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PALYNOLOGICAL INVESTIGATION OF DESMOINESIAN AND

MISSOURIAN STRATA, ELK CITY AREA, OKLAHOMA

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PALYNOLOGICAL INVESTIGATION OF DESMOINESIAN AND MISSOURIAN STRATA, ELK CITY AREA, OKLAHOMA

INTRODUCTION

During Pennsylvanian time tectonic movements associated with the Wichita orogeny caused rapid subsidence of the Anadarko Basin. Approximately ten thousand feet of poorly bedded conglomerates, sandstones, and shales accumulated. Because of the generally disordered nature of this sequence, and lack of marine fossils, correlation within the deposit has proven extremely difficult.

The present investigation was undertaken to determine if spores and pollen, blown and washed in from the adjacent Wichita Mountain landmass, would serve as a basis for zonation and correlation of this complex clastic wedge.

Through the efforts of Dr. L. R. Wilson, Research Professor of Geology, University of Oklahoma, funds were obtained to study the Desmoinesian and early Missourian strata of the Elk City Area. The Elk City Area lies within Townships 9 through 12 North of Ranges 19 through 22 West, in southwestern Oklahoma (See Fig. 1). This

576 square mile area encompassing parts of Beckham, Washita, Roger Mills, and Custer Counties, embraces several oil and gas fields, including the 100-million-barrel Elk City Field. More than 400 wells have been drilled in the area, including some of the deepest holes in the Anadarko Basin.

Other objectives of the investigation were a paleogeographic study of the area, determination of the nature and age of seismic events within Desmoinesian time, location of faults and unconformities, and the distribution of palynomorphs from various plant associations.

CHAPTER I

REGIONAL GEOLOGY

Geologic Setting

The Elk City Area lies near the axis of the Anadarko Basin, an asymmetric sedimentary and structural trough extending North 75° West along the north flank of the Wichita Mountains. The geology of this portion of the Anadarko Basin is as yet incompletely understood. For example, it was not until 1963 that some crystalline basement rocks were discovered to be of Middle Cambrian age, rather than Precambrian, and that these are underlain by up to 20,000 feet of metasediments. This discovery increased the known thickness of sediments in the basin by 50 percent.

Because the area is of considerable interest to petroleum companies, a large amount of industrial information is unavailable to the public. Published studies on the Elk City portion of the Anadarko Basin are restricted to superficial descriptions of producing oil and gas fields, including those by Ward (1952), Wilgus (1950), Kornfeld (1950), Beams (1951) (1952), Gelphman (1959), Christy

(1952), and Wellman (1948). Other investigations are restricted essentially to Late Paleozoic history of the entire basin, as Freie (1939), Lang (1951), McNeal (1953 and 1955) and Lyons (1955). Exceptions to these generalizations include papers by Wheeler (1955) and Wroblewski (1967).

Geologic History

The geologic history of the Elk City Area is divided into three stages: Precambrian to Middle Cambrian eugeosynclinal stage, Ordovician through Mississippian miogeosynclinal stage, and Pennsylvanian and Permian zeugogeosynclinal stage.

The initial, eugeosynclinal stage is represented by nearly 20,000 feet of graywacke and related sediments of the Tillman Metasedimentary Group deposited in an intracratonic sag termed the Southern Oklahoma Geosyncline by Ham, Denison, and Merritt (1964, p. 35). These marine sediments were intruded by gabbros, anorthosites and troctolites of the Raggedy Mountain Group, dated at 535 ± 25 M. Y. (Middle Cambrian) and locally covered by spilitic basalts and tuffs of the Navajoe Mountain Group. Subsequent movements along the Meers (?) Fault, and others, dropped the basin by more than a mile (Ham, 1966, p. 12). The accumulation of acidic pyroclastics and the extrusion of the Carleton Rhyolite of the Wichita Granite

Group, isotopically dated at $525^{\pm}$ M.Y. (Middle Cambrian) completed the eugeosynclinal stage.

Rocks of the eugeosynclinal stage do not crop out in the area of investigation, and only Wichita Granite has been encountered in the two wells that reach basement rocks. The relationships of these rocks, however, may be inferred from regional subsurface and outcrop data as described and interpreted by Ham, Denison and Merritt (1964).

The miogeosynclinal stage of the Anadarko Basin is represented by sandstones and carbonates. These rocks occur only in subsurface of the Elk City area, and have been encountered in only a few wells due to the great thickness (up to 18,000 feet) of overlying zeugogeosynclinal rocks. Wroblewski (personal communication) stated that the Hunton Group is considerably less argillaceous in the Elk City area than to the east, and noted (Wroblewski, 1967, p. 134) the possible presence of reefs in the Silurian Hunton and Bois d Arc equivalents. Isopach maps by Bokman (1954), and Cram (1964) indicate that these miogeosynclinal rocks thicken southward, the sedimentary axis of the miogeosyncline lying to the south of the Wichita-Criner Hills axis.

Post-Hunton diastrophism resulted in regional uplift and a series of subparallel folds trending at about North 40° West. Truncation to the Cambrian is observed on the Wichita Mountain flanks and in the shallow, northern and eastern portions of the basin.

The Middle Devonian erosion surface is unconformably overlain by black, cherty Woodford Shale (Late Devonian-Early Mississippian) and a nearly complete section of Mississippi limestones (about 3,500 feet thick). The Chester Series, which is of interest due to its incorporation into later rocks, consists of about 80 feet of soft, light-gray, waxy shale overlain by about 170 feet of gray limestone and calcareous shale with several thin sandstone beds.

Post-Chester stresses caused high-angle normal faulting parallel to the post-Hunton folds, in many cases elevating the crests of these structures as horsts or half-horsts. These movements constitute the first pulse of the Wichita Orogeny, and, together with the transgression of the Morrow Sea, initiated the zeugogeosynclinal stage in the development of the basin.

The truncation of pre-Morrow structures by the transgressing sea and the accompanying deposition of eroded Chester detritus in the low areas is shown by the lithofacies and isopach maps of Forgotson, Statler and David (1966). The presence of a reworked Springer rocks in basal Morrow strata is substantiated by palynological and clay-mineral X-Ray analyses, and explains the difficulty encountered in locating the base of the Morrow on sample and electric logs, a problem which Wroblewski (1967, p. 133) noted as being "...the most difficult correlation problem in the deep basin."

Whereas information regarding the nature of the Upper Cambrian through Mississippian rocks is available from surface exposures in the Wichita and Arbuckle Mountains, and from wells drilled on the flanks of the basin, data on the early zeugogeosynclinal sequence is available only through deep drilling. Well logs from Shell No. 5 Rumberger and P.C.I. Weatherly indicate the Morrowan and Lower Atokan strata to consist of about 4,500 feet of shale. This thickness is probably excessive due to thrusting.

An almost continuous series of orogenic pulses from Late Atokan into Virgilian time caused truncation of Morrowan and Atokan strata, and the formation of a thick clastic wedge adjacent to, and extending basinward from, the rising Wichita Mountains. The wedge consists of 3,000 to 10,000 feet of carbonate and granite wash, e.g., a poorly bedded, poorly sorted, till-like mixture of subrounded sand to cobble grade lithic debris with little matrix. Small lenses of shale and cross-bedded sandstone are common throughout. The lower several thousand feet of this wedge consists largely of reworked carbonates from Mississippian and Lower Pennsylvanian strata; and the upper portion of granitic detritus.

Accompanying the rapid accumulation of detrital debris, the basin subsided along a series of high-angle normal faults trending North 30° West. Progressive vertical and horizontal displacement along these faults indicate their activity into Missourian time.

In Late Missourian time continual rejuvenation of the Wichita Mountains ceased. As the mountains were progressively eroded and finally buried, the volume and grade of the sediments decreased, and their maturity increased. The Upper Pennsylvanian section consists of arkoses and sandstones grading basinward into maroon shales and local reef limestones.

In Late Pennsylvanian and Early Permian time, movements in the basin formed such folds as the Elk City Anticline, and caused faulting at North 45° East. These movements, probably related to the Arbuckle Orogeny, did not cause substantial rejuvenation in the Wichita Mountains, as evidenced by the lack of increased sedimentation marking the orogenic pulse.

The Permian section consists of about 6,000 feet of arkoses, sandstones and shales, which grade upwards into red shales and evaporites, especially gypsum.

Desmoinesian-Missourian Stratigraphy

Nomenclature

The stratigraphic nomenclature applied to the

Pennsylvanian clastic wedge has traditionally been that of the Ardmore Basin, e.g. Dornick Hills-Hoxbar-Deese-Pontotoc in ascending order. These groups, however, are of different facies, and the intergroup and intragroup breaks are not demonstrably comparable. Similarly, the group nomenclature of northern Texas, Bend-Strawn-Canyon-Cisco in ascending order, is not stratigraphically applicable with respect to the clastic wedge.

The alternative of bestowing a group or formation name to the clastic wedge could be stratigraphically justified, but would have little meaning in itself. Therefore, the Pennsylvanian clastic wedge is nomenclaturally described in terms of the mid-continent standard section, i.e. Morrowan, Atokan, Desmoinesian, Missourian, Virgilian. This system is not stratigraphically perfect, because of difficulties in the type sections, particularly in the upper Desmoinesian, but is believed preferable to the alternatives.

An additional factor in choosing this form of stratigraphic nomenclature is in the general acceptance and use of these stages by paleontologists and their more or less established relationships to the European section. Almost all pertinent American palynological assemblages have been disucssed in these terms.

Lithology

The Pennyslvanian clastic wedge consists of a mixture of cobbles, pebbles, sands and silts, characterized by a general lack of bedding, poor sorting, abrupt lateral variation, and immaturity. Within the wedge are cobble-pebble arkosic conglomerates, conglomeratic limestones, arkosic sandstones, conglomeratic mudstones, and graywackes, among others. As a unit, however, these sediments change so abruptly that none of these names is suitable. For this reason, the descriptive terms granite wash, carbonate wash, and mixed granite and carbonate wash have been used by previous investigators. The genetic implications of the term wash, inferring "dumped in," is considered an asset.

The discrete particles in the granite and carbonate wash range from sub-angular in the fine grades to subrounded in the cobbles. Overall, sorting is poor, although poorly defined lenses and "patches" of moderately well sorted sediments do occur. Even in the well sorted, crossbedded sandstones, however, flakes of mica and "clots" of mudstone are not uncommon. Silts and fine clays are generally lacking in the coarse lenses, but are abundant in the deep part of the basin. This deficiency is believed due more to the lack of maturity of the sediment, than to current winnowing. Rudimentary and generally incomplete graded bedding occurs in magnitudes of both tens of feet and inches.

Sedimentary immaturity is shown in cobble angularity, poor sorting, deficiency of fines, and especially, in the freshness of the biotite, feldspars, and gabbroic clasts. Although not observed in the study areas, zones of chemically altered granite wash occur several miles to the south in the Missourian of the West Sentinel Field. Gelphman (1959) interpreted these as due to subaerial exposure during orogenic paroxisms, an explanation which correctly infers their non-occurrence in the deeper part of the basin under study.

The Pennsylvanian clastic wedge may be divided into upper and lower portions on the basis of pebble and cobble lithology. The lower portion, generally referred to as carbonate wash, consists of dense carbonate wash near the Amarillo-Wichita Mountain front and grades basinward into carbonate sandy wash and mixed carbonate and granite wash. The upper portion of the wedge is characterized by granite wash, although carbonate detritus is common, particularly near the base. Further differences between the upper and lower portions of the Pennsylvanian wedge are noted in the darker gray and red shales associated with granite wash.

The boundary between the carbonate wash and granite wash portions of the wedge is neither distinct nor stratigraphically significant. It does not, as previous authors have inferred, mark the Desmoinesian-Missourian boundary, but rather merely reflects the status of erosion in the immediate provenance area. Flankward from the study area the carbonate wash portion becomes proportionately greater, whereas basinward, the granite wash becomes dominant.

Cementation, generally by calcite, is poor, particularly in the coarser zones. Although the carbonate wash tends to be better cemented than the granite wash, neither is well-cemented. The combination of silt and clay deficiency in the matrix and poor cementation causes the coarser zones to be friable. Evidence of the friable nature of the coarse washes is seen in the illustrated core slabs (Plate 1, Figs. 1 and 2). It is emphasized that well cuttings of such lithology consist almost solely of chips of the cobbles and pebbles, the scant matrix being lost during drilling, collecting and washing. The palynological consequences of this should be obvious, the recovered fossils being derived almost exclusively from the chips of recycled material.

The clastic maximum grade and the sedimentary mean grade of the wedge decrease irregularly into the basin, but apparently terminate abruptly at the limit of the wedge due to the deficiency of subsand grade sediment. Beyond the limit of the wedge, and interfingered with the wedge, are dark gray, calcareous shales similar to those occurring as irregular lenses and patches in the clastic wedge. These are believed to be, in part, of eastern provenance (Wilson, personal communication).

Transporting cobbles more than 25 miles into the basin without better sorting or rounding may best be explained by fluxoturbidity, "...the mechanism related to both turbidity currents and sliding," (Kuenen, 1964, p. 21). It is believed that a semi-subaqueous bahada-like apron of alluvium formed along the base of the intermittently uplifting Wichita Mountains. As the angle of repose of this apron exceeded its maximum angle of repose, periodic submarine or semisubmarine landslip redistributed the coarse material far into the basin. Although occurring periodically at any given location, such landslips, and their resulting turbidity currents, are envisioned as having been essentially continuous along the Wichita Front as a unit. That some areas were tectonically more active or topographically conducive to such occurrences is seen in an unpublished Hoxbar isopach map of the Glover, Hefner, Kennedy Oil Company, which shows a large crowfoot delta-like projection of granite wash extending into the basin.

Discrepancies between the Pennsylvanian carbonate and granite washes and some of the characteristics of the fluxoturbidites are explained by the immaturity of the Anadarko clastics, especially in their deficiency of the finer sedimentary grades. Hence, the terminal turbidity facies, as described by Walker (1967), does not exist. Comparison of the features of Walker's proximal turbidite facies with fluxoturbidites shows marked similarity, although the former are of finer grade, and leads the writer to believe that the process of fluxoturbidation was active in the proximal turbidite facies.

The Atokan-to-Virgilian clastic wedge is, therefore, interpreted as the proximal facies of a turbidite formed from a bahada-like apron of immature alluvium by fluxoturbidation. The terminal turbidite facies is absent due to the lack of fine grade material among the clastic. This interpretation is based on examination of only a few feet of core and less than three dozen well logs, and although this interpretation best fits the data, it must be considered only tentative. The detailed petrographic study necessary to substantiate this hypothesis is beyond the scope of this investigation.

CHAPTER II

PHILOSOPHY AND METHODOLOGY OF SAMPLING

Sampling

Although more than 400 oil and gas wells have been drilled in the Elk City Area, only about 5 percent of these completely penetrate Missourian strata, and only about 2 percent of these completely penetrate Desmoinesian strata. The exact number of each is impossible to determine because of difficulties in correlation within the Pennsylvanian System.

Twenty wells were utilized in this study. These were chosen on the basis of Missourian-Desmoinesian penetration, geographic location, and availability of samples. Location of these wells is shown in Figure 1.

It was intended to collect composite samples of about 50 feet each, centered on 100 to 150 foot intervals throughout the Desmoinesian and lower Missourian strata. However, the top of the Desmoinesian proved impossible to locate either by personal perusal of well-log data or by data from the Shell Oil Company, Glover, Heffner, Kennedy Oil Company, Oklahoma Corporation Commission, or published

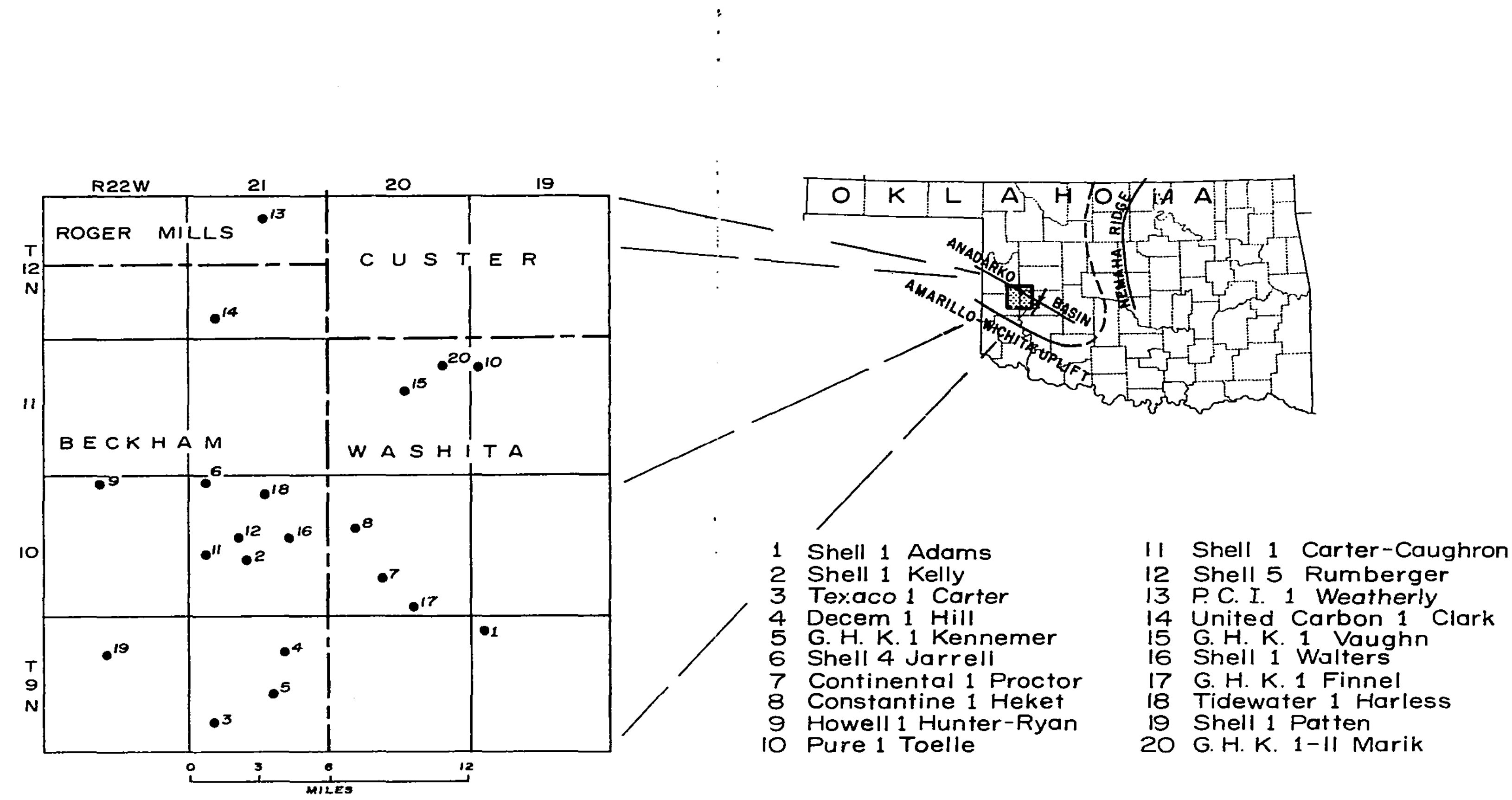

Figure 1

ELK CITY AREA

Showing location and numbers of wells studied sources (Lang, 1951; McNeal, 1953, 1955). Because of the disagreement regarding the Desmoinesian "top picks," the zone of sampling had to be increased by an amount exceeding that of disagreement. This amounted to between 1,200 and 3,600 feet in most wells. In order to keep the number of samples at a minimum, reconnaissance samples were taken at intervals of 500 to 1,000 feet. These samples were to be studied and the horizons of interest located for further study. However, study of the reconnaissance samples showed further sampling was not justifiable, due to the combination of caving and reworking contaminents which made stratigraphic determination impossible.

Sample spacing and the length of the composited intervals varied in order to make maximum use of shales, which generally yield more and better preserved palynomorphs, and which are less likely to contain reworked forms. Where shales could not be located on electric logs, or where electric logs were not available, sampling was based solely on depth.

Ideally, cores should be used in such a project. Only one well in the study area, Shell No. 1 Kelly, Sec. 21, T. 10 N., R. 21 W., was cored extensively through the strata of interest. Unfortunately, the six cored intervals in Desmoinesian-Missourian strata are of potential reservoir rocks, and therefore of the palynologically least desirable lithologies. At the time of collection, this core was in complete disarray, making composite sampling impossible. Only two of the five grab samples collected yielded palynomorphs. Short cores, equal to single sample intervals, were utilized in several wells.

Because of the lack of cores, well cuttings had to be used. The use of well cuttings introduces several problems: contamination by cavings; lack of lithologic knowledge; uncertainty of sample depth; and vagaries in sample collecting.

Contamination by cavings is a serious problem which is impossible to solve completely. Those forms that are introduced from significantly higher stratigraphic horizons are readily identifiable. However, the majority of caved chips are from horizons immediately above that being drilled. The fossils in these are apt to be closely similar to those at bit depth to be differentiated. In this project, those forms derived from Permian cavings are readily identified on the basis of morphology, staining characteristics, and preservation. However, those palynomorphs derived from strata immediately above that being drilled are not identifiable as contaminents. Therefore, the first stratigraphic appearance of a fossil cannot be used as a zonation criterion, in as much as it may be out of place. Examination of caliper logs of several wells in the study area has revealed that almost all of the 6,000 feet of Permian strata, and most of the Middle and Upper Pennsylvanian strata are highly susceptible to caving.

Generally, well cuttings cause several problems. The most important factor is the ability and integrity of the drilling crew. The driller who is lax about collection time intervals, or who takes the "short cut" of collecting several samples at once, or who does not wash, or who overwashes samples is doing irreparable damage. This factor can be controlled only in actively drilling wells, and hence is an unknown in this study. The integrity and ability of the driller's work is not assumed, and even if they were assumed, the calculation of the time required for cuttings to reach the surface would still be problematical.

Evidence of mud return time miscalculation has been observed in several of the samples, where sample lithology does not correlate with well log characteristics. This is a problem common to all deep drilling, and one must generally assume an error of about 50 feet in the indicated sample depth. In the discussions of these samples based on well cuttings depths are given as approximations about a single depth. Thus sample 19-2 is described as ca. 5,925 feet rather than 5,900-5,950 feet. It is felt that the longer form infers accuracy which is not justified.

An additional collection problem was encountered in this project. The coarse, granite and carbonate wash lithologies of the study area consist of pebbles and cobbles in a sand matrix, with little clay and silt sized matrix which would bear endemic palynomorphs. The churning action of the bit disaggregates these poorly indurated rocks, and chips of the cobbles are carried to the surface. Upon washing on the shale shaker, most of the minute quantity of matrix is lost. Therefore, the palynomorph assemblage of such samples is that of the cobbles with few, if any, endemic forms.

Sample Preparation

One hundred and forty-one samples of approximately 20 grams each were collected from well cuttings and cores of the 20 wells used in this study. Samples were processed in groups of four or eight using standard digestion techniques.

Hydrochloric and hydrofluoric acid treatments were carried to reaction completion, generally four and ten hours respectively. The use of Schultz' Solution, necessitated by a general abundance of fine organics and pyrite crystals in the sporomorphs, was kept at a minimum, generally one-half hour to one hour. The use of a strong base following Schultz' Solution proved generally destructive to the sporomorphs and was not employed. Repeated washing in Alcojet removed the humic acids and dispersed the fine organics.

In the majority of samples sporomorphs were concentrated by use of zinc chloride of density 1.58, 1.62, or 1.65. The heavier liquid worked best due to the presence of pyrite weighing down some forms. Few well cutting samples were found to be absolutely barren of fossils, most containing Permian contaminents, if nothing else. Those found absolutely or nearly barren were reprocessed with a few grains of modern pollen added as a guard against overdigestion. In almost all cases, reprocessing proved futile, the sample being validly barren, or essentially barren.

Prepared residues were stored in dilute Methanol containing Safranin O stain for several days and then swirled and mounted on microscope slides using Clearcol, Polyvinyl Alcohol, or Wilson's Mountant (Wilson, 1967). During study, representative palynomorphs, including those illustrated, were permanently located in numbered ink rings on the microscope slides.

The microscope slides and residues used in this study are stored in the Palynology Collection of the Oklahoma Geological Survey, Norman, Oklahoma. The code key consists of: well number - sample number - slide number - ring number. Thus 19-4-5-12 refers to well number 19 (Shell No. 1 Patton), sample number 4 (7,550-7,600 feet), slide number 5, ring number 12. Keys to the well, accession and sample numbers appear in the appendix.

CHAPTER III

CONTAMINATION PROBLEMS

General

Contamination is common in palynology and unavoidable where well cuttings are used. The major sources of contamination are recycling, well caving, drilling mud, and the atmosphere. Recycling, because of its potential usefulness, differs from other contamination, and is therefore discussed separately. Many contaminants may be differentiated from authigenic members of an assemblage by staining characteristics, color and preservation differences, differences in ecology, and differences in age as seen by morphology or phylogeny.

Modern spores and pollen grains may cause contamination during sample collection and washing, or in the laboratory. Because their morphology and staining characteristics permit instant recognition, modern contaminants present little problem in Paleozoic assemblages. The presence of modern pollen in almost all of the samples actually proved helpful as an index for over-maceration and, in fact, modern *Pinus nigra* pollen was added to some samples as a test of digestion technique.

Laboratory contamination from dirty laboratory equipment, palynomorph-contaminated chemicals or water, or from airborne debris occurs, but may be avoided if care is used. The only cases of such contamination found in this study were by airborne Pliocene diatoms and modern pine pollen, both of which are readily identifiable as foreign.

Drilling muds, especially those containing unprocessed bentonite or coal, are apt to contain palynomorph assemblages of their own. Contamination by drilling mud is possible in both core and well cutting derived samples. Highly porous, especially vuggy, lithologies are most susceptible to contamination, but all well samples must be washed very carefully to remove any adhering foreign material. Lists of the contaminants in several of the popular muds are available, but these are of little value in the study of old wells in which no detailed mud records were kept, and the muds of which, even if identifiable, would probably be from different raw material sources than that manufactured today.

The most serious source of contamination where well cutting samples are used is well cavings. As noted above, palynomorphs of a distinctly different age are readily recognized on the basis of differences in preservation, staining characteristics, morphology, or ecology.

Those forms derived from cavings from immediately above the drilling horizon, however, are apt to be so similar in these characters as to be indistinguishable from the in situ forms. The degree of danger of caving contamination is seen when one realizes that the bulk of cavings are derived from unstable horizons immediately above that being drilled. Thus, in the Elk City Pennsylvanian wedge, Permian contaminants are easily recognized, but Pennsylvanian contaminants from 100 to 200 feet stratigraphically above the drilling depth are not recognized. It is obvious that such contaminants are present, presumably in greater abundance than are the Permian forms, but they are rarely recognizable. It is for this reason that the lowest stratigraphic limit of a palynomorph may not be used as a zonation criterion in samples derived from well cuttings.

Recycling

The phenomenon of recycling, e.g., the incorporation of fossils into younger rocks through sedimentation, is well known. The importance of reworking, however, as applied to microfossils and palynomorphs, is still not generally realized, despite the efforts of Jones (1958) and Wilson (1964).

The likelihood, and hence the importance, of fossil recycling increases proportionately with the competence of the transporting medium and inversely with the fossil's size. Palynomorphs generally range from 30 to 150μ, and are, therefore, extremely susceptible to recycling, for even sand-sized grains may bear palynomorphs, and a pea-sized pebble might contain several hundred. The implications of this fact with respect to the matrix-poor, cobble conglomerates of the Pennsylvanian clastic wedge should be obvious, the assemblage being almost exclusively of recycled forms.

If recycled fossils are not recognized as such, especially in a unit barren of autocthonous forms, serious errors result. However, if recognized as recycled, these fossils may be used as clues to provenance area in the manner of heavy minerals. Recycled fossils are also of great importance in the delineation of unconformities, which are marked by the accumulation of a lag assemblage of recycled fossils.

In almost all of the project samples, Chester fossils were among the most abundant. This Chester assemblage, probably derived from Springer and Goddard shales, is characterized by its dark color (yellow-brown to brown) and fine state of preservation. Such a state of preservation is not unique to the Chester reworked palynomorphs, however. Palynomorphs known in Oklahoma only from the Stanley shale, though Devonian elsewhere, were also found, as were probable Devonian spores. The oldest fossils found in the Pennsylvanian clastic wedge are Chitinozoa known in Oklahoma only from the Ordovician Sylvan Shale. The occurrence of Devonian and Ordovician fossils does not necessarily imply the subaerial exposure of these strata during deposition of the clastic wedge as the fossils may be second, or third order recyclings.

As with well cavings, fossils that are substantially out of place are generally easily recognized, but those that are recycled from strata of only slightly older age are difficult or impossible to distinguish. Hence, whereas recycled Mississippian fossils are readily recognized, Desmoinesian fossils recycled into the basal Missourian across the hypothetical Desmoinesian-Missourian unconformity would be almost impossible to distinguish.

Further, the palynological criteria for the recognition of an unconformity is based upon reworking due to the clastics that generally mark unconformities. The entire Pennsylvanian clastic wedge has such characteristics, however, so the very presence of the Desmoinesian-Missourian unconformity cannot be proven. In addition, it is believed that this deposit was formed through fluxoturbidation, which entails the sporadic slumping and sliding of strata. Such a deposit is made up of many hundreds of minor unconformities and an undisturbed stratigraphic succession is probably rare, if present.

The combination of down-section inaccuracy introduced by the use of well cuttings, and the up-section inaccuracy due to recycling create a stratigraphic dilemma. A sample containing both Desmoinesian and Missourian index fossils could be of Desmoinesian age with Missourian cavings; of Missourian age with Desmoinesian recycled fossils; or be of either, or neither, age and endemically barren with all the fossils out of place. There is no easy solution to this problem.

CHAPTER IV

PALYNOMORPH PRESERVATION

Palynomorph preservation has been generally neglected as both a determinative factor in morphology and as a stratigraphically useful tool. Palynomorph preservation is a function of the chemistry of the environment of deposition; the thermal and pressure history of the strata in which the palynomorphs occur; and the maceration techniques used in removing them from the rocks. Vagaries in these factors are manifested as differences in color, staining characteristics, and exine corrosion.

Sporomorphs are introduced into almost all depositional areas. The few exceptions are those polar and desert areas with little or no vegetation, and those areas too far leeward of a landmass to receive pollen rain. Such deposits are so rare, however, that we may assume the original presence of sporomorphs in all sediments.

Preservation, however, is not so universal, sporomorphs being highly susceptible to destruction by oxidation, reduction or bacteria. It is assumed that an environment of deposition with an Eh greater than zero, or less than -0.3 is unfavorable for sporomorph preservation. These oxidation-reduction limits are only approximate, as different sporomorphs have different tolerances. In general, thin-walled, saccate and perinous forms are least resistant to destruction, and thick-walled, especially laevigate, forms are most resistant.

In a reducing environment the most common destructive agents are bacteria and pyrite. Pyrite is most commonly observed in the bladders of saccate palynomorphs, where it forms as euhedral or subhedral crystals (Pl. I, fig. 10) or as an irregular encrustation (Pl. I, fig. 11). Spherical growths of pyrite are also common (Pl. I, figs. 8 and 9). Love and Zimmerman (1961) have found that these pyritic spheres contain small hyaline spore-like bodies which they interpret as sulfate reducing bacteria. These cause precipitation of iron sulfide in the form of amorphous melnikovite which alters to pyrite. The melnikovite phase may explain the irregular encrustations of pyrite on some sporomorphs (Pl. I, fig. 11). Pyrite is generally removed during processing, leaving characteristic angular or spherical pits (Pl. I, figs. 8-10).

The end effects of pH on sporomorphs are not well known. The most acidic environments of deposition (peat bogs at pH 4) are among the most conducive to spore preservation. Excellent sporomorphs may be recovered from rocks deposited under conditions of high alkalinity, such as gypsum or anhydrite. Spores from these, however, and from the Permian redbeds of western Oklahoma, are distinctive in their failure to absorb Safranin O, a standard palynological stain. It is hypothesized that stain rejection is related to the environment of deposition and fossilization, as Permian sporomorphs from other lithologies absorb stain normally. The generally unstained nature of Permian redbed sporomorphs allows their instant recognition. However, many specimens of Virgilian-Permian sporomorphs were found which did absorb Safranin O. It is suspected that these stained forms are from non-redbed lithologies.

Unstained, fossilized sporomorphs vary from light yellow to brown, depending upon the thickness of the exine. Most are straw yellow. With increasing heat or pressure, sporomorphs darken through yellow-brown and brown to black. This color change is accompanied by progressive physical destruction, the finest membranes and processes corroding first.

Wilson (1961) correlated the color and physical characteristics of Pennsylvanian coal sporomorphs from the Ardmore Basin to the fixed carbon ratios of the enclosing coals. The threshold of physical alteration is cited at 50-55$^{\pm}$ percent fixed carbon (F.C.). At about 60 percent F.C. sporomorphs are yellow-brown and the finest processes and thinest membranes are partially destroyed. At 65 percent F.C. sporomorphs in coal are brown, and saccate structures and thin walls absent. At about 70 percent F.C. only the thickest walled sporomorphs remain, and often are too badly corroded for identification. Above 71 percent F.C. neither sporomorphs nor other plant material remains. Wilson (1961, p. 138) also noted the order of destruction of some of the Desmoinesian sporomorph form genera common in coal. *Reinschospora*, *Raistrickia*, *Laevigatosporites*, *Endosporites*, and *Wilsonites* are among the first sporomorphs to be destroyed, disappearing at about 61 percent F.C. *Triquitrites*, *Calamospora*, *Granulatisporites*, *Densosporites* and *Lycospora* do not occur in rocks of over 65 percent F.C. The last form to be destroyed, *Punctatisporites*, disappears at about 71 percent F.C. This is a very generalized form and its abundance in high fixed carbon rocks is probably due to destructively induced imitation by other sporomorphs as well as by valid occurrence. The sequence of generic destruction in the shales and limestones of the Anadarko basin, however, differs markedly from that of the Ardmore coals, in that *Endosporites*, *Wilsonites* and *Potonieisporites* are among the most durable. These may be out of place, however. The phenomenon of the selective and consequetive destruction of sporomorphs, although poorly understood, must be carefully considered in the comparison of assemblages.

The relationship between fixed carbon ratio and depth of burial is generally accepted as a function of both the geothermal gradient and geostatic pressure, and therefore, of depth burial. Fuller (1920) has presented data relating the fixed carbon ratio to tectonic features, and Wilson (1961) has shown that sporomorphs are darkened or absent in the vicinity of faults and folds, especially near the crests of anticlines. Thus, sporomorph preservation offers a clue as to the location and magnitude of folds and faults, and has potential value in the differentiation of sills from flows, and the determination of paleogeothermal gradients. As the limits of oil and gas occurrence, "deadlines" of Thom (1934), are within the range of fixed carbon ascertainment by sporomorph preservation, it may be possible to delineate petroleum provinces through palynology. It should be stressed, however, that the fixed carbon percentage is an index of the <u>maximum</u> stress imposed on the strata, and bears no relation to subsequent events, such as oil migration.

In the process of freeing and concentrating sporomorphs, physical alteration of the sporomorphs may occur. Schultz's solution, strong bases, and zinc chloride solution are corrosive to sporomorphs. In this study, the use of these was kept at a minimum, as many of the sporomorphs were already partially destroyed by syngenetic pyritization, or organic distillation. The physical effects of overmaceration are similar to those of other forms of destruction in that the finest tissues and processes are generally affected first.

The removal of ornamentation or sacci during processing causes the production of forms which mimic laevigate or less ornate forms. Overmaceration of round ornate spores of several genera may result in the manufacture of forms indistinguishable from *Punctatisporites*. Experiments by L. R. Wilson and J. H. Ruffin (Wilson, personal communication) have shown that forms apparently identical to *Lycospora microgranulata* and *L. noctuina* may be manufactured by the overmaceration of *L. torquifer*. Similarly, forms indistinguishable from *L. granata* and *L. parva* may be manufactured from *L. brevijuga*. Distinguishing real sporomorph form-species from manufactured form-species is difficult, and although it is occasionally necessary to use each form as a valid form-species, an attempt has been made herein to group such forms under a single nomen in order to conserve chart space and avoid confusion (see below).

Another variable introduced in the laboratory is in staining. Although all samples were processed similarly, differences in staining could not be prevented.

These are probably due to slight differences in the pH of the residue, although the differences in the volume or duration of staining might be factors. The result is that grains from different samples, even if of similar histories, may not stain similarly. However, as almost all endemic and recycled sporomorphs rejected stain, this variable is of little importance.

Because the preservation differences of sporomorphs are the result of differing depositional, diagenetic, and tectonic histories, a mixed assemblage may be divided into its various components by grouping the sporomorphs by their preservation characteristics. A typical sample showing three preservation types is illustrated as Pl. I, fig. 2. Such groups are termed "preservation assemblages" herein. Some preservation assemblages contain fossils of two or more ages, as seen in samples 13-1 and 13-3, but in others the preservation assemblage is apparently unique to an individual age assemblage. The assumption that an unknown or long-ranging fossil is of X age on the basis of its preservation being similar to that of an X index fossil is in no case entirely justified, but is generally made due to a lack of contrary evidence.

As many as ten preservation assemblages have been delineated in a single well cutting sample from the Pennsylvanian clastic wedge. A typical sample might contain the following preservation assemblages:

1) Well preserved, pink.

2) Well preserved, transparent to light yellow.

3) Well preserved, bright red.

4) Corroded and pyrite pitted, dark yellow.

5) Pyrite-pitted and corroded beyond recognition, black.

6) Well preserved, dark yellow-brown to brown.

Certain preservation assemblages are characteristic of specific age assemblages in most samples. Thus, well preserved yellow-brown to brown sporomorphs are generally found to be of the Chester recycled assemblage, and pink, light yellow or transparent sporomorphs of the Virgilian-Permian or recent contaminant assemblage. However, it must be stressed that the correlation of preservation type to age or origin is imperfect between samples, and often even within a sample. This is especially true with respect to the corroded or pyritized forms, which, unfortunately, generally constitute the endemic assemblage.

In samples from Pure No. 1 Toelle sporomorph "ghosts" were encountered. These are light gray bodies composed of a fine granular material. As only the sporomorph outline is retained in these pseudomorphs, identification is generally impossible. The only "ghost" identified is Hamiapollenites shown as Plate I, figure 7.

CHAPTER V

IDENTIFICATION

Approximately 500,000 thousand palynomorphs were observed during this study. About 70 percent of these were deemed unidentifiable due to poor preservation, poor orientation, or partial concealment by debris. The designation unidentifiable is based on the impossibility or improbability of identification to genus or generic group. The term unidentified differs in its reference to forms which were not identified, but which do have the potential for identification. It is used synonomously with "unknown."

The amenability of palynomorphs to recognition as genera or species in states of poor preservation, poor orientation, or when partially obscured varies greatly between forms. Some forms, such as *Raistrickia crinita*, *Potonieisporites*, and *Centonites* are identifiable on the basis of little more than fragments. Other taxa, in particular bisaccate forms, and *Lycospora* and *Densosporites*, are readily identifiable only when well preserved. Because of these vagaries in the possibility of identification, and because of the variable magnitude of taxa, a pragmatic approach to nomenclature and taxonomy was necessary.

A form species is meaningless in itself, gaining importance only when phylogenetic, ecologic, or stratigraphic implications are attached. As stratigraphic implications were considered of greatest importance in this study, a pragmatic stratigraphic approach to identification was made. The meaningful units of such a system are generally referred to as index fossils. An index palynomorph should have the following attributes: 1) be readily identifiable, which infers physical durability, distinctive morphology, and medium to large size; 2) have a short range or have a useful range termination or initiation; and 3) be present in most samples. Palynomorphs having ranges which are based on strata outside of the Southwestern United States are considered of less value than those of locally established range due to regional differences caused by plant migration or ecology. That such differences are of importance has been shown by Sullivan (1965, 1967) in describing regional differences in Mississippian sporomorph assemblages, and by Kosanke (1962) and Peppars (1961), who have shown that the upper limit of the ranges of *Lycospora* and *Densosporites* vary not only geographically, but lithologically as well. Thus *Lycospora*, the range of which in Illinois and Oklahoma coals terminates at the Desmoinesian-Missourian boundary, is known from shales of Missourian age and from French Stephanian B coals, and Densosporites, which in coals does not occur to the top of the Desmoinesian in Oklahoma, is reported from latest Desmoinesian and early Missourian shale (Kosanke, 1962). These may be recycled, however.

The vagaries in the stratigraphic ranges of some of the important palynomorphs constituted a serious problem in this study, for the Oklahoma ranges of Pennsylvanian palynomorphs are based almost exclusively on assemblages from coals, whereas the lithologies sampled were shales or limestones.

An attempt was made to identify all observed spores to form genus. Identification beyond the generic level was made only where it would be of stratigraphic significance.

In several long-ranging genera the time and effort involved in speciation would not have been justified in the amount of information obtained. In Potonieisporites, for example, phenotypic variation is extreme, transgressing the arbitrary species designations established by various workers. In Punctatisporites, most species are so generalized, and so many specimens are referred to this genus due to destructive deornamentation, that speciation is all but impossible. The taxonomic problems in these genera, together with those of Calamospora and Leiotriletes, would require considerable time and offer little stratigraphic information not available more readily from other palynomorphs. Exceptions occurred in the form of such distinctive species as Punctatisporites labiatus and Calamospora exigua, neither of which is believed a valid member of its respective genus.

As noted above, certain species of Lycospora may be manufactured by the overmaceration of others. Such species lose any stratigraphic value on the specific level, and must be taxonomically and stratigraphically grouped with the other members of its series. These series, referred to by the name of the original or "raw material" forms, are the L. brevijuga and L. granata series. Valid specimens of L. noctuina, a Chester index fossil, were observed, but because of their mimicry by manufactured forms, they generally had to be treated skeptically, and relegated to the L. brevijuga series. An exception was tolerable only where the suspected L. noctuina was especially well preserved and was part of a preservation assemblage demonstrably of Chesterian age, in which case no additional information is gained.

Approximately fifty well-preserved palynomorphs were observed which have not been identified. These forms are not to be confused with those poorly preserved or debris-obscured forms which are unidentifiable. Although several of these unidentified forms are morphographically interesting, only two are sufficiently abundant to be of stratigraphic importance. These are *incertae sedis* A (Pl. II, fig. 14), which although unnamed, is believed to be a Devonian index palynomorph, and unknown spore U_1 (Pl. II, fig. 17). Although Unknown U_1 was observed in 24 samples, its stratigraphic position, as well as its name, is unknown. It has been placed in Missourian assemblages seven times, Desmoinesian assemblages three times, Chesterian assemblages six times, a Morrowan-Missourian assemblage once, and undatable assemblages eight times.

Because this form has an abnormally thick wall, it is darker in color than the other members of its preservation assemblage, thus making preservation correlation to index fossils difficult. This palynomorph is similar to *Anapiculiretusotriletes*, known only from the Givetian of Belgium, but can not be definitely assigned to this genus.

When the stratigraphic position of this palynomorph is established, the analyses of the samples in which it has been observed should be emended.

CHAPTER VI

STRATIGRAPHIC PALYNOLOGY

The primary object of this study was the delineation of the intra-Desmoinesian and Desmoinesian-Missourian stratigraphic boundaries. As seen in Table 1, the compilation of the individual ranges of the identified palynomorphs spans the Paleozoic, and includes many forms obviously not endemic to the strata of interest. The separation of the stratigraphically allocthonous forms simplifies the data. Certain other forms, which are too long-ranging to be of use in the delineation of the intra-Desmoinesian or Desmoinesian-Missourian boundaries, or whose range is not known, may also be discussed separately in the interest of simplification.

Through cautious extrapolation of the physical preservation characteristics of the various assemblages, it is often possible to relate otherwise stratigraphically unknown forms to their stratigraphic assemblages. Associating the long-ranging and unknown forms to their age association as determined by index palynomorphs provides data on the abundance of that assemblage in the sample

Table 1: Stratigraphic ranges of commonly occurring palynomorphs in Desmoinesian-Missourian strata in the Anadarko basin

	Pre-Chester	Chesterian	Morrowan-Atokan	Krebs	Cabaniss	Missourian	Post-Missourian
Acritarchs	X	X	X	X	X	X	
Tasmanites	X						
Chitinozoa	X						
Calamospora	X	X	X	X	X	X	X
Leiotriletes	X	X	X	X	X	X	X
Punctatisporites	X	X	X	X	X	X	X
Potonieisporites		X	X	X	X	X	X
Endosporites ornatus			X	X	X	X	X
Wilsonites visicatus			X	X	X	X	X
Schopfipollenites		X	X	X	X	X	
Florinites pellucidus		X	X	X	X	X	
Wilsonites kosankei		X	X	X	X	X	
Endosporites micromanifestus	X	X					
Convolutispora florida		X	X				
Convolutispora tesselata		X	X				
Crassispora kosankei		X	X				
Densosporites aculeatus		X	X				
Densosporites rarispinosus		X	X				
Densosporites reynoldsburgensis		X	X				
Dictyotriletes insculptilus		X	X				
Knoxisporites triradiatus		X	X				
Procoronaspora ambigua		X	X				
Raistrickia sp.		X	X				
Raistrickia irregularis		X	X				
Savitrisporites nux		X	X				
Secarisporites remotus		X	X				
Velamisporites rugosus		X	X				
Convolutispora mellita		X	?				
Discernisporites irregularis		X	?				
Florinites dissacoides		X	?				
Florinites visendus		X	?				
Knoxisporites stephanephorus		X	?				
Aggerispora campta		X					
Alatisporites sp.		X					
Asperispora crickmayi		X					
Auroraspora solisorta		X					

Table 1: Stratigraphic ranges of commonly occurring palynomorphs in Desmoinesian-Missourian strata in the Anadarko basin (Cont.)

	Pre-Chester	Chesterian	Morrowan-Atokan	Krebs	Cabaniss	Missourian	Post-Missourian
Bullaspora sp.		X					
Cadiospora sp.		X					
Calamospora exigua		X					
Cincturaspora sp.		X					
Cingulatisporites landesii		X					
Convolutispora ampla		X					
Convolutispora venusta		X					
Convolutispora vermiculata		X					
Convolutispora sp.		X					
Cristatisporites echinatus		X					
Cyclogranisporites commodus		X					
Densosporites spitzbergensis		X					
Dictyptriletes clatriformis		X					
Grandispora		X					
Ibrahimisporites sp.		X					
Knoxisporites rotatus		X					
Knoxisporites carnosus		X					
Leiotriletes pyramidatus		X					
Lophotriletes sp.		X					
Mooreisporites trigallerus		X					
Microreticulatisporites fundatus		X					
Perotriletes perinatus		X					
Proprisporites laevigatus		X					
Punctatisporites labiatus		X					
Reticulatisporites corporeus		X					
Reticulatisporites lacunosus		X					
Reticulatisporites peltatus		X					
Savitrisporites concavus		X					
Schulzospora rara		X					
Spinozonotriletes tenuispinus		X					
Spinozonotriletes sp.		X					
Stenozonotriletes callosus		X					
Tripartites vetustus		X					
Velamisporites sp.		X					
Waltzispora sagittita		X					
Densosporites sphaerotriangularis	X	X	X	X	X		
Cirratriradites saturni		X	X	X	X		
Endosporites globiformis		X	X	X	X		

Table 1: Stratigraphic ranges of commonly occurring palynomorphs in Desmoinesian-Missourian strata in the Anadarko basin (Cont.)

	Pre-Chester	Chesterian	Morrowan-Atokan	Krebs	Cabaniss	Missourian	Post-Missourian
Lycospora brevijuga		X	X	X	X		
Lycospora torquifer		X	X	X	X		
Simozonotriletes		X	X	X	X		
Granulatisporites verrucosus			X	X	X		
Cyclogranisporites leopoldi				X	X		
Guthőrlisporites				X	X		
Reinschospora triangularis				X	X		
Converrucosisporites sulcatus				X	X	X	
Laevigatosporites minimus				X	X	X	
Raistrickia crinita				X	X	X	
Reticulatisporites muricatus				X	X	X	
Thymospora pseudothiessenii				X	X	X	
Triquitrites bransonii				X	X	X	
Triquitrites spinosus				X	X	X	
Cadiospora sphaera					X	X	
Cirratriradites maculatus					X	X	
Laevigatasporites minutus					X	X	
Vesicaspora wilsoni					X	X	X
Wilsonites delicatus					X	X	
Guthörlisporites magnificus					X		
Schopfites colchesterensis					X		
Triquitrites additus					X		
Triquitrites dividuus					X		
Centonites					X		
Granulatisporites elegans					?		
Acanthotriletes sp.							X
Alisporites							X
Cycadopites							X
Entylisa							X
Hamiapollenites							X
Lueckisporites							X
Nuskoisporites							X
Parasaccites							X
Striatites							X
Stroterosporites							X
Taeniaesporites							X
Vesicaspora shaubergeri							X
Vittatina							X

which would probably be unavailable if index forms were studied as individuals.

Post-Missourian Assemblage

Sporomorphs known to be of younger age than the sample from which they were recovered were found in almost all of the samples based on well cuttings. With the exception of Recent contaminants, these were derived from well cavings. Examination of caliper logs of wells in the study area indicates that the entire post-Missourian section is prone to caving.

The majority of the post-Missourian contaminants are readily distinguished from other palynomorphs in the samples by their better physical preservation. Many of these forms fail to absorb stain, remaining light yellow in color. Others, presumably from non-redbed lithologies, are stained pink to light red. Slight to moderate corrosion of these sporomorphs was observed in most samples, but in several samples, certain members of the well cutting assemblages were highly carbonized, indicating their origin from near a fault in the Permian section. In samples from Pure No. 1 Toelle (Well No. 10), the well caving assemblage contained abundant gray pseudomorph "ghosts," (Pl. I, fig. 7), the significance of which is unknown.

The most common genera in the post-Missourian well caving assemblages are: *Potonieisporites*, *Florinites*, Wilsonites, Vesicaspora, Alisporites, Acanthotriletes, Nuskoisporites, Entylisa, Cycadopites, Clavatasporites, Vittatina, Hamiapollenites, Taeniaesporites, Strotero-sporites, Striatites. The monocolpate and striate bisaccate forms serve as the best indicators of post-Missourian age. Vittatina, although a typical Permian form, has been reported in the Desmoinesian (Dolly, 1965) and is therefore of less diagnostic value. Similarly, one species of Vesicaspora, V. wilsoni, occurs in the late Desmoinesian and Missourian. The other Vesicaspora species, however, are apparently confined to Late Missourian through Permian strata. Taeniaepollenites, although best known from Permo-Triassic strata, has been reported in Virgilian strata by Jizba (as Striatosaccites tractiferinus) and its rare occurrence with similarly preserved Centonites indicates that it may have existed in late Missourian time. There is no evidence of that form's existence in Early Missourian strata, however.

The first three genera of the above list are extremely long-ranging forms and of little diagnostic value. Representative members of the post-Missourian assemblage are illustrated on Plate II, figs. 1-7.

Pre-Desmoinesian Assemblages

Palynomorphs known to be older than the sample from which they were recovered were common in almost all samples. In most samples several such forms were found, but only rarely does one of these appear in abundance, most forms occurring uniquely or rarely.

Chester Reworked Assemblage

Most of the recycled palynomorphs are forms which occur in the Chesterian strata of Oklahoma, the palynomorphs of which have been, or will be, described by Wiggins (1962), Wilson (1959a,b and 1966b), Felix and Burbridge (1967), Sullivan and Mischell (1967) and Sullivan (1967). Of these, only the two short papers by Wilson, both of which lack systematic description, have been published. The palynomorphs found include: (most commonly encountered forms marked by an asterisk)

*Savitrisporites nux (Butt. & Will.) Sull., 1964
Potonieisporites spp.
*Knoxisporites triradiatus Hoff., Stap. & Mall., 1955
*K. stephanephorus Love, 1960
*K. hederatus (Ish.) Play., 1963
Cirratriradites saturni (Ibs.) Sch., Wil., & Bent., 1944
Convolutispora florida Hoff., Stap., & Mall., 1955
*C. tesselata Hoff., Stap. & Mall., 1955
C. vermiformis Hughes & Play., 1961
*C. mellita Hoff., Stap. & Mall., 1955
C. venustus Hoff., Stap. & Mall., 1955
Lycospora noctuina Butt. & Will., 1958
Reticulatisporites lacunosus Kosanke, 1950
*R. peltatus (Waltz) Play., 1963
*R. corporeus (LOOse) Pot. & Kr., 1958
Proprisporites laevigatus Neves, 1961
Auroraspora solisortus Hoff., Stap. & Mall., 1955
*Tripartites vetustus Schem., 1951
*Densosporites irregularis Hacq. & Barss, 1957
D. rarispinosus Play., 1963
*D. aculeatus Play., 1963
Schulzospora rara Kosanke, 1950
*Velamisporites rugosus Bhard. & Venk., 1961
*Grandispora spinosa Hoff., Stap. & Mall., 1955
*Grandispora echinata Hacq., 1957
*Mooreisporites trigallerus Neves, 1961
Leiotriletes ornatus Ish., 1956

L. subintortus (Waltz) Ish., 1956
Perotriletes perinatus Hughes & Play., 1961
Endosporites micromanifestus Hacq., 1957
Cyclogranisporites lasius (Waltz) Play., 1962
*Waltzispora sagittata Play., 1962
*Secarisporites remotus Neves, 1961
Dictyotriletes clatriformis (Art.) Sull., 1964
Crassispora kosankei (Pot. & Kr.) Bhard., 1957
*Ibrahimisporites sp.
Simozonotriletes sp.
*Punctatisporites labiatus Play., 1962
*Cristatisporites echinatus Play., 1963
Leiotriletes pyramidatus Sull., 1964
Cristatisporites sp.
Discernisporites irregularis Neves, 1951
*Procoronaspora ambigua Butt. & Will., 1958
Florinites visendus (Ibr.) Schopf, Wils. & Bent., 1944
*F. dissacoides Alpern, 1959
Schopfipollenites ellipsoides Schopf, 1938
S. ovatus Schopf, 1938
Calamospora exigue Stap., 1960

and several forms to be named in a forthcoming paper by Felix and Burbridge (1967), including species of Cinctura-spora, Alatasporites, Spinozonotriletes, Raistrickia, Lophotriletes, Convolutispora, Cadiospora, and a spore assigned to Densosporites, but which is believed to be synonymous to Aggerispora campta (Venkatachala, 1962). Several forms not previously reported from Chesterian strata of Oklahoma, but which occur in similar stratigraphic positions elsewhere and which generally belong to the same preservation assemblage, are considered to be members of the Chester assemblage. These include: Knoxisporites carnosus, described from the Namurian of Scotland (Butt. & Will., 1958); Convolutispora ampla, Knoxisporites rotatus, Microreticulatisporites fundatus, and Stenozonotriletes callosus, described from the

Chester of Kentucky (Hoffmeister, Staplin & Malloy, 1955); Dictyotriletes caperatus, Cristatisporites echinatus and Cyclogranisporites commodus, described from the middle Visean of Spitzbergen (Playford, 1962); Dictyotriletes insculptilus and Leiotriletes pyramidalis, described from the upper Visean of Scotland (Sullivan, 1964); and Asperispora crickmayi, which although named and described from the Givetian of northern Canada, is reported (under the junior synonym: Vallatisporites galearis) from the upper Visean of England (Sullivan, 1964).

The most common and diagnostic members of the Chester recycled assemblage are denoted by an asterisk in the above list. Eighteen of these are illustrated on Plate III. Those chosen for illustration are forms which occur endemically in neither the Desmoinesian nor Missourian of Oklahoma, most being exclusively Chester or Chester-Morrow forms. Also figured is a sporangial wall cell (Pl. III, fig. 19), which, in Oklahoma, is apparently diagnostic of Springer strata.

These palynomorphs are generally characterized by their dark color, generally brown or dark yellow-brown, and fine state of preservation. In several samples, some of the Chester recycled fossils were corroded and dark brown to black, presumably due to the presence of a fault in the Chester at the provenance area. In a sample from Texaco 1 Carter, however, both the Chester recycled assemblage and the Pennsylvanian, assumed endemic, fossils are dark and corroded, indicating faulting during Pennsylvanian time. It must be emphasized that analysis of a partial assemblage must be done with cognizance of the whole.

Not all of the forms listed above are confined to Chester strata, but their shared physical preservation characteristics relate them to Chester index forms. That some of them were actually derived from rocks of other than Chester age is to be assumed, as the provenance area was undoubtedly an area in which more than Chester strata cropped out. These non-Chester forms, however, are not distinguishable from the diagnostic Chester forms on the basis of preservation, and, unless they are forms which did not exist in Chesterian time, their place in the Chester recycled assemblage must be assumed. The Chester recycled assemblage, therefore, although consisting mainly of Chester forms, is not necessarily exclusively of Chester forms. All of its constituents, however, are of possible Chester provenance.

The quantitative rarity of *Potonieisporites*, *Schulzospora*, *Florinites*, *Auroraspora* and other presumably upland forms in the Chester assemblage indicates the lack of extensive upland areas during Chesterian time.

Pre-Chester Reworked Assemblages

Palynomorphs restricted to pre-Chester strata were recovered from several samples. The number of forms recognized as pre-Chesterian is probably only a fraction of the actual number present, for little is known of the pre-Chester palynology of Oklahoma. With the exception of published notes on single species, only two studies of pre-Chester palynomorphs are available. These are Master of Science theses on the Woodford Shale, Upper Devonian (J. Urban, 1960) and on the Sylvan Shale, Ordovician (Hedlund, 1960). Palynomorphs recognized as pre-Chester include:

Tasmanites: (Pl. II, fig. 15) A Devonian form commonly encountered in the Chester.

Tapajonites sp. A: (Pl. II, fig. 13) Described from the Devonian of Brazil. Occurs in the Stanley Shale of Eastern Oklahoma, probably by recycling. Inferred to be Devonian.

Incertae Sedis A: (Pl. II, fig. 14) A rosette-like body similar to *Tapajonites* and probably of similar stratigraphic origin.

Chitinozoa: Only two of the eight Chitinozoans recovered were identified. Both of those, *Rhabdochitina* and *Lagenochitina*, are Ordovician forms. The unidentified chitinozoans assume the range of the group, Ordovidian-Devonian.

Acritarchs: The few acritarchs observed were not identified. The acritarch range of abundance is Cambrian-Devonian and Jurassic - Recent.

Mississippian-Triassic strata contain few acritarchs.

The presence of these forms endemic to pre-Chester strata does not necessarily imply that such strata were exposed in the provenance area during Mid-Pennsylvanian time, for these forms could be on their second or third cycle of deposition. This is especially true for Tasmanites, which is commonly observed in Springer strata. Four pre-Chester palynomorphs are illustrated on Plate II, figs, 13-16.

Morrow-Atokan Assemblages

No palynomorphs known to be restricted to the Morrow or Atokan series were observed. This is probably a function of our lack of knowledge of the palynology of these series rather than the lack of reworked Morrow-Atokan fossils. Many forms, such as Potonieisporites, which ranged through the Morrow and Atokan are present, and it is assumed that some of these are of Morrowan or Atokan age, for the truncation of Atokan and Morrowan strata in late Atokan time should have theoretically caused the redeposition of the Atokan-Morrowan palynomorphs.

Long-Ranging Forms

Certain palynomorphs, including the two most abundant forms, Potonieisporites and Punctatisporites, are so difficult to speciate, and, in general have such long ranges, that their presence is stratigraphically valueless, except in combination with other palynomorphs. These genera include Potonieisporites (Chester to Pennsylvanian), Punctatisporites (Silurian to Recent), Leiotriletes (Devonian to Recent), Calamospora (Devonian to Recent) and Schopfipollenties (Chester to Pennsylvanian). There are exceptions, like the readily recognized Chester indices Punctatisporites labiatus Playford, 1962, and Leiotriletes pyramidatis Sullivan, 1964. It is probable that detailed study of these genera would result in stratigraphically useful speciation, but the amount of data gained from such studies would not justify the several years labor required.

Some other palynomorphs are of little value at the specific level because of their excessively long ranges with respect to the Desmoinesian-Missourian strata of Oklahoma. These include:

Endosporites ornatus Wils. & Coe, 1940 (Atoka-Virgil)
Florinites pellucidus (Wils. & Coe), Wilson 1958 (Morrow-Missouri)
Wilsonites kosankei Bhard., 1957 (Morrow-Missouri)
Wilsonites vesicata Kosanke, 1950 (Morrow-Virgil)
Cyclobaculatisporites grandiverrucosis Kosanke, 1953 (Chester-Missouri)

Most long-ranging forms are listed with the reworked and well-caving assemblages, but their inclusion as parts of those assemblages is possible only when their physical preservation characteristics are similar to those index forms of that assemblage. Specimens of the long-ranging forms which are not removable as part of the well caving or reworked assemblages are nevertheless valueless. In rare cases it is possible to relate some of these long-ranging forms to Desmoinesian or Missourian forms by their physical preservation characteristics. However, preservation characteristics are not as distinctive between the Pennsylvanian assemblages as between these and the reworked or well caving assemblages. Their differentiation is generally impossible.

Desmoinesian-Missourian Assemblages

The palynology of the Desmoinesian rocks of Oklahoma is known through the studies of Desmoinesian coals by Dempsey (1964), Davis (1961), L. Urban (1965), Bordeau (1964), Bond (1963), Clarke (1961), Higgins (1961), Ruffin (1961), J. Urban (1962), Dolly (1965), Gibson (1961) and Wilson and Hoffmeister (1956). The palynology of Missourian strata in Oklahoma has been described by W. Edwards (1966) and Upshaw and Hedlund (1967).

With the exception of W. Edward's thesis on the Francis Shale (1966), all of the middle Pennsylvanian studies of Oklahoma are based on coals and associated shales closely adjacent to the coal seams. All of the studies cited above are based on rocks from the Ardmore and Arkoma Basins of Eastern Oklahoma, whereas the strata of interest are in the Anadarko Basin in Southwestern Oklahoma. Because there is no local evidence to the contrary, the stratigraphic ranges of the various palynomorphs must be assumed to be similar despite the differences in lithology and geography. The possibility of error in such application of ranges, however, should be noted.

The sporomorphs below are apparently confined to the Desmoinesian-Missourian strata of Oklahoma, and are useful for the recognition of the general strata of interest, but are valueless in the delineation of the Desmoinesian-Missourian boundary, as they are present throughout these strata.

Thymospora pseudothe~~ies~~ssenii (Kosanke) Wils. & Venk., 1958
Laevigatosporites minimus Wils. & Coe, 1940
Raistrickia crinita Kosanke, 1950
Converrucosisporites sulcatus (Wils. & Kos.) Pot. & Kr., 1955
Reticulatisporites muricatus Kos., 1950
Triquitrites spinosus Kos., 1943
and Triquitrites bransoni Wils. & Hoff., 1955

The following palynomorphs are believed to be confined to Desmoinesian strata:

Triquitrites dividuus Wils. & Hoff., 1955
Triquitrites additus Wils. & Hoff., 1955
Reinschospora triangularis Kosanke, 1950
Schopfites colchesterensis Kosanke, 1950
Cyclogranisporites leopoldi (Kr.) Pot. & Kr., 1954
Guthörlisporites magnificus Guen., 1958

These forms, together with those longer-ranging forms which do not occur above Desmoinesian strata, generally serve for the differentiation of Desmoinesian from

Missourian strata. The latter include:

*Granulatisporties verrucosus Scho., Wils. & Bent., 1944
(Atokan-Cabaniss)
*Lycospora (Dev. - Desm.)
*Densosporites (Dev.-Desm.)
*Cirratriradites saturni (Dev.-Desm.)
Simozonotriletes (Chest.-Desm.)
*Endosporites globiformis (Morrow-Desm.)

Those marked with an asterisk are considered of greatest importance in locating the top of the Desmoines series, the remaining forms are rarely encountered or identified. Densosporites and Cirratiradites saturni, although common, are of reduced value because their ranges, along with that of the rarely encountered spore Simozonotriletes, terminate below the Croweburg coal in the upper part of the Cabaniss group, and they do not appear to have been associated with living plants in the Late Desmoinesian time.

Densosporites, Lycospora, Cirratriradites, and Simozonotriletes also occur in the Chester reworked assemblage. These fossils can be used as Desmoinesian indices only where they can be proven to be part of a Desmoinesian-dated preservation assemblage. With the exception of Lycospora, the above thick-walled spores, and tend to be darker than other spores, making assignment to preservation assemblages difficult.

The only palynomorph observed which is believed to be confined to the Missourian strata of Oklahoma is Centonites. By extrapolation from the Illinois Basin, the rarely encountered spore Granulatisporites elegans, may be a valid Missourian index. However, most of the samples used in the project are from well cuttings, in which well cavings are present, and in which fossil indices of the younger strata can not be used as stratigraphic criteria. Neither of these palynomorphs were encountered in the seventeen samples from cores.

The palynological location of the intra-Desmoinesian unconformity in the Anadarko Basin is based upon criteria for the differentiation of Krebs and Cabaniss strata in the eastern basin. Palynomorphs found in the Anadarko Basin which are restricted to the Cabaniss Group of the Ardmore Basin are:

Triquitrites dividuus Wils. & Hoff., 1955
Triquitrites additus Wils. & Hoff., 1955
Schopfites colchesterensis Kosanke, 1950
Guthorlisporites magnificus Guennell, 1958

In the few samples in which well cavings do not occur, e.g., those samples based on cores, Vesicaspora wilsoni, whose range begins in the Cabaniss Group, may be used as a stratigraphic index.

The Desmoinesian and Missourian palynomorphs generally are the poorest preserved of the identifiable forms. They are characterized by pyritization and exine corrosion. The color is generally light yellow to yellow-brown, although Safranin-stained red forms have been observed. With extreme corrosion or pyritization the spores become black or yellowish-gray.

Separation of the middle-Pennsylvanian palynomorphs into stratigraphic assemblages based on preservation characteristics has proven impossible in most samples. The presence or absence of pyrite or corrosion, and the color of the palynomorph varies almost as much between different specimens of an index form as between palynomorph indices of different ages. This is believed due to the closeness of their geologic ages and similarity of their physio-chemical environments.

The occurrence of pyrite and corrosion is believed to be a function of the pH and sulfide ion concentration of the depositional environment and is a function correlative with sediment lithology rather than age. The slight color differences observed may be attributed to differences in lithology, resulting from both the chemistry of the diagenetic environment and differential responses of different rock types to the transmittal of stress during diastrophism.

Because the index fossils for Lower and Upper Desmoinesian and Missourian strata can not often be differentiated by preservation characteristics, the Desmoinesian and Missourian specimens of long-ranging forms are often unrelateable to the fossil indices of their strata, and hence are of little value.

The long-ranging genera, <u>Potonieisporites</u>, <u>Florinites</u>, <u>Wilsonites</u>, <u>Vesicaspora</u>, and <u>Endosporites</u>, appear to have been derived from the upland vegetation of the adjacent Amarillo-Wichita landmass. Only these upland forms occur in sufficient abundance for quantitative analysis, but their use for the location of the intra-Desmoinesian and Desmoinesian-Missourian boundaries by relative hemerae as envisioned at the outset of the project was not possible because it was not known which specimen were in place. Therefore, differentiation of Early and Late Desmoinesian and Missourian assemblages must be based upon the occurrence of the few index palynomorphs noted above or upon the range overlap of pairs of other palynomorphs which are assumed to be of similar stratigraphic origin. Because of the combination of recycling and well caving contamination in most samples, it was impossible to ascertain which palynomorphs are endemic. Therefore, although proving the presence of certain aged strata in a sample, the presence of an index palynomorph does not necessarily imply the age of the strata at sample depth.

In the seventeen core samples collected index palynomorphs are valid criteria for the minimum age of the sample because well caving contaminants are lacking. In the 127 samples based on well cuttings, however, the combination of potential well caving contaminants and reworked Pennsylvanian palynomorphs creates a stratigraphic dilemma.

CHAPTER VII

SAMPLE ANALYSES

Because of the large number of samples, some of which yielded as many as 150 palynomorph species of up to 10 preservation assemblages, it is impossible to give a written analysis of each. Therefore, tables have been constructed to convey as much of the sample data as possible. Table II, in the back cover folder, lists the most common palynomorphs observed in each sample. Tables III to XXIII, one for each well, present data on sample depth and lithology, palynomorph abundance, assemblage preservation, and assemblage age. Interpretation and evidential comments are included where desirable.

It is doubtful that any form of tabulation could present all of the data obtained from these samples. Much of the data not presented in the tables appears in the written summary and interpretation of the samples for each well which is presented with the assemblage tables.

Assemblage Tables

The assemblage tables (Tables III - XXIII), which appear in the Appendix, are complex, and need explanation.

The samples are listed in order of increasing depth. The sequence of sample numbers indicates only the chronology of sampling. An asterisk marking a sample no. indicates that sample was processed twice. The depths cited are subsurface depths as measured from either the derrick floor or kelly bushing, generally the latter.

The notation WC or core, which appear with the depth data, identifies the nature of the material from which samples were collected as well cuttings or core respectively. The lithologv of the samples is given using strip log abbreviations and the estimated percentage of each lithology is indicated.

Palynomorph abundance is cited using the notations defined below. These notations are also used in Table XXVI.

A: Palynomorphs Abundant, e.g., more than 50 observed per traverse of microscope preparation at 2 magnification of 100X.

N: Palynomorph abundance Numerous, e.g., approximately 20-40 palynomorphs observed per traverse.

S: Palynomorphs Scarce, e.g. 1-20 palynomorphs observed per traverse.

R: Palynomorphs Rare, e.g., an average of less than one palynomorph observed per traverse.

The percentage of unidentifiable palynomorphs is an index of the overall preservation of the sample as a whole. In samples of low palynomorph abundance (abundance description R or S), this index is apt to be greatly influenced by the presence of identifiable well-caving contaminants. In samples where this index presents an unrealistic picture of the sample, it is omitted or marked by an asterisk.

For purposes of age analysis, the palynomorphs are grouped into their respective preservation assemblages. Although there is the possibility of creating assemblages of mixed ages by this procedure, it is necessary for the analysis of these samples. By assuming the monogenesis of pairs of long-ranging forms, it is often possible to gain stratigraphic data from range-overlap, which is not available from the individual palynomorph.

The preservation characteristics of each assemblage are described using the abbreviations given below.

Colors	Color Adjective	Preservation Adj.
R = red	l = light	C = corroded
B = brown	br = bright	C+ = highly corroded
BK = black	d = dark	P = pyritized
Y = yellow	t = transparent	P+ = highly pyritized
Salm. = salmon	m = mottled	E = excellent
G = gray		G = good
Or = orange		

The order of code formulation is: color adjectives, color, preservation character.

Color terms are used in combination such as YB for yellow-brown. Designations set off in parentheses are not applicable to all members of the assemblage. For example: the code designation lYBC(P) refers to a light yellow-brown corroded assemblage, some of the constituents of which have been pyritized.

The preservation code is followed by the number of sporomorph types attributed to that assemblage. Non-sporomorphous palynomorphs are generally listed as individuals without preservation notation.

The age of the assemblage is given by a line through the appropriate age column, or part thereof. Solid lines are used to indicate the known or probable age of the assemblage and dashed lines are used to extend the ranges where the limits of probability are desired, or where there is inconclusive evidence of mixed assemblages.

Well No. 1

Shell No. 1 Adams

C SE¼ SE¼ Sec. 6, T. 9 N., R. 19 W.

Sample Analysis, Table III

The depth to the top of the Desmoinesian Series in this well has been reported as 10,900 feet (Research Oil Report scout cards), 11,520 feet (Glover, Hefner, Kennedy Oil Company cross section I-I'), 10,600 feet (Mr. Alfred Gaither, Shell Oil Company, personal communication) and 10,900 feet (Mr. Robert Hefner, Glover, Hefner, Kennedy Oil Company, personal communication). The intra-Desmoinesian unconformity was placed at 12,370 feet by Mr. Alfred Gaither (personal communication), of Shell Oil Company. Samples from 8,595 to 12,250 feet were collected from well cuttings of shales as determined from electric logs.

With the exception of the deepest sample (ca. 12,270 feet) which is highly carbonized, well-preserved Chester reworked fossils comprise the most abundant identifiable palynomorphs in the samples from this well. Post-Missourian sporomorphs derived from well cuttings were observed in all samples; their fine preservation and light color rendering them readily identifiable.

Desmoinesian palynomorphs were recovered from samples both above and below the Desmoinesian-Missourian boundary as defined by the various sources noted above. The presence of several Desmoinesian index spores at ca. 9,425 feet, which is 1,100 to 2,100 feet above the Desmoinesian-Missourian boundary according to the different sources listed above, proves that Desmoinesian strata was exposed in the provenance area during Missourian time.

All of the samples yielded a highly carbonized, corroded and pyritized assemblage from which only *Potonieisporites* was identifiable. This assemblage is volumetrically unimportant in samples above 11,400 feet, but below this depth the assemblage increases to 75 percent (ca. 10,775 feet, ca. 11,160 feet and ca. 11,575 feet) and 80 percent (ca. 12,260 feet). It is believed that the assemblage is reworked from near a fault or unconformity occurring at or below the intra-Desmoinesian unconformity. The decrease in the assemblage's abundance above 10,400 feet is thought to mark a decrease in outcrop area of this fault zone.

Well No. 2

Shell No. 1 Kelly

C NW¼ SE¼ Sec. 21, T. 10 N., R. 21 W.

Sample Analysis, Table IV

The Research Oil Report scout card places the top of the Missourian Series at 8,343 feet. The top of the Desmoinesian is not cited. Samples are based on remnants of cores, which, at the time of collection, were in such disarray that only spot sampling was possible. These cores are of potential reservoir beds, which are palynologically the least desirable strata.

Palynomorphs are scarce or rare, and generally poorly preserved in all of the samples. The presence of well-preserved modern contaminants in all samples indicates that the paucity and condition of fossils is not due to over-processing.

Because these samples are based on cores, it is possible to determine their stratigraphic position. Sample no. 1 (8,451-2 feet) on the basis of haploxylonoid bisaccate pollen grains is Missourian or younger in age with Chesterian and Desmoinesian-Missourian (*Converrucosisporites sulcatus*) recycled forms. Sample no. 3 (9,589-90 feet) yielded three preservation assemblages, all the palynomorphs of which are definite or possible Missourian or younger forms. Because samples 1 and 3 are demonstrably of Missourian age, sample 2 at 9,287-8 feet must also be of Missourian age. Therefore, the spore

<u>Converrucosisporites</u> <u>fistulosus</u> (Ibr.) Bhardwaj, heretofore not reported from North America, is, at least in part, of Missourian age.

The lack of palynomorphs in samples below 9,700 feet is not believed due to diastrophic distillation of the palynomorphs, but rather the genuine rarity of endemic fossils in the sample, as well-preserved tissues are present.

The conglomerate sample (no. 4) from 9,949-50 feet was divided into pebble and matrix factions which were processed separately. Both factions were barren.

Well No. 3

Texaco No. 1 Carter
C NW¼ SW¼ Sec. 24, T. 9 N., R. 21 W.
Sample Analysis, Table V

Samples were chosen from well cuttings at systematic depth intervals, because no shales were observed on the electric logs. Scout card data indicates the top of the Desmoinesian is at 8,400 feet, but a cross-section made by E. F. Wroblewski (Glover, Hefner, Kennedy Oil Company, structure section X-X^1) shows this horizon to have been encountered twice in the well, at 7,480 feet and 10,050 feet, due to repetition of beds along the North Carter Thrust. The latter source places the intra-Desmoinesian unconformity at 8,000 feet in the North Carter Thrust plate, and at 10,500 feet in the sole.

All of the samples from this well yielded abnormally low numbers, almost all of which are poorly preserved palynomorphs. This is probably due to the proximity of this well to the growth faults along the Wichita Mountain Front. The most abundant and best-preserved palynomorphs are those derived from well cavings, even though most of these are corroded and darkened, due to the presence of the Meers Thrust at about 4,700 foot depth. The Chester reworked forms present, or probably present, in each sample, range from darkened but well-preserved to highly corroded and pyritized.

If the four samples above the 7,000 foot depth are of Missourian age, as both sources indicate, the presence of Desmoinesian as well as Pre-Desmoinesian outcrops in the provenance area during Missouri time is confirmed, for several possible, and one definite Desmoinesian fossil, Guthörlisporites, were observed. It is not possible to determine whether this Desmoinesian exposure represents the hypothetical Desmoinesian-Missourian Unconformity or whether there was truncation to the Desmoinesian on a younger erosion surface.

Samples from below 8,000 feet are impossible to date due to the presence of many long-ranging forms and general inability to distinguish between endemic, reworked, or well-caving derived palynomorphs within the Pennsylvanian.

The dearth of palynomorphs and the high degree of carbonization of non-caved palynomorphs below 8,500 feet, indicate the proximity of the North Carter fault. Wroblewski's (Glover, Hefner, Kennedy Oil Co., Structure Section X-X[1]) depth of ca. 9,340 feet for this fault seems reasonable, but can not be confirmed to within several hundred feet.

Well No. 4

Decem No. 1 Hill

SE¼ SW¼ Sec. 11, T. 9 N., R. 21 W.

Sample Analysis, Table VI

Samples from well cuttings were chosen using 500 foot spacing without regard to lithology, because no well logs were available. McNeal (1955) placed the top of the Desmoinesian Series at a depth of 9,900 feet. However, this horizon is shown at 10,400 feet on a G. H. K. cross-section X-X[1]. The latter source shows the intra-Desmoinesian unconformity at 10,900 feet.

Decem No. 1 Hill is from near the edge of the Anadarko Basin, an area of tectonic activity. This is reflected in the high degree of carbonization of the samples. With the exception of the shallowest sample (no. 1, from ca. 8,503 feet), the samples from the Decem No. 1 Hill well are palynologically characterized by poor quality and quantity of the palynomorphs.

Samples from below about 10,400 feet are almost barren, containing mostly unidentifiable and well-cutting derived palynomorphs. Proximity to a tectonic feature, probably a fault, is suspected at about 11,000 feet.

Well preserved Chester palynomorphs are present in the more fossiliferous shallow samples. These Chester recycled palynomorphs together with the omnipresent well caving-derived, post-Missouri forms, are dominant in almost all of the samples. In sample no. 3 (ca. 9,525 feet), the well-caving forms are so abundant that the percentage of endemic forms considered unidentifiable is lowered from 95 percent to 10 percent.

Palynomorphs or assemblages restricted to the strata of interest were observed only in the sample at 8,530 feet, where _Reticulatisporites muricatus_, a Cabaniss-Missourian sporomorph, was observed. A pre-Croweburg (lower Cabaniss) age is indicated for the well-preserved brown assemblage in sample 1, which contains _Cadiospora sphaera_ (Desmoinesian-Missourian) and _Densosporites_ (Desmoinesian - middle-Cabaniss).

Confirmation of either the intra-Desmoinesian or Desmoinesian-Missourian boundary determination cited above is not possible.

Well No. 5

G. H. K. No. 1-22 Kennemer

C NE¼ Sec. 22, T. 9 N., R. 21 W.

Sample Analysis, Table VII

Research Oil Report scout cards place the top of the Hoxbar at 8,030 feet and the top of the Missourian at 8,107 feet. This is not understood. A G.H.K. Oil Company seismic section places the top of the Hoxbar at 7,685 feet, the "Deese Unconformity" at 10,260 feet, and the top of the Atoka at 12,780 feet.

Palynomorphs are scarce or rare in all samples. All of these samples were taken from well cuttings of shale, except no. 7 (15,020-15,029 feet) which was based on core chips of carbonate wash. The shallowest samples, nos. 8 (ca. 10,525 feet) and 9 (ca. 10,825 feet) are essentially barren, only highly carbonized sporomorph "skeletons" being observed. A sample from 100 feet deeper (no. 1) is quite similar, but a single Chester reworked spore and a long-ranging form which is probably from well cavings were recovered.

Deeper samples, nos. 4, 5, and 3 at ca. 12,550 feet, ca. 12,800 feet and 13,100 feet, yielded more and better preserved palynomorphs, but even these are rare and poorly preserved. Reworked Chester, Chester-Morrowan spores are present, along with long-ranging forms and a single occurrence of two diagnostic Desmoinesian-Missourian or Atokan-Desmoinesian spores. It is impossible to ascertain which of these are endemic, reworked, or derived from well cavings. According to scout card data, these samples should be Atokan. The decrease in the degree of palynomorph distillation from 10,000 to 13,000 feet indicates a fault at about 10,500 feet.

Samples from ca. 13,800 feet and 15,020 feet yielded only highly carbonized palynomorphs, and indicates the proximity of a fault.

Well No. 6

Shell No. 4 Jarrell
C NE¼ NE¼ Sec. 6, T. 10 N., R. 21 W.
Sample Analysis, Table VIII

Samples are from well cuttings of shales as determined from electric logs. According to scout card data, this well did not reach the Desmoinesian. It was chosen for study on the premise that it would serve as a Missourian reference section, and that the post-Atokan forms found in these samples could be deleted from the study of well cutting samples as occurring in the Missourian or post-Missourian. However, in addition to forms reworked across the Chester and Atokan unconformities, there are many Desmoinesian forms. This proves the existence of a Desmoinesian-Missourian unconformity.

The most abundant forms in each sample are of pre-Desmoinesian (Chester) and post-Missourian age. The fact that Cabaniss index forms such as *Schopfites* *colchesterensis* occur in the Missourian indicates that there is an unconformity of later age than that referred to as the intra-Desmoinesian unconformity, which is assumed to be equivalent to the Krebs-Cabaniss break.

Although referred to as the Desmoinesian-Missourian unconformity, there is no evidence indicating that this unconformity is not in the late Desmoinesian or early Missourian. The presence of Desmoinesian fossils in the Missourian of the Anadarko Basin does not, however, necessarily infer that an unconformity existed in the basin proper, but rather, only infers uplift and erosion of Desmoinesian strata in the provenance area.

Well No. 7

Continental No. 1 Procter
C NW¼ Sec. 28, T. 10 N., R. 20 W.
Sample Analysis, Table IX

Scout card data places the top of the "Deese" (=Desmoinesian Series) at 10,740 feet and Cherokee at 11,500 feet. A structural cross-section in the files of the Glover, Hefner, Kennedy Oil Company places the top of the Desmoinesian at a depth of 11,425 feet. Nine samples from 9,500-12,840 feet were taken from well cuttings at intervals selected on electric logs.

In each of the samples, except no. 1 (ca. 10,225 feet) and no. 8 (ca. 12,820 feet), which contain few identifiable fossils, Chester and post-Missourian assemblages are dominant. Pre-Chester reworked palynomorphs, including the Devonian form Tasmanites, were recovered from several samples. Although forms extant in the Desmoinesian were found in almost all of the samples, only the sample from ca. 11,870 feet yielded Desmoinesian index palynomorphs.

Two samples yielded few recognizable fossils. The four palynomorphs recovered from the sample from ca. 12,820 feet are highly carbonized and corroded, indicating the probable proximity of a fault. The sample from ca. 10,225 feet, however, contains well-preserved forms as well as highly carbonized forms, and, if tectonically controlled, the fault is either not so close or responsible for less transmittal of heat and pressure, than the deeper fault.

Although samples 2 and 2A overlap for one-half their interval, neither their palynomorph content nor preservation assemblages are any more comparable than are most of the other wells. Were the sample-depth relationship of these samples not known, there would be no evidence of their close association.

Well No. 8

Constantine No. 1 Heket
SW¼ NW¼ Sec. 17, T. 10 N., R. 20 W.
Sample Analysis, Table X

Research Oil Reports scout card data is inadequate for the determination of the top of the Desmoinesian

Series, citing only the top of the "Kansas City" at 9,270 feet. Samples are from well cuttings at depths shown to be shale as indicated on electric logs. Due either to miscalculation of mud-return time, or well caving contamination, the samples consist mostly of limestone.

Composite samples were collected from 10,850 to 10,880 feet (TD) and at ca. 10,660 feet. Both samples yielded definite well caving assemblages of Virgilian and Permian ages, and Chester reworked assemblages. Although Wilsonites delicatus was observed from sample no. 1, no exclusively Desmoinesian forms were encountered. There is no evidence of Desmoinesian strata having been reached, as the Wilsonites delicatus could have been recycled from Morrow or Atokan strata.

Well No. 9

Howell 1 Hunter-Ryan

C SE¼ NW¼ Sec. 4, T. 10 N., R. 22 W.

Sample Analysis, Table XI

As scout card data was not available, all well data is from the legend of a Glover, Hefner, Kennedy Oil Company cross-section (Structure-section X-X^1), which places the top of the Desmoinesian approximately 500 feet above total depth, or at ca. 10,830 feet. All of the samples are from well cuttings of shales, as determined from electric logs.

With the exception of the deepest sample, 11,300-11,344 feet, all of the samples yielded palynomorphs in abundance. Each of the better samples had one or more preservation assemblages of post-Missourian fossils introduced through well caving. Reworked Chester sporomorphs occurred in each of the good samples, generally in several different preservation assemblages in each sample. Chester forms are numerically the most abundant in almost all of the samples. In several samples Chester, pre-Chester and Permian forms apparently share a common set of preservation characteristics, making analysis difficult. Desmoinesian assemblages, based on range overlap or the presence of *Triquitrites* Spp. were found in all samples except the shallowest (ca. 9,125 feet) and deepest (ca. 11,325 feet). Although potential Missourian fossils occurred in almost all samples, only one Missourian index form, *Centonites*, was observed.

The Desmoinesian-Missourian boundary, supposedly just above 10,830 feet, is marked by no apparent change in the gross palynomorph assemblages. In fact, there is no apparent change in the palynomorph assemblage through the 2,000 feet of strata sampled.

Well No. 10

Pure No. 1 Toelle

SE¼ NW¼ Sec. 7, T. 11 N., R. 19 W.

Sample Analysis, Table XII

Research Oil Report scout card data places the Desmoinesian-Missourian boundary between 11,110 feet (Checkerboard) and 13,360 feet (Red Fork). Samples were taken from well cuttings of shales as determined from electric logs. Palynomorph preservation is poor in all samples with over 90 percent unidentifiable in each due to high carbonization.

Only sample 2, from ca. 12,125 feet, yielded sufficient palynomorphs for meaningful analysis. This sample has Chester, Morrow-Desmoinesian, and Missourian elements whose ranges do not overlap. The Chester element, *Cristatisporites echinatus*, is known to be recycled, but the origin of the other elements of the sample is not known. This sample is near the top of the Desmoinesian, according to scout card data, and either the pre- or post-Missourian element might be endemic.

Sample 3, at ca. 12,270 feet, contains several sporomorphs including *Lycospora*, an index of pre-Missourian age. There is no proof that this sporomorph is in place, however, and determination of the Desmoinesian-Missourian boundary is impossible due to uncertainty as to which fossils, if any, are allocthonous.

The predominance of highly carbonized sporomorphs in all of these samples, but especially in those below 13,350 feet can be attributed to one of several causes. The presence of well-preserved recycled Chester fossils at ca. 12,125 feet indicates that if the carbonized element is of tectonic origin, the fault or unconformity must be below 12,125 feet, probably at ca. 14,000 feet. This hypothesis necessitates reworking of the strata near this fault or unconformity in order to account for its presence in the shallow samples.

An alternative explanation attributes the corroded blackened nature of most of the palynomorphs to an unfavorable environment of deposition, presumably a sulfide-rich environment of low Eh and pH. The presence of the well-preserved forms might indicate their allocthonous origin or origin in different lithologies.

Post-Missouri contaminants were not found.

Well No. 11

Shell No. 1 Carter-Caughron

C SE¼ NW¼ Sec. 19, T. 10 N., R. 21 W.

Sample Analysis, Table XIII

Scout card and Glover, Hefner, Kennedy seismic data place the top of the Desmoinesian Series at 11,460 feet, and the intra-Desmoinesian Unconformity at 12,100 feet. The structural cross-section of Wroblewski (Glover, Hefner, Kennedy files), however, places these boundaries at 11,580 feet and about 12,150 feet respectively.

Samples from 10,380 to 12,070 feet based on well cuttings of shales as shown on electric logs were taken.

The samples of this well are characterized by an abnormal abundance of Permian forms, which in most samples are more abundant than the totality of other forms. Chester index forms or probable Chester forms are found in abundance in all samples except those at ca. 11,340 feet and ca. 11,480 feet, which yielded few identifiable non-Permian palynomorphs. The Chitinozoan *Lagenochitina* was found in the sample from ca. 12,050 feet, sample no. 10. The presence of an Ordovician palynomorph infers, but not necessarily indicates, the erosion of Ordovician strata during the deposition of sample no. 10.

Samples at ca. 10,400 feet, ca. 11,330 feet and ca. 11,470 feet contain assemblages with *Cadiospora sphaera*, or *Converrucosisporites sulcatus*, both of which are of Desmoinesian-Missourian age. Unfortunately, nothing occurs with these forms to permit the differentiation of these series. The dearth of non-caved palynomorphs in samples from ca. 11,200 feet and ca. 11,750 feet may indicate faults at these depths, especially in the former case. The evidence is not conclusive, however, and the presence of poorly preserved modern pollen in samples no. 5 and 6 indicate that these samples might be overmacerated. Unfortunately, the well cuttings on which these samples were based were lost, preventing re-processing.

Well No. 12

Shell No. 5 Rumberger

C NW¼ SW¼ Sec. 22, T. 10 N., R. 21 W.

Sample Analysis, Table XIV

These samples are from well cuttings of shales as indicated on electric logs. In the absence of scout card data, the strata of interest were located by extrapolation of data from Shell No. 1 Rumberger as indicated on structural and seismic cross sections of the Glover Hefner Kennedy Oil Company. These respective sources place the top of the Desmoinesian at 10,632 feet and 11,560 feet and the intra-Desmoinesian unconformity ("Deese" unconformity of Glover, Hefner, Kennedy Oil Co. terminology) at 12,200 feet and 12,471 feet.

Only the three samples above 10,700 feet contain sufficient numbers of identifiable palynomorphs for meaningful analysis. Almost all of the palynomorphs observed in these three samples are of Chesterian or post-Missourian age. The few (5-30 percent) potentially autochthonous palynomorphs in these samples are, for the most part, too long-ranging to be of much stratigraphic value. The presence of Raistrickia crinita (Desmoinesian-Missourian) and Lycospora torquifer(pre-Missourian) in the light yellow, slightly-corroded preservation assemblage of sample 3 (ca. 10,675 feet) indicates a Desmoinesian age for this assemblage.

Samples from below 11,645 feet yielded only a few spores, almost all of which were unidentifiable. Pennsylvanian forms were observed in each of the deep samples, but nothing diagnostic was noted. The high degree of palynomorph carbonization in samples at ca. 12,750 feet and ca. 12,425 feet is believed due to proximity to a fault. A seismic anomaly, interpreted by Glover, Hefner, Kennedy Oil Co. geologists as the "Deese" unconformity occurs between these depths.

Well No. 13

P.C.I. No. 1 Weatherly

C NW¼ SE¼ Sec. 3, T. 12 N., R. 21 W.

Sample Analysis, Table XV

Research Oil Report scout card data places the top of the Desmoinesian Series between 10,170 feet (Garrett Zone) and 13,532 feet (Atoka sand). A structural cross-section by Wroblewski (Glover, Hefner, Kennedy Oil Co. files), however, places the top of the Desmoinesian at 10,100 feet. The intra-Desmoinesian unconformity is placed at 11,280 feet by Wroblewski (op. cit.), but at 12,232 feet by Glover, Hefner, Kennedy Oil Co. seismic data. Samples were collected from well cuttings on about 500 feet spacing.

This well is near the structural axis of the Anadarko basin, and beyond the limits of granite-carbonate wash deposition. The strata penetrated is of simpler lithology and finer grade than that encountered in the other wells studied. All of the samples from this well consist almost exclusively of black shale.

Despite the fine-grade of the sediment, all of the samples yielded abundant recycled Chester palynomorphs, except those from ca. 11,025 feet and ca. 12,625 feet, which yielded few identifiable palynomorphs due to extreme carbonization. In most samples, there are about twice as many Chester or Chester-Morrow forms as Desmoinesian-Missourian forms. Although no well cavings were observed in the original samples, post-Missourian palynomorphs are only slightly less abundant than the Chester forms. Five preservation assemblages in two samples consisted of a mixture of Chesterian and post-Missourian fossils.

The few possible endemic palynomorphs in each sample are mostly long-ranging forms of little value in the division of Desmoinesian and Missourian strata.

Although almost all of the non-caved palynomorphs of these samples are darkened, the preservation and abundance of palynomorphs are good, with the exception of those samples at ca. 11,020 feet and ca. 12,625 feet, which are presumably near minor faults.

Sample no. 1, from ca. 10,025 feet, which is presumed to be Missourian, yielded both the Missourian index fossil Centonites and a preservation assemblage in which the mutual occurrence of Lycospora and Vesicaspora Wilsonites indicates a late Desmoinesian age. The

Desmoinesian age of this assemblage is based on the assumption that this assemblage is not of mixed derivation, a dangerous assumption. Centonites also occurs in sample no. 4 (ca. 11,425 feet).

The presence of a possible Desmoinesian assemblage in a probable Missourian sample indicates the presence of Desmoinesian outcrops in the provenance area during Missourian time.

Well No. 14

United Carbon No. 1 Clark

NE¼ NW¼ Sec. 32, T. 12 N., R. 21 W.

Sample Analysis, Table XVI

"Tops" were not reported on the Research Oil Report scout card for this well, which produces from the Desmoinesian in the Southwest Carpenter Field. The top of the Desmoinesian series is placed at a depth of 11,200 feet by McNeal (1953), 10,300 feet by Mr. Alfred Gaither of the Shell Oil Company, at 10,400 feet by Mr. E. F. Wroblewski of the Glover, Hefner, Kennedy Oil Company (G.H.K. Oil Co., structural cross-section X-X^1). The intra-Desmoinesian unconformity is placed at 11,400 feet on Wroblewski's structure section X-X^1 (G.H.K. Oil Co. files), and at 12,524 feet on a Glover, Hefner, Kennedy Oil Co. seismic section.

Samples from 10,900 to 12,580 feet were chosen from well cuttings of shales as indicated on electric logs. Samples shallower than 10,900 feet were chosen on 50 foot spacings, as logs were unavailable at these depths. The sample at 12,689 to 90 feet is based on chips.

The four samples over the interval 8,100 to 10,580 feet (nos. 1-4), are typical of Elk City Area samples in that abundant reworked Chester forms and well-caving derived post-Missourian palynomorphs are dominant. In each of these samples Desmoinesian-Missourian index forms were recovered, often of preservation characteristics indistinguishable from Chesterian forms. These mixed assemblages consist of several Chester index fossils with *Converrucosisporites sulcatus*, which is restricted to the Desmoinesian and Missourian in Oklahoma. It is questioned whether this form might not range into older strata in the Anadarko basin.

A Desmoinesian assemblage is believed present in samples no. 1 (ca. 8,125 feet) and 2 (ca. 9,525 feet) as determined by the overlap of the ranges of *Converrucosisporites sulcatus* or *Raistrickia crinita* with *Lycospora* or *Densosporites*. If these preservation assemblages are validly monogenetic and not of mixed ages, the presence of Desmoinesian outcrops in the provenance area during Missouri time is inferred.

The samples from ca. 11,000 feet and ca. 11,660 feet yielded an abnormally abundant palynomorph assemblage, about ten times that of a "normal" sample. A typical portion of this sample is illustrated as Plate I, fig. 2, form A. The majority of the sporomorphs (75 percent) in these samples are Potonieisporites, which are so highly carbonized and pyritized that they are barely recognizable as sporomorphs (See Pl. I, fig. 2, form A). The age of the carbonized assemblage, as interpreted from sample no. 6, is Chester-Desmoinesian. The dominance of this element in samples, which were naturally separated by 500 feet, and its presence in samples 900 feet below it indicate this to be a reworked or well-caving assemblage. It is presumably derived from a zone of faulting, or an unconformity.

The samples at ca. 11,025 feet, ca. 11,660 feet, and ca. 12,125 feet, the first two of which are discussed in part above, yielded several well-preserved Desmoinesian sporomorphs, but fewer Chester forms than other samples. The sample at ca. 11,025 feet, in fact, yielded no definitive Chester forms, but did yield the Devonian palynomorph Tapajonites. This sample, however, had an abnormally high percentage of long-ranging, potential Chester forms which had to be assigned to an unknown age.

The deepest samples, from ca. 12,550 feet and at 12,690 feet, are highly carbonized and yielded few identifiable fossils. The latter sample, being based on core chips, should be free from younger forms, and yet exquisitely preserved forms apparently out of place in the sample were recovered. The source of these assumed contaminants is not known. The relationship between the highly carbonized assemblages at ca. 12,600 feet and 11,000 to 11,600 feet is not known. The occurrence of this assemblage as almost the sole constituent of the deeper samples leads one to anticipate the presence of a fault at this depth. The proximity of such a fault is shown on Wroblewski's structural cross section X-X[1] (Glover, Hefner, Kennedy Oil Company files). The carbonized assemblage from 11,000 to 11,600 feet could conceivably be the result of the reworking of palynomorphs from the older fault zone. The placement of the intra-Desmoinesian unconformity at either 11,900 feet or 12,524 feet from the Glover, Hefner, Kennedy Company sources noted above, fits this palynological interpretation.

If the carbonized assemblages of the shallower samples are of well-caving derivation, the fault or unconformity responsible must lie between samples 4 and 5, i.e., in the depth interval of 10,560 to 11,000 feet.

Well No. 15

G.H.K. No. 1 Vaughn

C SE¼ NW¼ NW¼ Sec. 15, T. 11 N., R. 20 W.

Sample Analysis, Table XVII

Research Oil Reports scout card data indicates the top of the Desmoinesian Series between 11,450 feet (Checkerboard) and 13,400 feet (lower Desmoinesian).

Samples no. 1, 2, and 3-5, representing two fifty-foot depth zones, are from cores. The other two samples are from well cuttings.

Samples 1 and 2, at ca. 14,010 feet, are barren or nearly so, the single spore recovered indicating only a Chester-Desmoinesian age for this assumed Lower Desmoinesian sample. These samples are based on a total of only 40 grams of material from 5 feet of core. Samples based on only five feet of strata may be barren due to a real lack of fossils in the sediment prior to diagenesis as well as postdiagenetic causes.

The three samples at ca. 11,020 feet yielded Chesterian, pre-Missourian, and post-Missourian assemblages. Because the samples are based on cores, the age of the youngest fossils is a valid age criterion. Therefore, these samples are of late or post-Missourian age. The Chester and Morrow-Desmoinesian fossils are recycled.

From scout card data and from their position between samples of established age, the well cutting samples at ca. 12,025 feet and ca. 13,025 feet are believed to be of late Desmoinesian or early Missourian age. Definite pre-Missourian assemblages were recovered from the younger samples (ca. 12,025 feet) and a pre-middle-Missourian assemblage was observed in the deeper sample (ca. 13,025 feet). However, the palynomorphs observed in these samples are of little stratigraphic importance because it is not known which, if any, are endemic.

<u>Well No. 16</u>

Shell No. 1 Walters

NE¼ SW¼ Sec. 14, T. 10 N., R. 21 W.

Sample Analysis, Table XVIII

Samples are from well cuttings of shales as indicated on electric logs. The top of the Desmoinesian Series is placed at 10,400 feet by the Shell Oil Company, and at 11,550 feet on a Glover, Hefner, Kennedy Oil Company structure section. No data on the depth of the intra-Desmoinesian unconformity was found.

Although based on shale determinations the most abundant lithology in all samples is limestone, reflecting sample depth miscalculation during collection or lithology of the carbonate wash. Red shale, presumably from the Permian, is a significant constituent of two samples.

Almost all of the palymorphs observed in these samples are contaminants. One to three preservation assemblages of Chester palynomorphs were recovered from each sample. These reworked sporomorphs are generally dark-colored, yellowish-brown, dark red, or brown, and well-preserved or slightly corroded.

A post-Missourian well-caving assemblage, characterized by its light yellow or pink color and slight, corrosion, occurs in abundance in every sample except that from ca. 11,725 feet. Assemblages of well-preserved palynomorphs were recovered from all samples except that from ca. 10,225 feet, which yielded two Desmoinesian-Missourian assemblages. It is not known whether the Desmoinesian-Missourian assemblage is of one age or is a mixed-age assemblage.

Both samples below 11,200 feet yielded the Cabaniss index, Guthörlisporites magnificus. Although this coincides with the Glover, Hefner, Kennedy placement of the top of the Desmoinesian, it is not known whether these fossils are endemic or reworked, and no great importance should be attached to their presence.

The number of undatable assemblages in the samples from this well is abnormally high, with at least one assemblage of from 1 to 4 long-ranging forms from each sample.

Well No. 17

Glover, Hefner, Kennedy No. 1-34 Finnel

S½ NE¼ Sec. 34, T. 10 N., R. 20 W.

Sample Analysis, Table XIX

No scout card data was available at the time of sampling, so the Desmoinesian-Missourian boundary was assumed to be at about 10,500 feet, by extrapolation of data from the adjacent Shell No. 1 Adams and Continental 1 Proctor. Samples were collected from well cuttings of shales as noted on electric logs. Mr. Robert Hefner, Glover, Hefner, Kennedy Oil Company, placed the Desmoinesian-Missourian unconformity at 10,650 feet, and the intra-Desmoinesian unconformity at 11,600 feet (Personal communication).

Palynomorphs are rare or scarce in all samples, and generally poorly preserved. Samples from ca. 11,000 and ca. 13,050 feet are barren of identifiable forms, all palynomorphs being highly carbonized, corroded and pyritized. In both of these samples and in samples 1 and 2, modern pollen, well-preserved and pink, was observed, proving non-overprocessing.

Sample 3, ca. 12,000 feet, yielded a highly carbonized, brown to black, but well-preserved assemblage in which two species of *Lycospora* were abundant. The presence of *Mooreisporites trigallerus* proves Chester derivation, in part, but the assemblage could be of mixed age, presumably mostly of pre-Missourian. The deepest sample, no. 4, ca. 14,000 feet, yielded a single highly carbonized, but well-preserved brown-black assemblage bearing index palynomorphs of both Chesterian and post-Missourian strata. *Lycospora* is the most abundant spore, indicating a pre-Missourian age, probably Chester, for the majority of specimens.

Well No. 18

Tidewater No. 1 Harless

C SW¼ SW¼ Sec. 3, T. 10 N., R. 21 W.

Sample Analysis, Table XX

All of the samples are from well cuttings of shale intervals as indicated by electric logs. This well was sampled due to a misinterpretation of scout card data, which is based on an undefined alphabetical zonation. Seismic data of the Glover, Hefner, Kennedy Oil Company indicates that the well does not reach Desmoinesian strata. The samples from this well, however, are of interest, as Desmoinesian palynomorphs are common. Recycled Chester and pre-Chester palynomorphs and late or post-Missourian palynomorphs derived from well cavings are quantitatively important in all of the samples.

The presence of Guthōlisporites magnificus in all of the samples indicates either that the range of this form must be extended beyond the Desmoinesian or that Cabaniss strata was exposed in the provenance area during Missouri time. The occurrence of Densosporites with Converrucosisporites sulcatus, Triquitrites bransonii, and Cadiospora sphaera as part of a single preservation assemblage in sample no. 2 (ca. 9,875 feet) indicates a pre-Croweburg (lower Cabaniss) age of this assemblage. The combination of these indications of Cabaniss assemblages is believed sufficient for the inference of Desmoinesian outcrops in the provenance area. This infers the presence of a late or post-Cabaniss unconformity in the provenance area. There is no indication that the unconformity existed in the basin proper, however.

The high degree of carbonization observed below 11,000 feet indicates abnormally high geothermal gradient, or, more likely, the occurrence of faults.

It is impossible to determine the location of the pertinent boundaries from so little data.

Well No. 19

Shell No. 1 Patten
C NW¼ SE¼ Sec. 9, T. 9 N., R. 22 W.
Sample Analysis, Table XXI

The available source of information regarding this well (scout cards of Research Oil Reports Company) places the top of the Desmoinesian series at 8,448 feet. Samples were collected from well cuttings as determined from electric logs from 5,500 feet, which is presumably near the top of the Virgilian Series, to 9,750 feet, which is 80 feet above the Springeran according to scout card data, and therefore presumably Morrowan.

The Virgilian samples (at ca. 5,525 feet, ca. 5,925 feet, ca. 6,425 feet and ca. 6,575 feet) are noteworthy in that they yielded no definite reworked palynomorphs. Palynomorphs were scarce in the deeper two of these samples, especially at ca. 6,425 feet. This is not believed to be due to tectonics, for there is no evidence of carbonization, but rather as a result of palynomorph scarcity in the original sediment.

Samples from the assumed Missourian strata contain reworked palynomorphs of both Chesterian and Desmoinesian age in abundance, with the exception of samples at ca. 7,325 feet and ca. 7,825 feet, which, due to unfavorable arkosic lithology, yielded few palynomorphs other than those derived from well cavings. The presence of Desmoinesian index palynomorphs near the top of the Missourian Series, as well as in older Missourian samples, indicates the exposure of Desmoinesian strata in the provenance area throughout Missourian time.

Samples presumed to be from Desmoinesian strata yielded assemblages indistinguishable from those of the Missourian Series. The three samples below 9,180 feet yielded only a few darkened and corroded palynomorphs other than those from well cavings. It is assumed that the well penetrated a fault, presumably the North Carter thrust, at about 9,500 feet.

<u>Well No. 20</u>

Glover, Hefner, Kennedy No. 1-11 Marik
C NE¼ SW¼ Sec. 11, T. 11 N., R. 20 W.
Sample Analysis, Table XXII

Research Oil Reports Co. scout card data places the top of the Marmaton at 11,702 feet and the top of the lower Desmoinesian at 13,493 feet. Because no electric log was available, samples were selected from well cuttings by depth. Unfortunately, well cuttings from 11,000 to 13,200 feet were not available.

Because of unavailability of cuttings, only two samples were collected. Both have several Chesterian and post-Missourian assemblages. The dark yellow, corroded assemblage of sample no. 1 contains both *Densosporites* and *Vesicaspora wilsoni*, forms whose ranges overlap only in the pre-Croweburg part of the Cabaniss. This assemblage is probably of mixed age, however.

The deeper sample, ca. 13,525 feet, consists of only one sedimentary rock type, and one would suspect that well cavings are not present. However, post-Missourian fossils were found, indicating that monolithic appearing samples are not necessarily contamination-free. *Triquitrites additus*, a Cabaniss index sporomorph, was observed in this sample, which is from below the intra-Desmoinesian unconformity. It is not known whether this form is endemic or from well cavings.

CHAPTER VIII

INTERPRETATIVE SUMMARY

Definite well-caving contamination by post-Missourian palynomorphs was observed in 88 of the 127 samples derived from well cuttings. In almost all of the remaining 39 samples probable or potential well-caving derived forms were observed. For reasons not known, neither definitive nor probable well-caving contaminants were observed in the samples from Pure No. 1 Toelle.

The quantitative importance of the post-Missourian contaminants is not so great as indicated by their number of assemblages or the number of forms within these assemblages, for most of these forms are represented by only one or two specimens in each assemblage. However, in those 24 samples in which faulting has rendered the endemic and recycled palynomorphs unidentifiable, the few contaminants comprise a significant percentage of the total identifiable palynomorph assemblage.

Although most are well-preserved and of light color (pink or light yellow), it is impossible to so characterize the preservation characteristics of sporomorphs derived from 7,000 to 7,200 feet of penetrated Virgilian-Permian strata.

In many samples darkened and corroded sporomorphs of post-Missourian age were observed, indicating the presence of a fault in the Virgil-Permian section. The best example of this is the samples from Texaco No. 1 Carter, which penetrates the Meers thrust at about 4,700 feet.

Palynomorphs known to be restricted in Oklahoma to pre-Desmoinesian strata were observed in eighty of the 117 samples in which sufficient identifiable spores were recovered for meaningful analysis. All of the remaining 37 samples yielded palynomorphs of possible pre-Desmoinesian age. In almost all samples the abundance of pre-Desmoinesian palynomorphs exceeded that of Desmoinesian-Missourian forms.

Palynomorphs of definite pre-Chesterian age were recovered from eight samples, most of which are of Ordovician or Devonian age. Five more samples yielded palynomorphs of possible pre-Chesterian age. The presence of these pre-Chester palynomorphs does not necessarily indicate the presence of Ordovician or Devonian outcrops in the provenance area during middle Pennsylvanian time, for it is possible that they were derived from Chesterian or Morrowan strata in which they occur as recycled constituents. The presence of such outcrops in the provenance area is to be assumed, however, on the basis of regional geologic history.

The Chesterian assemblage is generally recognizable by its lack of staining, dark color (yellow-brown to brown), and good preservation. Many of the palynomorphs of the Chesterian assemblage are distinctive, and readily recognizable (see Plate III).

The Chesterian, Chester-Morrowan assemblage is characterized by species diversity, and although each form is generally represented by less than five specimens per sample, the large number of species makes this assemblage numerically dominant in the 80 samples bearing pre-Desmoinesian assemblages.

Palynomorph assemblages of potential Desmoinesian-Missourian age are present in all except those 18 samples made barren due to extreme carbonization. Palynomorph assemblages believed to be restricted to Desmoinesian-Missourian ages as determined by constituent index palynomorphs, or the range-overlap of pairs of fossils assumed on preservation criteria to be monogenetic, were observed in 56 samples. Most of these, unfortunately, are based on the forms Converrucosisporites sulcatus, Raistrickia crinita, Triquitrites bransonii, or T. spinosa, which range through both series, thus providing no basis for the differentiation of these strata. Assemblages datable as early Missourian were observed in only six samples, due to the lack of Missourian index fossils. Of the two fossils believed to be indicative of Missourian strata, only Centonites was found in more than one sample.

As indicated in Table XIV, only one of the Missourian assemblages was recovered from a sample of Missourian age as based on the determinations of the Desmoinesian-Missourian boundary combined from various sources. Three Missourian-dated assemblages, however, were recovered from supposedly Desmoinesian samples.

Table XXIV: Stratigraphic Distribution of Missourian Assemblages

Sample No.	Sample depth (feet)	Depth (feet) of Dm-Mo unconformity according to sum of sources	Sample age according to this data
1-9	12240	10600-11520	Dm
10-2	12130	11110, 13360	?
13-1	10025	10100, 13532	Mo
14-9	12125	10300-11200	Dm
16-5	11725	10400-11550	Dm

This is believed to be the result of well caving, and proves the assumption that the lower limit of the range of a fossil can not be used in samples based on well cuttings. Assemblages in 29 samples are dated as Desmoinesian. Most of these are based on the overlapping ranges of Lycospora or Densosporites, with Cadiospora sphaera, Converrucosisporites sulcatus, or Vesicaspora wilsoni, or by the presence of Schopfites colchesterensis, Triquitrites additus, or T. dividuus. The Desmoinesian assemblages, most of which are believed to be Cabaniss, occur both alone and below the Desmoinesian-Missourian boundary as cited from various sources.

The stratigraphic distribution of Desmoinesian and Atokan-Desmoinesian assemblages is shown in Table XXV. Only ten of the Desmoinesian assemblages are from supposedly Desmoinesian strata, whereas seventeen are from supposedly Missourian strata. Two Desmoinesian assemblages are in the zone of disagreement with respect to the top of the Desmoinesian.

The presence of Desmoinesian palynomorphs in Missourian strata is explicable by:

1) Extending the ranges of the Desmoinesian fossils.
2) Raising the Desmoinesian-Missourian boundary.
3) By the recycling of the Desmoinesian fossils.

The validity of the ranges of the Desmoinesian fossils must be assumed until definite evidence to the contrary is found. The Desmoinesian-Missourian boundary, although difficult to determine, could not logically be raised enough to place all of the Desmoinesian assemblages found in Desmoinesian strata.

The presence of Desmoinesian palynomorphs in Missourian strata, therefore, must be assumed to indicate the presence of Desmoinesian outcrops in the provenance area. As Cabaniss forms are among the most abundant Desmoinesian indices, the diastrophism responsible for

Table XXV: Stratigraphic Distribution of Desmoinesian Assemblages

Sample No.	Approx. sample depth (feet)	Depths (feet) of Dm-Mo boundary as determined from maxima of the sum of all data	Age of sample based on sample depth relative to depth of Dm-Mo boundary
1-2	9125		Mo.
1-6	10775	10600-11520	
1-8	11525		Dm.
4-3	8530	9900-10400	Mo.
6-1	7825		Mo.
6-3	8850	TD in Missourian (no estimate)	Mo.
6-4	9275		Mo.
6-5	9725		Mo.
6-6	11000		Mo.
7-3	11875	>10800, <11500	Dm.
9-2	9625	ca. 10830	Mo.
9-5	11075		Dm.
12-3	10675	?ca. 10632-11560	?
13-1	10025	>10100, <13532	Mo.
14-3	8125		Mo.
14-8	11660	10300-11200	Dm.
14-9	12125		Dm.
15-6	12025	>11450, <13400	Dm.
16-4	11225	10400-11550	?
16-5	11725		Dm.
17-2	10025	10500-10650	Mo.
18-2.	9875	TD in Missourian	Mo.
18-3	9940	(est. @ 12800)	Mo.
19-3(Atokan-Dm)	6925		Mo.
19-5	8100		Mo.
19-7	9200	8448	Dm.
19-13	6575		Mo.
19-16	8675		Dm.
20-1	10975	11702	Mo.
20-2	13525		Dm.

the exposure of Desmoinesian strata must have occurred in late Cabaniss or Missourian time. There is no indication that this tectonic event occurred precisely at the end of the Desmoinesian time, as is inferred by the term "Desmoinesian-Missourian unconformity."

It is likely that there was no single causative orogenic event, but rather a series of tectonic pulses, as described in the discussion of the geologic history of the Anadarko Basin, Chapter I.

The presence of Desmoinesian outcrops in the provenance area does not necessarily imply the presence of a major unconformity in the Anadarko Basin. It is believed that this uplift and unconformity was a feature of the Amarillo-Wichita landmass only, probably evolving through growth faulting along the North Carter thrust.

The occurrence of recycled Desmoinesian palynomorphs in Missourian strata, and of Missourian well cavings in Desmoinesian samples negates the value of both the initial and terminal stratigraphic occurrences of fossils as zonal criteria for well-cutting-based samples.

Differentiation of the endemic, recycled and well-caving elements within the Desmoinesian-Missourian section has proved impossible in the well-cutting samples used in this investigation. Without the differentiation of these elements, it is impossible to apply zonation by either index palynomorphs or by correlation by hemerae.

Those samples based on cored material, however, lack well cavings, and therefore the first stratigraphic occurrence of a fossil does have definite stratigraphic value. Thus, the 14 samples in wells 2, 5, 14 and 15, based on cores or core chips, are theoretically datable. Unfortunately, eight of these were found to be barren and three more yielded only long-ranging forms.

The overall preservation of the middle Pennsylvanian sporomorphs is poor. Almost all are, at best, slightly corroded, and highly corroded and pyritized sporomorphs are common in almost all samples. This is believed due to the chemistry of the environment of deposition. In the granite and carbonate wash lithology, the intermittent fluxoturbidation is believed to have caused periodic introduction of large volumes of organics, resulting in the development of a sulfide-rich, anaerobic sedimentary interface. The degree of both sulfide ion concentration and negative Eh was probably extremely variable throughout the area, varying as functions of currents, sediment composition, organic abundance, and benthozoids. Evidence supporting this hypothesis is 1) the absence of benthonic fossils other than scolecodonts 2) the variability in degree of poor preservation of the tophocoenosic palynomorphs, and presence of abnormally high amounts of organic tissues observed in the samples. That the corrosion and pyritization of the middle

Pennsylvanian palynomorphs is not due to tectonics is shown by the presence of well-preserved recycled palynomorphs in the same sample as highly corroded forms.

Orogenic stresses due to the proximity of faults or anticlinal axes to the samples causes carbonization, corrosion (and pyritization?) apparently indistinguishable from that occurring during sedimentation and diagenesis. Tectonic destruction, however, can be differentiated from diagenetic destruction as both endemic and recycled sporomorphs are subject to the former. By use of this principle, the presence of the North Carter thrust was shown at about 9,000 feet in Texaco No. 1 Carter (This is 340 feet above the position shown by E. F. Wroblewski on Glover, Hefner, Kennedy Oil Co. structural cross-section $X\text{-}X^1$). The aurora of high carbonization around this fault is about 1,500 feet thick. Faults of similar magnitude, but which are not reported on the Research Oil Reports scout cards, were located at about 6,000 and 9,500 feet in Shell No. 1 Patton. The latter fault is believed to be the North Carter thrust. Other faults, or anticlinal axes, located in this study are:

Major tectonic feature at ca.$\geq$13,000 feet, G.H.K. No. 1 Finnel

Tectonic feature of unknown magnitude at ca. 12,700 feet, United Carbon No. 1 Clark

Small tectonic feature (?) at ca.$\geq$11,000 feet, P.C.I. No. 1 Weatherly

Tectonic feature of unknown magnitude ca. 12,700 feet, P.C.I. No. 1 Weatherly

Major tectonic feature $\geq$12,500 feet, Shell No. 5 Rumberger

Tectonic feature of unknown magnitude $\geq$ca. 11,550 feet,
Pure No. 1 Toelle
Tectonic feature of unknown magnitude $\geq$ca. 11,300 feet,
Howell No. 1 Hunter-Ryan
Tectonic feature of moderate magnitude ca. 11,000 feet,
Decem No. 1 Hill

As noted above, the presence of the Meers fault cutting the Early Permian section was noted in Texaco No. 1 Carter by the presence of highly carbonized well caving contaminants in most samples.

The presence of well-caving or recent contaminants is of value in fault determination, as the aberrently good preservation of contaminants is proof against the destruction of tophogeonosic elements by over-digestion.

The seismic event interpreted as the intra-Desmoinesian, or "Deese" unconformity by Glover, Hefner, Kennedy Oil Company geologists was penetrated by nine of the study wells. As indicated in Table XXVI, there is no consistent palynomorph reflection of this feature. The samples from near this feature in the wells near the Amarillo-Wichita uplift yielded no palynomorphs, or only a few highly corroded, carbonized, and pyritized specimens. This is believed due to both the fortuitous proximity of faults and associated drag folds, as in the case of these samples from Texaco No. 1 Carter, and an unfavorable environment for preservation. Most of the samples from near this unconformity from wells near the structural axis of the Anadarko basin yielded well preserved palynomorphs in normal or above average abundance. An abnormally

Table XXVI: Palynology of samples near the intra-Desmoinesian unconformity

Well No.	Intra-Desm. Unconform. (feet)	Sample and Depth (feet)	Sporomorph Abundance	Comments
1	12,370	9) ca. 12270	S	Blackened, no Chest. spec.
3	8,000 & 10,500	*	*	*: samples from 7500 to 10550 feet yielded scarce or rare sporomorphs, almost all of which were highly carbonized, prob. due to North Carter thrust at 9,340 feet.
4	10,900	11) ca. 10525	S	Corroded
11	12,150	10) 12050	N	Well-preserved
12	11,550	10675	S	Poorly preserved
		11660	R	Blackened
		12425	R	Well-preserved
13	12,232	5) 12000	N	Well-preserved
		6) 12300	N	Well-preserved
14	11,400-12,524	5) 11035	A	Well-preserved
		6) 11660	A	Well-preserved
15	13,400 (?)	7) 13025	R	Highly carbonized
		1 & 2) 14400 CORE	R	Highly carbonized
20	13,493	2) 13525	N	Well-preserved, Chester common

high number of recycled palynomorphs is not present in the samples from above this feature.

The intra-Desmoinesian unconformity is not marked by a diagnostic palynologic feature, and is apparently not recognizable without supplementary, especially seismic, data.

The failure to zone or to identify time lines in this deposit should not be interpreted as a general failure of palynology, for the sedimentary material and mode of formation of this deposit are both highly unsuitable for palynological study.

CHAPTER IX

CONCLUSIONS

Palynological study of the Desmoinesian and Missourian Series of the Elk City Area of the Anadarko Basin, southwestern Oklahoma, reveals that:

1. Recycled palynomorphs, mostly of Chesterian age, but including forms as old as Ordovician, are the dominant element in almost all samples.
2. The palynomorphs of Desmoinesian and Missourian age are generally poorly preserved due to the unfavorable chemistry of the environment of deposition.
3. Desmoinesian palynomorphs are as common in the Missourian strata due to recycling as they are in the Desmoinesian strata.
4. There is an unconformity near or at the top of the Desmoinesian Series, or near the bottom of the Missourian Series in the provenance area.
5. There is no evidence that the Desmoinesian-Missourian unconformity was not confined to

the provenance area.

6. The combination of Desmoinesian recycled palynomorphs and well caving contaminants in the well-cutting samples makes it impossible to determine the location of the Desmoinesian-Missourian boundary.
7. Only samples based on cored material may be used for age determinations within the Desmoinesian-Missourian Series of the Elk City Area of the Anadarko Basin.
8. Location of fault zones or anticlines evidently not discovered during standard well drilling and logging studies is possible by palynological analysis.
9. The intra-Desmoinesian unconformity is not marked by a diagnostic palynologic feature in the Elk City Area.

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APPENDIX

Table III: Sample Analysis
Well No. 1
Shell No. 1 Adams

Sample	Depth and Lithology	Spore Abun. % Unident.	Age: Pre-Chester	Chester	Mor. - Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
1)	8595-8610' WC Sh, marn, sl calc.60% Sh, gy............20 Ls, pk, arg.......20	N 60								1RG:6 BG:1 Asperispora crickmayi YBE:5 YBC+Mixed(?) R(C):4
2)	9110-9150' WC Sh, gy, sl calc...40 Sh, marn, sl calc.30 Ls, pk, arg.......30	N 60				?				BG:6 1YC:3 YBG:4 dR:2 YB-BC+:3
3)	9400-9450' WC Dol, wht..........50 Sh, marn, calc....30 Sh, gy calc.......20	N 60								BG:10 YC:6 YBslC:5 RG:2 w/U_1 GBKC+P:2
4)	9845-9875' WC Dol, wht..........40 Sh, marn, calc....40 Sh, gy calc.......20	N 70								GRC+:1 YC:2 1Y:2 probably Permian RC+ YBG:3 OrC+:3
5)	10405-10450' WC Sh, marn calc.....40 Sh, lt gy calc....30 Sh, dk gy sl calc.20 Dol, wht..........10	N 80					?			tY:1 Vittitina abundant dRC:4 w/U_1 YB:6 Chester w/Converrucosisporites sulcatus (?) OrC+P:5 GRC+:3 brR:2

Table III: Sample Analysis (cont'd)
Well No. 1
Shell No. 1 Adams

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
6)	10750-10800' WC									*Tasmanites*
	Sh, red-br........60%									1YG:5
	Sh, gy, calc......20	N								BG:5 *Triquitrites dividuus* w/U_1
	Sh, bk,...........10	75								YBG:7 Mixed? Mostly Chester
	Orthoclase........10									BBKC+:6 Potonieisporites: 75%
										bR:8
7)	11150-1167' WC									BC:1 abundant
	Sh, med gy calc...40									dYC+:5 probably Chester
	Sh, lt gy calc....30	N								YBG:3
	Muscovite.........20	70								RC:3
	Sh, red-pur.......10									
8)	11500-11530' WC									BC:8
	Sh, lt gy calc....35									brRC:3
	Sh, dk gy calc....35	N								dRC:2
	Sh, red-gy........10	70								dYC:8 *Triquitrites additus* & *T. dividuus*
	Ss, gy-gn, v f gr.10									YslC:3
	Muscovite.........10									YBC(P):7
										BBkC+P (mixed)
										3 chitinozoa incl. *Rhabdochitina*
9)	12240-12290' WC									BBKC+P+: 80%
	(12250-12290 missing)									RC:4
										RG:2
	Sh, dk gy.........50									BC:2
	Sh, lt gy calc....20	S								YC:1
	Muscovite.........10	85								
	Sh, dk red calc...10									

Table IV: Sample Analysis
Well No. 2
Shell No. 1 Kelly

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
1)	8451-2 CORE Ls, dk gy, arg	S 95								BC+:4 YB:1 BG:4 Mixed
2)	9287-8' CORE Ss, v f gr, non-calc.	S 90								BG:9 YBG:1
3)	9589 CORE Dol, dk gy, Xln, arg	S 95								b+RG:2 dYC:1 - Common BkC+P+:3
6)	9700-1 CORE Ss, lt gy, f gr, sl calc, w/ debris & calcite Xlns	0								Modern contaminants only
4)	9949-50 CORE Congl, gy ls pebbles & arg qz snd in gy calc silty matrix (Peb & Matrix processed separately)	0								Modern: 1RE
5)	10189-90' CORE Ls, gy arg	R 100								b+RP+:1 one unidentifiable palynomorph

Table V: Sample Analysis
Well No. 3
Texaco No. 1 Carter

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
1)	5500-5550' WC Slts, bk, calc.....70% Sh, red............15 Ls, wht............15	S 98								1RC:2 No endemics? YBC+:2 RCP:5
2)	6000-6050' sample repeated WC Slts, bk calc.....50 Ls, wht...........20 Sh, bk............15 Sh, red...........15	R 80								dRC:1 YBC:3 1Y:2
3)	6500-6540' WC Ls, dk gy.........40 Qz, clear.........40 Ls, wht...........10 Sh, bk calc.......10	N 80		?						YBC:2 1RG:1 <u>Endosporites</u> <u>micromanifestus</u> RC(P):6 <u>Crassispora</u> <u>kosankei</u>(?) & <u>Guthörlisporites</u> YBC:2 YBCP:2 <u>Lycospora</u> common BC+P:3
4)	7000-7050' WC Sh, gy calc.......80 Sh, red...........20	S 98								YC:1 YBG:1 RC(P):4 BBkC:4 Mixed, mostly Chester
5)	7500-7550 WC Sh, gy, sl calc...50 Slts, gy..........30 Sh, red...........10 Gyp, wht..........10	R 98								1Y dBC(P) probably mixed

Table V: Sample Analysis (cont'd)
Well No. 3
Texaco No. 1 Carter

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
6)	8000'8050' WC									BC+
	Sh, dk gy sl calc..40%									YBC+
	Sh, dk br..........30	R								
	Slts, gy...........20	98								
	Sh, red............10									
7)	8500-8550' WC									dR
	Ls, dk br-gy.......40	R								BrC+(P)
	Dol, wht...........30	99								YC+
	Sh, red, w/gyp.....20									YBCP
	Sh, bk.............10									
8)	9000-9050' WC									RC+(P) mixed, Chester & Post-Chester
	Ls, dk br-gy.......45	R								Sporangial wall cell of Springer
	Dol, wht...........45	99								age (Plate III, fig. 19)
	Gyp, wht...........10									
9)	9500-9550' WC									RC+P+:1
	Dol, wht...........50									Br:1 * % unidentif.
	Sh, gy.............40	R								YC:1 Lycospora common abnormally low
	Slts, gr-gn........ 5	50*								YBC+(P):2 due to abundant forms
	Orthoclase......... 5									not recognizable as spores
10)	10000-10050' WC									RC+P+:2
	Dol, wht, chrt.....60	S								BrC:3
	Sh, gy.............15	99								YBC
	Sh, red............ 2									sporangial wall cell?
	Orthoclase......... 2									
11)	10500-10550' WC									1YC:7
	Sh, red............40									BC:2
	Dol, wht, chrt.....30	S								YBC:2
	Sh, bk.............20	90								YBG:1 Auroraspora
	Orthoclase......... 8									
	Ss, pur............ 2									

Table VI: Sample Analysis
Well No. 4
Decem No. 1 Hill

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
1)	8505-8550' WC Sh, red..........40% Dol, chrt, bf....40 Sh, dk gy........20	N 90								dY(slC): 6 prob. mixed dYBCP:2 B:5 Densosporites & Cadiospora sphaera 1RG:1 Retuculatisporites 1YC(P+) muricatus
2)	9000-9050' WC Sh, red..........50 Sh, gy, sl calc..40 Dol, wht.........10	S 90								RC+:3 1YC:3 BG:1 Asperispora crickmayi YP+C+:1 Modern: 1RE
3)	9500-9550' WC Sh, red..........35 Ls, wht..........35 Sh, bk...........30	S 10*								1Y&1R(C):9 60% BG:1 Cincturaspora sp. 1:Rhabdochitina, Ord. BC:2 Bk:2
4)	10300-10350' WC Ls, gy...........70 Sh, dk gy........15 Sh, red..........15	S 99								1Y:2 BC+:3 dRG:1 w/U_1 YBC+(P):5
5)	10850-10900' WC Ls, lt gy, arg...15 Sh, red..........20 Sh, gy...........15 Ss, f gy, gn-gy..15	R *						?		1YC:1 dYC+P+:5 Tissue, bk, rare Only contaminants identifiable
6)	11450-11500 WC Ls, lt gy, arg...40 Sh, gy, calc.....25 Sh, red, calc....20 Ss, f gy.........10 Dol, bf.......... 5	R *								B-Bk Unidentifiable dYC+P+:2 YC:1 Only contaminants identifiable Modern: 1RE

Table VII: Sample Analysis
Well No. 5
G.H.K. 1 Kennemer

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
8)	10500-10550' WC									YB
	Sh, bk.............33%									Bk Unidentifiable except
	Ls, gy.............33	R								Punctatisporites
	Sh, red............33	99								
	Orthoclase......... 1									
9)	10800-10850' WC									BBk All unidentifiable
	Ls, red............40									Schultze's solution not used
	Sh, bk.............30	R								
	Sh, red............20	100								
	Orthoclase.........10									
1)	10900'11008' WC									BG:2 Proprisporites
	Sh, bk.............50	S						?		dYC
	Ls, wht............30									Modern: 1RE
	Sh, red............20	-								
2)	12000-12050' WC									YBC:2
	Ls, gy.............90	S								BrC+:5
	Sh, red............10	-								
4)	12548-12600' WC									YG:3
	Ls, gy.............50	S								dRG:1
	Sh, bk.............50	90								brRC:1
										YBkC+P+:2 mixed
5)	12750-12800' WC									BC:2
	Ls, gy.............50	S								YBCP:3
	Sh, bk.............50	90								
3)	13100-13150' WC									YG:1
	Sh, bk.............50	S								YBkC++:5
	Ls, wht............30	80								BrC:4 Velamisporites
	Sh, red............20									

Table VII: Sample Analysis (cont'd)
Well No. 5
G.H.K. 1 Kennemer

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
6)	13780-13806' WC Ls, arg, bk	98 S							—	YB-BkC+P+
7)	15000-15029' Core Carb. wash & dk gy Ls, dk br & bk Sh, in bk sh & and matrix	R 100							—	BBkC+ None identifiable

Table VIII: Sample Analysis
Well No. 6
Shell No. 4 Jarrell

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
1)	7800-7850 WC Sh, dk gy calc.....50% Sh, marn............30 Slts, gn-gy........10 Dol, wht...........10	N 50								t-lYG:8 BG:7 YC:3 Triquitrites discoideus YB:6 brY:3 BBk:2 Salm:3 tC:3 Permian?
2)	8130-8180' WC Sh, dk gy, calc....75 Sh, marn...........20 Ls, wht............ 5	N 50								t-lyC:10 Mixed, all Permian except Lycospora. Vesicospora abundant. YBE:9 YBC:7 Salm: 9 mixed Leschikispora, Lycospora, Granulatisporites, Verrucosisporites. BBkC+:4 BRG:4 w/U_1 lRC:2 RE:2 w/U_1 brY:2
3)	8820-8870' WC Sh, dk gy, calc....95 Sh, marn........... 5	N 50								lYC:5 YBG:8 Schopfites colchesterensis OrBG:3 mixed BG:3 YC:3 brY:1

Table VIII: Sample Analysis (cont'd)
Well No. 6
Shell No. 4 Jarrell

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
4)	9250-9300' WC Sh, gy, calc......90% Sh, red, slty.....10	N 40				?				OrB:2 BG:9 BC:3 tYC may be mixed Y-YB:4 Mixed <u>Alatasporites</u> dRBG:1 w/U_1
5)	9700-9750' WC Sh, gy, calc......90 Sh, red........... 5 Slts, gy-gn, calc. 3 Muscovite......... 2	N 40		?						lYC:5 YBC:3 <u>Taeniaesporites</u> dR:3 w/U_1 YBE:8 BG:1 RC+:3 <u>Grandispora</u> BC+:2 <u>Striatites</u>
6)	11000' TD WC Sh, gy calc.......90 Slts, gy-gn, calc. 8 Sh, red........... 2	N 30								YB(C):19 mixed Chester & Desmoines BG:8 BRC:8 Mixed Chester & Desmoinesian <u>Cadiospora sphaera</u> brYG:2 <u>Schopfites colchesterensis</u> dYC:1 lYC:12 most abundant, mixed. All Permian or long-ranging except <u>Lycospora torquifer</u>. <u>incertae sedis</u> and chitinozoans unidentified

Table IX: Sample Analysis
Well No. 7
Continental No. 1 Proctor

Sample — Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor. - Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
4) 9500-9550' WC									OrG:1
Ls, dk gy..........35%	N								YBG:4
Ls, lt gy..........35	80								BE:2
Slts, gy...........20									dR:4 prob. Chester
Sh, brn............10									lYC:4
									MlR&Y:3 w/Guthörlisporites
									RC+P:2
									YBC+P:2
1) 10200-10250' WC									BG/YB/BkC+RC+P+/
Slts, gy...........60	R								One each of long-ranging forms
Sh, by.............20	90								
Ls, gy, petrolif...20									
2) 10805-10840' WC	90								t-lYC:2 mixed Vesicospora & Lycospora
Ls, bk............100	N								BG:1
									BC+P:3
									YBC:6
									RC+:3
2A) 10820-10850' WC	N								BCP+:2
Sl, bk............100	90								GCP+:2
									YBG:6
									YC:2
									dRC:3
6) 11000-11050' WC									YBG:9
Ls, gy, arg........60	N								OrB:3
Ls, bk.............40	80								lYC:1
									GCP:
									t-lRC+P Mixed Grandispora & Alisporites
									RBkC:1

Table IX: Sample Analysis (cont'd)
Well No. 7
Continental No. 1 Proctor

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
5)	11500-11550' WC									Tasmanites
	Ls, lt gy, Xtn.....70%	N								BBkC probably Chester
	Ls, dk gy...........28	90								RBG:2
	Sh, red............ 2									RC(+)P(+):2 probably Chester
										YC:2
										t-1YG:2
										YBC:5 Mixed Savitrisporites & Converrucosisporites sulcatus
3)	11850-11880' WC									1RC:2 abundant Lycospora, prob. Chester
	Ls, dk gy...........45	N								GBC:2
	Ls, lt gy...........45	80								1B-OrB:4
	Slts, gy............10									BC+P+
										dR:2 Cadiospora sphaera
										dY:2 Cyclogranisporties leopoldi
										1Y:2
7)	12380-12410' WC									BkC+P+:2
	Sh, lt gy, calc....60	N								YCP+:2
	Sh, dk gy, calc....20	95								YB:1
	Ls, lt gy, arg.....20									1-dR(C):3 abundant -Lycospora
					?					BG:2
8)	12800-12840' WC									BkC+P+:4 Punctatisporites
	Sh, gy, sl calc....99	R								
	Orthoclase......... 1	99								

Table X: Sample Analysis
Well No. 8
Constantine No. 1 Heket

Sample	Depth and Lithology	Spore Abun. % Unident.	Age: Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
1)	10640-10690' WC Ls, mic, wht......60% Sh, bk............30 Sh, red...........10	N 90								1YC(P):5 dYG:1 dY&RCP+:2 YBC+:3 based on <u>Ciratriradites saturni</u> and <u>Converrucosisporites sulcatus</u> 1BC+P/YBC+/1YP+RBP+
2)	10850-10880' TD WC Ls, mic, wht......60 Sh, bk............30 Sh, red...........10	N 95								1YE:4 dYC:4 RG/Y+RC B-OrB w/U_1

Table XI: Sample Analysis
Well No. 9
Howell No. 1 Hunter-Ryan

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor. - Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
1)	9100-9150' WC Sh, bk.............90% Ls, gy............. 8 Chrt, wht.......... 1 Sh, red............ 1	N 50								1YE:6 GC+:3 1RE:4 1RC:3 Lycospora & Leschikisporites, mixed RBG:10 mostly Chester w/U_1 dYC(P):9 Mixed(?) YBC:6 Taeniaesporites BG:6
2)	9600-9650' WC Sh, bk.............90 Ls, gy............. 5 Chrt, wht.......... 2 Sh, red............ 3	N 50								BG-BslC:22 dYBC:16 mixed, mostly Chester Seca isporites remotus with Taeniaesporites & Converrucosisporites sulcatus 1YC:6 1RC:3 YBKC+:1 Guthörlisporites dR:1 Laevigatosporites minimus
3)	10050-10100' WC Sh, bk.............85 Ls, gy.............10 Sh, red............ 5	N 50								1RG:11 mixed Lycospora & Hamiapollenites brR:3 BRG:12 Chester & Desmoines.(?) 1YG:5 1RC+P:5 dRC:4 Or-BG:14 GC+:4 dYG:10 acritarch

Table XI: Sample Analysis (cont'd)
Well No. 9
Howell No. 1 Hunter-Ryan

Sample	Depth and Lithology	Spore Abun. % Unident.	Age: Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
4)	10600-10650' WC									t-1R(C):4
	Sh, bk.............90%									BG-slC:18 most abundant
	Ss, wht, calc...... 9	N								R-dRC: 13 mixed. Chester, DM & Perm. indices
	Sh, red............ 1	50								1YslC: mixed Chester-Desmoines, Desmoines & Perm. indices
										dYB:5
										RBG:9
5)	11050-11000' WC									1YC:11 all Perm. exc. <u>Lycospora</u>
	Sh, bk.............80									1R:4
	Sh, wht, calc......15	N								1BC:9 mixed Chester & Perm.
	Sh, red............ 5	50								1BRC:7 mixed Dm-Mo. <u>Centonites</u> & <u>Cadiospora</u>
										dBG:9
										YB-dYC:7
										brY:2
										dYG:2
										GC+:1
6)	11300-11344' TD WC									RC:2 w/U_1
	Sh, bk.............90	S								BkC+P only <u>Potonieisporites</u> recog.
	Ss, wht............ 5	90								
	Sh, red............ 5									

Table XII: Sample Analysis
Well No. 10
Pure No. 1 Toelle

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
1)	11000-11050' WC	90								YBC:5
	Sh, dk gy, sl calc.100%	N								BkC:3
2)	12106-12150' WC									BkC:6 Potonieisporites abundant
	Sh, dk gy, sl calc.100	N								YBE:1
		90								BE:2 Centonites & U_1
										YBC:8
3)	13350-13385' WC	99								dYBC:2 Lycospora
	Sh, dk gy, sl calc.100	N								BkC+(P):2
4)	14510-14560' WC									BkC+P
	Sh, dk gy, sl calc. 60	R								
	Slts, gy-gn........ 20	100								
	Qz, clear.......... 8									
	Muscovite.......... 2									

Table XIII: Sample Analysis
Well No. 11
Shell No. 1 Carter-Caughron

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
1)	10380-10420' WC Sh, bk Ls, wht Sh, red	N 60								BBkC+P+:4 mixed (?) BG:3 RC+:4 YBG:3 YC:2 1YC+P+:2 dYC:4
2)	10935-11965' WC Sh, gy calc Sh, red Ls, wht, arg	S 60								BkP+:1 RG:1 B-BR:2 dY:1
3)	11190-11215' WC Sh, lt gy, calc Sh, red	S 70								t-1YG:4 RG:1 RCP:1 GC+P+:1 BG:1
4)	11310-11350' WC Ls, gy arg Sh, dk gy Sh, red	S 70								BG:4 t-1YG YBC:4 GC+P+
5)	11460-11490' WC Sh, dk gy Ls, wht Sh, red	N 70								t-1YC:9 BC:1 <u>Cadiospora</u> <u>sphaera</u> YC:4 YBC+:3 (Overprocessed?)
6)	11550-11570' WC Sh, gy calc Sh, red	S 90								t-1YC:6 OrBG:2 YBC(P) (Overprocessed?)

Table XIII: Sample Analysis (cont'd)
Well No. 11
Shell No. 1 Carter-Caughron

Sample	Depth and Lithology	Spore Abun. % Unident.	Age: Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
7)	11625-11645' WC Sh, gy, calc Ls, gy, arg Sh, red	N 80								t-1Y:3 1BC+:5 BRC:5 mixed Dm & Chester indices RC:5 dYG:4 <u>Mooreisporites</u> <u>trigallerus</u>
8)	117300-11770' WC Sh, lt gy, calc	N 80								t-1YG:11 1RG:1 BC+P+:5 <u>Taeniaesporites</u> RC+:5 dYC+:2 <u>Lycospora</u> spp. common
9*)	11900-11930' WC Sh, bk, calc Sh, red	N 80								t-1YG:5 BG:8 BC:3 1YC:1 <u>Lycospora</u> RC+:3 dY:3
10*)	12040-12070' WC Sh, bk, calc Sh, gy Sh, red	N 80								YBC+:6 <u>Lycospora</u> common t-1YG:2 BC+P+:5 B-RBC:4 Ord. <u>Lagenichitina</u>

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Table XIV: Sample Analysis
Well No. 12
Shell No. 5 Rumberger

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
1)	8750-8800' WC Sh, br, calc........25% Sh, dk gy, calc....25 Sh, med gy, calc...25 Ls, wht, mic.......25	N 80								brR:2 lYC:2 PC:3 mYB&B:4 dY:2 _Raistrickia crinita_ YB:13 RB:2 BG:4 OrG:2
2)	9870-9920' WC Sh, med gy.........30 Sh, dk gy..........20 Sh, br.............20 Ls, wht, arg.......20 Granite............10	N 75								t-lY:10 dYG:3 YBC+:10 mixed Chester & Desmoin. lRG:1 prob. Permian BC:3 YBG:1
3)	10650-10700' WC Sh, br.............25 Ls, wht, arg.......25 Sh, lt gr..........25 Sh, dk gy..........25	N 75								BG:7 w/U_1 t-lYG:3 BC+(P):1 YC+:6 prob. DM- _Lycospora_ & R&YC:1 _Raistrickia crinita_
4)	11645-11705' WC Sh, gy, calc.......45 Sh, gy, slty, calc.45 Slts............... 5 Muscovite.......... 5	S 90								YB-BkC+P+:8 mixed BG:1

Table XIV: Sample Analysis (cont'd)
Well No. 12
Shell No. 5 Rumberger

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
6)	12400-12450' WC Ls, gy, mic........70% Ls, wht, Xtl.......15 Ls, br.............10 Orth. & Musc....... 5	R 90	—	—	—	—	—	—		BC+:3 YBC:3 BkC+:1
5)	12725-12765' WC Sh, gy, calc.......50 Sh, dk gy, calc....30 Sh, red............10 Muscovite..........10	R 99			—	—	—	—		BkC+P+:2

Table XV: Sample Analysis
Well No. 13
P.C.I. No. 1 Weatherly

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
1)	10000-10050' WC Sh, dk gy..........100%	A 95								1YG:9 Most Chester 1YC:10 <u>Lycospora</u> & <u>Vesicaspora</u> YG:4 <u>Centonites</u> <u>wilsoni</u> BG:10 mixed. Mostly Chester with striate bisaccate forms BC:2 dYG:6 mixed. Chester-Mor. & Perm. age YB all Chester exc. <u>Entylissa</u> GG:1
2)	10500-10550' WC Sh, dk gy.......... 95 Dol, br-gy......... 5	S 98								BC(P):6 YC(P):3 YBG:3 1YC(P):2 prob. Post-Missourian
3)	11000-11050' WC Sh, bk, slty....... 45 Sh, bk, fis........ 50 Gyp................ 5	R 98								dB-BkC:3 Probl. Pre-Missourian dYC:2
4)	11400-11450' WC Sh, bk, non-fis....100	N 80								BG:6 dBG:1 <u>Centonites</u> BC:3 mixed Pre-Dm & Post-Mo. dY:6 mixed Chester & Post-Mo. 1YslC:3 YC:5

Table XV: Sample Analysis (cont'd)
Well No. 13
P.C.I. No. 1 Weatherly

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
5)	12000-12050' WC Sh, bk..............100%	N 80								BkP+:4 1YG:6 YBC:5 YBG:7 dY:3 dRB U_1 OrPC:1 GYC+:1 Lycospora common
6)	12280-12330' WC Sh, bk..............100	N 80								1YG:3 YC:3 YB-Or:6 RG:2 Densosporites 1RG:1 Cadiospora sphaera G-BkC+ abundant
7)	12600-12650' WC Sh, bk..............100	R 99								BkP+C+

Table XVI: Sample Analysis
Well No. 14
United Carbon No. 1 Clark

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
1)	8100-8150' WC Sh, dk gy, calc	N 75								YBC+:10 One Desmoinesian index dBG:7 BC:6 Converrucosisporites sulcatus BC+(P):3 & Lycospora YslC:4 Cristatisporites & dYC:2 Alisporites mixed dYG:2 RC:1
2)	9500-9550' WC Sh, dk gy, calc	N 75						?		BG:8 mixed: Centonites & Densospor-ites YBG:7 mixed Chester & Vesicaspora YBC(P):6 RBG:2 R-dBC+P:2 Hamiapollenites? dYC+P+:1 lRC:1 Lycospora
3)	10080-10130' WC Sh, bk, sl calc	N 50								lYslC(P):6 YBC+P:4 BG:9 Chester & Des.-Mos. indices YBG:2 dRslC:1 YB:1
4)	10560-10580' WC Sh, dk gy, calc	N 50								BG:2 mixed Chester & Converruco-sisporites sulcatus lYG GYP+C+:2 YBC:3 brY-YBC:2

Table XVI: Sample Analysis (cont'd)
Well No. 14
United Carbon No. 1 Clark

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
5)	11000-11050' WC Sh, dk gy, sl calc	A 10xN								(See Pl. 1, fig. 2) 1Ys1C:5 prob. Post-Missourian Bk-GC+P+:2 Potonieisporites 90% of RG-RC:15 w/U_1 tot. assembl. brR:2 dYC BG:6 Triquitrites additus 1B/1R/brY/dYG/RC/OrG/ only long-rg. Tapajonites forms
6)	11640-11680' WC Sh, dk gy, sl calc..60 Dol, lt gy, bf......40	A 95								brR:12 dR:4 RB:8 Velamisporites 1RC+P+:9 Triquitrites aff. additus BkP+:9 abundant mixed t-1YC+P:2 BG:9 SalmG:4 YBG:7 dY(R)CP+:5 Stroterosporites common
7)	12100-12150' WC Sh, med gy, calc....90 Orthoclase.......... 5 Qz................. 5	N 80								YG:3 brRG:5 BG:3 YBCP:4 Secarisporites remotus? dR:3 w/U_1 dRC+P:3 GBC+:1 Common SalmC+:5 1Y-1R(C-P):1 Potonieisporites comm.

Table XVI: Sample Analysis (cont'd)
Well No. 14
United Carbon No. 1 Clark

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
8)	12390-12450' WC	99								dR-Bk:2
	Sh, med gy, sl calc	N		?						OrE:4
										GBkC+P:2 abund., esp. <u>Potonieisporites</u>
										1RC:2 <u>Potonieisporites</u> spp.
										brY:1
										Salm:1
9)	12530-12580' WC									YBC+2
	Sh, dk gy, calc....90%	N								RG:1
	Ls, med gy, Xln.... 5	99								Bk Undt abundant
	Sh, red............ 5									
10)	12689-90 CORE CHIPS	N								brRE:1
	Ls, dk gy Xln, w/1mm	99								YE:2
	ls clasts									BkC+P+:4

Table XVII: Sample Analysis
Well No. 15
G.H.K. No. 1 Vaughn

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
3*)	11000-11021' CORE processed twice Sh, bk, calc & non-calc from zone of sdy arg. & gran. wash	S 90								1YB&BC:1 Bk-gy,CP:2 Wilsonites delicatus BkG:1
5)	11017-11020' CORE Sh, bk, w/slt, snd, orth. & qz pebbles	N 95								BkC:2 YB:2 YBCP:1
4)	11039-11058' CORE Sh, bk, carbonized plant foss.	N 95								BkP+C+:3 w/U_1
6)	12000-12050' W.C. Sh, bk.............80% Ls, wht.............10 Sh, red.............10	N 60*								BkC:4 Endosporites globiformis & Cadispora sphaera BC:2 GYP:2
7)	13000-13050' WC Sh; bk...........100	R 20*					?	?		Bk:3 YBCP:2 BP:2 (fault up hole?)
1)	14404-16 CORE Sh, bk, calc	O -								Barren
2)	14419-22 CORE Sh, bl, non-calc	R								Bk:1 one specimen

Table XVIII: Sample Analysis
Well No. 16
Shell No. 1 Walters

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
1)	9500-9550' WC									BC:3 w/U_1
	Ls, gy, Xln........50%									brY:1 *Cristatisporites* common
	Sh, bk.............45	N								YBG:2
	Orthoclase......... 5	95								IRC:2
										RBC:1
										RC:1
2)	10200-10250' WC									BC:2
	Ls, gy.............65	N								brY:9
	Sh, bk.............35	95								1YG:5
										YBC+:3
										YBG:2
										BKC+P:2
										tE:3 mixed
										Modern 1RE
3)	10500-10550' WC									YBC:3
	Ls, gy.............60									BG:4
	Sh, bk.............30	N								RP:6
	Sh, red............10	75								1YC:3
										1R:2
				?						BkC+:2 *Auroraspora*?
4)	11200-11250' WC									YBG:9
	Ls, gy.............60	N								1YC:2 *Triquitrites bransonii*
	Sh, bk.............34	95								dYC+:3
	Orthoclase......... 5									RBG
	Coal, or asphal-									RG:1
	tite.. 1									RC+:3/Bk:1
										Rhabdochitina (Ord.)

Table XVIII: Sample Analysis(cont'd)
Well No. 16
Shell No. 1 Walters

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
5)	11700-11750 WC									BG:7 w/U_1
	Ls, gy.............65%	N								dYB:5
	Sh, bk.............30	98								1R+1YslC:6 Missourian?
	Sh, red, slty...... 5									RC+:1 Guthörlisporites
										RBG
										BkC+

Table XIX: Sample Analysis
Well No. 17
G.H.K. No. 1 Finnel

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
1)	8200-8270' WC							—		brRCP/lRG:4
	Sh, red..............60%	R			—	—	—			lYC:1
	Sh, bk...............30	80							—	YBC:1
	Ls, gy...............10									
2)	10000-10050' WC				—	—	—	—		lYPC
	Sh; red..............50					—				YBC(P):3 <u>Wilsonites</u> <u>delicatus</u>
	Sh, bk...............30	R								
	Ls, gy...............20	70								
5)	11000-11020' WC								—	BkC+P+
	Sh, bl...............25	R								Modern: lRE
	Sh, red..............25	100								
	Ls, gy...............50									
3)	12000-12050' WC			—	- - -	- -				B-Bk? <u>Lycospora</u> common
	Ls, gy...............50	R								<u>Mooreisporites</u> <u>trigallerus</u>
	Sh, bk, w/qz grns...20	80								
6)	13020-13070' WC								—	BkC+P+
	Sh, bk, w/crinoid	R								Modern: lRE
	col'm-like Ls	100								
	pellets									
4)	14000-14050' WC			—	- - -	- - -	- -	—		BBkG:10 mixed (<u>Vittatina</u>,
	Sh, bk, non-calc....90	S								<u>Auroraspora</u>)
	Ls, bf...............10	95								<u>Lycospora</u>: not abundant
										Mostly Chester
										Overprocessed

Table XX: Sample Analysis
Well No. 18
Tidewater No. 1 Harless

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
1)	9680-9720' WC Sh, bk, calc.......70% Ls, wht............15 Sh, red.............15	N 50								BG:4 w/*incertae sedis* A dRG:10 probably Missourian YC:1 RC:5 mR&YG:2 brRE: 1 *Guthörlisporites*
2)	9850-9900' WC Sh, bk, calc.......70 Sh, red & Gyp......20 Ls, wht, chrty.....10	N 50								YC: 4+ mostly unidentified most abundant assemblage YE:1 dBG:14 *Converrucosisporites sulcatus* & *Densosporites* (mixed?) RC:7 *Guthörlisporites* dR:1 U_1 RB:3
3)	9980-10000' WC Sh, bk, calc.......80 Ls, wht............10 Sh, red.............10	N 66								BG:11 *Cadiospora sphaera* *Triquitrites bransoni* brRE:8 *Guthörlisporites* dR:5 w/U_1 RC:2 dY:1 *Tapajonites* & *Tasmanites* YC&dYB: 10 Mixed Mo. & Perm. dY:2 Y+RC:3

Table XXI: Sample Analysis
Well No. 19
Shell No. 1 Patton

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor. - Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
1)	5500-5550' WC									YBG:3
	Sh, red..............80%									BG:3
	Sh, lt gy-gn, calc..10	N								lYG:6
	Dol, wht............ 6	10								lRG:6
	Granite............. 4									RC:4 mixed
2)	5900-5950' WC									lRC:10
	Sh, marn calc.......50	N								mR(Y)C:7
	Sh, lt gy, calc.....25	70								dYB:2 Contaminants only
	Dol, br to gy.......25									BG/YG
8)	6400-6450' WC									dRG
	Ls, wht, slty.......90	R								
	Sh, marn............ 5	100								
	Sh, bk.............. 5									
13)	6550-6600' WC					?				dRB:3 <u>Laevigatosporites</u> <u>minimus</u>?
	Sh, slty, gy, calc..40	R								dYB:2
	Ls, gy..............35	98								
	Sh, red.............15									
	Orthoclase..........10									
3)	6900-6950' WC									tlYG:9
	Ls, wht, fis, Xln...40	N								lRslC:6
	Sh, marn, calc......30	70								YE:6
	Sh, gy, calc........30									RC:6
										BG:4
										YBC:11 Prob. Missourian
										RG:3
9)	7300-7350' WC									lRG:3
	Arkose..............80	S								Or:7 Primitive-locking <u>Vittitina</u>
	Sh, dk gy, calc.....10	95								RB(C):5
	Sh, marn............10									dR:3 w/U_1

Table XXI: Sample Analysis (cont'd)
Well No. 19
Shell No. 1 Patton

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
4)	7550-7600' WC									1Y-YG:8
	Ls, wht..............50%	N								1RE:7
	Sh, bk, gy, calc....30	70								BC:4
	Sh, marn, calc...... 5									YB:8
	Slts, gy-gn......... 5									RslC: 6 w/U_1
10)	7800-7850' WC									OrC:3 *Vesicaspora* sp.
	Arkose..............50	S								RC:3
	Ls, wht, mic........20	98								YB:3
	Sh, lt gy, calc.....20									
	Sh, br..............10									
5)	8070-8120' WC									tlY:1
	Ls, lt gy, aren.....60	N								LRG:4 probably post-Missourian
	Sh, bk, calc........30	70								YB:3
	Sh, br..............10									RB:3
										RC:7
										RG:11
11)	8450-8500 WC									BBkC+(P):4 w/U_1
	Ls gy...............50	S								BC:3
	Sh, dk gy...........20	95								1Y-C:3
	Sh, red.............10									RC:4
	Arkose..............10									dYBG:7 mixed: *Cristatisporites* & *Cadiospora sphaera*
	Ls, wht, mic........10									1Y-C:3
15)	8650-8700' WC									YBG:5 *Schopfites colchesterensis*
	Ls, gy-br...........30	S								t-lYC:2
	Dol, wht, chrt......30	95								dYBC:3
	Slts, gy-gn, calc...30									BkP+C:4
	Sh, red.............10									dBC:2
										OrBslC:2

Table XXI: Sample Analysis (cont'd)
Well No. 19
Shell No. 1 Patton

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
6)	8850-8880' WC Sh, bl, calc........80% Ls, gy, Xln.........15 Granite............. 5	N 70								1RC:1 1YC:2 Platysaccus dR(Y)C: YBC:5 dBC:7
7)	9180-1220' WC Ls, gy.............90 Sh, bk.............. 5 Sh, red............. 5	S 98								YBC:1 Cadiospora sphaera dBG:5 Tripartites vetustus dBC:1 Potonieisporites abundant 1YG:2
14)	9423-9480 Slts, gy-gn.........40 Sh, dk gy, calc....40 Sh, red.............10 Orthoclase..........10	R 98								1YE:2 assumed Perm. caving Potonieisporites elegans GBkC+ Barren of endemics
12)	9700-9750' WC Sh, dk gy, in lrg "chunks" that look caved........60 Ls, chrt...........20 Ls, lt gy...........10 Muscovite..........10	S 95		?						1Y(C):2 BBkC(+):3 BC:14 Mixed Triquitrites additus and Alisporites.

Table XXII: Sample Analysis
Well No. 20
G.H.K. No. 1 Marik

Sample	Depth and Lithology	Spore Abun. % Unident.	Pre-Chester	Chester	Mor.- Atok.	Desmoines.	Missourian	Post-Mo.	Unknown	Preservation Characteristics and Comments
1)	10950-11000' WC									bRC
	Sh, dk gy, calc....50%	N								dBG
	Sh, blk, calc......45	60								dYC
	Sh, red............ 5									1Y(CP)
2)	13500-13550' WC									YBC:2
	Sh, dk gy, calc....95	N								BG:3
	Muscovite.......... 5									RC:3
										dY/dR:1
										YBG:1 Triquitrites additus

PLATE I

LITHOLOGY AND PRESERVATION

1, 3. Core slabs of typical carbonate wash. Note the paucity of matrix and the fragmented nature of the slabs. Six inch scale for size comparison. Cores from G. H. K. No. 1-22 Kennemer. 1) 13,819 feet 3) 13,815 feet.

2. Typical preparation showing three preservation types. 14-5-2-A.

   A. Potonieisporites: black, highly corroded and pyritized. ca. 150 x 50μ. Member of Morrowan - post-Missourian.

   B. Potonieisporites: yellow-brown, corroded. ca. 148 x 100μ. Member of post-Missourian preservation assemblage.

   C. Punctatisporites: bright red, well-preserved. 80μ. Member of post-Missourian preservation assemblage.

4-13. Various forms of poor preservation typical of most samples. Fig. 12, a well preserved grain, is included for comparison.

   4. Highly carbonized and corroded, slightly pyritized spore. Black. May be Cirratriradites. 70μ. 11-8-1-10.

   5. Highly corroded, uncarbonized, unidentifiable spore. 55 x 50μ. 11-5-1-1.

   6. Highly carbonized, fragmented spore. May be Triquitrites. 37μ. 11-9-1-6.

   7. Pseudomorph "ghost" of Hamiapollenites. 75μ. 10-2-1-2.

   8. Pyritized, corroded Potonieisporites. The finely sculptured spheres which were occupied by pyrite spherules before treatment with nitric acid are presumably caused by bacterial precipitation of melnikovite, which alters penecontemporaneously to pyrite. 125 x 85μ. 19-4-1-1.

   9. Highly pyrite-pitted spore resembling Reticulatisporites, due to the pattern of spherule pitting. 60μ. 19-11-2-8.

10. *Potonieisporites* covered with pits made by euhedral and subhedral pyrite crystals. Pyrite removed during processing. 125 x 85μ. 19-5-1-1.

11. Highly pyritized *Wilsonites* ? from which the pyrite has not been removed. 100 x 88μ. 15-5-4-4.

12. Perfect specimen of *Potonieisporites simplex* Wilson, 1962, for comparison. From well cavings. 112 x 100μ. 22-3-5-1.

13. Highly corroded bisaccate pollen grain. Unidentifiable. Tube cell: 38μ. 11-4-1-4.

PLATE I

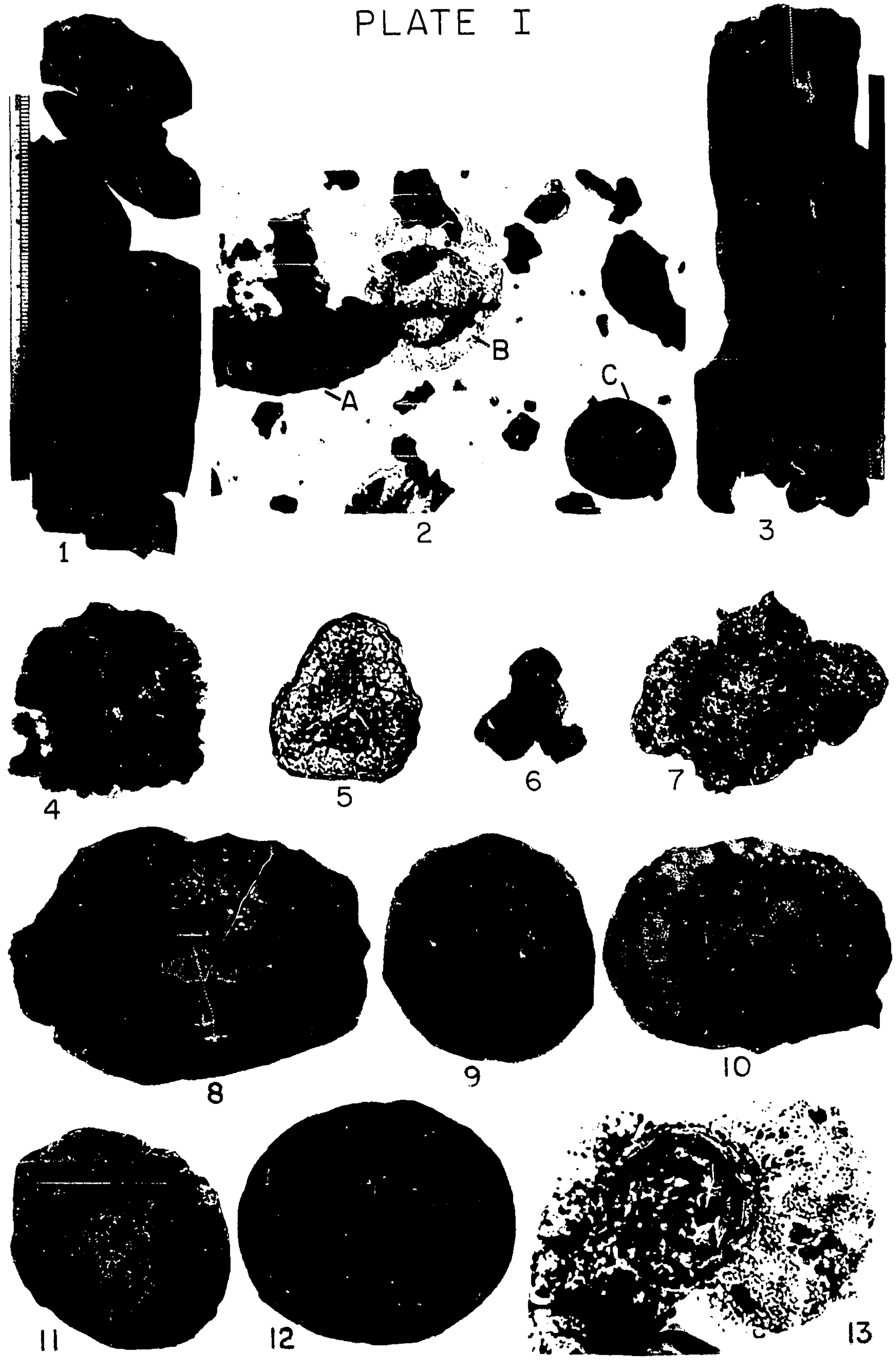

PLATE II

POST - MISSOURIAN, PRE - CHESTER, LONG-RANGING AND UNKNOWN PALYNOMORPHS

1-7. Post-Missourian contaminants derived from well cavings.

1. *Vittatina costabilis* Wilson, 1962. 50 x 40µ. 10-2-1-11.

2. *Vesicaspora schaubergeri* (Pot. & kl.) Jizba, 1962. 55 x 43µ. 19-2-2-3.

3. *Hamiapollenites perisporites* (Jizba) Tschudy and Kosanke, 1966. 95 x 92µ. 19-1-2-1.

4. *Stroterosporites* sp. 75 x 67µ. 1-6-1-14.

5. *Taeniaesporites* sp. 98 x 60µ. 6-6-3-6.

6. *Alisporites plicatus* Jizba, 1962. 75 x 52µ. 1-6-1-9.

7. *Clavatasporites irregularis* Wilson, 1962. 82µ. 19-2-1-12.

8-12. The most common non-diagnostic palynomorphs having ranges which neither begin nor terminate in Desmoinesian or Missourian strata.

8. *Potonieisporites* sp. Range: Chester - Permian. 137 x 125µ. 11-7-1-10.

9. *Punctatisporites* sp. Range: Silurian - Recent. 100µ. 19-4-1-12.

10. *Wilsonites kosankei* Bhardwaj, 1957. Range: Morrow - Missourian. 120 x 108µ. 19-2-1-13.

11. *Endosporites ornatus* Wilson & Coe, 1940. Range: Chester - post-Missourian. 102µ. 19-12-2-3.

12. *Schopfipollenites ellipsoides* (Ibr.) Pot. & Kr., 1955. Range: Chester - Permian. 140 x 83µ. 19-1-1-9.

13-16. Pre-Chesterian recycled palynomorphs.

13. *Tapajonites* sp. Inferred to be Devonian. 57µ. 6-1-5-1.

14. *Incertae sedis* A. Inferred to be Devonian. 112µ. 18-1-1-5.

15. *Tasmanites* sp. Devonian. 110 x 90µ.

16. *Lagenochitina* sp. Ordovician. 100 x 57µ. 11-10-3-4.

17. Unknown spore U_1. 120 x 100µ. 19-4-1-4.

PLATE II

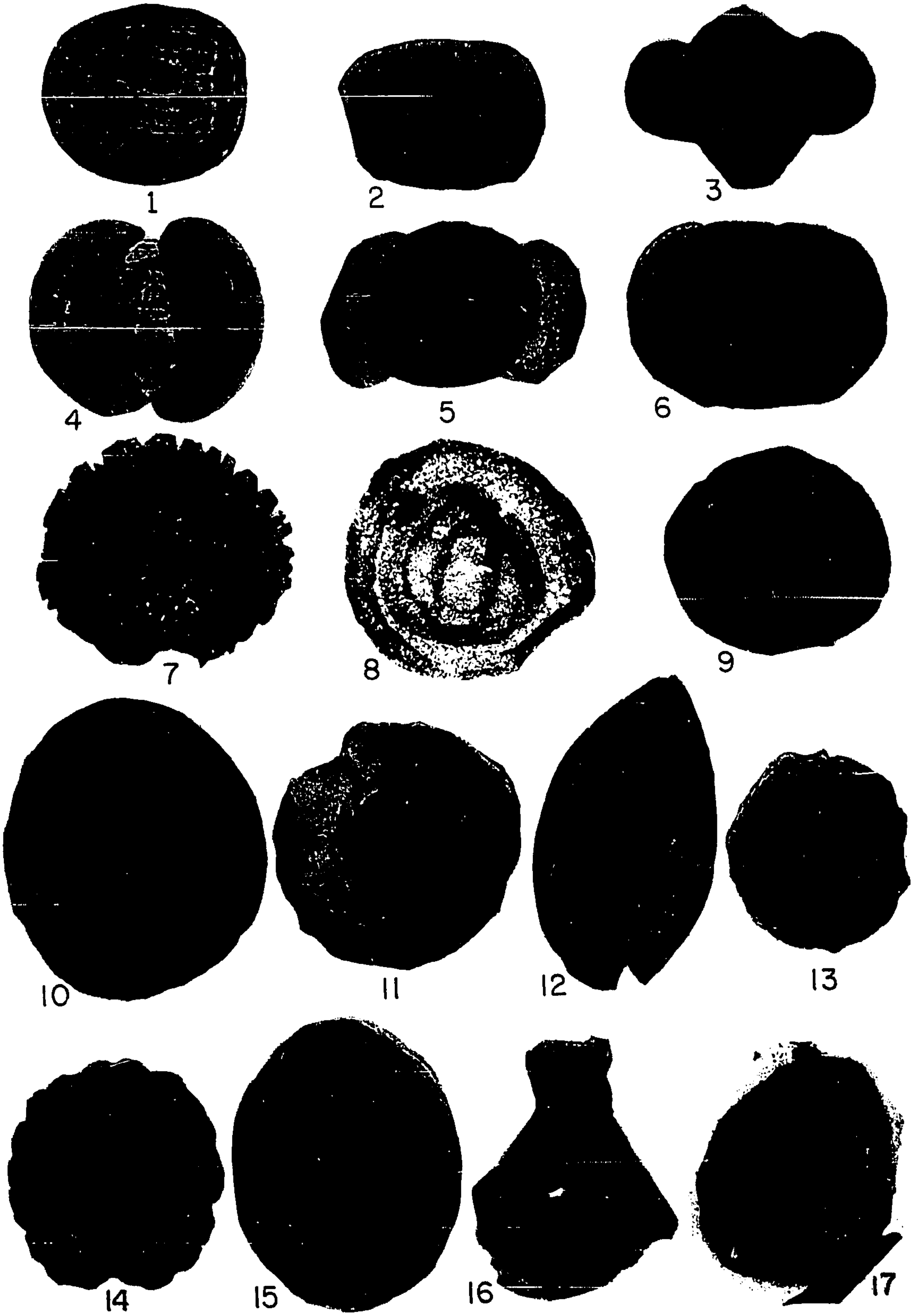

PLATE III

CHESTER RECYCLED PALYNOMORPHS

1. Asperispora crickmayi Staplin, 1964. Note galleae. 62 x 75µ. 1-2-1-3.

2. Densosporites rarispinosus Playford, 1963. 52 x 67µ. 6-6-1-12.

3. Secarisporites remotus Neves, 1961. 62 x 50µ. 9-2-1-3.

4. Tripartites vetustus Schemel, 1950. 38µ. 19-7-1-1.

5. Knoxisporites carnosus Butt. & Will., 1958. 62 x 72µ. 16-4-2-1.

6. Endosporites micromanifestus Hacquebard, 1957. 70µ. 19-12-1-2.

7. Savitrisporites nux (Butt. & Will.) Sullivan, 1964. 50µ. 6-6-1-7.

8. Discernisporites irregularis Neves, 1958. 88µ. 6-6-3-11.

9. Crassispora kosankei (Pot. & Kr.) Bhardwaj, 1957. 65 x 53µ. 19-5-5-1.

10. Punctatisporites labiatus Playford, 1962. 75µ. 6-6-2-8.

11. Cristatisporites echinatus Playford, 1963. 60µ. 6-2-2-3.

12. Convolutispora ampla Hoff., Stap. & Mall., 1955. 60µ. 18-2-1-6.

13. Reticulatisporites muricatus Kosanke, 1950. 72µ. 6-6-3-5.

14. Reticulatisporites peltatus (Waltz) Playford, 1962. 95µ. 10-2-2-3.

15. Reticulatisporites corporeus (loose) Pot. & Kr., 1955. 68 x 52µ. 6-6-1-10.

16. Convolutispora mellita Hoff., Stap. & Mall., 1955. 80µ. 6-6-3-10.

17. *Florinites dissacoides* Alpern, 1959. 100 x 82μ. 9-2-3-2.

18. *Velamisporites* sp. 200 x 150μ. 19-6-1-4.

19. Sporangial wall cell apparently restricted to Springer strata in Oklahoma. 50μ. 1-1-1-2.

PLATE III

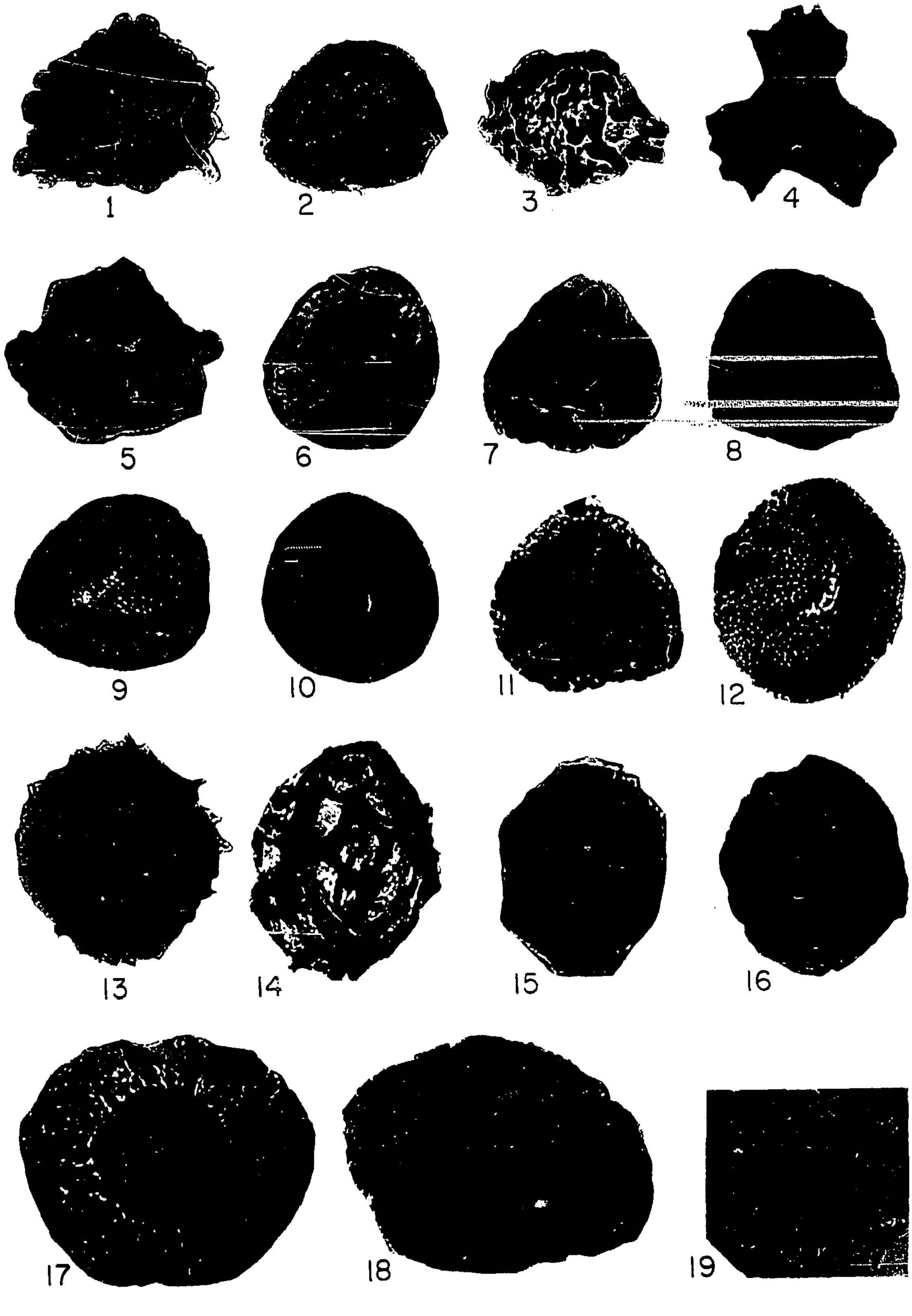

PLATE IV

DESMOINESIAN AND MISSOURIAN SPOROMORPHS

1. Granulatisporites verrucosus Wilson & Coe, 1940. Morrow - Desmoinesian. 30µ. 11-10-3-7.

2. Lycospora torquifer. (Loose) Pot. & Kr., 1956. Chester - Desmoinesian. 30µ. 11-10-2-1.

3. Laevigatosporites minutus (Ibr.) SWB, 1944. Cabaniss - Missourian. 20 x 17µ. 1-4-1-1.

4. Thymospora pseudothiessenii (Kosanke) Wils. & Venk., 1963. Desmoinesian - Missourian. 37µ. 18-3-1-4.

5. Lycospora torquifer (Loose) Pot. & Kr., 1956. More corroded than that shown in fig. 2. 33µ. Chester - Cabaniss. 19-7-1-5.

6. Cirratriradites saturni (Ibr.) SWB, 1944. Chester - Mid-Cabaniss. 65µ. 6-6-1-4.

7. Converrucosisporites sulcatus (Wils. & Kos.) Pot. & Kr., 1955. 45µ. 1-3-2-3.

8. Knoxisporites triradiatus Hoff., Stap. & Mall., 1955. Desmoinesian - Missourian. 58 x 65µ. 19-4-3-5.

9. Reinschospora triangularis Kosanke, 1950. Desmoinesian. 63µ. 11-5-1-4.

10. Triquitrites bransonii Wils. & Hoff., 1956. Desmoinesian - Missourian. 37µ. 18-2-1-1.

11. Triquitrites spinosa Kosanke, 1943. Desmoinesian - Missourian. 35µ. 6-6-3-13.

12. Raistrickia irregularis Kosanke, 1950. Chester - Desmoinesian (?). 67µ. 9-4-3-4.

13. Triquitrites additus Wils. & Hoff., 1956. Cabaniss. 45µ. 13-1-1-16.

14. Triquitrites dividuus Wils. & Hoff., 1956. Cabaniss. 55 x 50µ. 1-6-3-3.

15. Guthorlisporites magnificus Guennel, 1958. Cabaniss. 100µ. 18-1-1-3.

16. *Cadiospora sphaera* Butt. & Will., 1954. Cabaniss - Missourian. 62µ. 11-5-4-2.

17. *Punctatisporites quasioarcuatus* Kosanke, 1950. Desmoinesian - Missourian. 88µ. 19-9-1-6.

18. *Granulatisporites elegans* Peppers, 1964. Inferred to be Missourian. 75µ. 13-1-2-12.

19. *Schopfites colchesterensis* Kosanke, 1950. Cabaniss. 75µ. 19-15-2-1.

20. *Centonites* sp. Missourian. 95µ. 10-2-1-4.

21. *Raistrickia crinita* Kosanke, 1950. Desmoinesian - Missourian. 50µ. 18-2-1-8.

PLATE IV

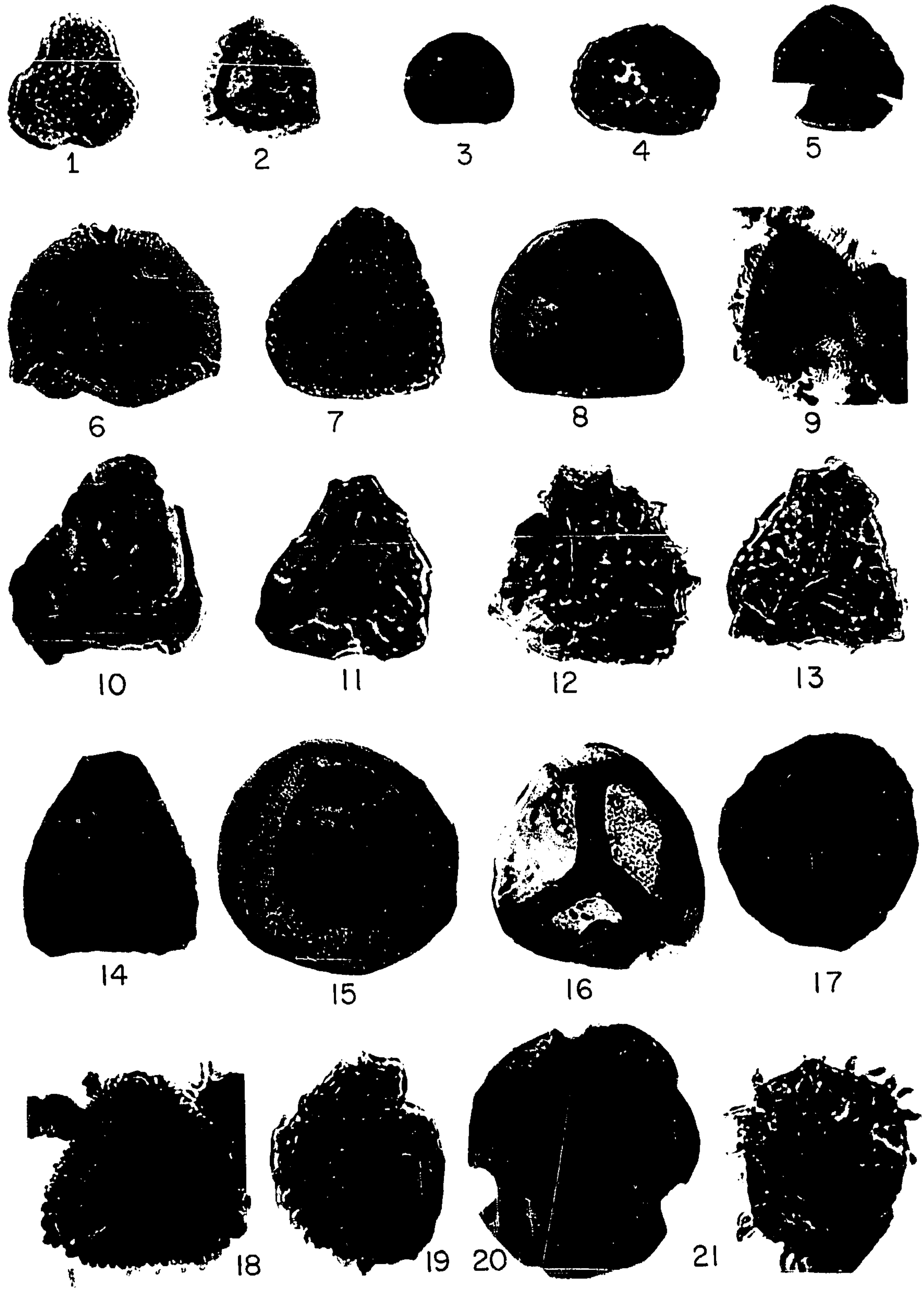

TABLE 2 R. B. SANDERS, 1967	PRE-CHESTER	CHESTER	MORROWAN-ATOKAN	KREBS	CABANISS	MISSOURIAN	POST-MISSOURIAN	1-1 1-2 1-3 1-4 1-5	1-6 1-7 1-8 1-9 2-1	2-2 2-3 2-4A 2-4B 2-5	3-1 3-2 3-3 3-4 3-5	3-6 3-7 3-8 3-9 3-10	3-11 4-1 4-2 4-3 4-4	4-5 4-6 5-1 5-2 5-3	5-4 5-5 5-6 5-7 5-8	5-9 6-1 6-2 6-3 6-4	6-5 6-6 7-1 7-2 7-2A	7-3 7-4 7-5 7-6 7-7	7-8 8-1 8-2 9-1 9-2	9-3 9-4 9-5 9-6 10-1	10-2 10-3 10-4 11-1 11-2	11-3 11-4 11-5 11-6 11-7	11-8 11-9
CALAMOSPORA	X	X	X	X	X	X	X	XX X	XXX	Barren Barren Barren	X		XXX	X	X Barren	Barren X	XX	X	XX X	X X	X Barren X		
LEIOTRILETES	X	X	X	X	X	X	X	X X	XXX	X			XX		X	XXXX	XX	X	X XX	XXX	X X	X	X
PUNCTATISPORITES	X	X	X	X	X	X	X	XXX	XXX X	XX	XXXXX	XX XX	XXXXX	X XXX	XX X	XXXX	X XXX	XXXXX	XXXXX	XXXXX	XX XX	XX XXX	X
POTONIEISPORITES		X	X	X	X	X	X	XXX X	X X X	X	XXXXX	XXXX	XXXXX	X XX	XXX	XXXX	X XX	XXXXX	XXXX	XXXXX	X XX	XX XXX	XX
ENDOSPORITES ORNATUS			X	X	X	X	X		X X ?			X	X X	X	X	X X	X XX	XX	XX X	X	X		X
WILSONITES VESICATUS			X	X	X	X	X		X		?		X			XX	XX X	X X	XX	X X	X	X	
SCHOPFIPOLLENITES		X	X	X	X	X		X	X X		X		X	X		XXX	X	X	XXX	X	X X	X	
FLORINITES PELLUCIDUS		X	X	X	X	X			XX				X			X			XX				X
WILSONITES KOSANKEI		X	X	X	X	X		X	X		X	XX	XX X	X	X	X	X X	X	X XX	X X	X X	XX	XX
ACRITARCHS	X	X	X	X	X	X			X							X				X			
TASMANITES	X								X									X					
CHITINOZOA	X								X				X				X						
ENDOSPORITES MICROMANIFESTUS	X	X							X		X	X X					X		X	X			
CONVOLUTISPORA FLORIDA		X	X					X	XX							XXX					X		
CONVOLUTISPORA TESSELATA		X	X					XX X									XX			X			X
CRASSISPORA KOSANKEI		X	X					XX	X		X	X		XX	X	X ?	XX X		? X	XXX	X	X	X
DENSOSPORITES ACULEATUS		X	X																	X			
DENSOSPORITES RARISPINOSUS		X	X													X	X			X			
DENSOSPORITES REYNOLDSBURGENSIS		X	X													X		X	X	XXX		X	
DICTYOTRILETES INSCULPTILUS		X	X														X			X		X	
KNOXISPORITES TRIRADIATUS		X	X					X								X				X			
PROCORONASPORA AMBIGUA		X	X						X				X							X			
RAISTRICKIA SP.		X	X								X		X										
RAISTRICKIA IRREGULARIS		X	X																X				
SAVITRISPORITES NUX		X	X						X				X				X	X		X			
SECARISPORITES REMOTUS		X	X							X							X						
VELAMISPORITES RUGOSUS		X	X										X			X							
CONVOLUTISPORA MELLITA		X	?					X?									X	X					
DISCERNISPORITES IRREGULARIS		X	?										X				X	X					
FLORINITES DISSACOIDES		X	?																				
FLORINITES VISENDUS		X	?															X					
KNOXISPORITES STEPHANEPHORUS		X	?						X							X							
AGGERISPORA CAMPTA		X						X X	X							X				X			
ALATISPORITES SP.		X														X							
ASPERISPORA CRICKMAYI	?	X						XX					X				X						
AURORASPORA SOLISORTA		X							X				X						XX	X		X	
BULLASPORA SP.		X								X					X								
CADIOSPORA SP.		X							X				X										
CALAMOSPORA EXIGUA		X						X	X X					X									
CINCTURASPORA SP.		X											X			X							
CINGULATISPORITES LANDESII		X						X								X XX	X	X					
CONVOLUTISPORA AMPLA		X															X X	X					
CONVOLUTISPORA VENUSTA		X																		X			
CONVOLUTISPORA VERMICULATA		X																	X		X		
CONVOLUTISPORA SP.		X																					
CRISTATISPORITES ECHINATUS		X						X X	X X		X		X			X	X	XXX	X XX	X X	X X	X	
CYCLOGRANISPORITES COMMODUS		X											X						X				
DENSOSPORITES SPITZBERGENSIS		X							X		XX					X		X X				X	
DICTYOTRILETES CLATRIFORMIS		X									X							X					
GRANDISPORA		X									X						X	X					
IBRAHIMISPORITES SP.		X														X			X				
KNOXISPORITES ROTATUS		X														X							
KNOXISPORITES CARNOSUS		X																					
LEIOTRILETES PYRAMIDATUS		X																					
LOPHOTRILETES SP.		X											X					X		X			
MOOREISPORITES TRIGALLERUS		X																X				X	
MICRORETICULATISPORITES FUNDATUS		X									X												
PEROTRILETES PERINATUS		X									X			X									

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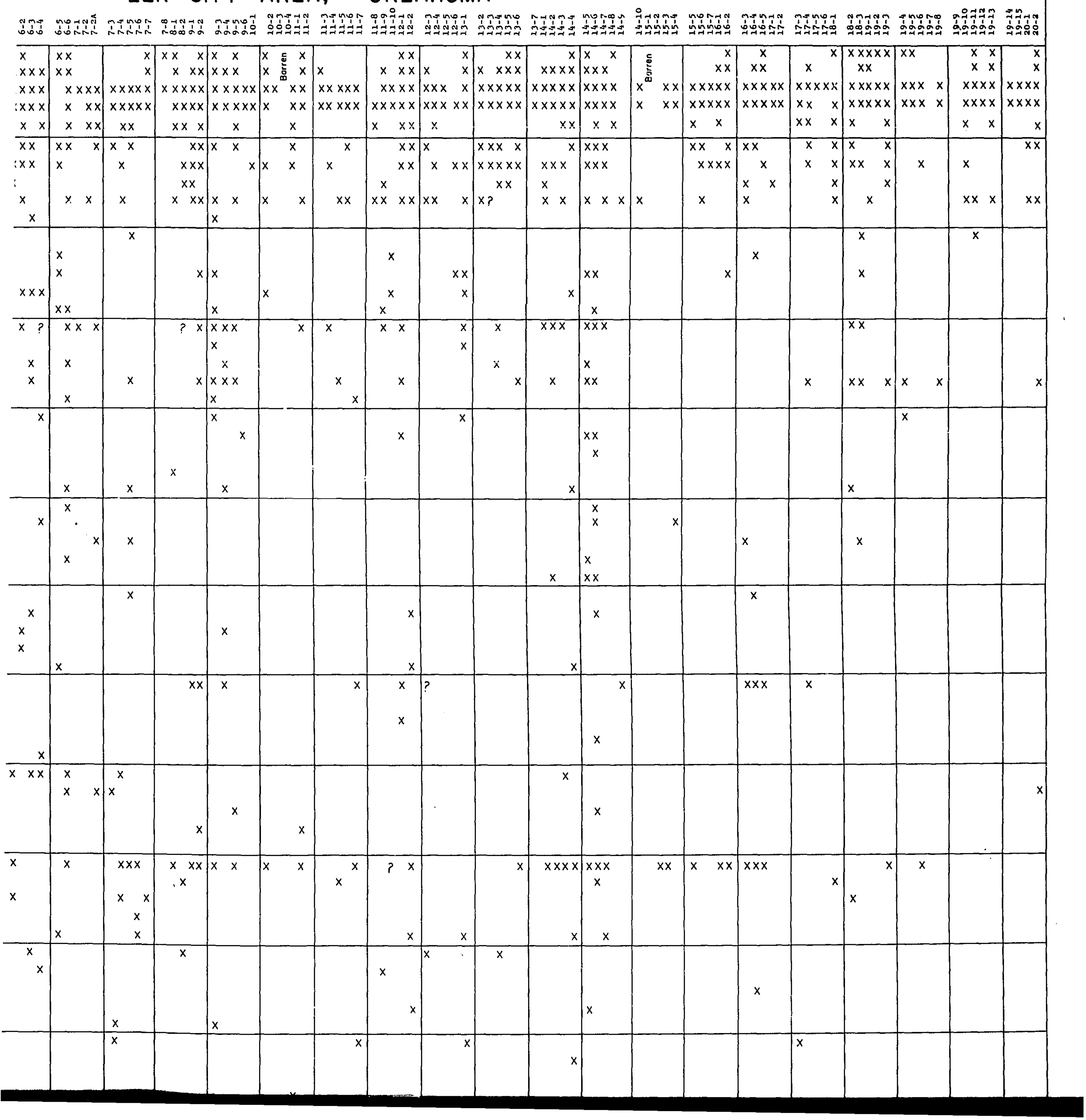

CADIOSPORA SP.		X							X				X									
CALAMOSPORA EXIGUA		X						X	X X					X								
CINCTURASPORA SP.		X											X			X						
CINGULATISPORITES LANDESII		X						X								X XX	X	X				
CONVOLUTISPORA AMPLA		X															X X	X				
CONVOLUTISPORA VENUSTA		X																		X		
CONVOLUTISPORA VERMICULATA		X																	X		X	
CONVOLUTISPORA SP.		X																				
CRISTATISPORITES ECHINATUS		X						X X	X X		X		X			X	X	XXX	X XX	X X	X X	X
CYCLOGRANISPORITES COMMODUS		X											X						X			X
DENSOSPORITES SPITZBERGENSIS		X							X		X X					X		X X				
DICTYOTRILETES CLATRIFORMIS		X									X							X				
GRANDISPORA		X									X						X	X				
IBRAHIMISPORITES SP.		X														X			X			
KNOXISPORITES ROTATUS		X														X						
KNOXISPORITES CARNOSUS		X																				
LEIOTRILETES PYRAMIDATUS		X																				
LOPHOTRILETES SP.		X											X					X		X		
MOOREISPORITES TRIGALLERUS		X																X				
MICRORETICULATISPORITES FUNDATUS		X									X											
PEROTRILETES PERINATUS		X									X			X								
PROPRISPORITES LAEVIGATUS		X												X							X	
PUNCTATISPORITES LAEIATUS		X						X	X								X				X	
RETICULATISPORITES CORPOREUS		X																				
RETICULATISPORITES LACUNOSIS		X																				
RETICULATISPORITES PELTATUS		X											X				X					
SAVITRISPORITES CONCAVUS		X											X									
SCHULZOSPORA RARA		X														X						
SPINOZONOTRILETES TENUISPINUS		X						X								X	X	XX		X	X	
SPINOZONOTRILETES SP.		X											X									
STENOZONOTRILETES CALLOSUS		X												X		?						
TRIPARTITES VETUSTUS		X																			X	
VELAMISPORITES SP.		X							X					X		X ?	X		X	X		
WALTZISPORA SAGITTITA		X																		X		
DENSOSPORITES SPHAEROTRIANGULARIS	X	X	X	X	X														X			
CIRRATRIRADITES SATURNI		X	X	X	X			?	? X								X		X X	X	X	
ENDOSPORITES GLOBIFORMIS		X	X	X	X			X XX	XXX	X	XXXX		X			XX X		X X		X X	XX	
LYCOSPORA BREVIJUGA		X	X	X	X							X	X			XX		XX	XX	X		
LYCOSPORA TORQUIFER		X	X	X	X				X ?			X	X? X			X	X XX	XXX X		XX	X	
SIMOZONOTRILETES		X	X	X	X												X					
GRANULATISPORITES VERRUCOSUS			X	X	X										?	XXX	X		X	X		
CYCLOGRANISPORITES LEOPOLDI				X	X				X							XX	X	X	X	X X		
GUTHÖRLISPORITES				X	X						X							X	X	XX		
REINSCHOSPORA TRIANGULARIS				X	X											X				X		
CONVERRUCOSISPORITES SULCATUS				X	X	X		XXX	X X					X			X X	X	X X	X	X	X
LAEVIGATOSPORITES MINIMUS				X	X	X			X										X			
RAISTRICKIA CRINITA				X	X	X											X	X	XX	X X		
RETICULATISPORITES MURICATUS				X	X	X							X				X					
THYMOSPORA PSEUDOTHIESSENII				X	X	X											X		X			
TRIQUITRITES BRANSONI				X	X	X																
TRIQUITRITES SPINOSUS				X	X	X													X			
CADIOSPORA SPHAERA					X	X							X				X	X X	X	XX	X	X
CIRRATRIRADITES MACULATUS					X	X														X		
LAEVIGATASPORITES MINUTUS					X	X		X								X						
VESICASPORA WILSONII					X	X	X	? X					X			XX	X		X	XX		
WILSONITES DELICATUS					X	X		XXXX	XXX X							X X			XX			
GUTHÖRLISPORITES MAGNIFICUS					X											X			X			
SCHOPFITES COLCHESTERENSIS					X						X					X X	X					
TRIQUITRITES ADDITUS					X				X							X				XX		
TRIQUITRITES DIVIDUUS					X			X	X X								X					
CENTONITES						X														X	X	
GRANULATISPORITES ELEGANS						?										?			X			
POST-MISSOURIAN FORMS							X	XXXXX	XX XXX	X X	XXXXX	XXXX	XXXX	?X?	X	?XX	XX XX	XXXXX	XXXXX	XXX	XXXXX	XXX
UNKNOWN U_1								X X	X		?		X	X		XX X	XX	X	XX	X	X	

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xx		x				xx	.	x	. x	x xx	x	x		x x	x x	x	xx	x
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