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ABSTRACT

PALEOECOLOGY OF PALYNOMORPHS IN THE MANCOS SHALE, SOUTHWESTERN COLORADO

by Gary G. Thompson

Two stratigraphic sections were measured and sampled for palynomorphs in the Upper Cretaceous marine Mancos Shale in southwestern Colorado. The two sections are located about 30 miles apart on a line that is normal to the trend of the Upper Cretaceous shoreline in this area. The position of the shoreline relative to all levels in the two sections was determined from published detailed stratigraphic studies in the area.

A graphic correlation technique was used to correlate between the two sections. This correlation was based on the lowest or highest stratigraphic occurrences of 25 selected pollen and spores.

Distance offshore is reflected in the fossil assemblages when the data from counts are subjected to factor analysis. By combining the results of factor analysis of 22 selected microplankton taxa in 72 samples with results of the correlation a picture is revealed of transgressing and regressing microplankton assemblages within the essentially homogeneous marine shale environment. These transgressions and regressions of the assemblages parallel the regressions and transgressions of the shoreline farther to the south.

The diversity of microplankton tends to vary directly with distance offshore while the diversity of pollen and spores tends to vary inversely with distance offshore.

Relative frequencies and numbers per gram of rock of some palynomorph taxa tend to reflect distance from shore. Among these the

best correlations exist for the following categories. Classopollis spp.,
Tricolpopollenites cf. T. micromunus, T. sp. 7, Cymatiosphaera spp.,
Form C. sp. 1, acritarchs with processes, chorate dinoflagellate cysts,
microplankton without processes, and cuticle fragments.

PALEOECOLOGY OF PALYNOMORPHS
IN THE MANCOS SHALE, SOUTHWESTERN COLORADO

By

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* * * * *

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INTRODUCTION

Purpose

The purpose of this investigation is to determine if fossil palynomorph species or fossil palynomorph assemblages reflect in any way their sedimentary environment as it can be interpreted from the lithology and facies relationships of the rocks that contain them. This is another approach to the classic problem of separating those variations in fossil assemblages through time that are due to reversible environmental change (facies change) from those that are due to irreversible changes such as evolution. Rather than seeking out only irreversible evolutionary or phytogeographical changes in the palynomorph assemblages that can be used for time correlation, the reversible environmentally-controlled changes in assemblages will be sought out in an effort to determine if some palynomorphs or palynomorph groups might be restricted in such a way that they could be employed as "environmental indicators." In addition, some insight into the autecology of some fossil palynomorphs might be gained.

Scope

The Upper Cretaceous rocks of the Western Interior of the United States contain a remarkable record of the transgressions and regressions of the shoreline of an epicontinental sea. This sea at times connected the Arctic Ocean with the Gulf of Mexico. At other times it was limited to an embayment of the Gulf and/or the Arctic Ocean (Reeside, 1957). As a result of the variation in areal extent and the influence of northern or southern waters, fluctuations occurred in temperature, salinity, water depth, turbidity and other parameters of the marine environment. Consequently these changes and the tectonic

and/or eustatic movements related to them are reflected in the sediments that were laid down at that time - reflected not only in the inorganic detritus but in the organic remains as well.

Over the years many stratigraphic sections have been measured throughout the Cretaceous of the Western Interior. Utilizing the abundant fossil mollusks for correlation, a detailed record has been compiled of the events of onlap and offlap of the Cretaceous shoreline (Weimer, 1960; Reeside, 1957; Young, 1955, 1957, 1960; and others).

Because of this remarkable record of events, the site of this study was chosen in this area and in these rocks. Two stratigraphic sections were measured in southwestern Colorado through Upper Cretaceous marine shales of the Mancos Shale (figs. 1 and 2). One section, here called the Point Lookout section, was measured at Point Lookout in Mesa Verde National Park, and is located in sections 26, 29, and 31, T. 36 N., and sections 5 and 6, T. 35 N., R. 14 W., Montezuma County, Colorado. The other section, here called the Ute Reservation section, is located within the boundaries of the Ute Indian Reservation in sections 9, 10, 11, 12, 13, 16, T. 32 N., R. 18 W., sections 9, 16, 20, 21, T. 32 N., R. 19 W., and section 18, T. 32 N., R. 17 W., Montezuma County, Colorado. These sections are approximately thirty miles apart and are on a line that is normal to the shoreline trend during the Late Cretaceous. The rock record contained in the two sections includes two major shoreline transgressions-regressions within which five minor transgressions-regressions are contained.

Samples for palynomorphs were taken at closely spaced intervals throughout both sections so that the palynomorph assemblages would be sampled through the entire time interval at various stages of shoreline transgression or regression. Ideally, the study of many more such

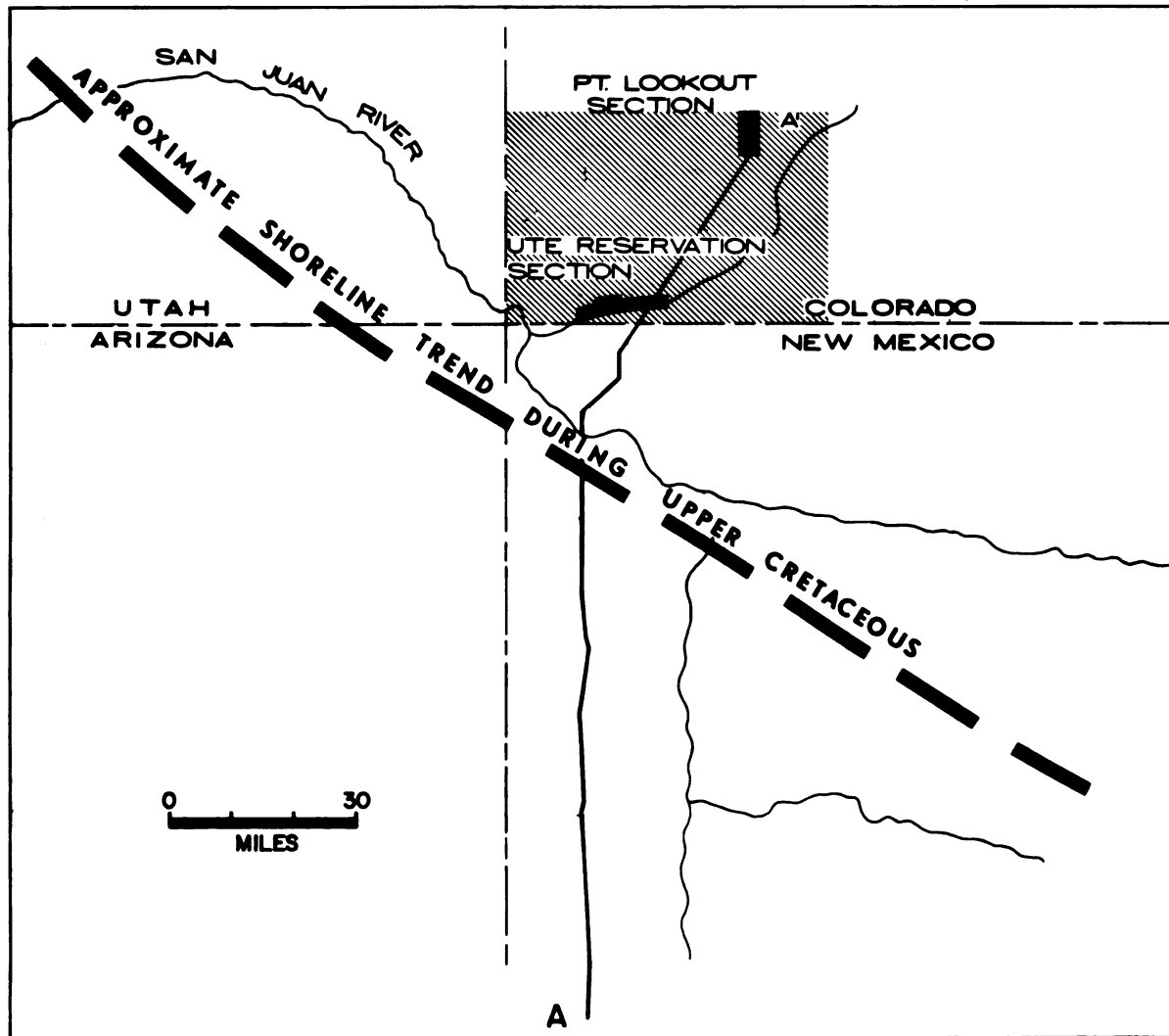


FIGURE 1.--Map of Four-corners Area showing location of study area (cross hatching), location of measured and sampled stratigraphic sections and line of section A-A' shown in figure 7.

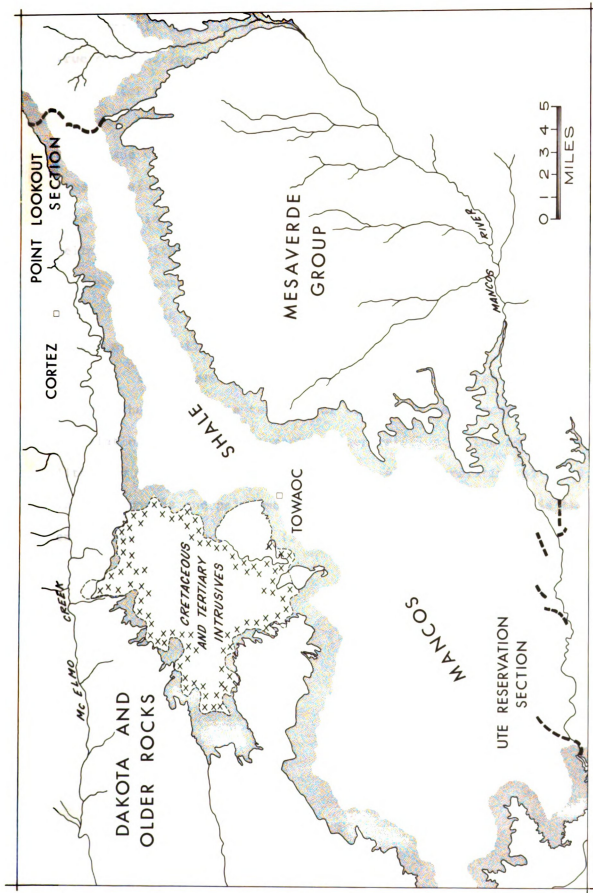


FIGURE 2.--Map of study area showing location of measured stratigraphic sections and the outcrop of the Mancos Shale. Line of section is indicated by dashed lines. (In part after Irwin, 1966, U.S. Geol. Survey Bull. 1576-G, pl. 1; and Wanek, 1959, U.S. Geol. Survey Bull. 1072-M, pl. 49).

stratigraphic sections would be desirable in order to determine the true distribution of the palynomorphs, but reasonable time limitations allowed for the study of only two sections.

The inferred evolutionary or phytogeographical changes that took place during the Upper Cretaceous in this area are utilized for time correlation. Ranges of selected land-derived palynomorphs are used to achieve relatively fine time control. This is essential in delimiting within the rocks the "time surfaces" across which variations in the environment may be expected.

Basic to all of these interpretations is a consistent taxonomy of the microfossils.

It follows then that there are four essential parts of this study. These are (1) a taxonomy of the fossil palynomorphs, (2) a time correlation, (3) an environmental interpretation of the rocks based on lithology and facies relationships, and (4) a correlation of the variations in palynomorphs and palynomorph assemblages with variations in the environments interpreted in (3).

I. METHODS

Field Methods

Because the rocks in the area of study are essentially horizontal, most of the two stratigraphic sections was measured using a hand level. In the upper part of the Ute Reservation section dips reached 10° and the use of the Brunton compass was required. Small measurements were made by sighting over a graduated mattock handle or over a tape measure. A composite sample was collected every $16 \frac{1}{2}$ to $17 \frac{1}{4}$ feet (three eye-heights using the hand level) and at every marked change in lithology. To sample shale a trench was made that was long enough to expose five feet of vertical section (less where the exposure was poor) and deep enough, where possible, to reach mechanically-unweathered rock. From this trench were picked about two pounds of shale pieces representing all minor variations in lithology over the five-foot interval.

The limestones in both sections are generally less than two feet thick. Samples of these limestones consist of chips that were taken a few inches apart in a vertical line across the bed. When an interval containing concretions was encountered, the nearest concretion was sampled by breaking off a few chips from freshly exposed surfaces.

Shaly partings in sandstones were sampled over their entire thickness. No well-sorted, quartzitic sandstones were sampled.

The fresh samples were placed in cloth sample bags. Later these bags were wrapped in several thicknesses of newsprint for their transport.

Maceration Procedures

In the laboratory a total of 234 samples were selected from the suite of samples brought from the field. These samples were selected at approximately a fifty-foot interval through both sections and at important lithologic changes. Each sample was subjected to the following treatment:

1. Crush the whole sample into pieces about one-fourth inch in largest dimension (avoid powdering). Use a large mortar and pestle and a pounding motion.
2. Mix the crushed sample thoroughly by placing it in a cone-shaped pile on a clean surface. Then scoop repeatedly with a spatula from the bottom of the pile and dump at the top of the pile.
3. Remove the desired amount (10 grams of limestone, 5 grams of shale) for maceration by scooping from the flank of the pile.
4. Place the sample in a 250 ml. plastic beaker and cover the sample to a depth of three-fourths inch with 10% hydrochloric acid and replenish the concentration, if needed, until effervescence ceases.
5. Wash the residue three times with distilled water.
6. Slowly add hydrofluoric acid to the residue, agitating constantly, until the residue is covered by about one inch of liquid. Allow the beaker to sit 24 hours, agitating frequently for the first one-half hour, then occasionally during the remaining period.
7. Wash the residue three times in distilled water.
8. Transfer the residue to a 90 ml. glass centrifuge tube.
9. Add 25 ml. Schulze's solution (one part concentrated nitric acid to seven parts saturated potassium chlorate solution) and place the tube in a hot water bath for 15 minutes agitating frequently.
10. Wash the residue three times in distilled water.

11. Add 25 ml. 5% potassium hydroxide solution to the residue and place the tube in a hot water bath for five minutes, agitating frequently.
12. Wash the residue in distilled water three times (or as many times as necessary to obtain a colorless supernatant liquid).
13. Transfer the residue to tapered 40 ml. glass centrifuge tube and add 13 ml. zinc chloride solution (sp. gr. 1.80) to the residue, mixing it thoroughly.
14. Place tube in a centrifuge (International Centrifuge Model K) and centrifuge at 1600 rpm for 15 minutes.
15. Pour the suspended residue and supernatant into a 90 ml. glass centrifuge tube and fill the tube with distilled water, mixing thoroughly.
16. Place the tube in the centrifuge and centrifuge for seven minutes at 1300 rpm.
17. Wash the residue three times with distilled water.
18. Transfer the residue to a 15 ml. tapered glass centrifuge tube.
19. Add five drops of 2% alcohol solution of Safranin "O" and then two drops of 10% ammonium hydroxide solution to the residue, allow to stand for 1 1/2 hours with occasional agitation.
20. Wash residue with distilled water.
21. Transfer the residue to a 2 dram vial and add 1 ml. of Cellosize solution containing 2% phenol.

Mounting Technique

Of the 234 samples that were macerated, the residues of 157 were mounted on slides. These 157 residues were selected as representative of the two sections as time became a factor in restricting the number of samples that could be studied. These residues were mounted according to the following procedure.

1. Add distilled water to the residue in the vial until the density of the suspended residue is suitable for one drop per slide.
2. Extract the suspended residue from the vial into a Pasteur capillary pipette equipped with a 1/4 oz. rubber bulb and count the number of drops of suspended residue as they fall with a regular frequency as the pipette is emptied back into the vial. Record the number of drops.
3. Prepare the microscope slides by cleaning the slide and cover slip with a dust-free cloth and then temporarily anchoring the cover slip to the slide with a fraction of a drop of distilled water.
4. Place two drops of a Cellosize (hydroxyethyl cellulose) solution on the cover slip (see Jeffords and Jones, 1959).
5. Thoroughly mix the suspended residue in the vial by a pumping action with the pipette and bulb. When a uniform suspension is obtained, quickly take up about 1/3 of a pipette of the suspension and transfer one drop to the Cellosize solution on the cover slip letting the drop free-fall from the pipette. Repeat this step for each drop that is transferred. Record the number of drops that are placed on the slide.
6. Rinse the pipette into the vial with a few mls. of distilled water.
7. Using a clean flat toothpick thoroughly mix the residue and the Cellosize solution on the cover slip and strew it evenly over the cover slip to within 1/2 mm. of the edge.
8. Cover the slide and cover slip and allow the water to evaporate from the residue leaving a hard film on the cover slip.
9. Remove the cover slip from the slide and wipe the slide dry with a dust-free cloth.

10. Place three drops of a 70% toluene solution of canada balsam on the center of the slide.
11. Place the cover slip film-side down onto the canada balsam solution and center the cover slip on the slide. Move any bubbles to the edge of the cover slip by pressing on it with a toothpick.
12. Allow the slides to dry for 24 hours in a 60° C. oven before attempting to examine them with oil-immersion objectives.

Of these 157 residues that were mounted, 72 of them were used in the study. This smaller number of samples resulted from discarding those samples with low yields or poor preservation of palynomorphs and from time limitations for examining each sample critically. Few, if any, samples could be considered totally barren.

Examination Procedure

Before any counts were made, preliminary examinations made possible the differentiation of most of the taxa of palynomorphs which are present in the samples.

A sum of 500 palynomorphs was counted from each sample. This sum included all palynomorphs that were preserved well enough to permit identification to about the genus level. Because Michrystridium spp. are extremely abundant so as to "dilute" the frequencies of other palynomorphs in some samples and are rare in others, the taxon was excluded from the sum. Other categories that were counted in addition to those within the sum of 500 reflect various stages of corrosion. These categories are: corroded trilete spores, corroded monolete spores, corroded bisaccate pollen, corroded tricolpate pollen, corroded triporate pollen, corroded monocolpate pollen, corroded pollen, corroded pollen or spore and corroded microplankton.

The sum of 500 was selected after first plotting a curve of the number of species encountered against the number of specimens identified in a sample, preferably one with a large number of taxa. These curves are similar to species-area curves used in terrestrial plant ecology to determine number and size of sample quadrats. Such curves for two samples are shown in figure 3. The dashed line on the graphs represents the probable shape of the curve if a truly random distribution of the residue were on the slide. The dashed lines were constructed free-hand by arbitrarily removing the major displacements in the line of points. Differential sorting of particle sizes on the cover slip appears to be the main cause of these displacements in the curve. In these samples the tiny specimens of Michrystridium spp. were counted. They are abundant and tend to be predominant near the edges of the cover slip. Whether this is due to movement of larger particles to the center of the cover clip or of smaller particles to the edges or both has not been demonstrated.

A sum that lies to the right of the sharp change in slope on the curve (represented by the points) would tend to include most of the taxa in the sample. Five hundred lies well to the right of the point.

Another curve was also referred to before selecting the sum. This curve is from a set of curves that was constructed by Rittenhouse (1940) to determine the proper number of heavy-mineral grains to be counted. These curves show the relationship between the probable error in percentage calculations and the number of grains that are counted. As shown in these graphs the calculation of percentages based on a sum of 500 would result in a probable error of $\pm 0.7\%$ for a calculated 5.0%, $\pm 1.5\%$ for a calculated 50.0% and $\pm 0.9\%$ for a calculated 90.0%.

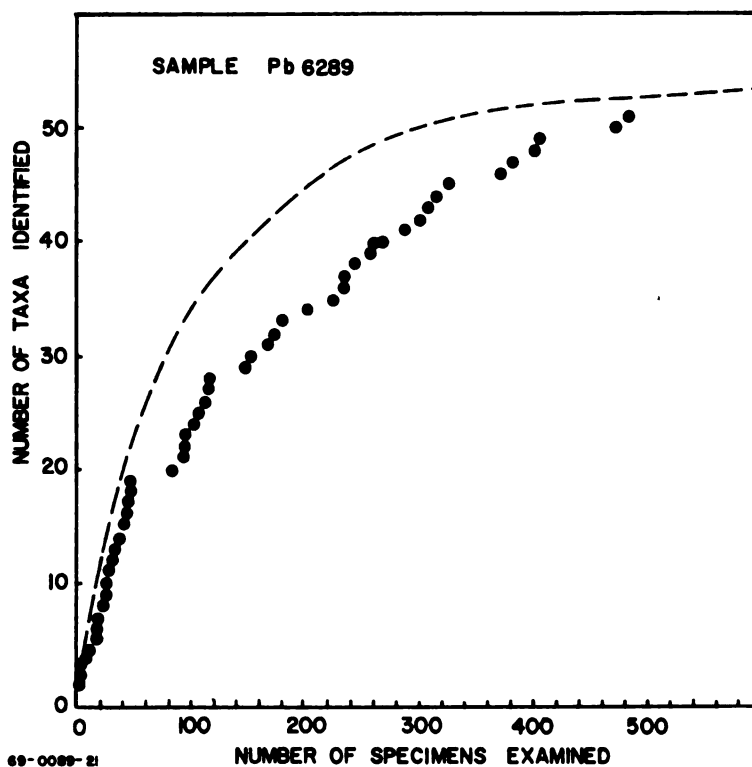
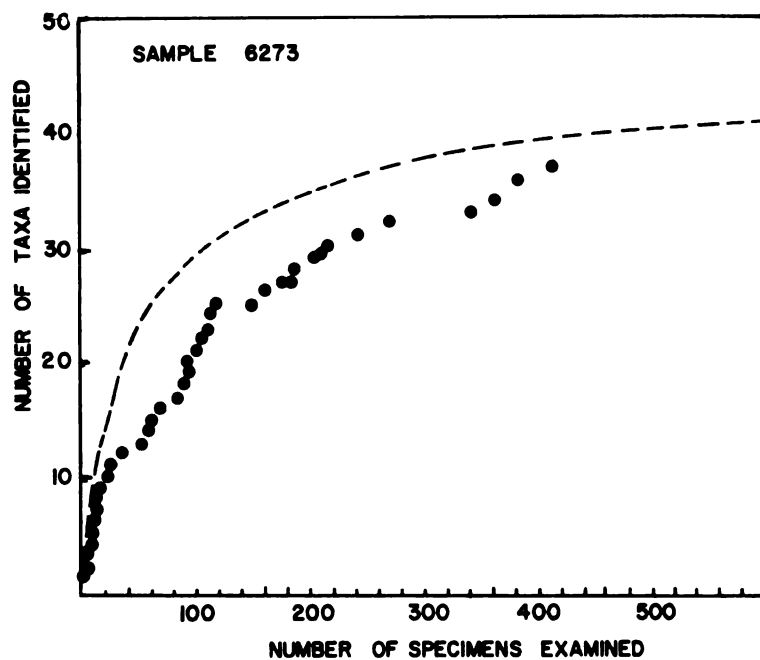


FIGURE 3.--Curves used in selecting the sum for palynomorph counts.

This indicates the reliability of interpretations made using low percentages of palynomorphs. For the purposes of this study the precision does not increase appreciably above sums of 500.

In counting the 500 specimens an intuitively prescribed pattern of traversing the cover slip was devised in an attempt to produce a random sample. The order of counting and position of the traverses was set. At least five traverses were made and no more than 100 specimens were counted in any one traverse. If 100 specimens were encountered before completing a traverse, the position of the one-hundredth specimen was recorded and the next traverse in the pattern was begun. Counting was carried out under a magnification of 800X. When 500 well-preserved specimens had been counted the fraction of the total area of the cover slip that was examined was recorded. Knowing (1) the mass of rock that was macerated, (2) the number of drops of suspended residue in the vial at the time the slide was prepared and (3) the number of drops of suspended residue that were placed on the cover slip; an estimate of the number of well-preserved palynomorphs per gram of rock can be calculated using the following formula (see also Traverse and Ginsburg, 1966):

$$\text{Number per gram} = 500 \frac{\text{Dr} \times \text{T}}{\text{G} \times \text{Dc} \times \text{Tc}}$$

where G = grams of rock macerated

Dr = number of drops of residue in vial

Dc = number of drops of residue placed on the
cover slip

T = number of traverses necessary to cover the
whole cover slip

Tc = number of traverses counted to reach sum
of 500

The total palynomorphs (including corroded categories) per gram was also calculated by substituting a larger sum for 500 in the formula.

In addition the slides were scanned until at least 2000 identifiable specimens had been examined from each sample. This established somewhat of a standard for determining first and last occurrences (an "occurrence" being at least one in 2000 or .05%). Statistically, at the .99 confidence level an occurrence would be about 0.2% or one in 500.

Photographic Techniques

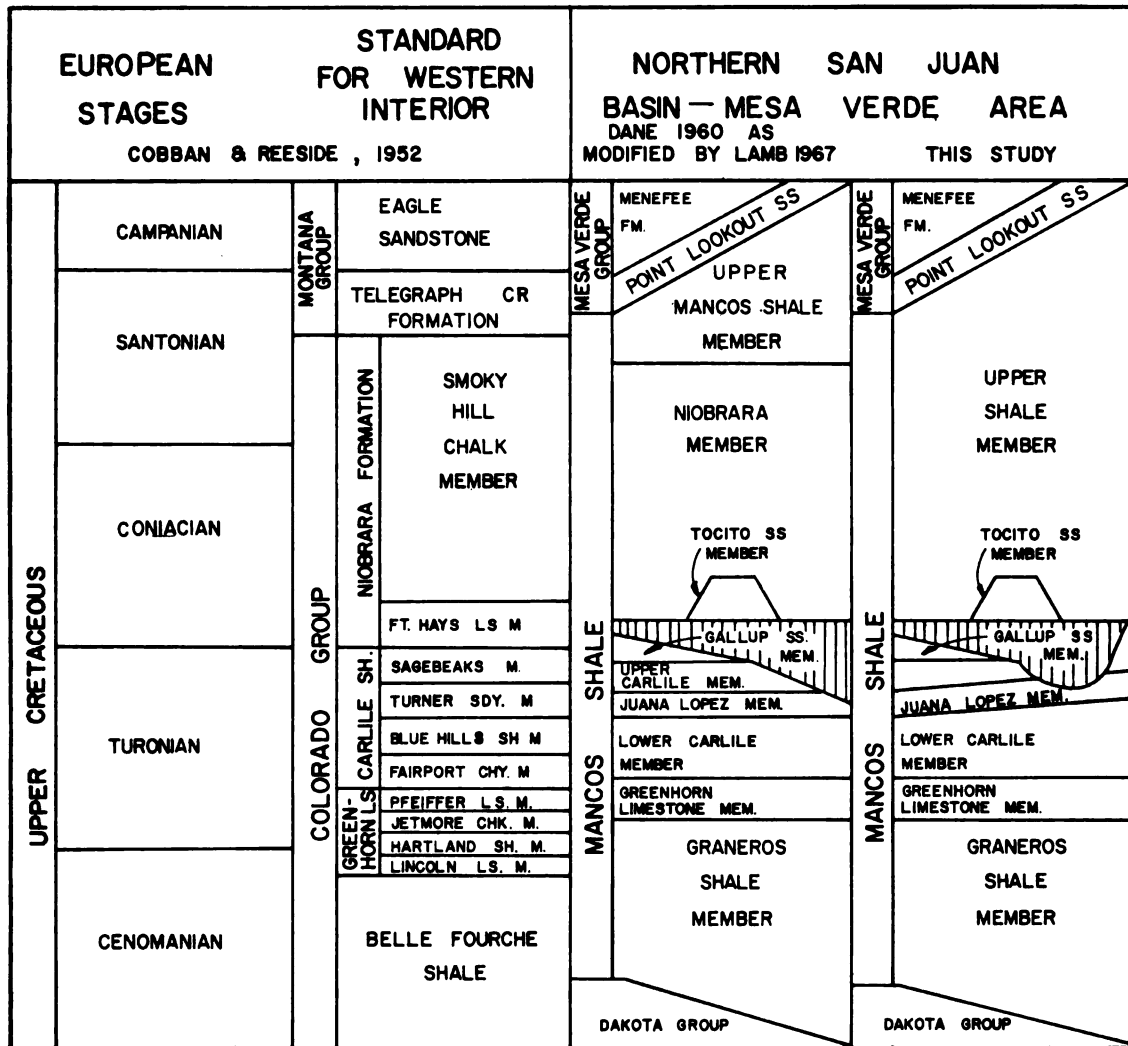
Photographs of palynomorphs were taken with a Leitz Orthomat automatic camera attached to a Leitz Ortholux microscope or a Zeiss GFL Standard microscope. Adox KB-14 film was used and developed with Kodak Microdol developer. The prints were made on Kodabromide F-2, F-3, and F-4 and Adox bromide F-5 papers. The prints were developed using Kodak D-76 developed. The original magnification of the palynomorphs was 1000X or 540X.

II. STRATIGRAPHY

Nomenclature

The Mancos Shale was named by Cross (1899) for a sandy gray shale about 2000 feet thick exposed in the Mancos River Valley in southwestern Colorado. Since that time lithologic units have been separated from this mass of shale and the Upper Cretaceous rock units east of the Rocky Mountains have been extended into the Mancos area. There is some controversy about the rock units that make up the old Mancos Shale (Dane, Kauffman, and Cobban, 1968, p.16) and the nomenclature as used here is tentative. The names and age relationship used in this study are shown in figure 4. This follows the nomenclature of Dane (1960) except for the use here of the term "Upper Shale Member" of the Mancos to include Dane's Upper Carlile Member, Niobrara Shale Member and Upper Shale Member. This term is used here because it is felt that in the two sections measured in this study the units referred by Dane and Lamb (1968) to the Niobrara and Carlile are indistinguishable from the Upper Mancos Shale Member.

The name "Tocito Sandstone" of Lamb (1968) is not applied in the two sections studied here. No sandstones were found just above the Juana Lopez in either section. The Tocito sandstone has a patchy distribution and extends across the San Juan Basin to the south-east. It is considered to be a transgressive sandstone laid down on a Carlile-Niobrara unconformity (Dane, 1960; Lamb, 1968). Lamb traces this unconformity into the vicinity of the Ute Reservation section but is unsure of its position and magnitude in the Point Lookout section. As interpreted in this study the unconformity is considered to be absent or to be represented by only a small diastem at Point Lookout. This interval and the problems it presents in environmental interpretations will be discussed later.



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FIGURE 4.--Correlation chart showing time relationships of the rocks in the study area with the European type section and the Western Interior standard section.

Description of the Rock Units in the Measured Stratigraphic Sections

A detailed description of both stratigraphic sections is given in Appendix I. Stratigraphic Columns of the two sections are presented in figure 5.

Dakota Group

Naturita Formation - The Naturita Formation of the Dakota Group (Young, 1960) consists of massive to thin-bedded sandstones interbedded with gray shales and coals in the vicinity of the measured sections. It is overlain by the clearly-demarcated sandy shales of the Graneros Shale. Only the upper few feet of Dakota rocks were measured and sampled in this study.

Mancos Shale

Graneros Shale Member - In both sections the Graneros Shale Member consists of sandy shale which immediately overlies the Dakota and becomes less sandy upwards. At Point Lookout the member is 104 feet thick and all but the lower 45 feet is calcareous. In the Ute Reservation section the entire unit, about 65 feet thick, is calcareous. The lower non-calcareous part of the formation at Point Lookout may be older than the base of the Graneros in the Ute Reservation section. This is indicated by the position of lowest occurrences of three palynomorphs at lower relative positions in the Ute Reservation section than in the Point Lookout section. Numerous thin bentonites, large limestone concretions, and thin, light to medium-gray, lenticular limestones occur in the upper part of the Graneros Shale Member in both sections.

Greenhorn Limestone Member - The Greenhorn Limestone Member consists of fine-grained, gray limestones one inch to one foot thick that are interbedded with calcareous gray shale. The thickest limestones occur near the top of the unit. The Greenhorn is 35 feet thick in the Ute Reservation section and 20 feet thick at Point Lookout. It is gradational with the

Graneros Shale Member below and the Lower Carlile Member above. Gryphaea newberryi is abundant in the lower one-half of the Member.

Lower Carlile Member - The Lower Carlile Member consists of about 300 feet of gray and olive-gray shale in both sections. Widely-spaced thin limestones and large limestone concretions occur in the upper 250 feet. The shale is calcareous only in the lower 50 feet. At the base is a two-inch thick calcarenite containing animal trails.

Juana Lopez Member - The Juana Lopez Member is characterized by thin, hard calcarenites one inch to two feet thick that weather brownish-red, contain abundant fossils and have a petroliferous odor. Although this unit is characterized by these calcarenites it consists mainly of gray shale between the calcarenites (Dane, et al, 1966). The interval here assigned to the Juana Lopez is 106 feet thick in the Ute Reservation section and 64 feet thick at Point Lookout. It is gradational with the rocks above and below.

Upper Shale Member - The term "Upper Shale Member" is used here to include all of the Mancos Shale above the Juana Lopez Member. The Upper Carlile Member, the Niobrara Shale Member and the Upper Mancos Shale Member of Dane (1960) and Lamb (1967) are included in this unit. It consists of gray and olive-gray calcareous and non-calcareous shales interbedded with widely-spaced lenticular limestones and large limestone concretions. This member is about 1550 feet thick at Point Lookout and about 1100 feet thick in the Ute Reservation section. The upper part is interbedded with the quartz sandstones of the overlying Point Lookout Sandstone. Below, it has a gradational contact with the Juana Lopez Member.

Mesaverde Group

Point Lookout Sandstone - The Point Lookout Sandstone intertongues with the upper part of the Mancos Shale. The contact between the two forma-

tions is placed just below the lowest massive sandstone above which sandstone predominates over the interbedded shale. Most of the Point Lookout is a massive cliff-forming sandstone with occasional very-thin shale partings. The only samples from the Point Lookout that were examined were from shale partings near the contact of the formation with the Mancos.

Correlation of the Two Stratigraphic Sections

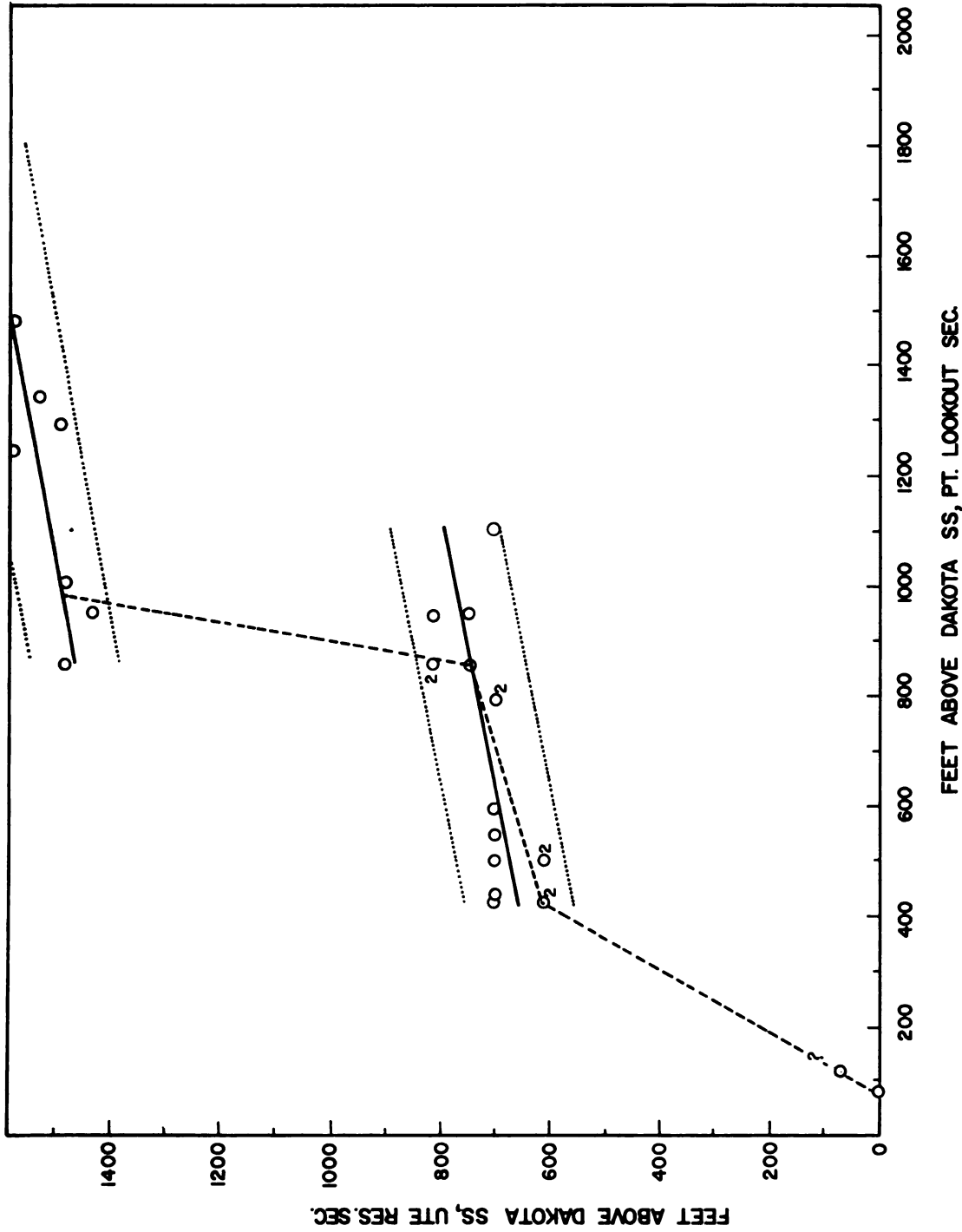
The graphic correlation method was used to correlate between the two stratigraphic sections in this study. This method was introduced by Shaw (1964) and is explained in detail by him. Briefly, the method consists of plotting the stratigraphically lowest and highest occurrences of taxa on a graph the abscissa of which is the stratigraphic thickness (in feet) of one section and the ordinate of which is that of a second stratigraphic section. For example, the lowest occurrence (bottom of local range) of a species might be at 500 feet above the base of the Point Lookout section while the lowest occurrence of the same species is at 200 feet above the base of the Ute Reservation section. This would be plotted as a point with coordinates (500,200). All true lowest and highest occurrences (tops and bottoms of local ranges) of the species or other taxa that are found in the two sections are plotted in the same manner. The line that is fitted to these points is called the "line of correlation" and is identical with the regression line used in statistics. Because this correlation is statistical one may correlate any level in one section with its assumed time-correlative level in another section and be able to give in feet the confidence limits of such a correlation.

The graph of correlations of the Point Lookout section and the Ute Reservation section is shown in figure 6. The correlation line is in two parts. The displacement in the line is interpreted to be the result

of a great difference between the sedimentation rates at the two sites. Because there is a certain error in such a purely statistical correlation (the solid line) the rock column must of course be compared with it. Slight adjustments in the graphic correlation of the sections were made after the positions of transgressions and regressions as reflected in the factor analysis (to be discussed below) were considered. The resulting correlation (shown by the dashed line in figure 6) is still within the 95% confidence limits of the original line of correlation as shown in figure 6. The correlation of the Point Lookout and Ute Reservation sections is shown in figure 5. This diagram incorporates the correlation line and the factor analysis interpretations. The correlation shown will be referred to later in the discussion of environmental interpretations.

The highest and lowest stratigraphic occurrences of 25 taxa were selected for the construction of the line of correlation. These taxa were selected because (1) they are morphologically distinctive and (2) their highest and/or lowest occurrence is well established within both sections. The species or other taxa used in this correlation are listed below.

Inaperturopollenites sp. 3
Classopollis sp. 1
Quadripollis krempii Drugg
Triatriopollenites cf. T. rurensis Pflug and Thompson
Tricolpopollenites sp. 4
T. sp. 8
?Trialapollis sp. 1
Retitricolpites cf. R. georgensis Brenner
Duplopollis cf. D. orthoteichus (Cookson and Pike) Krutzsch
large Tricolpites cf. T. explanata (Anderson) Drugg
Hexacolpate pollen grain
Triporopollenites cf. T. scabroporus Newman
T. cf. T. scabroporus Newman (with annulus)
T. cf. tectus Newman
T. sp. 1
Sporopollis laqueaeformis Weyland and Greifeld
Conclavipollis cf. C. wolfcreekensis Newman



95-00000-22

FIGURE 6.--Graph of correlation between the Point Lookout section and the Ute reservation section. A "2" next to a point indicates that two tops or a top and a bottom of range have those coordinates. The dotted lines represent the 95% confidence limits of the regression line (solid). The dashed line represents the final interpretation of the correlation based in part on factor analysis.

?Plicapollis silicatus Pflug
Labrapollis globosus Krutzsch
Proteacidites thalmanii Anderson, var. 1
P. thalmanii var. 2
P. thalmanii var. 4
Peromonolites peroreticulatus Brenner
?Extratroporopollenites spp.
Trudopollis cf. T. hemiparvus Pflug

Only land-derived pollen and spores were used in an effort to eliminate some of the error in the time correlation that is due to environmental influences. The distribution of a phytoplankton species is probably more directly controlled by the marine environment than are pollen and spores. The phytoplankton respond as living organisms to the marine environment whereas the pollen and spores respond merely as sedimentary particles. The lowest occurrences (bases) of each taxon in the list were utilized except Peromonolites peroreticulatus whose highest occurrence (top) was used.

III. SYSTEMATICS

General Statement

Identification of the palynomorphs was difficult because they were often poorly preserved. This has limited the number of taxa represented in this treatment for two reasons. (1) Specimens were simply too poorly preserved to be identified. (2) To be able to compare all samples with each other and to follow the changes in abundance of each taxon from sample to sample one must be able to recognize the same taxa in all the samples. Therefore the splitting was limited by the "weakest link" - the most poorly preserved sample.

A common damage to the palynomorphs was due to crystal growth within the central cavity and within the wall. Walls were often punctured in the six-sided outline that is attributable to the growth of pyrite crystals (Neves and Sullivan, 1964).

In the systematic treatment that follows, question marks and "cf." are used frequently. In some cases this reflects the poor preservation and the necessary lumping that was done to facilitate the sample comparisons for paleoecological interpretations. In other cases it reflects an inadequate knowledge of type specimens which results in unsure identifications.

Because this is not primarily a taxonomic study the treatment is brief.

Qualitative terminology for abundance is as follows: Rare, .05 to 1%; common, 1 to 2%; frequent, 2 to 10%; abundant, greater than 10%.

Systematic Descriptions

INCERTAE SEDIS

Group ACRITARCHA

Subgroup ACANTHOMORPHITAE Downie, Evitt and Sarjeant, 1963

Genus Baltisphaeridium Eisenack, 1937, emend.
Downie and Sarjeant, 1963

Baltisphaeridium cf. B. eypensis Wall, 1965
Pl. 1, Fig. 1

Occurrence: rare, in lowest 200 feet of both sections.

Reference specimen: slide Pb6273-4, 50.3 x 96.4

Baltisphaeridium cf. B. infalatum Wall, 1965
Pl. 1, Fig. 2

Occurrence: rare to abundant (sample Pb6222), in Lower Carlile Member,
Juana Lopez Member, lower part of upper Carlile Member.

Reference specimen: slide Pb6273-3, 46.7 x 93.1

Baltisphaeridium sp. 1
Pl. 1, Fig. 3

Diagnosis: Central body spherical, ellipsoidal to pear-shaped; psilate to granular (corroded?); processes numerous (ca. 50), tapering solid (?), with flat flared tips; diameter of central body 30 to 40 μ ; processes about 10 to 12 μ long.

Occurrence: rare to frequent, throughout section

Reference specimen: slide Pb638703, 39.5 x 93.2

Genus Michrystridium Deflandre, 1937, emend.
Downie and Sarjeant, 1963

Michrystridium spp.
Pl. 1, Figs. 4-7

Occurrence: rare to extremely abundant, throughout section

Reference specimens: slide Pb6273-1, 33.5 x 93.7, 33.2 x 99.0; slide Pb6368-9, 34.0 x 106.5.

Remarks: Numerous species of this genus were encountered in the Mancos. Because of the varied degree of preservation of these very small forms consistent identification could be made only to genus.

Form N sp. 1
Pl. 1, Fig. 10

Diagnosis: circular in outline; densely covered with fine hairs about 3 μ long; overall diameter about 20 μ .

Occurrence: rare, Lower Carlile Member in Ute Reservation section, Upper Shale Member of both sections.

Reference specimen: slide Pb6340-6, 125.8 x 30.5.

Form L sp. 1
Pl. 1, Fig. 9

Diagnosis: rounded pentagonal in outline; covered with hairs; overall diameter about 25 μ .

Occurrence: rare, in Lower Carlile Member and Upper Shale Member.

Reference specimen: slide Pb6357-7, 33.4 x 93.1.

Form X sp. 1
Pl. 1, Fig. 8

Diagnosis: oval in outline; "periphragm" held up by numerous crowded very short (1-2 μ) processes; overall diameter 15-20 μ .

Occurrence: rare to abundant, throughout sections except upper part of Upper Shale Member of Mancos.

Reference specimen: slide Pb6337-7, 34.1 x 100.4.

Form S sp. 1
Pl. 1, Fig. 12

Diagnosis: Spheres, 5 to 20 μ in diameter; densely covered with tiny spines less than one micron long, wall thin.

Occurrence: rare to frequent, throughout sections.

Reference specimen: slide Pb6351-7, 38.3 x 105.5.

Form S sp. 2
Pl. 1, Fig. 14

Diagnosis: Spheres, greater than 20 μ to about 35 μ in diameter; covered with tiny spines, but more widely spaced than in species 1, wall thick.

Occurrence: rare to common, in Upper Shale Member of the Mancos.

Reference specimen: slide Pb6282-6, 37.1 x 90.9.

Form T sp. 1
Pl. 1, Fig. 11

Diagnosis: spherical, about 30 to 40 μ ; granulate with very short hair-like extension on each granule giving the appearance of "terry cloth".

Occurrence: rare to common, throughout sections except for the upper part of the Upper Shale Member of the Mancos.

Reference specimen: slide Pb6295-6, 114.5 x 43.7.

Subgroup POLYGONOMORPHITAE Downie, Evitt and Sarjeant, 1963

Genus Veryhachium Deunff, emend. Downie and Sarjeant, 1963

Veryhachium cf. V. europeum Stockmans and Williere, 1960
Pl. 1, Fig. 16

Occurrence: rare to abundant (lowest sample in each section), throughout section except for the upper part of the Upper Shale Member.

Reference specimen: slide Pb6227-10, 29.4 x 118.1.

Remarks: The specimens in the Mancos are consistently smaller than the specimens described in the literature as this species.

Veryhachium cf. V. stellatum Deflandre, 1945
Pl. 1, Fig. 13

Occurrence: rare (Pb6262) and abundant (Pb6932) in its only two occurrences, one in the Graneros Shale and one in the Lower Carlile Member of the Mancos Shale.

Reference specimen: slide Pb6273-3, 41.8 x 102.0.

Veryhachium sp. 1
Pl. 1, Fig. 15

Diagnosis: Central body slightly polygonal spheroid; psilate; processes 5 to 7, tapering, with acuminate tips, some curved, solid, with indentation of body cavity into bases a few microns; central body about 15

to 22 μ in diameter, processes about 12 to 15 μ long.

Occurrence: rare, in two occurrences in the Graneros Shale.

Reference specimen: slide Pb6227-10, 114.5 x 43.9.

Subgroup NETROMORPHITAE Downie, Evitt and Sarjeant, 1963

Genus Leiofusa Eisenack, 1938

and

Genus Metaleiofusa Wall, 1965

Leiofusa spp. and Metaleiofusa spp.

Pl. 1, Fig. 18

Pl. 2, Fig. 1

Occurrence: rare, in Graneros Shale, Greenhorn Limestone and Lower Carlile and Upper Shale Members of the Mancos.

Reference specimens: slide Pb6357-10, 40.9 x 91.7, Pb6227-10, 112.8 x 44.0.

Remarks: Specimens identified with these two genera were grouped because the state of preservation did not always permit determination of the number and position of the processes.

Subgroup HERKOMORPHITAE Downie, Evitt and Sarjeant, 1963

Genus Cymatiosphaera O. Wetzel 1933,
emend. Deflandre, 1954

Cymatiosphaera spp.

Pl. 2, Figs. 2,5

Occurrence: rare to abundant, throughout the sections.

Reference specimens: slide Pb6273-1, 33.9 x 99.3, Pb6273-1, 33.7 x 97.2.

Remarks: Specimens identified with this genus were not determined to species.

Subgroup PTEROMORPHITAE Downie, Evitt and Sarjeant, 1963

Genus Pterospermopsis W. Wetzel 1952

Pterospermopsis spp.

Pl. 2, Fig. 3

Occurrence: rare to abundant, throughout sections except upper part of Upper Shale Member at Point Lookout.

Reference specimen: slide Pb6273-2, 49.0 x 98.4.

Subgroup SPHAEROMORPHITAE Downie, Evitt and Sarjeant, 1963

Within this subgroup are placed several smooth, granular, or low-spinned spherical, discoidal and ellipsoidal forms. They are referred to by informal code names only.

Form B sp. 1
Pl. 2, Fig. 7

Diagnosis: smooth to faintly granular or with scattered granules; 30 μ to 40 μ spheres; often broken and/or folded, thin-walled.

Occurrence: common to abundant throughout section.

Reference specimen: slide Pb6871-2, 38.0 x 88.6.

Form B sp. 2
Pl. 2, Fig. 6

Diagnosis: granular to coarsely granular, 30 μ to 55 μ spheres; often broken and/or folded, thin-walled.

Occurrence: rare to abundant, throughout sections.

Reference specimen: slide Pb6337-8, 46.4 x 92.4.

Form B sp. 3
Pl. 2, Fig. 4

Diagnosis: smooth to granular, 20 μ to 30 μ spheres; sometimes wrinkled and folded, thin-walled.

Occurrence: abundant throughout sections.

Reference specimen: slide Pb6273-1, 35.4 x 91.4.

Form B sp. 4
Pl. 2, Fig. 8

Diagnosis: smooth, 60 μ to 70 μ , ellipsoidal, wrinkled, thin-walled.

Occurrence: rare to common (abundant in sample Pb6902), in Lower Carlile Member and Upper Shale Member of Mancos.

Reference specimen: slide Pb6900-2, 38.9 x 91.1.

Form C sp.1
Pl. 2, Fig. 10

Diagnosis: smooth, 15 μ to 20 μ , discoid to spherical, with medium to thick wall.

Occurrence: common to abundant throughout section.

Reference specimen: slide Pb6902-6, 115.7 x 31.3.

Form C sp. 2
Pl. 2, Fig. 9

Diagnosis: smooth, less than 15 μ , spherical, with medium wall thickness.

Occurrence: rare to abundant throughout sections.

Reference specimen: slide Pb6273-1, 36.1 x 87.4.

Form C sp. 3
Pl. 2, Fig. 11

Diagnosis: smooth, 25 μ to 35 μ , spherical, thick-walled, characteristically a fold in surface.

Occurrence: rare to common, in Lower Carlile, Juana Lopez and Upper Shale Members of Mancos.

Reference specimen: slide Pb6223-2, 43.4 x 101.4.

ALGAE

DINOFLAGELLATES

Family Hystrichosphaeridiaceae Evitt
emend. Sarjeant and Downie

Genus Hystrichosphaeridium Deflandre, 1937,
emend. Davey and Williams in Davey et al, 1966

Histrichosphaeridium cf. H. tubiferum (Ehrenberg)
O. Wetzel, 1933
Pl. 2, Fig. 13

Occurrence: rare, in Lower Carlile Member and Upper Shale Member.

Reference specimen: slide Pb6289-6, 121.0 x 29.8.

Hystrichosphaeridium cf. H. deanei
 Davey and Williams in Davey et al, 1966
 Pl. 2, Fig. 12

Occurrence: rare, throughout sections except upper part of Upper Shale Member of Mancos.

Reference specimen: slide Pb6255-7, 39.5 x 96.7.

Remarks: Specimens here referred to this species could in some instances be corroded members of another species. Hystrichokolpoma unispinum Williams and Downie 1966 could take on a similar appearance. In all specimens a large antapical process with a broad attachment was present. This process is not mentioned or shown in figured specimens of this species in the literature.

Hystrichosphaeridium spp.

Specimens are included in this taxon when their state of preservation allows them to be identified only as having Hystrichosphaeridium-like characters.

Genus Oligosphaeridium Davey and Williams
 in Davey et al, 1966

Oligosphaeridium pulcherrimum (Deflandre and Cookson),
 Davey and Williams in Davey et al, 1966
 Pl. 3, Fig. 1

Occurrence: rare, throughout sections.

Reference specimen: slide Pb332-3, 40.8 x 92.5.

Oligosphaeridium spp.

Specimens were referred to this taxon if their state of preservation only allowed the recognition of a central body with process of the type and number most like Oligosphaeridium species.

Genus Cordosphaeridium Eisenack 1963, emend.
 Davey and Williams in Davey et al, 1966

Cordosphaeridium difficile (Manum and Cookson)
 Davey and Williams in Davey et al, 1966
 Pl. 3, Fig. 3

Occurrence: in Point Lookout section only, rare to common, in Greenhorn Limestone and lower part of Upper Shale Member.

Reference specimen: slide Pb6220-9, 36.0 x 91.2.

Cordosphaeridium sp. 1

Pl. 3, Fig. 2

Diagnosis: central body oval in outline; endophram granular, closely appressed to epiphram except at bases of processes; periphram striate with striae aligned along processes and radiating from the bases of the processes; processes about 25, all about 12 μ long, hollow, closed, tapering, branched or simple or two single processes with attached bases forming a "web" between them, tips bifid; overall diameter 60 μ to 70 μ ; archeopyle haplotabular apicle (?).

Occurrence: rare, restricted to Greenhorn Limestone and to very base of Lower Carlile Member.

Reference specimen: slide Pb6273-5, 50.2 x 102.9.

Genus Tanyosphaeridium Davey and Williams
in Davey et al, 1966

Tanyosphaeridium cf. T. variecalamum
Davey and Williams in Davey et al, 1966
Pl. 3, Figs. 4-5

Occurrence: rare to common, in Graneros Shale, Greenhorn Limestone, Lower Carlile Member and Upper Shale Member of Mancos.

Reference specimen: slide Pb6222-7, 41.0 x 87.2.

Genus Litosphaeridium Davey and Williams
in Davey et al, 1966

Litosphaeridium siphoniphorum (Cookson and Eisenack)
Davey and Williams in Davey et al, 1966
Pl. 4, Fig. 1

Occurrence: rare, Point Lookout section only, in upper Graneros Shale.

Reference specimen: slide Pb6252-6, 38.2 x 96.5.

Genus Hystrichokolpoma Klumpp 1953
emend. Williams and Downie in Davey et al, 1966

Hystrichokolpoma ferox (Deflandre)
Williams and Downie in Davey et al, 1966
Pl. 3, Fig. 6

Occurrence: rare, Point Lookout section only, in Greenhorn Limestone, Lower Carlile Member, Juana Lopez and lower part of Upper Shale Member of Mancos.

Reference specimen: slide Pb6289-6, 121.1 x 41.8.

Genus Diphyes Cookson, 1965,
emend. Davey and Williams in Davey et al, 1966

Diphyes cf. D. colligerum (Deflandre and Cookson)
Cookson, 1965
Pl. 4, Fig. 2

Occurrence: rare to common, throughout sections except for upper part of Upper Shale Member of Mancos.

Reference specimens: slide Pb6222-5, 42.5 x 103.3.

Genus Polysphaeridium Davey and Williams
in Davey et al, 1966

Polysphaeridium spp.
Pl. 4, Figs. 3-5

Occurrence: rare, throughout sections.

Reference specimens: slide Pb6382-3, 35.5 x 91.1; slide Pb6387-3, 44.0 x 99.3.

Remarks: Because of their rareness and generally poor state of preservation specimens referable to this genus were not identified to species.

Form O sp. 1
Pl. 4, Fig. 7

Diagnosis: central body oval to pear-shaped; endophragm granular; numerous processes, solid, with orthogonal to recurved aculeate tips; processes 10 μ to 15 μ long; central body 40 μ to 50 μ in diameter; archeopyle uncertain.

Occurrence: rare, limited to lowermost Graneros Shale in both sections.

Reference specimens: slide Pb6227-10, 115.0 x 39.9; slide Pb6227-12, 110.1 x 40.5.

Genus Surculosphaeridium
Davey, Downie, Sarjeant and Williams, 1966

Surculosphaeridium cf. S. vestitum (Deflandre)
 Davey, Downie, Sarjeant and Williams 1966
 Pl. 4, Fig. 6

Occurrence: rare, throughout Point Lookout section, one sample each in Lower Carlile and Upper Shale Members of the Mancos.

Reference specimen: slide Pb6857-2, 37.5 x 100.9.

Remarks: Specimens are rarely well-preserved. The forking of the processes is at a more acute angle than the type. One well-preserved specimen showed a good apical archeopyle.

Family Exochosphaeridiaceae Sarjeant and Downie

Genus Exochosphaeridium Davey and Williams
 in Davey et al, 1966

?Exochosphaeridium phragmites Davey, Downie,
 Sarjeant and Williams in Davey et al, 1966
 Pl. 5, Fig. 1

Occurrence: rare to common (Graneros Shale and Greenhorn Limestone), throughout sections except upper part of Upper Shale Member in the Ute Reservation section.

Reference specimen: slide Pb273-1, 34.8 x 94.5.

Remarks: the characteristic apical process is rarely seen in the specimens in the Mancos.

?Exochosphaeridium sp. 1
 Pl. 5, Fig. 2

Diagnosis: like E. phragmites but with much shorter spines; obvious precingular archeopyle; may be E. phragmites specimens with processes corroded away.

Occurrence: rare to common, in upper Graneros Shale, Greenhorn Limestone and Upper Carlile Member of Mancos.

Reference specimen: slide Pb6357-4, 30.7 x 104.2.

?Exochosphaeridium sp. 2
 Pl. 5, Fig. 4

Diagnosis: central body oval in outline with apical "nubbin"; endophram granular to striate near bases of processes, closely appressed to periphram except at the bases of the processes; periphram smooth,

drawn into ca. 50 closed, tapering, branched or simple processes, some specimens with fused bases forming a "web" (intratabular process complexes?), faintly striate at bases, with bifid or trifid tips, 20 μ to 25 μ long; one open antapical process ca. 10 μ long, cylindrical, ca. 6 μ in diameter; overall diameter 65 μ to 75 μ .

Occurrence: rare, in Lower Carlile Member and Upper Shale Member of Mancos.

Reference specimen: slide Pb6379-3, 40.8 x 101.2.

Family Hystrichosphaeraceae O. Wetzel, emend. Evitt,
emend. Sarjeant and Downie

Genus Hystrichosphaera O. Wetzel 1933,
emend, Davey and Williams in Davey et al, 1966

Hystrichosphaera ramosa (Ehrenberg) Davey and Williams
in Davey et al, 1966
Pl. 5, Fig. 3

Occurrence: rare to common, throughout sections.

Reference specimen: slide Pb6273-3, 48.5 x 97.1

Hystrichosphaera ramosa var. 1
Pl. 5, Fig. 5

Diagnosis: conforms to the circumscription of H. ramosa but is larger (80 μ to 90 μ overall diameter), has a heavier endophram and periphram, and stouter processes, compared with other specimens.

Occurrence: rare, in Greenhorn Limestone, Lower Carlile and Upper Shale Members of the Mancos.

Reference specimen: slide Pb6273-1, 35.0 x 89.5.

Hystrichosphaera ramosa var. 2
Pl. 5, Fig. 6
Pl. 6, Fig. 2

Diagnosis: conforms to the circumscription of H. ramosa but is consistently smaller (35 μ to 45 μ overall), compared with other specimens.

Occurrence: rare to frequent, throughout sections.

Reference specimen: slide Pb6371-1, 43.1 x 89.1.

Hystrichosphaera sp. 1
Pl. 6, Figs. 1-2

Diagnosis: central body circular to oval in outline; endophram granular, periphram faintly granular to smooth; processes $6\ \mu$ to $12\ \mu$ long, most about $8\ \mu$; crests consistently about $3\ \mu$ high. Separated from H. ramosa on bases of granular sculpturing and short processes.

Occurrence: rare to common, throughout sections except upper part of Upper Shale Member of Mancos.

Reference specimen: slide Pb6273-1, 36.5×92.0

Hystrichosphaera spp.

Any specimens resembling the genus Hystrichosphaera that are too corroded to show specific characters are placed in this category.

Genus Heslertonia Sarjeant
in Davey et al, 1966

Heslertonia heslertonensis (Neale and Sarjeant)
Sarjeant in Davey et al, 1966
Pl. 6, Fig. 4

Occurrence: rare, in Upper Graneros Shale, Greenhorn Limestone and lower part of Upper Shale Member of the Mancos.

Reference specimen: slide Pb6272-6, 108.2×41.3 .

Family Microdiniaceae Eisenack
emend. Sarjeant and Downie

Genus Microdinium Cookson and Eisenack 1960,
emend. Sarjeant in Davey et al, 1966

Microdinium cf. M. ornatum Cookson and Eisenack 1960
Pl. 6, Fig. 3

Occurrence: rare, in Greenhorn Limestone and Upper Carlile Member of Mancos.

Reference specimen: slide Pb6295-6, 39.5×92.8 .

Family Gonyaulacystaceae Sarjeant and Downie

Genus Gonyaulacysta Deflandre 1964
emend. Sarjeant in Davey et al, 1966

Gonyaulacysta spp.
Pl. 6, Figs. 6-7

Occurrence: rare, throughout section except upper part of Upper Shale Member.

Reference specimens: slide Pb6288-6, 36.7 x 99.3; slide Pb6289-7, 29.5 x 100.1; Pb6295-7, 49.5 x 109.7.

Remarks: Because of their rare occurrences and often poor state of preservation most specimens referable to this genus were not identified to species.

?Gonyaulacysta sp. 1
Pl. 7, Figs. 1-2

Diagnosis: circular to oval in outline, apparently spherical to oval; endophram granular, periphram thin, faintly granular; complete tabulation not determined because of inadequate specimens; sutures marked by a row of delicate slender processes to 6 μ long, branched and connected distally and at various levels of branching, thus forming an open crest; central body 50 μ to 60 μ in diameter; archeopyle precingular (?).

Occurrence: rare, only in Greenhorn Limestone of Ute reservation section.

Reference specimen: slide Pb6357-6, 40.1 x 90.2; slide Pb6357-4, 30.7 x 92.7.

Remarks: Like (?) Evitt's (1967) Forma AB which has a 6P archeopyle.

Genus Leptodinium Klement, 1960
emend. Sarjeant in Davey et al, 1966

?Leptodinium dispertitum
Cookson and Eisenack, 1965
Pl. 6, Fig. 5

Occurrence: rare to common, in Graneros Shale and Greenhorn Limestone.

Reference specimen: slide Pb6250-10, 37.0 x 92.7; slide Pb6289-6, 32.5 x 100.1.

Family Areoligeraceae Evitt
emend. Sarjeant and Downie

Genus Cyclonephelium Deflandre and Cookson 1955,
emend. Williams and Downie in Davey et al, 1966

Cyclonephelium spp.
Pl. 7, Figs. 5-6

Occurrence: rare, in Lower Carlile and Upper Shale Members of the Mancos.

Reference specimen: slide Pb6878-3, 47.0 x 3.0

Remarks: Because of generally poor preservation specimens referred to this genus are not identified to species. Included here are specimens possibly referable to Areoligera and Tenua.

Genus Areoligera Lejeunne-Carpentier, 1938
emend. Williams and Downie in Davey et al, 1966

Areoligera spp.
Pl. 7, Figs. 3-4

Occurrence: rare to common, in upper Graneros Shale and upward throughout sections.

Reference specimens: slide Pb6345-3, 44.5 x 95.4.

Remarks: Because of their generally poor state of preservation specimens here referred to this genus have not been identified to species. Included here are some specimens possible referable to Cyclonephelium and Tenua.

Family Fromeaceae Sarjeant and Downie

Genus Tenua Eisenack, 1958

Tenua spp.
Pl. 8, Fig. 1

Occurrence: rare to common, throughout sections.

Reference specimen: slide Pb6227-2, 38.9 x 105.0

Remarks: Because of their generally poor state of preservation specimens here referred to this genus are not identified to species. This has also resulted in the inclusion of poor specimens possibly referable to Cyclonephelium and Areoligera.

Genus Fromea Cookson and Eisenack, 1958

Fromea amphora Cookson and Eisenack 1958
Pl. 8, Fig. 4

Occurrence: rare to frequent, in Graneros Shale, Lower Carlile Member and Upper Shale Member of Mancos.

Reference specimen: slide Pb6282-6, 39.4 x 99.1.

Remarks: The specimens in the Mancos generally lack the "girdle" of the holotype.

Family Endoscriniaceae Vozzhennikova
emend. Sarjeant and Downie

Genus Palaeohystrichophora Deflandre, 1934,
emend. Deflandre and Cookson, 1955

Palaeohystrichophora infusoroides Deflandre, 1934
Pl. 8, Fig. 2

Occurrence: rare to extremely abundant, throughout sections

Reference specimen: slide Pb6899-2, 121.8 x 37.9.

Palaeohystrichophora infusoroides var. 1
Pl. 8, Fig. 3

Diagnosis: larger than P. infusoroides of type; girdle nearer antapex; hairs shorter and commonly fewer.

Family Deflandreaceae Eisenack emend.
Sarjeant and Downie

Genus Deflandrea Eisenack, 1938,
emend. Williams and Downie in Davey et al, 1966

Varied combinations of intercalary archeopyles (some of the archeopyles on endophragms may be apical) on the endophragm and periphragm are present among the specimens examined in this study. Forms without archeopyles and forms with 3I/3I, -/3I, I/3I, I/I, I/- types (Evitt, 1967) were found.

The species identifications below are tentative because it is felt that more work must be done on this genus and particularly those species that are represented here. They intergrade in shape and ornamentation making separation into species difficult. In reference to archeopyles the code of Evitt (1967) is used.

Deflandrea cf. D. minor Alberti, 1959
Pl. 8, Fig. 5

Occurrence: rare to common, in Graneros Shale and Lower Carlile Shale Member of Mancos.

Reference specimen: slide Pb6227-10, 124.1 x 29.6.

Deflandrea cf. D. acuminata Cookson and Eisenack, 1958
Pl. 8, Fig. 8

Occurrence: rare to frequent, in Lower Carlile Shale Member and Upper Shale Member.

Reference specimen: slide Pb6268-6, 38.0 x 99.0.

Remarks: Archeopyle is I/3I in all specimens observed in this study.

Deflandrea cf. D. granulifera Manum, 1963
Pl. 8, Fig. 7

Occurrence: rare to frequent, in Graneros Shale, Lower Carlile and Upper Shele member of the Mancos.

Reference specimen: slide Pb6340-7, 47.8 x 87.4.

Remarks: Archeopyle is I/3I. Specimens are generally smaller than the holotype and paratypes. Grades into D. verrucosa characteristics.

Deflandrea cf. D. verrucosa Manum, 1963
Pl. 8, Fig. 6

Occurrence: rare to frequent, in Lower Carlile and lower part of Upper Shale Members.

Reference specimen: slide Pb6268-7, 43.5 x 95.5.

Remarks: Archeopyle is I/I (some specimens show accessory sutures on the endophragm that gave the appearance of 3I). Smaller than types, grades into characteristics of D. granulifera.

Deflandrea cf. D. balmei Cookson and Eisenack, 1960,
 nov. nom., 1962
 Pl. 9, Figs. 1-3,5

Occurrence: rare to frequent, in Lower Carlile and Upper Shale Members of the Mancos.

Reference specimen: slide Pb6902-6, 39.1 x 88.9.

Remarks: Archeopyle is I/- (some larger specimens included in this species appear to be I/3I). Larger specimens appear to grade into forms resembling D. echinoides Cookson and Eisenack, 1960.

Deflandrea cf. D. micracantha Cookson and Eisenack, 1960
 Pl. 9, Fig. 7

Occurrence: rare to frequent, in upper part of Upper Shale Member of the Mancos.

Reference specimen: slide Pb6823-3, 41.0 x 89.2.

Remarks: Specimens encountered were without "shoulders" of the holotype.

Deflandrea sp. 1
 Pl. 9, Fig. 6

Diagnosis: ambitus oval elongated anterior-posterior, surmounted by low truncated acuminate apical horn; two antapical projections, one low, the other slightly longer--a pointed horn; endophragm smooth, oval to pear-shaped, not quite touching periphragm but roughly conforming to the shape of periphragm granular; archeopyle 3I/3I.

Occurrence: rare to abundant, in Graneros Shale, Greenhorn Limestone, Lower Carlile and lower Upper Shale Members of Mancos.

Reference specimen: slide Pb6340-7, 124.8 x 47.0.

Remarks: This species might be placed in Tyrythrodinium Drugg if it could be determined that the three epithema plates were removed as a unit. Like Evitt's (1967) Forma Q but with the inner body.

Deflandrea sp. 2
 Pl. 9, Fig. 8

Diagnosis: ambitus circular to oval surmounted by high rounded acuminate apical horn, two antapical projections, one a low bump, the other a long

acuminate horn; cingulum marked by sharp low ridges; inner capsule circular, smooth, touching periphragm on one side; periphragm faintly granular; no archeopyle.

Occurrence: rare to frequent, in Graneros Shale, Greenhorn Limestone, Lower Carlile Member and lower part of Upper Shale Member of Mancos.

Reference specimen: slide Pb6282-6, 30.8 x 90.8.

Remarks: Resembles Palaeopystrichophora infusoroides var. 1 but without hairs.

Deflandrea sp. 3
Pl. 10, Fig. 2

Diagnosis: epitract a broad bell-shape with small blunt but acuminate apical horn (some specimens without apical horn but with thickened apical area); hypotract trapezoidal with concave sides with two antapical processes at the corners, one a low bump the other a longer acuminate horn; wide cingulum separates epi- and hypotract and is marked by low interrupted ridges; endophragm smooth; periphragm either punctate, smooth or granular; archeopyle I/I; inner capsule circular to oval not touching periphragm as seen in dorso-ventral view.

Occurrence: rare to frequent, in Lower Carlile and Juana Lopez Members and in lower part of Upper Shale Member of Mancos.

Reference specimen: slide Pb6899-2, 120.9 x 43.0.

Remarks: More than one species are probably represented here but until more specimens can be studied it does not seem practical to split them.

Deflandrea sp. 4
Pl. 9, Fig. 4

Diagnosis: overall shape like D. acuminata but without a prominent antapical horn; periphragm smooth with small scattered warts or beads; endophragm smooth; cingulum marked by 5 or 6 paired linear groups of beads or warts; inner capsule circular in dorso-ventral view; archeopyle I/I.

Occurrence: frequent, in lower part of Upper Shale Member.

Reference specimen: slide Pb6327-6, 41.5 x 86.9.

Family Hexagoniferaceae Sarjeant and Downie

Genus Hexagonifera Cookson and Eisenack, 1961

Hexagonifera suspecta Manum and Cookson, 1964
Pl. 10, Fig. 4

Occurrence: common to abundant, throughout sections.

Reference specimen: slide Pb6899-4, 118.6 x 35.7.

Hexagonifera suspecta var. 1
Pl. 10, Figs. 1,3

Diagnosis: conforms to species description except that the endophragm is thinner and is smooth to granular, but not coarsely granular.

Occurrence: common to abundant, throughout sections.

Reference specimen: slide Pb6899-4, 120.1 x 43.7.

Remarks: Included within this variety of the species are possibly the isolated inner capsules of some of the Deflandrea species. Like Evitt's (1967) Forma P.

Hexagonifera suspecta var. 2
Pl. 10, Fig. 5

Diagnosis: conforms to the description of the species except that the endophragm is slightly thicker and the longer radial elements in the wall are aligned to form a reticulate sculpturing; specimens of this variety tend to be larger than the smooth and granular varieties.

Occurrence: rare, to frequent, in the middle part of the Upper Shale Member of the Mancos.

Reference specimen: slide Pb6900-2, 41.9 x 90.3.

Family Canningiaceae Sarjeant and Downie

Genus Canningia Cookson and Eisenack, 1960

Canningia cf. C. colliveri Cookson and Eisenack, 1960
Pl. 11, Fig. 6

Occurrence: rare, in Graneros Shale, Greenhorn Limestone and Lower Carlile Member of the Mancos.

Reference specimen: slide Pb6255-6, 43.8 x 103.9.

Family Pseudoceratiaceae Eisenack emend. Sarjeant and Downie

Genus Odontochitina Deflandre, 1935

Odontochitina striatoperforata Cookson and Eisenack, 1962
Pl. 11, Figs. 1-2

Occurrence: rare to common, in Graneros Shale, Greenhorn Limestone and the Lower Carlile and lower part of Upper Shale Members of Mancos.

Reference specimen: slide Pb6222-7, 50.0 x 89.2.

Form F sp. 1
Pl. 11, Fig. 3

Diagnosis: a distinct form; three large processes, one apical, one antapical and one "dog-leg" postcingular; in addition smaller Hystrichosphaeridium-like processes; tabulation not determined; apical (tetratabular) archeopyle.

Occurrence: rare, throughout Point Lookout section, Lower Carlile and lower part of Upper Shale Members of Mancos in Ute Reservation section.

Reference specimens: slide Pb6881-4, 40.6 x 87.4; slide Pb6250-9, 36.5 x 93.6.

Family Gymnodiniaceae Bergh

Genus Dinogymnium Evitt, Clarke and Verdier, 1967

Dinogymnium sp. 1
Pl. 11, Figs. 3, 4, 5, 7, 8

Diagnosis: tiny, 8 to 20 μ long; wide girdle up to 1/4 length of specimen; may have folds in epittract; apical archeopyle.

Occurrence: rare to frequent, throughout sections.

Reference specimen: slide Pb6244-3, 31.5 x 92.4.

Remarks: This is Dinogymnium sp. 6 of Evitt (1967).

Dinogymnium sp. 2
Pl. 12, Figs. 1-10

Diagnosis: included in this taxon are all species of Dinogymnium not referable to D. sp. 1.

Occurrence: rare to frequent, throughout sections.

Reference specimens: slides Pb6845-3, 38.1 x 94.2, 35.1 x 98.0, 36.2 x 105.5, 40.5 x 93.5; Pb6848-3, 37.8 x 98.3; Pb6888-3, 38.6 x 88.1; Pb6892-1, 43.6 x 98.4; Pb6891-3, 39.4 x 96.7.

Remarks: Included here are Dinogymnium sp. 1, D. sp. 2, D. sp. 5 of Evitt (1967).

Family Uncertain

Genus Diconodinium Eisenack and Cookson, 1960

? Diconodinium arcticum Manum and Cookson, 1964
Pl. 12, Fig. 11

Occurrence: rare to frequent, throughout sections.

Reference specimen: slide Pb6282-6, 48.2 x 91.4.

Remarks: Poorly preserved and folded specimens that have been assigned to this species may be specimens of Deflandrea or corroded Palaeohystichophora. Archeopyle is I in many specimens.

Genus Horologinella Cookson and Eisenack, 1962

? Horologinella spinosa Cookson, 1965
Pl. 12, Fig. 12

Occurrence: rare to common, in Graneros Shale and Lower Carlile and Upper Shale Members of the Mancos.

Reference specimen: slide Pb6899-4, 110.9 x 42.4.

Genus Trigonopyxidia Cookson and Eisenack, 1961

?Trigonopyxidia spp.
Pl. 13, Fig. 2

Occurrence: rare, in Graneros Shale, Greenhorn Limestone, Lower Carlile Shale Member and lower part of Upper Shale Member of Mancos.

Reference specimen: slide Pb6273-2, 44.7 x 91.2.

Remarks: The overall shape ranges from a blunt rounded form to a more pointed tetrahedral form.

Form D. sp. 1
Pl. 13, Fig. 1

Diagnosis: circular in outline in all specimens encountered; dense concentration of fine hairs about 5 μ long at periphery in places fused together; endophragm granular; overall diameter including hairs, 65 to 75 μ .

Occurrence: rare, in Lower Carlile Member and lower part of Upper Shale Member of Mancos.

Reference specimen: slide Pb6295-6, 38.1 x 92.5.

OTHER ALGAE

Genus Palambages O. Wetzel, 1961

Palambages cf. P. deflandrei Gorka, 1963
Pl. 12, Fig. 3

Occurrence: rare, in Lower Carlile Member and Upper Shale Member of the Mancos.

Reference specimen: slide Pb6899-4, 124.1 x 42.6.

Remarks: The colonies are not all circular in outline. Some consist of only a few assymetrically arranged spheres. All spheres have a polygonal plate situated on that part of a sphere opposite the center of a colony. This gives the impression of a "colonial dinoflagellate" if the polygonal openings are considered as archeopyles. Some isolated spheres were recognized.

Genus Pediastrum Meyen, 1829

Pediastrum spp.
Pl. 13, Fig. 4

Occurrence: rare, in upper part of Upper Shale Member of Mancos, plus one occurrence in the sandy interval in the Ute section equivalent to the Tocito Sandstone.

Remarks: All specimens encountered were badly corroded.

TRILETE SPORES

Genus Gleicheniidites Ross, 1949 ex Delcourt
and Sprumont, 1955

Gleicheniidites senonicus Ross, 1949
Pl. 13, Fig. 5

Occurrence: rare to common throughout sections.

Reference specimen: slide Pb6881-4, 34.5 x 105.3.

Gleicheniidites circinidites (Cookson) Brenner, 1963
Pl. 13, Fig. 7

Occurrence: rare, throughout Point Lookout section, in Graneros Shale and Upper Shale Member of Mancos at Ute Reservation section.

Reference specimen: slide Pb6881-4, 39.0 x 92.1.

Genus Leiotriletes Naumova, ex Potonié and Kremp, 1954

Leiotriletes pseudomaximus (Pflug and Thomson), Stanley, 1965
Pl. 13, Fig. 8

Occurrence: rare, in upper part of Upper Shale Member of Mancos.

Reference specimen: slide Pb6881-4, 33.8 x 91.8.

Large smooth Trilete spores
Pl. 14, Figs. 5, 10, 13

Occurrence: rare, throughout sections.

Reference specimens: slide Pb6227-10, 111.9 x 43.7; slide Pb6354-1, 37.1 x 93.1; Pb6227-3, 44.5 x 106.9.

Remarks: large smooth trilete spores are grouped together because they are often indistinguishable due to their poor state of preservation. Possibly included are species assignable to a number of genera such as Dictyophyllidites, Cyathidites, Lygodiumsporites, Todisporites, Hymenophyllumsporites, Leiotriletes, Matonisporites, etc.

Genus Sphagnumsporites Raatz, 1937

Sphagnumsporites antiquasporites (Wilson and Webster)
Potonie, 1956
Pl. 13, Fig. 6

Occurrence: rare, throughout Point Lookout section, in Lower Carlile Member only of Ute Reservation section.

Reference specimen: slide Pb6227-3, 32.2 x 96.6.

Genus Cardioangulina Malawkina, 1949,
emend. Potonie, 1960

Cardioangulina diaphana (Wilson and Webster)
Stanley, 1965
Pl. 13, Fig. 9
Pl. 14, Fig. 1

Occurrence: rare, throughout Point Lookout section, in Lower Carlile Member and Upper Shale Member of Ute Reservation section.

Reference specimen: slide Pb6340-6, 115.5 x 35.9.

Genus Deltoidospora Miner, 1935, emend. Potonie, 1956

?Deltoidospora hallii Miner, 1935
Pl. 14, Fig. 2

Occurrence: rare, throughout Point Lookout section, in Upper Shale Member of Mancos in Ute Reservation section.

Reference specimen: slide Pb6227-2, 40.9 x 94.3.

Genus Cyathidites Couper, 1953

Cyathidites cf. C. mesozoicus (Thiergart) Potonie', 1956
Pl. 14, Fig. 6

Occurrence: rare, in Upper Shale Member of Mancos in both sections, in Lower Carlile Member in Ute Reservation section.

Reference specimen: slide Pb6881-4, 44.5 x 95.3.

Genus Undulatisporites Pflug in Thomson and Pflug, 1953

Undulatisporites sp. 1
Pl. 14, Fig. 3

Diagnosis: Semiangular in Polar view; psilate; wall about 0.5 microns thick; leasurae sinuous, tectate (about 1.2 μ high); diameter 18 to 22 μ .

Occurrence: rare, upper part of Upper Shale Member of Mancos.

Reference specimen: slide Pb6881-4, 32.7 x 87.4.

Genus Concavisporites Pflug, 1953,
emend. Delcourt and Sprumont, 1955

?Concavisporites sp. 1
Pl. 14, Fig. 8

Diagnosis: Semilobate in polar view; punctate to vermiculate with muri about 0.5 μ wide, but contact area apparently smooth; wall about 0.5 μ thick; leasurae sinuous, extending to margins, about 1.4 μ wide; Kyrtocone on distal face; diameter 27 to 35 μ .

Occurrence: rare, throughout sections.

Reference specimen: slide Pb6227-3, 33.2 x 92.4.

Genus Triplanosporites Pflug in Thomson and Pflug, 1952

Triplanosporites sinuosus Pflug in Thomson and Pflug, 1952
Pl. 14, Fig. 7

Occurrence: rare, throughout Point Lookout section, in Lower Carlile Member and Upper Shale Member of Mancos.

Reference specimen: slide Pb6227-10, 119.0 x 36.4.

Triplanosporites cf. T. terciarius Pflug in Thomson and Pflug,
1953
Pl. 14, Fig. 4

Occurrence: rare, in Upper Shale Member of Mancos.

Reference specimen: slide Pb6881-4, 41.8 x 101.6.

Genus Cingulatisporites Thomson, 1953, emend. Potonié, 1956

Cingulatisporites radiatus Stanley, 1965
Pl. 14, Fig. 9

Occurrence: rare, throughout Point Lookout section, in lower part of Upper Shale Member of Mancos in Ute Reservation section.

Reference specimen: slide Pb6379-2, 42.9 x 46.5.

Genus Kuylisporites Potonié, 1956

Kuylisporites scutatus Newman, 1965
Pl. 14, Fig. 11

Occurrence: rare, Upper Shale Member of Mancos, Point Lookout section only.

Reference specimen: slide Pb6869-3, 35.7 x 98.9.

Genus Concavissimisporites Delcourt and Sprumont, 1955,
emend. Delcourt, Dettmann and Hughes, 1963

Concavissimisporites variverrucatus (Couper) Brenner, 1963
Pl. 14, Fig. 14

Occurrence: rare, in middle of Upper Shale Member of Mancos in Point Lookout section only.

Reference specimen: slide Pb6881-4, 43.0 x 97.2.

Genus Acanthotriletes Naumova, 1937,
emend. Potonié and Kremp, 1954

?Acanthotriletes varispinosus Pocock, 1962
Pl. 14, Fig. 12

Occurrence: rare to common, throughout sections.

Reference specimen: slide Pb6227-2, 41.5 x 103.0.

Genus Lycopodiumsporites Theirgart, 1938

Lycopodiumsporites cerniidites (Ross) Delcourt and Sprumont, 1955
Pl. 15, Fig. 1

Occurrence: rare to common, throughout sections.

Reference specimen: slide Pb6227-2, 42.2 x 92.0.

Genus Camarozonosporites Potonié¹, 1956, emend. Klaus, 1960

?Camarozonosporites insignis Norris, 1967
Pl. 15, Fig. 2

Occurrence: rare, throughout Point Lookout section, no occurrences in Ute Reservation section.

Reference specimen: slide Pb6227-2, 33.1 x 93.6.

Genus Converrucosisporites Potonié¹ and Kremp, 1954

Converrucosisporites cf. C. platyverrucosus, Brenner, 1963
Pl. 15, Fig. 3

Occurrence: rare, Upper Shale Member in Point Lookout section, in Lower Carlile Member and Upper Shale Member of Mancos in Ute Reservation section.

Reference specimen: slide Pb6227-11, 115.2 x 42.2.

Genus Appendicisporites Weyland and Krieger, 1953

Appendicisporites cf. A. tricornatatus Weyland and Greifeld
Pl. 15, Fig. 4

Occurrence: rare, throughout Point Lookout section; no occurrences in Ute Reservation section.

Genus Cicatricosisporites Potonié¹ and Gelletich, 1932

Cicatricosisporites cf. C. hallei Delcourt and Sprumont, 1955
Pl. 15, Fig. 5

Occurrence: rare, in Lower Carlile Member and Upper Shale Member of Mancos in Point Lookout section, only in upper sample of Upper Shale Member of Mancos in Ute Reservation section.

Reference specimen: slide Pb6865-2, 45.5 x 99.4.

Remarks: Some specimens of C. dorogensis Potonié¹ and Gelletich may be included here.

Cicatricosisporites cf. C. dorogensis Potonié¹ and Gelletich, 1932,
emend. Kedves, 1961
Pl. 15, Fig. 6

Occurrence: rare, middle of Upper Shale Member of Mancos in Point Lookout section, Lower Carlile Member and Upper Shale Member of Mancos in Ute Reservation section.

Reference specimen: slide Pb6227-2, 41.3 x 92.1.

Remarks: Specimens are much smaller than those described for this species in the literature.

Cicatricosisporites cf. C. carlylensis Pocock, 1962
Pl. 15, Fig. 10

Occurrence: rare, Upper Shale Member in Point Lookout section only.

Reference specimen: slide Pb6881-4, 44.2 x 97.2.

Genus Corrugatisporites Thomson and Pflug, 1953
non Ibrahim ex Weyland and Greifeld, 1953

?Corrugatisporites toratus Weyland and Greifeld, 1953
Pl. 15, Fig. 7

Occurrence: rare, in Graneros Shale and Upper Shale Member of Mancos in Point Lookout section, in Lower Carlile Member and Upper Shale Member of Mancos in Ute Reservation section.

Reference specimen: slide Pb6227-2, 36.3 x 95.8.

MONOLETE SPORES

Genus Laevigatosporites Ibrahim, 1933

Laevigatosporites cf. L. ovatus Wilson and Webster, 1946
Pl. 15, Fig. 8

Occurrence: rare to common, throughout both sections.

Reference specimen: slide Pb6227-11, 124.7 x 42.2.

Genus Verrucatosporites Pflug and Thomson, 1953

Verrucatosporites cf. V. favus (R. Potonié)
Pflug and Thomson, 1953
Pl. 15, Fig. 2

Occurrence: rare, in Lower Carlile Member of Mancos in Point Lookout section and Ute Reservation section, in Upper Shale Member of Mancos in Point Lookout section only.

Reference specimen: slide Pb6881-4, 47.9 x 106.7.

Reticulate Monolete spores
Pl. 15, Fig. 13

Occurrence: rare, in Upper Shale Member of Mancos (only uppermost sample in Ute Reservation section).

Reference specimen: slide Pb6881-4, 44.9 x 98.9.

Remarks: This category includes all monolete spores with a reticulate sculpturing. Most are large, 35 μ to 50 μ .

GYMNOSPERMOUS POLLEN

Few bisaccate pollen grains were well-preserved. Because of their poor preservation they have been lumped in the categories or taxa listed below.

Large Pinus-type pollen
Pl. 15, Fig. 14

Occurrence: rare to common, throughout both sections.

Reference specimen: slide Pb6282-6, 48.2 x 98.7.

Remarks: Included in this group are all grains that are like large pine pollen in shape and size. Overall length from 50 to 90 μ .

Small Pinus-type pollen
Pl. 15, Fig. 9

Occurrence: rare, Upper Shale Member of Mancos in Point Lookout section, lower part of Upper Shale Member in Ute Reservation section.

Reference specimen: slide Pb6881-4, 37.5 x 95.0.

Remarks: Size (overall long dimension) 30 to 40 μ .

Picea-type pollen
Pl. 16, Fig. 1

Occurrence: rare, throughout Point Lookout section, in Graneros Shale and Lower Carlile Member of Mancos in Ute Reservation section.

Reference specimen: slide Pb6282-6, 44.3 x 90.7.

Remarks: Included here are those grains like Picea pollen in shape and size.

Abies-type pollen
Pl. 16, Fig. 9

Occurrence: rare, Upper Shale Member of Mancos Point Lookout section only.

Reference specimen: slide Pb6869-2, 41.0 x 95.2.

Remarks: Included here are those pollen grains that are like Abies grains in size, shape, and apparent thickness of cap.

Genus Rugubivesiculites Pierce, 1961

Rugubivesiculites cf. R. reductus Pierce, 1961
Pl. 16, Fig. 7

Occurrence: rare, lower Carlile Member and Upper Shale Member of Mancos.

Reference specimen: slide Pb6327-7, 36.5 x 107.7.

Genus Vitreisporites Leschik, 1955

Vitreisporites pallidus (Reissinger) Nilsson, 1958
Pl. 15, Fig. 11

Occurrence: rare, in Juana Lopez Member in Upper Shale Member of Mancos in Point Lookout section, in Upper Shale Member of Mancos in Ute Reservation section.

Reference specimen: slide Pb6881-4, 33.7 x 99.1.

Genus Parvisaccites Couper, 1958

?Parvisaccites sp. 1, new species
Pl. 16, Fig. 4

Diagnosis: oval in polar view; bladders appear as thick granular folds with uneven margins; radially extending folds of the bladders opposite the sulcus; this pattern extends to the equator; rest of grain is granular; exine about 2 μ thick, proximal cap about 4 μ thick; total breadth 60 to 70 μ , length 50 to 60 μ .

Occurrence: rare, upper part of Upper Shale Member, Point Lookout section only.

Reference specimen: slide Pb6881-4, 35.7 x 102.1.

Genus Classopollis Pflug, 1953,
emend. Pocock and Jansonius, 1961

Classopollis cf. C. classoides Pflug,
emend. Pocock and Jansonius, 1961
Pl. 16, Figs. 2-3

Occurrence: rare to frequent, throughout both sections.

Reference specimens: slide Pb6340-7, 112.8 x 32.7; slide Pb6808-3, 30.7 x 89.4.

Remarks: Two size classes were counted, one less than 27 μ , the other greater than 27 μ . There appears to be two distinct size modes for this group in the Mancos.

Classopollis sp. 1
Pl. 16, Figs. 5-6

Diagnosis: consistently discoid and commonly with tetrad mark; tetrads appear deflated compared with C. classoides and angular in outline; in other respects similar to C. classoides.

Occurrence: rare to frequent, Upper Shale Member of Mancos.

Reference specimen: slide Pb6881-4, 45.7 x 86.6; 45.3 x 103.3; 45.8 x 96.3.

Genus Equisetosporites Daugherty, 1941
emend. Singh, 1964

Large Equisetosporites spp.
Pl. 16, Fig. 8

Occurrence: rare, throughout Point Lookout section, in lower part of Upper Shale Member of Mancos only in Ute Reservation section.

Reference specimen: slide Pb6357-10, 34.7 x 91.2.

Remarks: All Ephedra-like pollen grains greater than 25 μ in length (longitudinal dimension) are included here. These grains generally have a higher length to breadth ratio than the other group and have more ridges.

Small Equisetosporites spp.
Pl. 16, Fig. 10

Occurrence: rare, throughout Point Lookout section, in Greenhorn Limestone and Lower Carlile Member of Mancos in Ute Reservation section.

Reference specimen: slide Pb6282-6, 35.5 x 97.3.

Remarks: All Ephedra-like pollen less than 25 μ in length are included here. These grains generally have a length to breadth ratio of about 2:1 and 8 or 9 ridges.

Genus Inaperturopollenites Thomson and Pflug, 1953

Inaperturopollenites limbatus Balme, 1957
Pl. 17, Figs. 1-2

Occurrence: rare to frequent, throughout Point Lookout section, in Lower Carlile Member and Upper Shale Member of Mancos in Ute Reservation section.

Reference specimen: slide Pb6881-4, 42.9 x 96.9, 46.3 x 105.4.

Remarks: Two forms of this species were counted separately, one like the type, the other generally smaller and with faint "rudimentary" bladder or frill around the thin-walled area.

Inaperturopollenites sp. 1
Pl. 16, Figs. 11-12

Diagnosis: granular to granulate; usually split open; 25 to 40 μ , similar to I. dubius (Potonie and Venitz) Thomson and Pflug.

Occurrence: abundant, throughout sections.

Reference specimen: slide Pb6357-10, 38.2 x 87.6.

Inaperturopollenites sp. 2
Pl. 16, Fig. 13

Diagnosis: granular to scabrate; rarely split open; 15 to 20 μ .

Occurrence: rare to frequent, throughout sections.

Reference specimen: slide Pb6865-2, 48.9 x 98.7.

Inaperturopollenites sp. 3
Pl. 16, Fig. 14
Pl. 17, Fig. 7

Diagnosis: smooth to granular; circular in outline; sometimes split open; few showing possible tetrad mark; 30 to 40 μ .

Occurrence: rare to common, Upper Shale Member of Mancos.

Reference specimen: slide Pb6881-4, 37.4 x 101.8, 44.5 x 105.8.

Genus Quadripollis Drugg, 1967

Quadripollis krempii Drugg, 1967
Pl. 17, Fig. 4

Occurrence: rare, Upper Shale Member of Mancos.

Reference specimen: slide Pb6907-6, 32.3 x 101.3.

Genus Pflugipollenites Pocock, 1962

Pflugipollenites dampieri (Balme) Pocock, 1962
Pl. 17, Fig. 16

Occurrence: rare, Upper Shale Member of Mancos.

Reference specimen: slide Ph6881-4, 42.7 x 101.2.

Genus Exesipollenites Balme, 1957

Exesipollenites tumulus Balme, 1957
Pl. 17, Fig. 11

Occurrence: rare to common, Upper Shale Member of Mancos.

Reference specimen: slide Pb6881-4, 46.3 x 92.5.

Genus Cycadopites Wodehouse ex Wilson and Webster, 1946

?Cycadopites sp. 1
Pl. 17, Fig. 3

Diagnosis: smooth; exine less than one micron thick; pointed to bluntly pointed tapered oval in polar view; colpus full length of grain; 20 to 40 μ .

Occurrence: rare, throughout sections.

Reference specimen: slide Pb6881-4, 42.0 x 96.8.

Remarks: Two size classes were counted separately, one 20 to 25 μ (length), the other 25 to 45 μ .

?Cycadopites sp. 2
Pl. 17, Fig. 6

Diagnosis: smooth; exine less than or equal to one micron thick; slightly tapered oval; colpus full length of grain, widened at ends; 20 to 24 μ by 10 to 15 μ .

Occurrence: rare, Greenhorn Limestone, Lower Carlile Member and Upper Shale Member of Mancos in Point Lookout section; Lower Carlile Member and Upper Shale Member of Mancos in Ute Reservation section.

Reference specimen: slide Pb6252-6, 40.7 x 97.3.

?Cycadopites sp. 3
Pl. 17, Fig. 5

Diagnosis: foveolate: exine less than one micron thick; tapered oval in polar view; colpus full length of grain, often wider at its ends; 20 to 40 μ long.

Occurrence: rare, uppermost sample of Point Lookout section only.

Reference specimen: slide Pb6244-3, 40.9 x 99.7.

Genus Eucommiidites Erdtman, 1948, emend.
Hughes, 1961

Eucommiidites cf. E. couperi Anderson, 1960
Pl. 17, Fig. 9

Occurrence: rare to frequent, throughout both sections.

Reference specimen: slide Pb6881-4, 32.1 x 99.9.

Eucommiidites cf. E. troedssonii Erdtman, 1948.
emend. Hughes, 1961
Pl. 17, Fig. 8

Occurrence: rare, in Graneros Shale, Lower Carlile Member and lower two-thirds of Upper Shale Member of Mancos in both sections.

Reference specimen: slide Pb6881-4, 43.7 x 104.1.

Euccommiidites sp. 1, sp. nov.
Pl. 17, Fig. 10

Diagnosis: like E. troedssonii in arrangement of furrows; psilate; oval in polar view; oval appearing pointed at the ends and assymetrical in lateral view; about 8 to 18 μ long, 5 to 12 μ wide.

Occurrence: common to abundant, throughout both sections.

Reference specimen: slide Pb6357-10, 46.9 x 92.1.

ANGIOSPERMOUS POLLEN

Genus Tricolpopollenites Potonié¹, 1934

Tricolpopollenites cf. T. retiformis Pflug and Thomson
in Thomson and Pflug, 1953
Pl. 17, Figs. 12-14, 17

Occurrence: common to frequent, throughout sections.

Reference specimens: slide Pb6881-4, 43.5 x 98.6, slide Pb6337-6,
38.1 x 92.9.

Remarks: Because of the poor preservation in some samples other species may be included here. Other possibilities are Tricolpites hians Stanley, 1965, T. parvus Stanley, Pseudotricolpites reticulatus Stanley, Fraxinoipollenites crassimurus Groot and Penny.

Tricolpopollenites cf. T. micromunus Groot and Penny, 1960
Pl. 17, Figs. 15, 17-20

Occurrence: common to abundant, throughout sections.

Reference specimen: slide Pb6282-6, 35.1 x 105.5.

Tricolpopollenites henrici (R. Potonié¹)
Thomson and Pflug, 1953
Pl. 17, Fig. 18

Occurrence: rare to common, throughout sections.

Reference specimen: slide Pb6288-7, 45.3 x 92.2.

Tricolpopollenites sp. 1, sp. nov.
Pl. 18, Fig. 1

Diagnosis: usually preserved in polar view; polar view wide open circular; psilate, apparently ectexine thicker than endexine; exine thickest in inter-colpate areas, about 1 μ thick; colpi with smooth margins, rounded ends with constriction at equator; polar area index 1:3.5; diameter 20 to 25 μ .

Occurrence: rare, Graneros Shale in Ute Reservation section, Lower Carlile Member of Mancos in both sections, Juana Lopez Member of Mancos in Point Lookout section.

Reference specimen: slide Pb6373-4, 37.0 x 101.8.

Tricolpopollenites sp. 2, sp. nov.
Pl. 18, Fig. 11

Diagnosis: usually preserved in polar view; polar view open angular to semiangular to subangular; psilate to granular; exine less than one micron thick; colpi with smooth margins; polar area index 1:2 to 1:3; diameter 10 to 18 μ .

Occurrence: rare, Lower Carlile Member and Upper Shale Member of Mancos.

Reference specimens: slide Pb6881-4, 50.3 x 97.0, 41.9 x 91.8; slide Pb6255-6, 111.7 x 40.0.

Tricolpopollenites sp. 3, sp. nov.
Pl. 18, Fig. 9

Diagnosis: preserved in polar view; polar view open circular to inter-subangular; psilate (corroded?); exine about one micron thick; colpi with smooth margins, endexine extending across colpi as a thin granular membrane; polar area index 1:3.5; diameter 15 to 20 μ .

Occurrence: rare, Lower Carlile Member of Mancos in Ute Reservation section, Upper Shale Member of Mancos in Point Lookout section.

Reference specimen: slide Pb6282-6, 35.0 x 92.7.

Tricolpopollenites sp. 4, sp. nov.
Pl. 18, Fig. 7

Diagnosis: preserved in oblique view or polar view; polar view open semiangular; baculate (Erdtman); exine about 1.0 - 1.5 μ thick thinning towards colpi from inter-colpate area; ectexine thicker than endexine, tectate; colpi with smooth margins, with faintly granular margo about 2.0 - 2.5 μ wide formed by extension of endexine (ekt = 0, mem; code of Faegri and Inversion, 1964); polar area index 1:2 to 1:3.5; diameter 25 to 35 μ .

Occurrence: rare to common, Upper Shale Member of Mancos in both sections.

Reference specimen: slide Pb6881-4, 32.0 x 100.5.

Tricolpopollenites sp. 5, sp. nov.
Pl. 18, Figs. 4, 10

Diagnosis: preserved in polar view; polar view open semiangular; psilate (corroded?) to punctate; exine less than one micron thick, thicker at poles than elsewhere; colpi with smooth margins, with margo about one micron wide (ekt = 0, mem); polar area 1:3.25; diameter 13 to 16 μ .

Occurrence: rare, in Upper Shale Member of Mancos in both sections, Lower Shale Member of Mancos in Point Lookout section.

Reference specimen: slide Pb6881-4, 40.4 x 94.5.

Tricolpopollenites sp. 6, sp. nov.
Pl. 18, Figs. 2-3

Diagnosis: very slightly rhomboidal circle in equatorial view, wide open semiangular in polar view; punctate; exine about one micron thick in intercolpate areas and poles thinning towards the colpi; colpi with smooth margins, with margo (ekt - 0, mem) about 2.25 μ wide; polar area index about 1:7; diameter 18 to 22 μ .

Occurrence: rare, in Upper Shale Member of Mancos in both sections, in upper Lower Shale Member of Mancos in Ute Reservation section.

Reference specimen: slide Pb6881-4, 35.3 x 106.1, 39.9 x 93.7.

Tricolpopollenites sp. 7, sp. nov.
Pl. 18, Fig. 6

Diagnosis: nearly circular in all orientations; open circular in polar view; punctate to permicroreticulate, exine less than one micron thick; colpi with smooth margins; polar area index about 1:3.5; diameter 5 to 10 μ .

Occurrence: rare to frequent, Graneros Shale and Upper Shale Member of Mancos in both sections, upper Lower Carlile Member of Mancos in Point Lookout section.

Reference specimen: slide Pb6857-2, 41.0 x 103.1.

Tricolpopollenites sp. 8, sp. nov.
Pl. 18, Fig. 19

Diagnosis: polar view circular to slightly semiangular; exine less than one micron thick; reticulate, lumina one micron or less across, muri about .75 micron wide; colpi with smooth margins; polar area index about 1:3.5; diameter 15 to 20 μ .

Occurrence: rare to common, Graneros Shale, Greenhorn Limestone, Lower Carlile Member and lower part of Upper Shale Member of Mancos in both sections.

Reference specimen: slide Pb6337-1, 35.6 x 96.0.

Genus Tricolpites Cookson ex Couper, 1953

Tricolpites cf. T. explanata (Anderson) Drugg, 1967
Pl. 18, Figs. 12-13

Occurrence: rare to frequent in Upper Shale Member of Mancos in both sections, in Lower Carlile Member of Mancos in Point Lookout section.

Reference specimen: slide Pb6881-4, 42.0 x 100.3.

Remarks: Two size classes were counted in this group. Those less than about 20 μ were counted separately. The smaller group also tended to be more circular in polar view with a proportionally reduced size of lumina and muri.

Tricolpites cf. T. bathyreticulatus Stanley, 1965
Pl. 18, Fig. 16

Occurrence: rare to common, in Lower Carlile Member and Upper Shale Member of Mancos in Point Lookout section, in Greenhorn Limestone, Lower Carlile Member and lower part of Upper Shale Member of Mancos in Ute Reservation section.

Reference specimen: slide Pb6293-7, 35.5 x 94.9.

Tricolpites cf. T. anguloluminosus Anderson, 1960
Pl. 18, Fig. 18

Occurrence: rare, throughout Point Lookout section, in Lower Carlile Member and Upper Shale Member of Mancos in Ute Reservation section.

Reference specimen: slide Pb6244-3, 40.0 x 94.3.

Genus Retitricolpites (Van der Hammen) ex Pierce, 1961

Retitricolpites cf. P. geranioides (Couper) Brenner, 1963
Pl. 18, Fig. 20

Occurrence: rare, uppermost Point Lookout section.

Reference specimen: slide Pb6881-4, 41.9 x 93.9.

Retitricolpites cf. R. georgensis Brenner, 1963
Pl. 18, Fig. 15

Occurrence: rare, Upper Shale Member of Mancos in both sections.

Reference specimen: slide Pb6282-6, 33.0 x 91.4.

Genus Trialapollis Stanley, 1965

?Trialapollis sp. 1
Pl. 18, Fig. 14

Diagnosis: tricolpate (?); spherical rhomboidal to spherical apiculate in polar view; exine about one micron thick; punctate to per-microreticulate; colpi not obvious, what appear to be colpi may be folds; dimensions about 20 μ x 18 μ .

Occurrence: rare, Upper Shale Member of Mancos in both sections.

Reference specimen: slide Pb6878-3, 43.4 x 101.4.

Remarks: Stanley's description of the genus states that these grains are acolpate. The specimens included here may not possess colpi and fit well in this genus.

Genus Tricolporites Erdtman, 1947

Tricolporites rhomboides Anderson, 1960
Pl. 18, Fig. 8

Occurrence: rare to common, throughout sections.

Reference specimens: slide Pb6881-4, 44.3 x 94.2, 42.7 x 93.5.

Tricolporites traversei Anderson, 1960
Pl. 18, Fig. 5

Occurrence: rare to common, Upper Shale Member of Mancos in both sections, questionable occurrence in Lower Carlile Member of Mancos in Point Lookout section.

Reference specimen: slide Pb6244-2, 42.0 x 97.5.

Genus Duplopollis Krutzsch, 1959

Duplopollis cf. D. orthoteichus (Cookson and Pike) Krutzsch, 1959
Pl. 18, Figs. 17, 21, 22

Occurrence: rare, Upper Shale Member in both sections.

Reference specimens: slide Pb6875-2, 49.0 x 87.2.

Remarks: Possibly included here are some specimens of Cupanieidites reticularis Cookson and Pike, and C. major Cookson and Pike. Some specimens were syncolpate at only one pole. The colpi not reaching but one-half the way to the other pole.

Genus Porocolpopollenites Pflug in Thomson and Pflug, 1953

?Porocolpopollenites, sp. 1, sp. nov.
Pl. 19, Fig. 2

Diagnosis: Tricolpate (tricolporate?); very flat oblate oval in equatorial view, open semisubangular in polar view; scabrate; exine less than one micron thick; colpi with straight smooth margins; polar area index 5:7; diameter about 20 μ .

Occurrence: rare, Upper Shale Member of Mancos in Point Lookout section, in upper sample of Lower Carlile Member of Mancos in Ute Reservation section.

Reference specimen: slide Pb6881-4, 43.5 x 89.3.

Genus Dicotetradites Couper, 1953

Dicotetradites cf. D. clavatus Couper, 1953
Pl. 18, Fig. 25

Occurrence: rare to common, throughout Point Lookout section, in Graneros Shale, Lower Carlile Member and lower part of Upper Shale Member of Mancos in Ute Reservation section.

Reference specimen: slide Pb6227-10, 120.0 x 37.2.

Hexacolpate Pollen Grain
Pl. 18, Fig. 24

Diagnosis: Hexacolpate; circular in all orientations; tectate perforate, punctate; exine about $1.5\ \mu$ thick, ectexine thicker than endexine; colpi about 7 to $8\ \mu$ long, with smooth margins; colpi arranged so the intersections of their extended ends form three congruent spherical triangles on the pollen grain's surface (see Wodehouse, 1935, p. 170, fig. 27); diameter 25 to $30\ \mu$.

Occurrence: rare, Upper Shale Member of Mancos; uppermost part only in Ute Reservation section.

Reference specimen: slide Pb6907-6, 33.4×94.3 .

Remarks: This form of pollen grain may be simply a variant of the tricolpate grains referred to Tricolpopollenites retiformis Pflug and Thomson.

Genus Triporopollenites Pflug and Thomson
in Thomson and Pflug, 1953

Triporopollenites cf. T. scabroporus Newman, 1965
Pl. 18, Figs. 26-38

Occurrence: rare to frequent, Upper Shale Member of Mancos in both sections, in Juana Lopez Member of Mancos in Point Lookout section.

Reference specimen: slide Pb6881-4, 50.4×87.9 .

Remarks: Those specimens with especially protruding pores were counted separately.

Triporopollenites cf. T. tectus Newman, 1965
Pl. 19, Fig. 8

Occurrence: rare to common, in Upper Shale Member of Mancos.

Reference specimen: slide Pb6845-2, 33.1×96.4 .

Triporopollenites sp. 1
Pl. 18, Fig. 23

Diagnosis: preserved in polar view; semiangular in polar view; psilate to granular; exine less than one micron thick; pores 4 to $5\ \mu$ wide, with ulcerate margin; diameter 13 to $18\ \mu$.

Occurrence: rare to common, in Upper Shale Member of Mancos in both sections, in upper sample of Lower Carlile Member in Point Lookout section.

Genus Extratriporopollenites Pflug, 1952

?Extratriporopollenites spp.
Pl. 18, Fig. 29

Occurrence: rare, Greenhorn Limestone in both sections, in Lower Carlile Member and Juana Lopez Member of Mancos in Point Lookout section.

Reference specimen: slide Pb6289-5, 37.7 x 88.7.

Remarks: All of these specimens are poorly preserved. All are semilobate to lobate in polar view and many exhibit what may be inter-loculi and prevestibuli.

Genus Trudopollis Pflug, 1953, emend. Potonié, 1960

Trudopollis cf. T. hemiparvus Pflug, 1953
Pl. 19, Fig. 4

Occurrence: rare, Upper Shale Member of Mancos.

Reference specimen: slide Pb6881-4, 41.7 x 98.2.

Genus Labrapollis Krutzsch, 1968

Labrapollis globosus (Pflug) Krutzsch, 1968
Pl. 19, Fig. 6

Occurrence: rare, in Upper Shale Member of Mancos.

Reference specimen: slide Pb6881-4, 33.2 x 95.8.

Genus Triatriopollenites Pflug in Thomson and Pflug, 1953

Triatriopollenites cf. T. rurensis Pflug and Thomson
in Thomson and Pflug, 1953
Pl. 19, Fig. 1

Occurrence: rare to common, in Upper Shale Member of Mancos.

Reference specimen: slide Pb6880-4, 38.2 x 95.2.

Genus Plicapollis Pflug, 1953

?Plicapollis silicatus Pflug, 1953
Pl. 19, Fig. 3

Occurrence: rare to frequent, in Upper Shale Member of Mancos.

Reference specimen: slide Pb6851-3, 37.3 x 94.8.

Genus Sporopollis Pflug, 1953

Sporopollis cf. S. laqueaeformis Weyland and Greifeld, 1953
Pl. 19, Fig. 7

Occurrence: rare to common, in Upper Shale Member of Mancos.

Reference specimen: slide Pb6881-4, 45.8 x 97.1.

Genus Conclavipollis Pflug, 1953

Conclavipollis cf. C. wolfcreekensis Newman, 1965
Pl. 19, Fig. 5

Occurrence: rare, in Upper Shale Member of Mancos.

Reference specimen: slide Pb6881-4, 39.9 x 95.1.

Genus Proteacidites Cookson, 1950

Proteacidites thalmanii Anderson, 1960
Pl. 19, Fig. 12

Diagnosis: 15 to 22 μ in diameter; size of lumina decreases to punctate towards poles.

Occurrence: rare to common, in Upper Shale Member of Mancos of both sections.

Reference specimen: slide Pb6244-3, 35.4 x 104.5.

Proteacidites thalmanii var. 1
Pl. 19, Fig. 11

Diagnosis: 25 to 32 μ in diameter; semiangular in polar view.

Occurrence: rare, in Upper Shale Member of Mancos in both sections.

Reference specimen: slide Pb6244-3, 46.7 x 94.3.

Proteacidites thalmanii var. 2
Pl. 19, Fig. 10

Diagnosis: 30 to 45 μ ; angular to slightly semilobate in polar view.

Occurrence: rare, in one sample in upper part of Upper Shale Member of Mancos in Point Lookout section.

Reference specimen: slide Pb6869-3, 40.7 x 93.5.

Proteacidites cf. P. thalmanii var. 3
Pl. 19, Fig. 9

Diagnosis: 14 to 20 μ ; lumina of uniform size or only slightly smaller at the poles.

Occurrence: rare to common, Upper Shale Member of Mancos in both sections.

Reference specimen: slide Pb6881-4, 45.2 x 103.7.

Genus Liliacidites Couper, 1953

Liliacidites cf. L. leei Anderson, 1960
Pl. 19, Fig. 15

Occurrence: rare, throughout section except for Graneros Shale and Greenhorn Limestone in Ute Reservation section.

Reference specimen: slide Pb6881-4, 49.9 x 91.4.

Genus Peromonolites Couper, 1953

Peromonolites peroreticulatus Brenner, 1963
Pl. 19, Fig. 14

Occurrence: rare, in Greenhorn Limestone of both sections, in Lower Carlile Member of Mancos in Point Lookout section, in one sample in lower Upper Shale Member of Mancos in Ute Reservation section.

Reference specimen: slide Pb6273-5, 34.5 x 96.3.

Genus Trichotomosulcites Couper, 1953

Trichotomosulcites cf. T. contractus Anderson, 1960
Pl. 19, Fig. 13

Occurrence: rare, upper part of Upper Shale Member of Mancos in Point Lookout section only.

Reference specimen: slide Pb6881-4, 41.6 x 102.3.

IV. PALEOECOLOGY

Approaches to Studying the Relationships Between
and Ocean-Bottom Environments

To determine where different kinds of dispersed plant microfossils tend to occur in marine sediments two empirical approaches might be taken. One approach involves an examination of palynomorphs in modern marine environments and in modern plant communities. The other approach involves an examination of palynomorphs in rocks that can be identified with environments of deposition. The first type of approach has been carried out in a number of places around the world with greater or lesser degrees of experimental design, statistical reliability and areal coverage (Muller, 1959; Rossignol, 1961; Groot, 1966; Stanley, 1965, 1966; Traverse and Ginsburg, 1966; Cross, et al, 1966; Williams and Sargeant, 1967; Koroneva, 1957, 1964).

Aside from Staplin's (1961) study of Devonian reefs and de Jekhowsky's (1963) study of the Triassic of Madagascar, few deliberate approaches of the second type have been made. Usually they are in the form of secondary interpretations that are made after a large number of data have been gathered on certain fossils. Often these data are of varying reliability and often are not directly comparable from worker to worker. "Paleoecological" interpretations of rocks have been made by comparing them with vaguely documented analog models in the modern environment (Upshaw, 1959, 1964; Sarmiento, 1957; Zaitzeff, 1967). It seems that after the suggestion was made by Hoffmeister (1954) and Woods (1955) that certain ratios and quantities of palynomorphs may reflect distance offshore, palynologists have not rigorously tested its validity. Apparently nowhere have the data been published that are basic to these suggestions. Some of Hoffmeister's original ideas appear to be based on the assumption of wind transport of

pollen and spores from their source to the sea. Recent work has shown that wind may commonly not be a factor (Müller 1959; Cross, et al 1967; Stanley, 1965). Although Hoffmeister's hypotheses may well stand the test in some instances, they should be subjected to more testing before they are considered reliable tools.

Ideally, the second type of approach requires the identification of environments of deposition by simply examining the rocks and their facies relationships. These environments might be identified by estimations of water depth, distance offshore, water temperature, salinity, turbulence, or ion and particulates concentrations. In addition, all horizontal variations in these parameters should be detectable along firmly established "time surfaces".

An interpretation of pre-existing terrestrial plant communities might be based on extensive collecting and study of plant macro- and microfossils that are preserved in rocks of continental as well as of marine origin. But because little is actually known about how the continental part of the fossil record can be interpreted, there is essentially no record of the terrestrial communities when compared with the record of marine communities and environments. This limits the scope of interpretations that are based on this type of approach.

Because the distribution of the plants within the terrestrial environment is unknown, fossil pollen grains and spores occurring in rocks of marine origin might be considered merely as sedimentary particles originating from a stream mouth at the shore. This need not be the case for marine phytoplankton populations. Although algal cysts in settling to the bottom may drift from directly below their planktonic population, many of these cysts are, in fact, benthonic organisms (Wall and Dale, 1968) and their fossils may then be considered as part of a biocoenose. This second

type of approach is the most direct approach to learning about the habitats of extinct organisms, especially extinct microplankton.

This study is an example of this second kind of approach. The well-documented sequence of transgressions and regressions that is preserved in Upper Cretaceous rocks of southwestern Colorado was chosen as a conceptual model. This model is discussed below in detail. An explanation of this model is basic to the understanding of how the interpretations of the palynomorphs and their relation to the sedimentary environment were made.

The data gathered during this study were interpreted by subjecting them to multivariate analysis (factor analysis) in addition to simply plotting them in the form of relative frequencies of palynomorphs and numbers of palynomorphs per gram of rock.

Model of Transgressions and Regressions

Basis for Model

The conceptual model of a transgressing and regressing shoreline that is utilized in this study is based on the interpretations of Pike (1947), Dane (1960) and Lamb (1968) (see also Krumbein and Sloss, 1951, p. 261; Weller, 1960, p. 484-501) and is represented diagrammatically in figure 7. This diagram illustrates the stratigraphic relationships of the rock units present in a cross-section along a line that is normal to the trend of the shoreline and that includes the Point Lookout and Ute Reservation sections. The line of section is shown in figure 1 as line A-A'. It will be determined whether or not palynomorph assemblages from within the Mancos Shale reflect transgressing and regressing environments that parallel this oscillating shoreline.

The major transgressions and regressions that are represented by the Greenhorn Limestone, the Carlile Shale and the Upper Shale Member

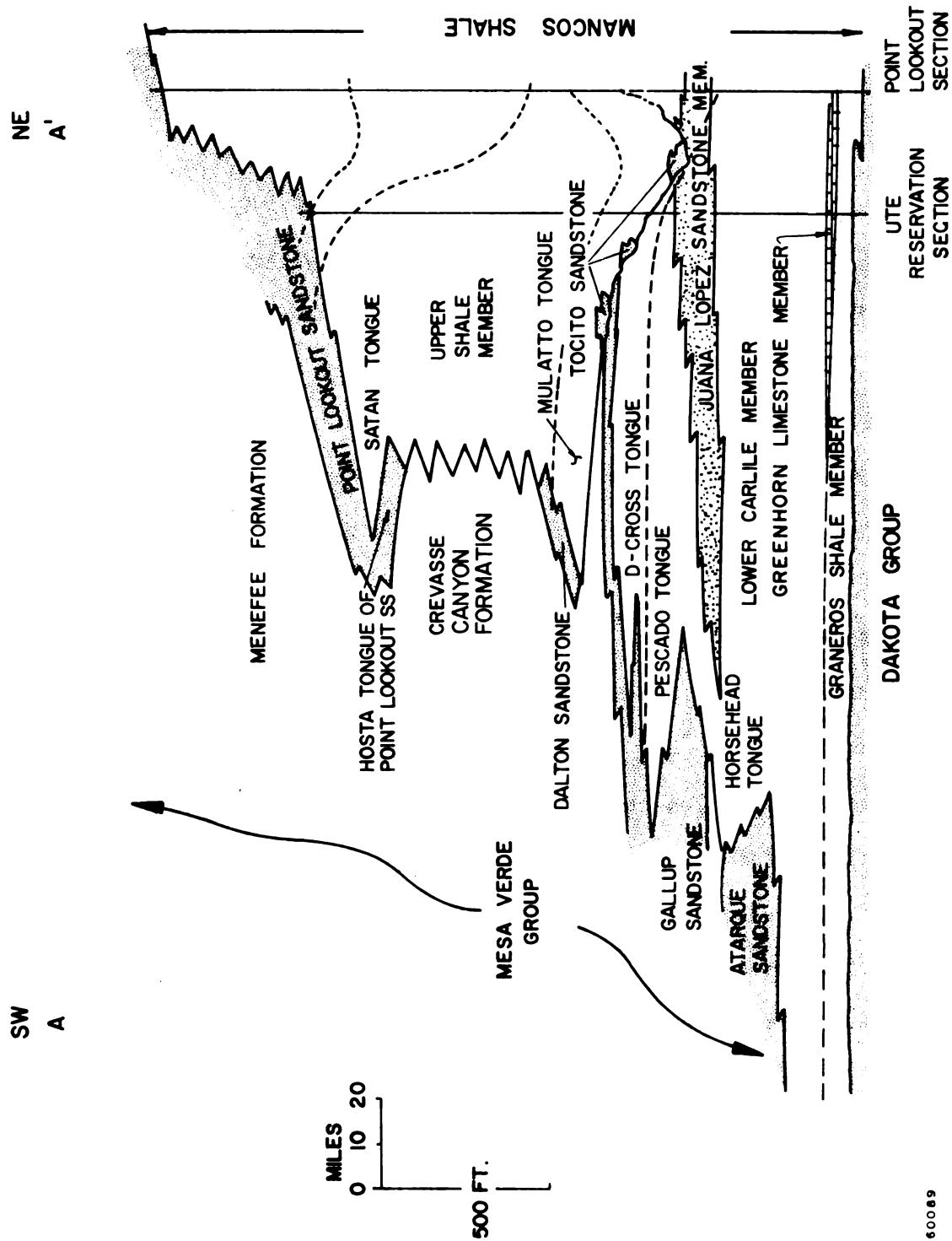


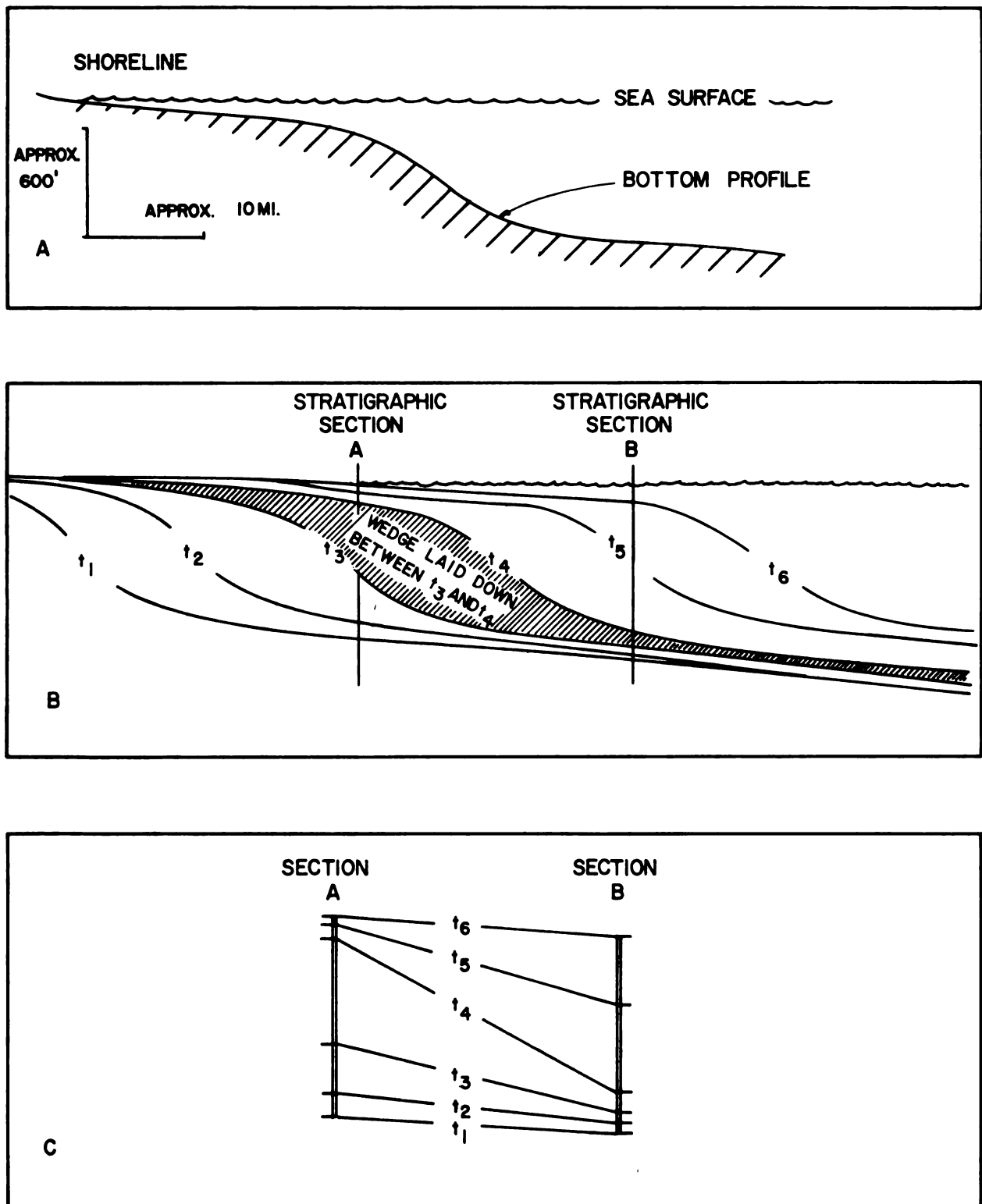
FIGURE 7.--Cross-section A-A' (see fig. 1) showing the position of the strandline sandstones and related formations in the study area and the area to the south. Dashed lines represent time correlations. (After Pike, 1947, Geol. Soc. Am. Mem. 24, pl. 11; and Dane, 1960, Am. Jour. Sci., v. 258-A, fig. 3, p. 51).

of the Mancos as shown in figure 7 are equivalent to T_1 , R_1 , T_2 , and R_2 of Weimer (1960); Transgressions 1 and 2 and Regressions 1 and 2 of Kauffman (1967); and in part to the Greenhorn Cyclothem of Hattin (1964). These oscillations of the shoreline are recognized over the whole western interior of the United States.

Steeply-Dipping "Time Lines"

Some explanation may be in order concerning the steeply-dipping "time lines" that have resulted from the graphic correlation between the two sections. Pike's (1947) correlations based on molluscs show the same steeply-dipping "time lines". Assuming this correlation is a good approximation of the actual case (this assumption is the basis for further interpretations made in this study), the sloping "time lines" may be explained in the following way.

One may consider that the Upper Cretaceous sea-bottom in southwestern Colorado was a plain with water depths and slope similar to those of a modern shelf environment. Sand, silt and clay were being dumped from rivers flowing into the west edge of the seaway. In the modern shelf environment, the profile of the surface over which sediment is accumulating offshore is generally in the shape of a sigmoid curve (fig. 8A). This curve is also a "time line" since it represents the present sea bottom. An example of this profile is the longitudinal profile of a delta. However, the geomorphic feature of a delta may not always be manifested. In an area undergoing active sedimentation, a profile offshore from an interdeltaic barrier island-type shoreline should have a similar although subdued profile. It is commonly assumed that this profile is near equilibrium with regard to water turbulence, current velocities, sediment supply, grain-size frequency distribution, etc. (Twenhofel, 1950, p. 230-233; Weller, 1960, p. 498-501; Shepard, 1960, p. 65; Scruton, 1960, p. 88-93; Curray and Moore, 1964).



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FIGURE 8.--Diagrams illustrating the development of a clastic wedge and "time lines" within it at times, t_1 , t_2 , t_3 , t_4 , t_5 , and t_6 . (A) shows bottom profile; (B) illustrates seaward migration - a regression; (C) shows straight-line time correlations that could be made between sections A and B.

If the shoreline regressed in response to seaward accretion of sediments the profile of equilibrium would migrate seaward. If the whole sediment pile is subsiding, a wedge-shaped mass of sediment would be outlined as this profile migrates (Scruton, 1960; Curray and Moore, 1964). This wedge would be contained between two "time lines" (or "surfaces" in the three dimensional sense). Figure 8B is a diagram depicting slight subsidence and the migration of the profile seaward and its position at several instants in time. In no case do the "time lines" (profiles) rise seaward.

If these sediments are preserved intact, the "time lines" should retain their same relationships. (With compaction and with subsidence that tends to be greatest in a seaward direction, the "time lines" may become even more steeply-inclined seaward.) Should two stratigraphic sections be examined at the positions indicated in figure 8B, the inclined "time lines" would cut the two sections as shown in figure 8C.

A transgressing shoreline would be accompanied by a shoreward movement of the profile. If there were subsidence and the sediments were preserved, this would result in a similar sequence of change in slope of the "time lines" between the two sections.

The rocks in the upper part of the Ute Reservation and Point Lookout sections reflect the northeastward migration of a clastic wedge associated with the regression of the shoreline represented by the Point Lookout Sandstone.

The position of the thickest part of a wedge in relation to the shoreline is probably chiefly determined by the grain-size frequency distribution of the contributing river's load and the velocity of the vector of water movement in a seaward direction. Apparently the thickest part of the wedge that is represented by the Upper Mancos Shale was composed

of silty and slightly-sandy clays and lay roughly 30 miles offshore.

(Evidence for this is presented later.)

In a situation like the Upper Cretaceous of Southwestern Colorado such a convergence and divergence of "time lines" between two sites can be interpreted as a change in the position of the clastic wedge.

Because the classic area of the standard Upper Cretaceous section in the Missouri Valley and the Great Plains is situated on the very thin seaward-edge of the wedge, the "time lines" between sections there will be essentially parallel. Probably only in the area of nearer-shore environments in western Colorado, eastern Utah and the Four-corners area can these dipping "time lines" be drawn between stratigraphic sections.

The Carlile-Niobrara Unconformity

The position of the "Carlile-Niobrara" unconformity in the diagrams (fig. 7) represents the latest published regional interpretation. This was made by Lamb (1968) and incorporates correlations that are based on Foraminifera in addition to that based on molluscs that were utilized in earlier correlations.

As depicted in figure 7 the unconformity truncates the Gallup Sandstone and to the north moves down through shale of Carlile age finally cutting into the Juana Lopez Member. Farther north it rises in the section and may terminate before it reaches the Point Lookout section.

The exact position at which the unconformity is placed in the Point Lookout and Ute Reservation sections is disputable. The unconformity is recognizable throughout the area to the south and southeast where the Tocito Sandstone unconformably overlies shale or the Gallup Sandstone.

(Lamb, 1968). Unfortunately the Tocito Sandstone is absent from both the Ute Reservation and the Point Lookout sections. The Tocito is a coarse-grained, commonly cross-bedded, clean quartz sandstone up to 40 feet thick. Aside from some quartz sandstones up to a few inches thick the only sandstones present in the two sections over this interval are calcarenites and these are up to only a few feet thick. These calcarenites are reasonably assigned to the Juana Lopez member. The decision to place the unconformity in the Point Lookout and Ute Reservation sections as it is shown in the diagram is based on the following pieces of evidence.

- (1) The only quartz sand in this interval in either section is situated in the Ute Reservation section about 50 feet above a unit of thin calcarenites interbedded with shale that is attributable to the Juana Lopez Member. This would correspond closely with the level of the unconformity as interpreted by Lamb.
- (2) A sandy (calcarenite) interval with very thin calcarenites occurs 225 feet above the Juana Lopez at Point Lookout. This probably reflects shoaling that can be correlative with a shallower area to the south which was undergoing appreciable erosion. As Lamb suggests, the unconformity is higher in the section at Point Lookout than in sections to the south. At Point Lookout it probably does not represent an appreciable hiatus.
- (3) In the range chart of palynomorphs arranged according to lowest occurrences in the Ute Reservation section (fig. 10) there are 17 forms that first occur just above the interval of thin sands and sandy shale that lies 50 feet above the Juana Lopez. This indicates an appreciable break in the rock record. No hiatus of such magnitude is indicated at Point Lookout (fig. 9).

- 1 *Fern O sp. 1*
 2 *Unidentified Verrucaria* sp.
 3 *Leiodia* sp. and *Metaleotia* sp.
 4 *Fern S sp. 2*
 5 *Odonotrichina striatoporella*
 6 *Deflandrea* sp. 2
 7 *Classopellis* cf. *C. classoides* (large)
 8 *Fern T sp. 1*
 9 *Lycopodiumsporites cernidites*
 10 *Diphyes* cf. *D. colligum*
 11 *Cicatricosisporites* sp. 1
 12 *Pteropemopsis* sp.
 13 *Hystrichosphaeridium* cf. *H. dearei*
 14 *Polysphaeridium* sp.
 15 *Unidentified Hystrichosphaera* sp.
 16 *Tanyosphaeridium* cf. *T. varicellatum*
 17 *Verrucium* cf. *V. europaeum*
 18 *Unidentified Psilata Monocolepale Pollen*
 19 *Hystrichosphaera ramosa*
 20 *Palaeohystrichophora infusoroides*
 21 *Cynasphaera* sp.
 22 *Concavispores* sp. 1
 23 *Tricolpopollenites henrici*
 24 *Unidentified Reticulate Tricolpale Pollen*
 25 *Hystrichosphaera ramosa* var. 2
 26 *Tenua* sp.
 27 *Palaeohystrichophora* sp.
 28 *Fern C sp. 1*
 29 *Fern B sp. 2*
 30 *Gleichenioidites senonius*
 31 *Cardianguina diaphana*
 32 *Triplanosporites sinuosus*
 33 *Camaronosporites insignis*
 34 *Appendicisporites* cf. *A. tricornatus*
 35 *Dicotrachites* cf. *D. clavatus*
 36 *Tricolpopollenites* sp. 1
 37 *Fern F sp. 1*
 38 *Oligosphaeridium pulcherrimum*
 39 *Tetracosphaeridium phaeomites*
 40 *Hexapollera suspecta*
 41 *Fern S sp. 1*
 42 *Inaperturopollenites* sp. 1
 43 *Camellia* cf. *C. collivieri*
 44 *Hystrichosphaeridium* cf. *H. tubiferum*
 45 *Fomes amphora*
 46 *Hystrichosphaera* sp. 1
 47 *Thorspinella spinosa*
 48 *Dicodinium arcticum*
 49 *Dinogymnium* sp. 2
 50 *Aeroligera* sp.
 51 *Acanthotrites varispinosus*
 52 *Tricolporites rhomboides*
 53 *Tricolpites* cf. *T. explanata* (small)
 54 *Unidentified Foveolate Monocolepale Pollen*
 55 *Unidentified Reticulate Monocolepale Pollen*
 56 *Dinogymnium* sp. 1
 57 *Sarcosphaeridium* cf. *S. vestitum*
 58 *Litosphaeridium siphonophorum*
 59 *Baltisphaeridium* cf. *B. srysensis*
 60 *Deflandrea* sp. 1
 61 *Hesleria hesleriana*
 62 *Unidentified Hystrichosphaeridium - type*
 63 *Eucommidiites trochodoni*
 64 *Unidentified Echinata Trilete Spores*
 65 *Fern X sp. 1*
 66 *Unidentified Baltisphaeridium* sp.
 67 *Tricolpopollenites* sp. 8
 68 *Baltisphaeridium* sp. 1
 69 *Unknown Cicatricose Trilete Spores*
 70 *Large Equisetoides* sp.
 71 *Unidentified Verrucaria Trilete Spores*
 72 *Condosphaeridium* sp.
 73 *Palaeohystrichophora infusoroides* var. 1
 74 *Hystrichosphaeridium* sp. 2
 75 *Sphaeromorphites antiquasporites*
 76 *Triplanosporites* cf. *T. lenticularis*
 77 *Cingulatisporites dakotensis*
 78 *Small Equisetoides* sp.
 79 *Inaperturopollenites linbaui*
 80 *Inaperturopollenites* sp. 2
 81 *Triplanosporites* sp.
 82 *Condosphaeridium difficile*
 83 *Hystrichosphaera ramosa* var. 1
 84 *Gonyaulacysta* sp.
 85 *Tricolpopollenites* sp. 2
 86 *Condosphaeridium* sp. 1
 87 *Micronidium* cf. *M. ornatum*
 88 *Perennellites perreticulatus*
 89 *Extratropopollenites* sp.
 90 *Hystrichosphaera fenos*
 91 *Tricolpopollenites* sp. 1
 92 *Fern B sp. 4*
 93 *Fern L sp. 1*
 94 *Tricolporites traversi*
 95 *Tricolpites* cf. *T. bathyreticulatus*
 96 *Unidentified Striate Tricolpale Pollen*
 97 *Fern D sp. 1*
 98 *Verrucosporites* cf. *V. foveus*
 99 *Rupicola vesiculites* cf. *R. reductus*
 100 *Baltisphaeridium* cf. *B. infatum*
 101 *Deflandrea* cf. *D. granulifera*
 102 *Tricolpopollenites* sp. 5
 103 *Unknown Dinoflagellate*
 104 *Deflandrea* cf. *D. verrucosa*
 105 *Unidentified Psilata Tricolpale Pollen*
 106 *Unidentified Psilata Monolete Spores*
 107 *Cyclonophelium* sp.
 108 *Cicatricosisporites* cf. *C. hallei*
 109 *Deflandrea* sp. 3
 110 *Deflandrea* cf. *D. balnei*
 111 *Unidentified Psilata Trilete Spores*
 112 *Unidentified Striate Trilete Spores*
 113 *Unidentified Verrucaria Tricolpale Pollen*
 114 *Unidentified Oligosphaeridium - type*
 115 *Deflandrea* cf. *D. minor*
 116 *Deflandrea* cf. *D. acuminata*
 117 *Unidentified Foveolate Tricolpale Pollen*
 118 *Verrucium* cf. *V. stellatum*
 119 *Cicatricosisporites* cf. *C. denegensis*
 120 *Tricolpites* cf. *T. explanata* (large)
 121 *Tricolpopollenites* sp. 1
 122 *Fern C sp. 3*
 123 *Vireisporites pallidus*
 124 *Tricolpopollenites* cf. *T. scabropes*
 125 *Inaperturopollenites* sp. 3
 126 *Tricolpopollenites* sp. 2
 127 *Tricolpopollenites* sp. 3
 128 *Tricolpopollenites* sp. 4
 129 *Reticulopollenites* cf. *R. neopensis*
 130 *Cyathoides* cf. *C. mesozoicus*
 131 *Duplopollis* cf. *D. orthocheilus*
 132 *Cenclavipollis* cf. *C. wolffreckensis*
 133 *Palaeobages* cf. *P. deflandrei*
 134 *Cicatricosisporites* cf. *C. carlyensis*
 135 *Peltoidospora halli*
 136 *Tricolpopollenites* sp. 6
 137 *Abies - type Pollen*
 138 *Triadapollis* sp. 1
 139 *Proteacidites thalassii*
 140 *Sporopollis lignosiformis*
 141 *Perocarpopollenites* sp. 1
 142 *Hexacolepale Pollen Grain*
 143 *Plicapollis silicatus*
 144 *Tricolpopollenites* cf. *T. latus*
 145 *Deflandrea* sp. 4
 146 *Proteacidites* cf. *P. thalassii* var. 3
 147 *Hexapollenites suspecta* var. 2
 148 *Unidentified Reticulate Monolete Spores*
 149 *Triadapollenites* cf. *T. nensis*
 150 *Proteacidites thalassii* var. 1
 151 *Deflandrea* cf. *D. micracantha*
 152 *Concavispores variaverrucatus*
 153 *Lubraepollis globosus*
 154 *Leiodites pseudomaculatus*
 155 *Kyrtisporites scutatus*
 156 *Pflaegpollenites dampieri*
 157 *Tetrapollis* cf. *T. hemiparvus*
 158 *Concavispores punctatus*
 159 *Classopollis* sp. 1
 160 *Unidentified Verrucaria Monolete Spores*
 161 *Tricolpopollenites* cf. *T. scabropes* (small)
 162 *Equisetoides bandus*
 163 *Small Pinus - type Pollen*
 164 *Concavispores* cf. *C. phylloporus*
 165 *Quadrupollis kempii*
 166 *Urdulatisporites* sp. 1
 167 *Parvisaccites* sp. 1
 168 *Inaperturopollenites linbaui* (with "bladder")
 169 *Fern H sp. 1*
 170 *Trichomesulcites* cf. *T. contractus*
 171 *Fern D sp. 1*
 172 *Proteacidites thalassii* var. 2
 173 *Reticulopollis* cf. *R. geranioides*
 174 *Tricolpopollenites* sp. 3

FIGURE 9

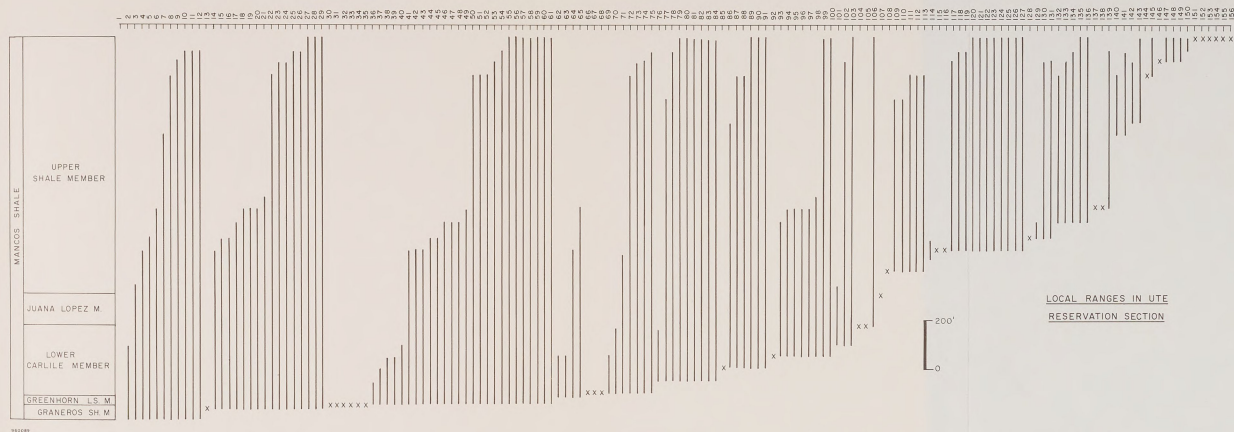


Fig. 10 - Local range chart of palynomorphs in the Ute Reservation section. See opposite for taxon names.

- 1 Form 0 sp. 1
 2 Tricolpites sp. 1
 3 Tricolpites sp. 8
 4 Baltisphaeridium cf. B. infatum
 5 Dicotrachites cf. D. clavatus
 6 Deflandrea sp. 1
 7 Form X sp. 1
 8 Unidentified Deflandrea sp.
 9 Verrucium cf. V. europaeum
 10 Dicodinium arctium
 11 Dinogonium sp. 1
 12 Form C sp. 1
 13 Verrucium cf. V. stellatum
 14 Tricoccosphaeridium phragmites
 15 Gleichenioides oerindites
 16 Aeroligera sp.
 17 Trigonozoidia sp.
 18 Hystichosphaera ramosa
 19 Hystichosphaeridium cf. H. deanei
 20 Unidentified Verrucium sp.
 21 Deflandrea sp. 2
 22 Form S sp. 2
 23 Deflandrea cf. D. granulifera
 24 Inaperturopollenites sp. 1
 25 Classopollis cf. C. classoides (large)
 26 Polyysphaeridium sp. (1)
 27 Large Pinus - type Pollen
 28 Unidentified Reticulata Tricolpate Pollen
 29 Tenua spp.
 30 Unidentified Reticulata Monolete Spores
 31 Tricoccosphaeridium sp.
 32 Corobosphaeridium sp. 1
 33 Form D sp. 1
 34 Hesleria hesleronense
 35 Verrucium sp. 1
 36 Baltisphaeridium cf. B. syriensis
 37 Tricoccosphaeridium sp. 2
 38 Hystichosphaera ramosa var. 1
 39 Corobosphaeridium sp.
 40 Hystichosphaeridium cf. H. tubiferum
 41 Unidentified Verrucata Tricolpate Pollen
 42 Leiotusa spp. and Metaleiotusa spp.
 43 Form T sp. 1
 44 Tanyosphaeridium cf. T. varicellatum
 45 Odenochitina striatoporella
 46 Hystichosphaera sp. 1
 47 Diphyes cf. D. colligerum
 48 Unidentified Baltisphaeridium sp.
 49 Tricolpites cf. T. bathyreticulatus
 50 Hystichosphaera ramosa var. 2
 51 Eucosmidites broedsonii
 52 Unidentified Hystichosphaera spp.
 53 Acanthotrites varispinosus
 54 Unidentified Foveolata Monocolpate Pollen
 55 Tricoccosphaerites sp. 1
 56 Eucosmidites cf. E. couperi
 57 Tricolpites rhomboides
 58 Unidentified Psilate Monocolpate Pollen
 59 Liliacites cf. L. leei
 60 Oligosphaeridium pulcherrimum
 61 Dinogonium sp. 2
 62 Picea - type pollen
 63 Small Equisetosporites spp.
 64 Peromonolites peroveticulatus
 65 Cardianguina diaphana
 66 Unidentified Striate Tricolpate Pollen
 67 Form L sp. 1
 68 Cernigia cf. C. colliveri
 69 Form D sp. 1
 70 Microdinium cf. M. ornatum
 71 Tricodopites sp. 2
 72 Deflandrea cf. D. acuminata
 73 Lycopodium spores cermidites
 74 Form H sp. 1
 75 Candad Palaeohystichophora sp.
 76 Tricolpites sp. 3
 77 Deflandrea sp. 3
 78 Palmbagae cf. P. deflandrei
 79 Gleichenioides senonicus
 80 Leiotrites pseudomaculatus
 81 Rugulobrevicollis cf. R. reductus
 82 Tricolpites sp. 2
 83 Unidentified Reticulata Monocolpate Pollen
 84 Deflandrea cf. D. balnei
 85 Inaperturopollenites limbatus (bladder)
 86 Formae amphora
 87 Triplanosporites sinuosus
 88 Form C sp. 3
 89 Lamigatosporites cf. L. oratus
 90 Inaperturopollenites limbatus
 91 Tricolpites cf. T. anguloluminosus
 92 Sphagnosporites antiquissimosporites
 93 Cyclosphegium sp.
 94 Conversucosporites cf. C. phlyvernucosus
 95 Cicatricosporites sp. 1
 96 Form F sp. 1
 97 Sarcosphaeridium cf. S. vestitum
 98 Cicatricosporites cf. C. denogensis
 99 Large Smooth Trilete Spores
 100 Cyathidites cf. C. mesozonicus
 101 Deflandrea cf. D. verrucosa
 102 Thomomella spinosa
 103 Palaeohystichophora idusoides var. 1
 104 Pericolpites sp. 1
 105 Deflandrea cf. D. minor
 106 Tricolpites sp. 6
 107 Deflandrea sp. 4
 108 Unidentified Oligosphaeridium - type
 109 Reticulites cf. R. georgensis
 110 Triplanosporites sp. 1
 111 Tricolpites sp. 4
 112 Tricolpites sp. 5
 113 Tricolpites cf. T. explanata (large)
 114 Small Pinus - type pollen
 115 Cingulatisporites dakotensis
 116 Large Equisetosporites spp.
 117 Tricolpites cf. T. homiparus
 118 Form B sp. 4
 119 Inaperturopollenites sp. 3
 120 Vitreosporites palidus
 121 Tricolpites traversi
 122 Tricolpites sp. 1
 123 Duploisites cf. D. orthoichus
 124 Tricolpites cf. T. explanata (small)
 125 Triplanosporites cf. T. scabroporus
 126 Cicatricolpites cf. C. wellfleetensis
 127 Protacacidites thamni
 128 Unidentified Verrucata Monolete Spores
 129 Tricolpites sp. 1
 130 Tricolpites cf. T. lectus
 131 Protacacidites cf. P. thamni var. 3
 132 Triplanosporites cf. T. lentarius
 133 Sporopollis laqueiformis
 134 Protacacidites thamni var. 1
 135 Unidentified Psilate Monolete Spores
 136 Tricolpites allicatus
 137 Phragmites dampieri
 138 Verrucosporites cf. V. faveus
 139 Unidentified Psilate Trilete Spores
 140 Hexapollenia suspecta var. 2
 141 Unidentified Verrucata Trilete Spores
 142 Unidentified Psilate Tricolpate Pollen
 143 Deflandrea cf. D. micracantha
 144 Unidentified foveolata Tricolpate Pollen
 145 Triplanosporites cf. T. nurensis
 146 Triplanosporites cf. T. scabroporus (annulus)
 147 Hexapollenia Pinus Grain
 148 Lamigatolites globosus
 149 Equisetosporites lunulus
 150 Quadrilobites lunulus
 151 Unilobites sp. 1
 152 Tricoccosporites punctatus
 153 Unidentified Echinata Trilete Spores
 154 Cicatricosporites cf. C. hallii
 155 Unidentified Reticulata Monolete Spores
 156 Classopollis sp. 1

FIGURE 10



Fig. 10 - Local range chart of palynomorphs in the Ute Reservation section. See opposite for taxon names.

1	Fern O sp. 1				
2	Tricolpollenites sp. 1				
3	Tricolpollenites sp. 8				
4	Baltisphaeridium cf. B. infatum				
39	<u>Cordosphaeridium</u> spp.				
40	<u>Hysteroisphaeridium</u> cf. <u>H. tubiferum</u>				
41	Unidentified Vernucula Tricolpate Pollen				
42	<u>Leiotusa</u> spp. and <u>Metaleiotusi</u> spp.				
77	<u>Deflandrea</u> sp. 3				
78	<u>Palumbops</u> cf. <u>P. deflandrei</u>				
79	<u>Gleichenioidites</u> <u>senonicus</u>				
80	<u>Leiotriletes</u> <u>pseudomacurus</u>				
108	Unidentified <u>Oligosphaeridium</u> - type				
109	<u>Retitricolpites</u> cf. <u>R. georgensis</u>				
110	<u>Triopopollenites</u> sp. 1				
111	<u>Tricolpopollenites</u> sp. 4				
141	Unidentified Vernucula Trilete Spores				
142	Unidentified Psilate Tricolpate Pollen				
143	<u>Deflandrea</u> cf. <u>D. micrantha</u>				
144	Unidentified fusulate Tricolpate Pollen				

- (4) Factor analysis (to be discussed later) indicates that a sample within the quartz sandy interval mentioned in (1) above in the Ute Reservation section was laid down "nearer shore" than samples immediately above or below. In this interval at Point Lookout no "near-shore" samples occurred.
- (5) The upper of two "time lines" based upon the graphic correlation in this interval rises going from the Ute Reservation section to Point Lookout. This could result from the removal of some of the rock column at the Ute Reservation section relative to the Point Lookout section.

Other possible interpretations of the position of the unconformity are summarized separately below. These are rejected hypotheses.

- (1) In both sections the unconformity cuts the Juana Lopez Member. The sand immediately above the unconformity may be formed from shell debris (producing a calcarenite) at these sites rather than being formed from quartz sand. The uppermost calcarenite assigned to the Juana Lopez at Point Lookout weathers lighter in color, has fewer fossils and is more regularly thin-bedded than the next lower calcarenite which is 30 feet below. This could be a calcarenite facies of the Tocito.
- (2) The unconformity is situated immediately above the Juana Lopez Member in the Ute Reservation section and is absent from the Point Lookout section. The Tocito equivalent in the Ute Reservation section might be a calcarenite that is indistinguishable from the Juana Lopez Member as in the

last paragraph. According to Lamb's interpretation the unconformity could lie immediately above the Juana Lopez at this locality.

- (3) The unconformity is not present in either section. The lack of any unequivocal lithologic evidence of an unconformity within the two measured sections suggests this.

Time-Transgressive Nature of the Juana Lopez Member

As interpreted here and in Lamb (1968) the Juana Lopez Member crosses time planes and is younger to the northeast. The correlation made here indicates that the sediments that were laid down at the time of the Pescado tongue transgression lie above the Juana Lopez in the Ute Reservation section and below the Juana Lopez in the Point Lookout section. The rocks of the Juana Lopez represent a shoal that migrated northeastward with the regression that laid down the sediments of the Gallup Sandstone further south.

Redeposition of Palynomorphs

Recycling, reworking or redeposition of palynomorphs has often been demonstrated and can intuitively be expected in any rock that contains terrigenous detritus. It is obvious that the presence of unrecognized redeposited palynomorphs could cause one to draw erroneous conclusions.

In the Mancos Shale one should expect to find some pre-Mancos palynomorphs. However, only about a dozen spores of recognizable pre-Mancos age were observed in the examination of all the residues used in this study. This indicates that reworking may not be statistically significant here. Of course reworking of long-ranging palynomorphs from pre- or older Mancos into younger Mancos may go undetected. However, the thickness of Upper Cretaceous rocks preserved in this area from both

continental and marine environments suggests that there was considerable subsidence relative to sea level during their deposition. This subsidence would tend to allow sediment to collect with little further erosion and transport once it had been deposited. The amount of reworking of microfossils within the Upper Cretaceous could be negligible on the time scale considered here. No "reworked palynomorph" group was recognized and all interpretations of the data assume that there is no reworking of palynomorphs.

Analysis of the Data

Assemblage Approach versus Taxon Approach

Two approaches to the interpretation of the fossil assemblage data can be made. One kind of approach considers the assemblage of each sample as a whole and is analogous to the interpretation of whole modern ^(Q mode) communities. The other kind of approach considers the distribution of each taxon separately and is analogous to interpretations of individual modern species populations. ^(R mode)

Factor analysis in the Q-mode, to be discussed below, is a community-type of approach. (although not applied in this study, factor analysis in the R-mode is of the population-type of approach.) In this study, in addition to Q-mode factor analysis, the calculation of diversity indices for each sample is of the first type of approach. The identity of each taxon is unimportant in this approach.

Interpretations of relative frequencies and numbers per gram of the individual taxa is the second type of approach. Here one is interested in learning something about the distribution of the original living population represented by the individual fossil taxa.

Factor Analysis

Instead of comparing samples qualitatively or graphically using a few common palynomorphs, as has been commonly done in palynology, it is desirable to compare each sample with all other samples on the basis of its complete assemblage considering the abundance of each species in each sample. A number of multivariate mathematical analyses are now known that can do just this. Among these is factor analysis. Factor analysis, as opposed to other methods, was used in this study because (1) a computer program was readily available (this type of analysis is essentially impossible without the use of a high-speed computer) and (2) this analysis technique had been used to interpret a number of different kinds of data, including paleontologic, with satisfactory results.

The specific objectives of factor analysis as given by Imbrie and van Andel (1964) are as follows:

"...vector (factor) analysis of a set of compositional data may be initiated with one or more of the following three objectives: (1) to achieve a parsimonious statement of the information contained in the table of data; (2) to classify the samples into natural groups; and (3) to resolve each sample into a small number of components, each component representing the contribution of a functional unit (or end member)."

The computer program utilized in this study is the Columbia Vector Analysis Program (COVAP) developed by Manson and Imbrie (1964). It was adapted for use on the CDC 3600 computer at Michigan State University and later on the UNIVAC 1108 computer at Shell Oil Company's Houston Data Service Center. A preliminary program was developed by Don Merritt of Michigan State University to simplify data input into COVAP. The mathematics of the program and some of the underlying theory is discussed in

Imbrie (1963, 1964), Manson and Imbrie (1964), and Imbrie and van Andel (1964). The theory of factor analysis is covered in detail by Harman (1960), Catell (1952) and others.

COVAP as it is utilized in this study handles the counts of palynomorphs as percentages and analyzes them in the Q-mode (see Catell, 1952). The program utilizes the principal components method of factor solution and the varimax method of factor rotation. In addition an oblique projection analysis is performed which resolves the samples into end members that are themselves actual samples (Imbrie and van Andel, 1964).

In addition to factor analysis of the whole set of data that included the samples from both sections and 220 taxa (variables), the analysis of each of the following sub-sets was also carried out.

- (1) pollen grains and spores (120 variables)
- (2) microplankton (100 variables)
- (3) all pollen grains, spores and microplankton that range completely over both sections (65 variables)
- (4) All pollen and spores that range completely over both sections (43 variables)
- (5) All microplankton that range completely over both sections (22 variables)

The analyses were performed using 10, 9, 8, 7, 6, 5, 4, and 3 end members for each set of variables. Reducing the number of variables from 220 to 65, from 120 to 43 and from 100 to 22 in the different sub-sets of data generally did not affect the end members that were chosen in each sub-set.

The simplest factor analysis of the data using 22 long-ranging microplankton and three end members with 70% communality appears to give

the most meaningful results. By restricting the number of variables to those species or other taxa that range completely through both sections it was hoped that the influences of evolutionary change on the analysis would in part be removed. Also, the changes in the marine environment should be more clearly shown by further restricting the variables to the microplankton. An interpretation of this analysis was made with objective (2) of Imbrie and van Andel in mind with the samples being distributed into three groups. Each group contains one end member together with all those samples that are most heavily "loaded" on that end member.

In figure 11 each factor group of samples is represented by a pattern. The distribution of the members of each group is shown in each stratigraphic section and "facies boundaries" are drawn between the samples of different groups. ✓

These boundaries directly reflect the transgressions and regressions of the shoreline as indicated in figure 11. As alluded to above, the occurrence of a member of factor group 3 immediately above a member of group 1 in the middle of the Ute Reservation section suggests the position of an unconformity. The inference is made here that these three factors are all largely correlated with distance offshore. Group 1 tends to be farthest from shore, Group 3 tends to be nearest to shore, and Group 2 appears to be intermediate.

The influences of environmental factors other than those related to distance offshore might be uncovered with further study. In this study however, "distance offshore" is the only environmental parameter that is "controlled" and its "effect" is the only one that can be reliably interpreted. The possible real environmental factors controlling this distribution, if this is indeed what they are, will be discussed after other kinds of evidence are presented.

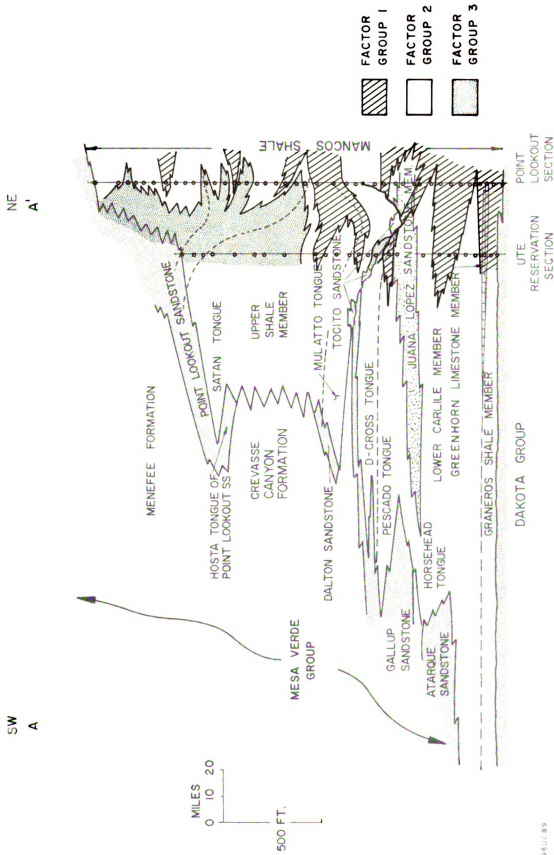


FIGURE 11.--Diagram showing the results of factor analysis of palynomorphs overlaid on the stratigraphic cross-section shown in figure 7.

The following microplankton were used in the factor analysis.

Hystrichosphaera ramosa var. 2
H. ramosa var. 3
 Form F sp. 1
Oligosphaeridium pulcherrimum
Cordosphaeridium spp.
Exochosphaeridium phragmites
Palaeohystrichophora infusoroides
P. infusoroides var. 1
Palaeohystrichophora spp.
Diconodinium arcticum
Hexagonifera suspecta var. 1
H. suspecta
Dinogymnium sp. 1
Dinogymnium sp. 2
 Form B sp. 1
 Form B sp. 2
 Form B sp. 3
 Form C sp. 1
 Form C sp. 2
 Form S sp. 1
Michrystridium spp.
Surculosphaeridium cf. S. vestitum

Estimation of Distance Offshore

The distance offshore at which each rock sample was deposited was determined by interpolation from curves (fig. 12). These curves were constructed from information shown in figure 7 (which is based on figure 7, page 94, and plate 11 of Pike, 1947, and figure 3, page 51, of Dane, 1960). The distances of the shoreline from the sites of the two stratigraphic sections as determined from these published illustrations were plotted on two graphs, one for each section. One graph has as its ordinate the distance (in feet) above the base of the Point Lookout section. The other graph has as its ordinate the distance (in feet) above the base of the Ute Reservation Section. Both graphs have distance offshore on the abscissa. The positions of each transgression and regression in either section was determined from the correlation lines and the pattern of factor groups shown in figure 11. Because the exact geometry of the rock record and the rates of change in subsidence

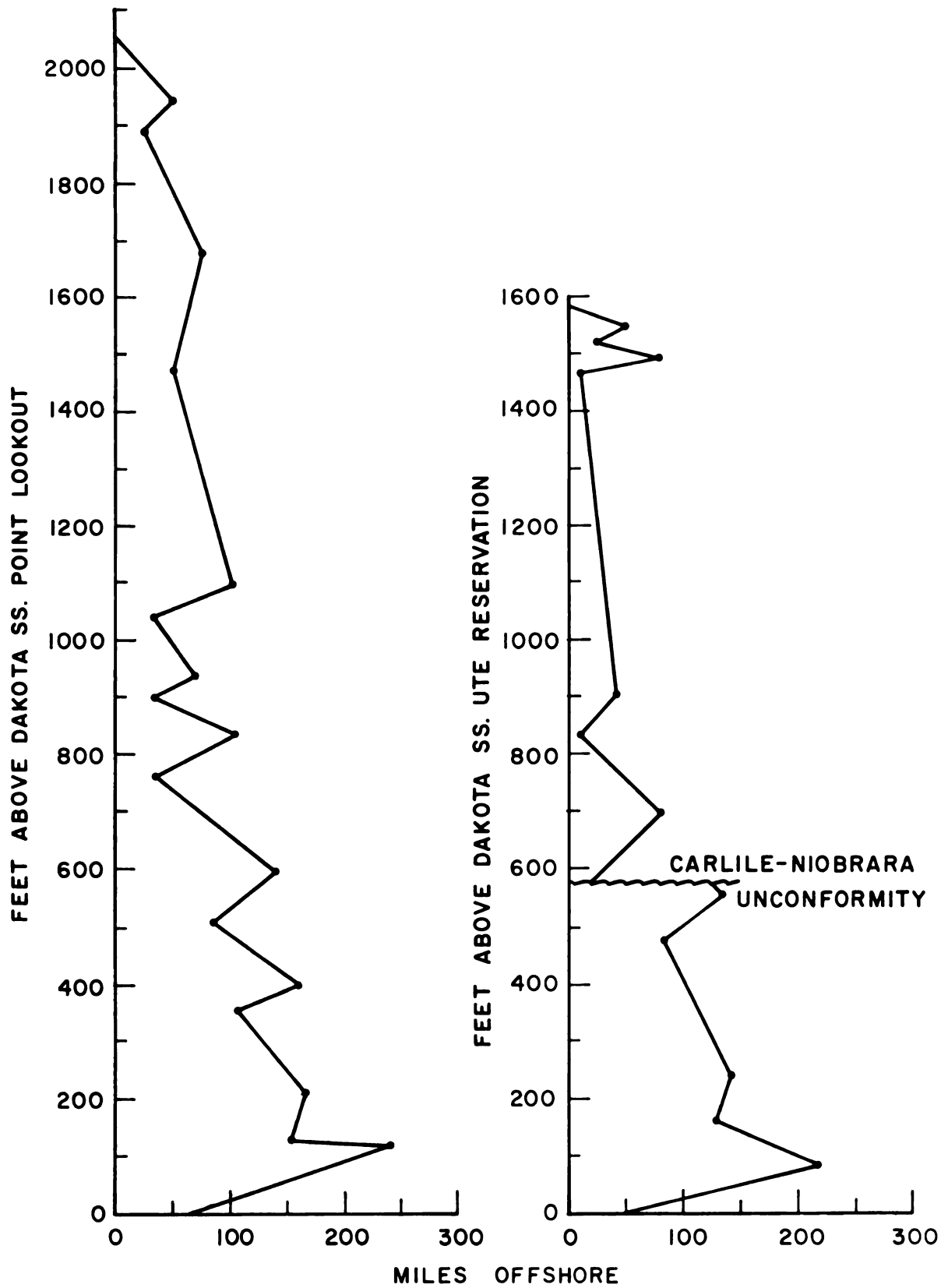


FIGURE 12.--Curves for the Point Lookout section (left) and the Ute Reservation section (right) used to determine distance offshore for each sample. These curves are based on the results of the factor analysis, Pike (1947) and Dane (1960).

and in shoreline oscillation are not known, the control points on the graph (positions in each section of changes from transgression to regression or regression to transgression) are connected simply by straight lines. The distance offshore at which each sample was deposited is taken as the X-coordinate of the intercept of the zigzag curve with the line representing the distance of the sample above the base of the section.

These values for distance offshore for each sample are the basis for the interpretations made below concerning diversity, relative frequency and numbers per gram of rock.

Diversity

"Diversity" as used here denotes both richness (number of species) and the distribution of numbers of individuals among the species. Diversity has thus been recognized as a character that is useful in comparing communities regardless of their genetic composition. To make such comparisons one must calculate same index of diversity for each community that is to be compared. Commonly within a community there are only a few species that are abundant while many are relatively rare, but the degree to which this is true varies from community to community. The ~~severity~~ ✓ of the physical or chemical environment or the intensity of interspecific competition within a community appears to be reflected in the diversity of that community (Odum, 1957; Odum, Cantlon, and Kornicker, 1960). When compared along gradients of latitude or of environmental factors (salinity, temperature fluctuation, insolation, etc.) communities vary in diversity. For example, a tropical rain forest is more diverse than an arctic tundra and a quiet-water environment is more diverse than a turbulent-water environment.

In this study diversity indices were calculated for the palynomorph assemblage in each sample in an effort to determine if an empirical relation exists between the estimated distance offshore (above) and the diversity of a fossil assemblage (being analogous to a community). Although several diversity indices have been proposed, one that is widely used in current ecological studies is an index derived from information theory. This form is used here. The advantages of this form of diversity index are discussed in Margalef (1957) and Patten (1962). The assemblage diversity index of a sample is given by:

$$D = -\sum_{i=1}^k n_i \log(n_i/N)$$

where n_i = number of individuals in species i

k = number of species in the sample

N = number of individuals in the sample (sample size)

These calculations are based on only those palynomorphs that were counted within the sum of 500 in each sample.

In figure 13 the diversity indices for (1) microplankton and (2) pollen and spores are plotted against the estimated distance offshore. The points on the graph appear to reflect distance offshore.

The diversity of microplankton tends to increase offshore while the diversity of pollen and spores decreases offshore. The specific causes for these changes are not known. However, it would appear that the causes are related to some environmental factors that correlate with distance offshore. The diversity of the pollen and spores assemblage might decrease offshore simply because of a sorting process. As the grains settle from suspension only those that have reached the sea in great abundance, have high buoyancy and that are resistant to corrosion may reach greater dist-

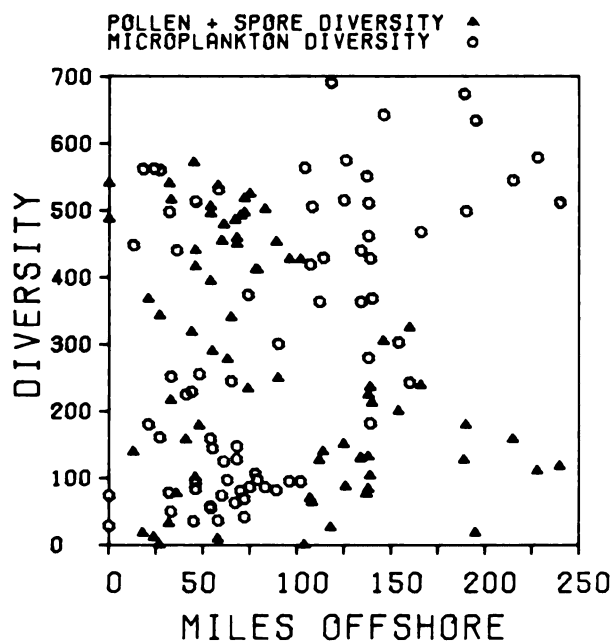


FIGURE 13.--Diversity of Microplankton and of pollen and spores plotted against distance offshore.

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ances offshore. Thus only a "specialized" few would reach far offshore.

Perhaps the microplankton are more diverse farther offshore because the environment is more stable there. There would be less fluctuation in salinity, turbidity and nutrients due to variations in the influx of stream waters. Because the water depths were probably greater farther offshore there would be less frequent agitation due to wave motion below certain depths.

The variation in diversity of both groups decreases with distance offshore. This, to may reflect the stability of the environment. Greater variation in diversity indices would indicate that the stability of the environment fluctuated.

"Paleoautecology"

As stated above, the factor analysis in the Q-mode and diversity indices fail to reveal any specific information about the individual taxa of palynomorphs. The term "paleoautecology" infers that some knowledge is gained about the autecology of the once-living organisms whose existence is recorded in the form of fossils. With our present state of knowledge inferences are usually limited to those concerning the habitat of some of these organisms and are commonly based on somewhat gross assumptions.

When interpreting fossil dinoflagellate cysts we must assume that (1) large numbers of cysts of a species reflect large numbers in its living population; (2) the cysts are found in their natural (but lithified) substrate (if it is assumed that they are benthonic life stages) or they are in the sediment directly beneath their motile planktonic population (if they are not considered benthonic); (3) a dominant of a fossil cyst assemblage was a dominant of the dinoflagellate plankton population in life - in other words, the intrinsic rates of cyst production and preservation are the same in all dinoflagellate species.

A check of the above assumptions applied to modern dinoflagellates would require studies of living populations. Because many dinoflagellate cyst-species are extinct these studies would have limited value. Even extant cyst-species that are found in the fossil record can not always be identified with their motile form. Wall and Dale (1968) have shown the apparent multiplicity of some cyst types attributable to single living motile species as well as the multiplicity of some motile species attributable to a single cyst type. Obviously many more data are needed on the morphology, life cycles, and population dynamics of living dinoflagellates before the ecology of fossil cysts can be interpreted correctly. Despite the realization of these shortcomings in interpreting these fossils, some interpretations will be made here that are based on (1), (2), and (3), above. These interpretations as well as those of pollen and spores are based on graphs of relative frequencies and numbers per gram of rock of various palynomorph taxa plotted against distance offshore.

Distributions of Individual Taxa

To interpret the relationship between distance offshore and the abundances of various palynomorphs two approaches are taken. (1) The abundances of a palynomorph in each of the two sections may be compared simply by considering the sections as two gross samples situated at different distances offshore. (2) The relative frequencies and numbers per gram of common long-ranging palynomorphs may be plotted on a graph against the estimated distance offshore to determine if they tend to reflect distance offshore.

When the two sections are compared as two gross samples most of the taxa occur in higher relative frequencies in the Point Lookout

section or they have essentially equal values in both sections. Those forms with higher relative frequencies in the Ute Reservation section are: Cyamtiosphaera spp., Pterispermopsis spp., Form C sp. 1, Form S sp. 1 and ?Horologinella spinosa Cookson. These few taxa tend to be more abundant nearer shore than the Point Lookout section and tend to lower the relative frequencies of all the other palynomorphs nearer shore.

In figures 14 through 22 are shown the graphs of percentages and numbers per gram of rock of the common palynomorphs found in the Mancos plotted against the estimated distance offshore.

By examining these graphs one should gain some idea of where the individual palynomorphs taxa tend to be differentially concentrated in relation to the shoreline. These distributions may be interpreted in light of the palynomorph sedimentation rates which in turn may be determined by the size and hydrodynamic properties of the palynomorphs, their supposed initial production, their susceptibility to decay, the location and size of their supposed source area and their mode of transport.

Distributions of numbers of various palynomorphs per gram of rock should aid in the interpretations of relative frequency distributions. However, they must be considered in view of sedimentation rates of inorganic detritus as well as those of the organic particles.

Although trends in some palynomorph distributions are suggested by these graphs, control of more lithologic parameters, more well-chosen stratigraphic sections and more samples taken at closer intervals are needed before one can really begin to understand the role of environment in controlling these distributions.

An attempt is made here to interpret the distributions of the more common palynomorphs in the Mancos Shale as reflecting reversible

environmental factors. Although they are not clear-cut, these distributions may at least serve to cast some doubt on the wide use of relative abundance peaks for time correlation.

Pollen and Spores

Classopollis spp. -- The distributions of the relative frequency (all percentages of pollen grains shown in the graphs are based on the sum of pollen and spores only) and the number per gram of rock of Classopollis spp. are shown in figure 14. The highest relative frequencies occur in samples from farthest offshore.

This distribution perhaps reflects the mode of transport of the grains. Contrary to what Pocock and Jansonius (1961) state, Classopollis pollen grains may have been relatively buoyant. The tegillate exine (see Petitt and Chaloner, 1964) could serve to make them less dense than most other pollen types. Also, they were probably produced in large numbers comparable to modern pine.

How such distributions of the pollen grains might be produced is suggested in the modern Gulf of California. In sample transects off the river mouths in the Gulf, percent pine pollen is high in the most seaward samples (Cross, et al, 1967). this may represent the distribution of pollen grains that are transported through the air to the sea surface as opposed to the distribution of grains that are transported to the sea by water. The air-transported grains would tend to be carried farther out to sea than the water-transported grains which would be deposited nearer shore. In addition to its being more widely dispersed by wind, pine pollen tends to predominate simply because it is so abundant relative to other pollen grains. Classopollis pollen may have behaved in a manner similar to pine pollen.

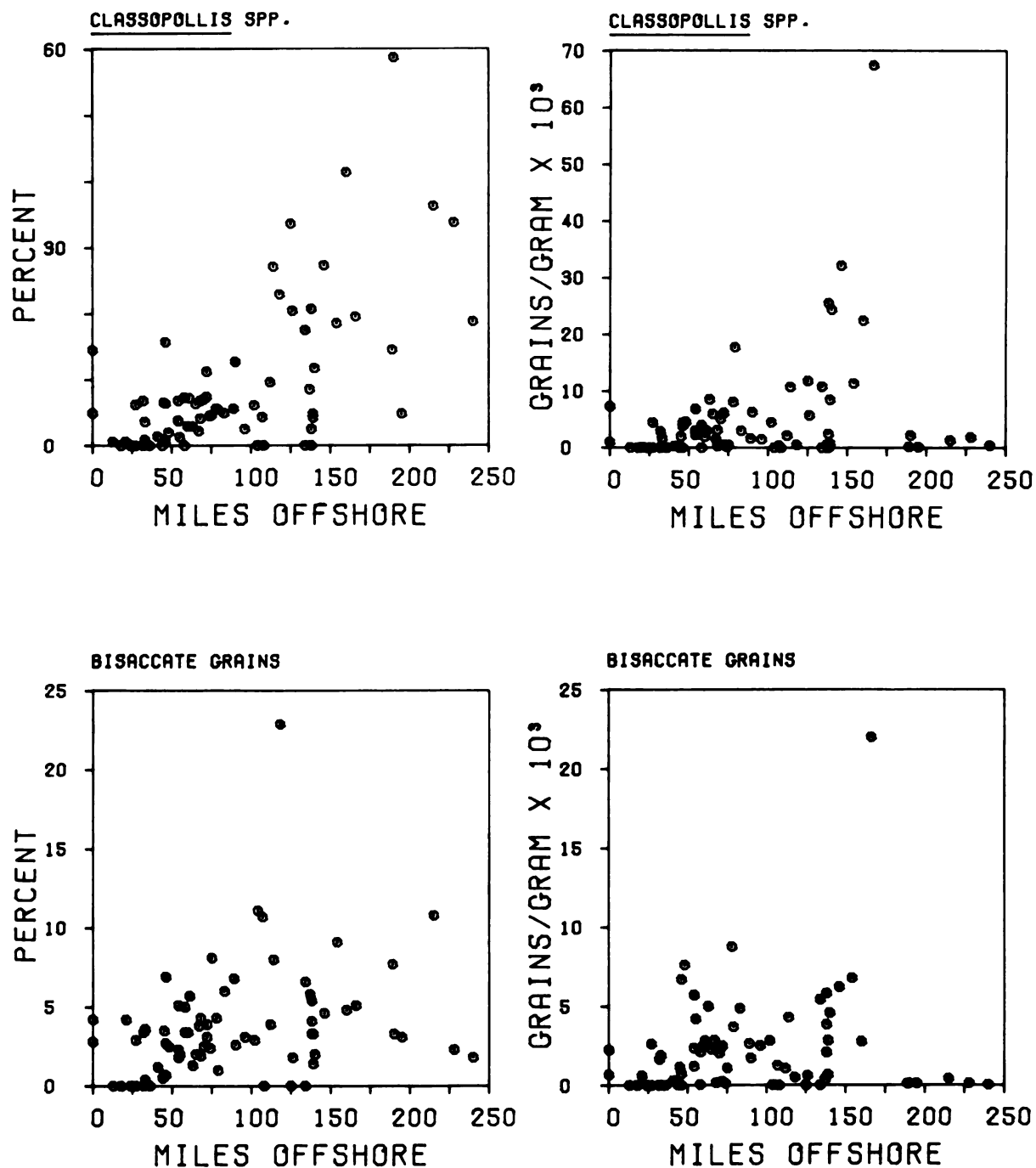


FIGURE 14.--Relative frequency and grains per gram of Classopollis spp. and of bisaccate grains plotted against distance offshore. The percentages are based on the sum of pollen and spores.

Another explanation is that Classopollis pollen may simply be more durable to the corrosion accompanying seaward transport. This reasoning can also be applied to the distribution of pine pollen since it has been shown to be more durable than most common pollen grains (Sangster and Dale, 1964; Havinga, 1964).

The highest numbers of Classopollis grains per gram of rock occur at intermediate distances offshore. A possible cause for this will be mentioned later.

Bisaccate Pollen -- If Classopollis pollen behaved similar to bisaccate pollen one would expect them to have similar distributions. Unfortunately bisaccate pollen is not overly abundant in the Mancos Shale. The distributions of bisaccate pollen shown in figure 14 show a slight tendency to increase offshore.

Inaperturopollenites sp. 1 -- The percentage of this taxon tends to increase offshore (fig. 15) this may reflect air transport for this Taxodiaceous pollen. Taxodium grows in mostly coastal, swampy riverside habitats and probably contributes pollen to the air for long-distance transport. Some may also be supplied to the stream's suspended load which could result in the moderate relative frequencies in the near-shore samples. Numbers per gram of rock are high over a wide range.

Tricolpopollenites cf. T. micromunus -- The distributions of percent of total pollen and spores and numbers per gram of rock of Tricolpopollenites cf. T. micromunus are shown in figure 15. The highest relative frequencies tend to occur near shore with the highest number per gram of rock at 75 to 100 miles offshore. Its abundance, size and form would suggest that it is wind pollinated. The approximate mean distance is 16 μ . As suggested by Hoffmeister (1954) the ratio of small diameter

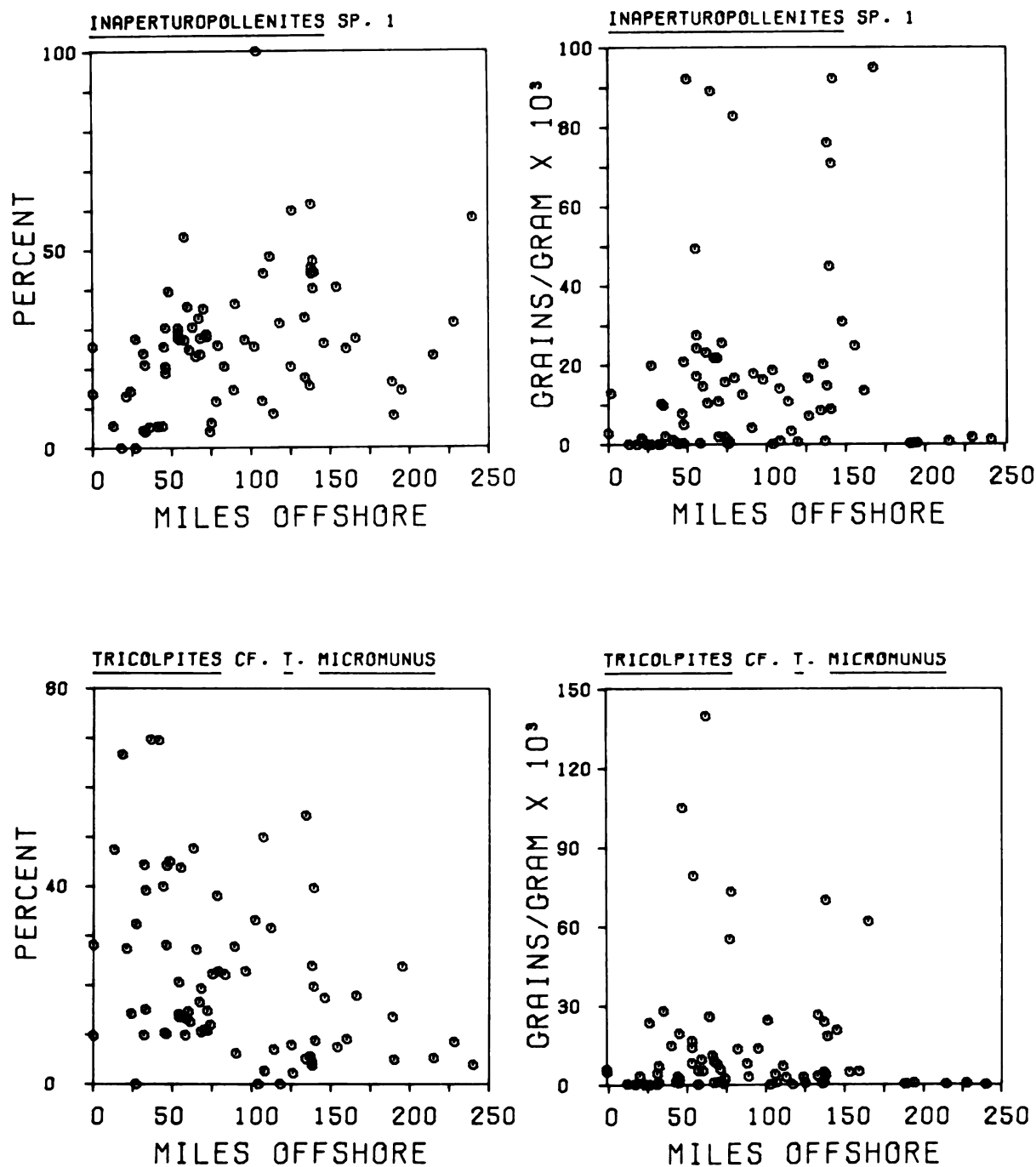


FIGURE 15.--Relative frequency and grains per gram of Inaperturopollenites sp. 1 and of Tricolpites cf. T. micromunus plotted against distance off-shore. Percentages are based on the sum of pollen and spores.

grains to larger diameter grains should increase with distance offshore. This does not appear to be the case when this grain's distribution is compared with that of the larger Classopollis and the smaller T. sp. 7.

Tricolpopollenites sp. 7 -- This grain has a mean diameter of about 8 μ . It occurs in greatest numbers nearer shore than the larger common pollen grains (fig. 16). One might reason that its small size and form indicate that it comes from a wind pollinated plant. Wind pollinated plants commonly produce large amounts of pollen. Because this taxon occurs in low frequencies one might then assume that it grew some distance inland.

Microplankton

Microplankton with processes -- Most of the hystichosphere (microplankton with processes) taxa tend to increase offshore. The relative frequency and number per gram of rock of the following hystich categories were plotted. Michrystidium spp. (fig. 16), acritarchs with processes (fig. 21), Hystichosphaera spp. (fig. 18), Palaehystichophora infusoroides (fig. 18), chorate cysts (fig. 21), and microplankton with processes (fig. 22).

All of the above taxa tend to increase in relative frequency with increase in distance of sample offshore except Paleohystichophora infusoroides. P. infusoroides tends to have higher relative frequencies in samples from intermediate distances offshore. This dinoflagellate might be considered a proximate cyst because its processes consist only of hairs and it exhibits a definite peridinoid shape. All of these taxa except P. infusoroides tend to have highest numbers per gram in samples from about 125 to 175 miles offshore. P. infusoroides has its high numbers per gram in samples from nearer shore.

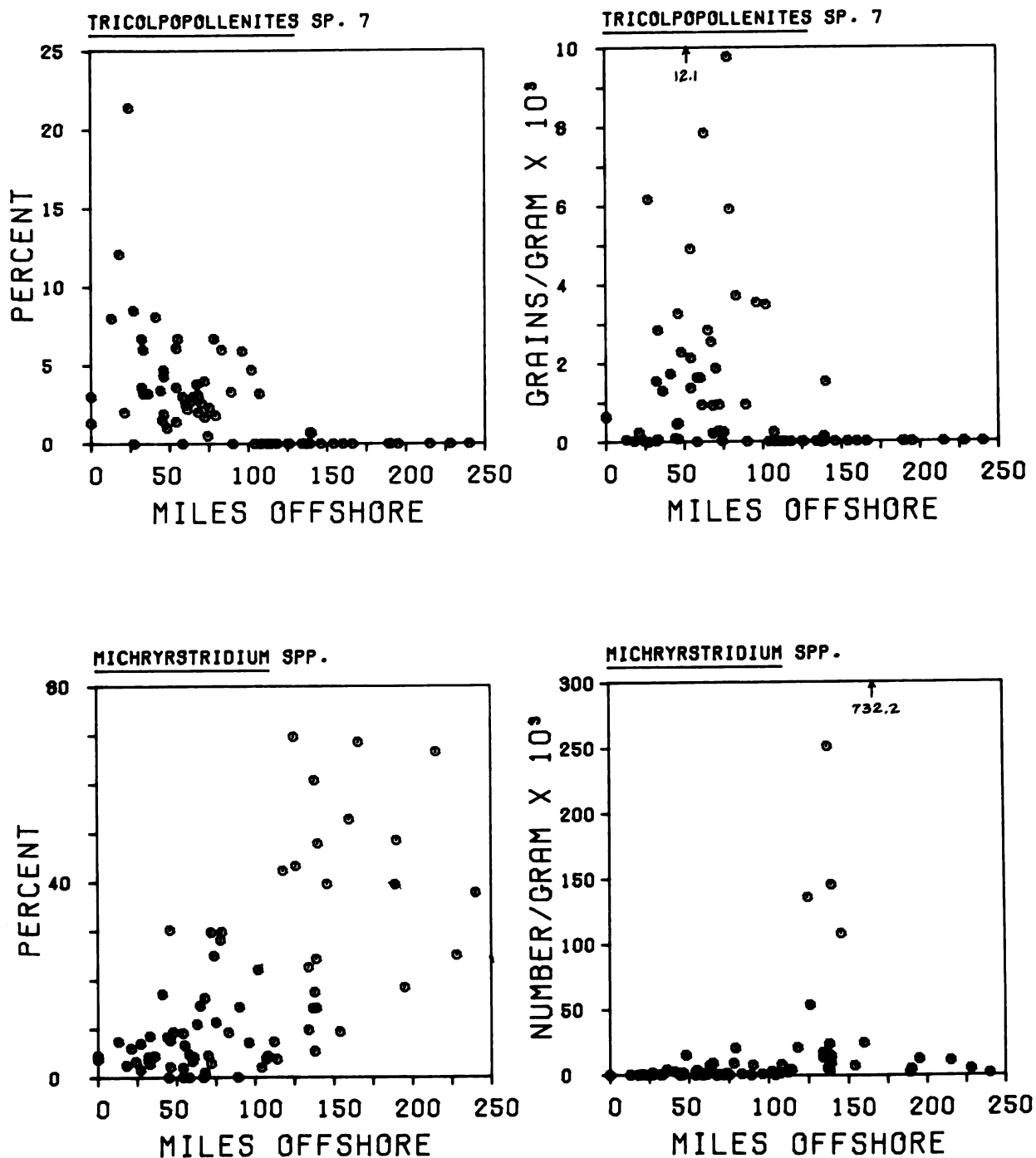


FIGURE 16.--Relative frequency and number per gram of Tricolpopollenites sp. 7 and of Michrystridium spp. plotted against distance offshore. Percentage of T. sp. 7 is based on the sum of pollen and spores. Percentage of Michrystridium is based on the sum of microplankton. Arrow denotes value off the graph.

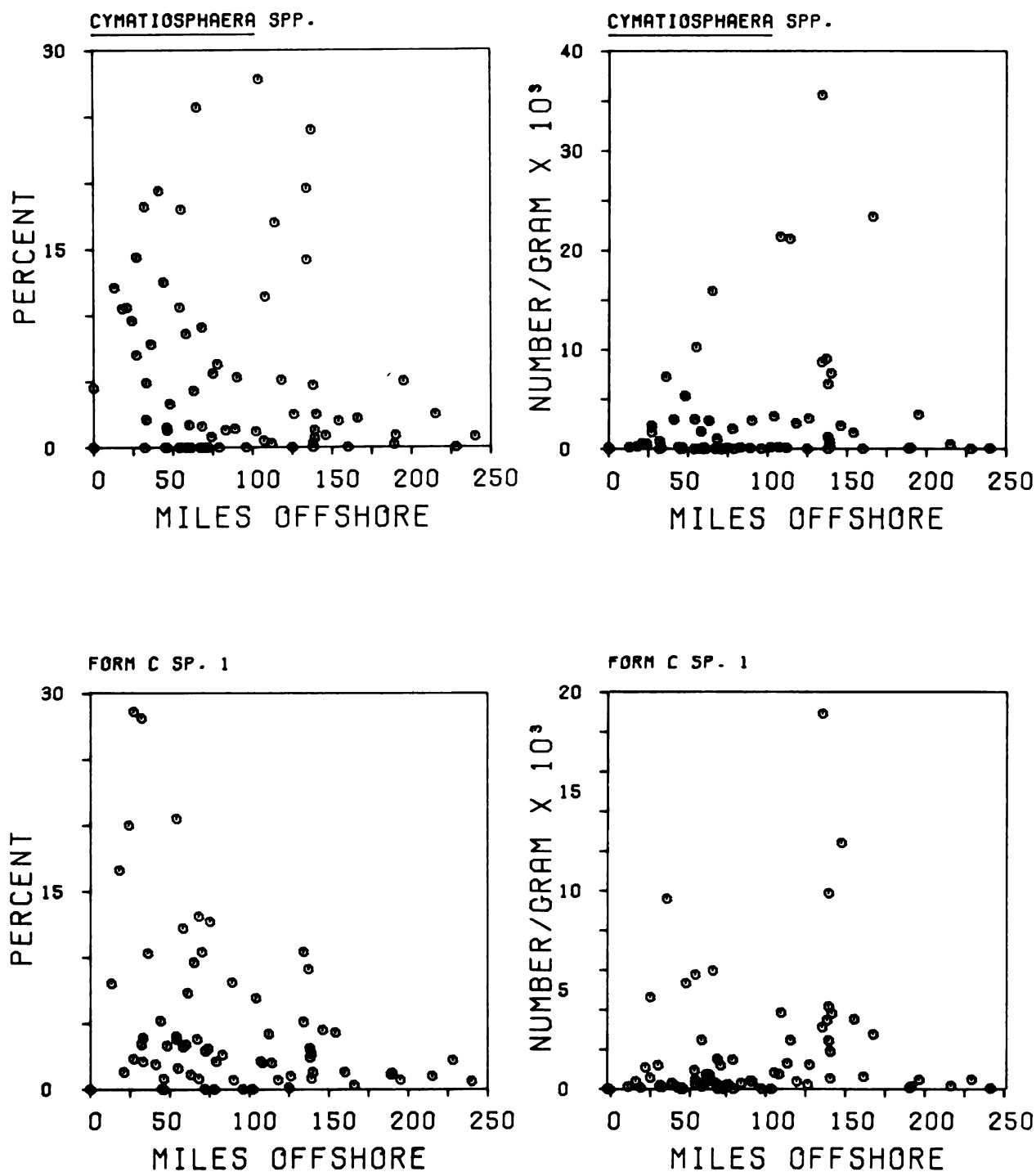


FIGURE 17.--Relative frequency and number per gram of *Cymatiosphaera* spp. and of Form C sp. 1 plotted against distance offshore. Percentages are based on the sum of microplankton.

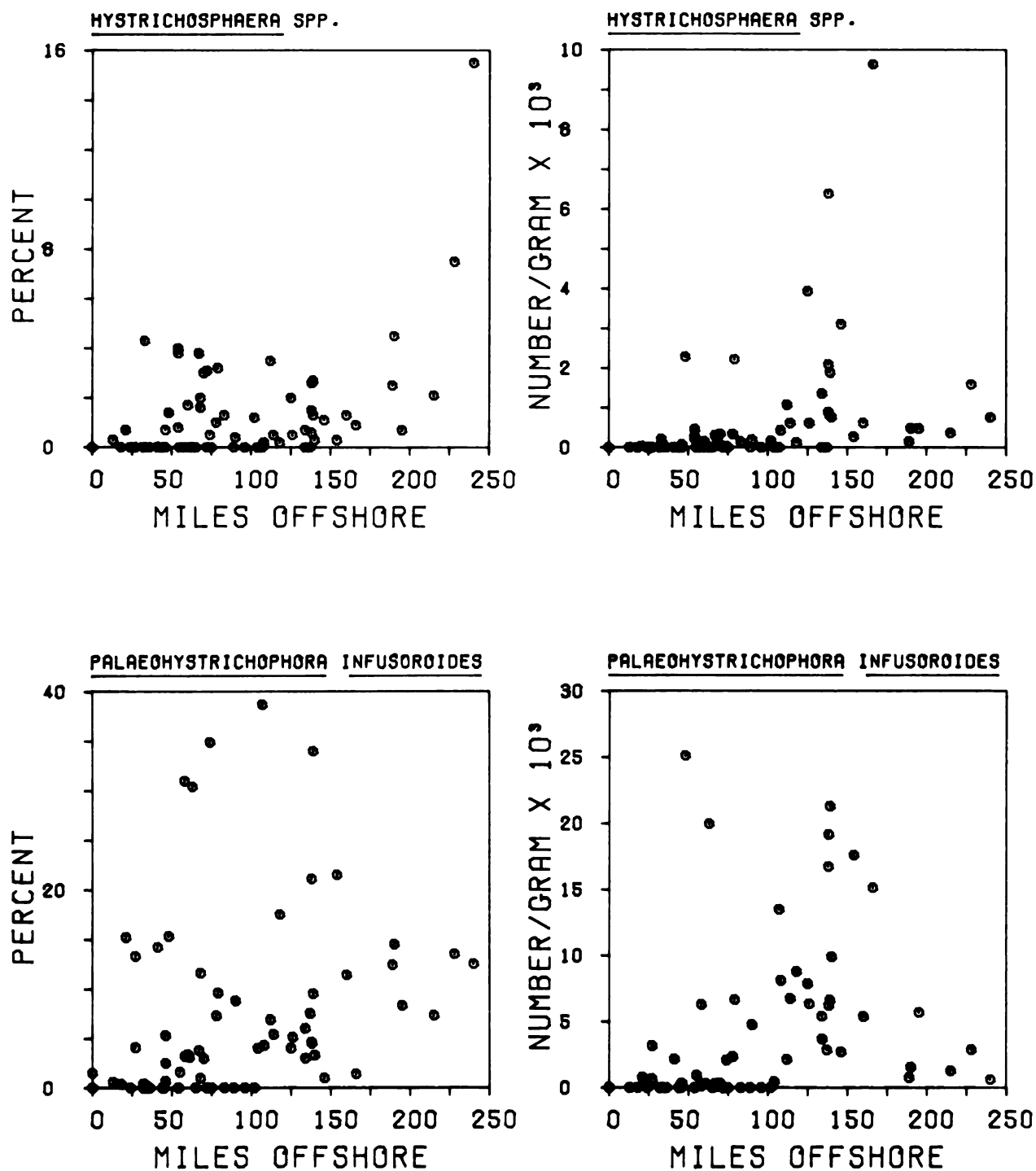


FIGURE 18.--Relative frequency and number per gram of *Hystrichosphaera* spp. and of *Palaeohystrichophora infusoroides* plotted against distance offshore. Percentages are based on the sum of microplankton.

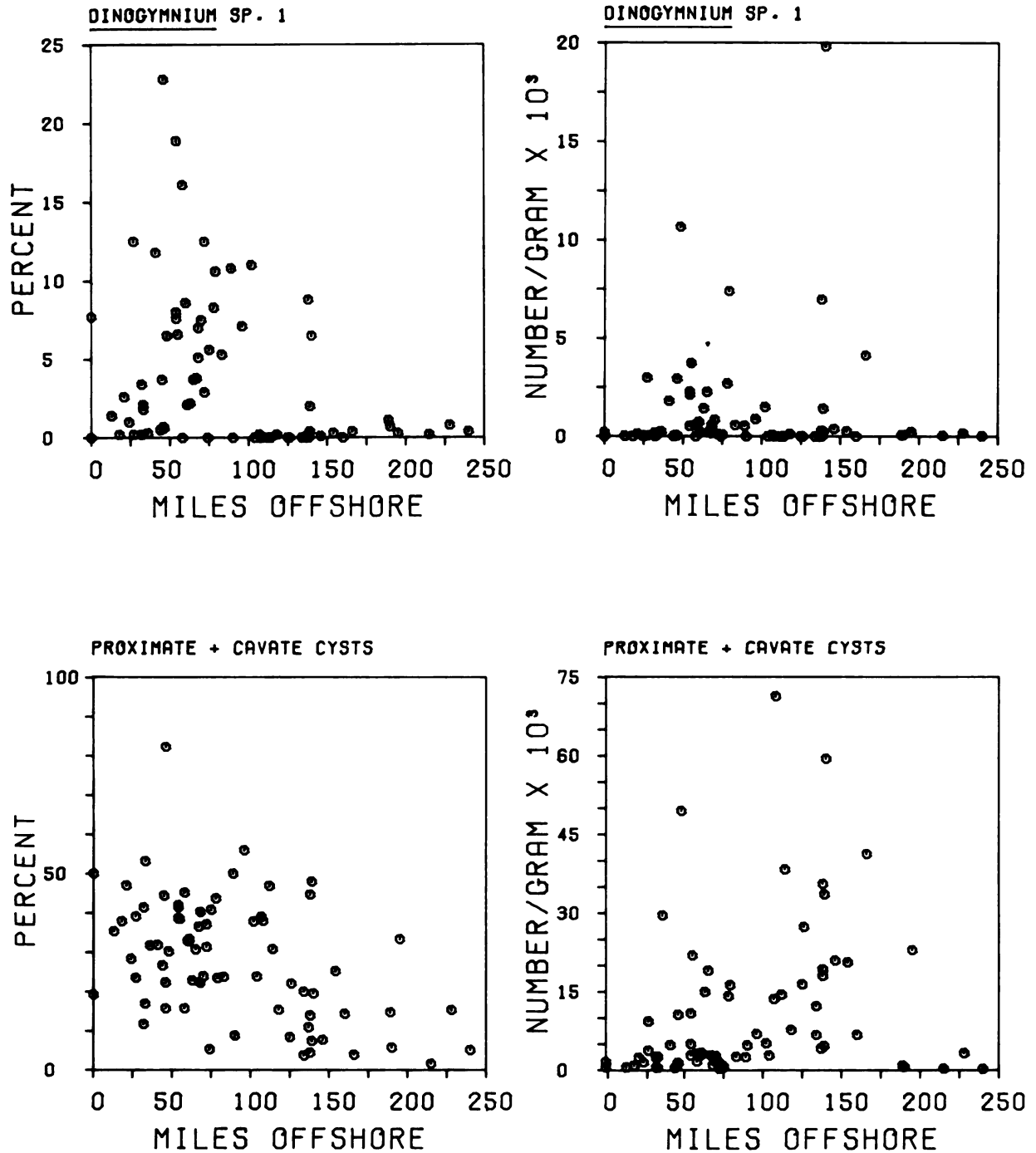


FIGURE 19.--Relative frequency and number per gram of *Dinogymnium* sp.1 and of proximate plus cavate cysts plotted against distance offshore. Percentages are based on the sum of microplankton.

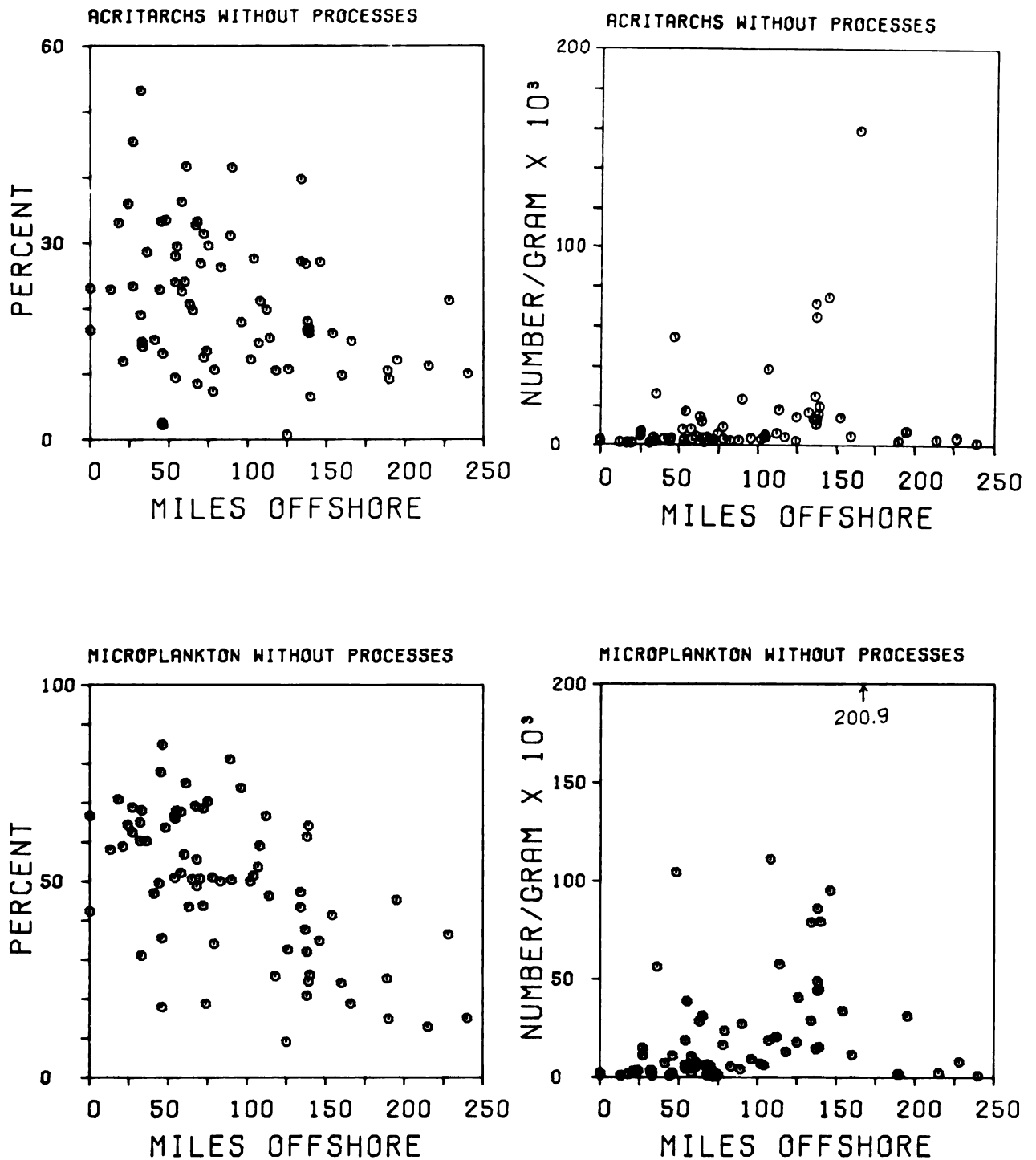


FIGURE 20.--Relative frequency and number per gram of acritarchs without processes and of microplankton without processes. Percentages are based on the sum of microplankton. Arrow denotes value off the graph.

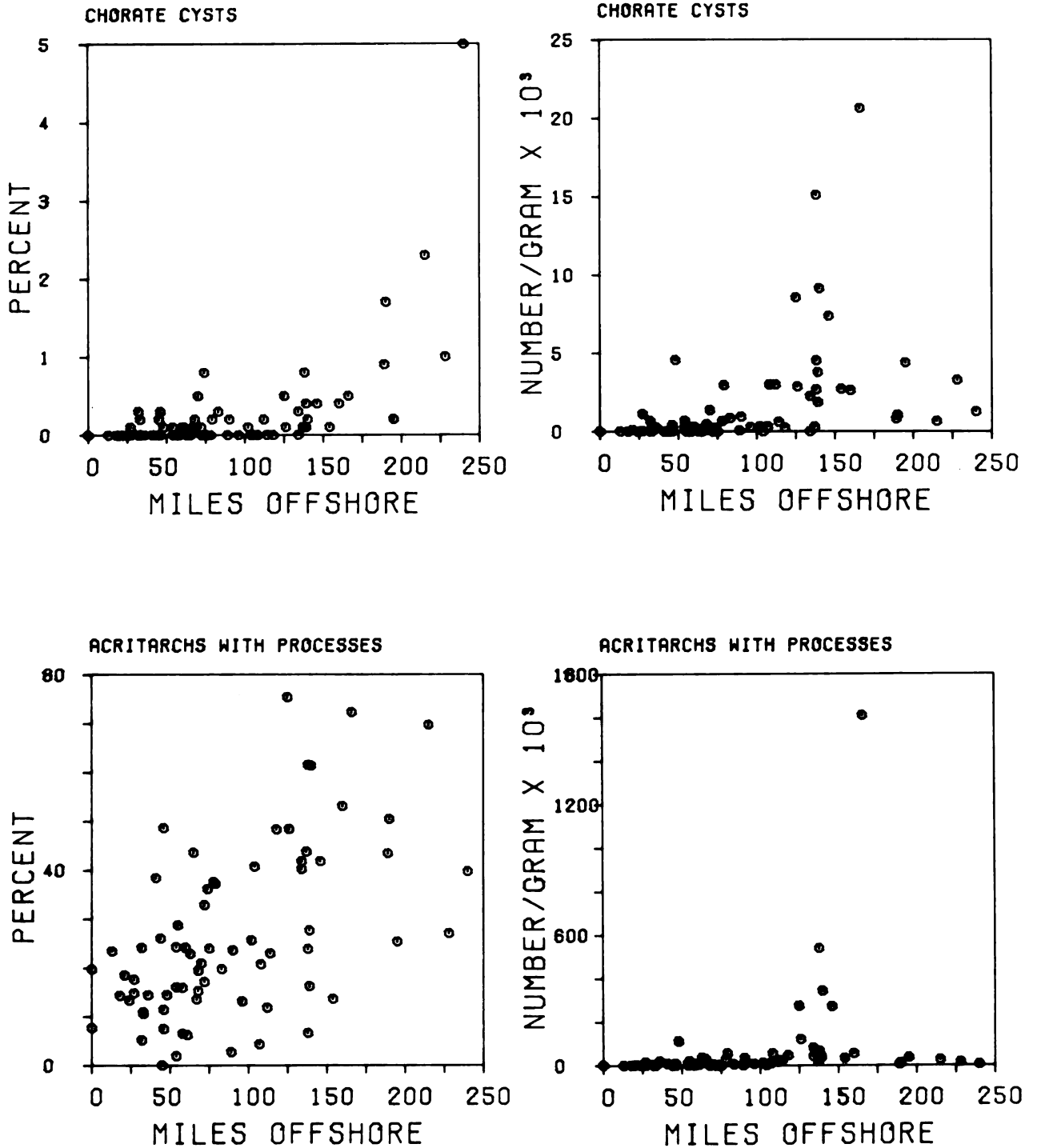


FIGURE 21.--Relative frequency and number per gram of chorate cysts and of acritarchs with processes plotted against distance offshore. Percentages are based on the sum of microplankton.

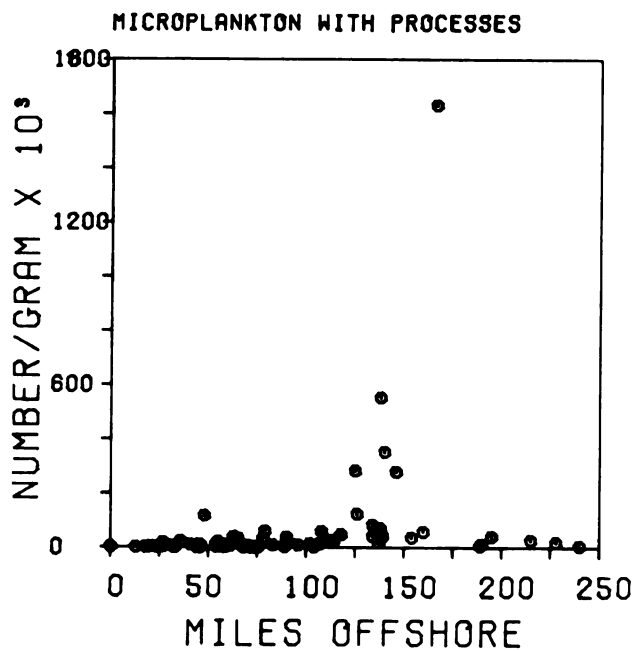
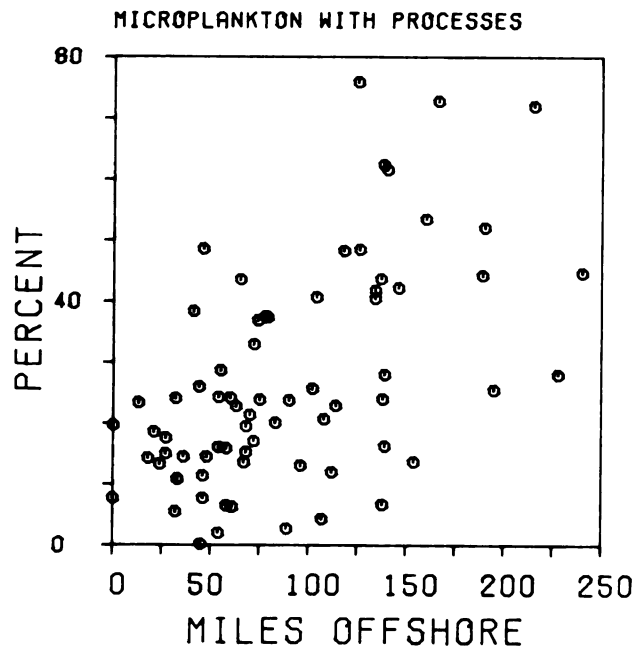


FIGURE 22.--Relative frequency and number per gram of microplankton with processes. Percentages are based on the sum of microplankton.

Michrystridium is the most abundant hystrich in most of the samples and dominates any more inclusive group into which it is placed. The distribution of total microplankton with processes reflects the distribution of Michrystridium.

Mickroplankton without Processes -- In this group the distributions of the following categories are illustrated. Cymatiosphaera spp. (fig. 17), Form C sp. 1 (fig. 17), Acritarchs without processes (fig. 20), Dinogymnium sp. 1 (fig. 19), proximate and cavate cysts (fig. 21), and microplankton without processes (fig. 20).

These distributions show high relative frequencies nearer shore than do the hystrichs. Cymatiosphaera (the most abundant) has high relative frequencies in samples from between 50 and 150 miles offshore while Form C sp. 1 and Dinogymnium sp. 1 have high relative frequencies in samples that are less than 75 miles offshore. All have highest numbers per gram in samples that are nearer shore than those containing large numbers of hystrichs.

The relative frequency of the category "microplankton without processes" is the complement of "microplankton with processes" because in all cases the sum of the two is 100 percent. Either graph could be interpreted as the ratio of one to the other.

The distributions of the various fossil microplankton taxa discussed above probably reflect the position of the living plankton populations in relation to the shoreline. Although the exact position of the living population may not be indicated, the original position of the living population probably influenced the present distribution of the cysts. The source for a given cyst was a living population and its position relative to the other living populations should produce distinct cyst

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distribution in the bottom sediments even though the cysts may have been moved about by currents. Complete mixing does not seem likely in light of studies of palynomorphs in modern sediments.

The inverse relationship between the relative frequency of hystrichs (microplankton with processes) and that of microplankton without processes as distance offshore increases contradicts somewhat the suggestions made by Wall (1965) concerning acritarchs in the Jurassic of the British Isles. However, Wall's offshore samples may represent open deep-sea conditions rather than great distances offshore in an epicontinental sea. However, the above relationship is similar to that found by Staplin (1961) off Devonian reefs. It has been suggested that the processes serve to present more surface area to the water and thus make the cysts more resistant to sinking in the deeper, less turbulent water offshore (see brief discussion in Davey and Williams, 1967, p. 393-394).

Total Palynomorphs per Gram of Rock

The number of total palynomorphs (all pollen, spores and microplankton) per gram of rock (e.g., Classopollis spp.) tend to be highest in samples from intermediate distances offshore (fig. 23). This reflects the distribution of rates of sedimentation of the organic particles superimposed on that of the inorganic particles. Near shore the rate of inorganic sedimentation is high because of streams dumping their loads. This rate of sedimentation decreases at intermediate distances offshore and the rate of sedimentation of land-derived palynomorphs probably increases. This increase may be due to the fact that the less dense organic particles are carried farther along in the direction of transport. Also, the microplankton apparently produce more cysts at intermediate

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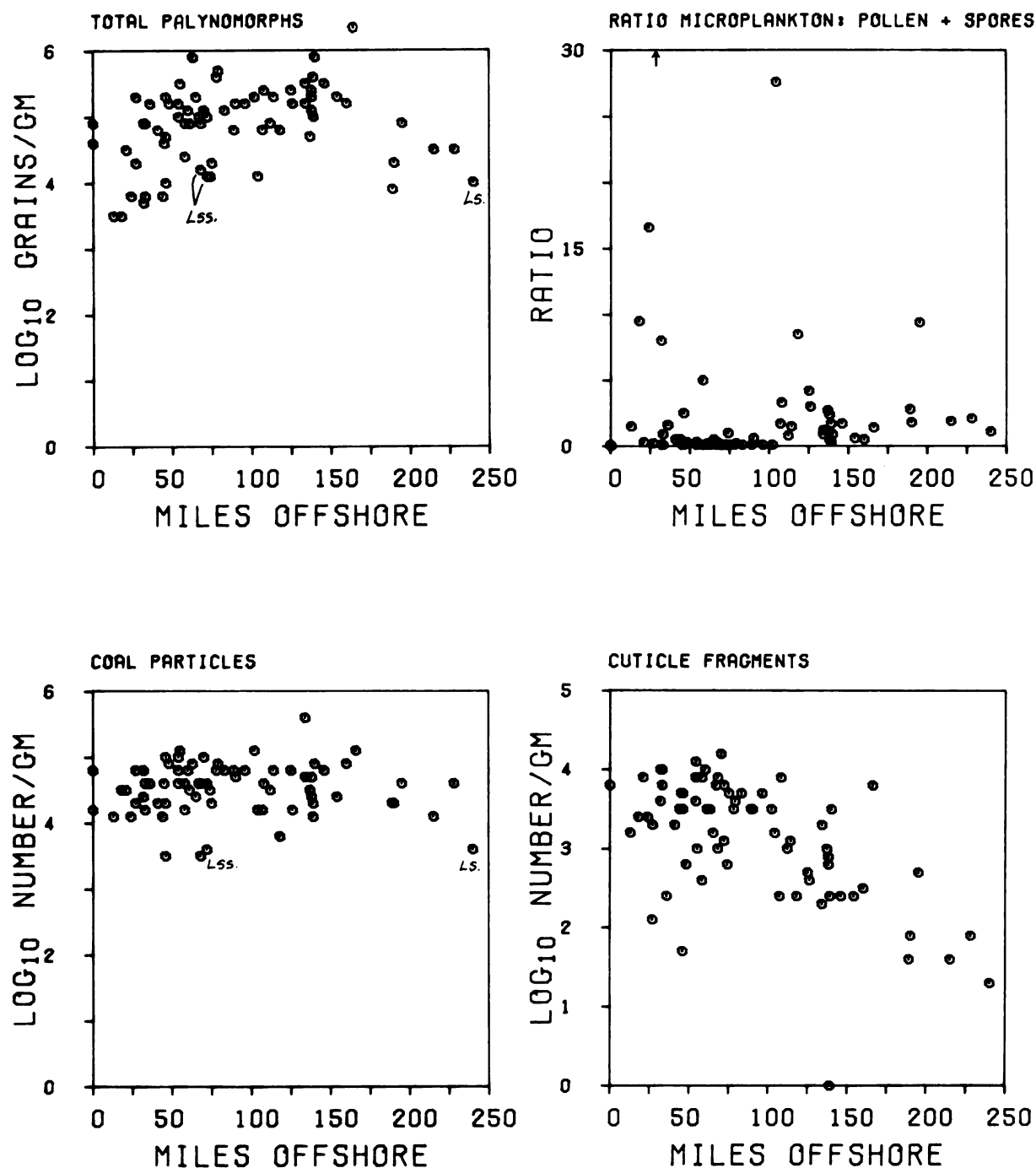


FIGURE 23.--Log₁₀ of palynomorphs per gram, log₁₀ coal particles per gram and ratio of the number of microplankton cysts to the number of pollen and spores all plotted against distance offshore. Arrow indicates value off the graph. Limestones are indicated by "Ls".

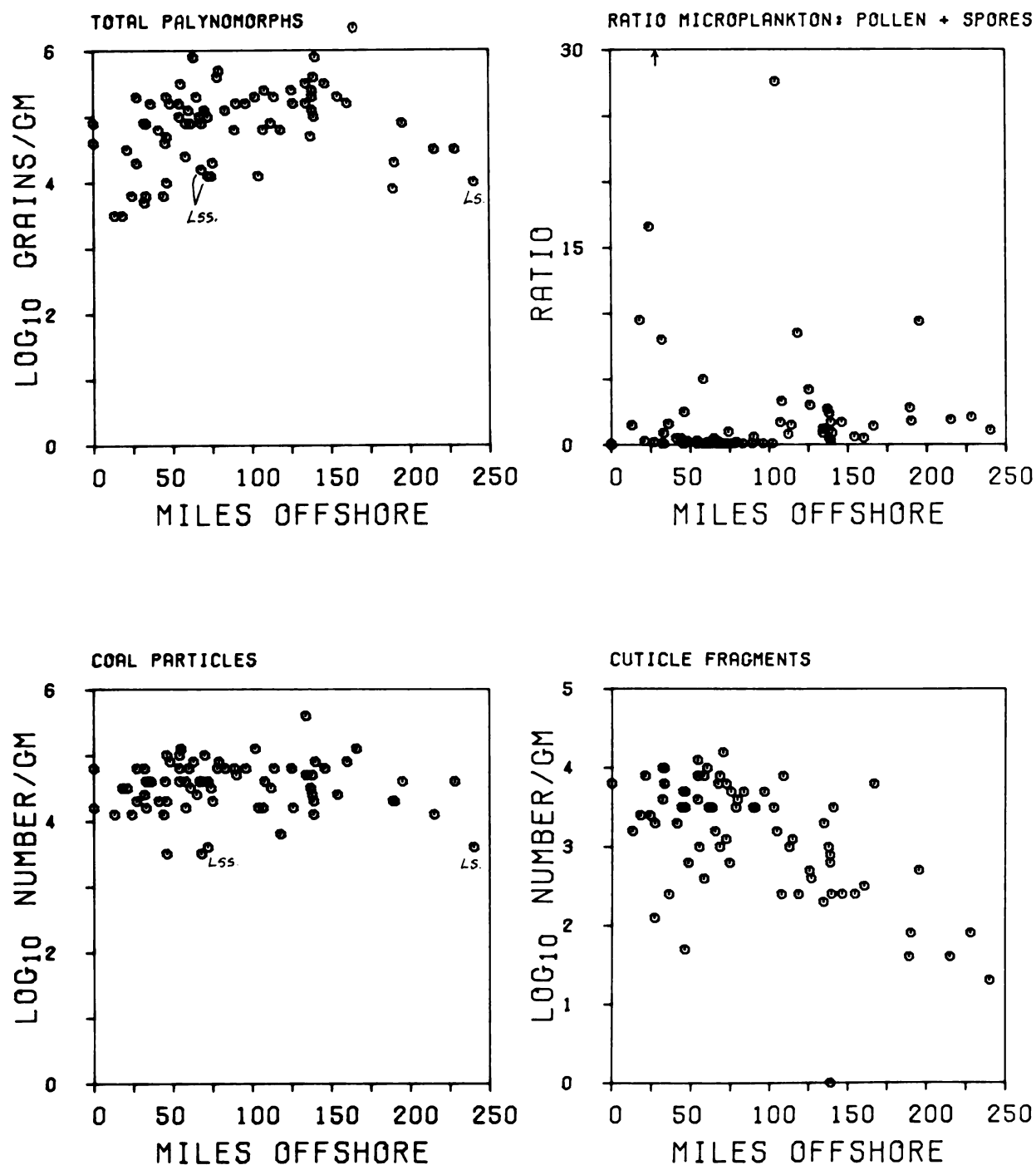


FIGURE 23.-- Log_{10} of palynomorphs per gram, log_{10} coal particles per gram and ratio of the number of microplankton cysts to the number of pollen and spores all plotted against distance offshore. Arrow indicates value off the graph. Limestones are indicated by "Ls".

distances offshore. Still farther offshore the land-derived palynomorphs and the microplankton sedimentation rates drop off.

The limestones that were examined consistently contain low numbers of palynomorphs per gram of rock. This would indicate that there were either (1) short spurts of high rates of calcium carbonate sedimentation, or (2) early lithification and subsequently less compaction of the limestones compared with the shales, (3) some palynomorphs that are not destroyed in the shales are destroyed during the formation of the limestones. Because the somewhat more resistant land-derived coal particles show a similar low density (fig. 23) in the limestones, the second hypothesis seems to be the more tenable. The sedimentation rate of coal particles would probably be independent of the special conditions responsible for the limestone deposition.

Ratio of Microplankton to Pollen and Spores

The distribution of this ratio is shown (fig. 23) because it is frequently used in the literature as a measure of distance offshore. Here it shows essentially no such relationship to distance offshore. In fact, the largest value is quite nearshore.

Coal Particles ($\geq 50 \mu$) per Gram of Rock

The distribution of coal particles (vitinite and fusainite, $\geq 50 \mu$ in largest dimension, per gram of rock) is similar to that of the total palynomorphs per gram. As mentioned above, the limestones contain small numbers of coal particles per gram (fig. 23).

Cuticle Fragments per Gram of Rock

The distribution of cuticle fragments (all recognizable sizes) shows a definite decrease with distance offshore. This is similar to the

distribution of these particles that was shown by Muller (1959) in sediments off the Orinoco Delta. This distribution may reflect the disintegration of the cuticle as it is transported. If fragments became so small that they showed no cuticular suture pattern they would not be counted.

Interpretation Assuming Only Time-Related Effects

Another interpretation of the diversity indices, relative frequencies, and numbers per gram of rock is possible. This interpretation is the kind that is made when abundance peaks are used for time correlation and eliminates the role of the local environment in determining the above distributions.

The correlation between distance offshore and distance above the base of the Mancos is better than between any of the other variables in this study. Also, the correlation between the diversity index, relative frequency or number per gram and distance offshore is rough. The diversity indices, relative frequencies, and numbers per gram also correlate roughly with distance above the base of the Mancos and thus may be related to time. This would reflect evolutionary or phytogeographical changes in the flora. As it is, a taxon that is abundant in the upper parts of the sections would tend to appear more abundant near shore and one abundant in the lower parts would appear more abundant far offshore. This relationship between the position of the strandline and the distance above the base of the Mancos was not realized until the study was well underway. Further study must be carried out in area where such a relationship can be avoided. Only then can any effect of the environment be unequivocally demonstrated.

Environmental Casual Factors

The only so-called "environmental parameter" that is controlled in this study is distance offshore. In the modern oceans, factors such as water depth, salinity and turbidity are commonly correlated with distance offshore. Because distance offshore correlates with these other environmental factors it would be impossible to determine that a single factor strongly influences the abundance of a fossil palynomorph if that factor also correlates with distance offshore.

In the modern ocean the distribution of plankton can be expected to be affected by water depth, salinity, and turbidity as well as temperature, substrate microenvironments, nutrient concentration, turbulence, current direction and duration, proximity to river mouths, wind direction, wind velocity and wind duration. Some of these factors also affect the distribution of purely sedimentary particles such as pollen and spores. Climatic influences on both land and sea such as rainfall and insolation are also involved.

A few examples of apparent control of palynomorph distribution by an environmental factor or group of factors have been found in the modern environment. Plankton blooms are known to occur in water masses that are rich in nutrients such as occur in upwellings and off some river mouths (Raymont, 1963; van Andel, 1964). In the Gulf of California, cysts of dinoflagellates occur in bottom sediments below some of these areas of plankton blooms although not below others (Cross, et al, 1967). Also, pollen and spores are known to be concentrated off river mouths (Cross, et al, 1967).

It follows that within the limits of this study it would be very difficult to determine what environmental factor actually might

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predominate in the control of the distribution of the various palynomorphs. **N**evertheless, it is felt that simply a determination of the distance off-**s**hore at which a rock sample was probably laid down is extremely valuable **i**n itself.

The most widely recognized value of being able to estimate the **d**istance offshore at which a rock was deposited lies in the determination **o**f paleogeography. What is sought is the position of the strandline in **r**elation to various other facies.

V. CONCLUSIONS

It may be concluded that, coupled with good time correlation, factor analysis appears to be useful in detecting the influence of environment on the composition of palynomorph assemblages. However, more work must be done in situations where more real environmental parameters can be measured and related to palynomorph assemblages. Perhaps then too, a more complete interpretation of a more rigorous factor analysis (more end members, greater communality) could be made.

A better understanding of environmental parameters might also allow one to determine the factors controlling the relative frequencies and numbers per gram of individual taxa.

The empirical use of diversity indices, factor analysis and, to a limited extent, relative frequencies and numbers per gram of rock, as tools for determining distance offshore is suggested as the result of this study. Although, the use of these methods has not been adequately tested in this work or in previous work, it is felt that the application of the relative frequency and number per gram of rock would be limited to the region surrounding the site of this investigation (where there is a similar assemblage of microfossils and a similar sediment regime). Factor analysis and the diversity indices could probably be applied in any area and to any group of fossils (especially microfossils because of their abundance; see Streeter, 1963).

The logical extension of the results of this study would be in determining distance offshore in the rocks of the Upper Cretaceous of the Western Interior purely on the basis of palynomorphs. However, coupled with all other lithologic and paleontologic data available, a much better reconstruction of ocean-bottom environments could result.

The use of relative abundance peaks of palynomorphs in correlation must be used cautiously and only after one understands the role of the local environment in affecting palynomorph abundances.

In general, the information contained in fossil assemblages that reflects environment is retrievable. Multivariate analysis techniques should be tested with reliable paleontologic data, measurements of environmental parameters, and adequate mathematical direction.

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APPENDICES

APPENDIX A

Measured Stratigraphic Sections

POINT LOOKOUT SECTION

Section measured in sections 26, 29 and 31, T. 36 N., Sections 5 and 6,
T. 35 N., R. 14 W., Montezuma County, Colorado

	Thickness		Distance above base of formation	
Point Lookout Sandstone	Ft	in	Ft	in
Sandstone, buff-yellow, fine to medium-grained, massive to platy, calcareous, one half inch to six feet thick; interbedded with shale.....	72	0	72	0
	72	0		
Mancos Shale				
Upper Shale Member				
	Ft	in		
Shale, sandy; interbedded with tan-yellow, calcareous, flaggy sandstone about five inches thick and from six inches to one foot apart.....	96	6	2056	10
Concretion layer; light-gray, weathers buff, fine-grained, sandy limestone; septarian (?) core and calcite crystals lining fractures and in center of spherical concretions about two feet six inches in diameter.....	2	6	1960	4
Shale, sandy; interbedded with tan-yellow, calcareous, flaggy sandstone beds about five inches thick and from six inches to one foot apart.....	53	1	1957	10
Shale, silty to sandy; interbedded with a few widely-spaced very-thin sandstone beds.....	12	4	1904	9

Mancos Shale--Continued

	Ft	in	Ft	in
Concretion layer; light to medium-gray, weathers buff to orange or reddish brown, silty to fine-grained, massive to platy, limestone concretions about two feet six inches in diameter; no fossils.....	2	6	1892	5
Shale, silty to sandy; interbedded with a few widely-spaced sandstone beds one half to two inches thick.....	33	0	1889	11
Sandstone, light-gray to tan, flaggy to platy, calcareous; plant fragments, animal trails.....		3	1856	11
Shale, silty to sandy; interbedded with a few widely-spaced very-thin sandstone beds.....	17	0	1856	8
Shale, silty to sandy.....	4	1	1839	8
Concretion, light to medium-gray weathers buff to orange or reddish-brown, silty to fine-grained, massive to platy limestone; no fossils.....	1	6	1835	7
Shale, medium to dark olive-gray to medium to dark gray-olive, silty, fissile to starchy (tending to "massive" mudstone in some layers), slightly calcareous to non-calcareous; small plant fragments; interbedded with light-gray to whitish limestones; one inch thick increasing to two inches towards the top; some lenticular; fine-sand-sized grains (calcarenite)....	24	8	1834	1
Mudstone, friable, massive, non-calcareous; no fossils.....	25	7	1809	5

Mancos Shale--Continued

	Ft	in	Ft	in
Shale, dark gray-olive, fissile, non-calcareous, silty, with sandy laminae; iron oxide (?) concretions throughout, two inches in diameter in zones about five feet wide.....	5	7	1783	10
Shale, dark gray-olive, silty, sandy, starchy, non-calcareous.....	5	7	1778	3
Shale, dark-gray, fissile to starchy, slightly calcareous; with some silt laminae, no sand; no fossils.....	4	3	1772	8
Bentonite, tan to pink, fissile, non-calcareous, gypsiferous (marked by conspicuous spring on slope).....		6	1768	5
Shale, dark-gray, some silt laminae, fissile to starchy, slightly calcareous; no fossils.....	21	4	1767	11
Shale, as above; with white to light-gray (at cores) limestone concretions about one foot in diameter, scattered throughout.....	5	7	1746	7
Shale, dark-gray to medium to dark olive-gray, fissile, sandy silt laminae; a few iron oxide-stained and cemented layers with concretions about one half inch thick.....	22	4	1741	0
Concretion layer; light to medium-gray, weathers buff to orange-yellow, massive to platy, limestone concretions to one foot 10 inches in diameter; baculites; compressed water-worn coalified wood fragments.....	1	10	1718	8
Shale, dark gray to dark to medium-gray, fissile, sandy silt laminae; a few iron oxide-stained and cemented layers with small concretions about one half inch thick.....	8	10	1716	10

Mancos Shale--Continued

	Ft	in	Ft	in
Concretion layer; orange-brown to light to medium-gray at cores, platy to massive, discoid limestone concretions about four inches thick and two feet wide; baculites, wood and other plant debris.....		4	1708	0
Shale, medium to dark olive-gray to medium to dark-gray, fissile to starchy, slightly calcareous to calcareous, gypsiferous; with silty laminae; no fossils.....	15	11	1707	8
Mudstone, lenticular, medium-gray, weathers buff to orange-yellow, massive to platy, laminated; animal trails on top; no fossils.....		4	1691	9
Shale, medium to dark olive-gray, silty, starchy, slightly calcareous; no laminae; a very few calcarenite layers about three-fourths inch thick; no fossils.	33	0	1691	5
Shale, medium to dark olive-gray, fissile, slightly calcareous; with sandy laminae; no fossils.....	16	9	1658	5
Concretion layer; medium-gray, weathers buff to orange-yellow, massive to platy, slightly calcareous, laminated mudstone concretions about three feet in diameter; baculites.....	3	0	1641	8
Shale, medium to dark olive-gray, fissile, slightly calcareous; with sandy laminae; no fossils.....	48	6	1638	8
Concretion layer; large, medium-gray, weathers buff to orange-brown, slightly calcareous mudstone concretions; a few baculites.....		7	1590	2

Mancos Shale--Continued

	Ft	in	Ft	in
Shale, medium to dark olive-gray, fissile non-calcareous to slightly calcareous; with sandy laminae; with some inter-bedded sandstones about one-fourth inch thick.....	58	4	1589	7
Concretion layer; yellow-orange to light-gray at center, weathers platy at edges, calcareous, discoid mudstone concretions about seven inches thick and three feet wide; gypsum in fractures; baculites, fish scales, coalified wood fragments.		7	1531	3
Shale, as above.....	1	0	1523	8
Sandstone, light-gray to yellow, slightly calcareous, laminated; plant fragments		4	1522	8
Shale, as above, sandstones about three-fourths inch thick.....	8	5	1522	4
Sandstone, platy, conspicuous.....		1	1513	11
Shale, medium to dark olive-gray, fissile, non-calcareous to slightly calcareous; with sandy laminae; inter-bedded with some thin sandstone layers one-fourth inch thick increasing to about three-fourths inch thick upwards.....	32	6	1513	10
Mudstone, lenticular, light to medium-gray, weathers buff, massive to flaggy laminated, slightly calcareous; fractures into prismatic pieces; inoceramus, plant fragments.....		9	1481	4
Shale, dark olive-gray, platy to blocky, slightly calcareous, gypsiferous; iron oxide stain on fractures; inter-bedded with white to yellow, calcareous, cross-laminated, very thin sandstones about one-fourth inch thick and about one foot apart; fish scales.....	132	3	1480	7

Mancos Shale--Continued

	Ft	in	Ft	in
Mudstone, lenticular, light to medium-gray, weathers buff, massive to platy, slightly calcareous, laminated; plant fragments.....	1	10	1348	4
Shale, sandy, medium to dark olive-gray, fissile, slightly calcareous; interbedded with a few very thin sandstone layers about one-fourth inch thick; fish scales.....	35	3	1346	6
Shale, medium to dark olive-gray, fissile, slightly calcareous; with silty laminae.....	16	9	1311	3
Shale, sandy, medium to dark olive-gray, fissile, slightly calcareous; interbedded with very thin sandstones about one-fourth inch thick and containing animal trails and plant fragments. (The steepness of the slope varies with the concentration of the thin sandstones in the shale).	46	5	1294	6
Mudstone, light-gray, weathers buff to orange-yellow, flaggy to platy, laminated; abundant plant debris--conifer needles, stem compressions, amber.....	1	0	1248	1
Shale, medium to dark olive-gray, fissile, slightly calcareous; with sandy silt laminae; interbedded with cross-laminated, calcareous to slightly calcareous thin sandstones about one inch thick containing animal trails, fine to coarse plant debris (including large leaf fragments), fine sand-sized grains...	16	11	1247	1
Shale, medium to dark olive-gray, fissile, slightly calcareous; with sandy silt laminae becoming more concentrated upward.....	41	1	1230	2

Mancos Shale--Continued

	Ft	in	Ft	in
Mudstone, lenticular, light-gray, weathers buff, massive to platy, non-calcareous, calcite in some fractures, laminated; <u>Inoceramus</u> , baculites, fish scales, plant fragments.....	1	0	1189	1
Shale, light to medium to dark olive-gray, fissile, non-calcareous except along some bedding planes; thick-shelled <u>Inoceramus</u> ; with sandy laminae thickening to one half inch cross-laminated sandstones every five to ten feet; quartz sand; animal trails, plant fragments.....	58	5	1188	1
Mudstone, medium to light-gray, weathers buff, massive to platy, laminated; tiny plant fragments (?)...	1	4	1129	8
Shale, medium olive-gray to medium gray-olive; light sandy laminae becoming more concentrated upwards; inter-bedded with few one half inch thick (two beds about four inches thick) calcarenite (?); no fossils.....	49	0	1128	4
Mudstone, light-gray, weathers buff, flaggy to thin-bedded, calcareous; no fossils.....		5	1079	4
Shale, medium olive-gray to medium-olive, fissile to platy, calcareous to slightly calcareous (appears due only to fine-sand laminae); with fine-sand laminae; hard sandy layers about one-fourth inch thick, inter-bedded in upper twenty to thirty feet; few fish scales; white specks on bedding planes.....	88	5	1078	11
Mudstone, light-gray, weathers buff to orange-yellow, flaggy to platy; <u>Inoceramus</u>		6	990	6
Shale, medium-gray to medium gray-olive, fissile, calcareous, gypsiferous; fish scales.....	37	9	990	0

Mancos Shale--Continued

Mudstone, light-gray, weathers buff, flaggy to thin-bedded, calcareous; fish scales, <u>Inoceramus</u>	Ft	in	Ft	in
			952	3
		6		
Shale, medium-olive gray, fissile, calcareous, gypsiferous; with light silt laminae; <u>Inoceramus</u> , fish scales. 14	14	10	951	9
Mudstone, light to medium-gray, weathers buff to orange-yellow, massive to thin- bedded; fish scales, <u>Inoceramus</u> , plant fragments (a leaf!).....		6	936	11
Shale, light to medium olive-gray, fissile to platy, calcareous, gypsiferous; fish scales common.....	22	1	936	5
Mudstone, lenticular, light to medium- gray, weathers buff to orange-yellow, thin-bedded to platy; large <u>Inoceramus</u> , fish scales, baculites (?).....		6	914	4
Shale, medium olive-gray to medium- gray, platy to fissile, calcareous, gypsiferous; fish scales, shell frag- ments.....	12	5	913	10
Bentonite, yellow, gypsiferous.....		2	901	5
Shale, medium olive-gray to medium-gray, fissile to platy, hard, brittle, calcareous, gypsiferous; fish scales, shell fragments.....	11	0	901	3
Bentonite, yellow-orange, gypsiferous.		2	890	3
Shale, medium olive-gray to medium-gray, fissile to platy, calcareous, gyp- siferous; fish scales, shell frag- ments.....	11	2	890	1

2 Mancos Shale--Continued

	Ft	in	Ft	in
Mudstone, lenticular, light to medium-gray, weathers tan to orange yellow, massive to platy; fish scales, large <u>Inoceramus</u> , oysters, baculites (?), ammonites, fish scales.			878	11
		6		
Shale, medium gray, fissile to platy, calcareous, gypsiferous.....	4	6	878	5
Bentonite, yellow-orange, slightly calcareous.....		1	873	11
Shale, medium gray, fissile to platy, calcareous, gypsiferous.....	10	8	873	10
Shale, medium olive-gray, fissile, calcareous, gypsiferous.....	19	4	863	2
Shale, medium-gray, hard fissile to platy (upper part more fissile), Calcareous, gypsiferous; large, thick-shelled <u>Inoceramus</u> , fish scales; white specks on bedding planes.....	14	0	843	10
Bentonite, yellow-orange to white.....		2	829	10
Shale, medium-gray, hard, fissile to platy, calcareous, gypsiferous; large thick-shelled <u>Inoceramus</u> ; white specks on bedding planes.....	5	7		
Limestone, medium to dark-gray, fissile to crumbly, hard, thin-bedded on weathered ridges; large <u>Inoceramus</u> shells, encrusted with oysters, together with other oysters.	1	5	824	1
Shale, sandy, gray-brown; weathers into tan plates one half inch thick (top of ridge).....	22	5	822	8

Mancos Shale--Continued

	Ft	in	Ft	in
Shale, sandy, medium olive-gray to medium to dark-gray, fissile to platy, calcareous; interbedded with sandstone (calcareenite) layers a few millimeters thick; steepness of slope varies with concentration of sandstone layers; lower 33 feet six inches forms a steep slope, the next 16 feet nine inches forms a cliff.....	61	5	800	3
Calcareenite, light to medium-gray; beds from a few millimeters to two centimeters; interbedded with sandy fissile to platy calcareous shale (beds a few mm. thick). Gradational with beds above and below but forms a distinct ledge; tiny plant fragments (?).....	4	0	738	10
Shale, medium olive-gray to medium to dark-gray, fissile to platy, calcareous, gypsiferous, with sandy laminae that are especially concentrated in the upper five feet; shale becomes harder upwards forming steep cliffs in the valley heads; fish scales, few <u>Inoceramus</u> ...	32	9	734	10
Shale, medium olive-gray to medium to dark-gray, fissile to platy, calcareous, gypsiferous, slightly bentonitic (?-rounded slope, "pop-corn" surface texture); fish scales, few <u>Inoceramus</u>	50	3	702	1
Shale, silty to sandy, light to medium olive-gray to olive-brown, starchy-fissile to starchy-platy and fissile, calcareous; contains three three-fourths inch light to medium-gray calcarenite beds, one at base, one in middle, and one at top, in places containing fossil hash of <u>Inoceramus</u> and oyster fragments; petroliferous odor.....	6	0	651	10

Mancos Shale--Continued

	Ft	in	Ft	in
Shale, olive-gray to olive-brown to olive (color may be due to strong oxidation on ridge crest), fissile to platy, cal- careous.....	16	9	645	10
Shale, medium to light olive-gray to medium to light-gray, fissile to platy, cal- careous.....	20	8	629	1
Shale, orange, fissile, non-calcareous (bentonite?).....		8	608	5
Shale, medium to light olive-gray to medium to light-gray, fissile, cal- careous.....	1	0	607	9
Shale, light to medium olive-gray, hard, platy; forms steep cliffs.....	22	4	606	9
Shale, sandy, light to medium olive-gray, fissile to starchy-platy, bentonitic ("popcorn" surface texture), cal- careous; sand grains consist of calcite prisms of broken <u>Inoceramus</u> shells; upper 24 feet forms steeper slope...	44	8	584	5
Shale, medium olive-gray, fissile, bentonitic, slightly calcareous at base, more calcareous upwards, gypsiferous; hard sandy one-fourth inch beds scattered throughout; dark- gray, weathering light-tan to buff, fine-grained, smooth, rounded, discoid, limestone concretions about one foot thick and two to three feet wide scattered throughout; concretion size decreased in upper part of unit; <u>Inoceramus</u>	31	11	539	9
Bentonite, orange-yellow to white, gypsiferous; two one-inch beds separated by one foot of shale.....	1	2	507	10

Mancos Shale--Continued

	Ft	in	Ft	in
Shale, medium olive-gray, fissile, bentonitic, gypsiferous, slightly calcareous; with sandy layers and concretions like above.....	6	0	506	8

Juana Lopez Member

Calcarenite, medium to dark-gray weathering tan to orange-yellow, platy thin beds interbedded with dark-gray to dark olive-gray, fissile, non-calcareous, gypsiferous shale with calcareous sandy laminae.....	1	2	500	8
Bentonite, orange-yellow, gypsiferous		1	499	6
Calcarenite, medium to dark-gray, weathering tan to orange-yellow, thin beds; slight petroliferous odor; interbedded with shale like above; <u>Inoceramus</u>	2	0	499	5
Bentonite, orange-yellow, gypsiferous		4	497	5
Calcarenite, medium to dark-gray weathering tan to orange-yellow, platy to flaggy, thin to thick beds; slight petroliferous odor; interbedded with dark-gray to dark olive-gray, papery to fissile, gypsiferous shale with calcareous sandy laminae; <u>Inoceramus</u> , ammonites.....	4	0	497	1
Shale, medium to dark-gray to medium olive-gray, fissile, slightly calcareous to non-calcareous, gypsiferous; with some calcareous sandy laminae; some cemented one-fourth inch sandy layers near top; <u>Inoceramus</u> , ammonites...	33	6	493	1
Calcarenite, medium-gray weathering orange-brown, thin-bedded; petroliferous odor; ammonites, <u>Inoceramus</u> , oysters, other mollusks.....		7	459	7

Mancos Shale--Continued

	Ft	in	Ft	in
Shale, light to medium olive-gray to olive-brown, non-calcareous except on planes of parting, fissile to platy, gypsiferous; iron-oxide stain on some planes; <u>Inoceramus</u> impressions common.....	10	8	459	0
Shale, medium to dark olive-gray, fissile, gypsiferous, non-calcareous; <u>Inoceramus</u> impressions; interbedded with some one-half inch calcarenites, with petroliferous odor.....	10	2	448	4
Calcarenite, medium-gray, weathering tan to orange-brown, thin-bedded; petroliferous odor; contains a few one-half inch layers of dark gray shale; <u>Inoceramus</u> , other pelecypods.....	1	0	438	2

Lower Carlile Member

Shale, medium to dark olive-gray to black, fissile, brittle, non-calcareous, gypsiferous; interbedded with a few medium gray, weathering yellow-orange to buff very thin calcarenites; two two-inch bentonites near top.....	37	6	437	2
Concretion layer; light-gray, weathering orange-yellow, large limestone concretions.....	1	0	399	8
Shale, medium to dark olive-gray to black, fissile, brittle, non-calcareous, gypsiferous.....	10	2	398	8
Limestone, lenticular, light-gray, weathers orange-yellow; with fractured septarian structure; <u>Inoceramus</u>	1	0	388	6
Shale, medium to dark olive-gray to medium to dark-gray, fissile, non-calcareous; large spherical limestone concretions scattered throughout.....	38	6	387	6
Bentonite, light tan to white to orange, gypsiferous.....		7	349	0

Mancos Shale--Continued

Shale, medium to dark olive-gray to medium to dark-gray, fissile, non-calcareous; fractured with iron oxide stain on planes; large selenite crystals at surface; spherical dark-gray limestone concretions about two to three feet in diameter, with rinds of cone-in-cone and hollow septarian cores with one-half to one inch calcite crystals at centers, scattered throughout.....	13	6	348	5
Bentonite, yellow-orange to white, sticky, fissile, gypsiferous.....		2	334	11
Shale, like above with concretions like above.....	42	2	334	9
Shale like above; with scattered bluish dark-gray discoid to spherical limestone concretions, weathering orange brown with a rind of cone-in-cone and about six inches thick and three feet in diameter.....	67	0	292	7
Shale like above; with scattered light-gray to medium-gray, weathering buff to tan, fine-grained, smooth, discoid limestone concretions up to six inches thick and three feet wide; one compressed ammonite in concretion near top.....	11	2	225	7
Shale, medium to dark olive-gray to medium to dark-gray, fissile, non-calcareous; compressed ammonites....	16	9	214	5
Shale, medium to dark olive-gray to medium to dark-gray, hard, platy to fissile, softer and more fissile near top, calcareous, gypsiferous; hard thin sandy layers common in about four feet about fifteen feet above base; <u>Inoceramus</u> (in lower eleven feet) oysters, compressed ammonites (especially abundant about 34 feet above base).....	55	10	197	8

Mancos Shale --Continued

	Ft	in	Ft	in
Bentonite, orange-yellow to white, gypsiferous, fissile.....	5		141	10
Shale, medium-gray, weathers light- gray to tan, platy, some fissile, calcareous; lower few feet with one or two one-half inch calcarenite layers; upper few feet with iron oxide-stained fractures and pyritized fossils; <u>Inoceramus</u> , oysters.....	16	4	141	5
Calcarenite, medium-gray, weathers buff to brown, laminated and cross- laminated; petroliferous odor; animal trails on top and bottom, <u>Inoceramus</u>		6	125	1

Greenhorn Limestone Member

Shale, medium grayish-brown, fissile, weathers papery, calcareous; shell fragments; interbedded with two two- inch calcarenite beds (like above); contains three-inch bentonite.....	2	1	124	7
Shale, medium gray-brown, fissile, calcareous; a few interbedded one- half inch "cemented shales".....	2	2	122	6
Limestone, medium-gray, fine-grained; <u>Inoceramus</u>	1	0	120	4
Limestone, medium-gray, fine-grained; interbedded with olive-brown, cal- careous, fissile shale containing shell fragments and forams.....	2	11	119	4
Bentonite, yellow, gypsiferous, fissile.....		10	116	5
Shale, dark-gray to olive, some mottled, fissile to platy, gypsiferous, cal- careous; <u>Gryphaea</u> (especially in concentrated layer at top).....	11	2	115	7
Bentonite, yellow to white, fissile, gypsiferous.....		4	104	5

Mancos Shale--Continued

	Ft	in	Ft	in
Graneros Shale Member				
Shale, light to medium-gray to light to medium olive-gray, fissile to platy, calcareous; no fossils.....	15	1	104	1
Limestone, light to medium-gray, weathers tan, platy, laminated, fine-grained; no fossils.....	1	6	89	0
Shale, light to medium olive-gray, fissile to starchy.....	9	2	87	6
Limestone, lenticular, light-gray, weathers tan to buff, massive, fine-grained; calcite crystals in fractures.....		7	78	4
Shale, dark to medium-gray, fissile, calcareous, gypsiferous; discoid limestone concretions about five inches thick and two feet wide scattered throughout.....	14	3	77	9
Limestone, lenticular, medium to light-gray, weathers orange-yellow to buff, massive, weathers into one-half to two inch blocks; well-rounded sand grains scattered throughout; calcite crystals in fractures; no fossils.....	1	1	63	6
Shale, sandy, dark-gray, fissile, calcareous, well-rounded sand grains floating in matrix.....	3	0	62	5
Sandstone, white, weathers tan to pink, calcareous; rounded to well-rounded sand grains; animal trails, shell fragments.....		2	59	5

Mancos Shale--Continued

	Ft	in	Ft	in
Shale, dark to medium-gray, fissile to papery, calcareous; with sand laminae; becomes almost shaly sand in thin layers; well-rounded sand grains floating throughout matrix.....	11	5	59	3
Bentonite, white and yellow, gypsiferous	1	0	47	10
Concretion layer; light-gray, weathering yellow-orange, fine-grained, discoidal limestone concretions about six to 12 inches thick and three feet wide; calcite crystals in fractures; no fossils...	1	0	46	10
Shale, dark-gray, fissile, non-calcareous, gypsiferous.....	1	0	45	10
Bentonite, white and yellow, gypsiferous		8	44	10
Shale, sandy, olive-gray, fissile, non-calcareous; olive to yellow sand laminae.....	14	9	44	2
Sandstone, tan, cross-bedded (with channel pattern), very irregular....	4	3	29	5
Shale, sandy (sand content increases in lower part), platy at top, blocky at bottom (a siltstone?).....	4	6	25	2
Sandstone and siltstone, gray to tan, carbonaceous; mica grains; interbedded with shale.....	8	2	20	8
Shale, medium-gray, platy to chippy; interbedded with dark green-gray siltstone with a two to three inch hard sandstone about two feet from top.....	5	0	12	6
Shale, sandy, light to medium gray-olive above, olive green-gray below, blocky.....	5	0	7	6
Concealed	<u>2</u>	<u>6</u>		
	2056	10		

UTE RESERVATION SECTION

Section of Mancos Shale measured in sections 9, 16, 20, 21, T. 32 N., R. 19 W., sections 9, 10, 11, 12, 13, 16, T. 32 N., R. 18 W., and section 18, T. 32 N., R. 17 W,

	Thickness		Distance above base of formation	
	Ft	in	Ft	in
Point Lookout Sandstone				
Sandstone.....	3	0	46	1
Sandstone interbedded with shale; sandstones up to three feet thick...	43	1	43	1
	46	1		
Mancos Shale				
Upper Shale Member				
Shale interbedded with sandstones and siltstones one to five inches thick.....	6	0	1641	7
Siltstone, dark-gray calcareous; with shale partings and tan sandstone streaks; plant fragments.....	7	10	1635	7
Siltstone with thin lenticular mud- stones and concretions.....	9	2	1627	9
Siltstone, non-calcareous; cliff- forming; plant fragments.....	7	7	1618	7
Shale, black, crumbly to platy; contains sandstone partings, and very thin beds; sandstone contain plant fragments and oyster shell fragments.....	77	6	1611	0
Limestone, brown-gray, weathers red, silty.....		8	1533	6
Dakota Sandstone				
Sandstone, massive, tan, cross- bedded.....	9	0	41	6
Shale, with thin, laminated carbon- aceous micaceous sandstones.....	1	0	32	6
Sandstone, tan, massive, cross- bedded.....	31	6	31	6
	41	6		

Mancos Shale--Continued

	Ft	in	Ft	in
Shale, black, fissile to platy; interbedded with sandstones a few millimeters to a few centimeters thick; sandstones vary from twenty to eighty percent of rock.....	86	2	1532	10
Limestone, gray, weathers pink, silty.	1	2	1446	8
Shale, black, sandy; interbedded with very thin sandstones a few millimeters to a few centimeters thick; sandstone vary from twenty five to sixty percent of rock.....	30	10	1445	6
Siltstone, calcareous, gray to pink, weathers red.....		8	1414	8
Shale, black, fissile to crumbly; interbedded with very thin sandstones from a few millimeters to a centimeter thick; concentration of sandstones varies but less than forty percent of rock.....	119	11	1414	0
Mudstone, lenticular, calcareous, laminated; plant fragments.....	1	6	1294	1
Shale, light to medium olive-gray, calcareous, gypsiferous; interbedded with sandstone laminae a few millimeters thick; sandstone makes up fifty percent of rock in some layers.....	49	1	1292	7
Mudstone, lenticular, medium-gray, weathers buff to orange-yellow, calcareous, blocky to platy.....	1	4	1243	6
Shale, light to medium olive-gray, calcareous, gypsiferous; interbedded with sandstone layers a few millimeters thick; sandstone makes up fifty percent of rock in some layers.....	22	8	1242	2

Mancos Shale--Continued

	Ft	in	Ft	in
Mudstone, lenticular, medium-gray, weathers buff to orange-yellow, massive to platy.....		10	1219	6
Shale, light to medium olive-gray, calcareous gypsiferous; interbedded with sandstone laminae and layers up to two inches thick...	26	2	1218	8
Mudstone, lenticular, light-gray, weathers buff to orange-yellow, calcareous, laminated, platy to massive.....	1	0	1192	6
Shale, light to medium olive-gray, calcareous, gypsiferous; interbedded with light sandstone laminae and a few beds up to one-half inch thick which appear concentrated in groups.....	32	5	1191	6
Mudstone, lenticular, light-gray, weathers buff to orange-yellow, calcareous; <u>Inoceramus</u> impressions		6	1159	1
Shale, medium to dark-gray, calcareous, gypsiferous, with light sandy laminae and some widely separated sandstone beds a few millimeters thick....	16	9	1158	7
Bentonite.....		1	1141	10
Shale, medium to dark gray, calcareous, gypsiferous; with sandy laminae and some widely separated sandstone beds a few millimeters thick.....	39	7	1141	9
Mudstone, lenticular, light-gray to buff, weathers buff to orange-yellow, platy to massive, laminated; <u>Inoceramus</u> , trace of a "horny" coiled ammonite.....	1	8	1102	2
Shale, medium to dark-gray, fissile, calcareous; with light sand laminae and widely separated sandstone beds a few millimeters thick....	23	1	1100	6

Mancos Shale--Continued

	Ft	in	Ft	in
Mudstone, lenticular, light to medium-gray, platy to thin bedded, slightly calcareous.....	1	0	1077	5
Shale, medium to dark-gray, fissile, calcareous, with light sand laminae and widely separated sandstone beds a few millimeters thick; fish scales, large <u>Inoceramus</u> weathers out on surface.....	32	8	1076	5
Sandstone, calcareous.....		6	1043	9
Shale, medium to dark-gray, fissile, calcareous; with light sand laminae and a few widely separated sandstone beds a few millimeters thick.....	2	4	1043	3
Mudstone, lenticular, medium-gray weathers orange-yellow, slightly calcareous.....	2	0	1040	11
Shale, medium to dark-gray, fissile, calcareous; with light sand laminae and a few widely separated sandstone beds a few millimeters thick.....	3	11	1038	11
Calcarenite.....		6	1035	0
Shale, sandy, light to medium-gray to light to medium olive-gray, brittle to papery, calcareous, gypsiferous; with a few sandstone beds a few centimeters thick.....	5	7	1034	6
Mudstone, lenticular, light to medium-gray, weathers buff to orange-yellow, slightly calcareous.....	1	0	1028	11
Shale, sandy, light to medium-gray to light to medium olive-gray, brittle, fissile to papery, calcareous, gypsiferous; with a few sandstone layers up to two centimeters thick	11	3	1027	11

Mancos Shale--Continued

	Ft	in	Ft	in
Mudstone, lenticular, light to medium-gray, weathers buff to orange-yellow, massive to platy, slightly calcareous to calcareous.....	1	2	1016	8
Shale, sandy, light to medium-gray to light to medium olive-gray, brittle, fissile to papery; with a few sandstone beds up to about two centimeters thick.....	18	7	1015	6
Mudstone, light-gray, weathers buff, massive, slightly calcareous; with parallel vertical fractures.....		6	996	11
Shale, sandy, silty, light to medium gray-brown, fissile to papery, calcareous; with a few sandstone beds up to two centimeters thick.....	5	6	996	5
Sandstone, somewhat lenticular, calcareous; bedding planes appear "pitted".....	2	0	990	11
Shale, sandy, silty, light to medium gray-brown, fissile to papery, calcareous; with a few sandstone beds in the upper part up to two centimeters thick.....	20	7	988	11
Mudstone, lenticular, medium-gray, weathers orange-yellow, slightly calcareous; plant fragments.....	2	6	968	4
Shale, sandy, silty, gray-brown to brownish gray, fissile; with some sand laminae a few millimeters thick.....	8	11	965	10
Mudstone, lenticular, medium-gray, weathers orange-yellow, massive to platy, calcareous.....	2	0	956	11

Mancos Shale--Continued

	Ft	in	Ft	in
Shale, slightly sandy, medium-gray layers alternating with light-brown layers, fissile, calcareous; with sand laminae up to a few millimeters thick.....	5	9	954	11
Mudstone, lenticular, medium-gray, weathers orange-yellow, massive to platy, calcareous; plant fragments, <u>Inoceramus</u> impressions, traces of coiled ammonites and baculites...	1	0	949	2
Shale, medium to light olive-gray to medium-gray, papery, to fissile, calcareous; with sand laminae and sandstones a few millimeters thick; large thick <u>Inoceramus</u>	14	9	948	2
Mudstone, lenticular, medium-gray, weathers orange-yellow, platy, calcareous; breaks up into large flat concretions in two layers along outcrop; trace of baculite.....	2	0	993	5
Shale, medium to light olive-gray to medium-gray, papery calcareous; sand laminae and sandstones a few millimeters thick; upper part hard, brittle; large thick <u>Inoceramus</u> ..	21	1	931	5
Mudstone, lenticular, light to medium-gray, weathers buff to orange-yellow, calcareous; fish scales, plant fragments (?).....		6	910	4
Shale, medium-gray, fissile to papery, calcareous; with sandstones a few millimeters thick.....	2	6	909	10
Concretion layer; medium-gray, weathers orange-yellow, massive, calcareous mudstone concretions; large, discoidal.....		7	907	4

Mancos Shale--Continued

	Ft	in	Ft	in
Shale, medium to dark gray to olive-gray, papery to fissile, calcareous; a few sandstones a few millimeters thick; large thick <u>Inoceramus</u>	9	11	906	9
Mudstone, lenticular, light to medium-gray weathers buff, massive to platy, calcareous; ammonite impressions..	1	8	896	10
Shale, light to medium olive-gray to gray to medium to dark-gray, fissile, papery to platy, calcareous; platy layers hold up steeper slope; with a few sandstones in the lower few feet a few millimeters thick; <u>Inoceramus</u> impressions.....	22	2	895	2
Mudstone, light-gray, weathers orange-yellow, platy, calcareous; <u>Inoceramus</u>		8	873	0
Shale, medium to dark-gray, papery to fissile, calcareous; with a few sandstones a few millimeters thick....	7	8	872	4
Mudstone, lenticular, medium-gray, weathers orange-yellow, massive to platy, calcareous; ammonites.....		10	864	8
Shale, light to medium-gray to light to medium olive-gray, fissile, calcareous; with tan to light gray calcarenites a few millimeters thick; large thick <u>Inoceramus</u>	17	0	863	10
Mudstone, lenticular, light to medium-gray, weathers buff to orange-yellow, massive to platy, slightly calcareous		10	846	10
Shale, black, papery to platy; with some sandstones a few millimeters thick interbedded.....	60	3	846	0
Sandstone, thin, platy; interbedded with thin fossiliferous, calcareous mudstone.....	12	9	785	9

Mancos Shale--Continued

	Ft	in	Ft	in
Shale, black, fissile to platy; parts with tan partings.....	113	6	773	0
Sandstone, brown-red, thin, platy...		1	659	6
Shale, black; weathers into tan, papery plates; interbedded with thin platy calcareenites (?).....	27	11	659	5
Shale, black, fissile to platy, slightly calcareous; some weathers into papery gray plates.....	50	3	631	6
Sandstone, red-brown, platy.....		2	581	3
Shale, light to medium olive-gray, papery to fissile, calcareous; thick- shelled <u>Inoceramus</u>	26	7	581	1
Bentonite.....		6	554	6
Shale, light to medium olive-gray, fissile, calcareous, slightly bentonitic.....	3	9	554	0
Bentonite.....		2	550	3
Shale, light to medium olive-gray, fissile to papery, calcareous; thick- shelled <u>Inoceramus</u> ; interbedded with a few calcarenites a few millimeters thick, more concentrated at bottom.	5	8	550	1
Bentonite.....		5	544	5
Shale, light to medium olive-gray, fissile to papery, calcareous; with a few cal- careenites a few millimeters thick.	17	0	544	0
Sandstone; weathers reddish; platy, with shale partings.....	1	0	527	0

Juana Lopez Member

Mancos Shale--Continued

	Ft	in	Ft	in
Sandstone (calcarenite), tan, cross-laminated; animal trails; some beds to two inches thick; interbedded with light to medium olive-gray fissile to papery calcareous shale; thick-shelled <u>Inoceramus</u>	15	0	526	0
Sandstones (calcarenite), tan to buff, platy, laminated and cross-laminated, ripple-marked; up to a few centimeters thick; with animal trails; interbedded with medium to dark-gray, fissile to papery, non-calcareous shale; contains large discoidal to spherical, light-gray limestone concretions with cone-in-cone and septarian structures.....	27	10	511	0
Bentonite.....		2	491	2
Sandstones (calcarenite), tan to buff, platy, laminated and cross-laminated, ripple-marked; up to a few centimeters thick; with animal trails; interbedded with medium to dark-gray, fissile to papery, non-calcareous shale; contains large discoidal to spherical, light-gray limestone concretions with cone-in-cone and septarian structures.....	4	8	491	0
			486	4
Sandstone (calcarenite?); weathers brown.....		5		
Sandstone (calcarenite), tan to buff, platy, laminated and cross-laminated, ripple-marked; up to a few centimeters thick with animal trails; interbedded with medium to dark-gray, fissile to papery, non-calcareous shale.....	5	9	485	11
Sandstone (calcarenite).....		6	480	2

Mancos Shale--Continued

	Ft	in	Ft	in
Sandstone (calcarenite), tan to buff, platy, laminated and cross-laminated, ripple-marked; up to a few centimeters thick, with animal trails; interbedded with medium to dark-gray, fissile to papery, non-calcareous shales.....	12	6	479	8
Calcarenite, medium-gray, flaggy to platy; petroliferous odor; pelecypods and ammonites.....	1	0	467	2
Sandstone (calcarenite), platy, to few inches thick; interbedded with medium-gray, non-calcareous shale with petroliferous odor; <u>Inoceramus</u> other clams, shark teeth.....	15	4	466	2
Calcarenite, medium to light-gray, weathers orange brown flaggy to platy, cross-laminated; petroliferous odor; <u>Inoceramus</u> , other clams.....	3	0	450	10
Shale, light to medium-gray to tan to buff to yellow, fissile to platy, non-calcareous, gypsiferous; <u>Inoceramus</u> ; interbedded with light-gray, weathering to buff, platy, cross-laminated calcarenite; animal trails, <u>Inoceramus</u> , tiny plant fragments.....	14	0	447	10
Concretion layer; concretions with light-gray limestone cores that weather tan to buff and have an earthy pink shell on underside; spherical to three feet in diameter; thin sandstone beds are draped over them.....	3	0	425	10
Shale, light to medium-gray to tan to buff to yellow, fissile to platy, non-calcareous, gypsiferous; <u>Inoceramus</u> ; interbedded with light-gray weathering to buff, platy, cross-laminated calcarenite; animal trails, <u>Inoceramus</u>	2	6	422	10

Mancos Shale--Continued

	Ft	in	Ft	in
Lower Carlile Member				
Shale, light to medium-gray to tan to buff to yellow, fissile to platy, non-calcareous, gypsiferous; interbedded with light-gray, weathering buff, platy, cross-laminated calcarenite; animal trails, <u>Inoceramus</u>	11	10	419	6
Bentonite.....		2	415	6
Shale, dark-gray, fissile to papery, brittle, non-calcareous, gypsiferous; large limestone concretions and a few thin lenticular limestones scattered throughout; also some one to two inch diameter (pyrite) concretions; some interbedded calcarenites a few millimeters to two centimeters thick...	5	2	407	4
Bentonites (two); separated by a few inches of shale; bentonites two inches thick.,.....		8	402	2
Shale, dark-gray, fissile to papery, non-calcareous, gypsiferous; large limestone concretions scattered throughout; some interbedded calcarenites a few millimeters to two centimeters thick	35	6	401	6
Limestone, lenticular, medium to dark-gray, weathers buff to yellow-orange, massive, fine-grained; calcite crystals in center in septarian like fractures; <u>Inoceramus</u> , coiled ammonite impressions.....	1	0	366	0
Shale, dark-gray, fissile to papery, non-calcareous, gypsiferous; some interbedded calcarenites a few millimeters to a centimeter thick; (snails, fish teeth, clams, in float).....	2	3	365	0
Shale, dark-gray, fissile to papery, non-calcareous, gypsiferous; fractured with iron-oxide and yellow stains on planes.....	30	5	362	9

Mancos Shale--Continued

	Ft	in	Ft	in
Bentonite, tan to yellow-orange, fissile to blocky.....	1	5	332	4
Shale, medium to dark-gray, blocky to fissile, non-calcareous, gypsiferous; iron-oxide stain on fractures; softer than shale above.....	14	4	330	11
Bentonite; layer of large spherical medium-gray limestone concretions centered at same level; they weather buff, are one to four feet in dia- meter and have a shell of cone-in- cone structure.....		3	316	7
Shale, medium to dark-gray, soft, fissile to platy, non-calcareous, gypsiferous; iron-oxide and yellow stain on bedding and fracture planes; large spherical, medium to dark-gray, fine-grained limestone concretions scattered throughout, up to four feet in diameter with calcite crystals at cores of septarian structure and a shell of cone- in-cone.....	34	0	316	4
Shale, medium to dark-gray, soft, fissile to platy, non-calcareous, gypsiferous; iron-oxide and yellow stain on plates	22	8	282	4
Shale, medium to dark-gray, hard, brittle fissile to platy, non-calcareous...	11	4	259	8
Shale, medium to dark-gray, soft, fissile bentonitic (?), non-calcareous....	18	6	248	4
Bentonite, tan to yellow to orange...		4	229	10
Shale, medium-gray, hard, brittle, fissile to platy, non-calcareous..	8	3	229	6
Bentonite.....		4	221	3

Mancos Shale--Continued

	Ft	in	Ft	in
Shale, medium to dark-gray to medium to dark olive-gray, fissile to platy, non-calcareous, gypsiferous; with silty laminae about one millimeter or less thick; coiled compressed ammonite; a calcareous layer a few feet thick near base.....	43	6	218	5
Bentonite.....		5	174	11
Shale, black, platy, non-calcareous; compressed coiled ammonite.....	11	4	174	6
Bentonite.....		2	163	2
Shale, black, platy, calcareous, gypsiferous; abundant oysters, ammonites, fish scales; lowest occurrence of compressed coiled ammonite at 15 feet below base...	26	6	163	0
Shale, black, platy, hard, calcareous; ammonites common.....	10	1	136	6
Bentonite.....		1	126	5
Shale, black to gray, platy, hard, calcareous; ammonites common; hard enough to be called a limestone in places (?); plant fragments (?)..	25	3	126	4
Calcarenite, light to medium-gray, weathers reddish-brown; fossiliferous.....		1	101	1

Greenhorn Limestone Member

Shale medium-gray platy, hard, calcareous; weathers into papery plates; one six-inch harder layer two feet from top.....	13	8	101	0
Limestone, medium-gray, weathers buff, fine-grained, massive; <u>Inoceramus</u>	1	6	87	4

Mancos Shale--Continued

	Ft	in	Ft	in
Shale, medium-gray, fissile to platy, calcareous.....	2	6	85	10
Limestone, medium-gray, weathers buff, fine-grained, platy to massive, <u>Inoceramus</u>	1	0	83	4
Shale, medium-gray fissile to platy, calcareous.....	3	6	82	4
Limestone, medium-gray, weathers buff, fine-grained, massive; <u>Inoceramus</u>	1	6	78	10
Shale, medium-gray, platy to fissile, calcareous.....	2	4	77	4
Limestone, medium-gray, platy to massive, fine-grained; <u>Inoceramus</u>	1	8	75	0
Shale, interbedded with limestone or calcareous mudstones; tan to light to medium-gray; one inch to one foot thick; calcareous, gypsiferous; <u>Gryphaea</u> in lower part.....	6	10	73	4
Bentonite.....		7	66	6

Graneros Shale Member

Shale, medium to dark-gray, fissile to platy, calcareous, gypsiferous; iron-oxide stain on some planes; <u>Gryphaea</u> restricted to upper five feet two inches and concentrated in a three-inch layer nine inches from the top; oysters, shark teeth	10	8	65	11
Bentonite.....		8	55	3
Shale, medium to dark-gray, fissile to platy, calcareous, gypsiferous; iron-oxide stain on some planes.....	7	11	54	7
Limestone, lenticular, light to medium-gray, weathers buff to tan, fine-grained; oysters; tends to break up into concretion layer.....		10	46	8

Mancos Shale--Continued

	Ft	in	Ft	in
Shale, medium to dark-gray, fissile to platy, calcareous, gypsiferous; oysters.....	1	6	45	10
Limestone, light to medium-gray, weathers buff to tan, fine-grained.....		4	44	4
Bentonite (three beds), separated from limestone above and each other by shale like below; upper bed is four inches thick, middle five inches, lower one and one-fourth inch thick and separated by nine inches and one foot two inches, respectively...	2	10	44	0
Limestone, lenticular to concretionary, light-gray to tan, weathers buff, massive, fine-grained weathers into two inch blocks.....	1	3	24	3
Mudstone, shaly, light to medium olive-gray, weathers light-gray, fissile to platy to starchy, calcareous, gypsiferous; small clams.....	8	3	23	0
Mudstone, as above; with fine-grained, massive light to medium-gray, weathers to brown; limestone concretions from a few inches to over one foot in diameter; bottom is marked by layer of "basketball-size" concretions; oysters.....	5	5	14	9
Mudstone, shaly, sandy, light to medium olive-gray, starchy to fissile, calcareous, gypsiferous.....	<u>9</u>	<u>4</u>	9	4
Dakota Sandstone	1641	7		
Sandstone, thick-bedded.....	12	0	14	0
Lignitic shale.....	1	0	2	0
Lignite.....	<u>1</u>	<u>0</u>	1	0
	14	0		

PLATES

PLATE 1

- 1 Baltisphaeridium cf. B. eypensis, X 1000
- 2 Baltisphaeridium cf. B. infalatum, X 1000
- 3 Baltisphaeridium sp. 1, X 750
- 4-7 Michrystridium spp., X 1000
- 8 Form X sp. 1, X 1000
- 9 Form L sp. 1, X 1000
- 10 Form N sp. 1, X 1000
- 11 Form T sp. 1, X 1000
- 12 Form S sp. 1, X 1000
- 13 Veryhachium cf. V. stellatum, X 750
- 14 Form S sp. 2, X 1000
- 15 Veryhachium sp. 1, X 1000
- 16 Veryhachium cf. V. europeum, X 1000
- 17 Veryhachium sp., X 1000
- 18 Leiofusa sp., X 1000

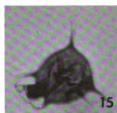
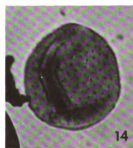
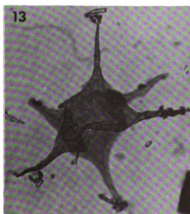
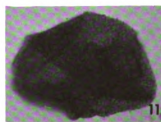
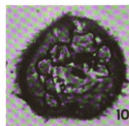
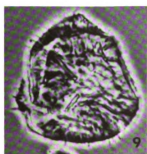
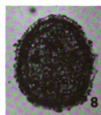
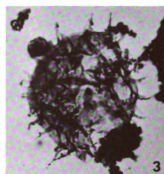
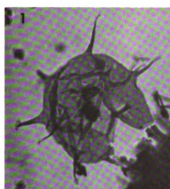


PLATE 1

PLATE 2

- 1 Metaleiofusa sp., X 1000
- 2,5 Cymatiosphaera app., X 1000
- 3 Pterospermopsis sp., X 1000
- 4 Form B sp. 3, X 1000
- 6 Form B sp. 2, X 1000
- 7 Form B sp. 1, X 1000
- 8 Form B. sp. 4, X 750
- 9 Form C sp. 2, X 1000
- 10 Form C sp. 1, X 1000
- 11 Form C sp. 3, X 1000
- 12 Hystrichosphaeridium cf. H. deanei, X 750
- 13 Hystrichosphaeridium cf. H. tubiferum, X 750

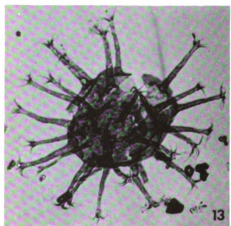
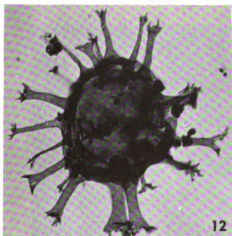
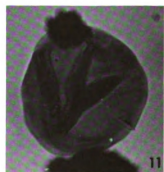
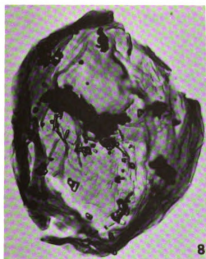
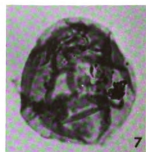
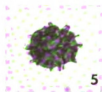
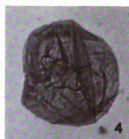
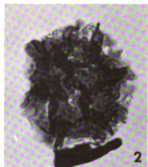
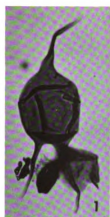


PLATE 3

- 1 Oligosphaeridium pulcherrimum, X 750
- 2 Cordosphaeridium sp. 1, X 750
- 3 Cordosphaeridium difficile, X 750
- 4-5 Tanyosphaeridium cf. T. variecalamum, X 1000
- 6 Hystrichokolpoma ferox, X 750

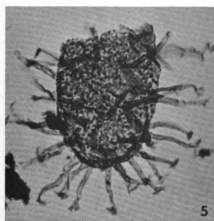
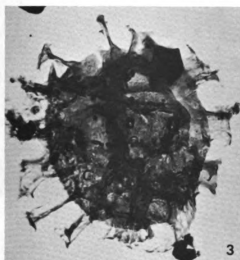
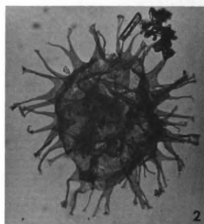
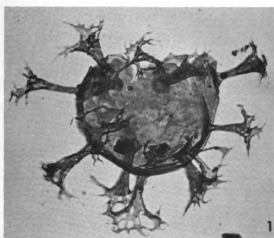


PLATE 4

- 1 Litosphaeridium siphonophorum, X 1000
- 2 Diphyes cf. D. colligerum, X 750
- 3-5 Polysphaeridium spp., X 750
- 6 Surculosphaeridium cf. S. vestitum, X 750
- 7 Form O sp. 1, X 750

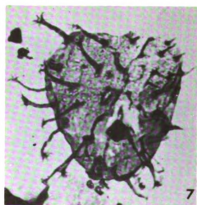
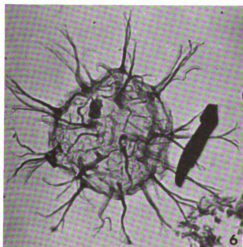
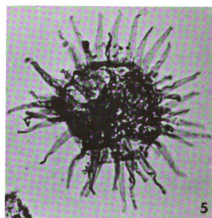
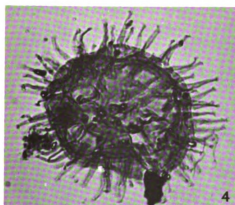
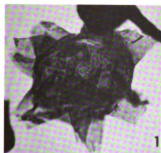


PLATE 5

- 1 ?Exochosphaeridium phragmites, X 750
- 2 ?Exochosphaeridium sp. 1, X 750
- 3 Hystrichosphaera ramosa, X 750
- 4 ?Exochosphaeridium sp. 2, X 750
- 5 Hystrichosphaera ramosa var. 1, X 750
- 6 Hystrichosphaera ramosa var. 2, X 750

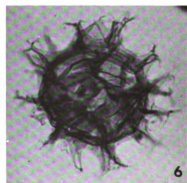
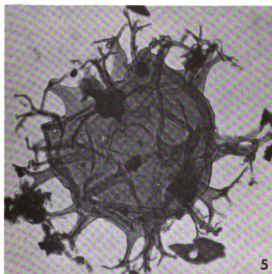
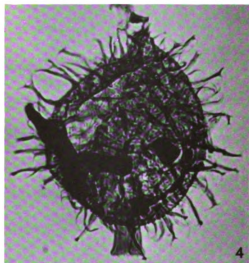
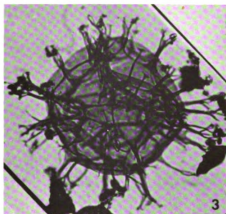
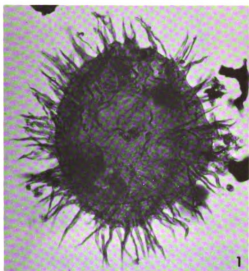


PLATE 6

- 1-2 Hystrichosphaera sp. 1, X 750
- 3 Microdinium cf. M. ornatum, X 1000
- 4 Heslerton heslertonesis, X 750
- 5 ?Leptodinium dispertitum, X 1000
- 6-7 Gonyaulacysta spp., X 750

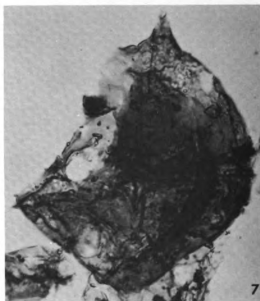
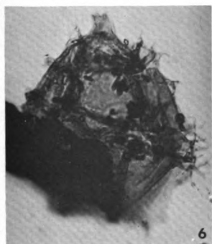
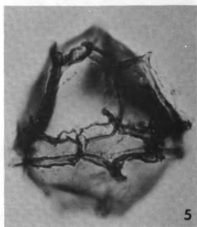
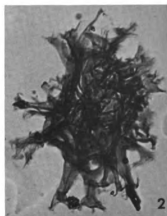
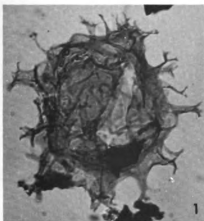


PLATE 7

- 1-2 ?Gonyaulacysta sp. 1, X 750. 2 shows crests missing(?)
- 3-4 Areoligera spp., X 750
- 5-6 Cyclonephelium spp., X 750

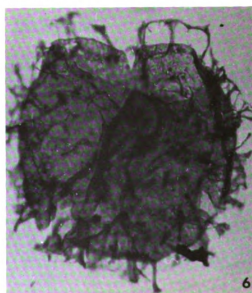
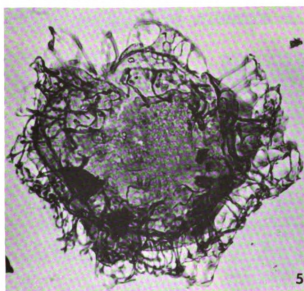
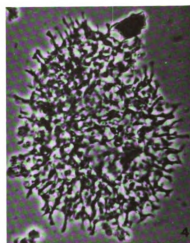
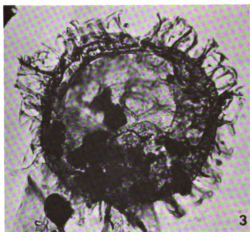
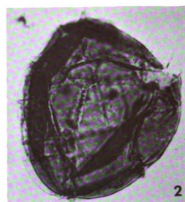
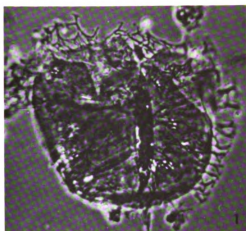


PLATE 8

- 1 Tenua sp., X 750
- 2 Palaeohystrichophora infusoroides, X 750. three specimens
- 3 Paleohystrichophora infusoroides var. 1, X 750
- 4 Fromea amorphia, X 1000
- 5 Deflandrea cf. D. minor, X 1000
- 6 Deflandrea cf. D. verrucose, X 750
- 7 Deflandrea cf. D. granulifera, X 750
- 8 Deflandrea cf. D. acuminata, X 750

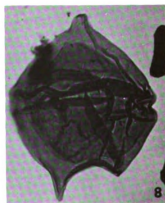
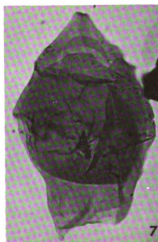
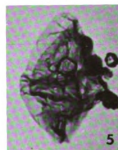
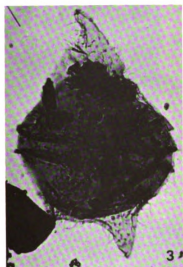
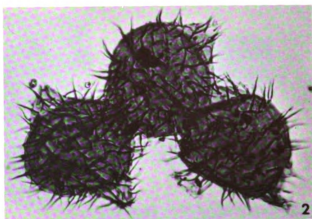


PLATE 9

- 1-3,5 Deflandrea cf. D. balmei, X 1000
- 4 Deflandrea sp. 4, X 750
- 6 Deflandrea sp. 1, X 1000
- 7 Deflandrea cf. D. micracantha, X 750
- 8 Deflandrea sp. 2, X 750

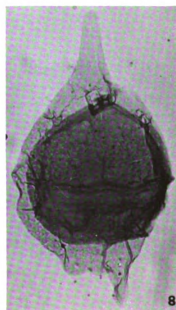
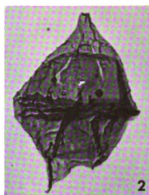


PLATE 10

- 1,3 Hexagonifera suspecta var. 1, X 750
- 2 Deflandrea sp. 3, X 750
- 4 Hexagonifera suspecta, X 750
- 5 Hexagonifera suspecta var. 2, X 750

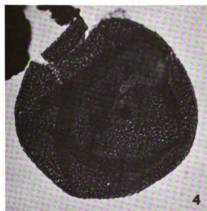


PLATE 11

- 1-2 Odontochitina striatoperforata, X 500
- 3 Form F sp. 1, X 750
- 4-5,7-8 Dinogymnium sp. 1, X 1000
- 6 Canningia cf. C. colliveri, X 750

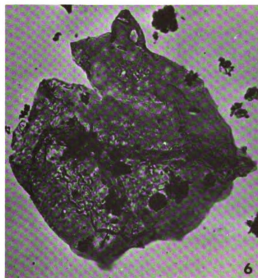
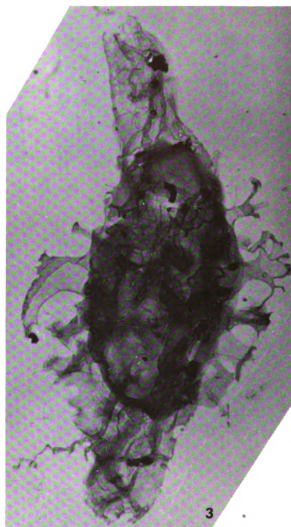


PLATE 12

- | | |
|------|--|
| 1-10 | <u>Dinogymnium</u> sp. 2, X 1000 |
| 11 | ? <u>Diconodinium</u> <u>arcticum</u> , X 1000 |
| 12 | ? <u>Horologinella</u> <u>spinosa</u> , X 1000 |

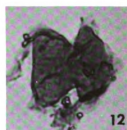
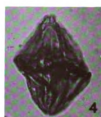


PLATE 13

- 1 Form D sp. 1, X 750
- 2 ?Trigonopyxidia sp., X 1000
- 3 Palambages cf. P. deflandrei, X 750
- 4 Pediastrum sp., X 750
- 5 Gleicheniidites senonicus, X 1000
- 6 Sphagnumsporites antiquasporites, X 1000
- 7 Gleicheniidites circinidites, X 1000
- 8 Leiotrilets pseudomaximus, X 1000
- 9 Cardioangulina diaphana, X 1000

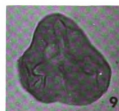
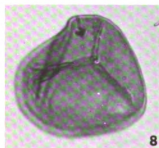
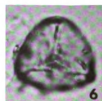
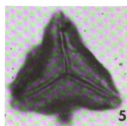
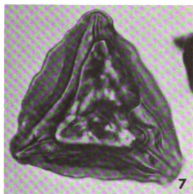
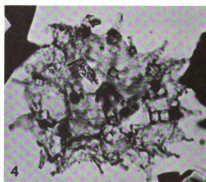
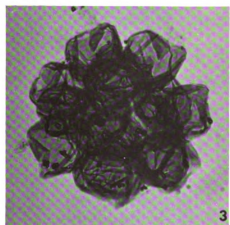
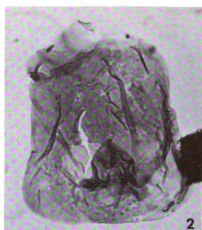
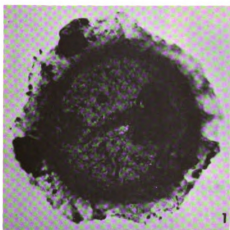


PLATE 14

- 1 Cardioangulina diaphana, X 1000
- 2 ?Deltoidospora hallii, X 1000
- 3 Undulatisporites sp. 1, X 1000
- 4 Triplanosporites cf. T. terciarius, X 1000
- 5,10,13 Undifferentiated large smooth trilete spores, X 1000
- 6 Cyathidites cf. C. mesozoicus, X 1000
- 7 Triplanosporites sinuosus, X 1000
- 8 ?Concavisporites sp. 1, X 1000
- 9 Cingulatisporites radiatus, X 750
- 11 Kuylisporites scutatus, X 1000
- 12 ?Acanthotriletes varispinosus, X 1000
- 14 Concavissimisporites variverrucatus, X 750

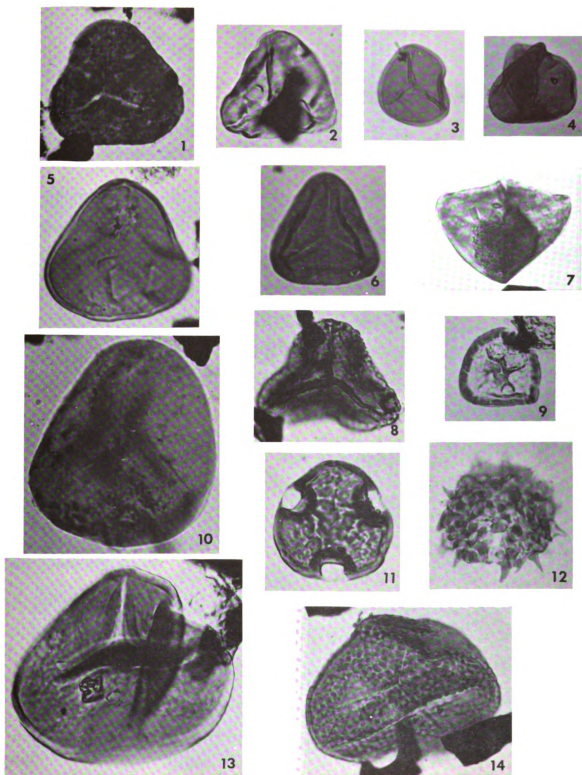


PLATE 14

PLATE 15

- 1 Lycopodiumsporites cerniidites, X 1000
- 2 ?Camarozonosporites insignis, X 1000
- 3 Converrucosisporites cf. C. platyverrucosus, X 1000
- 4 Appendicisporites cf. A. tricornatatus, X 1000
- 5 Cicatricosisporites cf. C. hallei, X 1000
- 6 Cicatricosisporites cf. C. dorogensis, X 1000
- 7 ?Corrugatisporites toratus, X 1000
- 8 Laevigatosporites cf. L. ovatus, X 1000
- 9 Small Pinus-type pollen grain, X 1000
- 10 Cicatricosisporites cf. C. carlylensis, X 1000
- 11 Vitreisporites pallidus, X 1000
- 12 Verrucatosporites cf. V. favus, X 1000
- 13 Reticulate monolete spore, X 750
- 14 Large Pinus-type pollen grain, X 750

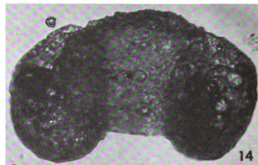
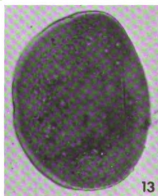
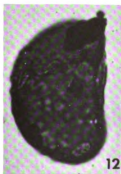
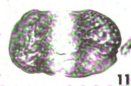
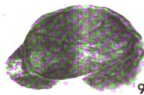
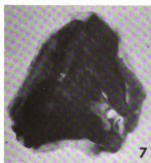
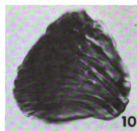
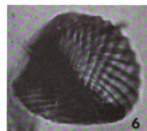
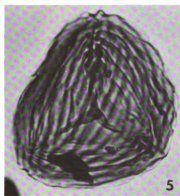
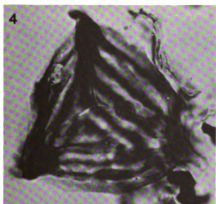
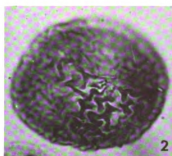
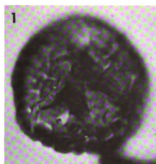


PLATE 16

- 1 Picea-type pollen grain, X 750
- 2-3 Classopollis cf. C. classoides, X 1000. 2 shows a tetrad
of small-size class; 1 is large-size class
- 4 ?Parvisaccites sp. 1, X 750
- 5-6 Classopollis sp. 1, X 1000. 5 shows a tetrad; 6 shows
tetrad mark on a single grain
- 7 Rugubivesiculites cf. R. reductus, X 750
- 8 Large Equisetoporites sp., X 1000
- 9 Abies-type pollen grain, X 750
- 10 Small Equisetoporites sp., X 1000
- 11-12 Inaperturopollenites sp. 1, X 1000
- 13 Inaperturopollenites sp. 2, X 1000
- 14 Inaperturopollenites sp. 3, X 1000

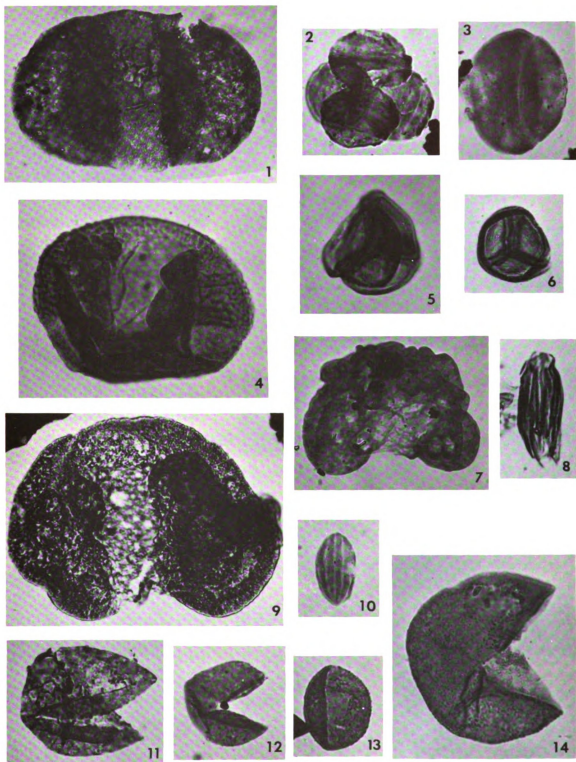


PLATE 16

PLATE 17

- 1-2 Inaperturopollenites limbatus, X 750. 2 shows type with rudimentary "bladder"
- 3 ?Cycadopites sp. 1, X 1000
- 4 Quadripollis Krempii, X 750
- 5 ?Cycadopites sp. 3, X 1000
- 6 ?Cycadopites sp. 2, X 1000
- 7 Inaperturopollenites sp. 3, X 1000
- 8 Eucommiidites cf. E. troedssonii, X 1000
- 9 Eucommiidites cf. E. couperi, X 1000
- 10 Eucommiidites sp. 1, X 1000
- 11 Exesipollenites tumulus, X 1000
- 12-14,17 Tricolpopollenites cf. T. retiformis, X 1000; 17 X 750
- 15,19-20 Tricolpopollenites cf. T. micromunus, X 1000
- 16 Pflugipollenites dampieri, X 1000
- 18 Tricolpopollenites henrici, X 1000

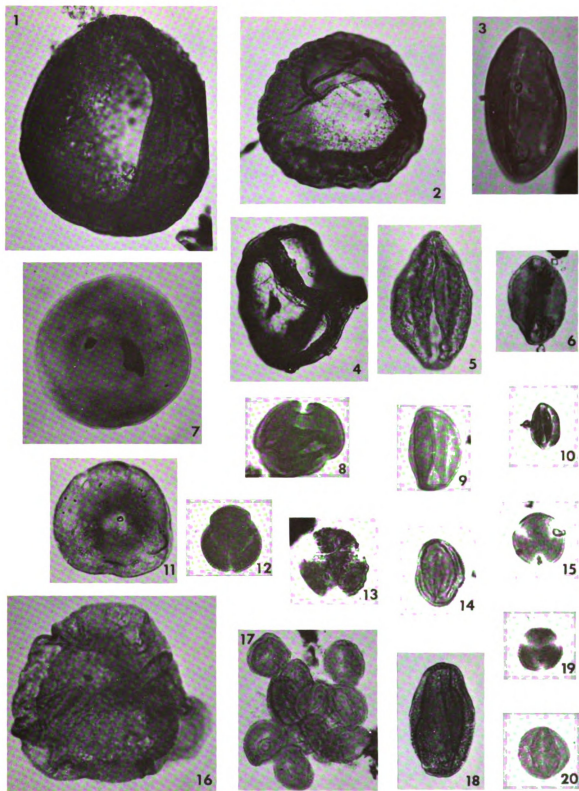


PLATE 17

PLATE 18

- 1 Tricolpopollenites sp. 1, X 1000
- 2-3 Tricolpopollenites sp. 6, X 1000
- 4,10 Tricolpopollenites sp. 5, X 1000
- 5 Tricolporites traversi, X 1000
- 6 Tricolpopollenites sp. 7, X 1000
- 7 Tricolpopollenites sp. 4, X 1000
- 8 Tricolporites rhomboides, X 1000
- 9 Tricolpopollenites sp. 3, X 1000
- 11 Tricolpopollenites sp. 2, X 1000
- 12-13 Tricolpites cf. T. explanata, X 1000. 12 shows the larger
size, 13 shows the smaller size
- 14 ?Trialapollis sp. 1, X 1000
- 15 Retitricolpites cf. R. georgensis, X 1000
- 16 Tricolpites cf. T. bathyreticulatus, X 1000
- 17,21-22 Duplopollis cf. D. orthoteichus, X 1000
- 18 Tricolpites cf. T. anguloluminosus, X 1000
- 19 Tricolpopollenites sp. 8, X 1000
- 20 Retitricolpites cf. R. geranioides, X 1000
- 23 Tripoporopollenites sp. 1, X 1000
- 24 Hexacolpate pollen grain, X 1000
- 25 Dicotetradites cf. D. clavatus, X 1000
- 26-28 Tripoporopollenites cf. T. scabroporus, X 1000. 27 shows
form with protruding pores
- 29 ?Extratripoporopollenites sp., X 1000

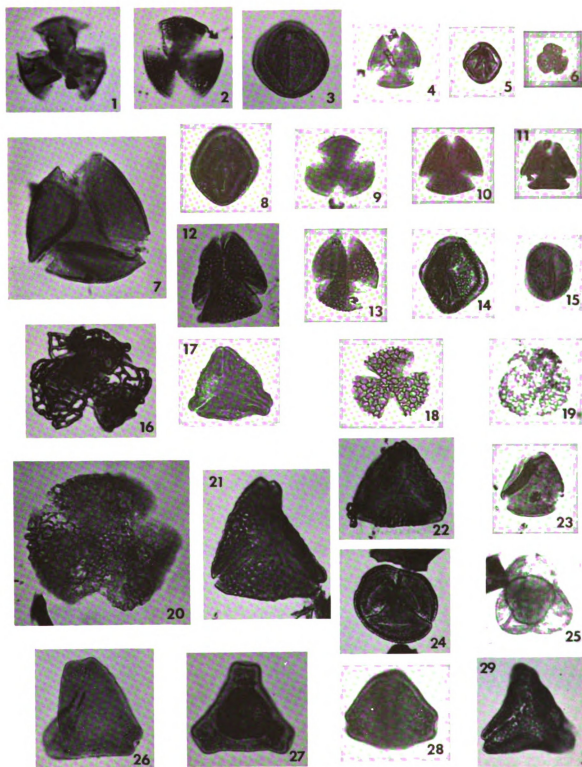
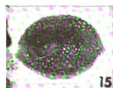
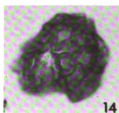
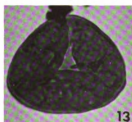
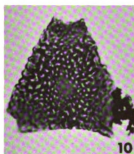
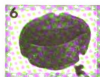
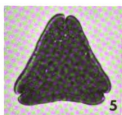


PLATE 18

PLATE 19

- 1 Triatriopollenites cf. T. rurensis, X 1000
- 2 ?Porocolpopollenites sp. 1, X 1000
- 3 ?Plicapollis silicatus, X 1000
- 4 Trudopollis cf. T. hemiparvus, X 1000
- 5 Conclavipollis cf. C. wolfcreekensis, X 1000
- 6 Labrapollis globsus, X 1000
- 7 Sporopollis cf. S. laqueaeformis, X 1000
- 8 Triporopollenites cf. T. tectus, X 1000
- 9 Proteacidites cf. P. thalmanii var. 4, X 1000
- 10 Proteacidites thalmanii var. 3, X 1000
- 11 Proteacidites thalmanii var. 2, X 1000
- 12 Proteacidites thalmanii var. 1, X 1000
- 13 Trichotomosulcites cf. T. contractus, X 1000
- 14 Peromonolites peroreticulatus, X 1000
- 15 Liliacidites cf. L. leei, X 1000



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