PALYNOLOGY AND PALEOECOLOGY OF THE BUCK TONGUE OF THE MANCOS SHALE (UPPER CRETACEOUS) FROM EAST CENTRAL UTAH AND WESTERN COLORADO

THESIS FOR THE DEGREE OF PH D

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EVAN JOSEPH KIDSON

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This is to certify that the

thesis entitled

PALYNOLOGY AND PALEOECOLOGY OF THE BUCK TONGUE
OF THE MANCOS SHALE (UPPER CRETACEOUS)
FROM EAST CENTRAL UTAH AND WESTERN COLORADO

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Evan J. Kidson

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Major professor

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ABSTRACT

PALYNOLOGY AND PALEOECOLOGY OF THE BUCK TONGUE
OF THE MANCOS SHALE (UPPER CRETACEOUS)
FROM EAST CENTRAL UTAH AND WESTERN COLORADO

By Evan J. Kidson

The sediments of the Buck tongue of the Mancos Shale were systematically collected from five localities along the Book Cliffs in east central Utah and western Colorado. The most westerly section is at Tuscher Wash north of Green River, Utah and the most easterly section is at West Salt Creek in Colorado about 70 miles east of Tuscher Wash. The line of sections is normal to the trend of the old Upper Cretaceous shoreline in this area.

The samples were treated by standard palynologic techniques and quantitative counts were made.

The fossil record of the Buck tongue is interpreted to represent a transitional environment in and around the basin of deposition, but the distant highlands (Wasatch Plateau) are thought to be relatively quiet. The pollen and spore spectrum is very diverse and is dominated by representatives of a floodplain environment which was evolving very rapidly. The relative low frequency of the indigenous marine fossils is discussed and possible explanations proposed.

The paleoecology of the basin of deposition is discussed with respect to the transgressive-regressive cycle as well as the floodplain environment, which is a dominant feature of the ancient landscape, and the upland source area.

The time of the Buck tongue transgression is interpreted to be of such short duration that no recognizable evolution of palynomorphs was observed.

Evan J. Kidson

Data was collected on 224 species of palynomorphs from the middle Campanian of the Book Cliffs and their possible botanical affinity, patterns of distribution and morphologic characteristics are discussed.

The results of a factor analysis are presented with a discussion of their interpretation.

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INTRODUCTION

Statement of problem

At the beginning of this study, a palynologic analysis of sediments of the Upper Cretaceous Buck tongue of the Mancos Shale in the Book Cliffs area of central Utah and Colorado (Fig. 1), the following goals were set.

1. List of all identifiable organic-walled palynomorphs recovered from the sediments.
2. Evaluate palynomorphs indigenous to the Buck tongue seas (autochthonous palynomorphs), and those that were transported from areas surrounding the Buck tongue seas (the land-derived, allochthonous palynomorphs).
3. Determine the systematic position of these palynomorphs and indicate their probable natural affinities.
4. Analyze the changes (both laterally and vertically) in the samples studied:
    a. To determine if computer-based florule zones can be established between the various samples studied.
    b. To determine recurrent cycles, if present, on the basis of the compositional components of the samples.
    c. To establish criteria to delineate the upper and lower boundaries of the Buck tongue on the basis of the microfossils found.
    d. To establish, if possible, florule relationships that can be used to delineate relative proximity to shorelines.

e. To establish time correlation between the various samples of this study if possible.

f. To determine if any evolutionary changes can be delineated in the species recovered from the samples studied.

5. To develop information on the paleoenvironment of the Buck tongue seas and the surrounding area.

Study methods

The sediments of the Buck tongue of the Mancos Shale were systematically described and collected from five localities along the Book Cliffs in western Colorado and eastern Utah. The samples were treated in the laboratory to concentrate all organic-walled palynomorphs and the concentrated residues were mounted on microscope slides for analysis at high magnification. A factor analysis program was used to assist in the interpretation of the data.

Previous work

Geologic.--The first geologic studies of the Book Cliffs were the Hayden and Powell surveys of 1875 to 1877. Numerous minor studies have been completed but the general geology of the Book Cliffs was not known until Spieker and Reeside (1925), Clark (1928), Erdmann (1934), and Fisher (1936), published their respective reports. Young (1955), in a paper on sedimentary facies and intertonguing in the Book Cliffs described in detail the contact between the Mancos Shale and the Mesaverde Group along the entire length of the cliffs. Several studies on the correlation, stratigraphy and paleontology of the Book Cliffs were published by the Intermountain Association of Petroleum Geologists

(Peterson ed., 1966). The cyclic nature of the sedimentary sequences of the Book Cliffs was first described by Spieker (1949), and later by Young (1957). Fisher, Erdmann and Reeside (1960), published a comprehensive study on the Cretaceous and Tertiary formations of the Book Cliffs, a reference which was used extensively during the collection phase of this work. The Geological Society of America Coal Division Field Trip Guidebook (Hamlin and Young, ed., 1966) contains several papers dealing with various aspects of the Mancos Shale along the Book Cliffs.

Palynology.--Several workers have published reports dealing with various aspects of Mesozoic or Mesozoic-Cenozoic palynology from the Rocky Mountains. The earliest study is by Wodehouse (1933), on the taxonomy and systematics of pollen from the Eocene Green River Formation, Garfield County, Colorado. Miner (1935) and Wilson and Webster (1946) reported on the palynology of some Cretaceous and Tertiary coals from Montana. Radforth and Rouse (1954) studied the palynology of the Upper Cretaceous Brazeau Formation of western Canada, and Rouse (1957, 1959), reported on studies of Upper Cretaceous and Jurassic-Lower Cretaceous formations from British Columbia. Sarmiento (1957) published range data, assemblages, and distribution of a variety of Upper Cretaceous palynomorphs from the Rocky Mountain region. Singh (1964) and Norris (1967) published studies on the Mannville Group microfossil flora of Alberta. Anderson (1960), Stanley (1965), Norton and Hall (1967, 1969), and Oltz (1969), reported on the palynology of rocks of the Cretaceous-Tertiary boundary of New Mexico, North Dakota and Montana, respectively, and more recently, Snead (1969) has published the results of his work across this boundary in Alberta. Gray, Patalski, and Schapiro (1966), Leffingwell (1962), Newman (1962, 1965), Tschudy (1961) and Leopold, in Dickinson, Leopold and Marvin (1968), discussed palynomorph assemblages from various Upper Cretaceous sediments.

Several unpublished studies have been completed and a number of theses are currently in progress on sediments of Upper Cretaceous age from the Rocky Mountain region.

Newman (1961, unpublished Ph.D. thesis) is the only other study that has included rocks of the Buck tongue of the Mancos Shale, and his study included only one sample from that stratigraphic unit.

GEOLOGY

Regional and structural setting

The Book Cliffs escarpment marks the southern boundary of the Uinta Basin in Utah and the Piceance Basin in Colorado (Fig. 1). For the entire length of the escarpment the dominant structural feature is the gently northward dipping nature of the strata into the two basins which constitute the northern margin of the Colorado Plateau, a region which has been stable throughout much of geologic time. The major structural features to the south of the Book Cliffs are the San Rafael Swell, Monument Upwarp and the Uncompahgre Uplift. There are also some smaller anticlines and domes and a minor amount of faulting. These features (except the Uncompahgre Uplift) are thought to be Tertiary in age (Osmund, 1965).

The Roan Cliffs, which mark the southern erosional edge of the northward-dipping Tertiary strata, form an irregular escarpment paralleling the underlying Book Cliffs. Both Tertiary and Cretaceous rocks dip generally northward into the Uinta Basin. To the south of the Book Cliffs escarpment, beyond the Mancos Shale flats, older rocks (primarily Jurassic and Triassic) form the surface though other Cretaceous strata are found near the Henry and the La Sal Mountains and locally elsewhere.

The area is drained by the Colorado and the Green Rivers and their tributaries.

Paleogeography

Early Cretaceous seas invaded the old Rocky Mountain Geosyncline and by Albian time had migrated westward to the eastern edge of the Colorado Plateau (Young, 1960). The seas apparently advanced to the west in intermittent irregular pulses, and remained relatively stable between

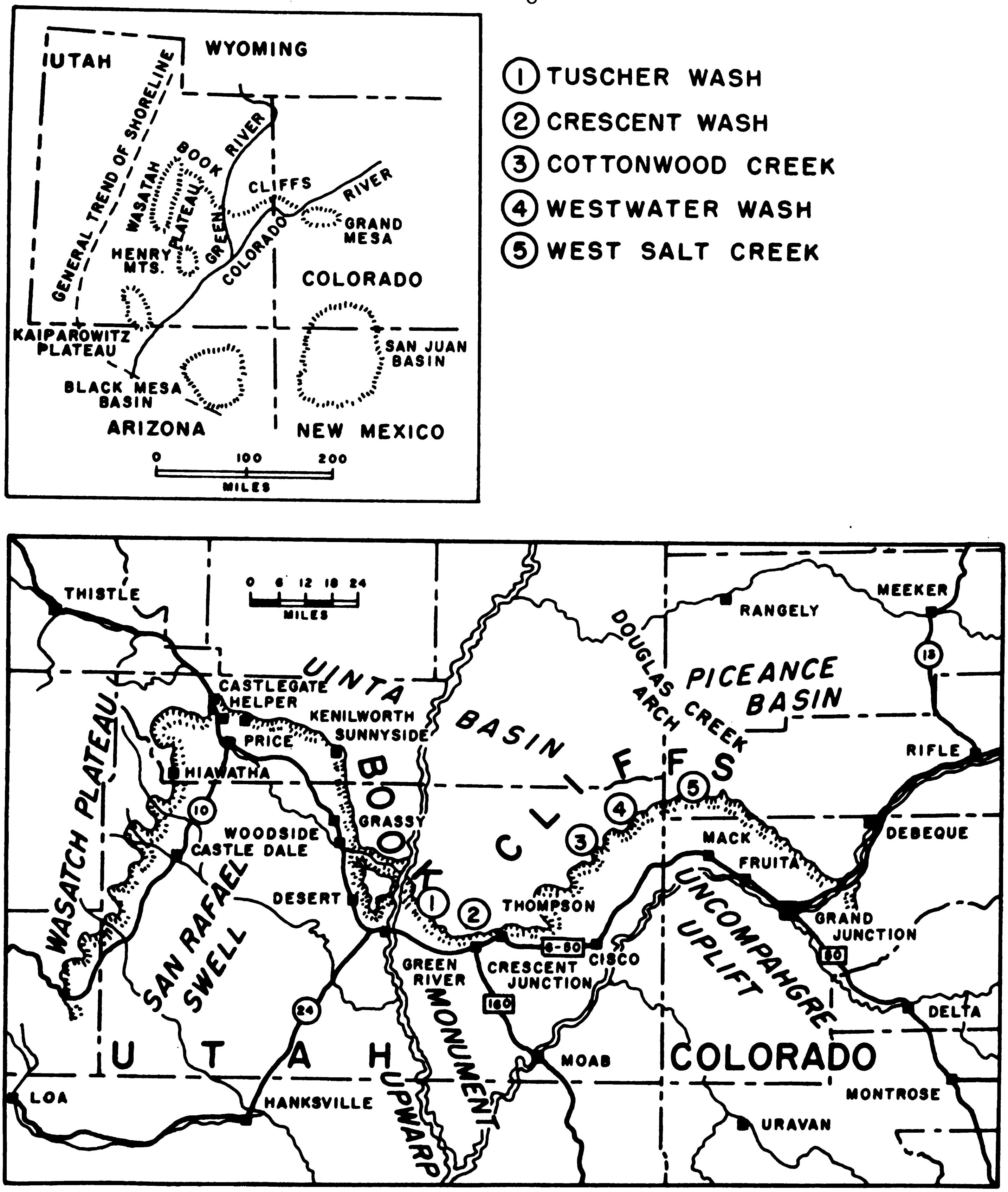

FIGURE 1 Index map and sample localities of this study.

these pulses. Westward transgression of the sea reached its limit (near the edge of the Mesocordilleran Geanticline) in Cenomanian time, where it remained until the regressive phase started during the Early Campanian.

At the time of maximum marine transgression, the typical dark-gray Mancos Shale was deposited as far as the Wasatch Plateau on the west. The main source of sediments was the Sevier Arch in western Utah which supplied sufficient clastic sediments to accumulate to over 12,000 feet in the area occupied now by the Uinta Basin (Osmund, 1965).

A thin blanket of Late Cretaceous sediments over the top of the Douglas Creek Arch in the east, indicates that this moderate tectonic feature, which forms the eastern margin of the Uinta Basin, has remained more positive than the subsiding basins on either side since the end of Cretaceous times (Kopper, 1962). The Uncompahgre Uplift to the south may have been positive through part of the Cretaceous period. This Pennsylvanian remnant of the ancestral Rocky Mountains resulted in thinner Upper Cretaceous strata than are found north and west of this structure.

The eastward withdrawal of the Late Cretaceous sea from Utah, Colorado, and Wyoming was interrupted by many partial readvances, as recorded by the regressive-transgressive cycles of the Late Campanian and younger strata of the area (Fig. 2).

Stratigraphy

General remarks.--The escarpment of the Book Cliffs in the area of this study, exposes regionally a cross section of the sediments approximately normal to the ancient shorelines of the Cretaceous seas. The intricate lateral intertounging of the Mancos Shale and Mesaverde sand-

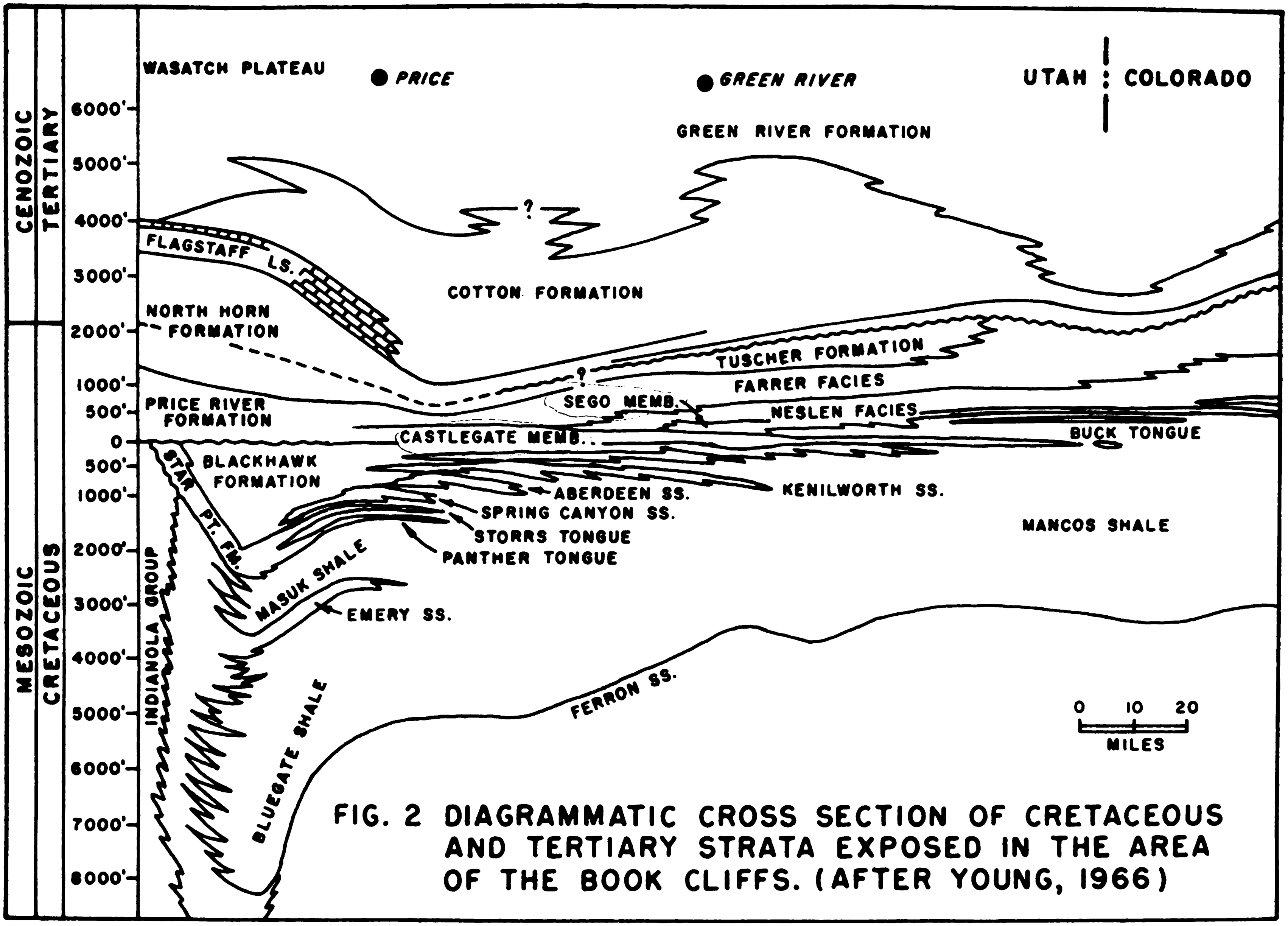

FIG. 2 DIAGRAMMATIC CROSS SECTION OF CRETACEOUS AND TERTIARY STRATA EXPOSED IN THE AREA OF THE BOOK CLIFFS. (AFTER YOUNG, 1966)

stones, which has been well-exposed by the erosional dissection of the cliffs, indicates that Early Cretaceous seas invaded the Rocky Mountain Geosyncline spreading westward over a basin that was subsiding in intermittent pulses. Maximum westward transgression of the sea reached the edge of the geanticline near the Utah-Nevada boundary. The shoreline remained close to the old highland during early Campanian time; by middle Campanian time eastward regression of the sea began with slowly recurring, positive pulses.

Young (1966) recognizes five distinct environmental belts present in the sediments of this area at any given time during Late Cretaceous sedimentation: a) narrow piedmont; b) inland floodplain; c) coastal swamps and marshes; d) mainland beach; e) wide lagoon bordered on the seaward side by a broad barrier beach or by barrier islands. During regression these belts migrated eastward across the old basin. Renewed uplift of the old highland in conjunction with reduced basinal subsidence, or perhaps positive basin movement, are thought to be the causes of the large scale regression of the seas.

A noticeable feature of the sandstone tongues, that extend generally eastward into the shales, is that the upper contact of these attenuated sandstone wedges is always well-defined and, where it is exposed, appears as an unconformable contact. The lower contact, by contrast, is a complex gradational sequence with many thin interfingering sandstone-shale units which make it difficult to define the upper boundary of the shale units. The eastward extension of the sandstones reflect either orogenic movement in the west, basinal uplift or additional clastics being brought in by shifting or new distributary channels or combinations of these conditions to spread thin sandstone units over the muddy bottoms of the Mancos seas. These complexly interfingered contacts suggest a slow, pulsating, withdrawal of the shale lithotope. The well-defined upper contact of the Castlegate Sandstone, which marks the base of the Buck tongue transgression, can be interpreted as a rapid cut off in source of clastics spreading out onto the floors of the basin or possibly a rapid rise in sea level which would smooth out the upper contact of the sand-shale interface.

The natural cross section, approximately normal to the Late Cretaceous shoreline, was provided by Late Tertiary and Quaternary erosional dissection of the Cretaceous sediments. Particularly well-exposed are the eastward littoral marine sandstones that are separated by westward-pointing marine tongues of the Mancos Shale, such as the Buck tongue. Spieker (1949) and Young (1955) have correctly interpreted these shale-sandstone interfaces as diachronous units.

Mancos Shale.--The Mancos Shale is defined as consisting of all strata from the top of the Dakota Sandstone to the base of the lowest sandstone unit of the Mesaverde Group. Cross (1899) first applied the name Mancos to exposures of shale near the town of Mancos in southwestern Colorado. Its use has since been extended to the thick shale, usually in part Coloradoan stage and in part of Montanan, which is exposed over a large region south of the Uinta Mountains and west of the Rocky Mountains.

The Mancos Shale is a well-marked lithologic unit. It appears as a drab, slightly bluish-gray marine shale with some thin lenses of calcareous sandstone, limestone and a few concretionary beds. The surface thickness of the formation is between 3,450 and 4,120 feet in Colorado;

thicknesses in excess of 5,000 feet have been reported for localized areas. The freshly exposed shale looks clayey but feels slightly gritty to the teeth yet is fine grained enough to be practically impervious to wetting by rain. Veinlets of gypsum and calcite are common and patches of white 'alkali' are often present on the surface of the outcrop. The top of the Mancos Shale rises about 2,700 feet stratigraphically between Castlegate, Utah and Palisade, Colorado (Spieker, 1949), a distance of 135 miles. Near Helper, Utah, it is middle Campanian, and near Palisade, Colorado, it is late Campanian at its upper contact (Young, 1966).

Buck tongue of the Mancos Shale.--A westward-thinning tongue of the Mancos Shale designated by Fisher (1936) as the Buck tongue, from the name of a canyon (T. 19 S., R. 23 E.), overlies the Castlegate Sandstone from the Beckwith Plateau (north of Green River, Utah) to a point west of the Colorado-Utah line. Farther west it feathers out into the predominantly sandy facies of the lower part of the Price River Formation and is not separable from it; Young (1966) has been able to identify the Buck tongue as far west as north of the Beckwith Plateau near Woodside, Utah. The thickness of the Buck tongue increases eastward from about 100 feet in the southern part of the Beckwith Plateau to 360 feet in Colorado. With the disappearance of the underlying Castlegate interval farther east, it merges with the Mancos Shale.

Lithologically the Buck tongue cannot be distinguished from the Mancos Shale. The Mancos Shale commonly contains invertebrate fossils and remains of vertebrates. Thin ash or bentonite zones are common. These features are not found in the shale of the Buck tongue. Its upper contact is gradational into the overlying Sego Sandstone, but its lower contact with the Castlegate sandstone is sharp with no evidence of any intertonguing. Fisher, et al. (1960) found that fossil-bearing limestones in the Buck tongue of the Mancos Shale has yielded a marine fauna most comparable to that of the Gregory member of the Pierre Shale to the east.

Areal extent of the Buck tongue.--The areal extent of the Buck tongue of the Mancos Shale is not fully known but it is reported to be a very thin unit in Cow Wash, Utah on the northern flank of the Uinta Basin, and thickens considerably near Rangely, Colorado (Zapp and Cobban, 1960). Newman (1965) found this unit to be over 270 feet thick on the north and east flank of the Piceance Basin. Hale and Van de Graaff (1964) report the thickness of the Buck tongue as 350 feet in the subsurface east of Rangely and 250 feet in the subsurface south of the Douglas Creek Arch in Garfield County, Colorado. The Buck tongue at West Salt Creek in the Book Cliffs east of the Colorado-Utah line is 360 feet thick.

A lithofacies map (Fig. 3) of the Castlegate Sandstone and its equivalents, after Hale and Van de Graaff (1964), shows the maximum westward advance of the shoreline of the Buck tongue transgression. It has been superimposed on the lithofacies map as interpreted by various investigators. The environmental belts as recognized by Young have been added to indicate the lithologic significance of the transgression. The figure includes the area north of the Rock Springs Uplift, Wyoming, an interpretation which is supported by Zapp and Cobban (1962). They state that the Upper Rock Springs transgressive phases are direct correlatives with the Castlegate regression and the Buck tongue transgression of the Book Cliffs. Further, Hale and Van de Graaff correlate the Buck tongue of the Mancos Shale in Colorado and the Black Butte tongue of the Mancos Shale from Sweetwater County, Wyoming.

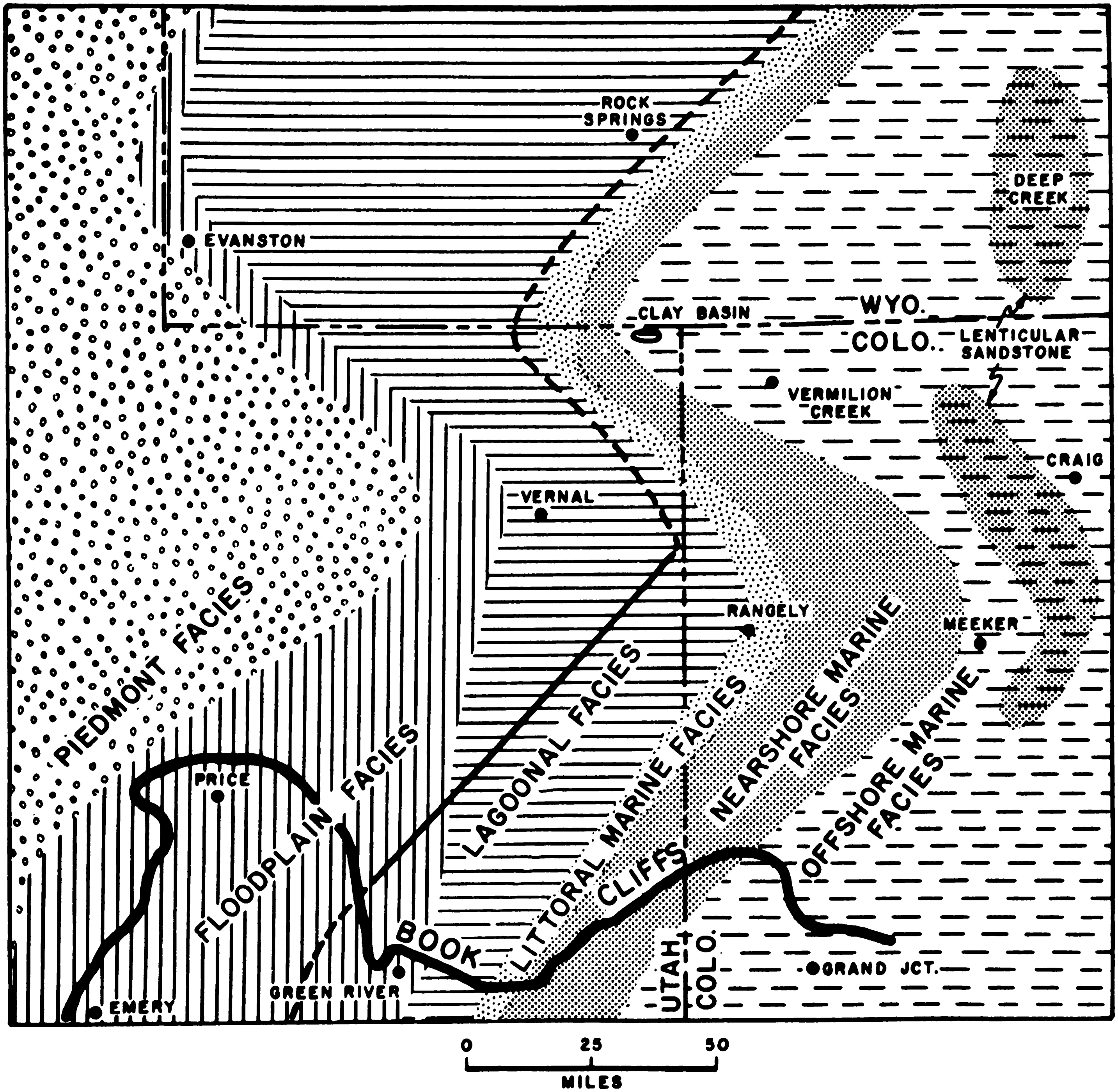

FIGURE 3 Lithofacies map of the Castlegate Sandstone and its equivalents. The maximum transgression of the overlying Buck tongue of the Mancos Shale is indicated by the dashed line (after Hale and Van de Graaff, 1964). The solid line indicates the limits of known deposits of the Buck tongue sea.

Mesaverde Group.--In the western portion of the Book Cliffs, the Mesaverde Group can be divided into four units which are (from the base upward): the Star Point Sandstone, the Blackhawk Formation, the Price River Formation and the lower part of the North Horn Formation (Fig. 2). As these units are traced eastward along the Book Cliffs, the most eastward extension of the Star Point Sandstone disappears, grading into Mancos Shale near Wellington, Utah. The Blackhawk Formation then becomes the basal sandstone until it disappears north of Cisco, Utah, leaving the Price River Formation as the basal unit throughout the eastern Book Cliffs. Cobban and Reeside (1952) indicate an age of middle Campanian to middle Danian for the Mesaverde Group.

Price River Formation.--Spieker and Reeside (1925) defined the Price River Formation as a series of non coal-bearing beds above the Blackhawk Formation from exposures in Price River Canyon near Castlegate, Utah. It was described as a "succession of predominantly gray sandstones, grits and conglomerates, with a minor amount of shale", and included all sedimentary rocks up to what was then called the Wasatch Formation, now the base of the North Horn Formation (Fig. 2). In the western portion of the Book Cliffs it consists of a massive, basal, orogenic sandstone (the Castlegate Member) and an overlying series of carbonaceous shales, sandy shales and lenticular sandstones. The basal Castlegate Member is separated from the remainder of the Price River near Woodside by a thin tongue of Mancos Shale (the Buck tongue) which grades upward into overlying littoral marine sandstone (the Sego Sandstone Member) that thickens to the east. Young (1955), proposed that the Castlegate, Sego and Neslen-Mt. Garfield units (subdivisions established by Erdmann, 1934, and Fisher, 1936) be considered as an eastward-climbing littoral, lagoonal and paludal facies (Neslen Facies). This facies is subdivided into Castlegate, Sego, Corcoran, Cozzette and Cameo Members on the basis of prominent, littoral marine sandstones and associated coal-bearing rocks. The non coal-bearing rocks stratigraphically and laterally equivalent to the Neslen Facies were assigned by Young to the Farrer Facies.

An unconformity marks the base of the Castlegate Sandstone Member in its western exposure where it overlies sands of the Blackhawk Formation. But this is lost to the east as the Mancos Shale replaces the Blackhawk rocks at the base of the Castlegate Sandstone. The Castlegate Sandstone can be traced as far east as West Salt Creek in Colorado, changing from a massive sandstone 500 feet thick in the type locality to 45 feet of interbedded shale and fine sand in Colorado.

The Sego Sandstone is a series of interbedded sandstones and shales which first appear near Woodside, Utah and thicken eastward to about 200 feet in western Colorado. The Sego Sandstone was designated a formation by Fisher (1936) and is a single unit in Utah, but in Colorado it is divided into lower and upper units, separated by the Anchor Mine tongue of the Mancos Shale.

The Corcoran Member, which lies above the Sego, consists of two basal littoral marine sandstones and an overlying unit of coal-bearing rocks which total about 100 feet, according to Young. This member can be found from southeast of Palisade to northwest of Grand Junction in Colorado.

Young (1966) interpreted the Cozzette Member as a basal littoral marine sandstone about 70 feet thick and an overlying sequence of lagoonal deposits up to about 175 feet.

The Cameo Member consists of a basal littoral marine sandstone about 100 feet thick and the overlying coal-bearing rocks which attain a thickness of about 250 feet. The Cameo coal zone is an important producer of coal in the Grand Junction area.

The Castlegate Sandstone Member in the western portion of the Book Cliffs has been interpreted by Young as a flood plain deposit and assigned to the Farrer Facies. These non-coal-bearing orogenic sandstones are massive, white to pink, and grade from coarse to fine-grained from west to east.

DATA COLLECTION

Localities

The Book Cliffs form a sinuous southward-facing escarpment that extends from the Wasatch Plateau in west-central Utah to Grand Mesa in western Colorado, an outcrop belt of about 220 miles (Fig. 1). The cliffs have formed in a semi-arid environment by the backwasting of strata gently dipping into the Uinta Basin, and are the product of differential erosion. The soft marine Mancos Shale forms the slope beneath the cliffs, the marine and brackish water Mesaverde and the Lower Tertiary Wasatch Formation hold up the lower (outercliffs) of a double escarpment. The upper cliffs are called the Brown or Roan Cliffs and are composed of Tertiary sediments. Because the face of the Book Cliffs are nearly vertical, choice unweathered exposures may be found.

The Buck tongue was measured and described in detail and samples were collected at close intervals from five localities. The most westerly section is at Tuscher Wash north of Green River, Utah. This section was measured as 98 feet thick but only the lower 45 feet are a typical Buck tongue sequence. The upper portion is a porcellanized shale-silt-sand transition upward into the Sego Sandstone. The most easterly section measured is at West Salt Creek in Colorado about 70 miles east of Tuscher Wash, where the Buck tongue is 360 feet thick. Here, the underlying Castlegate Sandstone has thinned to 45 feet of fine sand-silt. It could not be differentiated from sediments above and below east of this point. A register of measured stratigraphic sections is found in Appendix I.

Sampling

The samples used for analysis in this study were collected from trenches dug to a depth of two to three feet. This was done in order to sample below the zone of loosely weathered materials so that less oxidized samples could be collected. When the shale being sampled was typical, a collection was made approximately every eleven feet from trenches representing three feet thickness (vertically) of the shale. Care was taken to collect representative samples from the entire height (thickness) exposed in the trench. If a lithologic change in the generally uniform shale was noted, the different rocks were collected separately, irrespective of the location of the previous samples. In the case of limestones, occurring within the sampling unit, these limestones as well as the shale above and below were collected separately. If good, relatively unweathered zones near the upper and lower contacts of the Buck tongue were present, these rocks were also sampled at five feet intervals. Frequently, the shale at the contact of the Buck tongue and the Castlegate Sandstone was so deeply weathered that a fresh sample could not be obtained.

Samples were collected and placed in cloth collecting bags, and labeled with the month, day and year, with the stop for the day indicated by a Roman numeral following the date (e.g. 7/14/67 I). The serialized sample number followed this format in the form of an Arabic numeral placed inside a circle. The collection number was placed in front of the lithologic description in the field notebook.

Preparation of materials

All possible precautions were taken to prevent contamination and destruction of the organic-walled microfossils. A summary of the method used follows:

The samples were crushed to pass a 1/4-inch sieve, then a representative five gram aliquant was taken. The sample was then allowed to stand 24 hours each in 10% hydrochloric acid, and 70% hydroflouric acid. After washing with distilled water, a weak solution of Schulze (one part aqueous potassium chlorate to seven parts concentrated nitric acid) was used for five to 30 minutes in the steam bath at 98°C. This treatment was followed with five per cent potassium hydroxide solution. After several washes the sample was centrifuged twice in an aqueous solution of zinc chloride which had been adjusted to a specific gravity of 1.93. If a small amount of clay remained after the second centrifugation, a glassware-cleaning detergent was used to advantage to hold very fine debris in suspension during subsequent centrifugations. The residue was then stained in a two per cent aqueous solution of safranin O and stored in one dram screw top vials with HEC (hydroxyethyl cellulose, Union Carbide Corporation WP-09) and phenol, both in two per cent aqueous solutions.

Strewn slides were mounted by dispersing a portion of the residue on a 22 millimeter square coverslip, and allowed to dry. The mounts were then permanently cemented to a slide with HSR (Harleco synthetic resin, Hartmanledon Company, obtained from Eberbach and Son Company, Ann Arbor, Michigan).

Technique of study of palynomorphs

Number. After all samples were macerated and permanent slides prepared, a few of the best and most representative were selected for further study. These slides were used to establish the taxonomic structure to be followed for this study. When an adequate familiarity with those taxa encountered had been achieved so that all entities could be identified in a consistent manner, a few trial samples were counted.

The decision of the number of specimens to be counted involved the following considerations: 1. The total count per sample should be consistent for each sample for the best comparability and to the nearest 100 for ease of calculations. 2. Since paleoecology was to be the major interest, the greatest number of close interval samples possible would supply more information than fewer less closely spaced samples with more data collected per sample. 3. The total per sample count should be as small as possible but still reflect quantitative relationships for each sample. 4. The most important aspect of this phase of the study should be to have the data collected as consistently as possible.

To determine the fewest number of specimens that should be counted for a fixed sum for all samples, that would quantitatively reflect the relative population of each sample, a species-population curve was constructed. This curve was modeled after species-area curves used by plant ecologists, which are utilized to determine the number of sample measurements to take for a given area. The number of new or different species counted were plotted on the X axis against the total on the Y axis, and a curve was fitted to these points. The number at which the curve flattened out was chosen as a minimal number of specimens to be counted so that quantitative data could be considered unbiased and valid. That point for this study is about 200. To assure an adequate margin for sample variation, 300 was chosen as the total for the fixed sum counts. The count for several samples was extended to 500, but the additional new data in such counts added little significant information and the practice was not

continued. Every sample counted was at some time compared to the curve to be sure that an anomalous deviation did not occur.

Traversing technique. It is desirable in such studies to standardize as many of the variables as possible. An effort was made to macerate all samples as uniformly as practicable; all slides were mounted by the same person in the same way; and all microscope traverses were made in the same way. Since some bias may be introduced in the way that palynomorphs will distribute themselves on a coverslip it was decided to count each slide in precisely the same way. The first horizontal traverse was made across the middle of the coverslip 10mm in from the upper edge (farthest from the investigator), the second was made 1mm in from the upper edge and the third, three-quarters of the way down which is 15mm in from the edge. A maximum of one hundred entities were counted on any one traverse in order that at least three proportional traverses would be assured on all slides. The next three traverses, if they were needed, followed the same pattern but 12, 6 and 20mm respectively, in from the upper edge of the coverslip. All remaining traverses up to a total of 19 per slide were assigned from a random number system chosen by lot at the beginning of the study. All slides were counted in this manner at a magnification of 800X.

All samples of this study contained some palynomorphs, which varied in quality and quantity. No decision was made at the beginning of the microscope work as to a minimum standard of preservation which would be required to identify the palynomorphs correctly. Later it was determined that counts should be made only when at least ten well-preserved, identifiable entities could be encountered in any traverse. By following this formula, slides could be counted in a minimum of slightly less than

an hour, for the very well-preserved samples, to generally less than six hours for the slides with less well-preserved palynomorphs.

In order that consistency of sample quality and identifications might be checked, upon completion of all sample counts the first few samples were then recounted. The reason for counting these samples a second time was to assure data validity and to incorporate any new identifications or shifted species concepts. The identification of species did not become stable until several samples were counted. The first 10 samples were recounted and comparisons made with the original data; after the sixth sample was recounted visual comparison revealed only slight differences in the two sets of data.

A foot-switch-controlled tape recorder with the microphone attached to the microscope was used to record the data. All spores and pollen, which had previously been assigned a code identification formula (after Tschudy, 1957), were identified onto the tape as they were encountered. The microplankton in the counts were assigned to a genus and usually a coded specific epithet. A hand-tally was used simultaneously to record the total count. After three hundred entities were counted, the tape was then played back and the data transferred directly onto a computer card format count sheet. Computer data cards were punched from these sheets.

All microscopic work was carried out with a Carl Zeiss Standard GFL microscope. The photographs were taken with a Leitz Orthomat camera adapted to the Zeiss microscope; Adox KB-14 film was used and the prints were generally enlarged to standard magnifications of 750X or 1000X.

All slides are deposited in the palynology collection of the Geology Department, Michigan State University.

ANALYSIS OF DATA

Discussion of palynomorphs

In all, 224 species of palynomorphs were counted from five sections of the Buck tongue of the Mancos Shale of eastern Utah and western Colorado. During the analysis phase of this study more than 350 organic-walled entities were differentiated and kept separate for subsequent evaluation. Those forms which, after further study, were considered to be variations or unusual orientations of other established species were later combined for the analysis and interpretation of the data.

As discussed in the previous section, a fixed sum count of 300 entities was made for each sample studied. In addition to these fixed sum counts, any new or different species encountered during further studies of the slides (outside of the counts) were recorded as supplemental information for each sample. No prescribed measure of search was followed to collect and record qualitative data (*e.g.* extra slides scanned or certain numbers of traverses made, etc.). Only two new species of palynomorphs illustrated and described in this study were not included in the fixed sum counts. Plate I (in pocket) contains all of the raw statistical data collected for this study. An alphabetical list of all fossils by genus and species has been provided at the beginning of the section on systematics (Table IV).

During the collection of data for this study, four unusual aspects of palynologic distribution became apparent: 1) the paucity of bisaccate pollen and, gymnospermous pollen in general; 2) the small size of all palynomorphs, and particularly the angiospermous pollen; 3) the relative paucity of microplankton, particularly the dinoflagellates; 4) uni-

form distribution of all palynomorphs throughout those samples studied and the general lack of dominance within the flora.

Table I is a summary of the various groups of palynomorphs discussed.

Palynomorph Groups	% Occurrence for all Samples from each Locality					Nos. of: Genera	Species	% of all Palynomorphs
	1	2	3	4	5			
Number of Samples	(16)	(17)	(35)	(29)	(44)			
spores trilete	8.0	1.8	22.0	20.8	47.4	26	44	5.7
spores monolete	15.1	9.4	30.4	23.4	21.6	5	9	6.5
pollen angiosperm	14.6	6.7	23.8	18.3	36.6	21	67	41.5
pollen tricolpate	14.1	6.9	23.6	18.2	37.2	11	49	(37.8)
pollen monosulcate	20.1	9.3	29.1	19.2	22.2	2	4	(1.4)
pollen porate	18.5	2.9	24.0	19.7	34.9	8	14	(2.2)
pollen gymnospermous (except bisaccates)	9.2	16.0	27.8	25.1	21.8	16	23	33.2
pollen bisaccate	0.4	0.1	0.6	0.5	1.1	5	5	0.2
dinoflagellates	7.7	21.3	18.1	17.5	35.3	24	46	3.3
acritarchs	3.5	31.6	19.3	13.0	32.4	9	25	6.9
other non-terrestrial fossils	1.3	48.6	11.1	4.2	34.7	4	9	0.2

1=Tuscher Wash 2=Crescent Wash 3=Cotton Creek

4=Westwater Wash 5=West Salt Creek

TABLE I. DISTRIBUTION OF PALYNOMORPH GROUPS BY PERCENT REPRESENTATION AT EACH LOCALITY OF THE BUCK TONGUE

The relatively low numbers of bisaccate pollen (conifer type) have been observed by Anderson (1960), and Leopold (Dickinson, Leopold and Marvin, 1968) in the Fruitland Formation and the overlying Kirkland Shale from the Four Corners area in Colorado and New Mexico, which is the same general age as the Buck tongue. Leopold (1968) observed that the percentage of bisaccate grains increases near the top of the Kirkland Shale from a count of 0 to about 80% of the total palynomorphs. She further noted that the diverse conifer free florule during the Campanian was "undoubtedly a basin flora" (p. 140) as opposed to an upland environment, (i.e., lowland (?) vs. upland) at the Campanian-Maestrichtian boundary in the localities she studied. This suggestion that the conifer free florule represents a source area that was at a relatively lower altitude than when the conifer florule was dominant may be a logical conclusion but one would expect to be able to interpret such a change of provenance from the sediments. In the case of the Buck tongue sediments, no such change of sediments was noted. If a "basinal" type environment existed in the source area, then one should expect to find some evidence such as: a) reduced sedimentation rates; b) carbonate rich sediments; c) basinally deposited clays with small amounts of silt and/or fine sand in stringers or thin laminae and a minimal amount of shoreline sand buildups; d) an obvious change in relative abundances of other palynomorphs. Since none of the above criteria appear in the Buck tongue sediments studied and since none were mentioned by Leopold (1968), or Anderson (1960), then perhaps another alternative should be considered. Possibly the "upland conifer flora" was present but located some several tens of miles west or northwest from the basin of sedimentation in the Upper Cretaceous Wasatch highlands (Fig. 1). In addition to a very broad tidal flat or floodplain, longshore currents could have circulated the more buoyant upland palyno-

morphs out of the near-shore basin of sedimentation to deeper waters. This would be particularly feasible if a weak to moderate drainage system were present in central Utah. Also, there is good evidence of longshore currents to the north at this point in time, which supports this suggestion.

Locality:	West Salt Creek		Westwater Wash	Cottonwood Creek	Crescent Wash	Tuscher Wash
	Below Buck tongue	Buck tongue				
Number of samples:	(4)	(44)	(29)	(35)	(17)	(16)
Pollen type:						
taxodiacoid pollen	207	1875	1661	1920	897	610
ephedroid pollen	1	7	10	8	4	0
tsugoid pollen	1	41	41	24	6	4
bisaccate pollen	2	36	18	25	2	6
Classopollis pollen	10	67	28	36	3	6
eucomiiditian pollen	145	1099	1833	1964	1277	694
Total	366	3125	3591	2977	2189	1320
Total entities counted	1200	13200	8700	10500	5100	4800

TABLE II. DISTRIBUTION OF MORPHOTYPES OF GYMNOSPERM POLLEN IN MANCOS SHALE

The morphologic distribution of bisaccate pollen shown in Table II, demonstrates the relative paucity of this group as discussed above. Altogether this pollen group represents 0.2% of all the palynomorphs of this study. The ephedroid, tsugoid and *Classopollis* morphologic types are also under-represented as compared to older or younger rocks. None of these pollen types represent more than 0.3% of the sample counts in this study.

The taxodiaceous pollen are strongly represented in the rocks of the Buck tongue but the taxonomic positions of some of the morphologic types included in this group may be subject to question. For example, some investigators would attribute the inaperturate grains to the coniferous genus Araucaria; other smooth pollen with few morphologically diagnostic features included in this group are even less well-understood. So the taxodiaceous pollen may be over-represented by the presence of a small but, at the present time, poorly understood factor in these smooth inaperturate grains.

Statistical validity of the relative abundance of the Eucomiidites presents a difficult problem at this time because of uncertainty in morphologic interpretation. Some orientations of eucomiiditean grains recognized in this study might have been placed in the angiosperms by other investigators. This genus was originally described as an angiospermous tricolpate pollen, but was subsequently transferred to the gymnosperms. It has since been found in the micropyle of Early Cretaceous chlamydospermalean seeds, Hughes (1961). Studies by Couper (1958), and Hughes (1961), have demonstrated a very high degree of variability within this genus, which presents an even more complex problem of definition. The interpretations of Kuyl, Muller and Waterbolk (1955), that the lack of radial symmetry is a most critical feature in the interpretation of this genus, have been followed in this study. This discussion is not meant to cast doubt upon the valid representation of the Eucomiidites of this study, but more to explain why a fossil genus representing almost one-half of all of the gymnosperms might not be directly correlative to relative frequencies of other studies.

The gymnospermous pollen in the Buck tongue are distinctive by their pattern of distribution. The weakly represented groups such as Taxodiaceapollenites are ecologically significant but the strongly represented groups as discussed above, are ecologically less well-understood. The taxodiaceous pollen are dominant in flood plain flora. As previously discussed, a flood plain environment is thought to be a dominant feature in the area of the Buck tongue regression (Fig. 3). The eucomiiditean-type of pollen can only be assumed to represent an element of the flood plain flora as interpreted from its widespread occurrence and prominent representation in the pollen spectrum.

The second striking feature of the microfossils analyzed in this study is the general size of the palynomorphs recovered. The average size of spores and pollen is smaller than the same species from other parts of the world as interpreted from many different studies. The spores are normally only the minimum dimensions or smaller than the described types, and pollen are usually less than the minimum dimension of specimens. This feature is not apparent in other studies involving rocks of the same age. The microplankton element of this study is small in size but normally within the lower limits of the size range of the type species. The small size of the pollen is difficult to explain; but flower size, leaf size and plant size commonly respond to conditions of environment. Although confirming evidence is lacking, pollen and spore size may be influenced by such conditions as heat, drought, or nutrient poor soils, but there is no reported occurrence of a similar reduced palynomorph-size spectrum. The marine microplankton, although small, are not as greatly affected as the terrestrial pollen and spores.

The third feature that stands out in this study is the relatively low total number of microplankton found. Examination of the sediments does not indicate that such a relationship might exist. Even the cephalopod-bearing calcareous intervals do not contain large numbers of dinoflagellates. The Mancos Shale stratigraphically below the Buck tongue contains an abundant and diverse dinoflagellate flora. It also contains abundant cephalopods in the shale units along with fish scales and shark teeth. No cephalopods were found in non-calcareous shales in the Buck tongue nor were shark teeth or fish scales observed.

The relative absence of the autochthonous marine organic entities in these sediments is probably not fortuitous. It appears that for some reason the Buck tongue seas did not produce large numbers of either vertebrates or invertebrate organisms. Logically it seems that some "toxic factor" was effectively restricting the biology of these seas. This factor may have been nutrient poor waters or there may have been another factor such as excessive levels of copper, high water temperature or increased salinity. But it is evident that the Buck tongue seas did not produce as many indigenous organisms as one might reasonably except from examination of the sediments. A second reason for these relatively low populations might be simply that the Buck tongue seas were just not marine enough to permit the development of a diverse marine community, or perhaps the water of the relatively nearshore environment contained a heavy sediment load in suspension. There are, however, at least two fossiliferous horizons in the thicker part of the sequence. If the marine environment was simply too brackish or near to shore, one would expect to find a more abundant microplankton flora associated with the molluscan fauna but no association was observed. At no place in the Buck tongue shale unit was any evidence of a vertebrate fauna found although a single dinosaur femur has been reported from one locality (Fisher, et.al., 1960).

The fourth attribute that one might not expect is the extremely diverse flora recovered from all samples of the Buck tongue sediments. Based on other known studies of comparable age, many more species were encountered than were expected. In all but two samples, over 50 different species were found in a count of 300. The distribution was much more uniform than was expected. Also, a dominant species in a palynologic investigation may normally be expected to represent as much as 30 to 60% of the total flora in any given sample. In this study, the dominant element never exceeded 16% of the total flora and was generally on the order of 10 to 12%.

Conclusions.--With the foregoing discussion in mind, the extreme diversity presents a paradox. If one considers that the more favorable the environment, the more diverse the flora, then the paucity of the conifer type pollen must be explained, the small size of the pollen and spores could hardly represent a hostile environment and the indicated small recovery of marine fossils is not logical. Floodplains are normally very productive in terms of biomass, and waters adjacent to a floodplain should be expected to be high in both organic and inorganic nutrients. The large number of fossil plant remains found, indicates that the Buck tongue seas were receiving a relatively large amount of organic nutrients. Further a very diverse flora has a high inorganic requirement, so these elements should have been in abundant supply.

This evidence is difficult to explain in a non-contradictory way. The only explanation that can be given at this time is that the fossil record of the Buck tongue of the Mancos Shale represents a period of transition.

This transition is reflected both in the bathymetry of the basin of deposition (Fig. 2) and the upland source area. The marine sediments of the Mancos Shale stratigraphically below the Buck tongue are rich in indigenous fossils and appear to be lithologically very similar. Further, there are frequent horizons of bentonite in the Mancos Shale but none was observed in the Buck tongue. This probably indicates a period of relatively little volcanic activity and tectonic stability in the source area and a reduced flow of pollen-rich sediments from the distant highlands. The small pollen, largely representative of a flood plain flora, could be indicative of unstable conditions of growth on the flood plain as discussed above. The relative absence of marine microplankton probably represents a basin which could reflect hypersalinity or more simply just a shallow less-marine basinal environment. The writer has examined rocks of the same age (Pierre Shale from Niobrara Co., Wyoming) from the Great Plains and there is no indication of a comparable paucity of dinoflagellates. In fact, there is more accurately a paucity of pollen and spores with a very diverse microplankton flora. This feature is also observable in the sandier more shoreward facies of the Pierre Shale. The extreme diversity of pollen in sediments of the Buck tongue can best be explained by calling attention to the fact that this short period of time (middle-late Campanian) represents a time of rapidly evolving plant communities and may reflect a burst of angiosperm evolution. This is particularly true for those plants which produce triporate pollen. The first occurrence of this pollen is stratigraphically a short distance below the Buck tongue in the Mancos Shale of southwestern Colorado. Some twelve different triporate taxa were differentiated in this study. It might be said then that there were many new and available "niches" being occupied during this time and that the diversity of this study can best be explained in this way. With respect to the above discussion, pollen size could be related to a feature of competition in a rapidly evolving community and in this way be manifest in the smaller size of the palynomorphs considered in this study.

Paleoecology

Paleogeography.--As discussed above, the basin of deposition of the Buck tongue seas is believed to have developed as the result of a relatively sudden downwarping of the site of Castlegate sedimentation. Hale and Van de Graaff (1964) have interpreted this asymmetric cycle of deposition as an epeirogenic downwarping of the depositional environments. Rapid flooding "smeared" out the unconsolidated upper surface of the Castlegate sands to produce a smooth, relatively flat surface upon which the Buck tongue shale was deposited, forming a sharp sand-shale contact. This type of boundary is not common in other marine transgressions of the area and is thought to be the result of rapid flooding by the sea. The Buck tongue-Sego Sandstone boundary is, by contrast, a complexly interfingered contact that reflects a slowly retreating sea with pulsating water levels and/or a fluctuating supply of clastic sediments.

The spatial relationships of the depositional environments are not known, but Young (1966) suggests the various environmental belts in the area of this study during middle Campanian (approximate time of the Buck tongue Seas) are as follows: Littoral marine environment about 60 miles wide; lagoonal environment about 25 miles wide; floodplain environment about 100 miles wide; piedmont environment about 15 miles wide. Using these very general figures it might be estimated that the highland area is

140 miles west of the old shoreline and that the more open marine environment is 60 miles offshore.

Palynomorph distribution.--The distribution of palynomorphs by groups is shown in Table III. These values were derived by dividing the total number of occurrences for each group in all samples by the number of samples in each locality, this value was then divided by 300, the number of specimens counted per sample. The figures represent an average percent occurrence by morphologic group for each of the five sections studied. If the values for the major groups were added down the columns, the total would be 100%. The column on the right is the average for all sections, and is included as a standard reference column as is the column of West Salt Creek below the Buck tongue. The data for the latter column comes from four samples from shale intervals in the Castlegate and from the Mancos Shale below the Buck tongue. These samples as determined by lithologic relationships, represent a more near-shore environment than the others in this study, but since it is not an integral part of the Buck tongue, it is included in this section only as a basis for comparison.

Most of the palynomorphs discussed here have one of two possible sources: land-derived pollen and spores or indigenous marine fossil dinoflagellates and acritarchs. The land derived palynomorphs are produced by plants in varying amounts and are distributed by many different means. Several studies on distribution of pollen and spores (e.g., Muller, 1959; Koreneva, 1957, 1964; Cross et al., 1966; Traverse & Ginsburg, 1966; etc.) demonstrate that irrespective of the vector of pollenation, the overwhelming mass of pollen is distributed in the sediments by water. Traverse & Ginsburg (1966) point out that the great bulk of pine pollen (one of the most bouyant

	Tuscher Wash	Crescent Wash	Cotton-wood Creek	West-water Wash	West Salt Creek Buck t.	West Salt Creek Below Buck t.	Total for study
trilete spores	4.1%	0.1%	5.2%	5.9%	8.7%	12.9%	6.1%
monolete spores	8.8	5.2	8.2	9.6	4.6	13.0	6.9
angiosperm pollen	54.2	23.6	40.5	37.6	49.6	34.0	42.4
tricolpate	48.1	22.0	36.6	34.1	46.0	29.4	(38.6)
monosulcate	2.6	1.1	1.7	1.4	1.0	2.5	(1.5)
porate	3.7	0.1	2.2	2.2	2.5	2.2	(2.2)
gymnospermous pollen	27.4	44.9	37.9	41.3	23.7	29.4	34.0
coniferous	0.2	0.2	0.5	0.8	0.6	0.3	(0.4)
bisaccate	0.1	0.0	0.2	0.2	0.3	0.2	(0.2)
dinoflagellates	2.3	5.9	2.4	2.9	3.8	3.2	3.4
acritarchs	2.2	18.4	5.5	4.4	7.3	6.6	7.0
other non-terrestrial fossils	0.0	0.7	0.1	0.0	0.2	0.1	0.1

TABLE III. AVERAGE PER SAMPLE OCCURRENCE OF PALYNOMORPH GROUPS BY LOCALITY (TOTAL OCCURRENCE/NO. OF SAMPLES/300)

of the pollen types) is dropped from the air in a relatively few miles from its source but by contrast, it settles from a column of water very, very slowly. It has been well-documented that distribution of palynomorphs is, in general, a feature of hydrodynamics such as density, currents and turbulence, and that their distribution is influenced by their bouyancy. The dinoflagellates and other marine fossils of this study settle from the water in the same general ways as the pollen and spores except they have not evolved such highly developed flotation devices as have some of the pollen.

The differences between columns in Table III is predictable with the exception of Crescent Wash which appears to be anomalous. The percentages of trilete spores increase with distance from shore. This group can more or less be divided into two categories: 1) thin-walled spores which tend to settle out of suspension slowly and, 2) thick-walled forms which tend to settle out relatively faster. Although the distinction is subtle, the number of thicker walled forms are more common at and around the lower and upper contacts of the shale. Conversely, the thin-walled forms tend to be more common in the center of the shale unit. The high concentration of spores below the Buck tongue can be attributed to their relatively large size. The small palynomorphs have simply been winnowed out of these coarse sediments, thus increasing the relative abundance of larger spores.

Monolete spores demonstrate the gradational effect of relative abundance even more dramatically than do trilete spores. This is true because there are fewer species of monolete grains and their wall structure is uniformly thicker than the trilete grains in this study.

Angiosperm pollen is small and relatively more dense than spores, and are more abundant in the nearshore sediments of Tuscher Wash than the sections more distant from shore. The relative abundance of angiosperm pollen in the West Salt Creek section is greater than expected by comparison with the other sections. Careful examination of the raw data of Chart I (in pocket) will show that larger grains such as the Aquilapollenites tend to be more common in the offshore sections. These are only relative relationships and changes are so subtle that no absolute conclusions about distribution can be drawn.

The distribution of gymnospermous pollen inversely follows that of angiosperm pollen. The same general discussion of distribution probably holds for both groups.

The distribution of the marine component of this study calls attention to the anomaly at Crescent Wash and suggests a plausible explanation. The high frequencies of dinoflagellates and acritarchs at this locality demonstrate that this section is more marine than any other; even though relative to the suggested shoreline trends, this station should be only slightly more marine than Tuscher Wash and less marine than Cottonwood Creek. The distribution of all other palynomorphs indicates that Crescent Wash is affected by a barrier to normal gradational offshore distribution. If this section were simply deposited in a deep portion of the basin the non-marine fossils would not be expected to reflect this by their distribution. Since there is a noted reduction of allocthonous fossils at Crescent Wash it is clear that some landward barrier such as a bank or large barrier bar must have controlled the distribution of currents around this geographic area. The lithology of Crescent Wash does not reflect this barrier.

The distribution of palynomorphs is graphically displayed in Fig. 4. As discussed above, the relative marine influence appears to balloon at Crescent Wash with a much greater reduction in the relative numbers of spores than of pollen. The second greatest abundance of marine fossils is found at West Salt Creek, the section that is most distant from shore and would be expected to contain more marine fossils.

The relationships between non-angiosperm, marine and angiosperm fossils can be noted in Fig. 5. Traverse and Ginsburg (1966) point out that small dense pollen settle out of the water column close to shore, while larger

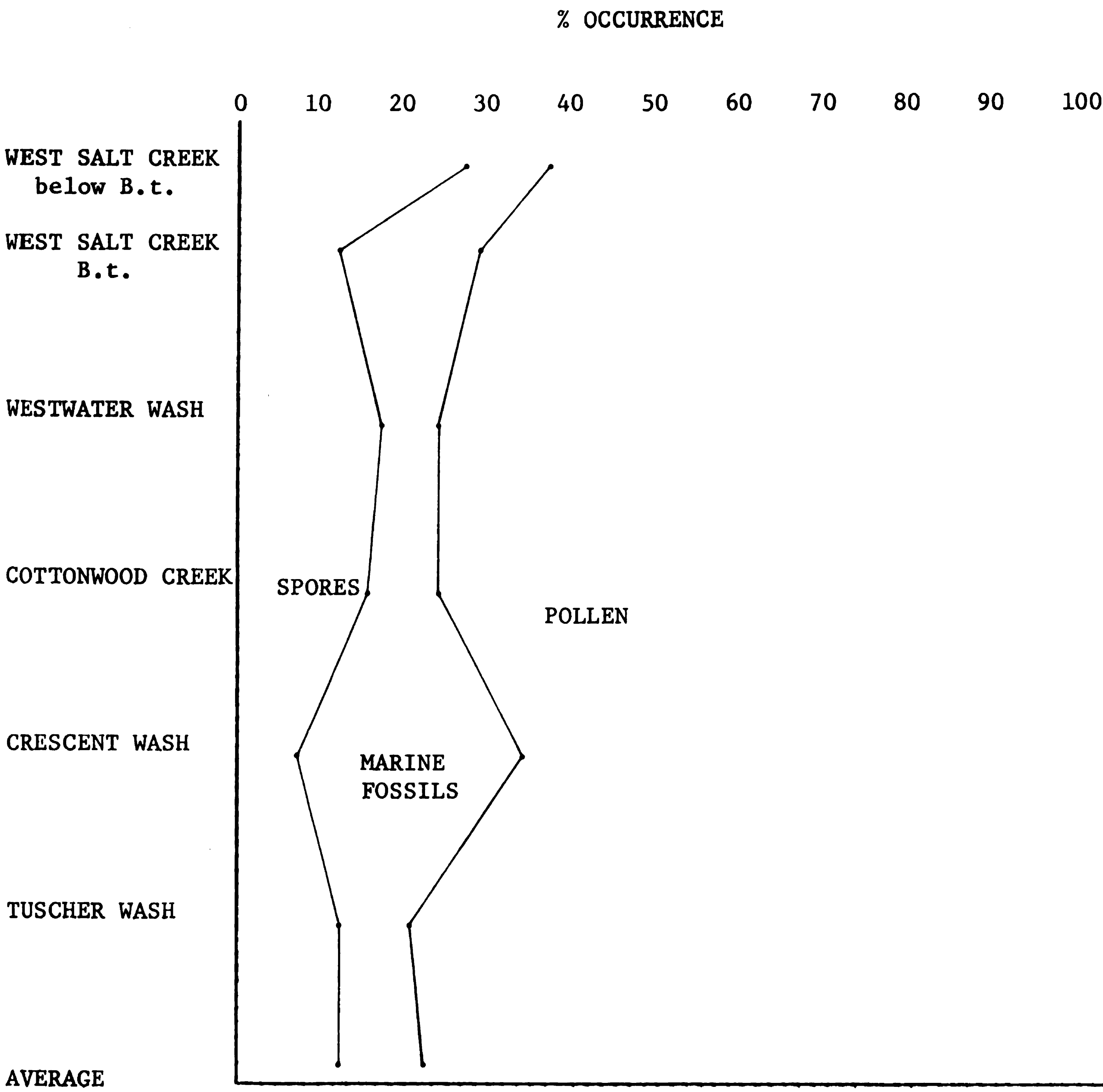

FIGURE 4. Per sample average by % composition of palynomorph groups from the Buck tongue of the Mancos Shale.

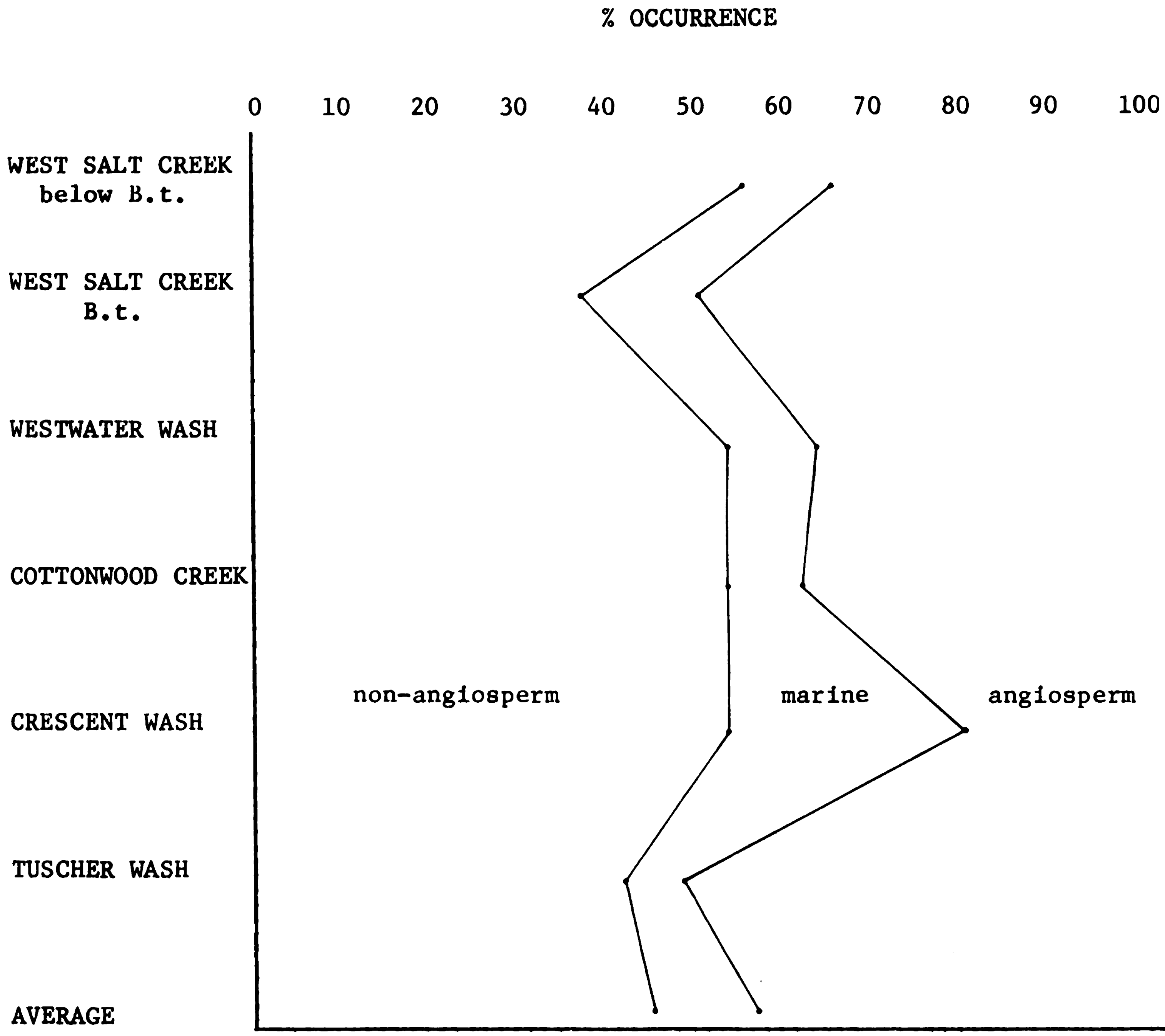

FIGURE 5. Per sample average by % composition of palynomorph groups from the Buck tongue of the Mancos Shale.

more bouyant microfossils settle out more slowly and therefore farther from shore. This point appears to be in conflict between Tuscher Wash (near shore) and West Salt Creek (most distant from shore). But as one examines the morphologic types and pollen distribution of Plate I (in pocket) a subtle difference can be noted in concentrations of angiosperm pollen between the two sections, but the relative differences are not obvious enough to describe. The marine component of Fig. 6 indicates that the West Salt Creek section is about normal and is above the average for the study as shown in Table III. The angiosperm distribution is entirely predictable for all other sections.

The fossil distribution of Fig. 6 further delineates the morphologic groups of palynomorphs of this study. The monolete and trilete spore categories have been separated and show some variation relative to degree of marineness. For example, monolete spores are strongly represented below the Buck tongue, as they are at Tuscher Wash, both represent near shore environments. The monolete spores found at other locations are more commonly the thinner-walled types such as Laevigatosporites ovatus.

The distribution of the gymnospermous pollen presents an interesting relationship (Fig. 6). This group at West Salt Creek is not as well represented as at other localities. On the surface one might suggest that this locality is far enough from shore (about 70-80 miles at maximum transgression) to allow the gymnospermous pollen to be reduced in their relative numbers. The facts are, however, that only the more dense forms have settled out at this point as can be noted in Table III. The coniferous pollen are well represented and the bisaccates in particular are more common at this locality than at any other.

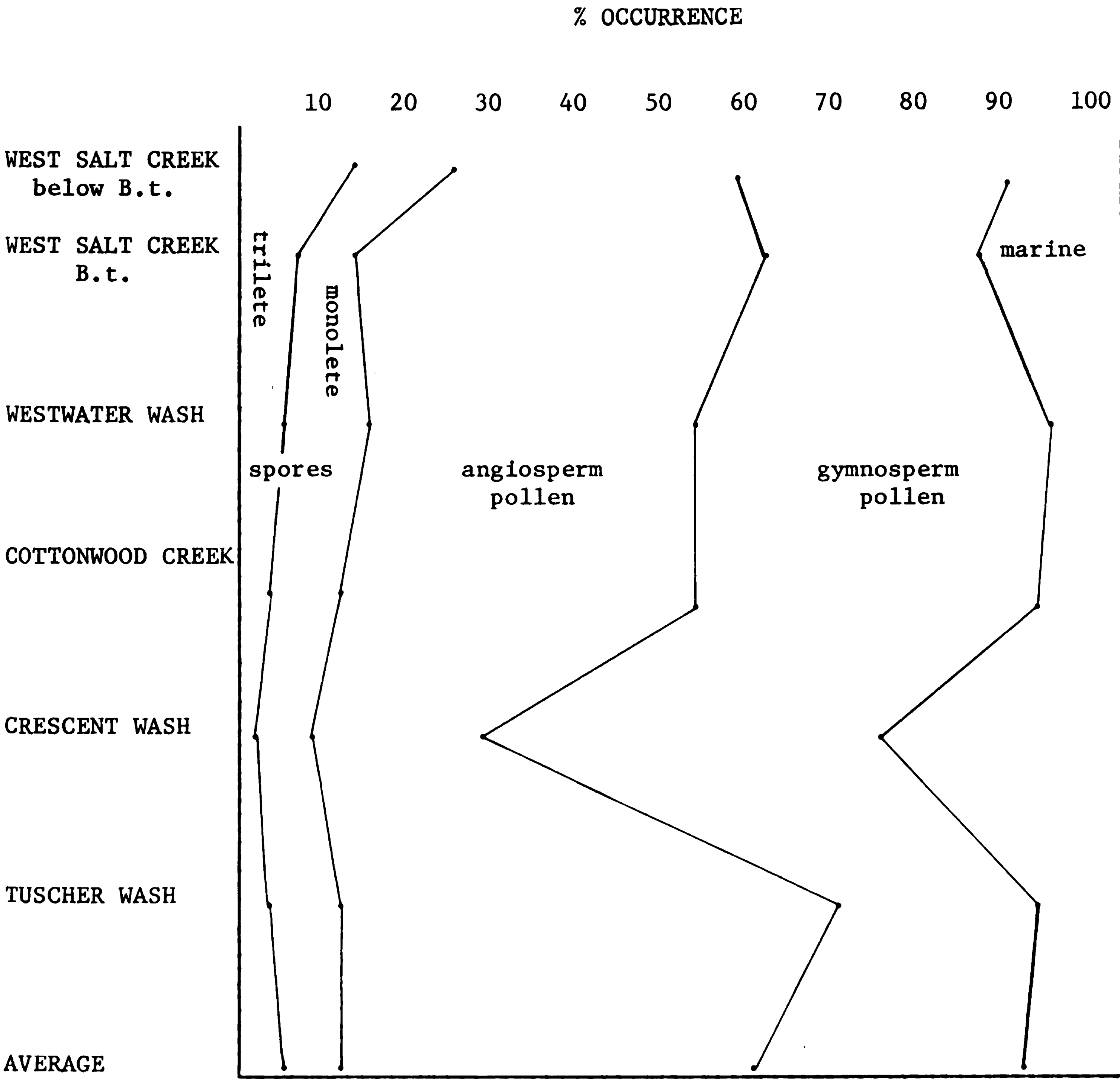

FIGURE 6. Per sample average by % composition of palynomorphs of Buck tongue of Mancos Shale.

Conclusions.--The basin of the Buck tongue seas developed relatively fast, spreading westward over the littoral and lagoonal area of the old Castlegate depositional site. The flood plain environmental belt appears to have been the dominant feature of the ancient landscape. This point is supported by the discussion on page 30, in that the diverse flora represents a flood plain environment. The upland flora was probably located in excess of 140 miles from the shoreline which lends support to the explanation for the paucity of coniferous pollen, particularly if this was associated with a weak drainage system in the area of the Book Cliffs.

The section at Crescent Wash appears to be more marine than any other section studied, in spite of the fact that this section was quite close to shore. A probable explanation for this unexpected marineness is a deeper depression at the site or possibly a landward barrier or sill which would dilute the land derived palynomorphs and freshening effect of local drainage. With the exception of Crescent Wash the evidence from palynology indicates a steady progression of marineness from Tuscher Wash to West Salt Creek. An increase in marineness of the stratigraphic sections from bottom and top into the middle can be interpreted from visual examination of the raw data (Plate I in pocket).

The monolete spores appear to be the best indicators of non-marineness. The Leiosphaeridium spp. and species of the genus Micrhystridium appear to be good indicators of a more open marine environment. The dinoflagellate genus Hexagonifera appears to be as common in near shore to brackish environments as they are to open marine. This statement is based on the assumption that the upper part of the Tuscher Wash section, which is composed of porcellaneous shale and sandstone stringers is probably brachish in origin

(Young, 1957) and is certainly less marine than the typical mancos-type marine shale.

Evolution

The increment of time involved in the deposition of the Buck tongue is geologically very short, probably in the general range of one million years, based on estimated rates of sedimentation. No extinctions or first occurrences were observed in this study and it is not possible to assess the meaning of any of the changes in relative abundances. However, there are some changes in the pollen spectrum that could reflect evolution as discussed on page 30 of this study. The species *Tricolpopollenites parvulus* and *T. debilis* tend to occur at a greater frequency above the mid-point (also the datum of Fig. 7) of at least three of the five sections. The same general kinds of trends can be noted in the distribution of several species of this study, particularly some of the tricolpate pollen.

Conclusion.--On the basis of our present understanding of morphologic variation in palynology, it is not possible to designate the cause of variation in species abundance through the section as a function of evolution or simply one of ecologic response. The best estimate of the shortest period of time then can be delineated on fossil evidence is 0.12 or 0.5 million years. These very impressive results are based on morphologic variation in several groups of well-known invertebrate fossils, Kauffmann and Kent (1968). So without more convincing evidence one should be reluctant to assign evolutionary significance to variation in frequency of occurrence of the fossils of this study, which probably represents well under one million years.

SUMMARY OF MAJOR FINDINGS

Discussion of Palynomorphs

1. The fossil record of the Buck tongue of the Mancos Shale is representative of a transitional environment, both in the bathymetry of the basin of deposition and the upland flora.
2. The distant highlands (Wasatch Plateau) were undergoing a period of relative quiescence during the time of the Buck tongue seas.
3. The diverse pollen and spore spectrum is largely representative of a floodplain environment during a period when plant communities were evolving very rapidly and may represent a burst in evolution of some of the angiosperm groups.
4. The paucity of dinoflagellates in the Buck tongue sediments probably indicates rather shallow seas and a restricted marine environment.
5. No completely acceptable explanation for the small size of the pollen has been found but it is suggested that it might be related to a rapidly evolving angiosperm community.

Paleoecology

6. The basin of deposition of the Buck tongue seas developed relatively fast, without leaving a record of the transition from lagoonal-littoral environments during the transgressive phase of the cycle, but these belts are well documented during the regressive phase.
7. The flood plain environment was the dominant feature of the ancient landscape and is postulated to have been about 100 miles wide.
8. The upland flora is suggested to have been 140 miles behind the shoreline and is thought to be the major factor in the unexpectedly low number of coniferous pollen of this study.

9. An anomaly in the trend from least marine in the west and most marine in the east is noted at Crescent Wash, the second section from the west. A local topographic high in the basin is postulated to the west diluting the effect of the land derived palynomorphs.
10. Monolete spores appear to be the best indicator of nearshore conditions.
11. The species of the genus Leiosphaeridium and the genus Micrhystridium are found to be the best indicators of a marine environment.
12. The dinoflagellate genus Hexagonifera, in this study, is found to be as common in near shore to brackish water sediments as they are in the more open marine sediments.

Evolution

13. The time of the Buck tongue transgression was of such short duration that evolution was insufficient to recognize terminations of old taxa or introductions of new taxa.

Taxonomy

14. Statistical data is recorded on 224 species of palynomorphs from middle Campanian sediments of the Book Cliffs, patterns of distribution and morphologic characteristics are discussed and natural affinities are suggested where possible.

SYSTEMATICS

Introduction

The flora described here consists of 33 genera and 54 species of spores, 16 genera and 23 species of gymnosperm pollen, 22 genera and 67 species of Angiosperm pollen, 12 genera and 32 species of Acritarch or Algae, 23 genera and 46 species of dinoflagellates and 2 categories of microforams. Table IV lists the palynomorph assemblage described from the Buck tongue of the Mancos shale.

This brief taxonomic treatment is arranged alphabetically within broader categories of spores, pollen and microplankton, and follows the botanical code throughout. The group acritarchs is used as proposed by Downie, Evitt and Sarjeant (1963).

Each specimen described carries a reference to a published type if one exists, the cryptic code used for informal identification, the number of occurrences within this study, comments and its botanic affinity for spores and pollen. If no published species exists a description if provided and an address of a typical species is given in millimeters down and to the right of the upper left hand corner of the cover slip with the slide placed in the microscope stage with the label to the left. The slide number refers to the paleobotany collection at Michigan State University. The occurrence lists the number of samples in which a species occurred and the number of times that it occurred in all counts, if the number is small the actual count is given, otherwise the range is given in percent of occurrence per sample.

Table IV: List of Flora (by genera and species) examined from the Buck tongue of the Mancos Shale.

TRILETE SPORES

Acanthotriletes levidensis Balme 1957
Acanthotriletes varispinosus Pocock 1962
Apiculatisporis ferox Muller 1968
Appendicisporites potomacensis Brenner 1963
Appendicisporites sp. A
Appendicisporites sp. B
Balmeisporites holodictyus Cookson & Dettmann 1958
Biretisporites potoniaei Delcourt & Sprumont 1955
Biretisporites psilatus (Groot & Penny) Dettmann 1963
Biretisporites spectabilis Dettmann 1963
Camarozonosporites insignis Norris 1967
Chomotriletes sp.
Cicatricosisporites brevilaesuratus Couper 1958
Cicatricosisporites dorogensis Potonie & Gelletich 1933
Cingulatisporites pseudoalveolatus Couper 1958
Cingutriletes clavus (Balme) Dettmann 1963
Cyathidites australis Couper 1953
Cyathidites minor Couper 1953
Deltoidospora hallii Miner 1935
Deltoidospora psilostoma Rouse 1959
Distaverrusporites simplex Muller 1968
Distaverrusporites (*Leptolepidites*) *verrucatus* (Couper, 1953) comb. nov.
Echinatisporis longechinus Krutzsch 1959
Foveospiris triangulus Stanley 1965
Gleicheniidites cercinidites (Cookson) Dettmann 1963
Gleicheniidites senonicus Delcourt & Sprumont 1955
Gleicheniidites sp.
Hamulatisporis hamulatis Krutzsch 1959
Klukisporites variegatus Couper 1958
Leiotriletes pseudomaximus (Pflug & Thomson) Stanley 1965
Lycopodiumsporites marginatus Singh 1964
Matonisporites equiexinus Couper 1958
Osmundacidites alpina Klaus 1960
Osmundacidites senectus Balme 1963
Osmundacidites wellmannii Couper 1953
Osmundacidites sp.
Rugutriletes toratus Pierce 1961
Stereisporites antiquasporites (Wilson & Webster) Dettmann 1963
Stereisporites minor (Raatz) Krutzsch sbsp. *minor* Krutzsch 1963
Todisporites minor Couper 1958
Toroisporis sp.
Trilites tuberculiformis Cookson 1947
Triplanosporites microsinuosus Pflanzl 1953
Triplanosporites sinuosus Pflug 1953
Triplanosporites sp.

MONOLETE SPORES

Laevigatosporites anomalus Norton 1969
Laevigatosporites gracilis Wilson & Webster 1946
Laevigatosporites haardti (Potonie & Venitz) Thomson & Pflug 1953
Laevigatosporites ovatus Wilson & Webster 1946
Microfoveolatosporis neogranuloides Krutzsch 1967
Perinomonoletes pliocaenicus Krutzsch 1967
Polypodiidites secundus (Potonie) Krutzsch 1967
Polypodiidites senonicus Ross 1949
Verrucatosporites megabalticus Krutzsch 1967
Umbosporites callosus Newman 1965

GYMNOSPERMOUS POLLEN

Alisporites similis (Balme) Dettmann 1963
Caytonipollenites pallidus (Reissinger) Couper 1958
Cedripites canadensis Pocock 1962
Circulina parva Brenner 1963
Classopollis classoides Pflug emend. Pocock & Jansonius 1961
Cycadopites fragilis Singh 1964
Cycadopites giganteus Stanley 1965
Equisetosporites multicostatus (Brenner) Norris 1967
Equisetosporites ovatus (Pierce) Singh 1964
Eucommiidites minor Groot & Penny 1960
Eucommiidites troedssonii Erdtman 1948
Eucommiidites (?) sp.
Foveoinaperturites forameniferus Pierce 1961
Ginkgocycadophytus nitidus (Balme) de Jersey 1962
Inaperturopollenites dubius (Potonie & Venitz) Thomson & Pflug 1953
Inaperturopollenites magnus (Potonie) Thomson & Pflug 1953
Parvisaccites radiatus Couper 1958
Podocarpidites ellipticus Cookson 1947
Schizosporis parvus Cookson & Dettmann 1959
Schizosporis sp.
Taxodiaceaepollenites hiatus (Potonie) Kremp 1949
Tsugaepollenites mesozoicus Couper 1958
Tsugaepollenites segmentatus (Balme) Dettmann 1963

ANGIOSPERM POLLEN (Monosulcate)

Liliacidites variegatus Couper 1953
Liliacidites sp.
Monosulcites sp. A
Monosulcites sp. B

ANGIOSPERM POLLEN (Tricolpate)

Aquilapollenites amplus Stanley 1961
Aquilapollenites delicatus Stanley 1961
Aquilapollenites novacolpites Funkhouser 1961
Aquilapollenites polaris Funkhouser 1961
Aquilapollenites pyriformis Norton 1965
Aquilapollenites quadrilobus Rouse 1957
Aquilapollenites reticulatus Stanley 1961
Aquilapollenites trialatus Rouse 1957
Aquilapollenites turbidus Tschudy & Leopold 1970
Aquilapollenites sp.
Cupanieidites reticularis Cookson & Pike 1954
Cupanieidites sp.
Fraxinoipollenites variabilis Stanley 1965
Gemmatricolpites gemmatus Pierce 1961
Gemmatricolpites pergammatus Muller 1968
Myrtaceidites sp.
Psilatricolpites psilatus Pierce 1961
Psilatricolpites sp.
Retitricolpites georgensis Brenner 1963
Retitricolpites geranioides Brenner 1963
Retitricolpites minutus Pierce 1961
Retitricolpites oblatoides Pierce 1961
Retitricolpites paraneus Norris 1967
Retitricolpites peroblatus Muller 1968
Retitricolpites prosimilis Norris 1967
Retitricolpites vermimurus Brenner 1963
Retitricolpites vulgaris Pierce 1961
Retitricolpites sp.
Tricolpites anguloluminosus Anderson 1960
Tricolpites bathyreticulatus Stanley 1965
Tricolpites erugatus Hedlund 1966
Tricolpites hians Stanley 1965
Tricolpites lilliei Couper 1953
Tricolpites parvus Stanley 1965
Tricolpites sagax Norris 1967
Tricolpites sp.
Tricolpopollenites debilis Groot, Penny & Groot 1961
Tricolpopollenites elongatus Groot & Groot 1962
Tricolpopollenites micromurus Groot & Penny 1960
Tricolpopollenites minutus Brenner 1963
Tricolpopollenites parvulus Groot & Penny 1960
Tricolpopollenites platyreticulatus Groot, Penny & Groot 1961
Tricolpopollenites retiformis Pflug & Thomson 1953
Tricolpopollenites sp. A
Tricolpopollenites sp. B

ANGIOSPERM POLLEN (Tricolporate)

Psilatricolporites acuticostatus Muller 1968
Psilatricolporites prolatus Pierce 1961
Tricolporopollenites microreticulatus Pflug & Thomson 1953

ANGIOSPERM POLLEN (Triporate)

Engelhardtioidites minutus Newman 1965
Momipites circularis Norton 1969
Myrtaceoipollenites peritus Newman 1965
Proteacidites mollis Samoilovitch 1961
Proteacidites retusus Anderson 1960
Proteacidites symphoenoides Cookson 1950
Proteacidites thalmannii Anderson 1960
Proteacidites sp.
Sporopollis laqueaeformis Weyland & Greifeld 1953
Triporopollenites rugatus Newman 1965
Triporopollenites tectus Newman 1965
Trudapollis meekeri Newman 1965

ANGIOSPERM POLLEN (Polyporate)

Liquidambarpollenites stigmosus (Potonie) Raatz 1937
Liquidambarpollenites sp.

Group ACRITARCHA Evitt 1963

Baltisphaeridium delicatum Wall 1965
Baltisphaeridium hirsutum (Ehrenberg) Downie & Sarjeant 1963
Baltisphaeridium infulatum Wall 1965
Baltisphaeridium sp.
Micrhystridium biornatum Deflandre 1937
Micrhystridium fragile Deflandre 1947
Micrhystridium inconspicum Deflandre emend. Deflandre 1937
Micrhystridium minutispinum Wall 1965
Micrhystridium roquesi Valensi 1948
Micrhystridium sp.

Subgroup POLYGONOMORPHITAE Downie, Evitt & Sarjeant 1963

Veryhachium reductum (Deunff) de Jekhowsky fa. breve de Jakhowsky 1961
Veryhachium reductum (Deunff) de Jakhowsky fa. reductum de Jakhowsky 1961

Subgroup SPHAEROMORPHITAE Downie, Evitt & Sarjeant 1963

Leiosphaeridia sp. A
Leiosphaeridia sp. B
Leiosphaeridia sp. C

Subgroup NETROMORPHITAE Downie, Evitt & Sarjeant 1963

Leiofusa jurassica Cookson & Eisenack 1958
Leiofusa sp. A

Subgroup HERKOMORPHITAE Downie, Evitt & Sarjeant 1963

Cymatiosphaera eupeolos (Valensi) Deflandre 1954
Cymatiosphaera exilissima (Deflandre) Deflandre 1954
Cymatiosphaera pachytheca Eisenack 1957
Cymatiosphaera stigmata Cookson & Eisenack 1958

Subgroup PTEROMORPHITAE Downie, Evitt & Sarjeant 1963

Pterospermopsis australiensis Deflandre & Cookson 1955
Pterospermopsis ginginensis Deflandre & Cookson 1955

Subgroup DINETROMORPHITAE Downie, Evitt & Sarjeant 1963

Diplotesta luna Cookson & Eisenack 1960

Subgroup UNCERTAIN

Palaeostomocystis laevigata Drugg 1967

Class CHLOROPHYCEAE

Order CHLOROCOCCALES

Family UNCERTAIN

Palambages deflandrei Gorka 1963
Palambages morulosa O. Wetzel 1961
Palambages forma "C" Manum & Cookson 1964
Quisquilites(?) *pluralis* Hemer & Nygreen 1967
Quisquilites(?) *ornatus* Hemer & Nygreen 1967
Tetraporina glabra (?) Namova 1950
Tetraporina horologia (Staplin) Playford 1963

Class DINOPHYCEAE

Cyst-Family GONYAULACYSTACEAE Sarjeant & Downie 1966

Leptodinium distertitum Cookson & Eisenack 1965

Cyst-Family PERIDINIACEAE Sarjeant & Downie 1966

Apteodinium grande Cookson & Hughes 1964
Spinidinium densispinatum Stanley 1965
Spinidinium styloniferum Cookson & Eisenack 1962

Cyst-Family PYXIDIELIACEAE Sarjeant & Downie 1966

Komewuia glabra Cookson & Eisenack 1960

Cyst-Family BROOMEACEAE Sarjeant & Downie 1966

Canningia colliveri Cookson & Eisenack 1960

Cyst-Family HYSTRICHOSPHAERIDACEAE Sarjeant & Downie 1966

Cleistosphaeridium heteracanthum (Deflandre & Cookson) Davey & Williams 1966
Cordosphaeridium fasciatum Davey & Williams 1966
Cordosphaeridium fibrospinosum Davey & Williams 1966
Hystrichokolpoma ferox (Deflandre) Williams & Downie 1966
Hystrichosphaeridium bowerbanki Davey & Williams 1966
Hystrichosphaeridium readei Davey & Williams 1966
Hystrichosphaeridium tubiferum (Ehrenberg) Davey & Williams 1966
Oligosphaeridium prolixispinosum Davey & Williams *in* Davey, *et al*. 1966
Oligosphaeridium complex (White) Davey & Williams 1966
Polysphaeridium subtile Davey & Williams 1966
Prolixosphaeridium deirense Davey & Williams 1966

Cyst-Family EXOCHOSPHAERIDIACEAE Davey *et al*. 1966

Exochosphaeridium phragmites Davey *et al*. 1966

Cyst-Family AREOLIGERACEAE Sarjeant & Downie 1966

Circulodinium deflandrei Alberti 1961

Cyst-Family HYSTRICHOSPHARACEAE Sarjeant & Downie 1966

Hystrichodinium pulchrum Deflandre ex. Deflandre 1936
Hystrichosphaera cingulata (O. Wetzel) Deflandre 1958
Hystrichosphaera ramosa (Ehrenberg) var. gracilis Davey & Williams in Davey et al. 1966
Hystrichosphaera ramosa var. multibrevis Davey & Williams 1966
Hystrichosphaera ramosa (Ehrenberg) var. ramosa Davey & Williams 1966
Hystrichosphaera ramosa (Ehrenberg) var. reticulata Davey & Williams 1966
Pterodinium aliferum Eisenack 1958

Cyst-Family DEFLANDRACEAE Sarjeant & Downie 1966

Deflandrea cincta Cookson & Eisenack 1958
Deflandrea diebeli Alberti 1959
Deflandrea oebisfeldensis Alberti 1959
Deflandrea pannucea Stanley 1965
Deflandrea scheii Manum 1963

Cyst-Family ENDOSCRINIACEAE Sarjeant & Downie 1966

Palaeohystrichophora infusorioides Deflandre 1934
Palaeohystrichophora isodiametrica Cookson & Eisenack 1958

Cyst-Family HEXAGONIFERACEAE Sarjeant & Downie 1966

Hexagonifera chlamydata Cookson & Eisenack 1962
Hexagonifera glabra Cookson & Eisenack 1961
Hexagonifera suspecta Manum & Cookson 1964

Cyst-Family PSEUDOCERATIACEAE Sarjeant & Downie 1966

Odontochitina striatoperforata Cookson & Eisenack 1962

Cyst-Family MEMBRANILARNACACEAE Sarjeant & Downie 1966

Chlamydophorella grossa Manum & Cookson 1964

Cyst-Family UNCERTAIN

Diconodinium arcticum Manum & Cookson 1964
Dinogymnium acuminatum Evitt 1967
Dinogymnium cretaceum (Deflandre) Evitt et al. 1967

Dinogymnium *digitus* (Deflandre) Evitt *et* *al*. 1967
Dinogymnium *westralium* (Cookson & Eisenack) Evitt *et* *al*. 1967
Dinogymnium sp. "2" Evitt 1967
Dinogymnium sp.
Hologinella *incurvatum* Cookson & Eisenack 1962
Microforam sp. A
Microforam sp. B

TRILETE SPORES

Genus Acanthotriletes (Naumova) Potonie & Kremp 1954

Type species Acanthotriletes ciliatus (Knox) Potonie & Kremp 1954

Acanthotriletes levidensis Balme 1957

Plate 1, Figures 2, 3

1957 C.S.I.R.O. Australia, Coal Res. Sect. T.C. 25, p. 18, pl. 1, figs. 18, 19.

Code. Tlsp-3.

Occurrence. 16 samples; 0.3 to 0.7%.

Comments. Different investigators interpret this species in various ways to include specimens with surface ornamentation from almost granular to those with quite long spines. For this reason there are many reports of this species in the literature. The type material ranged from 21 to 30 microns; the specimens examined in this study generally are less than 20 microns.

Affinity. Balme (1957) refers this species to the Selaginellaceae.

Acanthotriletes varispinosus Pocock 1962

Plate 1, Figure 1

1962 Palaeontographica, v. 111, Abt. B, p. 36, pl. 1, figs. 18-20.

Code. Tlsp-1.

Occurrence. 11 samples; 11 times.

Comments. Pocock (1962) states that there is little doubt that these spores are of selaginellacous affinity, and that it is probable that spores described under the generic names Selaginella, Pteris, or Lycopodiacidites are representatives of the same botanical group.

Affinity. Selaginella.

Genus Apiculatisporis Potonie & Kremp 1956

Type species Apiculatisporis aculeatus (Ibrahim) Potonie & Kremp 1956

Apiculatisporis cf. A. ferox Muller 1968

Plate 1, Figure 4

1968 Micropaleontology, v. 14, p. 6, pl. 1, fig. 5.

Code. Tlsp-2.

Occurrence. 7 samples; 8 times.

Comments. The specimens found in the Buck tongue compare very closely with those of Muller (1968) except that the type specimen has thin laesurae, and at least some of the specimens examined in this study have raised laesurae and thin margos.

Affinity. Unknown.

Genus Appendicisporites Weyland & Krieger 1953

Type species Appendicisporites tricuspidatus Weyland & Krieger 1953

Appendicisporites potomacensis Brenner 1963

Plate 1, Figures 5, 6

1963 Maryland Dept. Geol., Mines & Water Res. State, Bull. 27, p. 46, pl. 6, figs. 4, 5.

Code. Tlcic-4.

Occurrence. 4 samples; 4 times.

Comments. Norris (1967) placed several previously described species in synonomy with A. potomacensis thereby increasing the known distribution of this palynomorph from the Lower Cretaceous of England, Maryland, Nova Scotia and Alberta to the Cenomanian of Alabama. The two figures show the range of size and ornamentation of those entities found in this study.

Affinity. Schizaeaceae.

Appendicisporites sp. A

Plate 1, Figure 7

Code. Tlcic-7.

Description. Trilete, radial; laesurae simple straight slits, about three-fourths radius of spore; equatorial outline rounded-triangular; sides convex; apical angle well rounded; ektexine ornamented by flat, wide ribs, separated by narrow furrows, the outer rib forming an equatorial cingulum up to 5 microns wide. Diameter of the spore is 32 microns.

Occurrence. 2 samples; 2 times.

Comments. This specimen seems most closely allied with *A. cooksonii* (Balme) Pocock (1964), except the size is 10 microns smaller than the minimal size stated by Pocock and the ribs are not as wide.

Reference specimen. Pb4758-1 D18.2xR7.6.

Affinity. Schizaeaceae.

Appendicisporites sp. B

Plate 1, Figure 8

Code. Tlcic-8.

Description. Trilete, radial; laesurae simple straight slits, about three-fourths radius of spore; equatorial outline triangular with straight sides and rounded apices; proximal exine thickened in the area bordering the laesurae; distal ektexine ornamented with irregular ribs, each parallel to a side and the outer rib forming a thick equatorial girdle. Diameter, 37 microns.

Occurrence. 5 samples; 5 times.

Comments. This specimen agrees very closely to *A. perplexus* Singh

(1964) in size, shape and ornamentation, but differs in its wall thickness and the nature of its laesurae.

Reference specimen. Pb4737-7 D10.5xR7.2.

Affinity. Schizaeaceae.

Genus *Balmeisporites* Cookson & Dettmann 1958

Type species *Balmeisporites holodictyus* Cookson & Dettmann 1958

Balmeisporites holodictyus Cookson & Dettmann 1958

Plate 1, Figure 10

1958 Micropaleontology, v. 4, p. 42, pl. 2, fig. 1.

Code. *Balmeisporites*-1.

Occurrence. None were counted in the 300 sum.

Comments. One good specimen and 1 fragment of this species were found but none fell within the 300 count used for the quantitative aspects of this study.

Affinity. Unknown.

Genus *Biretisporites* Delcourt & Sprumont emend. Delcourt, Dettmann & Hughes 1963

Type species *Biretisporites potoniaei* Delcourt & Sprumont 1955

Biretisporites potoniaei Delcourt & Sprumont 1955

Plate 1, Figures 11, 12

1955 Mem. Soc. Belge Geol., n.s., no. 5, p. 40, fig. 10.

Code. Tlsm-16.

Occurrence. 67 samples; 0.3 to 1.3%.

Comments. This thin-walled spore generally occurs in the lowest percentage indicated (1 in 300) and demonstrates no recognizable pattern of distribution. The Buck tongue specimens are similar to those of the species of Delcourt & Sprumont (1955) except that they have a somewhat thinner exine and are smaller in size.

Affinity. *Hymenophyllum* (?).

Biretisporites cf. *B. psilatus* (Groot & Penny) Dettmann 1963

Plate 1, Figures 13, 14

1963 Proc. Roy. Soc. Victoria, v. 77, p. 26.

Code. Tlsm-17.

Occurrence. 24 samples; 0.3 to 1.3%.

Comments. This species appears to be quite similar to the specimen figured by Groot & Penny (1960) (under the generic name *Cingulatisporites*) which Dettmann (1963) placed in the emended genus *Biretisporites*.

Affinity. Unknown.

Biretisporites spectabilis Dettmann 1963

Plate 1, Figure 15

1963 Proc. Roy. Soc. Victoria, v. 77, p. 25, pl. 12, figs. 3-8.

Code. Tlsm-4.

Occurrence. 4 samples; 4 times.

Comments. This very distinctive fossil spore is the largest spore encountered in this study. It has been reported only from the lower horizons of the Upper Mesozoic strata of Victoria (Dettmann, 1963). Specimens of the type species range from 77 to 122 microns while the specimens seen in this study range from 55 to 75 microns. Rouse's (1957) genus *Hymenophyllumsporites* has been placed in synonomy with this genus.

Affinity. Rouse (1957) suggests a relationship of *B.* (*Hymenophyllumsporites*) *deltoidus* to the genus *Hymenophyllum* L.

Genus Camarozonosporites Pant ex. Potonie emend. Klaus 1960

Type species Camarozonosporites cretaceus (Weyland & Krieger) Potonie 1956

Camarozonosporites insignis Norris 1967

Plate 1, Figure 9

1967 Palaeontographica, v. 120, Abt. B, p. 96, pl. 13, figs. 12-16.

Code. Tlst-1.

Occurrence. 29 samples; 0.3 to 1.7%.

Comments. This species agrees with the type species of Norris (1967), but it tends to measure in the range of 30 microns, or smaller, the lower limit of the type description.

Affinity. Lycopodium.

Genus Chomotriletes (Naumova) ex. Naumova 1953

Type species Chomotriletes vedugensis (Naumova) ex. Naumova 1953

Chomotriletes sp.

(not figured)

Code. Chomotriletes-1.

Description. Trilete, radial, trilete mark very faint; equatorial outline circular; distal side ornamentated with concentric ridges about 1 micron wide. Diameter, 22 microns.

Occurrence. 2 samples; 2 times.

Comments. This species occurred in 2 samples and in both cases was rather corroded, and might well have been a reworked spore. A suitable specimen to photograph was not found.

Affinity. The structure of this spore indicates a schizaeaceous affinity.

Genus *Cicatricosisporites* Potonie & Gelletich 1933

Type species *Cicatricosisporites dorogensis* Potonie & Gelletich 1933

Cicatricosisporites cf. *C. brevilaesuratus* Couper 1958

Plate 2, Figures 4, 7

1958 Palaeontographica, v. 103, Abt. B, p. 136, pl. 18, figs. 1-3.

Code. Tlcic-3.

Occurrence. 38 samples; 0.3 to 1.3%.

Comments. Figure 7 was counted in this study as Tlcic-10, and occurred in 2 samples, so in order to facilitate the analysis, these two taxa were combined. The only difference in the two categories is their size; Tlcic-3 ranged from 40 microns up and Tlcic-10 is about 70 microns in diameter, the latter is more closely comparable to the species as described by Couper (1958).

Affinity. According to Couper (1958) this species compares closely to *Schizaeopsis americana* Berry from the Neocomian Patuxent Formation of Maryland.

Cicatricosisporites dorogensis Potonie & Gelletich 1933

Plate 2, Figure 2

1933 Gessellschaft Naturforschender Freunde zu Berlin, p. 522, pl. 1, figs. 1-5.

Code. Tlcic-2.

Occurrence. 28 samples; 0.3 to 1.3%.

Comments. (Identified in this study, *sensu* Couper, 1958). The range of this species has been established from Lower Cretaceous (possibly Upper Jurassic) to Eocene and it has been reported from both the southern and northern hemispheres. It has been reported from Upper Cretaceous sediments in Alberta, Colorado, Oklahoma, Alabama, the Atlantic Coastal Plains, and the Great Valley of California.

Affinity. *Cicatricosisporites dorogensis* is a fossil spore with definite schizaeaceous affinities, and is often assigned to the genus *Anemia* or *Mohria*.

Genus *Cingulatisporites* Thomson *in* Thomson & Pflug 1953

Type species *Cingulatisporites levispeciosus* Pflug *in* Thomson & Pflug 1953

Cingulatisporites cf. *C. pseudoalveolatus* Couper 1958

Plate 2, Figure 1

1958 Palaeontographica, v. 103, Abt. B, p. 147, pl. 25, figs. 5, 6.

Code. Tlf-1.

Occurrence. 7 samples; 7 times.

Comments. This species is similar to Couper's (1958) specimen, but it has a wider cingulum, and a thinner exine. As is typical for most of the spores found in the Buck tongue, the size range is slightly smaller than the type species.

Affinity. Unknown.

Genus *Cingutriletes* Pierce emend. Dettmann 1963

Type species *Cingutriletes congruens* Pierce 1961

Cingutriletes cf. *C. clavus* (Balme) Dettmann 1963

Plate 2, Figure 3

1963 Roy. Soc. Victoria, v. 77, p. 69, pl. 14, figs. 5-8.

Code. Tlp-4.

Occurrence. 11 samples; 12 times.

Comments. The species of the Buck tongue compare favorably with those of Dettmann (1963) except the writer is not clear as to how large the verrucae and granules are to which Dettmann refers when compared to the specimens of this study.

Affinity. Unknown.

Genus *Cyathidites* Couper 1953

Types species *Cyathidites australis* Couper 1953

Cyathidites australis Couper 1953

Plate 2, Figure 12

1953 New Zealand Geol. Survey Paleont. Bull. 22, p. 27, pl. 2, figs. 11, 12.

Code. Tlsm-10.

Occurrence. 8 samples; 9 occurrences.

Comments. The species, as described here, is slightly smaller than the specimens of the type material but is in the same range as that reported by Dettmann (1963).

Affinity. Couper (1953) reported this species as having affinities with both cyatheaceous and dicksoniaceous ferns.

Cyathidites minor Couper 1953

Plate 2, Figure 10

1953 New Zealand Geol. Survey Paleont. Bull. 22, p. 28, pl. 2, fig. 13.

Code. Tlsm-6.

Occurrence. 73 samples; 0.3 to 3.7%.

Comments. This smooth-walled spore is common in the Buck tongue. Its frequent occurrence may be a reflection of the cyatheaceous and dicksoniaceous ferns present along the coasts of the Buck tongue sea.

This species shows a world-wide distribution in Mesozoic sediments, and ranges from Lower Jurassic to Upper Cretaceous.

Affinity. Couper (1953) reported this species as having affinities with both cyatheaceous and dicksoniaceous ferns.

Genus *Deltoidospora* Miner emend. Potonie 1962

Type species *Deltoidospora hallii* Miner 1935

Plate 2, Figures 9, 11

1935 Amer. Midl. Nat., v. 16, p. 618, pl. 24, fig. 7.

Code. Tlsm-7.

Occurrence. 85 samples; 0.3 to 4.3%.

Comments. *D. hallii* was described from the Cretaceous Kootenai Formation of Montana by Miner (1935) and appears to be a common Cretaceous spore throughout North America; neither its presence nor its percentage occurrence in the samples studied here could be interpreted as demonstrating any trends.

Affinity. This spore is considered here to represent species of the family Gleicheniaceae.

Deltoidospora psilostoma Rouse 1959

Plate 2, Figure 8

1959 Micropaleontology, v. 5, pl. 2, figs. 7, 8.

Code. Tlsm-19.

Occurrence. 3 samples; 0.3 to 1.7%.

Comments. This species rarely occurs more than twice in a count of 300, and thus no trends of occurrence can be interpreted. The laesurae are often found in an open condition, and the size of these Buck tongue spores are often slightly smaller (10 microns) than those described by Rouse (1959).

Affinity. Unknown.

Genus *Distaverrusporites* Muller 1968

Type species *Distaverrusporites simplex* Muller 1968

Distaverrusporites simplex Muller 1968

Plate 2, Figures 5, 6

1968 Micropaleontology, v. 14, no. 1, p. 5, pl. 1, fig. 2.

Code. Tlp-10.

Occurrence. 13 samples; 14 times.

Comments. This species agrees in every detail with that of Muller (1968). The average size is about 25-35 microns.

Affinity. Unknown.

Distaverrusporites (*Leptolepidites*) *verrucatus* (Couper, 1953) *nov. comb.* (*pro parte*)

Plate 3, Figures 1, 2

1953 New Zealand Geol. Survey Paleont. Bull. 22, p. 28, pl. 2, figs. 14, 15.

Code. Tlp-1.

Occurrence. 10 samples; 11 times.

Comments. In Couper's (1953) original description of *Leptolepidites* he states, "...sculptured with large, irregularly shaped, verrucate projections, *ca*. 5-6 microns in diameter, equally developed on proximal and distal faces"; Dettmann (1963), without any formal indication of emendation of the genus, states on p. 29, "Contrary to the generic diagnosis, these spores are smooth proximally." Muller (1968) states under the diagnosis of his new genus *Distaverrusporites*, "...sculpture restricted to equatorial and distal areas, proximal face psilate." For these reasons, the specimens of this study are reassigned to the genus Distaverrusporites (Muller, 1968), and the writer feels that L. verrucatus as described by Dettmann (1963) should be placed in synonomy with species of Distaverrusporites.

Affinity. Unknown.

Genus Echinatisporis Krutzsch 1959

Type species Echinatisporis longechinus Krutzsch 1959

Echinatisporis cf. E. longechinus Krutzsch 1959

Plate 3, Figure 3

1959 Geologie, v. 8, p. 132, pl. , fig.

Code. T1sp-4.

Occurrence. 2 samples; 2 times.

Comments. This spinose spore is similar to the species of Krutzsch (1959) from the Middle Tertiary.

Affinity. Selaginellaceae.

Genus Foveasporis Krutzsch 1959

Type species Foveasporis fovearis Krutzsch 1959

Foveasporis triangulus Stanley 1965

Plate 3, Figure 10

1965 Bull. American Paleontology, v. 49, no. 222, p. 239, pl. 27, figs. 18-22.

Code. T1r-1.

Occurrence. 27 samples; 0.3 to 1.0%.

Comments. This specimen agrees very well with the species set up by Stanley (1965), but is also similar to the genus Microreticulatisporites except that the ornamentation is on both distal and proximal sides. The Buck tongue specimens tend to be convex to sub-circular and generally less than 35 microns.

Affinity. Stanley (1965) reports that this spore is similar to the *Selaginella repanda* group.

Genus *Gleicheniidites* (Ross) Delcourt & Sprumont 1955

Type species *Gleicheniidites denonicus* (Ross) Delcourt & Sprumont 1955

Gleicheniidites cercinidites (Cookson) Dettmann 1963

Plate 3, Figure 4

1963 Roy. Soc. Victoria, v. 77, p. 65, pl. 13, figs. 6-10

Code. Tlsm-12.

Occurrence. 98 samples; 0.3 to 2.7%.

Comments. This spore has a kyrtome that is not always visable unless one examines the specimen very carefully, the shape, laesurae, and wall texture make this species easily recognizable. Both Dettmann and Brenner set up the same combination of nomenclature in 1963, but the writer was unable to determine the date of issuance of Brenner's paper so the new combination was credited to Dettmann in this study. This is the most common of all the trilete spores in the Buck tongue samples, but no pattern of distribution is discernible.

Affinity. Cookson (1953) referred this species to the species *Gleichenia cercinata* Swartz.

Gleicheniidites senonicus Delcourt & Sprumont 1955

Plate 3, Figures 5, 6

1955 Mem. Soc. Belge Geol. n.s., no. 5, p. 26.

Code. Tlsm-11.

Occurrence. 51 samples; 0.3 to 1.0%.

Comments. Occasionally, specimens of this species were folded and compressed in such a manner as to give the appearance of the interradial thickenings being continuous around the ends of the laesurae, (see Fig. 5) but this is not common and these specimens are considered to belong to this genus rather than to Concavisporites.

Affinity. Fossil spores referred to this species are referable to the family Gleicheniaceae.

Gleichenidates sp.

Plate 3, Figure 7

Code. Tlsm-2.

Description. Spores trilete, radial; laesurae long, extending to the equator, bordered by arcuate interradial thickenings; equatorial contour trilobate, sides strongly concave; spore wall approximately 1.0 microns thick, smooth; diameter ranges from 18 to 30 microns.

Occurrence. 80 samples; 0.3 to 4.7%.

Comments. Pierce (1961) describes a similar form, Cingutriletes interruptus, from the Upper Cretaceous of Minnesota; Rouse (1957) described a similar form, Gleichenia concavisporites, from Western Canada, but these specimens more commonly have straight sides and are larger. The closest comparison to this species may be found with Gleichenia laeta Bolkhovitina (1953), from the Lower Cretaceous, Aptain, of Russia.

Reference specimen. Pb4796-2 D10.3xR14.2.

Affinity. Unknown but assumed to be similar to G. senonicus.

Genus _Hamulatisporis_ Krutzsch 1959

Type species _Hamulatisporis hamulatis_ Krutzsch 1959

Hamulatisporis hamulatis Krutzsch 1959

Plate 3, Figures 8, 9

1959 Geologie, v. 8, nos. 21-22, p. 157, pl. 29, figs. 326-328.

Code. Tlst-3.

Occurrence. 45 samples; 0.3 to 1.3%.

Comments. This species differs from _Camarozonosporites insignis_ (Tlst-1) in having heavier muri with greater distance between them, and although difficult to distinguish, this species does not have inter-radial crassitudes developed at the equator.

Affinity. Possibly _Lycopodium_.

Genus _Klukisporites_ Couper 1958

Type species _Klukisporites variegatus_ Couper 1958

Klukisporites variegatus Couper 1958

Plate 3, Figure 11

1958 Palaeontographica, v. 103, Abt. B, p. 137, pl. 19, figs. 6, 7.

Code. Tlr-2.

Occurrence. 10 samples; 11 times.

Comments. This distinctive thick walled spore occurs in the Westwater and West Salt Creek sections, but no discernible pattern can be recognized in these samples.

Affinity. Couper (1958) established this genus with the intention of its being a category to receive dispersed spores or the type from the Jurassic ferns, _Klukia exilis_ and _Stachypteris hallei_.

Genus <u>Leiotriletes</u> Naumova ex. Potonie & Kremp 1956

Type species <u>Leiotriletes sphaerotriangulus</u> (Loose) Potonie & Kremp 1956

<u>Leiotriletes pseudomaximus</u> (Pflug & Thomson) Stanley 1965

Plate 3, Figure 12

1965 Bull. Amer. Paleont., v. 49, no. 222, p. 254, pl. 31, figs. 10-12.

<u>Code</u>. Tlsm-9.

<u>Occurrence</u>. 25 samples; 0.3 to 2.7%.

<u>Comments</u>. This species, in at least a portion of its occurrences, could quite possibly be reworked from older strata because it frequently does not stain (safranin O) the same as other spores on the same slide, and because the appearance of the wall sometimes appeared to be more hyaline and less flexible than the other spores of the same sample; in other instances, however, this spore is indistinguishable from other spores in the sample. The specimens seen in this study are usually smaller than average spores described by other investigators.

<u>Affinity</u>. Stanley (1965) refers species of this genus to the fern families, Schizaeaceae and Polypodiaceae.

Genus <u>Lycopodiumsporites</u> Thiergart ex. Delcourt & Sprumont 1955

<u>Lycopodiumsporites marginatus</u> Singh 1964

Plate 3, Figure 13

1964 Res. Coun. Alberta, Bull. 15, p. 41, pl. 1, figs. 7-10.

<u>Code</u>. <u>Lycopodiumsporites</u>-1.

<u>Occurrence</u>. 2 samples; 2 times.

<u>Comments</u>. This species is slightly smaller than the previously described specimens, but is similar in all other respects. This species has a prior record of Aptian to Cenomanian.

Affinity. Lycopidium.

Genus Matonisporites Couper 1958

Type species Matonisporites phlebopteroides Couper 1958

Matonisporites cf. M. equiexinus Couper 1958

Plate 3, Figure 17

1958 Palaeontographica, v. 103, Abt. B, p. 140, pl. 20, figs. 13, 14.

Code. Tlsm-14.

Occurrence. 16 samples; 20 times.

Comments. Couper (1958) described this species from the Jurassic and Lower Cretaceous of Britain, the assignment is tentative at this time. This species is common in the Castlegate Sandstone below the Buck tongue, and is interpreted as being associated with coarser sediments.

Affinity. Couper (1958) has compared spores of this species to the modern fern Matonia pectinata; Hedlund (1966) places them more closely to the modern schizaeaceous ferns Anemia and Lygodium. Drugg (1967) reports a similar spore that he assigns to the fossil genus Lygodiumsporites.

Genus Osmundacidites Couper 1953

Type species Osmundacidites wellmanii Couper 1953

Osmundacidites cf. O. alpina Klaus 1960

Plate 3, Figure 14

1960 Jb. Geol. B.A. 5, p. 127, pl. 31, fig. 26.

Code. Tlp-5.

Occurrence. 11 samples; 0.3 to 1.0%.

Comments. Osmundacidites alpina Klaus (1960), was described by Klaus from the Triassic of the eastern Alps. The writer has reservations about this assignment because this specific designation would extend the range of this species over a considerable stratigraphic interval. The shape, size, laesurae, and surface ornamentation of the type material compares favorably with the Buck tongue specimens.

Affinity. Osmundaceae.

Osmundacidites cf. *O. senectus* Balme 1963

Plate 3, Figure 15

1963 Palaeontology, v. 6, pt. 1, p. 17, pl. 4, fig. 1.

Code. Tlp-9.

Occurrence. 13 samples; 14 times.

Comments. This large, thin-walled spore is closely similar to the species described by Balme (1963). The size and ornamentation are approximately the same, but the wall thickenings could not be verified. Balme's type material is from the Lower Triassic of Australia.

Affinity. Osmundaceae.

Osmundacidites wellmanii Couper 1953

Plate 4, Figure 16

1953 New Zealand Geol. Survey Paleont. Bull. 22, p. 20, pl. 1, fig. 5.

Code. Tlp-7.

Occurrence. 33 samples; 0.3 to 2.0%.

Comments. This species has a world-wide distribution in Jurassic and Cretaceous sediments.

Affinity. Singh (1964) reported that this species closely resembles *Todites hartzi* Harris, 1931 and *Osmundopsis plectophora* Harris, 1931, from the Lias of Greenland.

Osmundacidites sp.

Plate 3, Figure 16

Code. Tlp-2.

Description. Spores trilete, radial; laesurae three-fourths spore radius; equatorial outline triangular, sides straight to convex; ornamentation closely spaced baculae and tubercles up to 2 microns long, exine 2 microns thick. Diameter, 30-35 microns.

Occurrence. 54 samples; 0.3 to 1.7%.

Comments. The specimens examined in this study compare closely with a species soon to be validated by Dr. Stanley Pocock (under the genus Acanthotriletes). The species in this study have been assigned to the genus Osmundacidites because the spines of Acanthotriletes by definition must be several times longer than the diameter at the base of the spine; the surface ornamentation of this species are short tubercles or baculae and not spines.

Reference specimen. Pb4746-1 D14.4xR19.6.

Affinity. Osmundaceae.

Genus Rugutriletes Pierce 1961

Type species Rugutriletes regularis Pierce 1961

Rugutriletes cf. R. toratus Pierce 1961

Plate 4, Figure 6

1961 Minnesota Geol. Survey Bull. 42, p. 30, pl. 1, fig. 22.

Code. Tlst-4.

Occurrence. 2 samples; 2 times.

Comments. Pierce's (1961) specimen is larger and does not appear to have as heavy rugulo-striations as the species of the Buck tongue. This species also strongly resembles *Corrugatisporites toratus* Weylund & Greifeld (1953).

Affinity. Filicanaceae (?).

Genus *Stereisporites* Pflug 1953

Type species *Stereisporites stereoides* (Potonie & Venitz) Pflug 1953

Stereisporites antiquasporites (Wilson & Webster) Dettmann 1963

Plate 4, Figures 2, 3

1963 Proc. Roy. Soc. Victoria, v. 77, p. 25, pl. 1, figs. 20, 21.

Code. Tlsm-5.

Occurrence. 23 samples; 0.3 to 1.3%.

Comments. This species is known from Jurassic, Cretaceous, and Tertiary sediments of the northern and southern hemispheres. The ecology of the parent plant *Sphagnum* is well known and the presence of this spore indicates moist, possibly bog-like conditions in a near-by source area. The most common occurrence of this species is in samples from the lower middle portion of the Westwater section, and it is rare or lacking in the samples from Tuscher Wash and Crescent Butte.

Affinity. *Sphagnum*.

Stereisporites cf. *S. minor* (Raatz) Krutzsch sbsp. *minor* Krutzsch 1963

Plate 4, Figures 4, 5

1963 Atlas, pt. III, p. 36, pl. 1, figs. 1-40.

Code. Tlsm-20.

Occurrence. 53 samples; 0.3 to 2.0%.

Comments. This entity is tentatively placed in the subspecies described by Krutzsch (1963) because of its wall thickness and the size.

The laesurae are generally gaping and the proximal polar thickenings are very slight.

Affinity. Sphagnum.

Genus Todisporites Couper 1958

Type species Todisporites major Couper 1958

Todisporites minor Couper 1958

Plate 4, Figure 7

1958 Palaeontographica, v. 103, Abt. B, p. 135, pl. 16, figs. 9, 10.

Code. Tlsm-1.

Occurrence. 10 samples; 11 times.

Comments. This entity could easily be misinterpreted when extensively folded or crushed for species of the genus Calamospora.

Affinity. Todisporites minor is referable to the fern family Osmundaceae, genus Todea, according to Couper (1958).

Genus Toroisporis Krutzsch 1963

Type species Toroisporis torus (Pflug) Krutzsch 1963

Toroisporis sp.

Plate 4, Figures 8, 9

Code. Tlsm-3.

Description. Spores trilete, radial; laesurae distinct, approximately three-fourths radius of spore; kyrtome always present, extends around the end of the laesurae; equatorial contour rounded-triangular, sides convex; spore wall 2.0 microns thick, surface psilate. The spore diameter is 25 to 40 microns with an average of about 28.

Occurrence. 96 samples; 0.3 to 6.3%.

Comments. This genus was apparently established, Krutzsch (1959) to accommodate spores with kyrtomes and convex sides, the counterpart of which is Concavisporites. This species is one of the most important of the spores in the Buck tongue florule, having the highest number of occurrences in any sample (19 in 300 count) and the second highest number of samples (96).

Reference specimen. Pb4828-1 D1.4xR10.5.

Affinity. Stanley (1965) refers this genus to Schizaeaceae (?).

Genus Trilites Erdtman 1947 ex. Couper 1953 emend. Dettmann 1963

Type species Trilites tuberculiformis Cookson 1947

Trilites cf. T. tuberculiformis Cookson 1947

Plate 4, Figure 1

1947 B. A. New Zealand Antarctic Res. Exp. 1929-31, Rep. A2, p. 136, pl. 16, figs. 16, 17.

Code. Tlst-2.

Occurrence. 9 samples; 13 times.

Comments. This species differs from the species T. tuberculiformis by having straight to slightly concave sides whereas the type species has slightly convex sides; this species also resembles Corrugatisporites solodus Thomson & Pflug (1953).

Affinity. Dicksonia (?).

Genus Triplanosporites Pflug 1953

Type species Triplanosporites sinuosus (Pflug) Pflug 1953

Triplanosporites microsinuosus Pflanzl 1955

Plate 4, Figures 10, 11

1955 Notizbl. Hess. L.-Amt Bodenforsch, v. 83, 71-89.

Code. Tlsm-22.

Occurrence. 70 samples; 0.3 to 1.7%.

Comments. This species is distinguished from *T. sinuosus* (Tlsm-21) by its smaller size (about 20 microns) and its more angular outline. The two species are difficult to differentiate if the orientation is polar or oblique.

Affinity. Schizaeaceae (?).

Triplanosporites sinuosus Pflug 1953

Plate 4, Figures 12, 13

1953 Palaeontographica, v. 94, Abt. B, p. 58, pl. 3, figs. 5-16.

Code. Tlsm-21.

Occurrence. 83 samples; 0.3 to 2.0%.

Comments. This species is distinguished from *T. microsinuosus* (Tlsm-22) by its larger size (25 microns) and rounded outline. Although not readily discernible, this species tends to be more common in the coarse sediments and therefore more in the near-shore environments.

Affinity. Stanley (1965) questionably refers this genus to the family Schizaeaceae.

Triplanosporites sp.

Plate 4, Figures 14, 15

Code. Tlp-11.

Description. Spores trilete; with polar axis always longer than the maximal equatorial diameter; outline usually an elongate triangle to a long oval; length of polar axis 15-25 microns (generally about 20 microns);

spore wall approximately 0.5 microns thick, surface weakly echinate to baculate; laesurae approximately equal to the diameter of the spore.

Occurrence. 58 samples; 0.3 to 1.3%.

Comments. This spore is unusual in that it occurs in almost half of the samples but in low relative frequencies (rarely more than one in 300).

Reference specimen. Pb47542-1 D8.1xR0.8.

Affinity. Unknown.

MONOLETE SPORES

Genus *Laevigatosporites* (Ibrahim) emend. S. W. & B. 1944

Type species *Laevigatosporites vulgaris* (Ibrahim) Ibrahim 1933

Laevigatosporites anomalus Norton 1969

Plate 4, Figure 17

Code. Mr-2.

Occurrence. 66 samples; 0.3 to 2.3%.

Comments. This specimen is identical with figure 3 (of pl. 32, figs. 1-3) of the specimens reported by Stanley (1965) under the species *L. haardti*. Stanley makes no reference to the striking pattern of reticulation on the proximal side, but since the same character was found throughout the samples of the Buck tongue on several hundred specimens this feature was determined to be diagnostic ornamentation. Subsequently, Norton *in* Norton & Hall (1969) described this species from the Hell Creek and Tullock Formations. Norton's specimens differ from the Buck tongue material by being larger (48-58 microns long versus 25-35 microns long).

Laevigatosporites gracilis Wilson & Webster 1946

Plate 4, Figure 19

1946 Amer. Jour. Bot. v. 33, p. 273, fig. 4.

Code. Msm-1.

Occurrence. 129 samples; 0.3 to 7.7%.

Comments. This spore is differentiated from L. haardti (Msm-2) by its thinner more flexible wall. This very common spore most frequently occurred 3 to 6 times in 300; in only 21 samples was it found 10 or more times. This spore is a major, persistent entity in the Buck tongue. It should be mentioned that this spore is so close to L. haardti (Msm-2) that in the case of a poorly preserved sample the distinction is difficult to make.

Affinity. Polypodiaceae.

Laevigatosporites haardti (Potonie & Venitz) Thomson & Pflug 1953

Plate 4, Figure 18

1953 Palaeontographica, v. 94, Abt. B, p. 59, pl. 3, fig. 57.

Code. Msm-2.

Occurrence. 138 samples; 0.3 to 6.7%.

Comments. This spore was found in all but three of the Buck tongue samples examined, and all of the Castlegate Sandstone samples below the Buck tongue. The most significant point that can be made about the presence of this spore is its uniform occurrence, it occurs 1 time in only 8 samples and more than 10 in only 20 samples.

Affinity. Polypodiaceae.

Laevigatosporites ovatus Wilson & Webster 1946

Plate 4, Figure 20

1946 Amer. Jour. Bot., v. 33, p. 273, fig. 5.

Code. S_1sm-3.

Occurrence. 126 samples; 0.3 to 3.3%.

Comments. This spore was mistankenly coded-in as a monosulcate grain, upon re-examination the normally short laesurae was found to be torn, but the S_1 designation was not changed. This very common spore occurs in very low numbers (only 1 sample with more than 9), generally from 2 to 5 in 300. This species is distinguished from all other monolete spores by its rounded outline and distinct short monolete mark, approximately 1/2 of the maximal diameter.

Affinity. Polypodiaceae.

Genus Microfoveolatosporis Krutzsch 1959

Type species Microfoveolàtosporis pseudodentatus Krutzsch 1959

Microfoveolatosporis neogranuloides Krutzsch 1967

Plate 4, Figure 21

1967 Atlas, v. 4-5, p. 172, pl. 63, figs. 4-6.

Code. Mr-1.

Occurrence. 98 samples; 0.3 to 3.0%.

Comments. This species is quite variable in appearance, in that the surface ornamentation varies from a foveolate pattern to a rather strong reticulation as can be noted in the specimen figured. The pattern of recovery of this species is difficult to establish, but there is a slight trend for it to be more common near the contacts with the overlying or underlying sandstones than in the middle portion of the sections. This is not an obvious trend, and its interpretation is not certain.

Affinity. Polypodiaceae.

Genus Perinomonoletes Krutzsch 1967

Type species Perinomonoletes pliocaenicus Krutzsch 1967

Perinomonoletes cf. P. pliocaenicus Krutzsch 1967

Plate 4, Figure 24

1967 Atlas, v. 4-5, p. 222, pl. 87, figs. 2-6.

Code. Mst-1.

Occurrence. 1 sample; 1 time.

Comments. This specimen was found only 1 time in the 300 count, but is present outside of the 300 sum that was counted for each sample. The species P. pliocaenicus Krutzsch (1967) is very close to the species as figured on Plate 6, but Krutzsch reports that it was not found below the Pliocene.

Affinity. Pilularia (?).

Genus Polypodiidites Ross 1949

Type species Polypodiidites senonicus Ross 1949

Polypodiidites secundus (Potonie) Krutzsch 1967

Plate 4, Figure 25

Code. Mp-2.

Occurrence. 72 samples; 0.3 to 3.3%.

Comments. This species was described from the Eocene by Krutzsch (1963) and from the Maestrichtian by Drugg (1967), as Verrucatosporites secundus Krutzsch. This genus has been listed in synonymy with Polypodiidites by Krutzsch (1967).

Affinity. Polypodiaceae.

Polypodiidites senonicus Ross 1949

Plate 4, Figure 23

1949 Bull. Geol. Inst. Uppsala, v. 34, p. 33, pl. 1, figs. 8, 9.

Code. Mp-1.

Occurrence. 82 samples; 0.3 to 1.7%.

Comments. The specimens of this study agree in every detail with the type species of Ross (1949).

Affinity. Polypodium.

Genus Verrucatosporites Thomson & Pflug 1953

Type species Verrucatosporites alienus (Potonie) Thomson & Pflug 1953

Verrucatosporites megabalticus Krutzsch 1967

Plate 4, Figure 22

1967 Atlas, v. 4 & 5, p. 180, pl. 66, figs. 4-6.

Code. Mp-3.

Occurrence. 17 samples; 19 times.

Comments. This spore occurred 3 times in 1 sample and 1 time in all of the other samples in which it was found. The verrucae are quite variable on this species.

Affinity. Polypodiaceae.

Genus Umbosporites Newman 1965

Type species Umbosporites callosus Newman 1965

Umbosporites callosus Newman 1965

Plate 4, Figure 26

1965 Univ. Colo. Studies, No. 2, p. 10, pl. 1, fig. 2.

Code. Umbosporites.

Occurrence. Not found in counts; 2 samples.

Comments. This spore was found in 2 samples outside the counts of 300. The type was described from the Buck tongue of northwest Colorado but it occurred in low numbers, never more than 2%, and has a known range of early and middle Campanian.

Affinity. Polypodiaceae (?).

GYMNOSPERMOUS POLLEN

Genus Alisporites Daugherty 1941

Type species Alisporites oppii Daugherty 1941

Alisporites similis (Balme) Dettmann 1963

Plate 5, Figure 1

1963 Proc. Roy. Soc. Victoria, v. 77, p. 102, pl. 25, figs. 1-4.

Code. Alisporites.

Occurrence. 26 samples; 0.3 to 1.3%.

Comments. This species occurs in the Upper Jurassic and Lower Cretaceous sediments of western Australia. The diagnostic features of this species as identified in the Buck tongue is a smooth equatorial outline and maximum dimension greater than 40 microns long.

Affinity. Unknown.

Genus Caytonipollenites Couper 1958

Type species Caytonipollenites pallidus (Reissinger) Couper 1958

Caytonipollenites cf. C. pallidus (Reissinger) Couper 1958

Plate 5, Figure 6

1958 Palaeontographica, v. 103, Abt. B, p. 150, pl. 26, figs. 7, 8.

Code. Caytonipollenites.

Occurrence. 6 samples; 7 times.

Comments. This species is characterized by its small size (less than 40 microns long). This species has a known Cretaceous range.

Affinity. Couper (1958) states that this pollen grain (C. pallidus) is indistinguishable from modern pollen grains of Caytonanthus.

Genus Cedripites Wodehouse 1933

Type species Cedripites eocenicus Wodehouse 1933

Cedripites cf. C. canadensis Pocock 1962

Plate 5, Figures 2, 3

1962 Palaeontographica, v. 111, Abt. B, p. 163, pl. 10, figs. 149-150.

Code. Phyllocladidites.

Occurrence. 19 samples; 0.3 to 1.0%.

Comments. This specimen is similar to the type species described by Couper (1958) except it is slightly smaller than his minimal sizes in the length and width of the bladders.

Affinity. Cedrus.

Genus Circulina (Maljawkina) ex. Klaus 1960

Type species Circulina meyeriana Klaus 1960

Circulina parva Brenner 1963

Plate 6, Figure 3

1963 Maryland Dept. Geol., Mines & Water Res. Bull. 27, p. 84, pl. 34, figs. 2, 3.

Code. Circulina-1.

Occurrence. 41 samples; 0.3 to 1.3%.

Comments. There is question in the minds of some workers whether this genus should be separated from Classopollis. Brenner (1963) states that the small size and smooth exine distinguishes this species from Classopollis torosus.

Affinity. Coniferales-Incertae Sedis.

Genus Classopollis Pflug emend. Pocock & Jansonius 1961

Type species Classopollis classoides Pflug emend. Pocock & Jansonius 1961

Classopollis classoides Pflug emend. Pocock & Jansonius 1961

Plate 6, Figures 4, 5

1961 Micropaleontology, v. 7, p. 439-449, pl. 1.

Code. Class-2 & Class-3.

Occurrence. Class-2. 42 samples; 0.3 to 2.0%.

Class-3. 8 samples; 0.3 to 0.7%.

Comments. Class-2 and Class-3 were distinguished in this study on the basis of size; they were otherwise, very similar. The size distinction was broken at 30 microns. The description of C. classoides would include both of these types within the size range of the original description so they are here combined. C. classoides has a distribution of Jurassic and Cretaceous.

Affinity. Gymnospermous, probably belonging to the genera Cheirolepis, Pagiophyllum or Brachyphyllum.

Genus Cycadopites Wodehouse 1933 ex. Wilson & Webster 1946

Type species Cycadopites follicularis Wilson & Webster 1946

Cycadopites fragilis Singh 1964

Plate 6, Figure 6

1964 Res. Council Alberta, Bull. 15, p. 103, pl. 14, fig. 2.

Code. S_1sm-2.

Occurrence. 100 samples; 0.3 to 5.7%.

Comments. The most distinguishing character of this pollen grain is the thick margin of its colpus which is quite diagnostic.

Affinity. Cycadaceae.

Cycadopites giganteus Stanley 1965

Plate 5, Figure 9

1965 Bull. Amer. Paleont., v. 49, no. 222, p. 270, pl. 37, figs. 6-9.

Code. Cycadopites.

Occurrence. 53 samples; 0.3 to 1.7%.

Comments. This grain is distinguished by its very large size, thin exine and overlapping sulcus.

Affinity. Cycadaceae.

Genus Equisetosporites Daugherty 1941 emend. Singh 1964

Type species Equisetosporites chinleana Daugherty 1941

Equisetosporites multicostatus (Brenner) Norris 1967

Plate 6, Figure 15

1967 Palaeontographica, v. 120, Abt. B, p. 14, pl. 16, fig. 15.

Code. Ephedripites-2.

Occurrence. 10 samples; 12 times.

Comments. Singh (1964) (p. 129-31) logically discusses why the genus name Ephedripites Bolkhovitina (1953) cannot be used as a genetic name for this group on the basis of Daugherty's description of Equisetosporites in 1941, which has priority. For a complete discussion, see Singh. This genus is well represented in Cretaceous sediments of North America (Brenner, 1963; Singh, 1964; Hedlund, 1966; Norris, 1967; this study, etc.).

Affinity. Ephedra.

Equisetosporites ovatus (Pierce) Singh 1964

Plate 6, Figure 13

1964 Res. Council Alberta Bull. 15, p. 133, pl. 17, fig. 16.

Code. C^{oo}-1.

Occurrence. 11 samples; 0.3 to 0.7%.

Comments. This species is similar in size and description as originally described by Pierce (1961) from the Lower Upper Cretaceous of Minnesota.

Affinity. Ephedra.

Genus Eucommiidites Erdtman emend. Hughes 1961

Type species Eucommiidites troedssonnii Erdtman 1948

Eucommiidites cf. E. minor Groot & Penny 1960

Plate 6, Figure 8

1960 Micropaleontology, v. 6, p. 234, pl. 2, fig. 14.

Code. C_3sm-3.

Occurrence. 142 samples; 0.3 to 14.0%.

Comments. This trisulcate grain has a size range from 15 to 20 microns generally; but the walls are thick and range 1 1/2 to 2 microns which places it most closely related to the species E. minor as described by Groot & Penny (1960). The size range is slightly smaller than their material but the wall thickness is thicker than E. delcourtii of Hughes, 1961.

Affinity. Gymnospermous.

Eucommiidites cf. E. troedssonii Erdtman 1948

Plate 6, Figure 18

1948 Geol. Foren. Forh., v. 70, p. 267, text-figs. 5-10, 12-13.

Code. C_3sm-9.

Occurrence. 134 samples; 0.3 to 14.3%.

Comments. The size and wall thickness is comparable to E. troedssonii Erdtman (1948). This specimen shows a typical main furrow and a broken or discontinuous ring furrow. The assignment is tentative.

Affinity. Gymnospermous.

Eucommiidites (?) sp.

Plate 6, Figures 11, 12

Code. C_3sm-8.

Description. Very small eucommiiditian type grain; nearly circular in equatorial outline; wall psilate; exine less than 1 micron thick. Maximum dimension less than 10 microns.

Occurrence. 0.3 to 14.0%.

Comments. This very small, rather stiff-walled grain is one of the most common in the Buck tongue. This is probably in part because of its very small size, but the occurrence of this species is thought to have considerable ecological significance.

Reference specimen. Pb4854-6 D2.1xR6.2

Affinity. Gymnospermous.

Genus *Foveoinaperturites* Pierce 1961

Type species *Foveoinaperturites forameniferus* Pierce 1961

Foveoinaperturites cf. *F. foramenIferus* Pierce 1961

Plate 5, Figure 11

1961 Minnesota Geol. Surv., Bull. 42, p. 43; pl. 3, fig. 71.

Code. Osm-5.

Occurrence. 126 samples; 0.3 to 11.3%.

Comments. This species is similar to *Inaperturopollenites dubius* (Osm-1) but has a much thicker wall, the surface of which is foveolate and corrugate.

Affinity. Unknown.

Genus *Ginkgocycadophytus* Samoilovitch 1953

Type species *Ginkgocycadophytus caperatus* (Luber) Samoilovitch 1953

Ginkgocycadophytus nitidus (Balme) de Jersey 1962

Plate 6, Figure 7

1962 Qd. Dep. Mines. Publ., v. 307, p. 12, pl. 5, figs. 1-3.

Code. S_1sm-1.

Occurrence. 136 samples; 0.3 to 7.3%.

Comments. The species of this study are identical to the type and the specimens which are illustrated by Balme (1957). This species is represented in many Upper Mesozoic samples of Australia as well as North America.

Affinity. *Ginkgoales* (?).

Genus Inaperturopollenites Pflug ex. Thomson & Pflug emend. Potonie 1958

Type species Inaperturopollenites dubius (Potonie & Venitz) Thomson & Pflug 1953

Inaperturopollenites dubius (Potonie & Venitz) Thomson & Pflug 1953

Plate 5, Figure 12

1953 Palaeontographica, v. 94, Abt. B, p. 65, pl. 4, fig. 89; pl. 5, figs. 1-13.

Code. Osm-1.

Occurrence. 139 samples; 0.3 to 9.7%.

Comments. This species is widely distributed in Jurassic, Cretaceous and Tertiary strata of many parts of the world.

Affinity. Unknown.

Inaperturopollenites cf. I. magnus (Potonie) Thomson & Pflug 1953

Plate 6, Figure 14

1953 Palaeontographica, v. 94, Abt. B, p. 64, pl. 4, figs. 85-88.

Code. Leiosphaeridia-4.

Comments. This large thin-walled grain is difficult to distinguish from Hexagonifera glabra if an apical tear is present that could be interpreted as an apical archeopyle.

Affinity. Taxodiaceae--Cupressiaceae.

Genus Parvisaccites Couper 1958

Type species Parvisaccites radiatus Couper 1958

Parvisaccites radiatus Couper 1958

Plate 5, Figure 8

1958 Palaeontographica, v. 103, Abt. B, p. 154, pl. 29, figs. 5-8; pl. 30, figs. 1, 2.

Code. Pityiosporites.

Occurrence. 14 samples; 16 times.

Comments. The measurements and description of the specimens from the Buck tongue that are assigned to this species are very close to those of Couper (1958) and identical with those of Pocock (1962); there is little doubt of the assignment of this species. The known range of this species is Lower Cretaceous.

Affinity. Couper (1958) states that this pollen grain is very close to the genus Dacrydium (D. cupressinum and D. elatum). Pocock (1962) states that this genus is very close to Podocarpidites as described by him except that the sacci are relatively much smaller.

Genus Podocarpidites Cookson ex. Couper 1953

Type species Podocarpidites ellipticus Cookson 1947

Podocarpidites cf. P. ellipticus Cookson 1947

Plate 5, Figure 4

1947 B.A. New Zealand, Antarctic Res. Exp., 1929-31, Rep. A-2 (8), p. 131-2, pl. 13, figs. 5-7.

Code. Podocarpidites.

Occurrence. 3 samples; 3 times.

Comments. This species has a range from Lower Cretaceous to Lower Oligocene.

Affinity. Podocarpus.

Genus Schizosporis Cookson & Dettmann 1959

Type species Schizosporis reticulatus Cookson & Dettmann 1959

Schizosporis parvus Cookson & Dettmann 1959

Plate 6, Figure 2

1959 Micropaleontology, v. 5, p.213, pl. 1, figs. 15-20.

Code. Schizosporis-1.

Occurrence. 69 samples; 0.3 to 4%.

Comments. This genus is generally placed under the category *Incertae sedis*. This species has been reported from Upper Cretaceous sediments of Australia by Cookson & Dettmann (1959); Singh (1964), Canada; Clarke (1963), Colorado; Hedlund (1966), Oklahoma.

Affinity. Some specimens of *Schizosporis* appear to have monosulcate furrow and have been referred to Magnoliaceae.

Schizosporis sp.

Plate 5, Figure 7

Code. Or-1.

Description. Coarsely reticulate grain, rounded to elliptical in shape, splitting equatorially into two semi-circular sections. Diameter, 15 to 20 microns.

Occurrence. 102 samples; 0.3 to 2.7%.

Comments. This species is distinguished from members of *Liliacidites* by the nature of its equatorial furrow and general rounded shape.

Reference specimen. Pb4828-1 D5.7xR21.5.

Affinity. Unknown.

Genus *Taxodiaceaepollenites* Kremp 1949

Type species *Taxodiaceapollenites* (*Pollentites*) *hiatus* (Potonie) Kremp 1944

Taxodiaceapollenites hiatus (Potonie) Kremp 1949

Plate 6, Figure 1

1949 Palaeontographica, v. 90, Abt. B, p. 59.

Code. Osm-3.

Occurrence. 140 samples; 0.3 to 8.7%.

Comments. This species differs from *Inaperturopollenites dubius* (Osm-1) by having a slightly thinner wall and being slightly larger.

Affinity. *Thuja*.

Genus *Tsugaepollenites* Potonie & Venitz emend. Potonie 1958

Type species *Tsugaepollenites igniculus* (Potonie) Potonie & Venitz 1934

Tsugaepollenites mesozoicus Couper 1958

Plate 5, Figure 10

1958 Palaeontographica, v. 103, Abt. B., p. 155, pl. 30, figs. 8-10.

Code. *Tsuga*-2.

Occurrence. 12 samples; 0.3 to 1.0%.

Comments. *T. mesozoicus* can be distinguished from *T. segmentatus* by its larger size, which is 60 microns or greater (diameter of *T. segmentatus*, 45 microns or less).

Affinity. *Tsuga*.

Tsugaepollenites segmentatus (Balme) Dettmann 1963

Plate 5, Figure 5

1963 Proc. Roy. Soc. Victoria, v. 77, p. 101, pl. 24, figs. 11-16.

Code. *Tsuga*-1.

Occurrence. 50 samples; 0.3 tl 8.3%.

Comments. Sample Pb4768 contained 25 *T. segmentatus* grains and was the only sample that contained more than 5 grains; this sample is, therefore, considered an aberrant sample.

Affinity. Tsuga.

ANGIOSPERM POLLEN

(Monosulcate)

Genus Liliacidites Couper 1953

Type species Liliacidites kaitangensis Couper 1953

Liliacidites cf. L. variegatus Couper 1953

Plate 6, Figure 17

1953 New Zealand Geol. Survey, Paleont. Bull. 22, p. 56, pl. 7, fig. 100.

Code. S_1r-1.

Occurrence. 108 samples; 0.3 to 3.7%.

Comments. This species is a well-known Upper Cretaceous form, reported by Couper (1953); Groot, Penny & Groot (1961); Pierce (1961); and Hedlund (1966).

Affinity. Couper (1953) proposed this genus for the reception of fossil grains of liliaceous affinities that cannot be more accurately placed.

Liliacidites sp.

Plate 6, Figure 16

Code. S_1r-2.

Description. Monosulcate pollen grain, bilaterally symmetrical; grain slightly elongate to rounded; sulcus extending almost full length of the long axis of the grain on the distal face; surface ornamentation reticulate with small baculi on the reticulum; diameter of the muri of the reticulum .5 to 1 micron wide. Lumina 1 to 3 microns across. Maximum diameter 25 to 35 microns.

Occurrence. 99 samples; 0.3 to 3.7%.

Comments. This grain is characterized by the sculpture of the muri. This entity is similar to Schizosporis complexus Stanley (1965) which was interpreted by Stanley as an inaperturate pollen grain, but this specimen was interpreted in the Buck tongue to be a monosulcate pollen grain.

Reference specimen. Pb4713-1 D3.4xR14.2.

Affinity. Liliaceous.

Genus Monosulcites Cookson ex. Couper 1953

Type species Monosulcites minimus Cookson 1947

Monosulcites sp. A

Plate 6, Figure 10

Code. S_1f-1.

Description. Monosulcate pollen; furrow long, almost full length of grain. Outline in polar view, long ellipsoid; finely foveolate. Length 6 to 10 microns; width about 1/2 the length.

Occurrence. 141 samples; 0.3 to 6%.

Comments. This very tiny grain was found in most of the samples of this study. Its size is its most diagnostic feature.

Reference specimen. Pb4812-1 D17.4xR6.0.

Affinity. Unknown.

Monosulcites sp. B

Plate 6, Figure 9

Code. S_1f-2.

Description. Monosulcate pollen grain; furrow long, almost full length of grain, bordered by very narrow lip, *ca*. 1 micron wide; outline polar view is broadly elliptical. Size is generally around *ca*. 15 microns.

Occurrence. 97 samples; 0.3 to 4.7%.

Comments. This medium to small sized grain is thin-walled and microfoveolate.

Reference specimen. Pb48072-1 D2.9xR14.7.

Affinity. Unknown.

ANGIOSPERM POLLEN

(Tricolpate)

Genus *Aquilapollenites* Rouse emend. Funkhouser 1961

Type species *Aquilapollenites quadrilobus* Rouse 1957

Aquilapollenites amplus Stanley 1961

Plate 6, Figure 22

1961 Pollen et Spores, v. 3, p. 342, pl. 1, figs. 1-6; pl. 2, figs. 1-4; pl. 3, figs. 1-5.

Code. *Aquilapollenites*-5.

Occurrence. 13 samples; 18 times.

Comments. This species is characterized by the nature of its ornamentation and by being isopolar. This genus is usually considered to be Angiosperm *Incertae sedis*.

Affinity. Angiosperm pollen.

Aquilapollenites calvus Tschudy & Leopold 1970

Plate 7, Figures 8, 9

Code. Aquilapollenites-12.

Occurrence. 1 sample; 1 time.

Comments. This distinctive pollen is characterized by its large size and the shape and placement of the equatorial protrusions.

Affinity. Angiosperm pollen.

Aquilapollenites delicatus Stanley 1961

Plate 6, Figure 21

1961 Pollen et Spores, v. 3, p. 346, pl. 4, figs. 1-12.

Code. Aquilapollenites-6.

Occurrence. 42 samples; 56 times.

Comments. This, the most common of the aquilate grains, is characterized by its heteropolar form and its surface ornamentation.

Affinity. Angiosperm pollen.

Aquilapollenites novacolpites Funkhouser 1961

Plate 6, Figure 20

1961 Micropaleontology, v. 7, p. 196, pl. 2, figs. 2, 3.

Code. Aquilapollenites-3.

Occurrence. 29 samples; 37 times.

Comments. The unique characters of this species are the furrows and the demicolpi, and the twisted tips of the equatorial projections or wings.

Affinity. Angiosperm pollen.

Aquilapollenites polaris Funkhouser 1961

Plate 7, Figures 3, 4

1961 Micropaleontology, v. 7, p. 198, pl. 1, figs. 1, 2.

Code. *Aquilapollenites*-7.

Occurrence. 6 samples; 6 times.

Comments. This grain is characterized by its capitate spines and heteropolar form.

Affinity. Angiosperm pollen.

Aquilapollenites pyriformis Norton 1965

Plate 7, Figure 10

1965 Pollen et Spores, v. 7, p. 136, pl. 1, figs. 1-4.

Code. *Aquilapollenites*-9.

Occurrence. 2 samples; 2 times.

Comments. This characteristic grain has previously been reported from the Maestrichtian of Montana.

Affinity. Angiosperm pollen.

Aquilapollenites quadrilobus Rouse 1957

Plate 7, Figure 2

1957 Canadian Jour. Botany, v. 35, p. 371, pl. 2, figs. 8, 9.

Code. *Aquilapollenites*-8.

Occurrence. 4 samples; 4 times.

Comments. This species is characterized by its symmetrically developed projections.

Affinity. Angiosperm pollen.

Aquilapollenites cf. *A*. *reticulatus* Stanley 1961

Plate 7, Figure 1

1961 Pollen et Spores, v. 3, p. 348, pl. 8, figs. 1-12.

Code. *Aquilapollenites*-11.

Occurrence. 11 samples; 12 times.

Comments. An attempt was made to distinguish this species, in this study, on the basis of the size of its reticulum and the striate pattern on the projections. Both of these criteria seem to break down as a method of isolating this species from *A. trialatus* Rouse; in the opinion of the writer on the basis of this study, this species grades into *A. trialatus* and is probably conspecific with it.

Affinity. Angiosperm pollen.

Aquilapollenites trialatus Rouse 1957

Plate 7, Figure 7

1957 Canadian Jour. Botany, v. 35, p. 371, pl. 2, figs. 14, 15.

Code. *Aquilapollenites*-4.

Occurrence. 32 samples; 41 times.

Comments. This species is characterized by its large size, the nature of its projections and the surface ornamentation.

Affinity. Angiosperm pollen.

Aquilapollenites turbidus Tschudy & Leopold 1969

Plate 6, Figure 19

Code. *Aquilapollenites*-2.

Occurrence. 4 samples; 5 times.

Comments. This species is characterized by its shape and surface ornamentation.

Affinity. Angiosperm pollen.

(?)*Aquilapollenites* sp.

Plate 7, Figures 5, 6

Code. *Aquilapollenites*-1.

Description. Isopolar to subisopolar pollen grain with three distinct equatorial projections, slit-like colpi are present on broadly rounded ends of the equatorial expansions. The scabrate surface is covered with small sparsely placed verrucae. Polar dimension 28 microns, equatorial dimension 40 microns.

Occurrence. 1 sample; 1 time.

Comments. This rare form is similar to the genus *Fibulapollis* but lacks the rounded shape in equatorial view.

Reference specimen. Pb4728-5 D2.3xR15.7.

Affinity. Angiosperm pollen.

Genus *Cupanieidites* Cookson & Pike 1954

Type species *Cupanieidites orthoteichus* Cookson & Pike 1954

Cupanieidites cf. *C. reticularis* Cookson & Pike 1954

Plate 7, Figures 13, 14

1954 Australian Jour. Botany, v. 2, p. 214, pl. 2, figs. 87-89.

Code. C_3r-3.

Occurrence. This species is a reticulate syncolpate grain with straight to slightly convex sides; triangular in outline and appears to be quite similar to *C. reticularis* Cookson & Pike (1954). This species was described from Tertiary sediments but has been reported from the Upper Cretaceous.

Affinity. *Lepiterema*-*Sarcopteryx* according to Cookson & Pike (1954).

Cupanieidites sp.

Plate 7, Figure 12

Code. C_3r-14.

Description. Syncolpate pollen grains; finely reticulate ornamentation; walls straight to slightly concave. Dimensions, 12 to 18 microns in diameter.

Occurrence. 28 samples; 37 times.

Comments. This grain is characterized by its equatorial outline, often with an arcus-like thickening.

Reference specimen. Pb4735-1 D17.3xR6.2.

Affinity. Sapindaceae (?).

Genus Fraxinoipollenites Potonie 1960

Type species Fraxinoipollenites pudicus (Potonie) Potonie 1960

Fraxinoipollenites cf. F. variabilis Stanley 1965

Plate 8, Figures 8, 9

1965 Bull. Amer. Paleont., v. 49, no. 222, p. 306, pl. 45, figs. 29-35.

Code. C_3p-5.

Occurrence. 72 samples; 0.3 to 2.3%.

Comments. This species is characterized by its baculate sculptural elements and is similar to the species of Ilexpollenites Thiergart (1938) and Srivastava (1966).

Affinity. Fraxinus (in part).

Genus Gemmatricolpites Pierce 1961

Type species Gemmatricolpites gemmatus Pierce 1961

Gemmatricolpites cf. G. gemmatus Pierce 1961

Plate 7, Figure 11

1961 Minnesota Geol. Survey, Bull. 42, p. 49, pl. 3, figs. 96, 97.

Code. C_3p-1.

Occurrence. 126 samples; 0.3 to 6.0%.

Comments. This specimen is characterized by its relatively large size and gemmate surface ornamentation.

Affinity. Angiospermous pollen grain.

Gemmatricolpites cf. *G*. *pergammatus* Muller 1968

Plate 8, Figure 7

1968 Micropaleontology, v. 14, p. 18, pl. 4, fig. 12.

Code. C_3p-6.

Occurrence. 58 samples; 0.3 to 2.3%.

Comments. This species is characterized by its small size, thick wall and rather elongate, thin surface ornamentation.

Affinity. *Ilex* (?).

Genus *Myrtaceidites* Cookson & Pike emend. Potonie 1960

Type species *Myrtaceidites mesonesus* Cookson & Pike 1954

Myrtaceidites sp.

Plate 8, Figure 3

Code. C_3p-3.

Occurrence. Not found in 300 count.

Description. Tricolpate pollen; angulaperturate, pollen very small; sides straight to slightly concave, colpi reaching half-way to the poles; exine thin, weakly spinose. Diameter, *ca*. 15 microns.

Comments. A specimen similar to this species found in the Buck tongue is reported by Srivastava (1966) from the Upper Cretaceous of Canada; this species resembles M. eugeniioides Cookson & Pike (1954) from Australia.

Genus Psilatricolpites Van der Hammen 1956

Type species Psilatricolpites incomptus Van der Hammen 1956

Psilatricolpites psilatus Pierce 1961

Plate 8, Figure 1

1961 Minnesota Geol. Survey, Bull. 42, p. 49, pl. 3, figs. 98, 99.

Code. C_3sm-10.

Occurrence. 132 samples; 0.3 to 7.3%.

Comments. This rather thick-walled specimen is quite similar to the species as described by Pierce (1961). This species of the Buck tongue might be slightly more rounded than Pierce's, otherwise there is very little difference.

Affinity. Pierce (1961) refers this species to the family Fagaceae with a question mark, comparable to Quercus ilex L.

Psilatricolpites sp.

Plate 8, Figure 2

Code. C_3sm-12.

Description. Pollen grains, tricolpate; exine thin, smooth to scabrate; colpi usually spread open; triangular in polar view. Dimension, 13 to 17 microns.

Occurrence. 18 samples; 0.3 to 1.3%.

Comments. This species is similar to Tricolpopollenites (unnamed species) of Leopold & Pakiser (1964) (plate 5, figures 1-5) from the

Tuscalusa group; Tricolpites sp. B of Drugg (1967) (pl. 7, fig. 41) from the Maestrichtian, Danian of California; and Rhamnus minutapollenites from the Tertiary of British Columbia Rouse (1957).

Reference specimen. Pb4751a-1 D5.4xR3.6.

Affinity. Possibly Fagaceae.

Genus Retitricolpites Van der Hammen 1956

Type species Retitricolpites ornatus Van der Hammen 1956

Retitricolpites georgensis Brenner 1963

Plate 8, Figure 6

1963 Maryland Dept. Geol., Mines & Water Res., Bull. 27, p. 91, pl. 38, figs. 6-7.

Code. C_3r-19.

Occurrence. 22 samples; 0.3 to 1.3%.

Comments. This species as found in the Buck tongue is characterized by its large size (ca. 28-31 microns) and the reduced number of lumina in the polar area. This grain resembles Tricolpites reticulatus Cookson (1947) and is similar to R. sphaeroides Pierce (1961).

Affinity. Angiospermous grain.

Retitricolpites cf. R. geranioides Brenner 1963

Plate 8, Figures 4, 5

1963 Maryland Dept. Geol., Mines & Water Res., Bull. 27, p. 91, pl. 38, fig. 8; pl. 39, fig. 1.

Code. C_3r-8.

Occurrence. 38 samples; 0.3 to 1.3%.

Comments. This species is characterized by its rounded equatorial outline and its very long colpi which on occasion, if compressed obliquely appears to be a syncolpate grain.

Affinity. Brenner (1963) comments that this grain is very similar to living genus Geranium.

Retitricolpites minutus Pierce 1961

Plate 8, Figure 13

1961 Minnesota Geol. Survey, Bull. 42, p. 52, pl. 3, figs. 109, 110.

Code. C_3f-3.

Occurrence. 140 samples; 0.3 to 10.3%.

Comments. This grain is characteristically very small with a microfoveolate surface texture, generally spherical to ovoid in shape.

Affinity. Angiospermous grain.

Retitricolpites cf. R. oblatoides Pierce 1961

Plate 8, Figure 12

1961 Minnesota Geol. Survey, Bull. 42, p. 50, pl. 3, fig. 104.

Code. C_3r-1.

Occurrence. 89 samples; 0.3 to 5%.

Comments. This grain is distinguished from R. prosimilis by its slightly smaller size, thicker walls and its slightly more rounded appearance.

Affinity. Hamamelidaceae cf. Bucklandia sp.

Retitricolpites cf. R. paraneus Norris 1967

Plate 8, Figure 30

1967 Palaeontographica, v. 120, Abt. B, p. 109, pl. 18, figs. 15-20.

Code. C_3r-18.

Occurrence. 107 samples; 0.3 to 4%.

Comments. This species as found in the Buck tongue averaged about 20 microns and is almost spherical to slightly oval; Norris (1967) described R. paraneus as having a diameter of from 15 to 21 microns but his material was somewhat more elongate.

Affinity. Angiospermous pollen grain.

Retitricolpites peroblatus Muller 1968

Plate 8, Figure 32

1968 Micropaleontology, v. 14, p. 19, pl. 4, fig. 17.

Code. C_3f-2.

Occurrence. 136 samples; 0.3 to 16%.

Comments. This very persistent grain occurred 20 or more times out of a count of 300 in only 10 samples. This species is characterized by its thick wall structure and foveolate surface texture and is quite variable in size but is generally among the larger of the tricolpate grains.

Affinity. Angiospermous grain.

Retitricolpites cf. R. prosimilis Norris 1967

Plate 8, Figure 10

1967 Palaeontographica, v. 120, Abt. B, p. 108, pl. 18, figs. 5-14.

Code. C_3r-2.

Occurrence. 120 samples; 0.3 to 10.7%.

Comments. This species is characterized by its relatively large size and small reticulum. The reduction of the ornamentation on the polar area cannot always be clearly seen.

Affinity. Hamamelidaceae (?).

Retitricolpites cf. R. vermimurus Brenner 1963

Plate 8, Figure 17

1963 Maryland Geol. Mines & Water Res., Bull. 27, p. 92, pl. 39, figs. 2, 3.

Code. C_3st-1.

Occurrence. 15 samples; 16 times.

Comments. The vermiculate reticulum distinguishes this species from all other tricolpate grains.

Affinity. Angiospermous grain.

Retitricolpites vulgaris Pierce 1961

Plate 8, Figures 14, 15

1961 Minnesota Geol. Survey, Bull. 42, p. 50, pl. 3, figs. 101, 102.

Code. C_3r-21.

Occurrence. 118 samples; 0.3 to 4%.

Comments. This species is characterized by its small, round lumina.

Affinity. Hamamelidaceae cf. Hamamelis spp.

Retitricolpites sp.

Plate 8, Figure 11

Code. C_3r-9.

Description. Pollen grains tricolpate; round to prolate; colpi extending almost the length of the grain; most commonly found in polar compression; exine finely reticulate with distinctive psilate copal margins extending 2 microns from the lips. Frequently, the lumina are reduced in number in the polar area. Dimension, 15 to 20 microns in diameter in polar view.

Occurrence. 0.3 to 1.3%.

Comments. This grain is characterized by its smooth colpal margins.

Reference specimen. Pb4826-1 D11.2xR12.9.

Affinity. Angiospermous grain.

Genus *Tricolpites* Cookson ex. Couper 1953

Type species *Tricolpites reticulatus* Cookson 1947

Tricolpites anguloluminosus Anderson 1960

Plate 8, Figure 37

1960 New Mexico Bureau of Mines, Mem. 6, p. 26, pl. 6, figs. 15-17, pl. 8, figs. 17, 18.

Code. C_3r-20.

Occurrence. 51 samples; 0.3 to 2.0%.

Comments. This grain is characterized by its large size, coarse reticulum and generally its polar orientation with gaping colpi.

Affinity. Drugg (1967) refers this species to *Bucklandia populnea* of the Hamamelidaceae.

Tricolpites bathyreticulatus Stanley 1965

Plate 8, Figure 18

1965 Bull. Amer. Paleont., v. 49, no. 222, p. 320, pl. 47, figs. 18-23.

Code. C_3r-15.

Occurrence. 22 samples; 0.3 to 1.0%.

Comments. This pollen grain is distinguished by its coarse reticulum and rounded inter-colpate outline in equatorial plane.

Affinity. Angiospermous pollen.

Tricolpites erugatus Hedlund 1966

Plate 8, Figures 19, 20

1966 Oklahoma Geol. Survey, Bull. 112, p. 30, pl. 9, figs. 2a, b.

Code. C_3sm-16.

Occurrence. 26 samples; 0.3 to 2.0%.

Comments. This small thin walled tricolpate grain was counted as three separate entities in this study. Upon the completion of the counts it was determined that they were not significantly different nor did they occur in large enough numbers to warrant their separation. Of the 26 samples containing this species, 19 had an occurrence of only 1 entity in a count of 300. This grain appears to be similar to *Cyrilla minima* Anderson (1961).

Affinity. Cyrillaceae (?).

Tricolpites hians Stanley 1965

Plate 8, Figure 16

1965 Bull. of Amer. Paleont., v. 49, no. 222, p. 321, pl. 47, figs. 24-27.

Code. C_3f-1.

Occurrence. 140 samples; 0.3 to 10.0%.

Comments. This grain is distinguished by its microreticulate or foveolate surface texture and is relatively thinner walled than *T. parvus*.

Affinity. Angiospermous pollen.

Tricolpites cf. *T. lilliei* Couper 1953

Plate 8, Figure 21

1953 New Zealand Geol. Survey Paleont. Bull. 22, p. 62, pl. 8, figs. 116, 117.

Code. C_3p-2.

Occurrence. 113 samples; 0.3 to 4.3%.

Comments. This grain can be distinguished by its sparse, small conical spines. This species is similar to species of Gemmatricolpites and appears to be somewhat similar to Triptycha elegans Bolkhovitina (1953).

Affinity. Angiospermous pollen.

Tricolpites parvus Stanley 1965

Plate 8, Figure 22

1965 Bull. of Amer. Paleont., v. 49, no. 222, p. 322, pl. 47, figs. 28-31.

Code. C_3f-7.

Occurrence. 134 samples; 0.3 to 6.0%.

Comments. Stanley (1965) recorded this species from the Paleocene of South Dakota; Newman (1965) recorded a similar species (T. interangulus) from the Upper Cretaceous of Colorado which is slightly larger than T. parvus.

Affinity. Angiospermous grain.

Tricolpites cf. T. sagax Norris 1967

Plate 8, Figure 23

1967 Palaeontographica, v. 120, Abt. B, p. 107, pl. 17, figs. 12-19.

Code. C_3r-17.

Occurrence. 82 samples; 0.3 to 4.0%.

Comments. In his original description Norris (1967) indicated that some of his specimens were rather prolate whereas most of the specimens of this study were rounded to slightly oval in shape.

Affinity. Angiospermous grain.

Tricolpites sp.

Plate 8, Figure 24

Code. C_3r-16.

Description. Tricolpate pollen grain; round to sub-round in equatorial outline; colpi gaping, reaching the polar area; exine about 1 micron thick, finely reticulate surface ornamentation, lumina about 1 micron across. Diameter, 12-18 microns.

Occurrence. 45 samples; 0.3 to 1.7%.

Comments. This species is characterized by its small size, gaping colpi and small reticulum. The average size of this species in the Buck tongue is 16 microns.

Reference specimen. Pb47542-1 D7.6xR18.2.

Affinity. *Ilex* (?).

Genus *Tricolpopollenites* Pflug & Thomson 1953

Type species *Tricolpopollenites parmularis* Pflug & Thomson 1953

Tricolpopollenites debilis Groot, Penny & Groot 1961

Plate 8, Figure 33

1961 Palaeontographica, v. 108, Abt. B, p. 132, pl. 26, fig. 5.

Code. C_3sm-2.

Occurrence. 102 samples; 0.3 to 7.7%.

Comments. This species generally occurs in small numbers throughout the section, rarely being counted more than 5 times in any count of 300. This species has its greatest occurrence in the top of the West Salt Creek section. It is difficult to say with certainty but it appears that this species might be most prominent in the upper portion of the sections in which it occurs.

Affinity. Groot, Penny & Groot (1961) questionably refer this species to Labiatae (?).

Tricolpopollenites elongatus Groot & Groot 1962

Plate 8, Figures 25, 26

1962 Comunicacoes dos Servicos Geologicos de Portugal, v. 46, p. 164, pl. 9, fig. 1.

Code. C_3sm-4.

Occurrence. 116 samples; 0.3 to 2.3%.

Comments. This distinct pollen grain, although never occurring more than 7 times in a count of 300, occurred persistently throughout the Buck tongue samples of this study.

Affinity. Unknown.

Tricolpopollenites micromurus Groot & Penny 1960

Plate 8, Figure 29

1960 Micropaleontology, v. 6, p. 232, pl. 2, figs. 6, 7.

Code. C_3r-5.

Occurrence. 136 samples; 0.3 to 6%.

Comments. This small grain can be distinguished from T. minutus by its larger size and coarser reticulum, and is unique for its persistent occurrence in small numbers.

Affinity. Angiospermous pollen.

Tricolpopollenites minutus Brenner 1963

Plate 8, Figure 27

1963 Maryland Dept. Geol., Mines & Water Res., p. 93, pl. 40, figs. 5, 6.

Code. C_3r-4.

Occurrence. 139 samples; 0.3 to 913%.

Comments. This species is characterized by its extremely small-sized and reticulate sculpture, and is unique for its persistent low frequency of occurrence.

Affinity. Angiospermous pollen.

Tricolpopollenites parvulus Groot & Penny 1960

Plate 8, Figure 38

1960 Micropaleontology, v. 6, p. 232, pl. 2, figs. 8, 9.

Code. C_3sm-1.

Occurrence. 140 samples; 0.3 to 13.0%.

Comments. Norris (1967) reassigned this species to the genus Psilatricolpites Van der Hammen, but did not state his reasoning, so his reassignment is not followed by this writer. This species is differentiated from T. debilis (C_3sm-2) by its slightly smaller size and thicker wall.

Affinity. Groot, Penny & Groot (1961) state that it has been suggested that this species has an affinity with Cupuliferae (Fagaceae).

Tricolpopollenites cf. T. platyreticulatus Groot, Penny & Groot 1961

Plate 8, Figure 35

1961 Palaeontographica, v. 108, Abt. B, p. 133, pl. 26, figs. 14, 15.

Code. C_3r-12.

Occurrence. 96 samples; 0.3 to 4.3%.

Comments. This grain is characterized by its coarse reticulum and rounded equatorial outline.

Affinity. Ilex (?).

Tricolpopollenites cf. T. retiformis Pflug & Thomson 1953

Plate 8, Figure 28

1953 Palaeontographica, v. 94, Abt. B., p. 97, pl. 11, figs. 59-61.

Code. C_3r-6.

Occurrence. 120 samples; 0.3 to 4%.

Comments. This species can be distinguished from T. micromurus by its larger size and more rounded inter-colpate regions in equatorial view.

Affinity. Platanus-salix.

Tricolpopollenites sp. A

Plate 8, Figure 34

Code. C_3sm-5.

Description. Tricolpate pollen grains; shape, circular; foveolate-tectate; exine 2.5 microns thick; collumella prominent; margins of colpi thick, 2.7 microns. Diameter, 22 to 30 microns.

Occurrence. 135 samples; 0.3 to 4.7%.

Comments. This species is characterized by very thick-walled structure and thick margins of the colpate, and is similar to Pollenites edwardii Potonie (1933) but appears to be smaller.

Reference specimen. Pb48112-1 D2.6xR8.1.

Affinity. Angiospermous pollen.

Tricolpopollenites sp. B

Plate 8, Figure 36

Code. C_3r-7.

Description. Pollen grains tricolpate; prolate; colpi long; exine consists of wide-meshed reticulum; lumina greater than 5 microns in diameter, polygonal; muri very narrow, $\pm$ 1 micron high. Dimension, approximately 20 microns.

Occurrence. 15 samples; 16 times.

Comments. This grain was recognized for its very coarse-meshed reticulum, the shape was difficult to ascertain because of its usual crushed or distorted preservation.

Reference specimen. Pb4828-1 D11.0xR5.6.

Affinity. Angiospermous pollen.

ANGIOSPERM POLLEN

(Tricolporate)

Genus *Psilatricolporites* Pierce 1961

Type species *Psilatricolporites prolatus* Pierce 1961

Psilatricolporites acuticostatus Muller 1968

Plate 8, Figure 39

1968 Micropaleontology, v. 14, p. 21, pl. 4, fig. 10.

Code. CP_3sm-1.

Occurrence. 12 samples; 13 times.

Comments. This grain has long colpi that are bordered by slightly thickened ridges which is a diagnostic character.

Affinity. Angiospermous grain.

Psilatricolporites prolatus Pierce 1961

Plate 8, Figure 40

1961 Minnesota Geol. Survey Bull. 42, p. 53, pl. 3, fig. 114.

Code. CP_3sm-2.

Occurrence. 15 samples; 0.3 to 1.7%.

Comments. The species of the Buck tongue are slightly smaller than those described by Pierce (1961); however, they are in every other way satisfactory. This species resembles *Tricolporopollenites aliquantulus* Hedlund (1966).

Affinity. This species has been referred to the families Fagaceae, Myrsinaceae, Rutaceae and others.

Genus *Tricolporopollenites* Pflug & Thomson 1953

Type species *Tricolporopollenites kruschii* (Potonie) Pflug & Thomson 1953

Tricolporopollenites cf. *T. microreticulatus* Pflug & Thomson 1953

Plate 8, Figure 31

1953 Palaeontographica, v. 94, Abt. B, p. 106, pl. 14, figs. 27-42.

Code. CP_3f-1.

Occurrence. 7 samples; 9 times.

Comments. This tricolporite grain differs from that described by Pflug & Thomson *in* Thomson & Pflug (1953) by its smaller size.

Affinity. Angiospermous grain.

ANGIOSPERM POLLEN

(Triporate)

Genus *Engelhardtioidites* Potonie, Thomson, & Thiergart 1950

Type species *Engelhardtioides microcoryphaeus* (Potonie 1931)

Engelhardtioidites minutus Newman 1965

Plate 9, Figure 7

1965 University Colorado Studies, Earth Science Series, no. 2, p. 13, pl. 1, fig. 8.

Code. P_3sm-1.

Occurrence. 32 samples; 0.3 to 1.3%.

Comments. This grain is characterized by its exaggerated convex sides, psilate exine, and the notched pore.

Affinity. *Engelhardtia*.

Genus *Momipites* Wodehouse 1933

Type species *Momipites coryloides* Wodehouse 1933

Momipites circularis Norton *in* Norton & Hall 1969

Plate 9, Figures 9, 10

1969 Paleontographica, v. 125, Abt. B, p. 37, pl. 5, fig. 8.

Code. P_3sm-2.

Occurrence. 19 samples; 0.3 to 2.0%.

Comments. Norton & Hall (1969) described this species from the Maestrichtian and Paleocene of Montana. Stanley (1965) reassigned this genus (in part) to the genus *Engelhardtia*, including the type species *M. coryloides*.

Affinity. *Engelhardtia*.

Genus *Myrtaceoipollenites* Potonie 1951

Type species *Myrtaceoipollenites megagranifer* (Potonie 1931)

Myrtaceoipollenites peritus Newman 1965

Plate 9, Figure 6

1965 University Colorado Studies, Earth Science Series, no. 2, p. 14, pl. 1, fig. 11.

Code. P_3sm-3.

Occurrence. 34 samples; 0.3 to 1.0%.

Comments. The distinguishing characteristics of this grain are the shape and the pore structure. Newman (1965) reports this specimen from the middle Mese Verde Formation but did not find it in his Buck tongue samples.

Affinity. Angiospermous pollen.

Genus *Proteacidites* Cookson 1950

Type species *Proteacidites adenanthcoides* Cookson 1950

Proteacidites cf. *P. mollis* Samoilovitch 1961

Plate 9, Figure 8

1961 Trudy vscs. neft. nauchno-issled. geol.-razv. Inst. 177, p. 185, 186, pl. 59, figs. 1, 2.

Code. P_3r-5.

Occurrence. 48 samples; 0.3 to 1.0%.

Comments. The diameter of this triporate pollen grain rarely exceeds 25 microns which is slightly smaller than those reported by Drugg (1967) as well as those reported from western Siberia by Samoilovitch (1961). This small grain is characterized by the small generally round muri and reticulation which frequently becomes slightly smaller towards the pole, and by its small pores.

Affinity. Proteaceae (?).

Proteacidites retusus Anderson 1960

Plate 9, Figure 2

1960 New Mexico Bureau Mines & Mineral Res., Memoir 6, p. 21, pl. 2, figs. 5-7.

Code. P_3r-3.

Occurrence. 63 samples; 0.3 to 2.3%.

Comments. This species is characterized by its reticulate pattern and relatively large pores.

Affinity. Proteaceae.

Proteacidites symphonenoides Cookson 1950

Plate 9, Figure 3

1950 Australian Jour. Sci. Res., v. 3, p. 172, pl. 2, fig. 17.

Code. P_3r-2.

Occurrence. 65 samples; 0.3 to 1.7%.

Comments. The average size of this species found in the Buck tongue is the minimum of the range as found by Cookson (1950) in the Tertiary of Australia. This species is characterized by the uniform size of the reticulum.

Affinity. Proteaceae.

Proteacidites thalmannii Anderson 1960

Plate 9, Figure 1

1960 New Mexico Bureau Mines & Mineral Res., Mem. 6, p. 21, pl. 2, figs. 1-4; pl. 10, figs. 9-13.

Code. P_3r-4.

Occurrence. 43 samples; 0.3 to 1.7%.

Comments. This species has been described from Upper Cretaceous of California, western Canada and New Mexico. Because the original description was rather loose regarding dimensions of ornamentation and pore structure, this species has been reported with a great range of variation; its most diagnostic character is the coarse reticulum that is reduced toward the pole and its large pore size.

Affinity. Proteaceae.

Proteacidites sp.

Plate 9, Figure 13

Code. P_3r-1.

Description. Triporate reticulate grains; reticulum uniform over the surface; pore structure, simple, *ca*. 2 microns in diameter. Maximum diameter generally less than 15 microns.

Occurrence. 42 samples; 0.3 to 2%.

Comments. This grain is characterized by its very small size and even reticulate surface ornamentation.

Reference specimen. Pb4751a-1 D11.7xR10.5.

Affinity. Proteaceae.

Genus *Sporopollis* Pflug 1953

Type species *Sporopollis documentum* Pflug 1953

Sporopollis laqueaeformis Weyland & Greifeld 1953

Plate 9, Figure 11

1953 Palaeontographica, v. 95, Abt. B, p. 45, pl. 13, figs. 111, 112.

Code. P_3sm-7.

Occurrence. 46 samples; 0.3 to 2.0%.

Comments. The "Y-doppelmarke" is the most diagnostic character of this species, as seen in the figures of Pl. 10, this feature tends to vary somewhat. Newman (1965) described this species from the Buck tongue of northwestern Colorado.

Affinity. Angiospermous grain.

Genus _Triporopollenites_ (Pflug) Thomson & Pflug 1953

Type species _Triporopollenites coryloides_ Pflug _in_ Thomson & Pflug 1953

Triporopollenites rugatus Newman 1965

Plate 9, Figure 12

1965 University Colorado Studies, Earth Science Series, no. 2, p. 12, pl. 1, fig. 7.

Code. P_3f-1.

Occurrence. 59 samples; 0.3 to 3.0%.

Comments. This species agrees very well with the description of Newman (1965), the average dimension being similar to the smallest maximum dimension of the type material. Newman records this species from the Paleocene.

Affinity. Juglandaceae (?).

Triporopollenites cf. _T. tectus_ Newman 1965

Plate 9, Figure 5

1965 University Colorado Studies, Earth Science Series, no. 2, p. 12, pl. 1, fig. 6.

Code. P_3f-2.

Occurrence. 25 samples; 0.3 to 2.0%.

Comments. The small size, shape and the surface texture are the distinguishing features of this species, the pore structure is also diagnostic.

Affinity. Angiospermous pollen.

Genus _Trudapollis_ (Pflug) Potonie 1960

Type species _Trudapollis pertrudens_ (Pflug) Potonie 1960

Trudopollis meekeri Newman 1965

Plate 9, Figure 4

1965 University Colorado Studies, Earth Science Series, no. 2, p. 14, pl. 1, fig. 12.

Code. P_3sm-4.

Occurrence. 17 samples; 20 times.

Comments. The shape and pore structure are diagnostic on this species. Newman (1965) describes this species from the Buck tongue of northwestern Colorado.

Affinity. Angiospermous grain.

ANGIOSPERM POLLEN

(Polyporate)

Genus Liquidambarpollenites Raatz 1937

Type species Liquidambarpollenites stigmosus (Potonie) Raatz 1937

Liquidambarpollenites cf. L. stigmosus (Potonie) Raatz 1937

Plate 9, Figure 14

1937 Preussischen Geologischen Landesanstalt, Abhandlungen, Neue Folge, v. 183, p. 17, pl. 1, fig. 26.

Code. P^{oo}-1.

Occurrence. 10 samples; 12 times.

Comments. These grains are not thought to be modern contaminates although the possibility exists. They are very small, and some specimens are remarkably well preserved.

Affinity. These grains are similar to the pollen of Liquidambar.

Liquidambarpollenites sp.

Plate 9, Figure 15

Code. P^{oo}-2.

Description. Pollen grains polyporate; outline circular; exine granular; pores round, 2.0 microns in diameter, heavy granular annulus; grains about 20 microns.

Occurrence. 15 samples; 0.3 to 1.3%.

Comments. This grain could well be a modern contaminant. It was often found in an expanded condition, and sometimes appeared to stain slightly darker than other pollen in the same sample. This entity strongly resembles species of the modern family Chenopodiaceae.

Reference specimen. Pb4751a-1 D11.2xR12.6.

Affinity. Liquidambar?

Group ACRITARCHA Evitt 1963

Subgroup ACANTHOMORPHITAE Downie, Evitt & Sarjeant 1963

Genus Baltisphaeridium Eisenack emend. Downie & Sarjeant 1963

Type species Baltisphaeridium longispinosum (Eisenack) Eisenack 1958

Baltisphaeridium cf. B. delicatum Wall 1965

Plate 9, Figure 29

1965 Micropaleontology, v. 11, p. 156, pl. 1, figs. 11-13; pl. 7, fig. 6.

Code. Baltisphaeridium-1.

Occurrence. 6 samples; 6 times.

Comments. This species differs from that described by Wall (1965) by being thicker walled but is also similar to the Devonian species B. brevispinosum Eisenack (1931).

Baltisphaeridium hirsutum (Ehrenberg) Downie & Sarjeant 1963

Plate 9, Figure 23

1963 Geol. Soc. Amer., Mem. , p. 91.

Code. Baltisphaeridium-3.

Occurrence. 17 samples; 21 times.

Comments. This species is characterized by its folded and irregular surface pattern on its central body. B. hirsutum has been reported from the Cretaceous of Germany (Ehrenberg, 1838) and Upper Cretaceous of Britain (Cookson & Hughes, 1964).

Baltisphaeridium infulatum Wall 1965

Plate 9, Figure 30

1965 Micropaleontology, v. 11, p. 155, pl. 1, figs. 5-7; pl. 7, fig. 3.

Code. Baltisphaeridium-2.

Occurrence. 3 samples; 3 times.

Comments. This species is characterized by its long slender processes; Wall (1965) described this species with two varieties based on the length of their processes. The species found in this study are most similar to Wall's Baltisphaeridium infulatum var. infulatum, Wall (1965) described from the Jurassic of England.

Baltisphaeridium sp.

Plate 9, Figure 27

Code. Baltisphaeridium-4.

Description. Small acritarch; central body spherical; wall thickness about 1 micron; processes short cones, about 2 microns long (over 30). Diameter, about 25 microns.

Occurrence. 4 samples; 4 times.

Comments. This species is characterized by its short conical processes and is apparently a new species.

Reference specimen. Pb4828-1 D8.4xR10.5.

Genus *Micrhystridium* Deflandre 1937 emend. Downie & Sarjeant 1963

Type species *Micrhystridium inconspicuum* Deflandre 1935

Micrhystridium cf. *M. biornatum* Deflandre 1937

Plate 9, Figure 16

1937 Ann. Paleont. v. 26, p. 34, pl. 13, fig. 9.

Code. *Micrhystridium*-2.

Occurrence. 81 samples; 0.3 to 5%.

Comments. This distinctive species rarely occurs more than 4 times in a sample. Deflandre (1937) described this species from the Senonian of France and it has subsequently been reported from the Jurassic of Europe.

Micrhystridium fragile Deflandre 1947

Plate 9, Figure 28

1947 Bull. Inst. Oceanogr. Monaco no. 921, p. 8, figs. 13-18.

Code. *Micrhystridium*-9.

Occurrence. 13 samples; 14 times.

Comments. This species is characterized by its long sinuous processes (few in number). This entity is well known from Jurassic of France and Great Britain and has been reported from Upper Cretaceous of Texas (Zaitzeff, 1967) and Eocene of England (Williams, 1963). This species has been reported in more than 15 publications with a total range from Devonian through Eocene.

Micrhystridium inconspicum Deflandre emend. Deflandre 1937

Plate 9, Figure 19

1937 Ann. Paleont. v. 26, p. 80.

Code. *Micrhystridium*-4.

Occurrence. 68 samples; 0.3 to 5.3%.

Comments. This species as identified in this study probably contains more than one species and was generally characterized by those specimens having a small central body with numerous processes (more than 20), but in general the entity identified as *Micrhystridium*-4 in this study conforms to the description of the species *M. inconspicum* Deflandre (1937).

Micrhystridium minutispinum Wall 1965

Plate 9, Figure 18

1965 Micropaleontology, v. 11, p. 158, pl. 3, figs. 8-10; pl. 7, fig. 12.

Code. *Micrhystridium*-1.

Occurrence. 97 samples; 0.3 to 7.3%.

Comments. This very small entity is characterized by small conical to slightly rounded spines that are less than 1 micron long. Wall (1965) reported this species from the Jurassic of England.

Micrhystridium cf. *M. roquesi* Valensi 1948

Plate 9, Figure 17

1948 Bull. Society Geology France, v. 18, p. 545, fig. 5.

Code. *Micrhystridium*-5.

Occurrence. 31 samples; 0.3 to 5.0%.

Comments. This distinctive grain is characterized by its many blunt spines and is most similar to the species *M. roquesi* described by Valensi (1948) from Jurassic of France. This species rarely occurs more than 2 times in a sample.

Micrhystridium sp.

Plate 9, Figure 24

Code. *Micrhystridium*-3.

Description. Small acritarch; central body spherical to subspherical; processes slender, sinuous with a bifurcate or otherwise complex tip, about 15 in number. Central body is frequently split. Dimension, central body, about 12 microns maximum diameter; processes 3-7 microns long.

Occurrence. 46 samples; 0.3 to 5%.

Comments. This small acritarch is common in the samples of the Buck tongue and is characterized by its processes and small size. This species is distinct from any other species of *Micrhystridium* thus far described.

Reference specimen. 4713-1 D7.4xR14.5.

Subgroup POLYGONOMORPHITAE Downie, Evitt & Sarjeant 1963

Genus *Veryhachium* Deunff emend. Downie & Sarjeant 1963

Type species *Veryhachium trisulcum* (Deunff)

Veryhachium reductum (Deunff) de Jekhowsky fa. *breve* de Jekhowsky 1961

Plate 9, Figure 26

1961 Review Micropaleont., v. 3, p. 212, pl. 2, figs. 41-44.

Code. *Veryhachium*-6.

Occurrence. 4 samples; 4 times.

Comments. This species is characterized by its very short processes or apical spines and has a long range. This forma was described from the Permo-Triassic by de Jekhowsky (1961).

Veryhachium reductum (Deunff) de Jekhowsky fa. *reductum* de Jekhowsky 1961

Plate 9, Figure 22

1961 Review Micropaleont., v. 3, p. , pl. 2, figs. 33-37.

Code. *Veryhachium*-6a.

Occurrence. 2 samples, 2 times.

Comments. This forma is characterized by its shape and its processes and was initially differentiated by de Jekhowsky (1961) from the Permo-Triassic of Africa and Yugoslavia.

Subgroup SPHAEROMORPHITAE Downie, Evitt & Sarjeant 1963

Genus *Leiosphaeridia* Eisenack 1958

Type species *Leiosphaeridia baltica* Eisenack 1958

Leiosphaeridia sp. A

Plate 9, Figure 21

Code. *Leiosphaeridia*-1.

Description. Small acritarch; thick walled; less than 10 microns in diameter.

Occurrence. 139 samples; 0.3 to 15.7%.

Comments. This category was used as a "catch-all" group for very small inaperturate non-fungal palynomorphs with smooth walls. Generally this entity occurs as less than 3% of the total palynomorphs.

Leiosphaeridia sp. B

Plate 9, Figure 20

Code. *Leiosphaeridia*-2.

Description. Medium sized acritarch; from 10 to 20 microns in diameter; psilate wall texture; inaperturate.

Occurrence. 75 samples; 0.3 to 3.0%.

Comments. This smooth-walled acritarch category was used for all smooth-walled, medium sized, inaperturate palynomorphs, excluding fungal spores.

Leiosphaeridia sp. C

Plate 9, Figure 25

Code. *Leiosphaeridia*-3.

Description. Large acritarch; smooth-walled; inaperturate; generally spherical to subspherical in shape. Diameter, greater than 20 microns, average 25 microns.

Occurrence. 77 samples; 0.3 to 6.7%.

Comments. This category of large acritarchs was set up to accommodate all non-fungal inaperturate entities, with a diameter greater than 20 microns. This category rarely occurred more than 1% of the total count in any sample.

Subgroup NETROMORPHITAE Downie, Evitt & Sarjeant 1963

Genus *Leiofusa* Eisenack 1938

Type species *Leiofusa fusiformis* (Eisenack) Eisenack 1938

Leiofusa jurassica Cookson & Eisenack 1958

Plate 10, Figure 17

Code. Leiofusa-1.

Occurrence. 3 samples; 3 times.

Comments. This species is similar to some Lower Paleozoic species described by Cramer (1964) and Downie (1959), but is most like *L. jurassica* Cookson & Eisenack (1958) except it is slightly smaller in size.

Leiofusa sp. A

Plate 10, Figure 11

Code. Leiofusa-2.

Description. Small acritarch; central body fusiform, small, unornamented; with short spines at each end; no opening observed. Maximum diameter of the central body less than 15 microns; spines 1/3 to 1/2 maximum diameter of the central body.

Occurrence. 1 sample; 1 time.

Comments. One specimen of this species was encountered in the samples of the Buck tongue; to the writer's knowledge no similar species of comparable age has been reported.

Reference specimen. Pb4713-1 D14.4xR17.5.

Subgroup HERKOMORPHITAE Downie, Evitt & Sarjeant 1963

Genus *Cymatiosphaera* O. Wetzel emend. Deflandre 1954

Type species *Cymatiosphaera radiata* O. Wetzel 1933

Cymatiosphaera eupeplos (Valensi) Deflandre 1954

Plate 10, Figure 3

1954 Compte Rende Soc. Geol. France, v. 12, p. 258.

Code. Cymatiosphaera-1.

Occurrence. 24 samples; 0.3 to 1.7%.

Comments. This very small but distinctive acritarch is most common in the Crescent Butte section occurring only eight times in all other Buck tongue samples. This species was originally described as a Micrhystridium and does greatly resemble that genus.

Cymatiosphaera cf. C. exilissima (Deflandre) Deflandre 1954

Plate 10, Figure 2

1954 Compte Rende Soc. Geol. France, v. 12, p. 258.

Code. Cymatiosphaera-3.

Occurrence. 16 samples; 20 times.

Comments. This very small species has been described from the Jurassic by Deflandre (1947) and is therefore only compared to the samples of the Buck tongue.

Cymatiosphaera cf. C. pachytheca Eisenack 1957

Plate 10, Figure 4

1957 Neues Jahrb. Geol. Pal., v. 15, p. 245, pl. 19, figs. 4-5; pl. 20, fig. 11.

Code. Cymatiosphaera-2.

Occurrence. 29 samples; 0.3 to 1.3%.

Comments. This species is found most commonly in the bottom portion of the West Salt Creek section and is only scattered throughout the rest of sections sampled.

Cymatiosphaera cf. C. stigmata Cookson & Eisenack 1958

Plate 10, Figure 9

1958 Roy. Soc. Victoria, Proc., v. 70, p. 50, pl. 9, fig. 14.

Code. Cymatiosphaera-4.

Occurrence. 6 samples; 6 times.

Comments. This large acritarch with small polygonal fields is similar to the C. stigmata described by Cookson & Eisenack (1958) but is considerably smaller and differs slightly in other details also. This species has only one occurrence other than the Tuscher Wash Section, which is the most shoreward section of this study.

Subgroup PTEROMORPHITAE Downie, Evitt & Sarjeant 1963

Genus Pterospermopsis W. Wetzel 1952

Type species Pterospermopsis danica W. Wetzel 1952

Pterospermopsis australiensis Deflandre & Cookson 1955

Plate 10, Figures 7, 8

1955 Australian Jour. Marine & Freshw. Res., v. 6, p. 286, pl. 3, fig. 4.

Code. Pterospermopsis-2.

Occurrence. 14 samples; 0.3 to 3.0%.

Comments. This species is characterized by its size and the nature of the wing. This species was described from the Lower Cretaceous of Australia.

Pterospermopsis ginginensis Deflandre & Cookson 1955

Plate 10, Figure 6

1955 Australian Jour. Marine & Freshw. Res., v. 6, p. 287-8, fig. 49.

Code. Pterospermopsis-1.

Occurrence. 12 samples; 0.3 to 1.0%.

Comments. This species is characterized by its very small size. It has an Upper Cretaceous range.

Subgroup DINETROMORPHITAE Downie, Evitt & Sarjeant 1963

Genus *Diplotesta* Cookson & Eisenack 1959

Type species *Diplotesta glaessneri* Cookson & Eisenack 1960

Diplotesta luna Cookson & Eisenack 1960

Plate 10, Figure 1

1960 Micropaleontology, v. 6, p. 10, pl. 3, fig. 21.

Code. *Diplotesta*-1.

Occurrence. 2 samples; 2 times.

Comments. The Australian specimens of this species have an upper Albian to Cenomanian range. The species of this study are middle Campanian.

Subgroup UNCERTAIN

Genus *Palaeostomocystis* Deflandre 1935

Type species *Palaeostomocystis reticulata* Deflandre 1935

Palaeostomocystis laevigata Drugg 1967

Plate 10, Figure 16

1967 Palaeontographica, v. 120, Abt. B, p. 35, pl. 6, figs. 14, 15.

Code. *Palaeostomocystis*-1.

Occurrence. 4 samples; 4 times.

Comments. This species is characterized by the rim around its pylome and was described by Drugg (1967) from the Maestrichtian of California.

Class CHLOROPHYCEAE

Order CHLOROCOCCALES

Family UNCERTAIN

Genus Palambages O. Wetzel 1961

Type species Palambages morulosa O. Wetzel 1961

Palambages deflandrei Gorka 1963

Plate 10, Figure 19

1963 Acta. Paleont. Polonica, p. 76, pl. 11, fig. 2.

Code. Palambages-1.

Occurrence. 4 samples; 4 times.

Comments. This species resembles Palambages sp. A (in part) Manum & Cookson (1964) (pl. 7, fig. 6)

Palambages morulosa O. Wetzel 1961

Plate 10, Figure 18

1961 Micropaleontology, v. 7, p. 338, pl. 1, fig. 11.

Code. Palambages-2.

Occurrence. 4 samples; 4 times.

Comments. This species can be differentiated from P. deflandrei by its larger size and thinner wall structure. This species is similar to forms described by Manum & Cookson (1964), Cookson (1965), and Zeitzeff (1967).

Palambages forma "C" Manum & Cookson 1964

Plate 10, Figure 20

1964 Norske Vid-Aked. Skrifter I Mat-Naturv. Klasse no. 17, p. 24, pl. 7, fig. 7.

Code. Palambages-3.

Occurrence. 7 samples; 7 times.

Comments. This characteristic species can be differentiated by the

the large size of the cells, the thin wall structure and by normally present pylome.

Genus Quisquilites Wilson & Urban 1963

Type species Quisquilites buckhornensis Wilson & Urban 1963

Quisquilites(?) pluralis Hemer & Nygreen 1967

Plate 10, Figure 14

1967 Micropaleontology, v. 13, p. 192, pl. 3, figs. 14, 17, 18.

Code. Quisquilites-1.

Occurrence. 10 samples; 0.3 to 0.7%.

Comments. This species as described by Hemer & Nygreen (1967) is probably an invalid species in as much it was questionably assigned to the genus Quisquilites; however, the species as described by Hemer & Nygreen most closely agrees with the species found in the samples of this study. Other closely related taxa are some species of Schizosporis Cookson & Dettmann (1959), species of the genus Leioaletes Staplin (1960), or members of the Devonian genus Ellipsaletes Cramer (1966).

Quisquilites(?) ornatus Hemer & Nygreen 1967

Plate 10, Figure 12

1967 Micropaleontology, v. 13, p. 192, pl. 3, figs. 15, 16.

Code. Quisquilites-2.

Occurrence. Not found in count of 300 entities.

Comments. Although this species was not found in the fixed sum counts of the samples of this study, it was noted on several occasions as being present. The comments under the species Q. pluralis are also valid for this species.

Genus *Tetraporina* Naumova 1950

Type species *Tetraporina antiqua* Naumova 1950

Tetraporina glabra Naumova 1950

Plate 10, Figure 10

1950 Akad. Nauk. SSR, Izv., Geol. Ser., v. 3, p. 103-113.

Code. *Tetraporina*-2.

Occurrence. 4 samples; 4 times.

Comments. This species differs from *T. horologia* by having thicker walls and being slightly larger.

Tetraporina horologia (Staplin) Playford 1963

Plate 10, Figure 5

1963 Palaeontology, v. 5, p. 659, pl. 95, figs. 14, 15.

Code. *Tetraporina*-1.

Occurrence. 16 samples; 0.3 to 2.7%.

Comments. This is one of the few entities found in this study that appeared to be restricted to the lower parts of the sections from which it was recovered. This entity somewhat resembles the genera *Horologinella* of Cookson & Eisenack (1962) and *Schizocystia* Cookson & Eisenack (1962) but differs in the pore structure.

Class DINOPHYCEAE

Discussion. The Class DINOPHYCEAE embraces all fossil dinoflagellates and the typical hystrichospheres. Evitt (1961), Downie, Evitt & Sarjeant (1963), Evitt & Davidson (1964), and others have demonstrated that almost all, if not all, fossil dinoflagellates are representatives of the encysted state rather than the motile state of the living forms.

For this reason, the following cyst family classification of Sarjeant & Downie (1966) modified by Sarjeant (1967) is utilized in the taxonomic structure of this study.

Cyst-Family GONYAULACYSTACEAE Sarjeant & Downie 1966

Genus _Leptodinium_ Klement 1960

Type species _Leptodinium_ _subtile_ Klement 1960

Leptodinium cf. _L_. _dispertitum_ Cookson & Eisenack 1965

Plate 11, Figure 1

1965 Proc. Roy. Soc. Victoria, v. 79, p. 122, pl. 12, figs. 5, 6.

Code. _Gonyaulax_-1.

Occurrence. 3 samples; 4 times.

Comments. This species was described from the Upper Eocene of Australia and the four specimens recovered from the Buck tongue sediments are tentatively assigned to it.

Cyst-Family PERIDINIACEAE Sarjeant & Downie 1966

Genus _Apteodinium_ Eisenack 1958

Type species _Apteodinium_ _granulatum_ Eisenack 1958

Apteodinium _grande_ Cookson & Hughes 1964

Plate 11, Figure 5

1964 Palaeontology, v. 7, p. 52, pl. 6, figs. 8, 9.

Code. _Apteodinium_-1.

Occurrence. 9 samples; 9 times.

Comments. This species is characterized by its large size and pre-cingular archeopyle. The occurrence of this species tends to be greatest in the middle of the stratigraphic sections from which it is recovered; however, the number of occurrences is not sufficient to draw accurate conclusions.

Genus Spinidinium Cookson & Eisenack 1962

Type species Spinidinium styloniferum Cookson & Eisenack 1962

Spinidinium densispinatum Stanley 1965

Plate 11, Figure 2

1965 Bull. Amer. Paleont., v. 49, no. 222, p. 226, pl. 21, figs. 1-3.

Code. Spinidinium-2.

Occurrence. 15 samples; 0.3 to 1.7%.

Comments. This species is restricted to those samples collected from the lower portion of the sections of the Buck tongue.

Spinidinium styloniferum Cookson & Eisenack 1962

Plate 11, Figure 6

1962 Micropaleontology, v. 8, p. 489, pl. 1, figs. 1, 2.

Code. Spinidinium-1.

Occurrence. 12 samples; 0.3 to 1.3%.

Comments. This species is differentiated from S. densispinatum Stanley (1965) by its less rounded shape and stronger sculptural elements.

Cyst-Family PYXIDIELIACEAE Sarjeant & Downie 1966

Genus Komewuia Cookson & Eisenack 1960

Type species Komewuia glabra Cookson & Eisenack 1960

Komewuia glabra Cookson & Eisenack 1960

Plate 10, Figure 13

1960 Palaeontology, v. 2, p. 257, pl. 39, fig. 8.

Code. _Komewuia_-2.

Occurrence. 1 sample; 1 time.

Comment. A single specimen of this species was found within the fixed sum counts. This species has been reported from the Upper Jurassic of Australia.

Cyst-Family BROOMEACEAE Sarjeant & Downie 1966

Genus _Canningia_ Cookson & Eisenack 1960

Type species _Canningia_ _reticulata_ Cookson & Eisenack 1960

Canningia cf. _C_. _colliveri_ Cookson & Eisenack 1960

Plate 11, Figure 3

1960 Palaeontology, v. 2, p. 38, fig. 4.

Code. _Canningia_.

Occurrence. 9 samples; 13 times.

Comments. This species is only tentatively assigned to this genus. The location of the archeopyle is not known with certainty; morphologically it resembles _C_. _colliveri_.

Cyst-Family HYSTRICHOSPHAERIDACEAE Sarjeant & Downie 1966

Genus _Cleistosphaeridium_ Davey, _et_ _al_. 1966

Type species _Cleistosphaeridium_ _diversispinosum_ Davey _et_ _al_. 1966

Cleistosphaeridium _heteracanthum_ (Deflandre & Cookson) Davey & Williams 1966

Plate 11, Figure 7

1966 Bull. British Museum (Nat. History) Geol. Supplement 3, p. 168, pl. 2, figs. 6, 7.

Code. Cleistosphaeridium-1.

Occurrence. 8 samples; 0.3 to 2.0%.

Comments. This species is characterized by its apical archeopyle and its processes, and is not readily differentiated from the genus *Exochosphaeridium*.

Genus *Cordosphaeridium* Eisenack 1963

Type species *Cordosphaeridium inodes* (Klumpp) Eisenack 1963

Cordosphaeridium fasciatum Davey & Williams 1966b

Plate 11, Figure 8

1966 Bull. British Museum (Nat. History) Geol. Supplement 3, p. 90, pl. 7, figs. 5, 6.

Code. Cordosphaeridium-1.

Occurrence. 4 samples; 4 times.

Comments. This species most resembles *C. fasciatum* and is assigned to this genus even though the original designation by Davey & Williams (1966) is doubtfully validated in as much as they questioned the genus to which they assigned the species.

Cordosphaeridium cf. *C. fibrospinosum* Davey & Williams 1966b

Plate 12, Figure 6

1966 Bull. British Museum (Nat. History) Geol. Supplement 3, p. 86, pl. 5, fig. 5.

Code. Cordosphaeridium-3.

Occurrence. 4 samples; 5 times.

Comments. This Tertiary species was recorded from the Maestrichtian of Texas by Zaitzeff (1967) and is found in the Campanian Buck tongue samples of this study.

Genus Hystrichokolpoma Klumpp 1953

Type species Hystrichokolpoma cinctum Klumpp 1953

Hystrichokolpoma ferox (Deflandre) Williams & Downie 1966

Plate 11, Figure 4

1966 Bull. British Museum (Nat. History) Geol. Supplement 3, p. 181.

Code. Hystrichokolpoma ferox.

Occurrence. 1 sample; 1 specimen.

Comments. The documentation of this species is well substantiated from middle Neocomian to the Cretaceous Tertiary boundary.

Genus Hystrichosphaeridium Deflandre 1937

Type species Hystrichosphaeridium tubiferum (Ehrenberg) Davey & Williams 1966b

Hystrichosphaeridium cf. H. bowerbanki Davey & Williams 1966b

Plate 12, Figure 3

1966 Bull. British Museum (Nat. History) Geol. Supplement 3, p. 69, pl. 8, figs. 1, 4.

Code. Hystrichosphaeridium-2.

Occurrence. 2 samples; 3 times.

Comments. The previously recorded range of this species is Albian to Cenomanian.

Hystrichosphaeridium readei Davey & Williams 1966a

Plate 12, Figure 2

1966 Bull. British Museum (Nat. History) Geol. Supplement 3, p. 64, pl. 6, fig. 3.

Code. Hystrichosphaeridium-4.

Occurrence. 2 samples; 2 times.

Comments. This species was described from Cenomanian of England and is reported by its authors as being undoubtedly related to the Upper Jurassic species H. costatum Davey & Williams (1966).

Hystrichosphaeridium tubiferum (Ehrenberg) Davey & Williams 1966

Plate 12, Figure 7

1966 Bull. British Museum (Nat. History) Geol. Supplement 3, p. 56, pl. 6, figs. 1; pl. 8, fig. 5; pl. 10, fig. 2, text-fig. 13.

Code. Hystrichosphaeridium-1.

Occurrence. 2 samples; 2 times.

Comments. This species has a known range of Albian to Eocene.

Genus Oligosphaeridium Davey & Williams 1966a

Type species Oligosphaeridium complex (White) Davey & Williams 1966a

Oligosphaeridium prolixispinosum Davey & Williams 1966a

Plate 12, Figure 5

1966 Bull. British Museum (Nat. History) Geol. Supplement 3, p. 76, pl. 8, figs. 2, 3.

Code. Oligosphaeridium-3.

Occurrence. 1 sample; 1 time.

Comments. This species has a recorded range from the Middle Neocomian to Lower Eocene.

Oligosphaeridium complex (White) Davey & Williams 1966a

Plate 12, Figure 4

1966 Bull. British Museum (Nat. History) Geol. Supplement 3, p. 71, pl. 7, figs. 1, 2; pl. 10, fig. 10.

Code. Hystrichosphaeridium sp.

Occurrence. 4 samples; 4 times.

Comments. This long-ranging species is found in sediments from Valanginian (middle Neocomian) to Lower Eocene.

Genus Polysphaeridium Davey & Williams 1966b

Type species Polysphaeridium subtile Davey & Williams 1966b

Polysphaeridium subtile Davey & Williams 1966b

Plate 12, Figure 1

1966 Bull. British Museum (Nat. History) Geol. Supplement 3, p. 92, pl. 11, fig. 1.

Code. Polysphaeridium-1.

Occurrence. 6 samples; 6 times.

Comments. This species is characterized by its short slender processes with expanded distal ends.

Genus Prolixosphaeridium Davey et al. 1966

Type species Prolixosphaeridium deirense Davey et al. 1966

Prolixosphaeridium deirense Davey et al. 1966

Plate 10, Figure 15

1966 Bull. British Museum (Nat. History) Geol. Supplement 3, p. 171, pl. 3, fig. 2, text-fig. 45.

Code. Prolixosphaeridium-1.

Occurrence. 1 sample; 1 time.

Comments. This species is characterized by its elongated central body, apical archeopyle, and two antapical processes.

Cyst-Family EXOCHOSPHAERIDIACEAE Davey *et al*. 1966

Genus *Exochosphaeridium* Davey *et al*. 1966

Type species *Exochosphaeridium phragmites* Davey *et al*. 1966

Exochosphaeridium cf. *E*. *phragmites* Davey *et al*. 1966

Plate 13, Figure 5

1966 Bull. British Museum (Nat. History) Geol. Supplement 3, p. 165, pl. 2, figs. 8-10.

Code. *Exochosphaeridium*-1.

Occurrence. 1 sample; 1 time.

Comments. This species differs from *Cleistosphaeridium* in having a precingular archeopyle whereas *Exochosphaeridium* has an apical archeopyle, orientation is a critical factor in the proper identification of these genera and it could easily be misidentified.

Cyst-Family AREOLIGERACEAE Sarjeant & Downie 1966

Genus *Circulodinium* Alberti 1961

Type species *Circulodinium hirtellum* Alberti 1961

Circulodinium deflandrei Alberti 1961

Plate 13, Figure 3

1961 Palaeontographica, v. 116, Abt. B, p. 29, pl. 4, figs. 7-13.

Code. *Circulodinium deflandrei*.

Occurrence. 3 samples; 5 times.

Comments. This species is characterized by its general form and the nature of its processes.

Cyst-Family HYSTRICHOSPHAERACEAE Sarjeant & Downie 1966

Genus Hystrichodinium Deflandre ex. Deflandre 1936

Type species Hystrichodinium pulchrum Deflandre 1936

Hystrichodinium cf. H. pulchrum Deflandre ex. Deflandre 1936

Plate 13, Figure 4

1936 Ann. Paleont., v. 25, p. 182, pl. 8, figs. 3, 4.

Code. Hystrichodinium-1.

Occurrence. 1 sample; 5 times.

Comments. This species resembles H. pulchrum as defined by Deflandre (1936) except the dimensions are much smaller; the Buck tongue species are 60-70 microns long whereas the type material is 110-125 microns long.

Genus Hystrichosphaera O. Wetzel 1933

Type species Hystrichosphaera ramosa (Ehrenberg) O. Wetzel 1933

Hystrichosphaera cingulata (O. Wetzel) Deflandre 1958

Plate 13, Figure 2

1954 Compte Rende Soc. Geol. France, v. 12, p. 258.

Code. Hystrichosphaera-3.

Occurrence. 4 samples; 6 times.

Comments. This species is characterized by its high sutural crests and its short gonal processes.

Hystrichosphaera ramosa (Ehrenberg) var. gracilis Davey & Williams 1966a

Plate 13, Figure 1

1966 Bull. British Museum (Nat. History) Geol. Supplement 3, p. 34, pl. 1, fig. 5; pl. 5, fig. 6.

Code. Hystrichosphaera-6a.

Occurrence. 13 samples; 13 times.

Comments. This, the most common of the Hystrichosphaera species is characterized by its relatively small central body. This species has been reported from the Cenomanian of England and the Miocene of Australia.

Hystrichosphaera cf. ramosa var. multibrevis Davey & Williams in Davey et al. 1966

Plate 14, Figure 4

1966 Bull. British Museum (Nat. History) Geol. Supplement 3, p. 35, pl. 1, fig. 4; pl. 4, fig. 6; text-fig. 9.

Code. Hystrichosphaera-8.

Occurrence. 2 samples; 2 times.

Comments. This species is characterized by its numerous processes.

Hystrichosphaera ramosa (Ehrenberg) var. ramosa Davey & Williams 1966a

Plate 14, Figure 7

1966 Bull. British Museum (Nat. History) Geol. Supplement 3, p. 33, pl. 1, figs. 1-6; pl. 3, fig. 1; text-fig. 8.

Code. Hystrichosphaera-1.

Occurrence. 19 samples; 0.3 to 1.0%.

Comments. This species is characterized by its thin-walled large central body which is relatively unornamented.

Hystrichosphaera ramosa (Ehrenberg) var. reticulata Davey & Williams 1966a

Plate 13, Figure 6

1966 Bull. British Museum (Nat. History) Geol. Supplement 3, p. 38, pl. 1, figs. 2, 3.

Code. Hystrichosphaera-2.

Occurrence. 8 samples; 8 times.

Comments. This species can be distinguished from *H. ramosa* var. *ramosa* by its thicker, ornamented central body wall. This species is reported from the Cenomanian of England.

Genus *Pterodinium* Eisenack 1958

Type species *Pterodinium aliferum* Eisenack 1958

Pterodinium aliferum Eisenack 1958

Plate 14, Figure 6

1958 Neues Jb. Geol. Palaeont., v. 106, p. 395.

Code. *Pterodinium*-1.

Occurrence. 3 samples; 3 times.

Comments. This readily recognizable species has a previously reported range of Albian.

Cyst-Family DEFLANDRACEAE Sarjeant & Downie 1966

Genus *Deflandrea* Eisenack 1938

Type species *Deflandrea phosphoritica* Eisenack 1938

Deflandrea cincta Cookson & Eisenack 1958

Plate 14, Figure 3

1958 Proc. Roy. Soc. Victoria, v. 70, p. 26, pl. 4, figs. 1-3.

Code. *Deflandrea*-5.

Occurrence. 13 samples; 16 times.

Comments. This species is characterized by its general shape, antapical horns and shape and position of its archeopyle and the nature of its girdle.

Deflandrea diebeli Alberti 1959

Plate 14, Figure 8

1959 Mitt. Geol. Staatsinst. Hamburg, v. 28, p. 99-100, pl. 9, figs. 18-21.

Code. *Deflandrea*-1.

Occurrence. 21 samples; 0.3 to 1.3%.

Comments. This species is characterized by its apical and antapical horns and by the striations of folding of the periphram.

Deflandrea oebisfeldensis Alberti 1959

Plate 14, Figure 1

1959 Mitt. Geol. Staatsinst. Hamburg, v. 28, p. 95, pl. 8, figs. 10-13.

Code. *Deflandrea*-2.

Occurrence. 6 samples; 0.3 to 1.0%.

Comments. The gross outline and nature of the apical horn agree with the species *D. oebisfeldensis*; however, there are a number of characters that do not agree with the original diagnosis of this species which has been reported only from the Eocene.

Deflandrea pannucea Stanley 1965

Plate 14, Figure 9

1965 Bull. Amer. Paleont., v. 49, no. 222, p. 220, pl. 22, figs. 1-4, 8-10.

Code. *Deflandrea pannucea*.

Occurrence.

Comments. This species is characterized by the longitudinally folded periphram and the nature of its horns, and has been previously reported from the Paleocene of South Dakota and the Maestrichtian of Texas.

Deflandrea scheii Manum 1963

Plate 14, Figure 2

1963 Norsk Polarinstitutt-Arbok Oslo, p. 56, pl. 1, fig. 1-16.

Code. Deflandrea-12.

Occurrence. 9 samples; 0.3 to 2%.

Comments. This species is characterized by its tetragonal shape and the seven spinous areas or zones of the girdle.

Cyst-Family ENDOSCRINIACEAE Sarjeant & Downie 1966

Genus Palaeohystrichophora Deflandre 1934

Type species Palaeohystrichophora infusorioides Deflandre 1934

Palaeohystrichophora infusorioides Deflandre 1934

Plate 15, Figure 1

1934 Compte Rende Acad. Sci. France, v. 199, p. 967, pl. , fig. 8.

Code. Palaeohystrichophora-1.

Occurrence. 16 samples; 0.3 to 1.0%.

Comments. This very characteristic species is reported from the Upper Cretaceous of France, Australia and North America.

Palaeohystrichophora isodiametrica Cookson & Eisenack 1958

Plate 15, Figure 3

1958 Proc. Roy. Soc. Victoria, v. 70, p. 38, pl. 12, fig. 12.

Code. Palaeohystrichophora-2.

Occurrence. 5 samples; 5 times.

Comments. This species is characterized by its shape, nature of processes and the outline of the archeopyle. This species has only been reported from the Campanian and the lower parts of the Maestrichtian of the Upper Cretaceous.

Cyst-Family HEXAGONIFERACEAE Sarjeant & Downie 1966

Genus *Hexagonifera* Cookson & Eisenack 1961

Type species *Hexagonifera suspecta* Manum & Cookson 1964

Hexagonifera chlamydata Cookson & Eisenack 1962

Plate 15, Figure 6

1962 Palaeontology, v. 8, p. 496, pl. 7, figs. 1-3, 5-8.

Code. *Hexagonifera*-3.

Occurrence. 28 samples; 0.3 to 1.0%.

Comments. This small thick-walled specimen is characterized by its surface ornamentation and has been recorded from the Albian to the Cenomanian.

Hexagonifera cf. *H. glabra* Cookson & Eisenack 1961

Plate 15, Figure 5

1961 Proc. Roy. Soc. Victoria, v. 74, p. 73, pl. 12, figs. 9-13.

Code. *Hexagonifera*-2.

Occurrence. 114 samples; 0.3 to 4.7%.

Comments. This species differentiated from *H. suspecta* by having a thinner, smoother wall and in generally being slightly larger. This species has been reported from the Upper Cretaceous sediments ranging from the Coniacian to the top of the Campanian.

Hexagonifera suspecta Manum & Cookson 1964

Plate 15, Figures 4, 7

1964 Norske Vid-Akad. Skrifter I Mat-Haturv. Klasse no. 17, p. 9, pl. 1, figs. 9-13.

Code. Hexagonifera-1.

Occurrence. 124 samples; 0.3 to 5%.

Comments. This species is considered to be a species of Deflandrea by Sarjeant (1966) and not entirely without justification as this specimen is found in this study, on rare occasions, with a periphram similar to, if not identical with, the genus Deflandrea; however, it usually occurs with only the central body which has a three-plate (hexagonal in outline) archeopyle. This species has previously been reported from Cenomanian sediments.

Cyst-Family PSEUDOCERATIACEAE Sarjeant & Downie 1966

Genus Odontochitina Deflandre 1935

Type species Odontochitina striatoperforata Cookson & Eisenack 1962

Odontochitina striatoperforata Cookson & Eisenack 1962

Plate 16, Figure 10

1962 Micropaleontology, v. 8, p. 490, pl. 3, fig. 16.

Code. Odontochitina-1.

Occurrence. 1 sample; 1 time.

Comments. This easily recognizable microplankton species was found only one time within the constant sum count but was present in several samples outside the 300 count. This species has previously been recorded from the Albian to the Cenomanian of Australia Cookson & Eisenack (1962) and from the Maestrichtian of Texas Zaitzeff (1967).

Cyst-Family MEMBRANILARNACACEAE Sarjeant & Downie 1966

Genus Chlamydophorella Cookson & Eisenack 1958

Type species Chlamydophorella nyei Cookson & Eisenack 1958

Chlamydophorella cf. C. grossa Manum & Cookson 1964

Plate 15, Figure 2

1964 Norske Vid-Akad. Skrifter I Mat-Haturv. Klasse no. 17, p. 17, pl. 5, figs. 1, 2.

Code. Chlamydophorella-1.

Occurrence. 4 samples; 5 times.

Comments. This genus differs from the type species of Chlamydophorella in being smaller, and differs from the genus Gardodinium Alberti (1961) by not having an apical process.

Cyst-Family UNCERTAIN

Genus Diconodinium Eisenack & Cookson 1960

Type species Diconodinium multispinum (Deflandre & Cookson) Eisenack & Cookson 1960

Diconodinium arcticum Manum & Cookson 1964

Plate 14, Figure 5

1964 Norske Vid-Akad. Skrifter I Mat-Haturv. Klasse no. 17, p. 18, pl. 6, figs. 1-4.

Code. Diconodinium-1.

Occurrence. 22 samples; 0.3 to 1.7%.

Comments. This species differs from D. glabrum Cookson & Eisenack (1960) by being smaller and by the natrue of its apical horn.

Genus Dinogymnium Evitt et al. 1967

Type species Dinogymnium acuminatum Evitt et al. 1967

Dinogymnium acuminatum Evitt 1967

Plate 16, Figure 3

1967 Stanford Univ. Publ. Geol. Sciences, v. 10, p. 8, pls. 1, 2; pl. 3, figs. 1-8, 10, 11, 20, text-fig. 11-23.

Code. Dinogymnium-3.

Occurrence. 5 samples; 5 times.

Comments. For the complete discussion of the relationship of this species to other species of this genus the reader is referred to Evitt et al. (1967). This species was described from the Maestrichtian of California but probably has a range at least from the Cenomanian to the Maestrichtian.

Dinogymnium cf. D. cretaceum (Deflandre) Evitt et al. 1967

Plate 16, Figure 6

1967 Stanford Univ. Publ. Geol. Sciences, v. 10, p. 17, pl. 3, figs. 18, 19.

Code. Dinogymnium-5.

Occurrence. 11 samples; 13 times.

Comments. This species is referred to D. cretaceum and does indeed resemble the many reports of this species; however, the generally accepted size range of this small species is 25 to 42 microns. The specimens found in this study are about 15 microns; for this reason these specimens have been tentatively assigned to this species.

Dinogymnium cf. *D. digitus* (Deflandre) Evitt *et al*. 1967

Plate 16, Figure 4

1967 Stanford Univ. Publ. Geol. Sciences, v. 10, p. 18.

Code. *Dinogymnium*-4.

Occurrence. 4 samples; 4 times.

Comments. The specimens of this study are doubtfully assigned to *G. digitus* in as much as the location of the cingulum appears to be somewhat different than the cingulum of the type material; otherwise, this species is the same as those described by Deflandre (1935).

Dinogymnium westralium (Cookson & Eisenack) Evitt *et al*. 1967

Plate 16, Figure 1

1967 Stanford Univ. Publ. Geol. Sciences, v. 10, p. 23.

Code. *Dinogymnium*-1.

Occurrence. 20 samples; 0.3 to 2.3%.

Comments. This species has a reported range from the Cenomanian to the middle Maestrichtian and is characterized by its large size, CI (cingulum index) and wall texture.

Dinogymnium cf. *D*. sp. "2" Evitt *et al*. 1967

Plate 16, Figure 2

1967 Review Paleobot. & Palynol., v. 2, pl. 1, fig. C, H-J.

Code. *Dinogymnium*-2.

Occurrence. 19 samples; 0.3 to 1.7%.

Comments. This species as recovered from the samples of the Buck tongue does not occur in the upper part of any of the sections in which it was found. This species, apparently undescribed in the literature, most resembles the Gymnodinium sp. 2 Evitt (1967) but has a somewhat smaller CI.

Dinogymnium sp.

Plate 16, Figure 5

Code. Dinogymnium-8.

Description. Test essentially elongate cylinder with rounded ends, cingulum less than 1/3 of the maximum dimension from one end, CI=70; wall thin and porous; archeopyle present. Maximum dimension greater than 110 microns, range 110 to 220 microns.

Occurrence. 6 samples; 0.3 to 2.7%.

Comments. This extremely long narrow thin species has not been previously reported to the writer's knowledge. The diagnostic features are the overall length, the thin wall, and the location of the cingulum.

Reference specimen. Pb4735-1 D15.9xR3.3.

Genus Horologinella Cookson & Eisenack 1962

Type species Horologinella lineata Cookson & Eisenack 1962

Horologinella cf. H. incurvatum Cookson & Eisenack 1962

Plate 16, Figure 7

1962 Proc. Roy. Soc. Victoria, v. 75, p. 272, pl. 37, fig. 5.

Code. Horologinella-1.

Occurrence. 2 samples; 2 times.

Comments. This entity is tentatively assigned to this genus and species because of its central capsule and wall structure; it differs from *Tetraporina* in having a central capsule.

Microforam A

Plate 16, Figure 8

Code. Microforam A

Description. Uniserial, planispiral, evolute microforaminiferal chitinous innerlining.

Occurrence. 2 samples; 2 times.

Comments. All planispiral forms were collectively included within this group with no attempt being made to speciate.

Microforam B

Plate 16, Figure 9

Code. Microforam B

Description. Uniserial, linear microforaminiferal chitinous innerlining.

Occurrence. 9 samples; 14 times.

Comments. All linear nonfungal spore forms were collectively included within this category.

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APPENDICES

APPENDIX I

Register of measured stratigraphic sections

Tuscher Wash.--8 miles north and 2 east of Green River, Utah, SE 1/4, Sec. 13, T.20S., R.16E., field locality 7/12/67 I -1 through -17.

	Type of Sample:	Sample No.:	Feet Above Base:	Mascer-ation No.:
Buck tongue of the Mancos Shale				
Shale, dark gray, compact, weathers bluish gray, gritty to teeth, typical mancos type of shale.	3'channel	1	base	Pb4860
Shale - same as above.	3'channel	2	11'	Pb4861
Shale - same as above.	3'channel	3	16'6"	Pb4862
Shale - same as above.	3'channel	4	22'	Pb4863
Shale - same as above.	3'channel	5	27'6"	Pb4864
Shale - same as above.	3'channel	6	33'	Pb4865
Shale - same as above.	3'channel	7	38'6"	Pb4866
Shale - same as above, with discontinuous silty lenses.	3'channel	8	44'	Pb4867
Shale - same as sample above, with 8" sandstone below sample site.	3'channel	9	49'6"	Pb4868
Shale, sandy, porcelaneous, giving the appearance of being case hardened.	3'channel	10	55'	Pb4869
Shale - same as above with laminated to thin bedded fine sand and shale.	3'channel	11	60'6"	Pb4870
Shale - same as sample 10 above.	3'channel	12	66'	Pb4871
Shale - same as sample 10 above, with thin beds of fine sand.	3'channel	13	71'6"	Pb4872
Shale - same as sample 13 above.	3'channel	14	77'	Pb4873
Shale, with increasing amounts of sand, beds up to 3" thick.	3'channel	15	82'6"	Pb4874
Shale - same as sample 15 above	2'channel	16	88'	Pb4875

Tuscher Wash (cont.)

	Type of Sample:	Sample No.:	Feet Above Base:	Mascer-ation No.:
Shale and sandstone interbedded with slightly more shale than sand.	2'channel	17	93'6"	Pb4876
Sandstone and shale interbedded with slightly more sand, but with good shale partings.	2'channel	18	99'	Pb4877

Crescent Wash.--below Crescent Butte, north of Crescent, Utah, Sec. 35,T.20S.,

R.19E., field locality 7/11/67 III -1 through -23.

Buck tongue of the Mancos Shale

Shale, dark gray, compact, weathers bluish gray, gritty to teeth, typical mancos type of shale.	3'channel	1	11'	Pb4837
Shale - same as above, with thin layers of fine sand dispersed throughout.	3'channel	2	16'6"	Pb4838
Shale - same as above.	3'channel	3	22'	Pb4839
Shale - same as sample 1 above.	3'channel	4	27'6"	Pb4840
Shale - same as above.	3'channel	5	33'	Pb4841
Shale - same as above.	3'channel	6	38'6"	Pb4842
Shale - same as above.	3'channel	7	44'	Pb4843
Shale - same as above.	3'channel	8	49'6"	Pb4844
Shale - same as above.	3'channel	9	55'	Pb4845
Shale - same as above.	3'channel	10	60'6"	Pb4846
Shale - same as above, with gypsum crystals in the joints.	3'channel	11	71'6"	Pb4847
Shale - same as above.	3'channel	12	82'6"	Pb4848
Shale - same as above.	3'channel	13	93'6"	Pb4849
Shale - same as above.	3'channel	14	104'6"	Pb4850
Shale - same as above.	3'channel	15	115'6"	Pb4851
Shale - same as above.	3'channel	16	121'	Pb4852

Crescent Wash (cont.)

	Type of Sample:	Sample No.:	Feet Above Base:	Mascer-ation No.:
Shale - same as above.	3'channel	17	126'6"	Pb4853
Shale - same as above.	3'channel	18	132'	Pb4854
Shale - same as above.	3'channel	19	137'6"	Pb4855
Shale - same as above, with silt-stone interbedded.	3'channel	20	143'	Pb4856
Shale - same as above, with fine sandstone interbedded.	3'channel	21	148'6"	Pb4857
Shale partings typical of mancos in bedded fine sandstone.	3'picked	22	154'	Pb4858
Shale partings of mancos type below 3' massive sandstone.	1'picked	23	159'6"	Pb4859

Cottonwood Creek.--northeast of Cottonwood, Utah, SE 1/4, Sec. 13, T.19S., R.23E., field locality 7/6/67 I -1 through -34.

Buck tongue of the Mancos Shale

Shale, dark gray, compact, weathers bluish gray, gritty to teeth, typical mancos type of shale.	1'channel	1	base	Pb4794
Shale - same as above.	2'channel	2	5'6"	Pb4795
Shale - same as above.	2'channel	3	11'	Pb4796
Shale - same as above.	1'channel	4	16'6"	Pb4797
Shale - same as above.	2'channel	5	22'	Pb4798
Shale - same as above.	2'channel	7	33'	Pb4800
Limestone, nonfossiliferous 1 1/2" thick.	spot	7a	33'	Pb4801
Shale - same as sample 1 above.	3'channel	8	49'6"	Pb4802
Shale - same as above.	3'channel	9	61'6"	Pb4803
Shale - same as above.	3'channel	10	72'6"	Pb4804

Cottonwood Creek (Cont.)

	Type of Sample:	Sample No.:	Feet Above Base:	Mascer-ation No.:
Shale - same as above, just below 1' limestone.	1'channel	11	80'	Pb4805
Limestone, brown nodular, fossiliferous badly recrystallized in places, 1' thick.	spot	11a	81'	Pb4806
Shale - same as sample 11 above, but just above limestone.	1'channel	12	83'	Pb4807
Shale - same as sample 1 above.	3'channel	13	88'	Pb4808
Shale - same as above.	3'channel	14	99'	Pb4809
Shale - same as above.	3'channel	15	110'	Pb4810
Shale - same as above.	3'channel	16	121'	Pb4811
Shale - same as above.	3'channel	17	133'	Pb4812
Shale - same as above.	3'channel	18	144'	Pb4813
Shale - same as above.	3'channel	19	155'	Pb4814
Shale - same as above.	3'channel	20	166'	Pb4815
Shale - same as above.	3'channel	21	177'	Pb4816
Shale - same as above.	3'channel	22	188'	Pb4817
Shale - same as above.	3'channel	23	199'	Pb4818
Shale - same as above from a 2" parting between 3" thick massive sandstone units that hold up a small nose on the slope.	spot	24	202'	Pb4818
Shale - same as sample 1 above.	3'channel	25	210'	Pb4819
Shale - same as above.	3'channel	26	221'	Pb4820
Shale - same as above, with slightly sandy zones, just below 2' sandstone.	3'channel	27	228'6"	Pb4821
Shale - same as above from between 6", 4" and 14" sandstones.	picked	28	229'	Pb4822

Cottonwood Creek (Cont.)

	Type of Sample:	Sample No.:	Feet Above Base:	Mascer-ation No.:
Shale - same as above sandstone of sample 29, sand-shale contact is very sharp.	2'channel	29	231'	Pb4824
Shale - same as above, with sandstone partings.	3'channel	30	243'	Pb4825
Shale - same as above, with lenticular buff sand partings.	3'channel	31	254'	Pb4826
Sandy shale with plant fragments.	3'channel	32	259'6"	Pb4827
Shale, sandy with sharp contact between sand and shale units, sand may be the basal unit of Castlegate Sandstone.	picked	33	265'	Pb4828
Shale from 2" composite at base of massive sandstone.	2" picked	34	267'	Pb4829

Westwater Wash.--1/4 mile south of ranch house, Sec. 4, T.18S., R.24E.,

field locality 7/5/67 I -1 through -37.

Buck tongue of the Mancos Shale

Shale, dark gray, compact, weathers bluish gray, gritty to teeth, typical mancos type of shale.	3'channel	1	5'6"	Pb4756
Shale - same as above.	3'channel	2	11'	Pb4757
Shale - same as above.	3'channel	3	16'6"	Pb4758
Limestone, 1 1/4" thick.	spot	4	21' 11"	Pb4759
Shale - same as sample 1 with small calcareous nodules.	3'channel	5	23'	Pb4760
Shale - same as above.	3'channel	6	38'6"	Pb4761
Shale - same as sample 1 above.	3'channel	7	49'6"	Pb4762
Shale - same as above, 6" below limestone.	spot	8	60'	Pb4763
Limestone, 6" thick fossiliferous, buff, somewhat recrystalized.	spot	9	60'6"	Pb4764

Westwater Wash (Cont.)

	Type of Sample:	Sample No.:	Feet Above Base:	Mascer-ation No.:
Shale - same as sample 1 above.	3'channel	10	71'6"	Pb4765
Shale - same as above.	3'channel	11	82'6"	Pb4766
Shale - same as above collected above and below fossiliferous limestone.	3'channel	12	93'6"	Pb4767
Limestone, irregular thickness, about 6", recrystalized.	spot	12a	94'	Pb4768
Shale - same as sample 1 above.	3'channel	13	104'6"	Pb4769
Shale - same as above.	3'channel	14	115'6"	Pb4770
Shale - same as above.	3'channel	15	126'6"	Pb4771
Shale - same as above.	3'channel	16	137'6"	Pb4772
Shale - same as above with some sand.	3'channel	17	148'6"	Pb4773
Shale - same as sample 1 above.	3'channel	18	159'6"	Pb4774
Shale - same as above.	3'channel	19	170'6"	Pb4775
Shale - same as above.	3'channel	20	181'6"	Pb4776
Shale - same as above.	3'channel	21	192'6"	Pb4777
Shale - same as above.	3'channel	22	203'6"	Pb4778
Shale - same as above.	3'channel	23	214'6"	Pb4779
Shale - same as above.	3'channel	24	225'6"	Pb4780
Shale - same as above.	3'channel	25	236'6"	Pb4781
Shale - same as above.	3'channel	26	247'6"	Pb4782
Shale - same as above.	3'channel	27	258'6"	Pb4783
Shale - same as above.	3'channel	28	269'6"	Pb4784
Shale - same as above.	3'channel	29	280'6"	Pb4785
Shale - same as above.	3'channel	30	291'6"	Pb4786
Shale - same as above with silt and fine sand.	3'channel	31	302'6"	Pb4787

Westwater Wash (Cont.)

	Type of Sample:	Sample No.:	Feet Above Base:	Mascer-ation No.:
Shale changing abruptly into sandstone.	picked	32	305'6"	Pb4788
Shale and siltstone same as above.	3'channel	33	313'6"	Pb4789
Shale - same as sample 1 above.	3'channel	34	324'6"	Pb4790
Shale - same as above with 2-8" sandstone beds dispersed throughout.	3'channel	35	330'	Pb4791
Siltstone or fine sandstone with shale partings.	3'channel	36	346'6"	Pb4792
Shale - same as above.	spot	37	357'6"	Pb4793

West Salt Creek.--about 15 miles north of highway 50, Sec. 35, T.7S.,R.104W., Colorado. Field locality 7/9/67 I -1 through -51.

Mancos Shale

Shale, dark gray, compact, weathers bluish gray, gritty to teeth, typical mancos shale.	3'channel	1	base	Pb4705
Shale - same as above.	3'channel	2	22'	Pb4706
Shale - same as above.	3'channel	3	38'6"	Pb4707

Castlegate Sandstone

Shale, sandy in partings between thin sandstones	picked	4	55'	Pb4708
Shale - same as above.	3'channel	5	66'	Pb4709
Sandstone, fine grained with plant debris.	picked	6	71'6"	Pb4710
Shale, sandy just below 6' massive capping sandstone.	picked	7	77'	Pb4711

Buck tongue of the Mancos Shale

Shale - same as sample 1 above.	3'channel	8	85'6"	Pb4712

West Salt Creek (Cont.)

	Type of Sample:	Sample No.:	Feet Above Base:	Mascer-ation No.:
Shale - same as above.	3'channel	9	96'6"	Pb4713
Shale - same as above.	3'channel	10	107'6"	Pb4714
Limestone thin limy interval in shale.	spot	11	118'6"	Pb4715
Shale - same as sample 1 above.	3'channel	12	124'	Pb4716
Shale - same as sample above.	3'channel	13	135'	Pb4717
Shale - same as above just below limestone.	3'channel	14	151'6"	Pb4718
Limestone, buff to orange, 6" thick, no fossils found.	spot	15	153'6"	Pb4719
Siltstone, 5" thick resistant bed.	spot	16	163'6"	Pb4720
Shale - same as sample 1 above.	3'channel	17	169'	Pb4721
Siltstone - same as sample 26 above.	spot	18	171'	Pb4722
Siltstone - same as above.	spot	19	174'6"	Pb4723
Siltstone - same as above but limy.	spot	20	180'	Pb4724
Shale - same as sample 1 above.	3'channel	31	185'6"	Pb4725
Siltstone - same as sample 16 above.	spot	22	192'6"	Pb4726
Siltstone - same as above.	spot	23	197'	Pb4727
Siltstone - same as above.	spot	24	198'6"	Pb4728
Siltstone - limy, 12" thick.	picked	25	201'	Pb4729
Limestone, buff to red, fossil baculites and Inoceramus, 18" thick.	picked	26	206'6"	Pb4730
Limestone, nonfossiliferous, 8" thick.	picked	27	214'	Pb4731
Limestone, shaly with nodules.	picked	28	230'6"	Pb4732
Limestone, nodular containing fossils as nucleai, 18" thick.	picked	29	234'6"	Pb4733
Shale - same as sample 1 above.	3'channel	30	237'	Pb4734

West Salt Creek (Cont.)

	Type of Sample:	Sample No.:	Feet Above Base:	Mascer-ation No.:
Shale - same as above with silty limy zone.	3'channel	31	252'6"	Pb4735
Shale - same as sample 1 above with silty zones throughout.	4'channel	32	264'6"	Pb4736
Shale - same as above.	3'channel	33	275'6"	Pb4737
Shale - same as above.	3'channel	34	297'6"	Pb4738
Shale, silty and limy.	1'channel	35	303'	Pb4739
Shale - same as sample 1 above.	3'channel	36	319'6"	Pb4740
Shale - same as above.	3'channel	37	330'6"	Pb4741
Shale - same as above with buff colored zone at top of channel	1'channel	38	341'6"	Pb4742
Shale - same as sample 1 above.	3'channel	39	352'6"	Pb4743
Shale - same as above.	3'channel	40	363'6"	Pb4744
Shale - same as above.	3'channel	41	374'6"	Pb4745
Shale - same as above.	3'channel	42	385'6"	Pb4746
Limestone, possibly dolomitic, 3" thick.	spot	43	387'	Pb4747
Shale - same as sample 1 above.	3'channel	44	396'6"	Pb4748
Shale - same as above, with sand partings.	3'channel	45	413'	Pb4749
Shale - same as above.	3'channel	46	424'	Pb4750
Shale - same as above with beds of sand.	3'channel	47	429'6"	Pb4751
Shale - same as above.	3'channel	48	435'	Pb4752
Shale - same as above.	3'channel	49	440'6"	Pb4753
Shale - same as above, with silty zones.	3'channel	50	446'	Pb4754
Sandstone, tan with silty partines.	picked	51	451'	Pb4755

APPENDIX II

Factor Analysis of Data

As stated in the goals of this study, one of the primary objectives was to formulate a computer based model to help explain the vertical variation in the stratigraphic sections in terms of degrees of marineness. Factor analysis seemed ideally suited for this and was chosen, for reasons outlined below, to provide the values used to construct Fig. 7. Certain questions have been raised concerning evaluation of variables and the advisability of running Q mode analysis without the R mode. Since these questions have not been entirely and satisfactorily answered at this time, this section is placed in the appendix of this study.

As can be noted from the lithologic descriptions in Appendix I, the rocks of the Buck tongue are virtually homogenous throughout. There are very few lithologically distinct units megascopically discernible in the dark marine shale in the area of the Book Cliffs.

The Westwater Wash section contained three thin limestone stringers which appeared in the field to be similar both lithologically and in stratigraphic position to only two units in the Cottonwood Creek Section. Except for these units it was not possible to correlate lithostratigraphic units in the Buck tongue from field relationships.

As the Buck tongue is such a homogenous rock unit and because detailed superpositional control was available (e.g., close interval samples, structurally uncomplicated outcrops, sample transect almost perpendicular to the depositional strike, a clearly defined datum at the base of the rock unit, etc.) factor analysis was selected as an analytic statistic. The problem to be solved by this statistical tool was to determine the relatedness of all samples both linearly and vertically. The factor analysis program chosen for this study includes a complete listing of coefficients of correlation between all samples in the data matrix and it uses actual samples as reference vector end-members.

The analysis of the data presented in Fig. 7 utilizes the factor-vector analysis technique. This analysis was carried out by using the Control Data Corporation model 3600 digital computer at Michigan State University. The program used was that of Manson and Imbrie, Columbia Vector Analysis Program (COVAP) and for this study only the Q mode analysis and a maximum of 72 samples per computer run were used, because of storage limitations imposed by the computer.

Factor analysis is a multivariate method of classifying a large data matrix into a small number of closely related groups which can be examined and geologically interpreted. These groups are numerically related to those samples (end-members) which can account for the greatest amount of variation in the data matrix. In this objective classification, the classes are formed first and their geologic significances are determined after the classification is complete. The number of end members to be used are pre-selected by the program and are based on natural boundaries. Statistical and matrix algebra techniques are used to determine which samples will become end members. All of the original data are used in constructing the classification.

Many mathematical techniques are available for quantitatively classifying a set of data into sample groupings. The reason that factor-vector analysis was chosen in this study is because it classifies the data into natural partitions; and because a communality value is given for every sample in the data matrix, that is, a coefficient of correlation is calculated for each sample so that it can be numerically related to any sample in any group. For a more complete discussion of the factor analysis program used see Manson and Imbrie (1964). Some pertinent references on the historical development and theory of application of factor analysis are Catell (1952), Lauley and Maxwell (1964) and Thurstone (1967).

The basic premise of this study is that the Buck tongue can be viewed as a small sedimentary cycle, that is, a complete transgression-regression is recorded. Although no lithic units can be traced for more than a few miles through any part of this cycle, it was hoped at the beginning of this study, that "biogenic units" might be established and traced through the transgressive-regressive phases of the sediments of the Buck tongue. The palynologic composition of the sediment is used for this interpretation and is superimposed on the stratigraphic succession of the outcrop sections in Fig. 7. This "natural model" sensu Kauffman (1967), delineates the broad horizontal V-shaped biogenic units as interpreted from the factor analysis program. The communality values (Appendix II A-J) were rounded off until natural groupings occurred (Dahlberg & Griffiths, 1967) as plotted in the model of Fig. 7. The lines that separate the different biogenic units are drawn between sample groupings as inferred from factor analysis. The matrix size limitations imposed by the computer required that several runs be made so that all data within the matrix could be compared. When several sets of communality values were available for the same samples, some interpretation was necessary to determine the unit boundaries. This overlap demonstrated that although actual numerical values can not be directly correlated between different sets of data, relative values do exist between closely related samples.

In this phase of the study, a basic attempt is made to interpret the environs of a restricted cycle of sedimentation based solely on the floristic composition of the sediments. The consistent biotic associations or groupings are very much in evidence and undoubtedly reflect the paleoenvironment. A somewhat similar approach has been taken by Kauffman (1967), in which he constructs a model based on the different lithologies of a marine cycle. He then interpreted environments based on lithologic and faunal distributions. In the Buck tongue of the Mancos Shale, the lithology is essentually one homogenous unit but the highly diversified floral content is used to construct a model. Conceptually the palynomorphs, recovered from the sediments, are being distributed on the surface, a time plane, at any point in time during the evolution of a basin albeit at differing rates and conditions of sedimentation. The distribution of palynomorphs, which reflect environmental changes with time, are more closely related laterally than vertically. The function of factor analysis as applied to this study has been to show mathematically the degree of lateral relatedness through time and that is what is intended in Fig. 7.

By examining a restricted marine transgression-regression, the time increment and the area of study are small enough to minimize the broad regional blending effects. The changes in sediment content tend to be of a local nature and the statistical technique used is very sensitive to slight changes in the data. Each leg (zonule) of the horizontal V shows that those samples within that zonule are more closely inter-related laterally than they are to associations assemblages vertically. The boundaries between these zonules are diagnostically representative of distinct change in the environment both ecologically and depositionally. No evolutionary

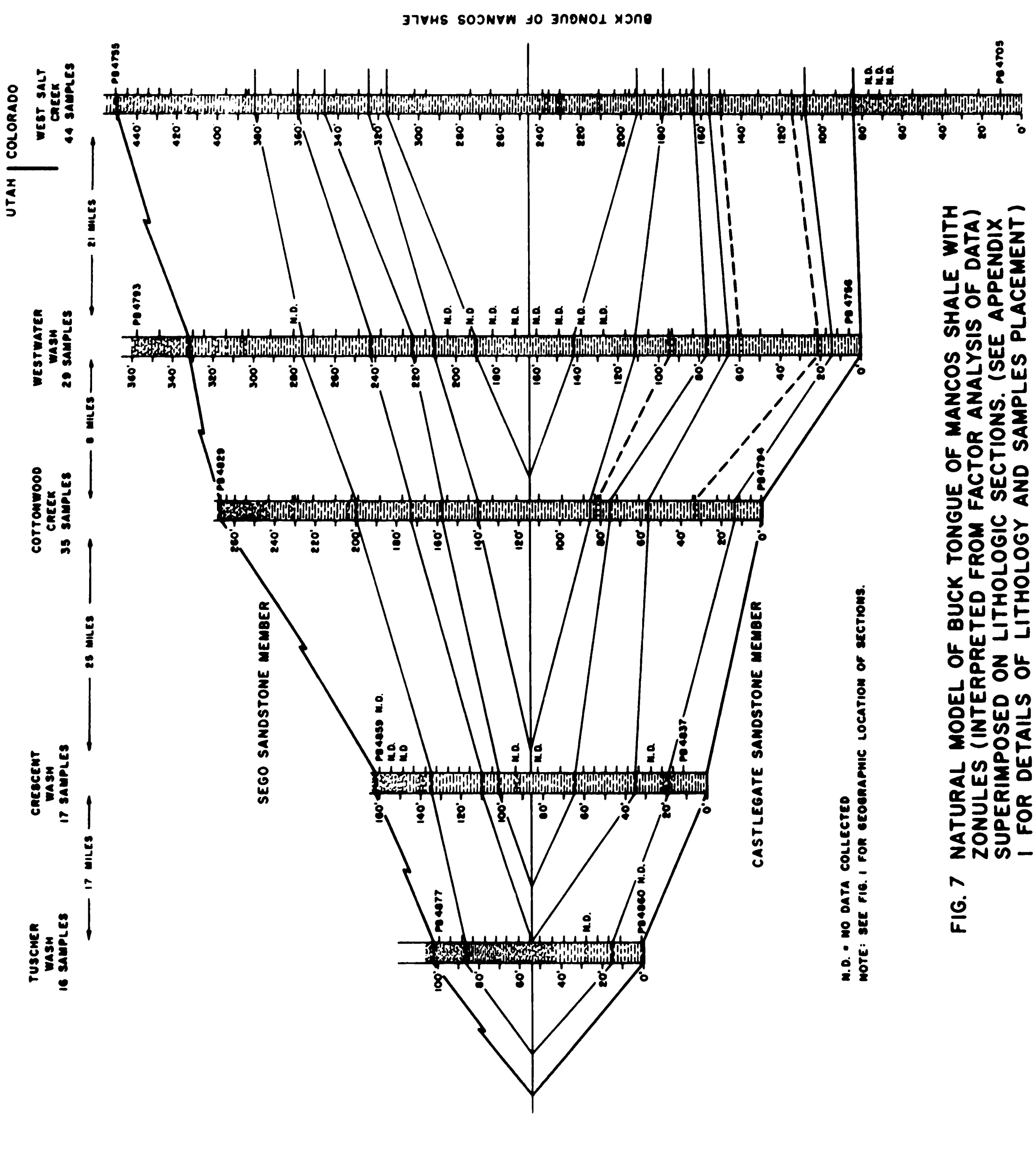

FIG. 7 NATURAL MODEL OF BUCK TONGUE OF MANCOS SHALE WITH ZONULES (INTERPRETED FROM FACTOR ANALYSIS OF DATA) SUPERIMPOSED ON LITHOLOGIC SECTIONS. (SEE APPENDIX I FOR DETAILS OF LITHOLOGY AND SAMPLES PLACEMENT)

first occurrences or extinctions have been observed in this study, and the variation in relative abundance is interpreted as a response to the environment rather than one of evolution.

The significance attached to each biogenic unit is only interpretive and is probably not the same for the different zonules. Factor analysis demonstrates that based on the palynomorphs recovered from the sediments, these units are similar. The environment of deposition was certainly similar for any zonule in each stratigraphic section, but more important is the fact that the land derived pollen and spores dominate all palynomorphs recovered and each zonule represents a unit of sedimentation. This does not mean that the basal 12 feet at Westwater Wash took the same time to be deposited as the basal 33 feet of West Salt Creek. But within the framework of the various and multiple factors influencing the sedimentation of these rocks, the same or similar land plants were shedding pollen, etc., and similar conditions of sediment distribution were active. For these reasons, the variation in thickness of any biogenic unit is probably more responsive to varying rates of sedimentation than varying duration in time at any location.

As the Buck tongue sea invaded old coastal areas of the hinterland, a particular condition of environment was met as indicated by both the marine and terrestrial fossils, as the sea regressed a different but somewhat similar condition was again met as recorded by the fossils recovered from the sediments. This is the reason that the zonules are connected at their apices although the point at which the regression starts is not perfectly clear. Future investigation might demonstrate that in fact three actual biogenic zonules exist: the clearly delineated transgressive phase, a second phase in which the shift in direction of shoreline movement is noted and thirdly, the regressive phase zonule. This intermediate phase is not clear at this time, but a sharp break in the communality values indicates that a common datum plane exist through all five stratigraphic sections in this study. In the Tuscher Wash section a definite lithologic change coincides with the break as deduced from factor analysis. Although no such lithologic break was noted for the other four localities, the same numerical break can be traced through all stratigraphic columns studied and is used as a datum for Fig. 7.

A geologic explanation of the significances of all relationships indicated by the factor analysis is not possible at this time, but several of the coefficients and their alignment can be interpreted in a geologic way. Of the various sample combinations tried for the factor runs, in each case the first end-member selected accounted for at least 63% (up to 77%) of the total variation in the samples. This, of course, demonstrates the homogenity of the palynomorphs recovered from the samples. Typically a value of less than 50% would be expected. The first six end-members to be selected generally could account for over 90% of the total variation of the samples being tested. The second end-member to be selected was generally stratigraphically quite different from the first. For example, if the first end-member selected was a sample at the top of the section, the second end-member was generally very close to the base of the section. This reflects the fact that factor analysis is programed to select the most dissimilar samples as reference vectors. The upper contact of the Buck tongue is gradational and the boundary cannot be picked precisely. Based on their coefficients of correlation the two top samples of the Westwater

Wash section were determined to be from the Sego Sandstone rather than the Buck tongue as had been interpreted when the section was measured and described. In other words, the results of the factor analysis aided in picking the Buck tongue-Sego Sandstone contact more precisely than was possible from field relationships.

Field interpretations indicated that two thin limestone units in the Cottonwood Creek section were related to three limestones in the Westwater Wash section. Factor analysis confirmed that the middle unit of the Westwater section did not have a genetic relationship with the other four beds. The lowest limestone unit at both localities had almost identical numerical values, the top limestones were similar enough to say they were, without question, the same limestone units. An interesting point is that a thin limy unit in the West Salt Creek section was not suspected of being genetically related to the middle limestone from the Westwater section until the results of the factor analysis were studied. So factor analysis can, under some circumstances, be used as a direct method of stratigraphic correlation. If this is so, one would expect to find a limy zone at West Salt Creek between the 160 and 180 foot level which would correspond with the limestone at 94 feet at Westwater and 80 feet at Cottonwood Creek. A subsequent visit to West Salt Creek to look for such a unit did in fact confirm the presence of a 6 inch limy siltstone at West Salt Creek. This unit had been observed and described during the original field descriptions but, because of an oversight, had not been plotted on Fig. 7. At the same time, an effort was made to locate a third limestone unit at Cottonwood Creek to correlate with the middle limestone at Westwater Wash. This attempt proved futile as the limestone could not be found; however, it should be noted that the nodular limestone at Westwater weathers readily and that this interval slumped badly at Cottonwood Creek. It is postulated that if adequate time were available the limestone could be traced in the field and its relative position could be intercalated into the Cottonwood Creek section.

One inherent feature of factor analysis is the difficulty of isolating the cause of different factor loading values. For example, visual examination of the palynomorph occurrence on either side of the datum of Fig. 7 does not reveal the cause for the datum. The quantities vary so subtly that no individual or group of individual taxa can be selected out as exercizing greater influence than any other individual or group of individuals in the comparisons between samples. This is one of the problems that has become apparent in this study. By considering all of the data in the matrix, factor analysis is extremely sensitive to very subtle changes in abundance. The interpretation of a floristic change is not only impossible to pick out by visually studying the raw data, but is also masked by the similarities between numerical values in the results of the factor analysis. This would likely not be a problem if the data were not so homogenous, but then that is also the real advantage of using this statistic. Had it been possible to run both the R and Q modes of the Covap program on the data, the causes for different factors being selected might have been more readily understood. As mentioned previously, storage capacity of the computer limited the utilization of the full program and the number of species to be considered exceeded the limitations of the program.

The sample positions of Fig. 7 that are marked "N.D." are samples that were not counted because they did not meet the minimum requirements of preservation as discussed above. These samples were collected from outcrop areas which had weathered deeper than was suspected at the time the field work was done. Westwater Wash, for example, was the first section to be collected and the series of samples from Pb4771 to 4778 came from a nose or bench on the otherwise steeply sloping surface. As more samples were collected this feature became apparent and greater care was taken to deepen the ditches on this type of slope. Another area of deeply weathered rocks is around the sand-shale contact where oxygenated water could more readily penetrate below the outcrop surface.

Conclusions.--Factor vector analysis was selected as an analytic statistic because all of the information is used to classify the data into natural partitions using actual samples as reference end-members. All samples are inter-related numerically. Historically, this statistic was developed to clarify and correlate data with unknown parameters. As used here, factor analysis has proved its effectiveness to correlate genetically related samples within the data matrix. The original intent of statistically delineating broad florules within the Buck tongue has been more effective than had been originally hoped. Many of the groupings interpreted from the analysis can be given geologic and paleoecologic significance. Factor analysis will become increasingly more valuable as larger studies are undertaken and should become more important as more is learned about interpreting the results within a geological framework. The real advantage of factor analysis will come as larger computers become generally available so that both Q and R modes can be run simultaneously on large data matrices.

APPENDIX II-A

Q MODE ANALYSIS OF BUCK TONGUE OF THE MANCOS SHALE

REORDERED OBLIQUE PROJECTION MATRIX

West Salt Creek and Tuscher Wash

NAME	INDEX	4751	4720	4712	4729	4744	4718
		40	9	1	18	33	7
4751	40	1.000	0.000	0.000	0.000	0.000	0.000
4738	27	0.988	0.031	0.098	0.074	0.091	-0.277
4749	38	0.961	-0.120	0.023	0.102	0.023	-0.024
4752	41	0.957	-0.168	-0.139	0.102	-0.004	0.221
4753	42	0.923	-0.160	-0.152	0.052	0.045	0.270
4755	44	0.877	0.020	0.097	0.001	0.073	0.000
4735	24	0.851	0.015	0.156	0.215	0.018	-0.304
4750	39	0.826	-0.079	-0.209	0.313	0.035	0.193
4746	35	0.824	-0.176	-0.285	0.398	0.083	0.146
4742	31	0.823	-0.038	0.316	0.061	-0.024	-0.089
4748	37	0.799	-0.091	-0.202	0.325	0.188	0.140
4739	28	0.791	-0.186	0.071	0.405	0.106	-0.219
4741	30	0.783	-0.211	0.045	0.317	0.006	-0.000
4747	36	0.773	-0.076	0.130	0.308	-0.012	-0.129
4754	43	0.757	-0.034	-0.018	0.044	0.012	0.334
4872	55	0.682	-0.226	-0.030	0.188	0.080	0.356
4743	32	0.649	-0.031	-0.351	0.521	0.149	0.204
4737	26	0.605	0.049	0.184	0.299	0.126	-0.065
4877	60	0.553	-0.069	0.140	0.100	0.090	0.372
4736	25	0.533	-0.062	0.106	0.300	0.138	0.164
4874	57	0.524	-0.194	0.361	0.132	0.096	0.201
4873	56	0.423	-0.205	0.322	0.224	0.029	0.320
4871	54	0.411	-0.368	0.337	0.334	-0.014	0.290
4720	9	0.000	1.000	0.000	0.000	0.000	0.000
4725	14	0.272	0.894	-0.022	0.161	0.000	-0.090
4726	15	-0.132	0.752	-0.293	0.605	-0.015	0.265
4721	10	0.272	0.534	0.155	0.405	-0.026	-0.186
4712	1	0.000	0.000	1.000	0.000	0.000	0.000
4714	3	0.254	0.059	0.867	-0.078	-0.059	-0.062
4715	4	0.070	0.218	0.672	-0.081	-0.050	0.251
4865	48	-0.289	-0.275	0.651	0.256	0.166	0.549
4869	52	0.007	-0.254	0.564	0.255	0.156	0.382
4867	50	-0.051	-0.335	0.513	0.423	0.041	0.444
4729	18	0.000	0.000	0.000	1.000	0.000	0.000
4723	12	0.058	-0.066	-0.076	0.921	0.037	0.265
4728	17	0.010	0.247	-0.166	0.908	0.062	0.111
4730	19	0.016	0.019	0.038	0.889	0.090	0.111
4734	23	0.215	-0.095	-0.114	0.868	0.081	0.158
4727	16	-0.111	0.350	-0.065	0.865	0.015	0.077
4724	13	0.008	0.116	-0.349	0.825	0.140	0.521
4722	11	0.320	-0.161	-0.169	0.821	0.172	0.153
4861	45	-0.166	-0.488	0.479	0.623	0.065	0.450
4732	21	0.334	0.076	0.044	0.622	0.056	0.002
4731	20	0.454	0.009	0.068	0.569	0.041	-0.046

APPENDIX II-A CONT.

Q MODE ANALYSIS OF BUCK TONGUE OF THE MANCOS SHALE

REORDERED OBLIQUE PROJECTION MATRIX

West Salt Creek and Tuscher Wash

NAME	4751	4720	4712	4729	4744	4718
INDEX	40	9	1	18	33	7
4744 33	0.000	0.000	0.000	0.000	1.000	0.000
4745 34	-0.223	0.088	0.106	0.026	0.973	0.046
4718 7	0.000	0.000	0.000	0.000	0.000	1.000
4733 22	0.098	0.150	-0.174	0.137	0.015	0.948
4719 8	0.051	0.067	-0.171	0.493	-0.023	0.834
4862 46	-0.024	-0.321	0.299	0.430	0.036	0.654
4717 6	-0.338	0.277	0.082	0.524	0.132	0.647
4866 49	-0.077	-0.132	0.407	0.206	0.146	0.621
4740 29	0.537	-0.019	-0.488	0.429	0.124	0.620
4875 58	0.107	-0.264	0.187	0.310	0.253	0.613
4868 51	-0.442	-0.260	0.547	0.303	0.367	0.611
4716 5	-0.244	0.078	0.503	0.142	0.139	0.548
4863 47	0.032	-0.404	0.472	0.310	0.024	0.539
4876 59	0.311	-0.213	0.354	0.078	0.174	0.483
4870 53	0.199	-0.108	0.447	-0.008	0.181	0.464

APPENDIX II-B

Q MODE ANALYSIS OF BUCK TONGUE OF THE MANCOS SHALE

REORDERED OBLIQUE PROJECTION MATRIX

West Salt Creek below Buck tongue, West Salt Creek Buck tongue and Tuscher Wash

NAME	4738	4712	4729	4720	4718	4705
INDEX	31	5	22	13	11	1
4738 31	1.000	0.000	0.000	0.000	0.000	0.000
4755 48	0.977	0.046	-0.231	0.045	0.123	0.127
4751 44	0.904	-0.093	0.088	-0.073	0.383	-0.181
4753 46	0.894	-0.240	0.032	-0.203	0.552	-0.043
4749 42	0.845	-0.059	0.256	-0.213	0.386	-0.253
4752 45	0.840	-0.225	0.238	-0.250	0.626	-0.240
4748 41	0.823	-0.291	0.279	-0.118	0.394	0.019
4739 32	0.774	-0.025	0.401	-0.226	0.051	-0.024
4754 47	0.756	-0.076	-0.020	-0.054	0.529	-0.013
4742 35	0.749	0.244	0.123	-0.090	0.225	-0.165
4746 39	0.704	-0.368	0.593	-0.272	0.558	-0.267
4735 28	0.696	0.058	0.450	-0.097	0.135	-0.300
4874 61	0.691	0.300	-0.209	-0.127	0.142	0.344
4741 34	0.657	-0.036	0.497	-0.301	0.378	-0.254
4737 30	0.626	0.142	0.276	0.025	0.124	-0.044
4877 64	0.604	0.062	-0.026	-0.069	0.464	0.148
4744 37	0.581	-0.075	0.563	-0.182	0.572	-0.381
4736 29	0.572	0.028	0.234	-0.075	0.309	0.075
4873 60	0.500	0.280	0.064	-0.189	0.331	0.143
4876 63	0.483	0.298	-0.225	-0.153	0.386	0.367
4871 58	0.437	0.289	0.243	-0.368	0.348	0.076
4712 5	0.000	1.000	0.000	0.000	0.000	0.000
4714 7	0.183	0.816	-0.016	0.038	0.080	-0.069
4865 52	-0.088	0.687	-0.013	-0.200	0.257	0.342
4715 8	-0.011	0.670	0.063	0.175	0.364	-0.177
4708 4	0.187	0.614	-0.371	0.444	0.234	-0.100
4869 56	0.147	0.555	0.036	-0.199	0.247	0.276
4867 54	0.083	0.511	0.184	-0.273	0.252	0.284
4716 9	-0.129	0.488	-0.027	0.130	0.375	0.283
4863 51	0.146	0.484	0.094	-0.351	0.381	0.233
4861 49	0.011	0.478	0.301	-0.393	0.180	0.399
4870 57	0.382	0.431	-0.288	-0.054	0.329	0.314
4729 22	0.000	0.000	1.000	0.000	0.000	0.000
4723 16	0.065	-0.065	0.913	-0.060	0.290	-0.018
4728 21	0.060	-0.182	0.826	0.263	0.060	0.124
4730 23	0.101	0.029	0.745	0.061	0.038	0.170
4745 38	0.564	-0.324	0.717	-0.273	0.626	-0.281
4722 15	0.396	-0.190	0.707	-0.144	0.199	0.108
4743 36	0.592	-0.405	0.679	-0.105	0.545	-0.188
4732 25	0.293	0.006	0.677	0.045	0.161	-0.068
4734 27	0.331	-0.129	0.632	-0.034	0.081	0.237
4747 40	0.584	0.073	0.620	-0.201	0.328	-0.427

APPENDIX II-B CONT.

Q MODE ANALYSIS OF BUCK TONGUE OF THE MANCOS SHALE

REORDERED OBLIQUE PROJECTION MATRIX

West Salt Creek below Buck tongue, West
Salt Creek Buck tongue and Tuscher Wash

NAME	4738	4712	4729	4720	4718	4705
INDEX	31	5	22	13	11	1
4727 20	0.007	-0.079	0.619	0.426	-0.111	0.307
4721 14	0.161	0.147	0.616	0.459	0.032	-0.279
4731 24	0.445	0.047	0.580	-0.016	0.102	-0.077
4724 17	0.182	-0.375	0.496	0.204	0.315	0.424
4720 13	0.000	0.000	0.000	1.000	0.000	0.000
4725 18	0.260	-0.035	0.168	0.880	-0.001	-0.052
4726 19	-0.120	-0.283	0.583	0.760	0.199	0.047
4713 6	0.103	0.541	-0.319	0.588	0.182	-0.176
4718 11	0.000	0.000	0.000	0.000	1.000	0.000
4733 26	0.079	-0.184	0.147	0.144	0.989	-0.002
4719 12	0.004	-0.190	0.532	0.059	0.887	-0.019
4707 3	0.063	-0.082	0.450	-0.220	0.886	0.039
4740 33	0.588	-0.568	0.286	-0.000	0.731	0.164
4872 59	0.587	-0.098	0.344	-0.306	0.688	-0.204
4750 43	0.651	-0.290	0.593	-0.198	0.658	-0.360
4706 2	-0.127	0.036	0.167	-0.088	0.636	0.510
4862 50	-0.006	0.265	0.386	-0.311	0.628	0.110
4717 10	-0.275	0.083	0.480	0.297	0.519	0.152
4866 53	0.049	0.402	0.013	-0.081	0.479	0.261
4705 1	0.000	0.000	0.000	0.000	0.000	1.000
4868 55	-0.025	0.550	-0.351	-0.068	0.056	0.862
4875 62	0.434	0.145	-0.248	-0.124	0.282	0.675

APPENDIX II-C

Q MODE ANALYSIS OF BUCK TONGUE OF THE MANCOS SHALE

REORDERED OBLIQUE PROJECTION MATRIX

Cottonwood Creek and Tuscher Wash

NAME	4824	4861	4815	4872	4804	4807
INDEX	30	36	21	46	10	13
4824 30	1.000	0.000	0.000	0.000	0.000	0.000
4828 34	0.967	0.594	-0.685	-0.226	0.122	0.179
4827 33	0.860	0.541	-0.166	-0.337	-0.138	0.260
4829 35	0.839	0.328	-0.202	-0.106	0.014	0.176
4826 32	0.816	0.402	-0.645	-0.133	0.146	0.421
4819 25	0.763	0.045	-0.065	0.012	0.273	0.035
4822 28	0.763	0.180	-0.211	-0.035	0.201	0.162
4825 31	0.745	0.121	-0.260	0.112	0.115	0.243
4802 8	0.622	-0.215	-0.150	0.358	-0.155	0.545
4806 12	0.500	-0.330	0.283	0.004	0.245	0.277
4798 5	0.497	-0.274	-0.303	0.307	0.383	0.394
4801 7	0.497	-0.174	-0.086	0.189	0.379	0.261
4821 27	0.493	0.428	-0.310	0.030	0.292	0.158
4809 15	0.414	0.288	-0.098	0.305	-0.130	0.295
4861 36	0.000	1.000	0.000	0.000	0.000	0.000
4867 41	-0.225	0.789	0.076	0.216	0.140	0.046
4863 38	-0.129	0.730	-0.005	0.137	0.582	-0.238
4869 43	0.046	0.729	0.143	-0.101	0.578	-0.321
4820 26	0.557	0.622	-0.251	-0.438	0.501	0.035
4862 37	0.098	0.581	-0.085	0.143	-0.164	9.492
4812 18	-0.045	0.527	0.184	-0.016	0.338	0.073
4815 21	0.000	0.000	1.000	0.000	0.000	0.000
4808 14	0.026	-0.366	0.658	0.298	0.085	0.378
4875 49	-0.083	0.130	0.655	0.577	0.218	-0.373
4813 19	0.295	0.017	0.338	-0.083	0.288	0.226
4872 46	0.000	0.000	0.000	1.000	0.000	0.000
4874 48	-0.335	-0.028	0.646	0.988	0.228	-0.389
4877 51	0.160	-0.115	0.540	0.855	-0.056	-0.280
4873 47	-0.368	0.196	0.267	0.837	0.240	-0.066
4876 50	-0.172	-0.016	0.597	0.709	0.367	-0.306
4871 45	-0.171	0.500	-0.057	0.668	0.190	-0.072
4810 16	0.399	-0.173	-0.112	0.601	0.154	0.196
4805 11	0.312	0.002	0.003	0.459	-0.012	0.323
4804 10	0.000	0.000	0.000	0.000	1.000	0.000
4796 3	-0.182	-0.094	0.246	0.160	0.823	0.131
4811 17	0.168	0.439	0.044	-0.102	0.795	-0.240
4803 9	0.403	0.253	-0.406	-0.202	0.781	0.141
4868 42	-0.254	0.578	0.627	-0.328	0.705	-0.297
4865 39	-0.380	0.683	0.296	-0.176	0.699	-0.065
4870 44	-0.127	0.200	0.470	0.400	0.671	-0.494
4794 1	0.010	-0.025	0.454	0.114	0.642	-0.135
4823 29	0.450	0.586	-0.051	-0.032	0.609	-0.515
4866 40	-0.299	0.429	0.103	-0.006	0.574	0.290

APPENDIX II-C CONT.

Q MODE ANALYSIS OF BUCK TONGUE OF THE MANCOS SHALE

REORDERED OBLIQUE PROJECTION MATRIX

Cottonwood Creek and Tuscher Wash

NAME	4824	4861	4815	4872	4804	4807
INDEX	30	36	21	46	10	13
4817 23	0.425	0.361	-0.344	-0.260	0.528	0.356
4807 13	0.000	0.000	0.000	0.000	0.000	1.000
4800 6	0.289	0.128	-0.476	0.009	0.283	0.778
4818 24	0.551	0.093	-0.275	0.066	-0.115	0.717
4797 4	0.185	-0.080	0.076	0.485	-0.224	0.650
4814 20	-0.046	-0.017	0.432	0.069	-0.003	0.586
4816 22	-0.147	0.068	0.335	0.266	0.114	0.480
4795 2	0.146	-0.373	0.255	0.344	0.236	0.433

APPENDIX II-D

Q MODE ANALYSIS OF BUCK TONGUE OF THE MANCOS SHALE

REORDERED OBLIQUE PROJECTION MATRIX

West Salt Creek and Crescent Wash

NAME		4751	4844	4729	4712	4720	4733
INDEX		40	51	18	1	9	22
4751	40	1.000	0.000	0.000	0.000	0.000	0.000
4738	27	0.961	0.369	0.238	0.034	-0.001	-0.551
4749	38	0.949	-0.149	0.087	0.094	-0.133	0.074
4752	41	0.898	-0.013	0.076	-0.044	-0.233	0.239
4753	42	0.884	-0.022	0.024	-0.059	-0.209	0.276
4755	44	0.879	0.429	0.140	-0.014	0.018	-0.360
4735	24	0.797	-0.057	0.269	0.228	-0.043	-0.230
4748	37	0.789	0.112	0.357	-0.113	-0.158	0.049
4739	28	0.788	0.174	0.499	0.097	-0.221	-0.381
4746	35	0.778	-0.120	0.352	-0.106	-0.244	0.224
4742	31	0.777	0.255	0.155	0.264	-0.072	-0.266
4750	39	0.766	-0.095	0.266	-0.056	-0.164	0.285
4754	43	0.732	0.109	0.033	-0.016	-0.069	0.262
4741	30	0.730	-0.181	0.282	0.179	-0.254	0.140
4747	36	0.706	-0.051	0.334	0.223	-0.156	-0.060
4744	33	0.674	-0.149	0.219	0.167	-0.156	0.284
4745	34	0.616	-0.028	0.473	-0.085	-0.292	0.285
4743	32	0.616	-0.085	0.505	-0.121	-0.143	0.258
4737	26	0.574	0.461	0.453	0.124	-0.021	-0.391
4736	25	0.472	0.187	0.358	0.196	-0.170	0.041
4740	29	0.463	0.238	0.410	-0.357	-0.161	0.463
4844	51	0.000	1.000	0.000	0.000	0.000	0.000
4839	47	-0.002	0.979	0.036	0.035	0.073	-0.037
4841	48	0.092	0.954	0.047	-0.099	-0.018	0.070
4845	52	-0.138	0.923	0.059	0.084	-0.066	0.133
4852	57	0.148	0.851	0.070	-0.140	0.309	-0.051
4846	53	-0.135	0.847	0.157	-0.007	-0.017	0.241
4842	49	0.036	0.847	0.108	-0.263	0.178	0.190
4837	45	0.044	0.825	0.047	-0.028	0.047	0.060
4854	59	0.099	0.817	-0.119	-0.003	0.144	0.154
4851	56	-0.010	0.804	-0.075	0.203	0.183	0.011
4843	50	-0.014	0.784	0.055	0.052	-0.027	0.239
4853	58	-0.004	0.707	-0.020	0.071	0.339	0.123
4713	2	0.065	0.654	-0.223	0.504	0.422	-0.442
4847	54	0.001	0.599	-0.006	0.577	0.042	-0.113
4838	46	0.050	0.521	0.082	0.050	0.039	0.430
4856	61	0.226	0.511	-0.075	0.069	0.185	0.266
4855	60	0.215	0.420	-0.135	0.176	-0.011	0.377
4729	18	0.000	0.000	1.000	0.000	0.000	0.000
4734	23	0.188	0.335	0.951	-0.107	-0.149	-0.139
4730	19	0.004	0.219	0.949	0.028	-0.022	-0.055
4723	12	0.009	0.186	0.940	-0.038	-0.139	0.143
4727	16	-0.114	0.162	0.913	-0.122	0.346	-0.050

APPENDIX II-D CONT.

Q MODE ANALYSIS OF BUCK TONGUE OF THE MANCOS SHALE

REORDERED OBLIQUE PROJECTION MATRIX

West Salt Creek and Crescent Wash

NAME	4751	4844	4729	4712	4720	4733
INDEX	40	51	18	1	9	22
4728 17	0.012	-0.116	0.868	-0.112	0.250	0.194
4722.11	0.329	0.178	0.859	-0.102	-0.207	-0.029
4724 13	-0.019	-0.062	0.767	-0.183	0.045	0.515
4732 21	0.285	0.142	0.682	0.109	0.003	-0.113
4731 20	0.429	0.022	0.598	0.126	-0.009	-0.091
4712 1	0.000	0.000	0.000	1.000	0.000	0.000
4714 3	0.176	0.214	0.010	0.864	-0.019	-0.201
4715 4	-0.051	0.062	-0.059	0.759	0.085	0.260
4720 9	0.000	0.000	0.000	0.000	1.000	0.000
4725 14	0.240	0.063	0.215	-0.042	0.866	-0.109
4726 15	-0.191	-0.169	0.543	-0.220	0.703	0.451
4721 10	0.263	-0.043	0.419	0.126	0.538	-0.106
4733 22	0.000	0.000	0.000	0.000	0.000	1.000
4719 8	-0.073	-0.132	0.338	0.083	-0.089	0.965
4717 6	-0.382	-0.184	0.389	0.279	0.172	0.835
4718 7	-0.165	0.365	-0.047	0.114	-0.199	0.827
4716 5	-0.258	-0.154	0.021	0.655	0.032	0.683
4850 55	0.078	0.410	0.106	-0.051	-0.034	0.607

APPENDIX II-E

Q MODE ANALYSIS OF BUCK TONGUE OF THE MANCOS SHALE

REORDERED OBLIQUE PROJECTION MATRIX

Westwater Wash and Cottonwood Creek

NAME		4764	4828	4815	4804	4812	4788
INDEX		9	63	50	39	47	24
4764	9	1.000	0.000	0.000	0.000	0.000	0.000
4795	31	0.977	-0.559	-0.044	0.132	-0.100	0.575
4763	8	0.951	-0.233	-0.313	-0.152	0.332	0.399
4798	34	0.887	-0.025	-0.290	0.310	-0.169	0.275
4758	3	0.859	-0.114	0.081	-0.007	0.090	0.142
4802	37	0.846	0.294	0.155	-0.083	-0.275	0.077
4797	33	0.740	0.057	0.199	-0.158	0.240	-0.012
4761	6	0.736	-0.097	-0.311	-0.343	0.270	0.611
4810	45	0.695	0.092	-0.320	0.063	0.204	0.264
4800	35	0.687	-0.085	-0.226	0.203	0.216	0.215
4801	36	0.683	0.109	-0.035	0.318	-0.141	0.133
4760	5	0.671	-0.377	-0.000	-0.045	0.316	0.452
4818	53	0.611	0.346	0.158	-0.112	-0.089	0.142
4807	42	0.548	-0.114	0.418	0.215	0.129	-0.152
4828	63	0.000	1.000	0.000	0.000	0.000	0.000
4827	62	0.060	0.886	0.552	-0.272	-0.167	0.019
4829	64	0.029	0.816	0.341	-0.046	-0.162	0.121
4767	12	-0.310	0.805	0.351	0.113	-0.158	0.249
4766	11	0.223	0.755	0.484	0.005	-0.201	-0.150
4824	59	0.426	0.724	0.409	-0.087	-0.486	0.060
4826	61	0.454	0.710	-0.096	-0.064	-0.051	0.078
4822	57	0.372	0.636	0.205	0.120	-0.149	-0.093
4791	27	-0.324	0.616	-0.055	-0.079	0.395	0.320
4780	17	0.088	0.596	0.277	0.224	-0.248	0.148
4821	56	0.149	0.557	0.018	0.032	0.244	0.083
4825	60	0.425	0.538	0.054	-0.021	-0.143	0.234
4781	18	0.103	0.505	0.011	-0.043	0.236	0.250
4805	40	0.417	0.488	0.238	0.100	-0.038	-0.141
4820	55	-0.131	0.456	0.062	0.167	0.352	0.142
4819	54	0.363	0.414	0.134	0.107	-0.188	0.248
4815	50	0.000	0.000	1.000	0.000	0.000	0.000
4792	28	-0.357	0.441	0.810	0.239	0.018	-0.046
4768	13	0.483	0.046	0.806	0.545	-0.471	-0.536
4777	15	-0.435	0.776	0.796	0.492	-0.628	0.043
4806	41	0.460	0.358	0.678	0.466	-0.654	-0.253
4789	25	-0.147	0.093	0.643	0.039	-0.080	0.498
4808	43	0.578	-0.214	0.601	0.258	0.020	-0.155
4793	29	-0.232	0.042	0.574	-0.132	0.280	0.499
4813	48	0.325	0.107	0.558	0.209	-0.116	0.024
4814	49	0.543	-0.129	0.545	0.080	0.223	-0.238
4769	14	-0.089	0.402	0.436	0.067	0.016	0.261
4804	39	0.000	0.000	0.000	1.000	0.000	0.000
4796	32	0.074	-0.272	0.048	0.858	0.235	0.124

APPENDIX II-E CONT.

Q MODE ANALYSIS OF BUCK TONGUE OF THE MANCOS SHALE

REORDERED OBLIQUE PROJECTION MATRIX

Westwater Wash and Cottonwood Creek

NAME		4764	4828	4815	4804	4812	4788
INDEX		9	63	50	39	47	24
4759	4	0.105	0.343	0.487	0.846	-0.545	-0.224
4765	10	0.294	-0.144	0.282	0.690	0.235	-0.323
4803	38	0.165	0.234	-0.178	0.640	0.070	0.061
4812	47	0.000	0.000	0.000	0.000	1.000	0.000
4756	1	0.393	-0.303	-0.618	0.118	0.797	0.568
4757	2	0.411	0.003	0.404	-0.489	0.675	-0.013
4809	44	0.340	0.271	-0.083	-0.287	0.545	0.240
4823	58	-0.437	0.496	-0.120	0.253	0.540	0.278
4816	51	0.304	-0.017	0.371	0.143	0.376	-0.091
4788	24	0.000	0.000	0.000	0.000	0.000	1.000
4762	7	0.610	-0.396	-0.547	0.095	0.410	0.808
4786	22	0.092	0.183	-0.006	0.015	-0.014	0.766
4811	46	-0.129	0.024	-0.165	0.269	0.358	0.678
4783	20	0.044	0.184	-0.258	0.064	0.353	0.666
4784	21	0.026	0.273	0.264	0.199	-0.378	0.646
4782	19	-0.084	0.279	0.330	0.164	-0.191	0.551
4779	16	0.497	-0.267	0.516	0.023	-0.023	-0.325
4790	26	0.170	0.280	0.266	-0.026	-0.145	0.505
4787	23	0.197	0.407	-0.108	0.115	0.012	0.437
4817	52	0.345	0.150	-0.095	0.213	0.096	0.350

APPENDIX II-F

Q MODE ANALYSIS OF BUCK TONGUE OF THE MANCOS SHALE

OBLIQUE PROJECTION PROGRAM

West Salt Creek and Tuscher Wash

NAME		4751	4720	4712	4729	4744	4718
	INDEX	40	9	1	18	33	7
4712	1	0.000	0.000	1.000	0.000	0.000	0.000
4713	2	0.209	0.595	0.545	-0.412	-0.118	0.019
4714	3	0.254	0.059	0.867	-0.078	-0.059	-0.062
4715	4	0.070	0.218	0.672	-0.081	-0.050	0.251
4716	5	-0.244	0.078	0.503	0.142	0.139	0.548
4717	6	-0.338	0.277	0.082	0.524	0.132	0.647
4718	7	0.000	0.000	0.000	0.000	0.000	1.000
4719	8	0.051	0.067	-0.171	0.493	-0.023	0.834
4720	9	0.000	1.000	0.000	0.000	0.000	0.000
4721	10	0.272	0.534	0.155	0.405	-0.026	-0.186
4722	11	0.320	-0.161	-0.169	0.821	0.172	0.153
4723	12	0.058	-0.066	-0.076	0.921	0.037	0.263
4724	13	0.008	0.116	-0.349	0.825	0.140	0.521
4725	14	0.272	0.894	-0.022	0.161	0.000	-0.090
4726	15	-0.132	0.752	-0.293	0.605	-0.015	0.265
4727	16	-0.111	0.350	-0.065	0.865	0.015	0.077
4728	17	0.010	0.247	-0.166	0.908	0.062	0.111
4729	18	0.000	0.000	0.000	1.000	0.000	0.000
4730	19	0.016	0.019	0.038	0.889	0.090	0.111
4731	20	0.454	0.009	0.068	0.569	0.041	-0.046
4732	21	0.334	0.076	0.044	0.622	0.056	0.002
4733	22	0.098	0.150	-0.174	0.137	0.015	0.948
4734	23	0.215	-0.095	-0.114	0.868	0.081	0.158
4735	24	0.851	0.015	0.156	0.215	0.018	-0.304
4736	25	0.533	-0.062	0.106	0.300	0.138	0.164
4737	26	0.605	0.049	0.184	0.299	0.126	-0.065
4738	27	0.988	0.031	0.098	0.074	0.091	-0.277
4739	28	0.791	-0.186	0.071	0.405	0.106	-0.219
4740	29	0.537	-0.019	-0.488	0.429	0.124	0.620
4741	30	0.783	-0.211	0.045	0.317	0.006	-0.000
4742	31	0.823	-0.038	0.316	0.061	-0.024	-0.089
4743	32	0.649	-0.031	-0.351	0.521	0.149	0.204
4744	33	0.000	0.000	0.000	0.000	1.000	0.000
4745	34	-0.223	0.088	0.106	0.026	0.973	0.046
4746	35	0.824	-0.176	-0.285	0.398	0.083	0.146
4747	36	0.773	-0.076	0.130	0.308	-0.012	-0.129
4748	37	0.799	-0.091	-0.202	0.325	0.188	0.140
4749	38	0.961	-0.120	0.023	0.102	0.023	-0.024
4750	39	0.826	-0.079	-0.209	0.313	0.035	0.193
4751	40	1.000	0.000	0.000	0.000	0.000	0.000
4752	41	0.957	-0.168	-0.139	0.102	-0.004	0.221
4753	42	0.923	-0.160	-0.152	0.052	0.045	0.270

APPENDIX II-F CONT.

Q MODE ANALYSIS OF BUCK TONGUE OF THE MANCOS SHALE

OBLIQUE PROJECTION PROGRAM

West Salt Creek and Tuscher Wash

NAME	4751	4720	4712	4729	4744	4718
INDEX	40	9	1	18	33	7
4754 43	0.757	-0.034	-0.018	0.044	0.012	0.334
4755 44	0.877	0.020	0.097	0.001	0.073	0.000
4861 45	-0.166	-0.488	0.479	0.623	0.065	0.450
4862 46	-0.024	-0.321	0.299	0.430	0.036	0.654
4863 47	0.032	-0.404	0.472	0.310	0.024	0.539
4865 48	-0.289	-0.275	0.651	0.256	0.166	0.549
4866 49	-0.077	-0.132	0.407	0.206	0.146	0.621
4867 50	-0.051	-0.335	0.513	0.423	0.041	0.444
4868 51	-0.442	-0.260	0.547	0.303	0.367	0.611
4869 52	0.007	-0.254	0.564	0.255	0.156	0.382
4870 53	0.199	-0.108	0.447	-0.008	0.181	0.464
4871 54	0.411	-0.368	0.337	0.334	-0.014	0.290
4872 55	0.682	-0.226	-0.030	0.188	0.080	0.356
4873 56	0.423	-0.205	0.322	0.224	0.029	0.320
4874 57	0.524	-0.194	0.361	0.132	0.096	0.201
4875 58	0.107	-0.264	0.187	0.310	0.253	0.613
4876 59	0.311	-0.213	0.354	0.078	0.174	0.483
4877 60	0.553	-0.069	0.140	0.100	0.090	0.372

APPENDIX II-G

Q MODE ANALYSIS OF BUCK TONGUE OF THE MANCOS SHALE

OBLIQUE PROJECTION PROGRAM

West Salt Creek below Buck tongue, West
Salt Creek Buck tongue and Tuscher Wash

NAME	4738	4712	4729	4720	4718	4705
INDEX	31	5	22	13	11	1
4705 1	0.000	0.000	0.000	0.000	0.000	1.000
4706 2	-0.127	0.036	0.167	-0.088	0.636	0.510
4707 3	0.063	-0.082	0.450	-0.220	0.886	0.039
4708 4	0.187	0.614	-0.371	0.444	0.234	-0.100
4712 5	0.000	1.000	0.000	0.000	0.000	0.000
4713 6	0.103	0.541	-0.319	0.588	0.182	-0.176
4714 7	0.183	0.816	-0.016	0.038	0.080	-0.069
4715 8	-0.011	0.670	0.063	0.175	0.364	-0.177
4716 9	-0.129	0.488	-0.027	0.130	0.375	0.283
4717 10	-0.275	0.083	0.480	0.297	0.519	0.152
4718 11	0.000	0.000	0.000	0.000	1.000	0.000
4719 12	0.004	-0.190	0.532	0.059	0.887	-0.019
4720 13	0.000	0.000	0.000	1.000	0.000	0.000
4721 14	0.161	0.147	0.616	0.459	0.032	-0.279
4722 15	0.396	-0.190	0.707	-0.144	0.199	0.108
4723 16	0.065	-0.065	0.913	-0.060	0.290	-0.018
4724 17	0.182	-0.375	0.496	0.204	0.315	0.424
4725 18	0.260	-0.035	0.168	0.880	-0.001	-0.052
4726 19	-0.120	-0.283	0.583	0.760	0.199	0.047
4727 20	0.007	-0.079	0.619	0.426	-0.111	0.307
4728 21	0.060	-0.182	0.826	0.263	0.060	0.124
4729 22	0.000	0.000	1.000	0.000	0.000	0.000
4730 23	0.101	0.029	0.745	0.061	0.038	0.170
4731 24	0.445	0.047	0.580	-0.016	0.102	-0.077
4732 25	0.293	0.006	0.677	0.045	0.161	-0.068
4733 26	0.079	-0.184	0.147	0.144	0.989	-0.002
4734 27	0.331	-0.129	0.632	-0.034	0.081	0.237
4735 28	0.696	0.058	0.450	-0.097	0.135	-0.300
4736 29	0.572	0.028	0.234	-0.075	0.309	0.075
4737 30	0.626	0.142	0.276	0.025	0.124	-0.044
4738 31	1.000	0.000	0.000	0.000	0.000	0.000
4739 32	0.774	-0.025	0.401	-0.226	0.051	-0.024
4740 33	0.588	-0.568	0.286	-0.000	0.731	0.164
4741 34	0.657	-0.036	0.497	-0.301	0.378	-0.254
4742 35	0.749	0.244	0.123	-0.090	0.225	-0.165
4743 36	0.592	-0.405	0.679	-0.105	0.545	-0.188
4744 37	0.581	-0.075	0.563	-0.182	0.572	-0.381
4745 38	0.564	-0.324	0.717	-0.273	0.626	-0.281
4746 39	0.704	-0.368	0.593	-0.272	0.558	-0.267

APPENDIX II-G CONT.

Q MODE ANALYSIS OF BUCK TONGUE OF THE MANCOS SHALE

OBLIQUE PROJECTION PROGRAM

West Salt Creek below Buck tongue, West
Salt Creek Buck tongue and Tuscher Wash

NAME		4738	4712	4729	4720	4718	4705
INDEX		31	5	22	13	11	1
4747	40	0.584	0.073	0.620	-0.201	0.328	-0.427
4748	41	0.823	-0.291	0.279	-0.118	0.394	0.019
4749	42	0.845	-0.059	0.256	-0.213	0.386	-0.253
4750	43	0.651	-0.290	0.593	-0.198	0.658	-0.360
4751	44	0.904	-0.093	0.088	-0.073	0.383	-0.181
4752	45	0.840	-0.225	0.238	-0.250	0.626	-0.240
4753	46	0.894	-0.240	0.032	-0.203	0.552	-0.043
4754	47	0.756	-0.076	-0.020	-0.054	0.529	-0.013
4755	48	0.977	0.046	-0.231	0.045	0.123	0.127
4861	49	0.011	0.478	0.301	-0.393	0.180	0.309
4862	50	-0.006	0.265	0.386	-0.311	0.628	0.110
4863	51	0.146	0.484	0.094	-0.351	0.381	0.233
4865	52	-0.088	0.687	-0.013	-0.200	0.257	0.342
4866	53	0.049	0.402	0.013	-0.081	0.479	0.261
4867	54	0.083	0.511	0.184	-0.273	0.252	0.284
4868	55	-0.025	0.550	-0.351	-0.068	0.056	0.862
4869	56	0.147	0.555	0.036	-0.199	0.247	0.276
4870	57	0.382	0.431	-0.288	-0.054	0.329	0.314
4871	58	0.437	0.289	0.243	-0.368	0.348	0.076
4872	59	0.587	-0.098	0.344	-0.306	0.688	-0.204
4873	60	0.500	0.280	0.064	-0.189	0.331	0.143
4874	61	0.691	0.300	-0.209	-0.127	0.142	0.344
4875	62	0.434	0.145	-0.248	-0.124	0.282	0.675
4876	63	0.483	0.298	-0.225	-0.153	0.386	0.367
4877	64	0.604	0.062	-0.026	-0.069	0.464	0.148

APPENDIX II-H

Q MODE ANALYSIS OF BUCK TONGUE OF THE MANCOS SHALE

OBLIQUE PROJECTION PROGRAM

Cottonwood Creek and Tuscher Wash

NAME		4824	4861	4815	4872	4804	4807
INDEX		30	36	21	46	10	13
4794	1	0.010	-0.025	0.454	0.114	0.642	-0.135
4795	2	0.146	-0.373	0.255	0.344	0.236	0.433
4796	3	-0.182	-0.094	0.246	0.160	0.823	0.131
4797	4	0.185	-0.080	0.076	0.485	-0.224	0.650
4798	5	0.497	-0.274	-0.303	0.307	0.383	0.394
4800	6	0.289	0.128	-0.476	0.009	0.283	0.778
4801	7	0.497	-0.174	-0.086	0.189	0.379	0.261
4802	8	0.622	-0.215	-0.150	0.358	-0.155	0.545
4803	9	0.403	0.253	-0.406	-0.202	0.781	0.141
4804	10	0.000	0.000	0.000	0.000	1.000	0.000
4805	11	0.312	0.002	0.003	0.459	-0.012	0.323
4806	12	0.500	-0.330	0.283	0.004	0.245	0.277
4807	13	0.000	0.000	0.000	0.000	0.000	1.000
4808	14	0.026	0.366	0.658	0.298	0.085	0.378
4809	15	0.414	0.288	-0.098	0.305	-0.130	0.295
4810	16	0.399	-0.173	-0.112	0.601	0.154	0.196
4811	17	0.168	0.439	0.044	-0.102	0.795	-0.240
4812	18	-0.045	0.527	0.184	-0.016	0.338	0.073
4813	19	0.295	0.017	0.338	-0.083	0.288	0.226
4814	20	-0.046	-0.017	0.432	0.069	-0.003	0.586
4815	21	0.000	0.000	1.000	0.000	0.000	0.000
4816	22	-0.147	0.068	0.335	0.266	0.114	0.480
4817	23	0.425	0.361	-0.344	-0.260	0.528	0.356
4818	24	0.551	0.093	-0.275	0.066	-0.115	0.717
4819	25	0.763	0.045	-0.065	0.012	0.273	0.035
4820	26	0.557	0.622	-0.251	-0.438	0.501	0.035
4821	27	0.493	0.428	-0.310	0.030	0.292	0.158
4822	28	0.763	0.180	-0.211	-0.035	0.201	0.162
4823	29	0.450	0.586	-0.051	-0.032	0.609	-0.515
4824	30	1.000	0.000	0.000	0.000	0.000	0.000
4825	31	0.745	0.121	-0.260	0.112	0.115	0.243
4826	32	0.816	0.402	-0.645	-0.133	0.146	0.421
4827	33	0.860	0.541	-0.166	-0.337	-0.138	0.260
4828	34	0.967	0.594	-0.685	-0.226	0.122	0.179
4829	35	0.839	0.328	-0.202	-0.106	0.014	0.176
4861	36	0.000	1.000	0.000	0.000	0.000	0.000
4862	37	0.098	0.581	-0.085	0.143	-0.164	0.492
4863	38	-0.129	0.730	-0.005	0.137	0.582	-0.238
4865	39	-0.380	0.683	0.296	-0.176	0.699	-0.065
4866	40	-0.299	0.429	0.103	-0.006	0.574	0.290
4867	41	-0.225	0.789	0.076	0.216	0.140	0.046
4868	42	-0.254	0.578	0.627	-0.328	0.705	-0.297
4869	43	0.046	0.729	0.143	-0.101	0.578	-0.321

APPENDIX II-H CONT.

Q MODE ANALYSIS OF BUCK TONGUE OF THE MANCOS SHALE

OBLIQUE PROJECTION PROGRAM

Cottonwood Creek and Tuscher Wash

NAME	4824	4861	4815	4872	4804	4807
INDEX	30	36	21	46	10	13
4870 44	-0.127	0.200	0.470	0.400	0.671	-0.494
4871 45	-0.171	0.500	-0.057	0.668	0.190	-0.072
4872 46	0.000	0.000	0.000	1.000	0.000	0.000
4873 47	-0.368	0.196	0.267	0.837	0.240	-0.066
4874 48	-0.335	-0.028	0.646	0.988	0.228	-0.389
4875 49	-0.083	0.130	0.655	0.577	0.218	-0.373
4876 50	-0.172	-0.016	0.597	0.709	0.367	-0.306
4877 51	0.160	-0.115	0.540	0.855	-0.056	-0.280

APPENDIX II-I

Q MODE ANALYSIS OF BUCK TONGUE OF THE MANCOS SHALE

OBLIQUE PROJECTION PROGRAM

West Salt Creek and Crescent Wash

NAME		4751	4844	4729	4712	4720	4733
	INDEX	40	51	18	1	9	22
4712	1	0.000	0.000	0.000	1.000	0.000	0.000
4713	2	0.065	0.654	-0.223	0.504	0.422	-0.442
4714	3	0.176	0.214	0.010	0.864	-0.019	-0.201
4715	4	-0.051	0.062	-0.059	0.759	0.085	0.260
4716	5	-0.258	-0.154	0.021	0.655	0.032	0.683
4717	6	-0.382	-0.184	0.389	0.279	0.172	0.835
4718	7	-0.165	0.365	-0.047	0.114	-0.199	0.827
4719	8	-0.073	-0.132	0.338	0.083	-0.089	0.965
4720	9	0.000	0.000	0.000	0.000	1.000	0.000
4721	10	0.263	-0.043	0.419	0.126	0.538	-0.106
4722	11	0.329	0.178	0.859	-0.102	-0.207	-0.029
4723	12	0.009	0.186	0.940	-0.038	-0.139	0.143
4724	13	-0.019	-0.062	0.767	-0.183	0.045	0.515
4725	14	0.240	0.063	0.215	-0.042	0.866	-0.109
4726	15	-0.191	-0.169	0.543	-0.220	0.703	0.451
4727	16	-0.114	0.162	0.913	-0.122	0.346	-0.050
4728	17	0.012	-0.116	0.868	-0.112	0.250	0.194
4729	18	0.000	0.000	1.000	0.000	0.000	0.000
4730	19	0.004	0.219	0.949	0.028	-0.022	-0.055
4731	20	0.429	0.022	0.598	0.126	-0.009	-0.091
4732	21	0.285	0.142	0.682	0.109	0.003	-0.113
4733	22	0.000	0.000	0.000	0.000	0.000	1.000
4734	23	0.188	0.335	0.951	-0.107	-0.149	-0.139
4735	24	0.797	-0.057	0.269	0.228	-0.043	-0.230
4736	25	0.472	0.187	0.358	0.196	-0.170	0.041
4737	26	0.574	0.461	0.453	0.124	-0.021	-0.391
4738	27	0.961	0.369	0.238	0.034	-0.001	-0.551
4739	28	0.788	0.174	0.499	0.097	-0.221	-0.381
4740	29	0.463	0.238	0.410	-0.357	-0.161	0.463
4741	30	0.730	-0.181	0.282	0.179	-0.254	0.140
4742	31	0.777	0.255	0.155	0.264	-0.072	-0.266
4743	32	0.616	-0.085	0.505	-0.121	-0.143	0.258
4744	33	0.674	-0.149	0.219	0.167	-0.156	0.284
4745	34	0.616	-0.028	0.473	-0.085	-0.292	0.285
4746	35	0.778	-0.120	0.352	-0.106	-0.244	0.224
4747	36	0.706	-0.051	0.334	0.223	-0.156	-0.060
4748	37	0.789	0.112	0.357	-0.113	-0.158	0.049
4749	38	0.949	-0.149	0.087	0.094	-0.133	0.074
4750	39	0.766	-0.095	0.266	-0.056	-0.164	0.285
4751	40	1.000	0.000	0.000	0.000	0.000	0.000
4752	41	0.898	-0.013	0.076	-0.044	-0.233	0.239
4753	42	0.884	-0.022	0.024	-0.059	-0.209	0.276
4754	43	0.732	0.109	0.033	-0.016	-0.069	0.262

APPENDIX II-I CONT.

Q MODE ANALYSIS OF BUCK TONGUE OF THE MANCOS SHALE

OBLIQUE PROJECTION PROGRAM

West Salt Creek and Crescent Wash

NAME	4751	4844	4729	4712	4720	4733
INDEX	40	51	18	1	9	22
4755 44	0.879	0.429	0.140	-0.014	0.018	-0.360
4837 45	0.044	0.825	0.047	-0.028	0.047	0.060
4838 46	0.050	0.521	0.082	0.050	0.037	0.430
4839 47	-0.002	0.979	0.036	0.035	0.073	-0.037
4841 48	0.092	0.954	0.047	-0.099	-0.018	0.070
4842 49	0.036	0.847	0.108	-0.263	0.178	0.190
4843 50	-0.014	0.784	0.055	0.052	-0.027	0.239
4844 51	0.000	1.000	0.000	0.000	0.000	0.000
4845 52	-0.138	0.923	0.059	0.084	-0.066	0.133
4846 53	-0.135	0.847	0.157	-0.007	-0.017	0.241
4847 54	0.001	0.599	-0.006	0.577	0.042	-0.113
4850 55	0.078	0.410	0.106	-0.051	-0.034	0.607
4851 56	-0.010	0.804	-0.075	0.203	0.183	0.011
4852 57	0.148	0.851	0.070	-0.140	0.309	-0.051
4853 58	-0.004	0.707	-0.020	0.071	0.339	0.123
4854 59	0.099	0.817	-0.119	-0.003	0.144	0.154
4855 60	0.215	0.420	-0.135	0.176	-0.011	0.377
4856 61	0.226	0.511	-0.075	0.069	0.185	0.266

APPENDIX II-J

Q MODE ANALYSIS OF BUCK TONGUE OF THE MANCOS SHALE

OBLIQUE PROJECTION PROGRAM

Westwater Wash and Cottonwood Creek

NAME		4764	4828	4815	4804	4812	4788
INDEX		9	63	50	39	47	24
4756	1	0.393	-0.303	-0.618	0.118	0.797	0.568
4757	2	0.411	0.003	0.404	-0.489	0.675	-0.013
4758	3	0.859	-0.114	0.081	-0.007	0.090	0.142
4759	4	0.105	0.343	0.487	0.846	-0.545	-0.224
4760	5	0.671	-0.377	-0.000	-0.045	0.316	0.452
4761	6	0.736	-0.097	-0.311	-0.343	0.270	0.611
4762	7	0.610	-0.396	-0.547	0.095	0.410	0.808
4763	8	0.951	-0.233	-0.313	-0.152	0.332	0.399
4764	9	1.000	0.000	0.000	0.000	0.000	0.000
4765	10	0.294	-0.144	0.282	0.690	0.235	-0.323
4766	11	0.223	0.755	0.484	0.005	-0.201	-0.150
4767	12	-0.310	0.805	0.351	0.113	-0.158	0.249
4768	13	0.483	0.046	0.806	0.545	-0.471	-0.536
4769	14	-0.089	0.402	0.436	0.067	0.016	0.261
4777	15	-0.435	0.776	0.796	0.492	-0.628	0.043
4779	16	0.497	-0.267	0.516	0.023	-0.325	0.535
4780	17	0.088	0.596	0.277	0.224	-0.248	0.148
4781	18	0.103	0.505	0.011	-0.043	0.236	0.250
4782	19	-0.084	0.279	0.330	0.164	-0.191	0.551
4783	20	0.044	0.184	-0.258	0.064	0.353	0.666
4784	21	0.026	0.273	0.264	0.199	-0.378	0.646
4786	22	0.092	0.183	-0.006	0.015	-0.014	0.766
4787	23	0.197	0.407	-0.108	0.115	0.012	0.437
4788	24	0.000	0.000	0.000	0.000	0.000	1.000
4789	25	-0.147	0.093	0.643	0.039	-0.080	0.498
4790	26	0.170	0.280	0.266	-0.026	-0.145	0.505
4791	27	-0.324	0.616	-0.055	0.079	0.395	0.320
4792	28	-0.357	0.441	0.810	0.239	0.018	-0.046
4793	29	-0.232	0.042	0.574	-0.132	0.280	0.499
4794	30	0.206	-0.457	-0.014	0.418	0.255	0.584
4795	31	0.977	-0.559	-0.044	0.132	-0.100	0.575
4796	32	0.074	-0.272	0.048	0.858	0.235	0.124
4797	33	0.740	0.057	0.199	-0.158	0.240	-0.012
4798	34	0.887	-0.025	-0.290	0.310	-0.169	0.275
4800	35	0.687	-0.085	-0.226	0.203	0.216	0.215
4801	36	0.683	0.109	-0.035	0.318	-0.141	0.133
4802	37	0.846	0.294	0.155	-0.083	-0.275	0.077
4803	38	0.165	0.234	-0.178	0.640	0.070	0.061
4804	39	0.000	0.000	0.000	1.000	0.000	0.000
4805	40	0.417	0.488	0.238	0.100	-0.038	-0.141
4806	41	0.460	0.358	0.678	0.466	-0.654	-0.253
4807	42	0.548	-0.114	0.418	0.215	0.129	-0.152
4808	43	0.578	-0.214	0.601	0.258	0.020	-0.155

APPENDIX II-J CONT.

Q MODE ANALYSIS OF BUCK TONGUE OF THE MANCOS SHALE

OBLIQUE PROJECTION PROGRAM

Westwater Wash and Cottonwood Creek

NAME	4764	4828	4815	5804	4812	4788
INDEX	9	63	50	39	47	24
4809 44	0.340	0.271	-0.083	-0.287	0.545	0.240
4810 45	0.695	0.092	-0.320	0.063	0.204	0.264
4811 46	-0.129	0.024	-0.165	0.269	0.358	0.678
4812 47	0.000	0.000	0.000	0.000	1.000	0.000
4813 48	0.325	0.107	0.558	0.209	-0.116	0.024
4814 49	0.543	-0.129	0.545	0.080	0.223	-0.238
4815 50	0.000	0.000	1.000	0.000	0.000	0.000
4816 51	0.304	-0.017	0.371	0.143	0.376	-0.091
4817 52	0.345	0.150	-0.095	0.213	0.096	0.350
4818 53	0.611	0.346	0.158	-0.112	-0.089	0.142
4819 54	0.363	0.414	0.134	0.107	-0.188	0.248
4820 55	-0.131	0.456	0.062	0.167	0.352	0.142
4821 56	0.149	0.557	0.018	0.032	0.244	0.083
4822 57	0.372	0.636	0.205	0.120	-0.149	-0.093
4823 58	-0.437	0.496	-0.120	0.253	0.540	0.278
4824 59	0.426	0.724	0.409	-0.087	-0.486	0.060
4825 60	0.425	0.538	0.054	-0.021	-0.143	0.234
4826 61	0.454	0.710	-0.096	-0.064	-0.051	0.078
4827 62	0.060	0.886	0.552	-0.272	-0.167	0.019
4828 63	0.000	1.000	0.000	0.000	0.000	0.000
4829 64	0.029	0.816	0.341	-0.046	-0.162	0.121

PLATES

PLATE 1

Figure	1	Acanthotriletes varispinosus Pocock	1000X
Figures	2, 3	Acanthotriletes levidensis Balme	1000X
Figure	4	Apiculatisporis cf. A. ferox Muller	1000X
Figures	5, 6	Appendicisporites potomacensis Brenner	1000X
Figure	7	Appendicisporites sp. A	1000X
Figure	8	Appendicisporites sp. B	750X
Figure	9	Camarozonosporites insignis Norris	1000X
Figure	10	Balmeisporites holodictyus Cookson & Dettmann	500X
Figures	11, 12	Biretisporites potoniaei Delcourt & Sprumont	1000X
Figures	13, 14	Biretisporites cf. B. psilatus (Groot & Penny) Dettmann	1000X
Figure	15	Biretisporites spectabilis Dettmann	750X

PLATE 1

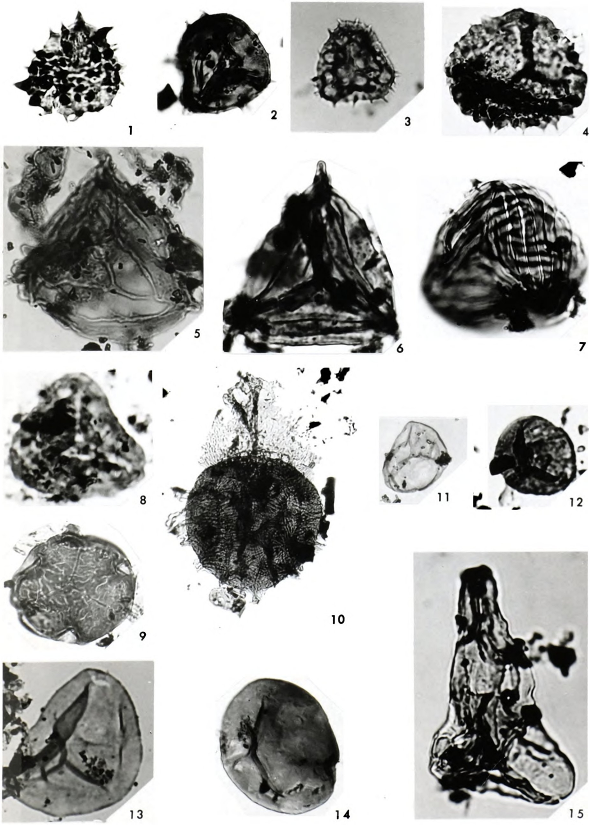

PLATE 2

Figure 1	Cingulatisporites cf. C. pseudoalveolatus Couper	1000X
Figure 2	Cicatricosisporites dorogensis Potonie & Gelletich	1000X
Figure 3	Cingultriletes cf. C. clavus (Balme) Dettmann	1000X
Figures 4, 7	Cicatricosisporites cf. C. brevilaesuratus Couper	1000X
Figures 5, 6	Distaverrusporites simplex Muller	1000X
	5--proximal view 6--distal view	
Figure 8	Deltoidospora psilostoma Rouse	1000X
Figures 9, 11	Deltoidospora hallii Minor	1000X
Figure 10	Cyathidites minor Couper	1000X
Figure 12	Cyathidites australis Couper	1000X

PLATE 2

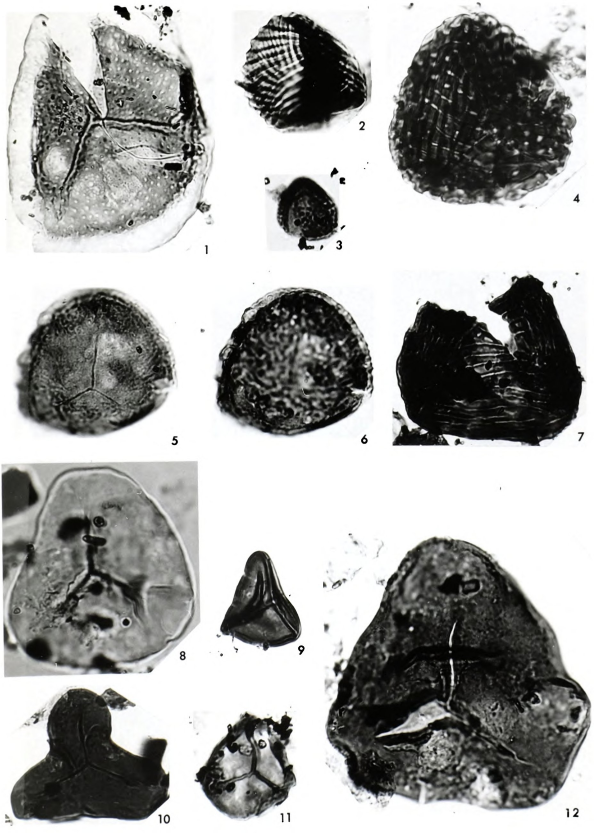

PLATE 3

Figures	1, 2	Distaverrusporites verrucatus (Couper) nov. comb.	1000X
		1--proximal view 2--distal view	
Figure	3	Echinatisporis cf. E. longechinus Krutzsch	1000X
Figure	4	Gleicheniidites cercinidites (Cookson) Dettmann	1000X
Figures	5, 6	Gleicheniidites senonicus (Delcourt & Sprumont) Skarby	1000X
Figure	7	Gleicheniidites sp.	1000X
Figures	8, 9	Hamulatisporis hamulatis Krutzsch	1000X
		8--proximal view 9--distal view	
Figure	10	Foveasporis triangulus Stanley	1000X
Figure	11	Klukisporites variegatus Couper	1000X
Figure	12	Leiotriletes pseudomaximus (Pflug & Thomson) Stanley	750X
Figure	13	Lycopodiumsporites marginatus Singh	750X
Figure	14	Osmundacidites cf. O. alpina Klaus	1000X
Figure	15	Osmundacidites cf. O. senectus Balme	750X
Figure	16	Osmundacidites sp.	1000X
Figure	17	Matonisporites cf. M. equiexinus Couper	750X

PLATE 3

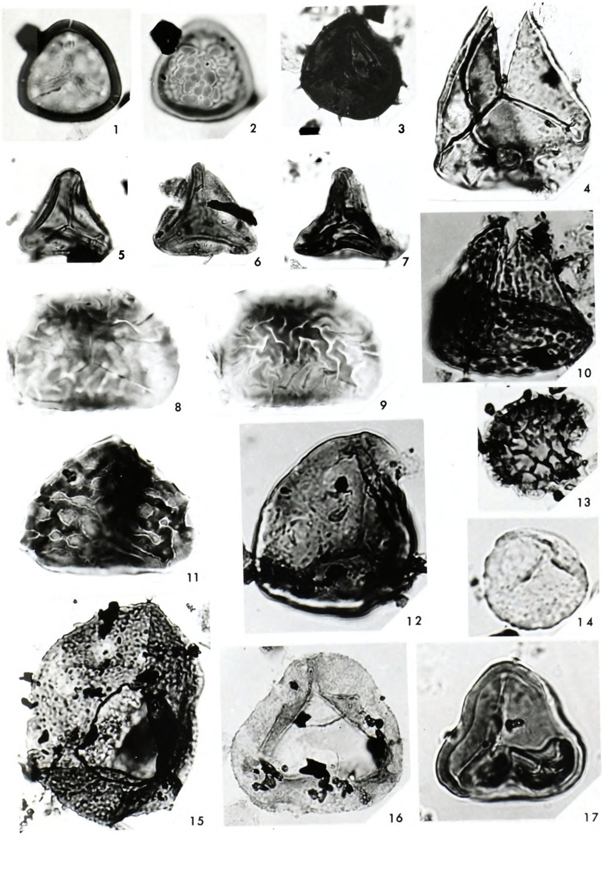

PLATE 4

Figure 1	*Trilites* cf. *T. tuberculiformis* Cookson	1000X
Figures 2, 3	*Stereisporites antiquasporites* (Wilson & Webster) Dettmann	1000X
Figures 4, 5	*Stereisporites* cf. *S. minor* (Raatz) Krutzsch sbsp. *minor* Krutzsch	1000X
Figure 6	*Rugutriletes* cf. *R. toratus* Pierce	1000X
Figure 7	*Todisporites minor* Couper	1000X
Figures 8, 9	*Toroisporis* sp.	1000X
Figures 10, 11	*Triplanosporites microsinuosus* Pflanzl	1000X
Figures 12, 13	*Triplanosporites sinuosus* Pflug 12--1000X 13--750X	
Figures 14, 15	*Triplanosporites* sp.	1000X
Figure 16	*Osmundacidites wellmanii* Couper	1000X
Figure 17	*Laevigatosporites anomalus* Norton	1000X
Figure 18	*Laevigatosporites haardti* (Potonie & Venitz) Thomson & Pflug	1000X
Figure 19	*Laevigatosporites gracilis* (Ibrahim) Ibrahim	1000X
Figure 20	*Laevigatosporites ovatus* Wilson & Webster	1000X
Figure 21	*Microfoveolatosporis neogranuloides* Krutzsch	1000X
Figure 22	*Verrucatosporites megabalticus* Krutzsch	1000X
Figure 23	*Polypodiidites senonicus* Ross	1000X
Figure 24	*Perinomonoletes* cf. *P. pipliocaenicus* Krutzsch	1000X
Figure 25	*Polypodiidites secundus* (Potonie) Krutzsch	1250X
Figure 26	*Umbosporites callosus* Newman	1000X

PLATE 4

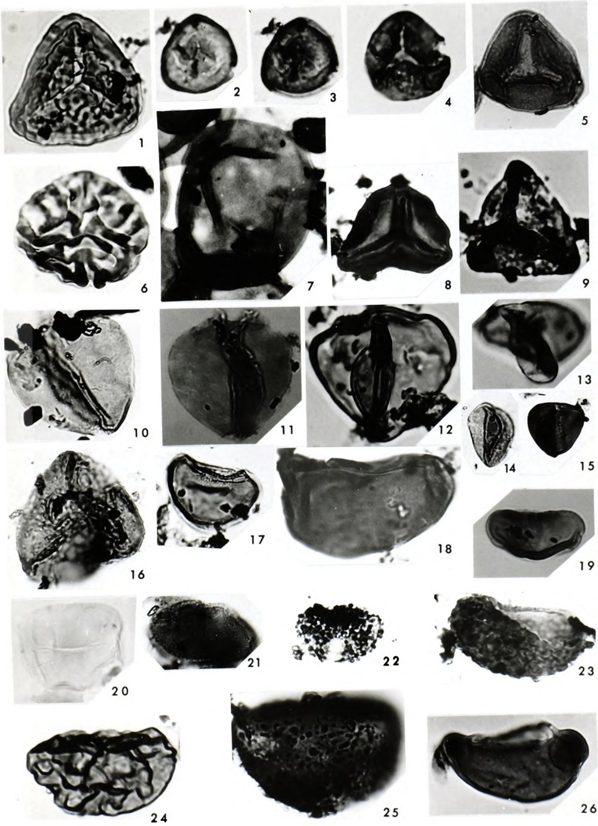

PLATE 5

Figure 1	*Alisporites similis* (Balme) Dettmann	1000X
Figures 2, 3	*Cedripites* cf. *C. canadensis* Pocock	1000X
Figure 4	*Podocarpidites* cf. *P. ellipticus* Cookson	1000X
Figure 5	*Tsugaepollenites segmentatus* (Balme) Dettmann	1000X
Figure 6	*Caytonipollenites* cf. *C. pallidus* (Reissinger) Couper	1000X
Figure 7	*Schizosporis* sp.	1000X
Figure 8	*Parvisaccites radiatus* Couper	1000X
Figure 9	*Cycadopites giganteus* Stanley	1000X
Figure 10	*Tsugaepollenites mesozoicus* Couper	1000X
Figure 11	*Foveoinaperturites forameniferus* Pierce	1000X
Figure 12	*Inaperturopollenites dubius* (Potonie & Venitz) Thomson & Pflug	1000X

PLATE 5

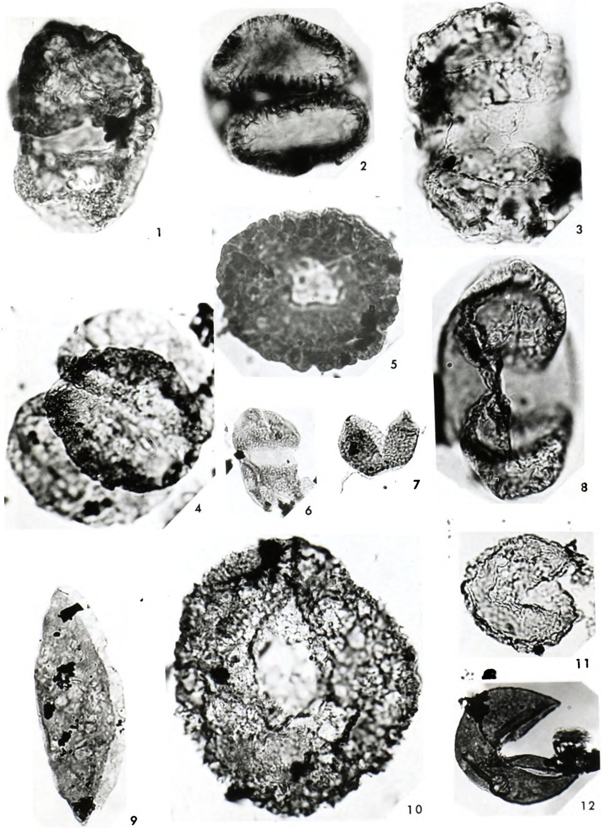

PLATE 6

Figure	1	*Taxodiaceapollenites hiatus* (Potonie) Kremp	1000X
Figure	2	*Schizosporis parvus* Cookson & Dettmann	1000X
Figure	3	*Circulina parva* Brenner	1000X
Figures	4, 5	*Classopollis classoides* Pflug emend. Pocock & Jansonius	1000X
Figure	6	*Cycadopites fragilis* Singh	1000X
Figure	7	*Ginkgocycadophytus nitidus* (Balme) de Jersey	1000X
Figure	8	*Eucommiidites* cf. *E. minor* Groot & Penny	1000X
Figure	9	*Monosulcites* sp. A	1000X
Figure	10	*Monosulcites* sp. B	1000X
Figures	11, 12	*Eucommiidites* sp.	1000X
Figure	13	*Equisetosporites ovatus* (Pierce) Singh	1000X
Figure	14	*Inaperturopollenites* cf. *I. magnus* (Potonie) Thomson & Pflug	1000X
Figure	15	*Equisetosporites multicostatus* (Brenner) Norris	1000X
Figure	16	*Liliacidites* sp.	1000X
Figure	17	*Liliacidites* cf. *L. variegatus* Couper	1000X
Figure	18	*Eucommiidites* cf. *E. troedssonii* Erdtmann	1000X
Figure	19	*Aquilapollenites turbidus* Tschudy & Leopold	1000X
Figure	20	*Aquilapollenites novacopites* Funkhouser	1000X
Figure	21	*Aquilapollenites delicatus* Stanley	1000X
Figure	22	*Aquilapollenites amplus* Stanley	1000X

PLATE 6

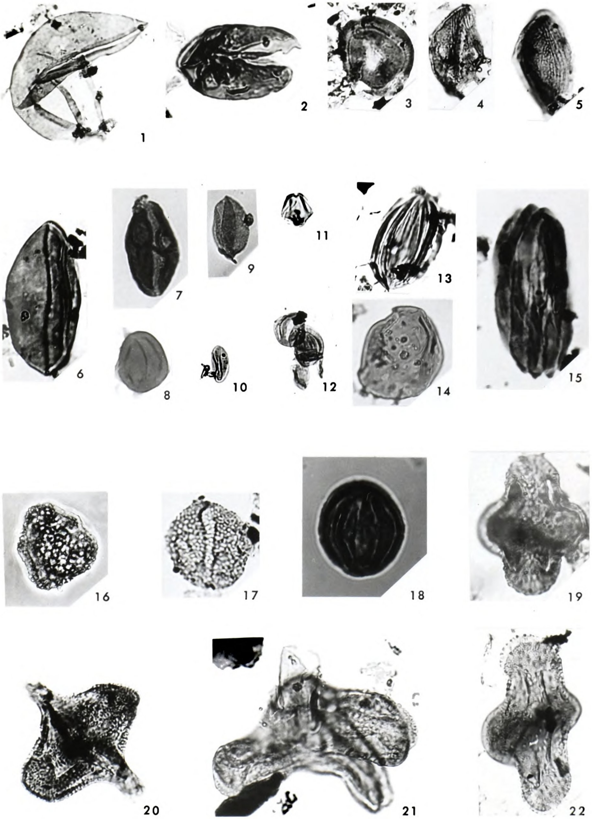

PLATE 7

Figure	1	Aquilapollenites cf. A. reticulatus Stanley	1000X
Figure	2	Aquilapollenites quadrilobus Rouse	1000X
Figures	3, 4	Aquilapollenites polaris Funkhouser	1000X
Figures	5, 6	Aquilapollenites sp.	1000X
Figure	7	Aquilapollenites trialatus Rouse	1000X
Figures	8, 9	Aquilapollenites calvus Tschudy & Leopold	1000X
Figure	10	Aquilapollenites pyriformis Norton	1000X
Figure	11	Gemmatricolpites cf. G. gemmatus Pierce	1000X
Figure	12	Cupanieidites sp.	1000X
Figures	13, 14	Cupanieidites cf. C. reticularis Cookson & Pike	1000X

PLATE 7

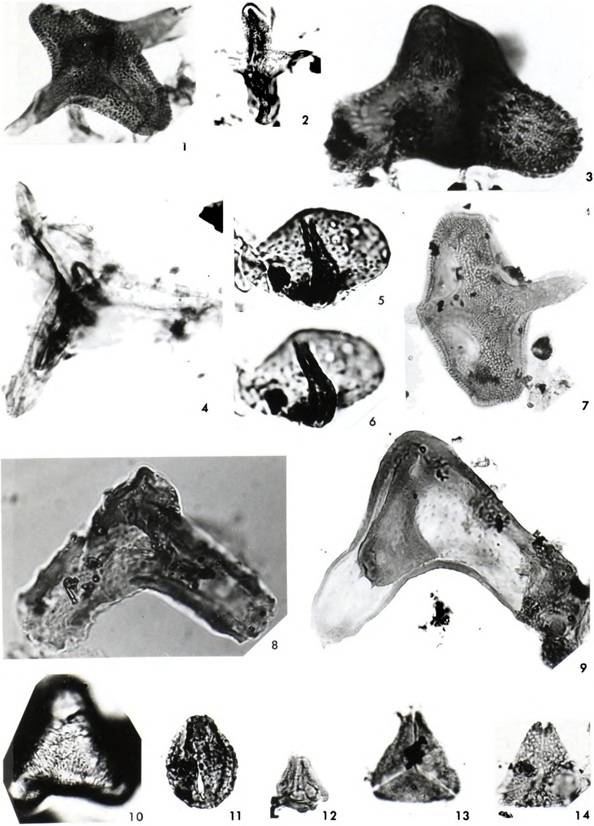

PLATE 8

Figure 1	*Psilatricolpites psilatus* Pierce	1000X
Figure 2	*Psilatricolpites* sp.	1000X
Figure 3	*Myrtaceidites* sp.	1000X
Figures 4, 5	*Retitricolpites* cf. *R. geranioides* Brenner	1000X
Figure 6	*Retitricolpites georgensis* Brenner	1000X
Figure 7	*Gemmatricolpites* cf. *G. pregammatus*	1000X
Figures 8, 9	*Fraxinoipollenites* cf. *F. variabilis* Stanley	1000X
	8--600X 9--1000X	
Figure 10	*Retitricolpites* cf. *R. prosimilis* Norris	1000X
Figure 11	*Retitricolpites* sp.	1000X
Figure 12	*Retitricolpites* cf. *R. oblatoides* Pierce	1000X
Figure 13	*Retitricolpites minutus* Pierce	1000X
Figure 14, 15	*Retitricolpites vulgaris* Pierce	1000X
	14--high focus 15--medial focus	
Figure 16	*Tricolpites hians* Stanley	1000X
Figure 17	*Retitricolpites* cf. *R. vermimuris* Brenner	1000X
Figure 18	*Tricolpites bathyreticulatus* Stanley	1000X
Figures 19, 20	*Tricolpites erugatus* Hedlund	1000X
Figure 21	*Tricolpites* cf. *T. lilliei* Couper	1000X
Figure 22	*Tricolpites parvus* Stanley	1000X
Figure 23	*Tricolpites* cf. *T. sagax* Norris	1000X
Figure 24	*Tricolpites* sp.	1000X
Figures 25, 26	*Tricolpopollenites elongatus* Groot & Groot	1000X
Figure 27	*Tricolpopollenites minutus* Brenner	1000X

PLATE 8 Continued

Figure 28	Tricolpopollenites cf. T. retiformis Pflug & Thomson	1000X
Figure 29	Tricolpopollenites micromurus Groot & Penny	1000X
Figure 30	Retitricolpites cf. R. paraneus Norris	1000X
Figure 31	Tricolporopollenites cf. T. microreticulatus Pflug & Thomson	1000X
Figure 32	Retitricolpites peroblatus Muller	1000X
Figure 33	Tricolpopollenites debilis Groot, Penny & Groot	1000X
Figure 34	Tricolpopollenites sp. A	1000X
Figure 35	Tricolpopollenites cf. T. platyreticulatus Groot, Penny & Groot	1000X
Figure 36	Tricolpopollenites sp. B	1000X
Figure 37	Tricolpites anguloluminosus Anderson	1000X
Figure 38	Tricolpopollenites parvulus Groot & Penny	1000X
Figure 39	Psilatricolporites acuticostatus Muller	1000X
Figure 40	Psilatricolporites prolatus Pierce	1000X

PLATE 8

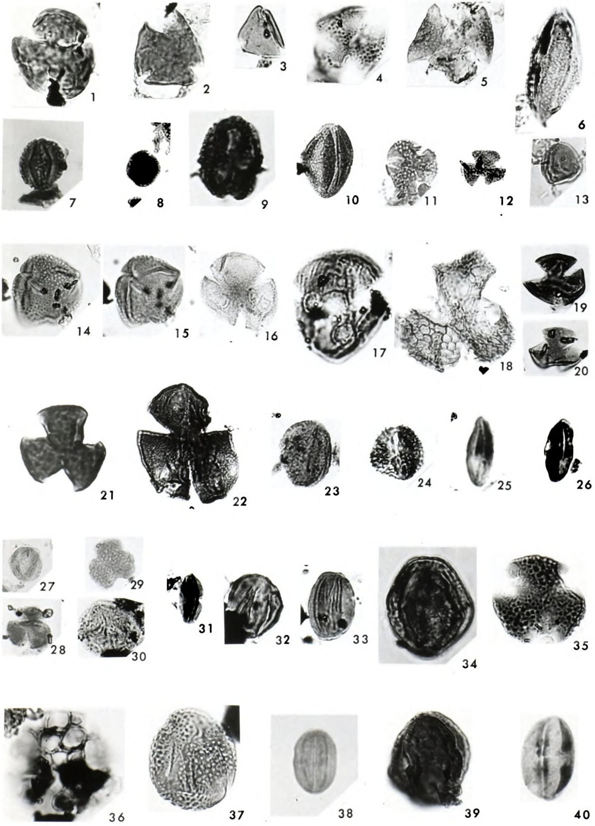
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PLATE 9

Figure 1	*Proteacidites thalmannii* Anderson	1000X
Figure 2	*Proteacidites retusus* Anderson	1000X
Figure 3	*Proteacidites symphonenoides* Cookson	1000X
Figure 4	*Trudapollis meekeri* Newman	1000X
Figure 5	*Triporopollenites* cf. *T. tectus* Newman	1000X
Figure 6	*Myrtaceoipollenites peritus* Newman	1000X
Figure 7	*Engelhardtioidites minutus* Newman	1000X
Figure 8	*Proteacidites* cf. *P. mollis* Samoilovitch	1000X
Figures 9, 10	*Momipites circularis* Norton	1000X
Figure 11	*Sporopollis laqueaeformis* Weyland & Greifeld	1000X
Figure 12	*Triporopollenites rugatus* Newman	1000X
Figure 13	*Proteacidites* sp.	1000X
Figure 14	*Liquidambarpollenites* cf. *L. stigmosus*	1000X
Figure 15	*Liquidambarpollenites* sp.	1000X
Figure 16	*Micrhystridium* cf. *M. biornatum* Deflandre	1000X
Figure 17	*Micrhystridium* cf. *M. roquesi* Valensi	1000X
Figure 18	*Micrhystridium minutispinum* Wall	1000X
Figure 19	*Micrhystridium inconspicum* Deflandre emend. Deflandre	1000X
Figure 20	*Leiosphaeridia* sp. B	1000X
Figure 21	*Leiosphaeridia* sp. A	1000X
Figure 22	*Veryhachium reductum* (Deunff) de Jakhowsky fa. *reductum* de Jakhowsky	1000X
Figure 23	*Baltisphaeridium hirsutum* (Ehrenberg) Downie & Sarjeant	1000X
Figure 24	*Micrhystridium* sp.	1000X

PLATE 9 Continued

Figure 25	*Leiosphaeridia* sp. C	1000X
Figure 26	*Veryhachium reductum* (Deunff) de Jakhowsky fa. *breve* de Jekhowsky	1000X
Figure 27	*Baltisphaeridium* sp.	1000X
Figure 28	*Micrhystridium fragile* Deflandre	1000X
Figure 29	*Baltisphaeridium* cf. *B. delicatum* Wall	1000X
Figure 30	*Baltisphaeridium infulatum* Wall	1000X

PLATE 9

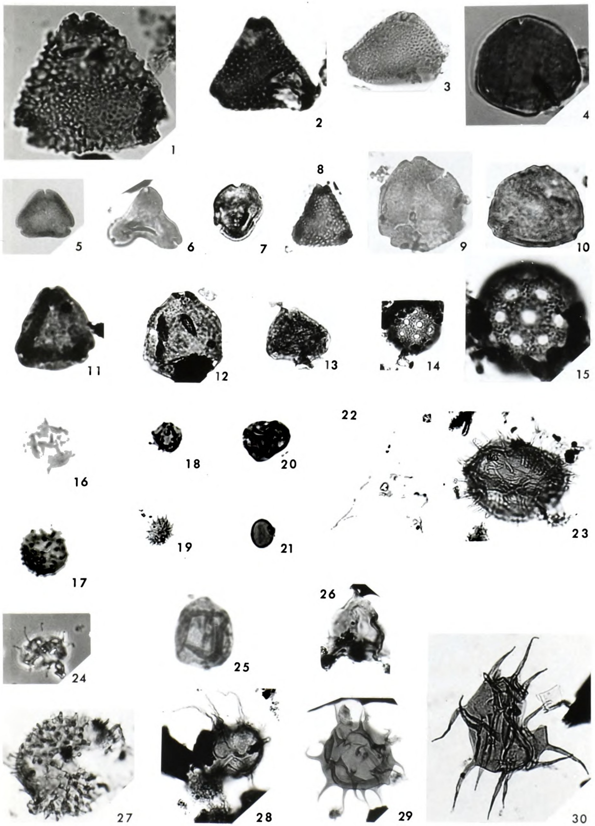
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PLATE 10

Figure 1	Diplotesta luna Cookson & Eisenack	1000X
Figure 2	Cymatiosphaera cf. C. exilissima (Deflandre) Deflandre	1000X
Figure 3	Cymatiosphaera eupeplos (Valensi) Deflandre	1000X
Figure 4	Cymatiosphaera cf. C. pachytheca Eisenack	1000X
Figure 5	Tetraporina horologia (Staplin) Playford	1000X
Figure 6	Pterospermopsis ginginensis Deflandre & Cookson	1000X
Figures 7, 8	Pterospermopsis australiensis Deflandre & Cookson	1000X
Figure 9	Cymatiosphaera cf. C. stigmata Cookson & Eisenack	1000X
Figure 10	Tetraporina glabra Naumova	1000X
Figure 11	Leiofusa sp. A	1000X
Figure 12	Quisquilites (?) ornatus Hemer & Nygreen	1000X
Figure 13	Komewuia glabra Cookson & Eisenack	1000X
Figure 14	Quisquilites (?) pluralis Hemer & Nygreen	1000X
Figure 15	Prolixosphaeridium deirense Davey & Williams	1000X
Figure 16	Palaeostomocystis laevigata Drugg	1000X
Figure 17	Leiofusa jurassica Cookson & Eisenack	1000X
Figure 18	Palambages morulosa O. Wetzel	1000X
Figure 19	Palambages deflandrei Gorka	1000X
Figure 20	Palambages forma "C" Manum & Cookson	1000X

PLATE 10

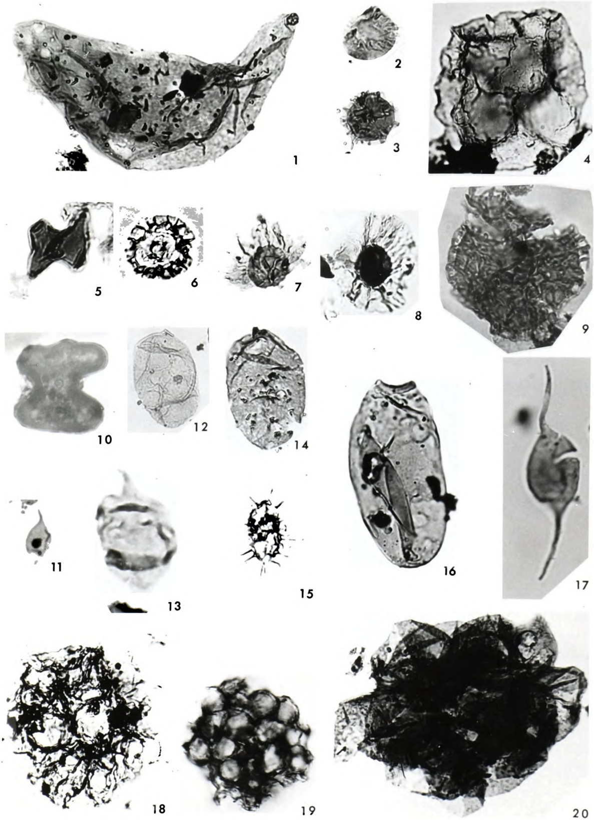


PLATE 11

Figure	1	Leptodinium cf. L. distertitum Cookson & Eisenack	750X
Figure	2	Spinidinium densispinatum Stanley	750X
Figure	3	Canningia cf. C. colliveri Cookson & Eisenack	750X
Figure	4	Hystrichokolpoma ferox (Deflandre) Williams & Downie	500X
Figure	5	Apteodinium grande Cookson & Hughes	400X
Figure	6	Spinidinium styloniferum Cookson & Eisenack	750X
Figure	7	Cleistosphaeridium heteracanthum (Deflandre & Cookson) Davey & Williams	750X
Figure	8	Cordosphaeridium fasciatum Davey & Williams	750X

PLATE 11

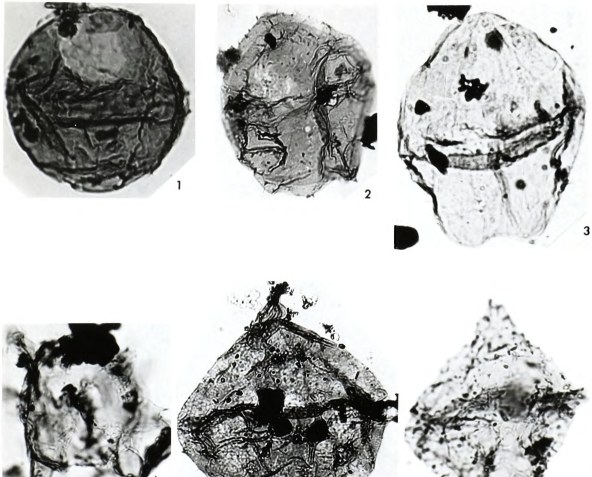
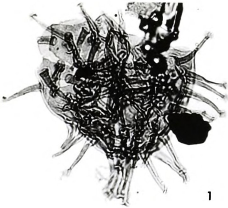


PLATE 12

Figure	1	*Polysphaeridium subtile* Davey & Williams	750X
Figure	2	*Hystrichosphaeridium readei* Davey & Williams	750X
Figure	3	*Hystrichosphaeridium* cf. *H. bowerbanki* Davey & Williams	750X
Figure	4	*Oligosphaeridium complex* Davey & Williams	750X
Figure	5	*Oligosphaeridium prolixispinosum* Davey & Williams	750X
Figure	6	*Cordosphaeridium* cf. *C. fibrospinosum* Davey & Williams	750X
Figure	7	*Hystrichosphaeridium tubiferum* (Ehrenberg) Davey & Williams	750X

PLATE 12



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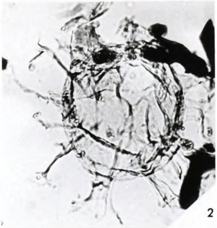

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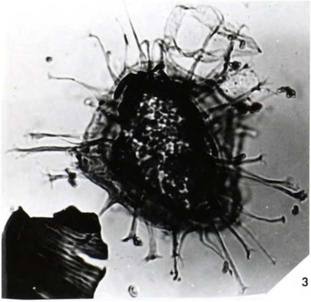

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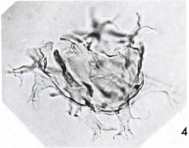

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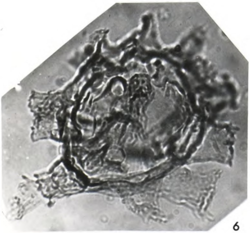

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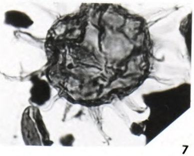

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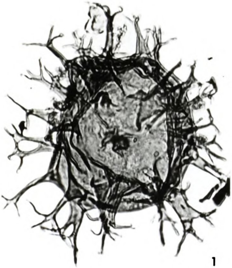
PLATE 13

Figure	1	Hystrichosphaera ramosa (Ehrenberg) var. gracilis Davey & Williams	750X
Figure	2	Hystrichosphaera cingulata (O. Wetzel) Deflandre	750X
Figure	3	Circulodinium deflandrei Alberti	750X
Figure	4	Hystrichodinium cf. H. pulchrum Deflandre ex. Deflandre	750X
Figure	5	Exochosphaeridium cf. E. phragmites Davey & Williams	750X
Figure	6	Hystrichosphaera ramosa (Ehrenberg) var. reticulata Davey & Williams	750X

PLATE 13



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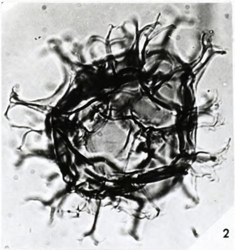

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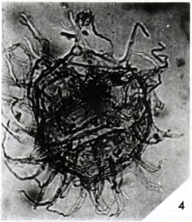

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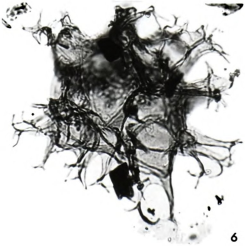

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PLATE 14

Figure 1	*Deflandrea oebisfeldensis* Alberti	750X
Figure 2	*Deflandrea scheii* Manum	750X
Figure 3	*Deflandrea cincta* Cookson & Eisenack	750X
Figure 4	*Hystrichosphaera* cf. *H. ramosa* (Ehrenberg) var. *multibrevis* Davey & Williams	750X
Figure 5	*Diconodinium arcticum* Manum & Cookson	750X
Figure 6	*Pterodinium aliferum* Eisenack	750X
Figure 7	*Hystrichosphaera ramosa* (Ehrenberg) var. *ramosa* Davey & Williams	750X
Figure 8	*Deflandrea diebeli* Alberti	500X
Figure 9	*Deflandrea pannucea* Stanley	750X

PLATE 14

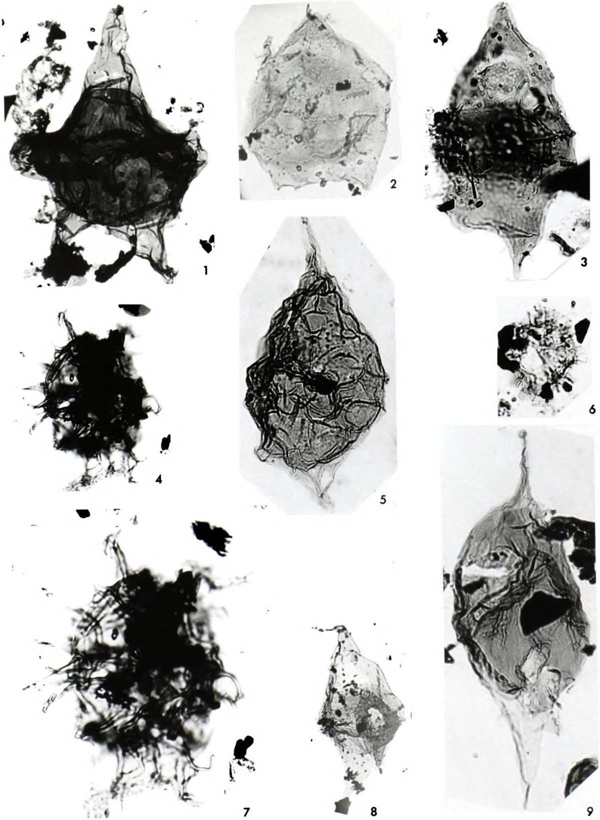

PLATE 15

Figure	1	Palaeohystrichophora infusorioides Deflandre	750X
Figure	2	Chlamydophorella cf. C. grossa Manum & Cookson	750X
Figure	3	Palaeohystrichophora isodiametrica Cookson & Eisenack	750X
Figures	4, 7	Hexagonifera suspecta Manum & Cookson	750X
Figure	5	Hexagonifera cf. H. glabra Cookson & Eisenack	750X
Figure	6	Hexagonifera chlamydata Cookson & Eisenack	750X

PLATE 15


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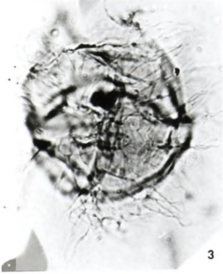
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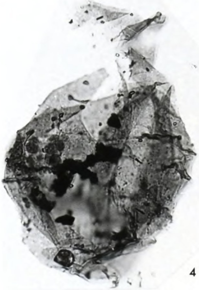
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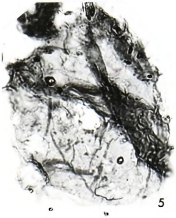
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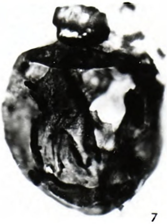
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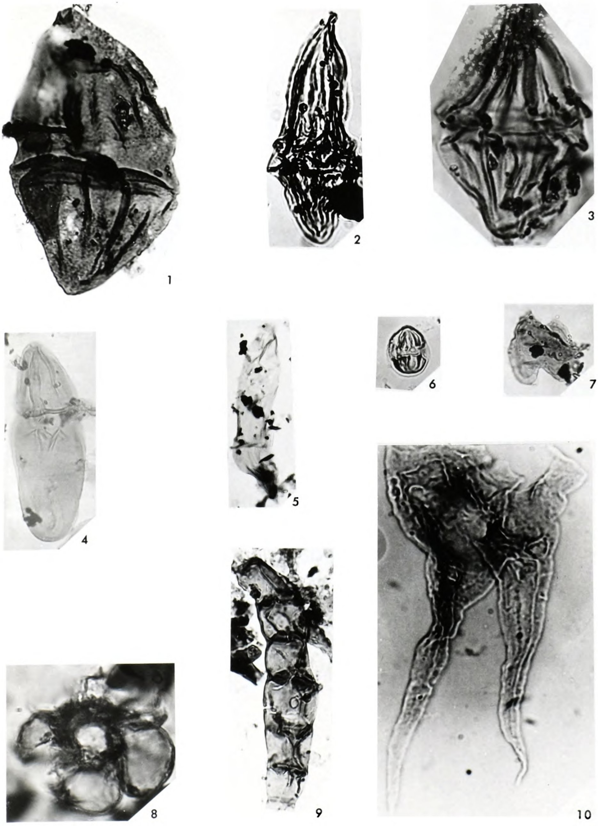
PLATE 16

Figure	1	Dinogymnium westralium (Cookson & Eisenack) Evitt et al.	750X
Figure	2	Dinogymnium cf. D. sp. "2" Evitt et al.	750X
Figure	3	Dinogymnium acuminatum Evitt	750X
Figure	4	Dinogymnium cf. D. digitus (Deflandre) Evitt et al.	750X
Figure	5	Dinogymnium sp.	400X
Figure	6	Dinogymnium cf. D. cretaceum (Deflandre) Evitt	1000X
Figure	7	Horologinella cf. H. incurvatum Cookson & Eisenack	750X
Figure	8	Microforam A	750X
Figure	9	Microforam B	750X
Figure	10	Odontochitina striatoperforata Cookson & Eisenack	750X

PLATE 16



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