

Rock Name .... brachiopod biomicrosparite; fine calcirudite

Orthochems - 90.7

Mineral	Percentage
Micrite	29.5
Microspar	33.5
Sparry Calcite	0.8
Limonite	
Quartz	
Chert	
Pyrite	
Glauconite	0.5
Clay Matrix	26.2
Unidentified	0.2

Allochems - 9.0

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	
Foraminiferids	
Ectoprocts	
Ostracodes	
Brachiopods	5.4
Bivalves	3.6
Echinoids	
Criniods	

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	0.3

Allochem mean grain size = 1.2 mm

Bed U-2

Rock Name .... recrystallized brachiopod biomicrosparite; fine calcirudite

Orthochems - 81.6

Mineral	Percentage
Micrite	34.9
Microspar	21.2
Sparry Calcite	7.8
Limonite	
Quartz	
Chert	2.0
Pyrite	
Glauconite	1.2
Clay Matrix	14.5
Unidentified	

Allochems - 18.4

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	2.0
Foraminiferids	
Ectoprocts	2.7
Ostracodes	
Brachiopods	10.9
Bivalves	1.2
Echinoids	
Criniods	1.6

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	

Allochem mean grain size = 1.2 mm

Bed U-1

Rock Name .... recrystallized brachiopod bio-microsparite; fine calcirudite

Orthochems - 71.1

Mineral	Percentage
Micrite	27.3
Microspar	16.8
Sparry Calcite	9.8
Limonite	0.4
Quartz	
Chert	0.8
Pyrite	
Glauconite	2.7
Clay Matrix	13.3
Unidentified	

Allochems - 28.9

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	1.9
Foraminiferids	2.7
Ectoprocts	1.5
Ostracodes	0.4
Brachiopods	14.5
Bivalves	3.9
Echinoids	0.4
Criniods	3.6

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	

Allochem mean grain size = 1.1 mm

Bed T-2

Rock Name .... brachiopod biomicrite; fine calcirudite

Orthochems - 80.6

Mineral	Percentage
Micrite	21.3
Microspar	9.9
Sparry Calcite	3.0
Limonite	
Quartz	
Chert	0.8
Pyrite	
Glauconite	
Clay Matrix	43.7
Unidentified	1.9

Allochems - 19.4

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	1.1
Foraminiferids	0.4
Ectoprocts	
Ostracodes	
Brachiopods	15.6
Bivalves	1.9
Echinoids	
Criniods	0.4

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	

Allochem mean grain size = 1.1 mm

Bed T-1

Rock Name .... recrystallized brachiopod biomicrosparite; fine calcirudite

Orthochems - 83.3

Mineral	Percentage
Micrite	37.2
Microspar	19.2
Sparry Calcite	2.4
Limonite	
Quartz	
Chert	1.2
Pyrite	
Glauconite	
Clay Matrix	22.4
Unidentified	0.9

Allochems - 16.6

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	1.2
Foraminiferids	0.8
Ectoprocts	0.8
Ostracodes	
Brachiopods	9.8
Bivalves	1.6
Echinoids	
Criniods	2.4

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	0.1

Allochem mean grain size = 1.5 mm

Thin Section Data for Locality L

Bed L-3

Rock Name .... fossiliferous micrite; medium calcarenite

Orthochems - 92.2

Mineral	Percentage
Micrite	68.8
Microspar	6.8
Sparry Calcite	
Limonite	1.4
Quartz	
Chert	1.1
Pyrite	
Glauconite	
Clay Matrix	14.1
Unidentified	

Allochems - 7.6

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	0.7
Foraminiferids	
Ectoprocts	1.1
Ostracodes	
Brachiopods	4.3
Bivalves	0.4
Echinoids	
Criniods	1.1

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	0.2

Allochem mean grain size = 0.4 mm

Bed L-2*

Rock Name .... fossiliferous micrite; coarse calcarenite

Orthochems - 89.6

Mineral	Percentage
Micrite	58.4
Microspar	6.9
Sparry Calcite	0.3
Limonite	2.3
Quartz	
Chert	0.1
Pyrite	
Glauconite	0.2
Clay Matrix	21.4
Unidentified	

Allochems - 10.4

Skeletal Frags	Percentage
Calc.Algae	0.7
Encrust.Algae	1.7
Foraminiferids	0.6
Ectoprocts	1.9
Ostracodes	0.5
Brachiopods	4.0
Bivalves	0.2
Echinoids	0.1
Criniods	0.7

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	

Allochem mean grain size = 0.8 mm

*1400 points counted

Bed L-1

Rock Name .... brachiopod algal biomicrite; coarse calcarenite

Orthochems - 77.1

Mineral	Percentage
Micrite	38.4
Microspar	6.4
Sparry Calcite	0.8
Limonite	0.8
Quartz	0.8
Chert	
Pyrite	
Glauconite	0.3
Clay Matrix	29.5
Unidentified	0.1

Allochems - 22.6

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	6.5
Foraminiferids	3.0
Ectoprocts	0.8
Ostracodes	0.8
Brachiopods	7.0
Bivalves	0.8
Echinoids	
Criniods	0.8

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	0.3

Allochem mean grain size = 0.8 mm

Bed M-2

Rock Name .... brachiopod biomicrite; coarse calcarenite

Orthochems - 85.0

Mineral	Percentage
Micrite	45.9
Microspar	12.7
Sparry Calcite	0.4
Limonite	3.4
Quartz	
Chert	2.2
Pyrite	0.4
Glauconite	
Clay Matrix	19.6
Unidentified	0.4

Allochems - 15.0

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	1.9
Foraminiferids	
Ectoprocts	0.4
Ostracodes	0.4
Brachiopods	8.9
Bivalves	
Echinoids	
Criniods	3.4

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	

Allochem mean grain size = 0.8 mm

Bed M-1

Rock Name .... recrystallized brachiopod biomicrite; coarse calcarenite

Orthochems - 83.2

Mineral	Percentage
Micrite	44.6
Microspar	21.6
Sparry Calcite	1.5
Limonite	2.6
Quartz	
Chert	
Pyrite	
Glauconite	0.4
Clay Matrix	12.4
Unidentified	0.1

Allochems - 15.9

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	1.0
Foraminiferids	
Ectoprocts	0.7
Ostracodes	0.4
Brachiopods	8.6
Bivalves	1.5
Echinoids	
Criniods	3.7

Non Skeletal Frags	Percentage
Intraclasts	0.7
Pellets	
Unidentified	0.2

Allochem mean grain size = 0.8 mm

Thin Section Data for Locality W

Bed L-3*

Rock Name .... recrystallized brachiopod biomicrite, fine calcirudite

Orthochems - 86.6

Mineral	Percentage
Micrite	50.3
Microspar	20.6
Sparry Calcite	3.8
Limonite	0.4
Quartz	0.1
Chert	0.1
Pyrite	0.4
Glauconite	0.2
Clay Matrix	10.6
Unidentified	0.1

Allochems - 13.4

Skeletal Frags	Percentage
Calc.Algae	0.4
Encrust.Algae	0.4
Foraminiferids	0.8
Ectoprocts	1.9
Ostracodes	
Brachiopods	6.8
Bivalves	1.1
Echinoids	0.3
Criniods	1.7

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	

Allochem mean grain size = 1.1 mm

*1400 points counted

Bed L-2

Rock Name .... brachiopod biomicrite; coarse calc-arenite

Orthochems - 86.6

Mineral	Percentage
Micrite	55.5
Microspar	7.9
Sparry Calcite	1.2
Limonite	1.0
Quartz	
Chert	
Pyrite	0.3
Glauconite	0.3
Clay Matrix	20.2
Unidentified	0.2

Allochems - 11.7

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	2.7
Foraminiferids	2.3
Ectoprocts	
Ostracodes	0.4
Brachiopods	4.3
Bivalves	0.4
Echinoids	0.4
Criniods	1.2

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	0.7

Allochem mean grain size = 0.7 mm

Bed L-1

Rock Name .... recrystallized brachiopod algal biomicrite; fine calcirudite

Orthochems - 53.8

Mineral	Percentage
Micrite	29.3
Microspar	5.6
Sparry Calcite	1.9
Limonite	0.6
Quartz	
Chert	
Pyrite	
Glauconite	
Clay Matrix	16.2
Unidentified	0.2

Allochems - 46.1

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	7.5
Foraminiferids	1.9
Ectoprocts	3.0
Ostracodes	0.8
Brachiopods	26.2
Bivalves	1.1
Echinoids	0.4
Criniods	5.2

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	0.1

Allochem mean grain size = 2.0 mm

Bed M-3

Rock Name .... recrystallized brachiopod biomicrite; fine calcirudite

Orthochems - 85.1

Mineral	Percentage
Micrite	46.3
Microspar	18.3
Sparry Calcite	1.1
Limonite	
Quartz	0.4
Chert	1.1
Pyrite	
Glauconite	
Clay Matrix	17.9
Unidentified	

Allochems - 14.7

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	
Foraminiferids	1.1
Ectoprocts	
Ostracodes	
Brachiopods	9.7
Bivalves	1.5
Echinoids	
Criniods	2.4

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	0.2

Allochem mean grain size = 1.2 mm

Bed M-2

Rock Name .... recrystallized brachiopod bio-micrite; coarse calcarenite

Orthochems - 85.4

Mineral	Percentage
Micrite	43.2
Microspar	17.9
Sparry Calcite	0.4
Limonite	
Quartz	0.2
Chert	1.9
Pyrite	
Glauconite	
Clay Matrix	21.8
Unidentified	

Allochems - 14.5

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	1.5
Foraminiferids	
Ectoprocts	1.2
Ostracodes	
Brachiopods	9.5
Bivalves	0.8
Echinoids	
Criniods	1.5

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	0.1

Allochem mean grain size = 0.8 mm

Bed M-1

Rock Name .... recrystallized brachiopod ecto-proct biomicrite; coarse calcarenite

Orthochems - 74.2

Mineral	Percentage
Micrite	49.8
Microspar	5.9
Sparry Calcite	1.5
Limonite	0.8
Quartz	0.4
Chert	0.4
Pyrite	
Glauconite	
Clay Matrix	15.4
Unidentified	

Allochems - 25.5

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	1.1
Foraminiferids	1.5
Ectoprocts	7.9
Ostracodes	
Brachiopods	9.4
Bivalves	1.1
Echinoids	
Criniods	4.5

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	0.3

Allochem mean grain size = 0.9 mm

Bed U-1

Rock Name .... recrystallized brachiopod bio-micrite; fine calcirudite

Orthochems - 88.3

Mineral	Percentage
Micrite	35.8
Microspar	28.7
Sparry Calcite	
Limonite	
Quartz	0.8
Chert	1.6
Pyrite	
Glauconite	1.2
Clay Matrix	19.5
Unidentified	0.7

Allochems - 11.7

Skeletal Frags	Percentage
Calc.Algae	
Encrust.Algae	
Foraminiferids	
Ectoprocts	
Ostracodes	
Brachiopods	8.2
Bivalves	2.7
Echinoids	
Criniods	0.8

Non Skeletal Frags	Percentage
Intraclasts	
Pellets	
Unidentified	

Allochem mean grain size = 1.5 mm

APPENDIX V

WATFIV computer program written by R. J. Harris for IBM system 370 with example for calculating degree of similarity using Dice correlation coefficient and printouts of data.

Fossils marked with an asterisk in fig. 6 were not included in the computer program.

```
$JOB                          TIME=(,45)
      DIMENSION DATAM(50,50),SMATR(50,50),LOCAT(100),LMC(50),LMR(5
      REAL NJK,NJLK,NLJK
    1 FORMAT(2I3)
    2 FORMAT(40F2.0)
    3 FORMAT(1H0,10X,24HALL TERMS=0,SET COMPLETE)
    4 FORMAT(1H0,10X,11HCORR.LEVEL=,F5.3,2X,10HSAMPLE NO.,24I3)
    5 FORMAT(1H1,10X,7HSET NO.,I3)
    6 FORMAT(1H0,10X,11HDATA MATRIX)
    7 FORMAT(1H ,10X,50F2.0)
  200 FORMAT(1H0,10X,38HINITIAL CORRELATION COEFFICIENT MATRIX)
  202 FORMAT(1H ,10X,25F5.3)
      ISET=0
    9 READ(5,1,END=100) NSA,NSP
      DO 10 I=1,NSA
      DO 10 J=1,NSP
   10 DATAM(I,J)=0.0
      DO 300 I =1,NSA
      DO 300 J =1,NSA
  300 SMATR(I,J)=0.0
      NJLK=0.0
      NJK=0.0
      DO 11 J=1,NSP
   11 READ(5,2)(DATAM(I,J),I=1,NSA)
      NSB=NSA-1
      DO 16 I=1,NSB
      I1=I+1
      DO 16 J=I1,NSA
      DO 15 K=1,NSP
      IF(DATAM(I,K).NE.DATAM(J,K))GO TO 12
      IF(DATAM(I,K).EQ.0.0) GO TO 15
      NJK= NJK+1.
      GO TO 15
   12 NJLK=NJLK+1.
   15 CONTINUE
      SMATR(J ,I)=(NJK*2.)/(NJK*2. +NJLK)
      NJK=0.0
   16 NJLK=0.0
      ISET=ISET+1
      WRITE(6,5) ISET
      WRITE(6,6)
      DO 17 J=1,NSP
   17 WRITE(6,7) (DATAM(I,J),I=1,NSA)
      WRITE(6,200)
      DO 20 J=1,NSB
      J1=J+1
      DO 20 I=J1,NSA
   20 SMATR(J,I)=SMATR(I,J)
      DO 201 N=1,NSA
  201 WRITE(6,202)(SMATR(M,N),M=1,NSA)
   21 SMAX=0.0
      DO 30 I=1,NSB
      I1=I+1
      DO 30 J=I1,NSA
      IF(SMATR(I,J).EQ.0.0) GO TO 30
      IF(SMAX.GT.SMATR(I,J))GO TO 30
      IF(SMAX.LT.SMATR(I,J))GO TO 29
      K=K+ 1
      LMC(K)=I
      LMR(K)= J
```

```
      GO TO 30
   29 SMAX=SMATR(I,J)
      K= 1
      LMC(K)= I
      LMR(K)= J
   30 CONTINUE
      IF(SMAX.EQ.0.0)GO TO 60
      DO 35 I=1,K
      IK=I+K
      LOCAT(I)=LMC(I)
   35 LOCAT(IK)=LMR(I)
      KK=K+K-1
      KKK=K+K
      DO 40 I=1,KK
      I1=I+1
      DO 40 J=I1,KKK
      IF(LOCAT(J).LT.LOCAT(I))GO TO 40
      IF(LOCAT(J).EQ.LOCAT(I))GO TO 36
      LDUMY =LOCAT(I)
      LOCAT(I)=LOCAT(J)
      LOCAT(J)=LDUMY
      GO TO 40
   36 LOCAT(J)=0
   40 CONTINUE
      K1=K+1
      WRITE (6,4) SMAX,(LOCAT(I), I=1,K1)
      DO 50 I=1,NSA
      SUM=0.0
      DO 42 J=1,K1
      IF(I.EQ.LOCAT(J))GO TO 45
      IRS=LOCAT(J)
   42 SUM=SUM +SMATR(IRS,I)
      J=LOCAT(1)
      AK1=K1
      SMATR(J,I)=SUM/AK1
      DO 44 J=2,K1
      LJ=LOCAT(J)
   44 SMATR(LJ,I)=0.0
      GO TO 50
   45 DO 46 J=1,K1
      LJ=LOCAT(J)
   46 SMATR(LJ,I)=0.0
   50 CONTINUE
      DO 55 I=1,K1
      IRS=LOCAT(I)
      DO 55 J=1,NSA
   55 SMATR(J,IRS)=SMATR(IRS,J)
      GO TO 21
   60 WRITE (6,3)
      GO TO 9
  100 CONTINUE
      STOP
      END

$ENTRY
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SET NO. 4 (LOCALITY L)

DATA MATRIX

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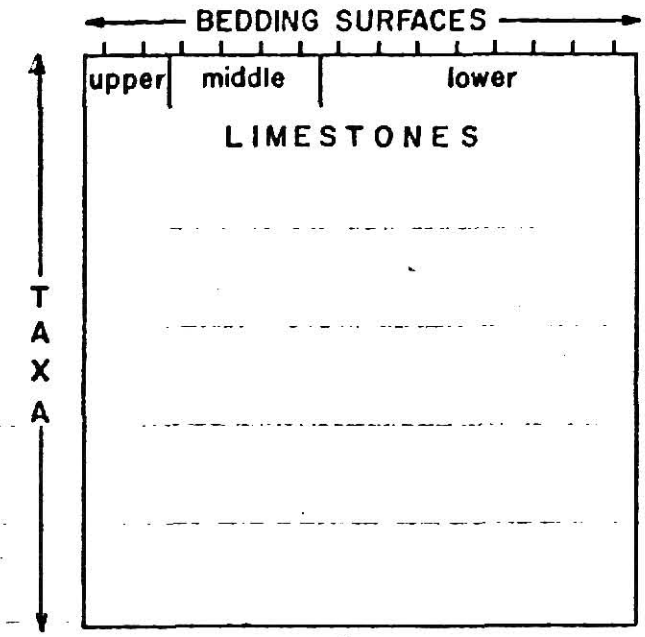

INITIAL CORRELATION COEFFICIENT MATRIX

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CORR.LEVEL=0.514   SAMPLE NO. 10  5

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CORR.LEVEL=0.389   SAMPLE NO. 14  2

CORR.LEVEL=0.382   SAMPLE NO.  9  7

CORR.LEVEL=0.322   SAMPLE NO. 10  9

CORR.LEVEL=0.316   SAMPLE NO. 14 10

CORR.LEVEL=0.128   SAMPLE NO. 14 12

CORR.LEVEL=0.023   SAMPLE NO. 14 13
```

APPENDIX VI

Weight Percent Insolubles, Calciumcarbonate, Organic Carbon, and Lithologic Classification

Sample No.	Insoluble Residues* (Weight Percent)	$CaCO_3$* (Weight Percent)	Organic Carbon Ct.* (Weight Percent)	Lithology
BR-U-1	36.94	49.02	14.04**	Mudstone
BR-M-1	50.38	43.78	5.84	Mudstone
BR-M-2	41.16	53.00		Limestone
BR-M-3	56.73	37.43		Mudstone
BR-L-1	30.35	69.05	.60	Limestone
BR-L-2	30.09	69.31		Limestone
BR-L-3	31.38	68.02		Limestone
DC-T-1	48.52	47.68	3.80	Mudstone
DC-U-1	51.56	40.30	8.04	Mudstone
DC-M-1	38.89	51.47	9.64	Limestone
DC-L-1	49.78	46.98	3.24	Mudstone
DC-L-2	33.97	62.79		Limestone
DC-L-3	50.85	45.91		Mudstone
P -T-1	20.90	75.06	3.48	Limestone
P -U-1	17.54	77.62	4.84	Limestone
P -U-2	26.67	68.49		Limestone
P -M-1	27.36	59.44	13.20	Limestone
P -L-1	32.40	65.80	1.80	Limestone
P -L-2	23.14	75.06		Limestone
P -L-3	25.13	73.07		Limestone
L -U-1	25.35	71.97	2.68	Limestone
L -M-1	28.06	69.42	2.52	Limestone
L -M-2	36.99	60.49		Limestone
L -L-1	29.63	70.09	.28	Limestone
L -L-2	27.85	71.87		Limestone
L -L-3	34.38	65.34		Limestone
W -U-1	38.17	50.03	11.80	Limestone
W -U-2	35.76	52.44		Limestone
W -M-1	29.48	61.40	9.12	Limestone
W -M-2	38.15	52.73		Limestone
W -M-3	42.62	48.26		Mudstone
W -L-1	39.25	53.07	7.68	Limestone
W -L-2	24.15	68.17		Limestone
W -L-3	58.14	34.28		Mudstone

* Weight Percent Insolubles, $CaCO_3$ and Organic Content equal 100 percent
**only one sample/per bed

APPENDIX VII

Weight Percentages Sand, Silt, Clay
in Insoluble Fraction

Sample No.	Sand (Wt.%) 4 0	Silt (Wt.%) 4-9 0	Clay (Wt.%) 9 0
BR-U-1	.10	24.92	11.92
BR-M-1	.35	31.28	18.75
BR-M-2	.31	25.18	15.04
BR-M-3	.36	30.31	26.06
BR-L-1	.19	19.24	10.92
BR-L-2	.23	18.17	11.69
BR-L-3	.16	20.31	10.91
DC-T-1	.82	21.05	26.65
DC-U-1	.37	32.67	18.52
DC-M-1	.44	21.53	16.92
DC-L-1	.91	25.29	23.58
DC-L-2	.45	19.56	13.87
DC-L-3	.43	35.51	14.91
P -T-1	.30	.50	20.10
P -U-1	.64	5.20	11.70
P -U-2	.51	9.63	16.53
P -M-1	.64	10.79	15.93
P -L-1	.50	13.76	18.14
P -L-2	.27	8.89	13.98
P -L-3	.31	10.06	14.76
L -U-1	.21	6.93	18.21
L -M-1	.20	8.39	19.47
L -M-2	.67	12.91	23.41
L -L-1	.23	10.91	18.49
L -L-2	.17	9.56	18.12
L -L-3	.32	11.88	22.18
W -U-1	.26	20.89	17.02
W -U-2	.32	16.99	18.45
W -M-1	.24	9.65	19.59
W -M-2	.34	14.44	23.37
W -M-3	.52	19.45	22.65
W -L-1	.33	15.48	23.44
W -L-2	.20	7.36	16.59
W -L-3	.61	32.08	25.45

APPENDIX VIII

To my knowledge no one has ever applied Nelson's Sedimentary Phosphate Fractionation Technique (SPM) to carbonate rocks. New working techniques had to be developed to obtain satisfactory results.

Three different sample treatments were applied to two samples and palaeosalinities estimated. These three treatments were: 1) centrifuge 4-9Ø fraction, 2) centrifuge 9Ø fraction, and 3) centrifuge HCl-treated 9Ø fraction. A crushed sample was scanned for phosphate concentrating organisms and their shell fragments removed. After sieving the sample, the palaeosalinity was determined on the 4-9Ø fraction. Salinity values for two independent samples (BR-M and DC-U) ranged from 1.7 to 2.7 parts per thousand. A centrifuged 9Ø clay fraction including carbonates was used for a second run.

Salinity values ranged from 19.8 to 20.1 parts per thousand indicating a possible concentration of inorganic phosphate in clay sized grains. Finally, a HCl-treated sample of 9Ø clays proved to be the optimal preparation technique and the remaining 23 samples were run this way (Table 16). Values obtained were in the narrow range from 32.50 °/oo to 34.4 °/oo, indicating a normal marine environment (Table 16). Four subsamples from the BR section were used to test the precision of the sedimentary phosphate method. Although absolute abundances of the phosphate fractions varied, the Ca-phosphate ratios and salinity values are consistent and assure the reproducibility of the method.

Experimental Runs of Palaeosalinity Estimates
Using Different Size Fractions of Two Samples

Treatment	Sample	Size fraction	$Ca-PO_4$ Conc. (ppm)	$Fe-PO_4$ Conc. (ppm)	$\frac{Ca}{Ca+Fe}$	Salinity (%)
1	*BR-M	4 - 9Ø	.085	.473	.152	2.7
2	BR-M	9Ø	.247	.156	.612	19.8
3	**BR-M	9Ø	1.662	.011	.993	33.4
1	*DC-U	4 - 9Ø	.065	.507	.114	1.7
2	DC-U	9Ø	.718	.446	.617	20.1
3	**DC-U	9Ø	.735	.025	.967	32.5

* using 1/1 Fe^+ / Ca^+ aliquot ratios

** using 9/1 Fe^+ / Ca^+ aliquot ratios

Treatments:

1) centrifuged 4 - 9Ø fraction
2) centrifuged 9Ø fraction containing $CaCO_3$
3) centrifuged 9Ø fraction without $CaCO_3$

Results of Sedimentary Phosphate Method Replications

Sample BR-U

Run #	$CaPO_4$ Con. (ppm)	$FePO_4$ Conc. (ppm)	Amount Aliquot Fe^+/Ca^+ (ml)	$\frac{Ca}{Ca+Fe}$	Salinity (%)
1	.888	.012	9/1	.987	33.24
2	1.344	.026	9/1	.981	33.02
3	1.341	.027	9/1	.980	33.00
4	.954	.014	9/1	.986	33.20

Mean	($\bar{X}$)	33.12
Variance	(S^2)	0.0151
Standard Error of Mean	($S_{\bar{x}}$)	0.0614

EXPLANATION OF PLATE I*

Ectoprocts

Ramose Type 1

upper left; specimen encrusting *Petrocranis* cf. *modesta* (surface P-6-3, specimen number 32).
left middle; surface BR-3-1, specimen number 29.
left bottom; specimen encrusting *Myalina* (surface P-6-2, specimen numbers 11 and 12).
upper right; washed residue P-6-2.
right middle; washed residue DC-6-2.
bottom right; surface DC-6-4, specimen number 10.

Ramose Type 2

top; washed residue BR-3-3.
left; surface P-6-2, specimen number 17.
right; surface DC-6-4, specimen number 15.

Ramose Type 3

left; surface P-6-3, specimen number 27.
right; washed residue BR-3-3.

Ramose Type 4

surface DC-6-5, specimen number 9.

Fenestrate Type 1

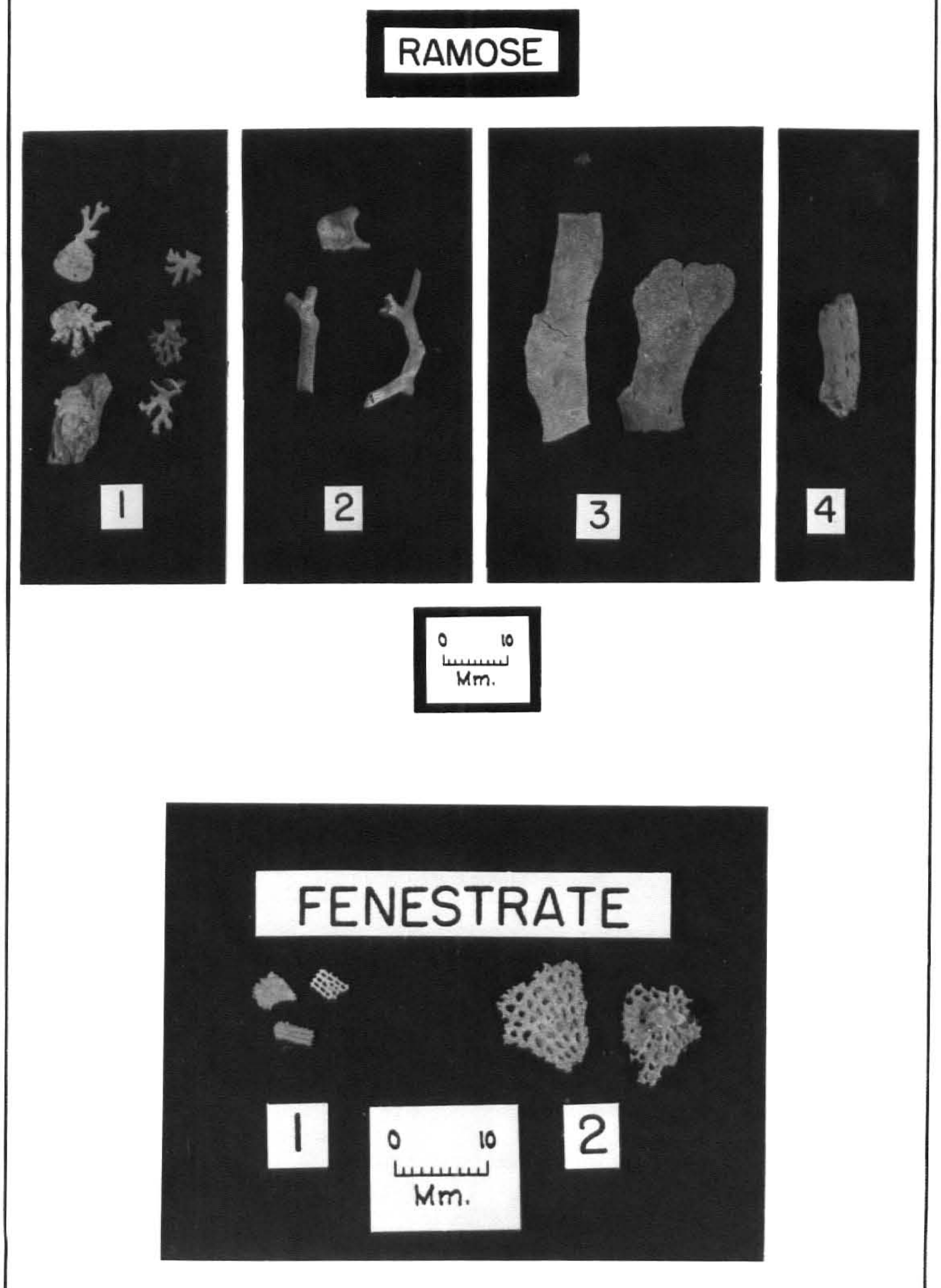
upper left; surface DC-6-4, specimen number 36.
upper right; surface DC-6-2, specimen number 13.
lower; washed residue DC-6-2.

Fenestrate Type 2

left; surface P-6-3, specimen number 2.
right; surface BR-3-3, specimen number 29.

*Plate I and the description of Plate I are taken directly from Yarrow, 1974.

PLATE I



EXPLANATION OF PLATE II

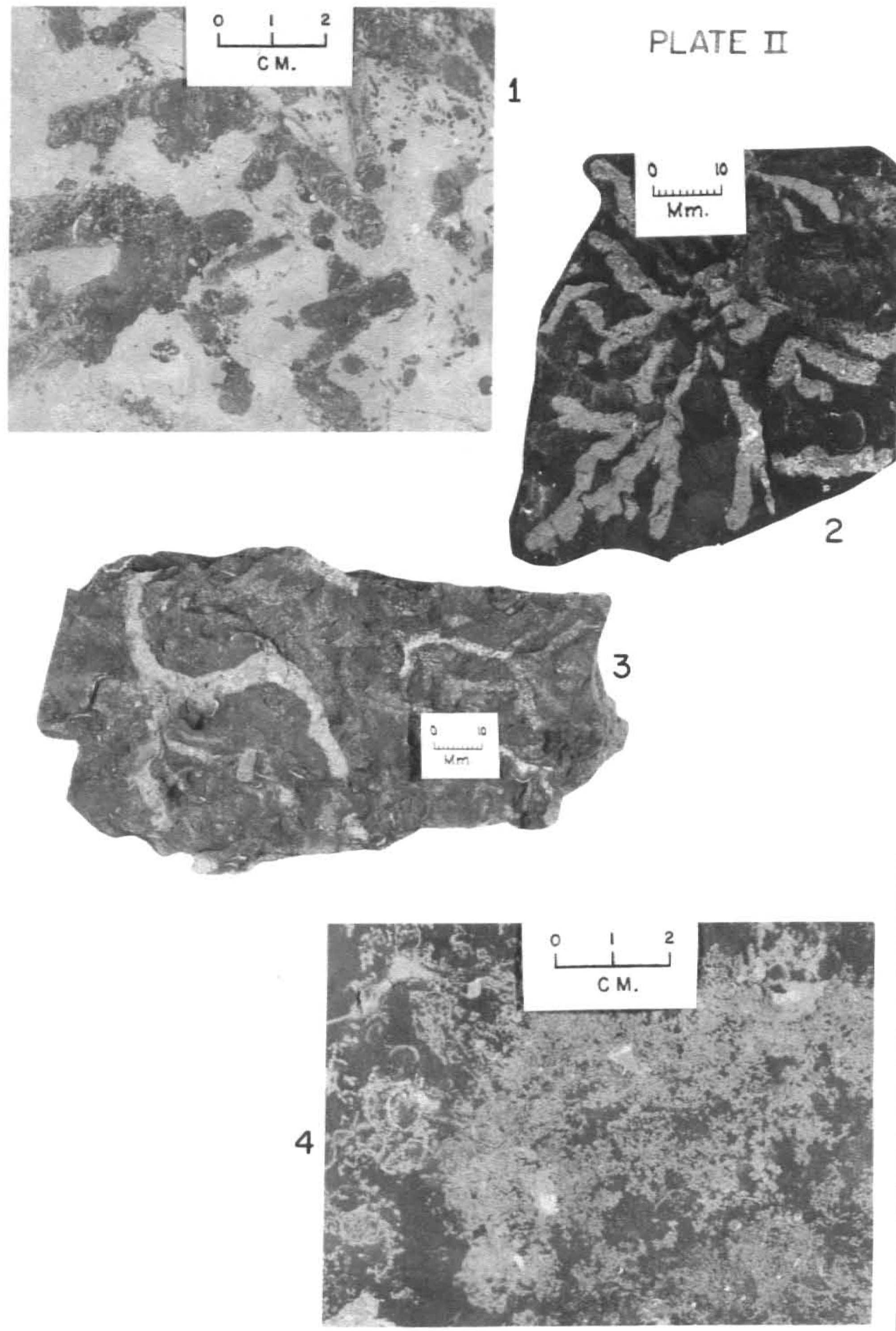
Fig. 1. Bedding surface W-L-2, horizontal burrows created by infaunal organisms.

2. Bedding surface P-T-1, branching horizontal burrows made by *Chondrites*.

3. Bedding surface P-T-1, sinuous horizontal burrow created by infaunal deposit feeder (*Chondrites?*).

4. Bedding surface BR-U-2, extensively burrowed bedding plane.

PLATE II



EXPLANATION OF PLATE III

Fig. 1. Thin section P-L-1, x 10, vertical cut through Isogramma cf. renfrarum; shell fragment showing prismatic wall structure, punctae filled with micritic matrix.

2. Thin section P-L-1, x 10, vertical cut through Isogramma cf. renfrarum, shell fragment showing encrustations of a algal foraminiferid consortium Osagic.

3. Thin section W-L-1 x 10, horizontal cut through Isogramma cf. renfrarum showing dark matrix filled irregular punctae.

4. Triticites sp. and Pseudofusulina from bed BR-M.

5. Thin section DC-L-2, x 10, top left, transverse section of Triticites sp., lower right, axial section of Triticites sp.

6. Thin section P-U-2, x 10, longitudinal section of opthalimid foraminiferid embedded in recrystallized biomicrosparite.

7. Thin section BR-L-3, x 10, unidentified object (foraminifera?) encrusted by a algal foraminiferid consortium Osagic.

8. Thin section W-L-2 x 10, ectoproct fragment filled with glauconite.

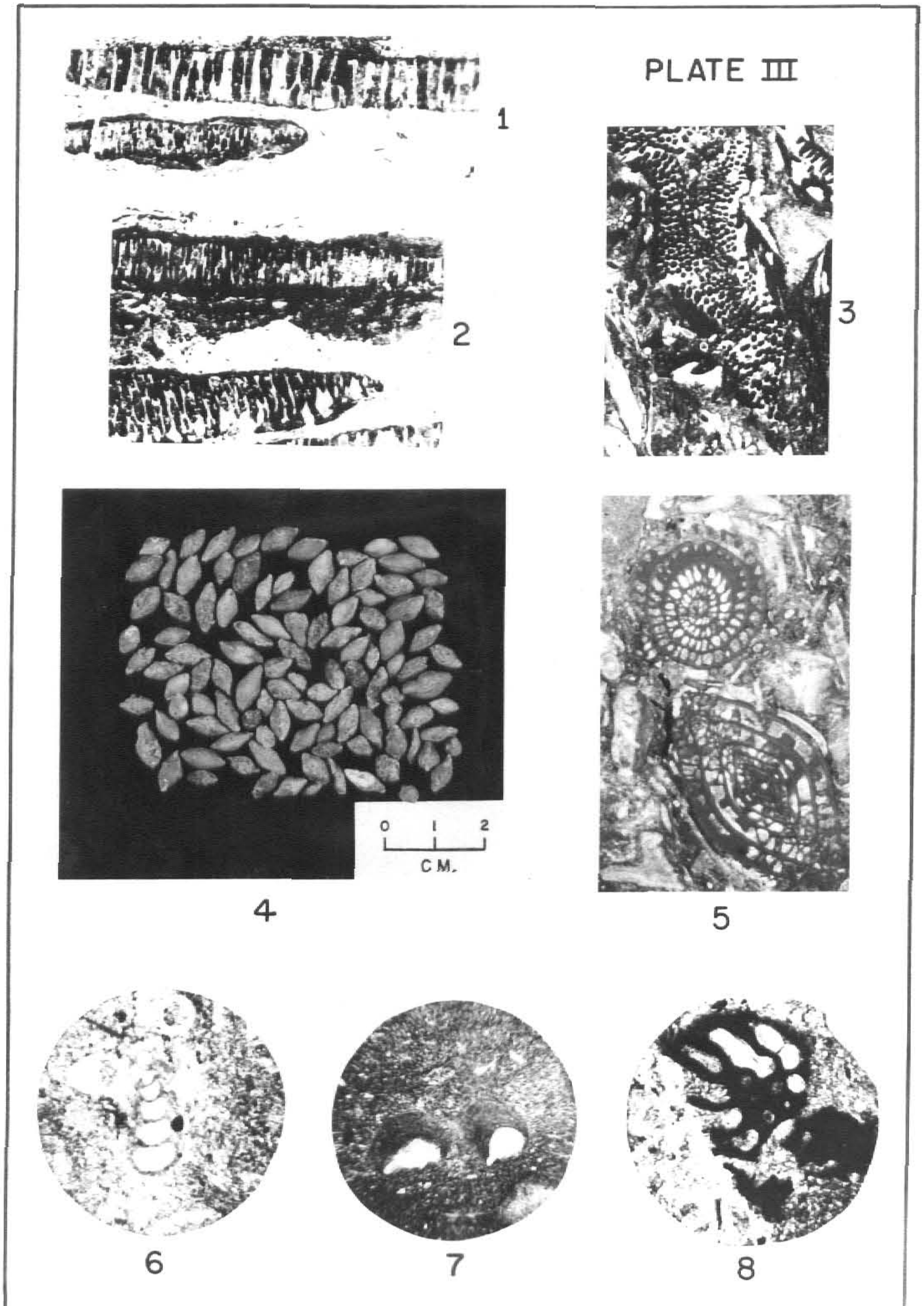


PLATE III

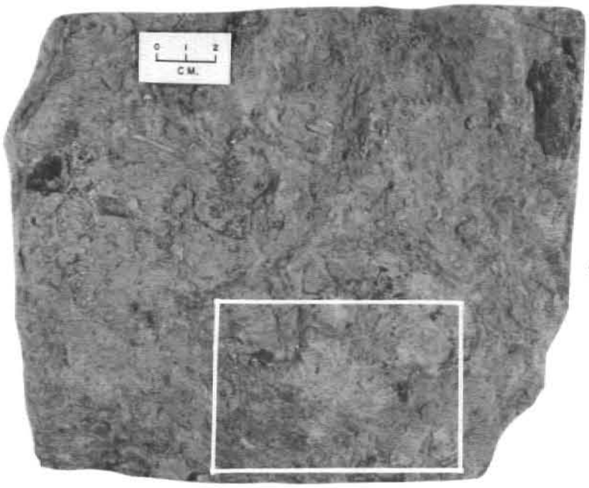
EXPLANATION OF PLATE IV

Fig. 1. Bedding plant P-L-8 showing accumulation of fragmented Isogramma cf. renfrarum shells.

2. Bedding plant P-L-8, enlarged view showing semielliptical outline of large Isogramma fragment with concentric ornamentation.

3. Bedding plant BR-U-3 showing accumulated pedicle and brachial valves of Crurithyris cf. expansa.

PLATE IV



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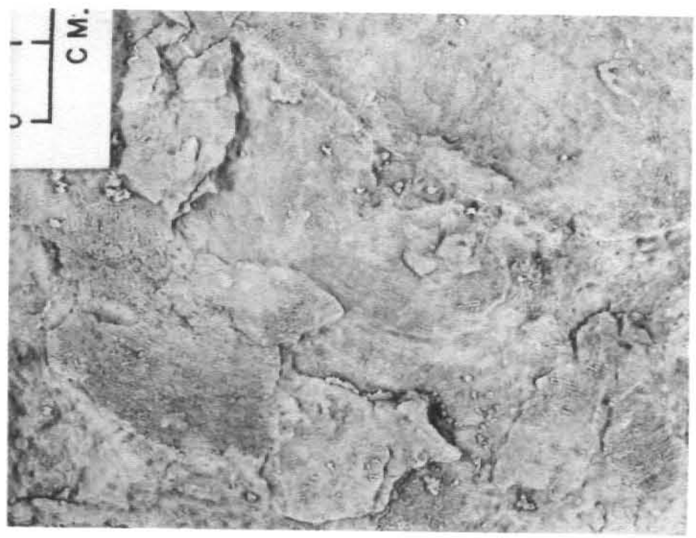

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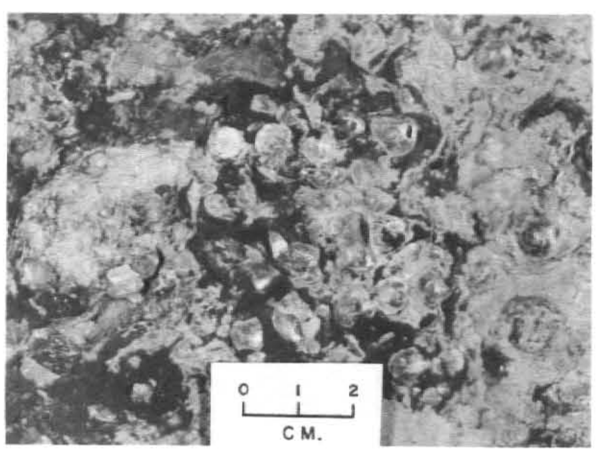

3

PALAEOBIOLOGY AND CARBONATE PETROLOGY OF PART OF THE HUGHES CREEK SHALE IN NORTHEASTERN KANSAS

by

WINFRIED SCHMIDT

Vordiplom, Justus-Liebig Universität
Giessen, 1972

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Geology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1974

ABSTRACT

A comprehensive palaeoecology study should involve an integration of nearly every aspect of geology from structural features and basement relief to geochemistry and carbonate petrology. Within this framework a limestone-mudstone sequence from part of the Hughes Creek Shale Member of the Foraker Limestone from five localities was undertaken to: 1) identify and determine the ecological significance of the fossil record, 2) study the petrology and determine the depositional environments, 3) determine lateral and vertical differences in the benthic fossil assemblages, and 4) determine the effects of the Nemaha Anticline on the biota and petrology.

Using fossil assemblages from 92 horizontal surfaces, diversity, equitability and Q-mode cluster analysis of beds within one locality and of beds between localities suggest no significant relationship between the structural features of the Nemaha Anticline and the fossil assemblages encountered. Using the total interval, localities on opposite sides of the Nemaha Anticline show greatest similarity, possibly indicating some local effect of the Zeandale Dome on the fossil assemblages. Dominance of the brachiopod *Crurithyris*, a high level suspension feeder, indicated no difference between localities in all beds concerning ecological parameters. Concentrations of fragmented *Isogramma* shells in the lower part of the lower limestone and an abundant fusulinid zone in the middle limestone bed occur at all localities.

Insoluble residues, weight percent silt and clay decrease from the lower to the top limestone bed, whereas weight percent organic carbon increases upward. Palaeosalinity estimations are nearly constant with values $\pm$ 33.5 0/00. Illite is the dominating clay mineral with chlorite ranking second.

The limestones represent uniformly recrystallized biomicrites or biomicrosparites ranging from calcarenites to medium calcilutites. The investigated part of the Hughes Creek Shale is an incomplete cyclothem with a diverse brachiopod dominated assemblage, deposited in a shallow, well lit marine environment.