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SYSTEMATIC AND STRATIGRAPHIC PALYNOLOGY OF EOCENE TO PLIOCENE STRATA IN THE IMPERIAL NUKTAK C-22 WELL, MACKENZIE DELTA REGION, DISTRICT OF MACKENZIE, N.W.T.

G. NORRIS

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PREFACE

Terrestrial and marine organic-walled palynomorphs are important microfossils for correlation, and have proved to be valuable for subsurface studies of hydrocarbon-bearing strata. This report provides detailed information on the distribution and taxonomy of palynomorphs (spores, pollen, dinoflagellates) in a well from the region of the southern Beaufort Sea, an area of continuing commercial interest for petroleum exploration. The information and interpretations given in this publication will help in the correlation of sedimentary basins and in a regional evaluation of Tertiary strata in Arctic Canada for hydrocarbon fuel potential.

R.A. Price
Director General
Geological Survey of Canada

PRÉFACE

Les palynomorphs organiques à parois, terrestres et marins, sont d'importants microfossiles pour l'établissement de la corrélation et aussi ils s'avèrent précieux pour les études en subsurface de strates d'hydrocarbures. Ce rapport donne des renseignements détaillés sur la distribution et la taxonomie des palynomorphes (spores, pollens, dinoflagellés) à partir d'un puits du sud de la mer de Beaufort, région d'une importance économique notoire d'exploration pétrolière. Les renseignements et les interprétations qu'apportent cet ouvrage est d'un intérêt certain pour la corrélation des basins sédimentaires et l'évaluation régionale des strates tertiaires de l'Arctique canadien en ce qui a trait au potentiel d'hydrocarbures.

R.A. Price
Directeur général
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SYSTEMATIC AND STRATIGRAPHIC PALYNOLOGY OF EOCENE TO PLIOCENE STRATA IN THE IMPERIAL NUKTAK C-22 WELL, MACKENZIE DELTA REGION, DISTRICT OF MACKENZIE, N.W.T.

Abstract

The stratigraphic ranges and taxonomy of 133 species of spores and pollen, 12 species of dinoflagellate cysts, and one acritarch species from the C-22 well (Lat. 69° 41'07"; Long. 134° 51'30"), which penetrates 12 650 feet (3856 m) of Pliocene, Miocene, Oligocene, and Upper and Middle Eocene strata in the Richards Island Basin are documented. Results from analyses of cutting samples composited over intervals of 100 feet (30.5 m) are supplemented by information from 32 sidewall core samples taken at irregular intervals.

The Nuktak Formation (Pliocene-Late Miocene) contains an impoverished spore-pollen flora of boreal aspect and one stratigraphically-restricted dinoflagellate cyst, together with common to abundant recycled Tertiary, Mesozoic, and Paleozoic palynomorphs. It was deposited, following a short hiatus, on the Mackenzie Bay Formation (Miocene), which contains a more abundant terrestrial palynoflora that records the extinction of various angiosperm, conifer and pteridophyte elements. The Mackenzie Bay Formation also contains palynomorphs commonly recycled from lower horizons.

A major microfloral break separates the underlying Kugmallit Formation (an Oligocene coastal plain-delta front complex) from overlying Neogene strata. The Kugmallit palynofloras as a whole are characterized by about 90 terrestrial species and are divisible into two zones, approximately corresponding to the Arnak Member above and the Ivik Member below. The Kugmallit palynofloras record conifer-polypodiaceous fern dominance with less abundant but diverse temperate angiosperms and pteridophytes, and fungal spores of uncertain affinities and significance.

The delta-front Ivik Member is underlain by prodeltaic muds of the Richards Formation (Middle Eocene-Early Oligocene) characterized by a further 48 terrestrial and 12 marine palynomorph species divisible into three zones. The lowest 1000 feet (30.8 m) penetrated in this well contains a great diversity of dinoflagellate assemblages that are representative of a marine environment of deposition near the bottom of the Richards Formation.

The *Pesavis* Zone (marine, middle Eocene) occurs in the lowest beds of the Richards Formation penetrated in the well and is correlated with the upper marine part of the Lower member of the Reindeer Formation outcropping in the Caribou Hills. The palynoflora of the Upper member of the Reindeer Formation in the Caribou Hills appears to correlate with Neogene palynofloral zones identified in the Nuktak Formation of the C-22 well. All palynofloral zones recognized in the well also have been recognized in other wells in the Richards Island Basin. The Eureka Sound Formation exposed in northern Banks Island is older (Paleocene) than the section in the C-22 well. The Beaufort Formation in the Banks Basin, however, probably can be correlated with the Mackenzie Bay Formation in the Richards Island Basin.

All palynomorph species are illustrated and many are described, including the following new taxa of fungal palynomorphs, miospores, and dinoflagellates:

> Fungi: *Rhizophagites cerasiformis* sp. nov., *Dicellaesporites obnixus* sp. nov., *Imprimospora tankensis* gen. et sp. nov., *Reduviasporonites anangus* sp. nov., *Staphlosporonites delumbus* sp. nov.,
>
> Miospores: *Osmundacidites richardsii* sp. nov., *Laevigatosporites novus* sp. nov., *Ericipites antecursoroides* sp. nov., *Chenopodipollis nuktakensis* sp. nov.,
>
> Dinoflagellate cysts: *Palaeoperidinium ariadnae* sp.. nov., *Maduradinium turpis* sp. nov., *Dioxya* (?) *pignerata* sp. nov.

Résumé

Dans le présent article, sont documentées les gammes stratigraphiques et la taxonomie de 133 espèces de spores et pollens, de 12 espèces de dinoflagellés (formes enkystées) et d'une espèce d'acritarche, provenant du puits étudié (lat. 69°41'07", long. 134°51'30"), qui traverse 12 650 pi de strates du Pliocène, Miocène, Oligocène, et de l'Eocène moyen et supérieur dans le bassin de Richards Island. Les résultats donnés par l'analyse d'échantillons composés de débris de forage ordonnés sur des intervalles de 100 pi, sont complétés par l'information obtenue sur 32 échantillons recueillis par carottage latéral à des intevalles irréguliers.

La formation de Nuktak (Pliocène-Miocène supérieur) contient une flore appauvrie, composée de spores et pollens d'affinités boréales et un type de dinoflagellé enkysté, de gamme stratigraphique étroite, qui accompagnent des palynomorphes recyclés, en grand ou très grand nombre, datant du Tertiaire, du Mésozoïque et du Paléozoïque. Elle recouvre en légère discordance stratigraphique la formation de Mackenzie Bay (Miocène), laquelle contient une palynoflore terrestre plus prolifique, qui témoigne de l'extinction de divers angiospermes, conifères et ptéridophytes. La formation de Mackenzie Bay contient aussi des palynomorphes souvent recyclés à partir d'horizons plus profonds.

Une importante lacune dans la microflore sépare la formation sous-jacente de Kugmallit - qui est un complexe oligocène de plaine côtière et de front de delta - des strates néogènes sus-jacentes. Prises dans leur ensemble, les palynoflores de Kugmallit sont caractérisées par environ 90 espèces terrestres, et se laissent subdiviser en deux zones, correspondant respectivement, de façon approximative, au membre d'Arnak aux niveaux supérieurs et au membre d'Ivik aux niveaux inférieurs. Les palynoflores de Kugmallit sont caractérisées par une flore dominante composée de conifères et de fougères polypodiacées, une flore moins abondante mais diversifiée d'angiospermes et de ptéridophytes de la zone tempérée, et la présence de spores fongiques d'affinités et d'importance indéterminées.

Le membre d'Ivik de type front de delta recouvre les boues prodeltaïques de la formation de Richards (Eocène moyen-Oligocène inférieur), caractérisées par 48 autres espèces de palynomorphes terrestres et 12 autres espèces de palynomorphes marins, et divisibles en trois zones. Les 1000 derniers pieds que traversent ce puits contiennent des assemblages très diversifiés de dinoflagellés, et représentent un milieu sédimentaire marin proche de la base de la formation de Richards.

La zone de *Pesavis* (Eocène moyen marin) occupe les plus bas niveaux de la formation de Richards qu'ait traversé le puits étudié; elle peut être mise en corrélation avec le niveau marin supérieur du membre inférieur de la formation de Reindeer, qui affleure dans les collines Caribou. La palynoflore du membre supérieur de la formation de Reindeer, dans les collines Caribou semble correspondre aux zones palynoflorales néogènes identifiées dans la formation de Nuktak que traverse le puits étudié. Toutes les zones palynoflorales identifiées dans le puits examiné ont aussi été reconnues dans les autres puits du bassin de l'île Richards. La formation d'Eureka Sound exposée dans le nord de l'île Banks est dans son ensemble plus âgée (Paléocène) que les terrains traversés par le puits. Cependant, dans le bassin Banks, la formation de Beaufort peut probablement être mise en corrélation avec la formation de Mackenzie Bay dans le bassin de l'île Richards.

On a donné des illustrations de toutes les espèces de palynomorphes, et décrit un grand nombre d'entre elles, y compris les nouveaux taxa de palynomorphes fongiques, miospores, et dinoflagellés suivants:

> Champignons: *Rhizophagites cerasiformis* sp. nov., *Dicellaesporites obnixus* sp. nov., *Imprimospora tankensis* gen. et sp. nov., *Reduviasporonites anangus* sp. nov., *Staphlosporonites delumbus* sp. nov.
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> Miospores: *Osmundacidites richardsii* sp. nov., *Laevigatosporites novus* sp. nov., *Ericipites antecursoroides* sp. nov., *Chenopodipollis nuktakensis* sp. nov.;
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> Dinoflagellés enkystés: *Palaeoperidinium ariadnae* sp. nov., *Maduradinium turpis* sp. nov., *Dioxya* (?) *pignerata* sp. nov.

INTRODUCTION AND OUTLINE OF STRATIGRAPHY

Exploration activity for hydrocarbons in the Mackenzie Delta region has yielded detailed information on Tertiary lithostratigraphy, which has been summarized and synthesized recently by Young and McNeil (1984). These strata accumulated in the Richards Island Basin, a molasse basin whose structural relationships to the Canada Basin and Arctic Ocean have been summarized by Yorath and Norris (1975) and Young et al. (1976).

The Tertiary sediments of the Mackenzie Delta are dominantly deltaic-coastal plain complexes with some marine strata occurring mainly in the lower Paleogene and in the Neogene. The importance and potential of palynology to the stratigraphy of this region have been outlined in a paper edited by Staplin (1976) in which the unique contribution of spore-pollen distributions to correlation of continental and marine facies is emphasized.

Several Geological Survey of Canada Open File reports summarize the palynostratigraphy of selected wells in the Mackenzie Delta. In addition, short papers on selected intervals in the surface and subsurface have provided valuable information on ages and environments – for example, Brideaux (1973), Brideaux and Myhr (1976), Brideaux et al. (1976), Rouse and Srivastava (1972). Little has been done, however, to describe systematically the entire palynofloral sequence, although some species have been illustrated (e.g. Ioannides and McIntyre, 1980) and a few described (Brideaux, 1976). Other published contributions have focused attention on specific taxonomic groups (Elsik and Jansonius, 1974; Sepulveda and Norris, 1982).

The purpose of this paper is to systematically describe, illustrate and document occurrences of palynomorphs throughout an entire Tertiary section penetrated by one well, and to assess their stratigraphic and paleoecologic significance. Previous reconnaissance studies had suggested that the Imperial Nuktak C-22 could contain a relatively complete record of Tertiary sedimentation and palynofloras from the Middle Eocene upwards.

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The cooperation of Austin and Cumming Exploration Consultants, Calgary, in making available earlier analyses of this well and providing information on other wells in the Delta is gratefully acknowledged.

Stratigraphy

Cenozoic sediments beneath the Mackenzie Delta accumulated within the Richards Island Basin (Young et al., 1976), also known as the Mackenzie Basin (Lerand, 1973). Strata of the Richards Island Basin represent part of a major accumulation of late Mesozoic and Cenozoic sediments along the continental shelf of the southern Beaufort Sea, which resulted from opening of the Canada Basin (Yorath and Norris, 1975). The Richards Island Basin was the result of Laramide tectonism associated with downwarping along the dextral Kaltag-Rapid fault complex, north of the Eskimo Lakes Fault zone of the Aklavik Arch Complex (Young et al., 1976).

Cenozoic sediments in this basin comprise the molasse phase of deposition of the upper part of the Brookian Sequence (Lerand, 1973) and were derived predominantly from uplift of the Cordilleran Orogen to the west and south of the Mackenzie Delta, starting in the latest Cretaceous and continuing throughout the Paleogene into the Late Neogene (Young and McNeil, 1984). Several tectono-sedimentary pulses are reflected in large scale, regressive, deltaic or alluvial cycles which built generally northward and eastward. Three major regressive cycles: the Moose Channel, Reindeer, and Kugmallit formations, are recorded in the Paleogene; and two regressive cycles: the Beaufort, and Nuktak formations, are present in the Neogene. Following the complexities of glaciation in the Pleistocene, the modern Mackenzie Delta is again prograding northward (Vilks et al., 1979).

In the late Paleogene, sedimentation was interruped in the Richards Island Basin by tectonism (related in part to lutokinetic diapirism) resulting in erosion and cannibalization of some parts of the earlier Paleogene molasse (Young et al., 1976; Young and McNeil, 1984). This phase of tectonism appears to have been most intense south of a line running approximately from Pullen Island through Hooper Island and between Pelly and Garry islands (Fig. 1). A major WNW-ESE uplift (the Langley High) in the southern part of Richards Island resulted in the removal of large parts of the Paleogene (Young and McNeil, 1984) but, in the vicinity of the Imperial Nuktak C-22 well (Hooper Island), there is probably very little missing (Fig. 2).

The Nuktak C-22 well does not penetrate the entire Cenozoic section. Consequently, in the review that follows, attention will be focused on those formations penetrated in the well, starting with the lowest.

Richards Formation

This is the lowest formation penetrated in the C-22 well. Young and McNeil (1984) have demonstrated that this formation, in the Richards Island Basin, overlies the Reindeer Formation of Paleocene to Middle Eocene age, a major deltaic regressive wedge of sandstone and silty mudstone with minor amounts of conglomerate.

The Richards Formation is a thick mudstone unit of probable prodeltaic origin, the bottom part of which passes southward laterally into the upper part of Reindeer Formation. Its contact with the superjacent Kugmallit formation is abrupt but conformable. Young and McNeil

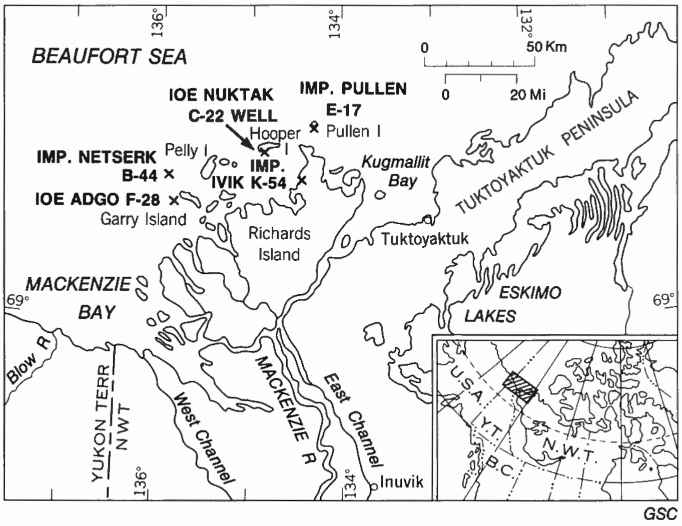

Figure 1. Location map for Imperial Nuktak C-22 well.

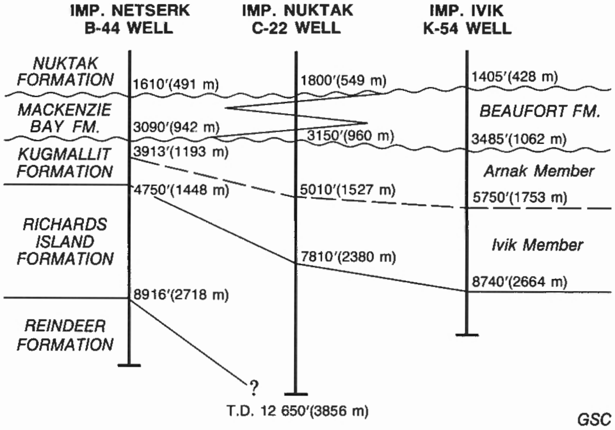

Figure 2. Vertical section and Tertiary lithostratigraphy of Mackenzie Delta (after Young and McNeil, 1984).

(1984) indicate that its thickness increases northwestward from 1300 feet (396 m) in southern Richards Island, to more than 5000 feet (1524 m) near Garry and Pelly islands. Thickness variations may be due in part to lutokinetic diapirism and in part to the presence of listric growth faults (Bowerman and Coffman, 1975). In the Nuktak C-22 well, the formation is 4840 feet (1475 m) thick but its base was not penetrated (Fig. 2).

The Richards Formation is composed mainly of light grey, marine mudstone and shale with minor amounts of smectite, and bentonite seams near the top. Poorly sorted and poorly stratified pebble conglomerates are common, which suggests deposition by subaqueous debris flows on prodeltaic, sloping surfaces.

The lowest few hundred feet of the Richards Formation are composed of grey marine shale containing fairly rich foraminiferal and less diverse dinoflagellate assemblages. In these beds Young and McNeil (1984) have recognized the *Haplophragmoides* spp. foraminiferal assemblage, which attains its greatest diversity in the offshore wells of the shallow Beaufort Sea. In these wells, the assemblage consists of *Alveolophragmium* spp., *Bathysiphon pseudoloculus* (Myatliuk), *Jadammina* sp., and *Recurvoides* sp. Less common are *Ammomarginulina* cf. *A. foliaceus* (Brady), *Gravellina* sp., *Haplophragmoides* cf. *H. carinatus* Cushman and Renz, *Saccammina* sp., and *Trochammina* sp. The calcareous benthic foraminifer *Brizalina* cf. *B. substriatula* (Asano) occurs rarely in the strata penetrated by offshore wells, which suggests deposition on the outer shelf or uppermost slope.

Farther south, the diversity of the *Haplophragmoides* spp. assemblage is reduced and, in the area of southern Richards Island, comprises only one species (*Jadammina* sp.).

Elements of the *Haplophragmoides* spp. assemblage are in part endemic to the Arctic Ocean area and indicate an Eocene age. The almost exclusively agglutinated composition of this assemblage suggests a low salinity marine environment although other factors, such as low oxygen levels, high carbon dioxide levels, and high turbidity also may have been important. The relatively sparse dinoflagellate floras (described herein and by Staplin, 1976) in the Richards Formation are discussed later. The sparsity supports the interpretation that these strata were deposited in a restricted, marine environment, which became less saline in higher horizons.

The Richards Formation penetrated in the C-22 well is believed to span the Middle and Late Eocene and part of the Early Oligocene (a further discussion follows in this report).

Kugmallit Formation

The Kugmallit Formation is a thick deltaic complex of soft, semi-consolidated, clastic sediments, with its type section in the Imperial Nuktak C-22 well (Young and McNeil, 1984).

The formation has been largely removed by erosion over the Langley High but thickens abruptly to the north. It becomes very thick under Richards Island and Kugmallit Bay and reaches in excess of 6500 feet (1981 m) under northeast Richards Island. It is 4660 feet (1420 m) thick in Imperial Nuktak C-22 well. The formation is divided into two members: in the C-22 well the lower Ivik Member is 2800 feet (853.4 m) thick and is overlain by the Arnak Member which is 1860 feet (567 m) thick.

The Ivik Member is transitional in character between the prodeltaic mudstone of the Richards Formation and the delta plain sediments of the upper part of the Kugmallit Formation. It consists of rhythmic alternations of mudstone and sandstone that commonly display medium scale, coarsening-upward trends typical of progradational deltas.

In contrast, the overlying Arnak Member is characterized by fining-upward rhythmic units of gravel, sand, siltstone, and coal, probably deposited in meandering stream channels on an alluvial or deltaic plain.

Agglutinated foraminifers of the *Haplophragmoides* spp. assemblage have been reported by Young and McNeil (1984) from the Ivik Member. Only three species of the assemblage have been found in the Ivik Member, namely *Alveolophragmium* sp., *Bathysiphon* sp., and *Haplophragmoides* sp. Throughout much of the Delta, the Kugmallit Formation is barren of foraminifers. However, in the offshore wells of the shallow Beaufort Sea, calcareous foraminifers of the *Cibicides* spp. assemblage occur in the upper half of the Kugmallit Formation, signifying marine beds of Oligocene age (Young and McNeil, 1984). An Oligocene age for the Kugmallit Formation is confirmed by its prolific terrestrial palynoflora, which is described and discussed in a later section. It is noteworthy that no dinoflagellates have been reported from the Kugmallit Formation of the C-22 well in spite of the rare (but possibly caved) occurrences of elements of the *Cibicides* spp. assemblage namely: *Cibicides perlucidus* Nuttall, *Cyclogyra involvens* (Reuss), *Melonis* cf. *M. affine* (Reuss) and *Miliolinella* sp. reported by Young and McNeil (1984) from the Ivik and Arnak members.

Mackenzie Bay Formation

This marine mudstone unit varies from 1100 to 2000 feet (335 to 610 m) thick north and northwest of Richards Island. It becomes thinner and intertongues with the fluvial Beaufort Formation toward the south and east.

The Mackenzie Bay Formation rests abruptly, and usually unconformably, on the Kugmallit or older formations, except in the area northwest of Pelly Island. There, foraminifer data (Young and McNeil, 1984) suggest that it may be conformable. It is overlain abruptly by the Nuktak Formation which, according to Young and McNeil (*op. cit.*), is unconformable in most well sections on structural highs. Basinward, however, only a non-erosional hiatus marked by a limy hardground seems to be present.

The Mackenzie Bay Formation comprises predominantly light grey, soft mudstones with some silt or sand laminae, scattered chert and plant fragments, and pyritized infillings of burrows. Water-laid volcanic ash beds and bentonites occur commonly in the lower part of the formation. The Mackenzie Bay Formation was laid down on a shallow marine shelf with gradual shoaling and freshening of the water occurring to the southeast. Biofacies studies (Young and McNeil, *op. cit.*) indicated environments of deposition representative of the inner shelf or near the middle shelf, but this cannot be confirmed palynologically (see a later section in this report).

The Nuktak C-22 well is located in an area where the Mackenzie Bay Formation interfingers with the Beaufort Formation. Mudstone units between 1800 and 1950 feet (548.6 and 594.4 m) and between 2400 and 2920 feet (731.5 and 890.0 m) represent interbeds of the Mackenzie Bay Formation.

Calcareous benthic foraminifers of the *Cibicides* spp. assemblage occur throughout the Mackenzie Bay Formation in the area northwest of Richards Island, but disappear south as the transition to the fluvial Beaufort Formation is approached (Young and McNeil, 1984). The assemblage is relatively diverse, and includes the following: *Asterigerina guerichi* s.l. (Francke), *Cibicides grossa ten* Dam and Reinhold, *C. perlucidus* Nuttall, *C.* cf. *C. tenellus* (Reuss), *Cyclogyra involvens* (Reuss), *Elphidiella* (?) *brunnescens* Todd, *Eponides binominatus* Subbotina, *Globocassidulina subglobosa* Brady, *Globulina inaequalis* Reuss, *Melonis* cf. *M. affine* (Reuss), *Miliolinella* sp., *Scutuloris* sp., *Trifarina fluens* (Todd), and *Turrilina alsatica* Andreae. Less common species in the assemblage include *Ehrenbergina variabilis* Trunkô, *Lagena semilineata*, Wright, *Miliolinella circularis* (Bornemann), *Nodosaria* spp., *Oolina* (?) sp., *Parafissurina* sp., *Pullenia* sp., *Pyrgo* cf. *P. rotalarius* Loeblich and Tappan, *Quinqueloculina* sp., *Rotaliatina* cf. *R. mexicanus* Cushman, *Saracenaria* sp., and *Sphaerodina bulloides* d'Orbigny.

This assemblage is dated Oligocene to Miocene by Young and McNeil (*op. cit.*). *Turrilina alsatica* is believed to be restricted to the Oligocene. Hence the Oligocene-Miocene boundary is drawn about the middle of the Mackenzie Bay Formation in the area near Pelly Island. Foraminifer assemblages are absent in the Beaufort-Mackenzie Bay interval in the C-22 well but the palynomorph assemblages (discussed later) indicate a probable Miocene age, although a Late Oligocene age also is considered possible.

Beaufort Formation

The Beaufort Formation is a lateral facies equivalent of the Mackenzie Bay Formation and, in the Richards Island Basin, is best developed and thickest under the northeastern part of Richards Island and adjacent offshore areas to the east (Young and McNeil, *op. cit.*). Also, it mantles much of the Arctic Coastal Plain and the mainland east of the Mackenzie Delta (Tozer, 1960; Thorsteinsson and Tozer, 1962; Hills, 1970; Yorath and Norris, 1975). Young (1978) and Price et al. (1980) have recognized the Beaufort Formation outcropping in the northern Caribou Hills in a part of the section formerly identified as the upper member of the Reindeer Formation (Doerenkamp et al., 1976).

The Beaufort Formation is in excess of 3000 feet (914.4 m) under the northeastern part of Richards Island and contiguous offshore regions, but thins westward and northwestward, interfingering with the Mackenzie Bay Formation. It is completely absent west of a line running south from Pelly Island (Young and McNeil, 1984).

The Beaufort Formation rests unconformably on older formations and is overlain mainly disconformably by the Nuktak Formation. In the C-22 well, Beaufort gravels occur between 1950 and 2400 feet (594.3 and 731.5 m) and between 2920 and 3150 feet (890.0 and 960.1 m) interbedded with Mackenzie Bay Formation mudstones. For brevity of discussion in subsequent parts of this paper, the entire section is referred to the "Mackenzie Bay Formation", although interfingering relationships with the Beaufort Formation should not be forgotten in this context.

Lithologically, the Beaufort Formation is dominated by quartzitic and cherty sands with numerous thick and thin gravel beds, and minor amounts of interbedded mudstone containing lignitic woody fragments. Hills and Fyles (1973) reported numerous plant macrofossils, including spruce cones and walnuts, from the Beaufort Formation on Banks Island and Prince Patrick Island.

Terrestrial palynomorphs are the dominant microfossils in the same beds and are discussed in a later section. Young and McNeil (1984) have reported an impoverished *Cibicides* spp. assemblage (*Asterigerina guerichi* s.l. and *Elphidiella* (?) *brunnescens*) from the middle part of the Beaufort Formation in northeastern Richards Island, and suggest a probable Miocene age on this basis, an assignment confirmed by the palynoflora.

The Beaufort Formation represents alluvium laid down by braided streams, probably coalescing to form alluvial fans adjacent to a shallow marine shelf to the west and northwest.

Nuktak Formation

A wedge-shaped gravel unit occurs at the base of the Nuktak Formation, thickening from a zero edge on the Langley High and east Richards Island up to 1500 feet (457.2 m) in northern Richards Island. This unit, probably representing a gravel-rich delta plain, is overlain by a mud member that may reach a thickness in excess of 600 feet (182.9 m) and which was deposited probably in a marine embayment. The Nuktak Formation occurs to a depth of 1800 feet (548.6 m) in the Nuktak C-22 well, its type section (Young and McNeil, 1984).

The Nuktak Formation lies disconformably, with little evidence of erosion, on the Mackenzie Bay or Beaufort formations. Its upper contact is poorly known, but it is probably overlain unconformably by sand, gravel, till, and mud of the Herschel Island Formation.

A marine, shallow-water biofacies of probable Pliocene or Pleistocene age occurs in the Nuktak Formation of northern Richards Island, and is characterized by calcareous foraminifers of the *Elphidium* spp. assemblage (Young and McNeil, *op. cit.*). Principal elements of the assemblage include *Elphidiella hannai* (Cushman and Grant), *Elphidium bartletti* Cushman, *E. clavatum* Cushman, *Protelphidium anglicum* Murray, *P. orbiculare* (Brady), and *P.* cf. *P. orbiculare* (Brady). Less common elements include *Buccella frigida* (Cushman), *Elphidium ustulatum* Todd, *Islandiella helenae* Feyling-Hanssen and Buzas, *I. islandica* (Norvang), *Quinqueloculina seminulum* (Linné), and rare, agglutinated species of the genera *Haplophragmoides*, *Ammodiscus*, and *Miliammina* (?). Similar assemblages are common to Holocene sediments deposited in low-salinity waters of the Beaufort Shelf, in front of the modern Mackenzie Delta (Vilks et al., 1979).

The *Elphidium* spp. assemblage is largely absent in the southern areas of the Delta and is replaced by nonmarine ostracodes, charophytes, and terrestrial plant remains in the Nuktak Formation. This nonmarine biofacies has been recorded in the lower part of the Nuktak Formation as far north as the Nuktak C-22 well (Young and McNeil, 1984). The impoverished marine and nonmarine palynofloras in the Nuktak Formation are described below and indicate a Pliocene age.

Curation of materials

The slides used in this study are stored in three locations. Those provided by Esso Resources Canada Ltd. (see Appendix 2) are stored in the Palynology Laboratory of that company in Calgary; slides of unillustrated and unfigured material are stored in the Palynology Collection of the Institute of Sedimentary and Petroleum Geology, Calgary. All illustrated and figured specimens are maintained in the type collection held at the Geological Survey of Canada, Ottawa.

PALYNOSTRATIGRAPHY

The distribution of palynomorphs in Imperial Nuktak C-22 well (Lat. 69°41'07", Long. 134°51'30") is shown in Figure 7, and discussed in Appendix 1. Details of slides and the depths or intervals examined are listed in Appendix 2. More than 200 samples were examined; 32 were sidewall core samples but the majority were cuttings. Analytical results are grouped into 100-foot (30.5 m) intervals for the cutting samples whereas results from the sidewall core samples are plotted separately.

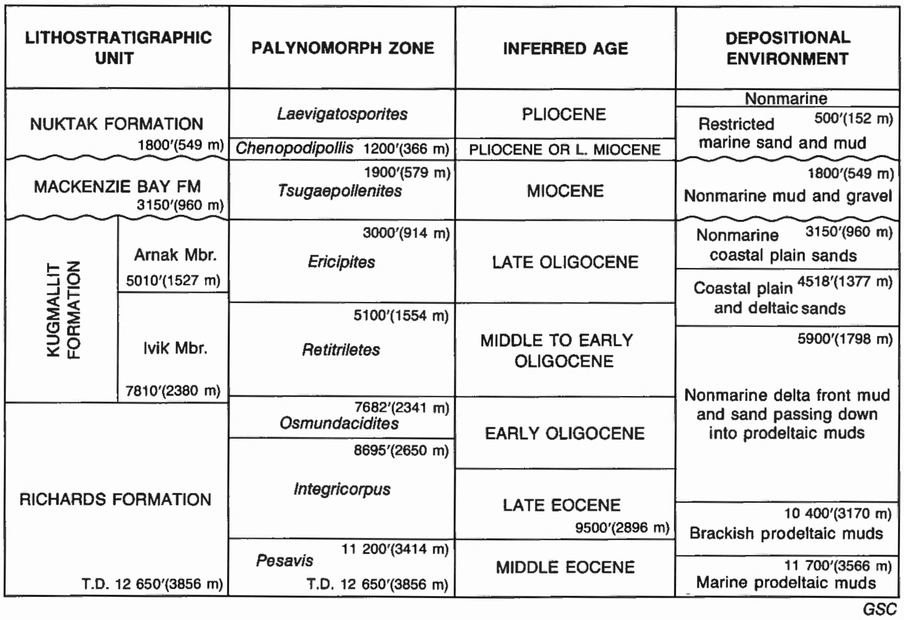

Figure 3. *Correlation chart and age determinations. Depths are for bottoms of lithostratigraphic units, and for tops of palynomorph zones and depositional environments.*

A visual estimate of relative abundance was made using three categories: present, common, and dominant. Palynomorphs are not abundant in the residues, less than 10 per cent of all particles greater than 15 µm being miospores or microplankton.

Recycled palynomorphs occur frequently in the section examined, and are particularly common in the Neogene. These are indicated separately in Figure 7 where their recycled origin is not in doubt. It is possible that the occurrences of some species as plotted may be erroneous, as the result of unidentified recycling, and these are discussed in the appropriate part of the text.

Zonation

A consideration of range tops for selected palynomorph species allows an interval zonation (Hedberg, 1976) to be established in this well. The palynofloras record a progressive deterioration of climate from possible temperate conditions in the Paleogene to a boreal climate in the late Neogene (see discussion of paleoecology). Overall floral diversity decreases during this period, and certain species have distinctive restricted ranges. A major microfloral break at approximately 3000 feet (914.4 m) is coincident with an erosional break between Neogene and Paleogene. Three interval zones can be established in the Neogene and five interval zones in the Paleogene, principally by using range tops of terrestrial palynomorphs (see Fig. 3). Marine dinoflagellates are rare except in the lowest part of the Richards Formation where they characterize the lowest interval zone established in this well.

The interval zones are named using an eponymous taxon which, however, is a matter of convenience and has no particular stratigraphic significance. Recognition of the zone requires consideration of all species listed and thus involves also the concepts of Oppel zonation (see Hedberg, 1976).

The zones are described from the top of the well downwards to emphasize the fact that they are based on the successive disappearance of species. The ranges of the species indicated terminate within the designated interval. The base of an interval zone is defined by the top of the subjacent zone.

***Laevigatosporites* Zone** (0-1199 ft; 0-365.5 m)

Taxodiaceaepollenites hiatus
Pinuspollenites sp. A
Polyvestibulopollenites verus
Trivestibulopollenites claripites
Stereisporites minor
Salixpollenites discoloripites (possibly recycled)
Laevigatosporites novus
Corsinipollenites triangulatus (possibly recycled)
Piceaepollenites grandivescipites
Trivestibulopollenites betuloides (possibly recycled)
Sigmopollis psilatus
Fungal hyphae type A
Rhizophagites cerasiformis
Pyxidiella sp. A (possibly recycled)

Some species are believed to be recycled because of the large stratigraphic disjunction between their occurrence in the *Laevigatosporites* Zone and the main part of their range approximately 1000 feet (305 m) or more lower in the section.

***Chenopodipollis* Zone** (1200-1899 ft; 365.8-578.8 m)

Chenopodipollis sp. A
Chenopodipollis nuktakensis
Fractisporonites sp. cf. *F. canalis*
Chenopodipollis sp. B
Fungal hyphae type C
Echinatisporis sp. A
Graminidites sp. A
Trivestibulopollenites betuloides (possibly recycled above this zone)
Stereisporites stereoides
Pyxidiella sp. A is confined to the *Chenopodipollis* Zone apart from a single occurrence in the superjacent zone which may be due to recyling.

***Tsugaepollenites* Zone** (1900-2999 ft; 579.1-914.1 m)

Baculatisporites comaumensis
Stereisporites microgranulus
Myricipites annulites (possibly recycled)
Polyvestibulopollenites trinus (possibly recycled).
Tsugaepollenites igniculus
Retitriletes sp. cf. *R. oligocenicus*
Ulmipollenites undulosus
Osmundacidites wellmanii
Deltoidospora hallii
Baculatisporites crassiprimarius (possibly recycled)
Tsugaepollenites viridifluminipites
Retitriletes annotinioides
Ericipites compactipollinatus (possibly recycled)
Laevigatosporites ovatus
Carpinipites sp. cf. *C. spackmaniana*
Sequoiapollenites polyformosus
Cyathidites minor
Polyatriopollenites stellatus
Fungal hyphae type B
Monoporisporites singularis

This zone contains recycled Paleogene elements. Some occurrences of the species listed above however, may also be the result of recycling above the base of the Mackenzie Bay Formation, but this is impossible to prove conclusively. Alternatively, the Paleogene-Neogene unconformity (base of the *Tsugaepollenites* Zone) may be located higher than indicated by Young and McNeil (1984). The base of the *Tsugaepollenites* Zone is currently drawn at 2999 ft/914.1 m, which is virtually coincident with the base of the Mackenzie Bay Formation (3150 ft/960 m), considering the limits of accuracy imposed by use of cutting samples.

The *Tsugaepollenites* Zone is characterized by the range tops of several pteridophyte species together with several gymnosperm and angiosperm range tops.

***Ericipites* Zone** (3000-5099 ft; 914.4-1554.2 m)

This zone is characterized by the common occurrence of the eponymous genus. *Ericipites compactipollinatus* does, however, occur in the superjacent zone either as a rare component of floras in the lower part of the Mackenzie Bay Formation or as recycled material. It is impossible to ascertain the nature of its occurrences above the Kugmallit Formation.

The *Ericipites* Zone is based on a large number of range tops of terrestrial palynomorphs, some of which appear to have temperate climatic significance, as discussed later in this report.

Intratriporopollenites crassipites
Cupuliferoipollenites oviformis
Dicellaesporites popovii
Ostryoipollenites sp. cf. *O. rhenanus*
Sparganiaceaepollenites neogenicus
Annutriporites tripollenites
Dyadosporites oblongatus
Biretisporites potoniaei
Fungal hyphae type G
Staphlosporonites delumbus
Baculatisporites quintus
Baculatisporites crassprimarius
Pinuspollenites labdacus
Tricolpites hians
Reduviasporonites anangus
Quercoidites microhenrica
Ulmoideipites tricostatus
Reduviasporonites sp. A
Striacolporites sp. A
Salixpollenites discoloripites (possibly recycled above)
Corsinipollenites triangulatus (possibly recycled above)
Lonicerapollis spiniformis
Staphlosporonites sp. A
Triporisporonites verus
Reduviasporonites sp. cf. *R. catenulatus*
Fungal hyphae type D
Centonites sp. A
Piceaepollenites sp. A
Diporicellaesporites bellulus
Quercoidites sp. A
Inapertisporites circularis
Dyadosporites sp. cf. *D. schwabii*
Fungal hyphae type E
Fungal hyphae type F
Diporisporites communis
Multicellaesporites margaritus
Monoporisporites sp. A
"*Multicellaesporites*" sp. A
Momipites tenuipolus
Margocolporites stenosus
Monoporisporites sp. cf. *M. cupuliformis*
Plochmopeltinites masonii
"*Hologinella*" sp. A

The *Ericipites* Zone is virtually coextensive with the Arnak Member of the Kugmallit Formation.

***Retitriletes* Zone** (5100-7600 ft; 1554.5-2316.5 m)

Retitriletes sp. cf. *R. novomexicanus*
Phragmothyrites sp. cf. *P. eocaenicus*
Microthyriacites sp. A
Polybrevicolporites sp. A
Trichothyrites sp. A

The base of the *Retitriletes* Zone occurs within 200 feet (61 m) of the base of the Ivik Member of the Kugmallit Formation.

***Osmudacidites* Zone** (7682-8600 ft; 2341.5-2621.3 m)

Cupuliferoipollenites pusillus
Osmundacidites richardsii
Didymosporisporonites ovatus
Indeterminate peltate fruiting bodies
Brachysporisporites sp. cf. *B. cotalis*
Verrucatosporites favus
Diporisporites sp. A

The *Osmundacidites* Zone occupies approximately the upper 2000 feet (609.5 m) of the Richards Formation and extends into the lowest 100 feet (30.5 m) approximately of the Kugmallit Formation.

***Integricorpus* Zone** (8695-11 199 ft; 2650.2-3413.4 m)

Leptolepidites sp. A
Ericipites antecursoroides
Striadiporites sanctaebarbarae
Integricorpus sp. A
Striadiporites multistriatus
Striadiporites bistriatus
Staphlosporonites sp. cf. *S. conoideus*
Multicellaesporites compactilis
Brachysporisporites cotalis
Lacrimasporonites sp. A
Striadiporites inflexus
Imprimospora tankensis
Microthallites sp. cf. *M. lutosus*
Pesavis tagluensis (possibly recycled from subjacent zone)
Multicellaesporites leptaleus
"*Inapertisporites*" sp. cf. *I. vittatus*
Diporicellaesporites sp. cf. *D. bellulus*
Multicellaesporites lanceolatus
Annutriporites sp. A
Dyadosporites sp. A
Monoporisporites abruptus
Azolla sp. A
Ctenosporites wolfei
Microthyrites sp. A
Caryapollenites veripites
Inapertisporites sp. A
Brachysporisporites opimus

The ranges of the dinoflagellates *Palaeoperidinium ariadnae* and *Dioxya* (?) *pignerata* terminate approximately 1000 feet (305 m) above the base of the *Integricorpus* Zone.

The *Integricorpus* Zone occupies the middle part of the Richards Formation penetrated in this well.

***Pesavis* Zone** (11 200-12 650 ft TD; 3413.8-3855.7 m)

Pesavis tagluensis (possibly recycled in superjacent zone)
Dicellaesporites aculeolatus
Callimothallus pertusus

Fractisporonites sp. A
Pistillipollenites mcgregorii
Diporicellaesporites laevigatiformis
Fractisporonites sp. B
Dicellaesporites obnixus
Inapertisporites sp. cf. *I. subovoidus*
Fusiformisporites sp. A
Intratriporopollenites minimus
Multicellaesporites sp. cf. *M. conicus*
Marine dinoflagellates restricted to the *Pesavis* Zone include:
Wetzeliella sp. cf. *W. hampdenensis*
Glaphyrocysta ordinata
Palaeoperidinium sp. A
Distatodinium sp. A
Cordosphaeridium gracile
Maduradinium turpis
Senoniasphaera sp. A
Spinidinium sp. cf. *S. sagittulum*

Paleoecology and paleoenvironments

The spore-pollen assemblages from the C-22 well are derived principally from strata deposited in relatively high-energy, deltaic and coastal plain environments with periodic nearshore marine intervals. These contrast with the low-energy depositional environments favoured by Quaternary palynologists (small lakes, bogs, moss polsters) for palynological interpretation of regional vegetation zones. The higher energy environments represented by fluviodeltaic and coastal clastic sediments tend to alter the natural spore-pollen associations because of aerodynamic and hydrodynamic sorting and may include exotic components introduced by long-distance transport by wind or water. Furthermore, interpretation of pre-Quaternary spore-pollen assemblages, in terms of vegetation zones, is complicated by the difficulty in recognizing extant low-level taxa in older Tertiary deposits. An additional factor, which must be taken into account in the high Arctic, is that few plants are anemophilous and, therefore, late Quaternary pollen diagrams are not readily interpretable in terms of regional vegetation change (Ritchie and Lichti-Federovich, 1967; Ritchie, 1974). How far back in time this factor persisted is not readily ascertained. Consequently, the following discussion on paleoecology of Tertiary palynomorph assemblages must be considered tentative until further knowledge is available about sedimentary sorting, affinities of miospores, and pollination paleoecology for the Tertiary, comparable in detail to that available or the Quaternary (see the comprehensive discussion in Birks and Birks, 1980).

Recent studies, by Ritchie (1974) in the western Arctic and Davis (1980) in northern Newfoundland, on modern pollen spectra near the boreal forest-tundra transition, provide relevant information on palynologic assemblages in low energy environments near the arctic and sub-arctic tree line. This information may be used for comparative purposes with Pliocene and older assemblages described herein from the Mackenzie Delta. Ritchie (1974) showed that for the Mackenzie Delta region, forest site spectra comprise the co-dominants *Picea*, *Betula* (dominantly tree birch) and *Alnus*, whereas tundra spectra have larger proportions of Cyperaceae, Ericaceae, Gramineae, *Alnus*, *Betula* (dwarf birch) and other non-arboreal pollen and smaller values for *Picea*. In northern Newfoundland, Davis (1980) showed that in a variety of forest, marsh, and bog sites, *Picea* and *Alnus* pollen are constant co-dominants, with lesser proportions of *Betula* and *Alnus* and occasional high values for Ericaceae, Gramineae, Cyperaceae, *Myrica* and *Sphagnum*.

Nuktak Formation (Pliocene or Late Miocene)

The spore-pollen assemblages in the upper part of this formation (*Laevigatosporites* zone) comprise species with the following suggested affinities with extant taxa:

Stereisporites minor - *Sphagnum*
Laevigatosporites novus - Polypodiaceae
Piceaepollenites grandivescipities - *Picea*
Pinuspollenites sp. A - *Pinus*
Taxodiaceaepollenites hiatus - (?) Taxodiaceae
Polyvestibulopollenites verus - *Alnus*
Trivestibulopollenites betuloides - *Betula*
Salixpollenites claripites - *Salix*
Corsinipollenites triangulatus - *Epilobium*

This sparse assemblage clearly shows some similarities with the boreal assemblages described by Ritchie (1974). However, the complete absence of Ericaceae, Cyperaceae, Gramineae, *Artemisia*, *Myrica*, and other herbs noted by Ritchie as characteristic of the modern pollen spectra of the Mackenzie Delta, is noteworthy, and may be due in part to the effects of differing depositional environments. *Laevigatosporites novus*, which may be a polypodiaceous fern, is common in this interval. This family of ferns has a wide distribution, including boreal regions where exposed rock faces are a preferred habitat. The presence of *Epilobium* - if it is not recycled in this interval - further confirms a boreal flora interpretation, since it presently ranges into Alaska (Britton and Brown, 1970) and northern Canada.

Taxodiaceaepollenites hiatus is common. It may have taxodiaceous affinities but its simple morphology precludes close identification to extant taxa.

If *Salix* pollen is indigenous to the Nuktak Formation, it probably indicates the presence of one or more species of boreal willow or dwarf willow.

The lower part of the Nuktak Formation contains several distinctive species. The presence here of *Rhizophagites cerasiformis* indicates that endogoniaceous michorhizal fungi were actively producing chlamydospores in the root systems of some plants. Little is known of the ecology of the Endogoniaceae, but they are common to specific pteridophyte taxa in temperate floras of Canada today (Shannon M. Berch, Department of Biology, University of Waterloo, pers. comm.).

Other species in the lower part of the Nuktak Formation include various fungal hyphae and spores which may be associated with michorhizal fungi. This however, is conjectural.

Various species of *Chenopodipollis* may indicate the presence of Chenopodiaceae in the lower Nuktak Formation. The Family Chenopodiaceae has a wide distribution and many species prefer open ground or dry soils. The association of Chenopodiaceae pollen with boreal pollen assemblages indicates a cool climate. *Echinatisporis* sp. A may be *Selaginella*, which would be consistent with the above interpretation since the genus ranges in boreal regions at present.

The significance of *Sigmopollis psilatus* is not clear. It may be a pollen grain but, in Staplin (1976) it is suggested that it may be a planktonic alga.

Pyxidiella sp. A is a probable marine dinoflagellate in the lower part of the Nuktak Formation. This dinoflagellate is quite dissimilar, however, to species in Recent and sub-Recent dinoflagellate assemblages of the Beaufort Sea (Harland et al., 1980). Cool water dinoflagellate assemblages described from Recent or sub-Recent argillaceous sediments from the area near the Dome Kopanoar and Tingmiark offshore drilling sites (approximately 40-50 mi/64-80 km north or northeast of Imperial Nuktak C-22) are dominated by species of *Spiniferites*, *Rottnestia*, and *Operculodinium*, none of which occurs in the Nuktak Formation or in older formations in the area of Richards Island. However, they do occur in the Miocene of the offshore region (E.H. Davis, Atlantic Geoscience Centre, Dartmouth, pers. comm.). Presumably, differences in water temperature, salinity, or degree of turbidity are responsible for the differences in the dinoflagellate flora, but information critical to the understanding of ecologic control of dinoflagellates in Arctic waters is not available.

Mackenzie Bay Formation (Miocene)

The palynoflora from the upper part of the Mackenzie Bay Formation above 2300 feet (701 m) is essentially the same as that from the lower part of the Nuktak Formation and thus reflects boreal floras. Species having affinities with *Sphagnum*, Polypodiaceae, *Pinus*, *Picea*, Chenopodiaceae, *Alnus* and *Betula* are common. However, in addition the following species, which characterize the lower part of the Mackenzie Bay Formation (*Tsugaepollenites* Zone), suggest a milder climate.

Tsugaepollenites igniculus and *T. viridifluminipites* - *Tsuga*
Retitriletes spp. - *Lycopodium*
Osmundacidites - Osmundaceae
Carpinipites cf. *C. spackmaniana* - *Carpinus*
Ericipites compactipollinatus (possibly recycled) - Ericaceae

The *Tsuga* biome presently occurs in British Columbia northward into southeastern Alaska, where it reaches an altitude of 2000 feet (610 m) (Shelford, 1963). Other species of *Tsuga* are common in temperate floras but do not extend northward beyond the mixed conifer forest of the Great Lakes region. Moisture is critical for *Tsuga* to survive (Preston, 1975). The presence of *Tsuga* pollen in the lower part of the Mackenzie Bay Formation may thus indicate the former presence of the *Tsuga* biome in the region. Alternatively, the Mackenzie Bay pollen assemblages may have been derived from distant sources through long-distance transport.

Carpinus presently occurs in temperate woodlands that may be moist or swampy. The common presence of ferns and club mosses is consistent with this interpretation. For example, *Osmunda* is presently distributed from Newfoundland to Minnesota and farther south, preferring swampy ground.

Other species of possible climatic significance near the bottom of the Mackenzie Bay Formation include:

Ulmipollenites undulosus - *Ulmus*
Sequoiapollenites polyformosus - *Sequoia* or *Metasequoia*
Polyatriopollenites stellatus - *Pterocarya*

Ulmus presently occurs in the Great Lake region and farther south and east. *Sequoia* presently occurs in mountainous coastal regions of California. *Pterocarya* occurs only in temperate regions of Asia at the present time.

Evidently, the Mackenzie Bay palynofloras reflect a cool temperate climate, which was moister than the boreal climate of the Nuktak Formation. *Alnus*, *Betula*, *Pinus*, and *Sphagnum* are, however, common constituents of the Mackenzie Bay flora. The flora from the lower part of the Mackenzie Bay Formation records warmer conditions where temperate elements, presently occurring in eastern and western North America and Asia become common.

Kugmallit Formation (Oligocene)

A hiatus exists between the Mackenzie Bay Formation floras of temperate aspect and the underlying palynofloras of the Arnak Member of the Kugmallit Formation. Cool temperate species that characterize the Neogene may also occur in the Arnak Member (Late Oligocene) of the Kugmallit Formation, but these are accompanied by the following additional species, some of which are apparently related to or identical with thermophylic extant taxa as indicated:

Intratriporopollenites crassipites - *Tilia*
Cupuliferoipollenites oviformis - *Castanea*
Ostryoipollenites sp. cf. *O. rhenanus* - *Ostrya*
Polyatriopollenties stellatus - *Pterocarya*
Quercoidites microhenrica - *Quercus*
Ulmipollenites undulosus - *Ulmus*
Ulmipollenites tricostatus - *Ulmus*
Lonicerapollis spiniformis - Caprifoliaceae
Margocolporites stenosus - Leguminoseae
Sequoiapollenites polyformosus - *Sequoia* or *Metasequoia*
Sparganiaceaepollenites neogenicus - *Sparganium*, *Typha*

Some of these also occur in the overlying Mackenzie Bay Formation as indicated previously, but the higher proportion of species with affinites to thermophylic taxa in the Arnak Member of the Kugmallit Formation is noteworthy. Fungal spores and hyphae are also diverse, but their climatic significance is not known. The presence of Ericaceae and *Typha* or *Sparganium* suggest swamp or marsh conditions by comparison with modern floras. *Castanea* also occurs in this interval and presently ranges in North America across the southeast temperate and subtropical regions, further supporting the possibility of a termperate or warm temperate climate for this interval. The cool temperate taxa in this interval may be present due to the effects of cavings from above, or to long distance transport from mountainous regions.

The palynofloras of the Arnak Member are notably more diverse than those in the underlying Ivik Member. The average number of species in the Arnak Member is 16; this contrasts with 8 for the Ivik Member. This increase in diversity may be related to changing depositional environments, as the waning prodeltaic conditions, leading to deposition of Ivik sediments, were replaced by alluvial or deltaic plain conditions of the Arnak Member. However, the downward reduction in diversity in the Ivik Member is related partly to the lessened frequency or total disappearance of the following species, which occur commonly in the underlying prodeltaic Richard Formation and become more abundant again in the Arnak Member:

Fungi
  Fungal hyphae Type E
  Fungal hyphae Type G
  Staphlosporonites delumbus

Reduviasporonites anangus
Inapertisporites circularis
Diporisporites communis
Monoporisporites sp. A

Bryophytes and Pteridophytes
Stereisporites stereoides
Baculatisporites crassiprimarius
Retitriletes sp. cf. *R. oligocenicus*
Cyathidites minor
Biretisporites potoniaei

Gymnosperms
Pinuspollenites sp. A
Sequoiapollenites polyformosus

Angiosperms
Ulmipollenites undulosus
Intratriporopollenites crassipites
Cupuliferoipollenites oviformis
Tricolpites hians
Quercoidites microhenrica
Ericipites compactipollinatus

The lack or scarcity of the above species in the Ivik Member is unlikely to be due entirely to the change of depositional environment; vegetational changes associated with climatic change must also be considered a possibility (see Norris, 1982). The reduction in diversity of Ivik palynofloras is accentuated by the appearance, in the overlying Arnak Member, of the following species, which are not known in the Ivik Member or subjacent strata:

Fungi
Reduviasporonites sp. A
Reduviasporonites sp. cf. *R. catenulatus*

Bryophytes and Pteridophytes
Stereisporites microgranulus
Laevigatosporites novus

Angiosperms
Trivestibulopollenites betuloides
Myricipites annulites
Ostryoipollenites sp. cf. *O. rhenanus*
Sparganiaceaepollenites neogenicus

Species that are frequently present in the Ivik Member include the following:

Bryophytes and Pteridophytes
Stereisporites minor
Baculatisporites comaumensis
Osmundacidites wellmanii
Laevigatosporites ovatus
Retitriletes sp. cf. *R. novomexicanum*

Gymnosperms
Taxodiaceaepollenites hiatus
Piceapollenites grandivescipites
Pinuspollenites labdacus
Piceapollenites sp. A
Tsugaepollenites viridifluminipites

Angiosperms
Polyvestibulopollenites verus
Trivestibulopollenites claripites
Carpinipites sp. cf. *C. spackmaniana*
Polyatriopollenites stellatus
Annutriporites tripollenites

All the above species are present also in the Arnak Member except for ***Retitriletes*** sp. cf. ***R. novomexicanum*** which disappears at the top of the Ivik Member and ***Piceaepollenites*** sp. A which is only sporadically present in the Arnak Member.

The significance of the reduction in diversity of the palynofloras in the Ivik Member is not clear. However, it is noteworthy that species related to ***Pinus, Metasequoia, Ulmus, Tilia, Castanea*** and ***Quercus*** are absent in the Ivik Member, in contrast with strata below and above, suggesting that these dominantly temperate taxa were adversely affected by environmental changes during Ivik time (Norris, 1982). Species that remain common in the Ivik Member include various bryophyte and fern taxa, ***Picea, Pinus, Tsuga, Alnus, Betula, Carpinus*** and ***Pterocarya*** (the latter only in the middle part of the member).

These data suggest that somewhat cooler conditions might have prevailed during deposition of the Ivik Member - possibly early Oligocene, although age determinations are still tentative (see later section). Leaf floras from North America suggest that a profound cooling occurred during the late Eocene (Wolff, 1980). A similar climatic change near the Eocene-Oligocene boundary is indicated by oxygen isotope studies (Buchardt, 1978; Savin, 1977). These changes have been attributed to change in obliquity of the ecliptic or to the development of a planetary ring system (see discussion in O'Keefe, 1980). A critical review of floristic changes in the Eocene of southern England (Collinson, Fowler, and Boulter, 1981) suggests that cooling occurred in two major periods starting in the early Eocene, the final period in the late Eocene perhaps being more rapid than the first. The palynofloral data from the Mackenzie Delta region indicate that the earliest Oligocene in this location recorded possibly cooler conditions compared with those of the middle and late Eocene and the late Oligocene respectively (see Norris, 1982). However, age determinations are tentative.

Richards Formation (Middle Eocene to Early Oligocene)

Climatic interpretations are difficult for the assemblages in this interval because of the unknown or at best tenuous connections of the palynomorphs with extant taxa. It is noteworthy that fungal palynomorphs are common and diverse in this formation but their ecologic significance is uncertain.

Of the spore-pollen taxa which can be related to extant genera, the following temperate or warm temperate forms occur in the Richards Formation: ***Pinus, Metasequoia, Ulmus, Tilia, Castanea, Quercus, Tsuga, Pterocarya,*** in addition to cool temperate or boreal taxa such as ***Picea, Alnus, Betula*** and ***Sphagnum***. These assemblages, containing species with conflicting climatic significance, may be due to caving in cuttings samples or to long distant transport from cooler – perhaps mountainous – regions into warm temperate lowlands prevailing in the Mackenzie Delta region. Further work is required to resolve this problem.

A species of *Azolla* occurs in the lower part of the Richards Formation. This genus is lacustrine and is at present distributed widely in the temperate and tropical regions of North and Central America. Its present-day freshwater habitat contrasts with occurrences in the Richards Formation, which are coincident with marine or brachish-water dinoflagellate assemblages. Possibly these

Eocene species of *Azolla* grew in coastal habitats. The lowest occurrences are with fully marine dinoflagellate assemblages and are presumably the result of washing into the marine environment, along with many other palynomorphs of terrestrial origin. The higher occurrences, together with *Palaeoperidinium ariadnea* and *Dioxya pignerata* (probably brackish-water dinoflagellates) may be autochthonous or parautochthonous in coastal swamps or lagoons of abnormally low salinity.

The dinoflagellate assemblages characterizing the lowest 1000 feet (305 m) of the Richards Formation contain few specimens and few species. Numbers of dinoflagellate species in assemblages from this interval range from 2 to 7 with an average of about 5, being drawn from a total of 10 possible species. Assemblages are dominated by several dozen terrestrial palynomorph species (see Fig. 7) indicating proximity to a shoreline.

The composition of these dinoflagellate assemblages is unique to the Richards Island Basin; close comparisons are not possible with, for example, the Lower Tertiary dinoflagellate assemblages of northwest Europe, which are more diverse and whose paleoecology has been discussed by Downie et al. (1971). Ioannides and McIntyre (1980) concluded that dinoflagellate assemblages containing *Wetzeliella* and *Apectodinium* in the Eocene of the Caribou Hills reflect a hyposaline marine environment. The assemblages from the Richards Formation, which are probably slightly younger, do not contain *Apectodinium*, thus precluding a close comparison. However, this interval in the Richards Formation is characterized by the *Haplophragmoides* spp. assemblage of agglutinated foraminifers (Young and McNeil, 1984) which is believed to be related to a low-salinity environment, induced either locally by deltaic conditions or by widespread hyposalinity (and perhaps other physical factors such as temperature and oxygen balance) of the Arctic Ocean at that time.

In northwest Europe, the presence of dominant *Wetzeliella* is believed to be related to estuarine conditions (Downie et al., 1971), but these assemblages also contain species of *Deflandrea* and *Apectodinium* which are not known in this interval of the Richards Formation. The presence of *Cordosphaeridium* in the Richards Formation is noteworthy in this regard. In the Paleogene of England, this genus occurs in open-sea environments (Downie et al., 1971). However, the assemblages are more diverse and may contain dominant *Spiniferites*, *Hystrichosphaeridium*, and *Achomosphaera*, genera not reported in this particular interval of the Richards Formation. *Cordosphaeridium* is characteristic of marine Tertiary assemblages on the east Canadian Shelf (Williams, 1975; Gradstein and Williams, 1976). Thus, there are some discrepancies in the paleoecological interpretation of the dinoflagellate assemblages which have yet to be resolved, although the bulk of the evidence points towards a restricted marine, perhaps hyposaline, prodeltaic environment of deposition for this interval in the Richards Formation. It is also important to bear in mind the effect of fluctuating light intensity and prolonged photoperiod on phytoplankton in high latitudes (Norris, 1975). The ecologic controls for dinoflagellate assemblages have not been rigorously investigated, but doubtless would have drastically affected assemblage composition at high latitudes, along with other important factors, such as salinity. Harland et al. (1980) pointed out that dinoflagellate assemblages in the Neogene of the Beaufort Sea are dramatically different from those in the North Atlantic, but did not identify specific controls.

Discussion of age determinations

General comments

Difficulty is encountered in attempts to assign ages to the palynofloras from Arctic Canada (e.g. Young, 1975; Staplin, 1976; Doerenkamp et al., 1976; Rouse, 1977; Ioannides and McIntyre, 1980). In the Richards Island Basin particularly, marine dinoflagellate assemblages are virtually absent above the Eocene except for some impoverished, highly endemic assemblages in the Neogene (e.g. *Pyxidiella* sp. A in the *Chenopodipollis* Zone and possibly higher). Sub-Recent dinoflagellate cyst assemblages of the Beaufort Sea include species of *Spinidinium*, *Rottnestia*, and *Operculodinium* (Harland et al., 1980), but these are not present in the C-22 well or other wells examined by the writer in the Mackenzie Delta region.

Diverse, post-Eocene, spore-pollen assemblages typically show a progressive impoverishment upward through the Tertiary, and become very restricted in the Neogene of the Mackenzie Delta. Previous workers have dated post-Eocene, nonmarine, palynomorph assemblages by comparisons with palynofloras of putative known age in lower latitudes of North America and Europe (see Ioannides and McIntyre, 1980, for a general discussion). However, it is clear that ranges of some taxa are diachronous across latitude, particularly in the Neogene (but probably also to a lesser extent in the Paleogene) when climatic gradients were high. For example, the Paleogene floras of the Beaufort-Mackenzie Basin contain genera such as *Ulmipollenites*, *Intratriporopollenites*, *Quercoidites*, *Cupuliferoipollenites*, *Ostryoipollenites*, *Azolla*, and *Tsugaepollenites* which do not occur in the Neogene of this area but whose spore-pollen types are represented in extant temperate taxa viz. *Ulmus*, *Tilia*, *Quercus*, *Castanea*, *Ostrya*, *Azolla*, and *Tsuga*. On the other hand, at the species level, there is no close resemblance between Paleogene and low latitude extant species. Nevertheless, some species that range into the higher Tertiary of mid-latitude Europe and North America are not known above the Paleogene in northern Canada (e.g. *Verrucatosporites favus*, *Baculatisporites quintus*, *Pinuspollenites labdacus*, *Tsugaepollenites igniculus*, *Cupuliferoipollenites oviformis*, *Cupuliferoipollenites pusillus*, *Quercoidites microhenrica*, *Polyatriopollenites stellatus*, *Sparganiaceaepollenites neogenicus*).

A large number of species appear to be endemic to this northern region or are newly reported without records elsewhere.

For the above reasons, ages of assemblages from the lowest Paleogene penetrated in the C-22 well can be determined with confidence, whereas spore-pollen assemblages from the higher Paleogene and Neogene are less certain.

That problems of age determination are not confined to the higher Tertiary is illustrated by a series of interesting figures provided by Staplin (1976, p. 132) regarding placement of the Paleocene-Eocene boundary in Imperial Reindeer D-27 well. This boundary was placed variably by four commercial laboratories as follows at the depths indicated:

Gulf (Houston)		5300 ft	(1615 m)
Mobil (Calgary)		6300 ft	(1920 m)
Gulf (Calgary)	below	9600 ft	(2926 m)
Imperial (Calgary)		9700 ft	(2956 m)

This very large difference illustrates the problems in interpreting the chronostratigraphic significance of palynofloras from this region.

Age assignments of the palynologic zones from the bottom of the C-22 well upward, are discussed. Ages and other information are summarized in Figure 3. Details of range zones for individual species may be found in the systematic section of this bulletin.

***Pesavis* Zone** (lower part of the Richards Formation)

Two dinoflagellates that are restricted to the *Pesavis* Zone do have restricted ranges on the Labrador Shelf, Grand Banks, or Scotian Shelf: *Glaphyrocysta ordinata* ranges from Middle to Late Eocene and *Cordosphaeridium gracile* from Late Paleocene to Eocene. More diverse dinoflagellate assemblages (including the above species) characterized by associations of *Wetzeliella* and *Apectodinium* species were described from the lower part of Interval C of the Reindeer Formation in the Caribou Hills by Ioannides and McIntyre (1980) and dated as Early to Middle Eocene. The lack of dinoflagellates belonging to *Apectodinium*, *Hystrichokolpoma*, *Diphyes* and the absence of species of *Punctodiporites*, *Paraalnipollenites*, *Saxonipollis* (all restricted to the lower part of Interval C according to Ioannides and McIntyre, 1980) suggests that the *Pesavis* Zone can be correlated with the upper part of Interval C of the Reindeer Formation. *Wetzeliella* sp. cf. *W. hampdenensis* also is restricted to the upper part of Interval C, and ranges to the top of the *Pesavis* Zone. An age of Middle Eocene for the *Pesavis* Zone would accord with this correlation and with age determinations on the palynofloras of the Reindeer Formation by Ioannides and McIntyre (1980).

Pistillipollenites mcgregorii does not occur above the *Pesavis* Zone. In a comprehensive review of this species, Rouse and Srivastava (1970) indicated that it does not occur above the Middle Eocene, thus confirming the Middle Eocene age of the *Pesavis* Zone.

Fungal spores are common in the *Pesavis* Zone. The ranges of the following spores terminate in this Zone. *Dicellaesporites aculeolatus* occurs in the Middle Eocene Claiborne Formation of Tennessee but is said to occur in the Oligocene of northeast China (Sung et al., 1978). *Callimothallus pertusus* also occurs in the Middle Eocene of Tennessee (Dilcher, 1965) but has not been reported elsewhere to date. *Pesavis tagluensis* has been reported widely from Paleocene-Eocene strata of Washington, British Columbia, Alaska, and the Northwest Territories (Elsik and Jansonius, 1974) but, according to Rouse (1977), its range terminates at the top of the Eocene in British Columbia but somewhat earlier in the Late Eocene interval in the Arctic. *Pesavis tagluensis* is recycled in the Paleogene of the Beaufort-Mackenzie Basin (e.g. probably in the superjacent *Integricorpus* Zone in the C-22 well), which may account for its indefinite higher range into the Late Eocene, as indicated by Rouse (1977).

The *Pesavis* Zone possibly can be correlated with the middle part of Assemblage 2b described by Doerenkamp et al., (1976) from the top of the lower member of the Reindeer Formation, Caribou Hills, and with the upper part of Interval C of the Reindeer Formation from the same area, described by Ioannides and McIntyre (1980).

The palynologic zones established by Doerenkamp et al., (1976) in the Eureka Sound Formation of Banks Island do not correspond precisely with any assemblages from the C-22 well. Their Zone TII spans the upper member of the Eureka Sound Formation in northern Banks Island and contains *Pistillipollenites mcgregorii* throughout and *Wetzeliella - Apectodinium - Hystrichokolpoma* associations near the bottom. Doerenkamp et al. (1976) suggested that these marine horizons are somewhat older than the marine horizons at the top of the lower member of the Reindeer Formation in the Caribou Hills, since the latter occur above the range zone of *Pistillipollenites mcgregorii* and contain somewhat different dinoflagellate assemblages. They believed these different assemblages indicated an Early Eocene age. Ioannides and McIntyre (1980) on the basis of further information on the distribution of *Nudopollis* and *Saxonipollis* in the Caribou Hills and Banks Island sections suggested that Doerenkamp et al.'s Zone TII is Late Paleocene and can be correlated with Interval B in the Reindeer Formation, Caribou Hills. Thus, the entire upper member of the Eureka Sound Formation in northern Banks Island appears to be older than the *Pesavis* Zone in the Beaufort-Mackenzie Basin.

Palynofloras from the Kitsilano Formation of southwest British Columbia share a number of species in common with the *Pesavis* Zone and were dated by Hopkins (1969) as Middle to Late Eocene.

***Integricorpus* Zone** (middle part of Richards Formation)

No marked palynofloral break occurs between the *Pesavis* and *Integricorpus* zones other than a marked reduction in dinoflagellate diversity in response to presumed marine regression. *Palaeoperidinium ariadnae* occurs throughout the lowest 1000 feet (305 m) of this zone in association with *Dioxya* (?) *pignerata*, but their environmental significance is poorly understood. Presumably they are associated with markedly hyposaline conditions possibly passing into brackish or freshwater estuarine or prodeltaic environments. These dinoflagellates are apparently endemic to the Beaufort-Mackenzie Basin and, therefore, cannot be used for correlation elsewhere.

The range of *Striadiporites sanctaebarbarae* terminates at the top of the *Integricorpus* Zone. It occurs also in the Upper Eocene and Oligocene of California (Elsik and Jansonius, 1974) and in the Oligocene of northeast China (Sung et al., 1978). *Integricorpus* sp. A occurs in the upper part of the *Integricorpus* Zone; its range is reported to be Middle Eocene-Oligocene by Staplin (1976) but exclusively Early Oligocene by Rouse (1977).

Ctenosporites wolfei terminates below the middle of the *Integricorpus* Zone. It ranges into Middle or Upper Eocene in the Arctic (Elsik and Jansonius, 1974; Rouse, 1977).

Since no break is apparent between the Middle Eocene *Pesavis* Zone below and the *Integricorpus* Zone above, a Late Eocene age for the latter seems most probable, with a possible early Oligocene age for the highest part. The ranges of several fungal species terminate in the *Integricorpus* Zone and the same species also characterize the Oligocene of northeast China (Sung et al., 1978).

Zone O-1 of Rouse (1977) is assigned an early Oligocene age on the basis of the presence of *Integricorpus* sp. A. If this is accepted, the Oligocene-Eocene boundary might be drawn at the lowest occurrence of this species in the C-22 well at 9500 feet (2896 m). The possibility that the lowest occurrences might be related to cavings, however, cannot be ruled out. Ranges of a large number of species terminate in the interval 9500 to 9000 feet (2895 to 2743 m), indicating the possibility of some missing section, or a lithologic change to a facies unfavorable for palynomorph preservation, or a climatic change (the last possibility is favoured, as discussed by Norris, 1982).

***Osmundacidites* Zone** (uppermost Richards Formation and lowest part of Kugmallit Formation)

Didymosporisporonites ovatus terminates in the *Osmundacidites* Zone (although it is common in subjacent zones). It is characteristic of the Lower Oligocene of northeast China (Sung et al., 1978). *Verrucatosporites favus* also characterizes the Oligocene of China, although it ranges into the Neogene in northwest Europe.

There does not appear to be any section missing between the *Osmundacidites* and *Integricorpus* zones; presumably the *Osmundacidites* Zone is also Early Oligocene.

***Retitriletes* Zone** (most the Ivik Member, Kugmallit Formation)

None of the species whose ranges terminate in this zone are known elsewhere at present, except for *Cupuliferoipollenites pusillus* the upper range of which is in the Middle Oligocene of northeast China (Sung et al., 1978) but which occurs up to the Neogene in northwest Europe (Thomson and Pflug, 1953).

No break is evident between the *Retitriletes* Zone and the underlying *Osmundacidites* Zone, the latter being of probable Early Oligocene age. A similar or slightly younger age (perhaps up to Middle Oligocene) seems likely for the *Retitriletes* Zone. The assemblages from the *Retitriletes* Zone are moderately diverse, as confirmed by palynofloras extracted from cores taken in this interval, and include a number of taxa reported by Piel (1971) from the Oligocene of British Columbia. The presence of *Corsinipollenites triangulatus* in core from the *Retitriletes* Zone is significant because Piel (1971) reported it as a characteristic element of the Oligocene of British Columbia. Rouse (1977) indicated that this species, in association with *Quercoidites* and *Faguspollenites*, characterizes the Early Oligocene of the Mackenzie Delta. However, other species of restricted range that characterize the Early Oligocene, such as *Diervilla echinata* Piel, *Boisduvalia clavatites* Piel, *Saxonipollis saxonicus* Krutzsch, and *Fisheripollis undulatus* Krutzsch (Rouse, 1977; Ioannides and McIntyre, 1980), are not known from the C-22 well.

***Ericipites* Zone** (uppermost Ivik Member and Arnak Member, Kugmallit Formation)

A large number of species with terminal ranges in this zone have been reported in the Paleogene of the western interior of North America, northeast China, and northwest Europe, with ranges no higher than Oligocene. Included in this number are *Quercoidites microhenrica*, *Ulmoideipites tricostatus*, *Triporisporonites verus*, *Multicellaesporites margaritus*, *Momipites tenuipolus*, *Margocolporites stenosus*, *Intratriporopollenites crassipites*, *Dicellaesporites popovii*, *Annutriporites tripollenites*, *Dyadosporites oblongatus*, and *Baculatisporites crassiprimarius*. Thus, an Oligocene age assignment is favoured for the *Ericipites* Zone.

Sparganiaceaepollenites neogenicus ranges from Early Oligocene to Middle Miocene. *Corsinipollenites triangulatus* is restricted to the Oligocene in China, as are *Lonicerapollis spiniformis* and *Diporisporites communis*. The presence of *Plochmopeltinites masonii* is particularly noteworthy: it has, up to the time of this writing, never been reported outside the southern hemisphere in the southwest Pacific, where it ranges in strata from Upper Oligocene to Miocene. This would suggest that the *Ericipites* Zone may be Late Oligocene in age. A few species, such as *Salixpollenites discoloripites*, and *Diporicellaesporites bellulus*, which occur in the *Ericipites* Zone elsewhere, seem to be restricted to the Eocene. Their occurrence in the *Ericipites* Zone may be the result of recycling.

***Tsugaepollenites* Zone** (most of Mackenzie Bay Formation)

Age determination of this zone is difficult due to impoverishment of the palynofloras and lack of species with well-established short ranges.

Several species that have ranges spanning the middle and upper Tertiary in North America or Europe include *Tsugaepollenites igniculus*, *Ulmipollenites undulosus*, *Tsugaepollenites viridifluminipites*, *Retitriletes annotinioides*, *Sequoiapollenites polyformosus*, and *Polyatriopollenites stellatus*). *Polyvestibulopollenites trinus* and *Monoporisporites singularis* have not been reported elsewhere above the Eocene. *Myricipites annulites* characterizes the Eocene and Oligocene of British Columbia, but also occurs in the Upper Miocene and Pliocene of the Queen Charlotte Islands. *Stereisporites microgranulus* does not occur above the Miocene in Germany (Krutzsch, 1963).

The subjacent *Ericipites* Zone is Oligocene, probably Late Oligocene, and appears to be truncated by an erosion surface evidenced by the abrupt change in palynofloras across the *Ericipites* Zone - *Tsugaepollenites* Zone boundary (essentially the contact between the Kugmallit and the Mackenzie Bay Formation). No information is available as to the extent of the hiatus represented by the erosion surface. Also, the abrupt change in palynofloras is almost certainly associated with a deterioration of the climate but, again, no information is available on the rate of climatic change. In this regard, it is perhaps significant that strong attenuation of palynofloral assemblages accelerates through the Arnak Member, and termination of ranges is emphasized by the erosional break.

Thus, the *Tsugaepollenites* Zone might be latest Oligocene, or more probably Miocene, an age assignment supported by the correlation of the Mackenzie Bay Formation with the Beaufort Formation by Young and McNeil (1984). The Beaufort Formation is believed to be Middle to Late Miocene by Hills and Fyles (1973), on the basis of plant megafossils and microfossils, but no details are available. Plauchut and Jutard (1976) reported that the Beaufort Formation from northwest Banks Island yielded *Tsugaepollenites* and numerous recycled Cretaceous palynomorphs. An age of younger than Miocene for the

Tsugaepollenites Zone is not considered likely, because of the presence of *Stereisporites microgranulus*, which is unknown in the Pliocene or Quaternary in Europe. The range of *Stereisporites microgranulus* in the Arctic has not been established precisely.

Martin and Rouse (1966) have emphasized the remarkably uniform generic composition of the flora around the north Pacific rim up to the Miocene and prior to its withdrawal southwards and eastwards across North America, probably in the Pliocene. The genera *Metasequoia*, *Pterocarya*, *Pinus*, *Picea*, *Tsuga*, *Salix*, *Alnus*, *Betula*, *Ostrya*, *Castanea*, *Myrica*, *Ulmus-Zelkova*, *Tilia*, and *Typha* are probably represented in the *Tsugaepollenites* Zone of the Mackenzie Bay Formation, and also occur up to the Miocene in China, Japan, and the Pacific coast of North America, according to Martin and Rouse (1966). Thus, the presence of these genera and the termination of many of their ranges in the *Tsugaepollenites* Zone, supports, in a general way, the Miocene age assignment for this Zone. However, it is probable that the climatic changes occurring in the Late Tertiary in the Richards Island Basin (which is on the east side of the Cordillera and borders the Arctic Ocean) differed from, and occurred at somewhat different times to those around the north Pacific rim.

Chenopodipollis Zone (lower part of Nuktak Formation)

This zone is impoverished in species of spores and pollen. Of the species with terminal ranges in this zone, *Stereisporites stereoides* occurs throughout the Tertiary in Europe, and *Echinatisporis* sp. A has previously been reported from the Miocene of Poland.

The base of the *Chenopodipollis* Zone is virtually coincident with the contact between the Nuktak and Mackenzie Bay formations, which may be marked by a short period of erosion, according to Young and McNeil (1984), but is not marked by a particularly strong microfloral break. Thus, there is probably little difference in age between the *Chenopodipollis* Zone and the subjacent, probably Miocene, *Tsugaepollenites* Zone.

Pollen of Chenopodiaceae, which characterizes this zone, has been reported in association with Gramineae pollen (also occurring in the *Chenopodipollis* Zone) from the uppermost part of Assemblage 3. This palynofloral assemblage, recorded by Doerenkamp et al. (1976) from the Upper Member of the Reindeer Formation of the Caribou Hills, is dated as probably Miocene to Pleistocene (?).

The *Chenopodipollis* Zone contains pollen of *Pinus*, *Picea*, *Betula*, and *Alnus* but none of the temperate taxa listed in the discussion of the previous zone, and which are common up to the Miocene (or perhaps early Pliocene) around the north Pacific rim.

Thus, although a late Miocene age is possible for the *Chenopodipollis* Zone, a Pliocene assignment would be consistent with the highly impoverished terrestrial flora represented in this Zone.

The probable marine dinoflagellate, *Pyxidiella* sp. A, occurs in the *Chenopodipollis* Zone but is endemic to the Beaufort-Mackenzie Basin and is useless for extra-basinal correlation. This dinoflagellate assemblage is distinctive and quite different from species in the *Rottnestia-Spinidinium-Operculodinium* assemblages characteristic of the Late Quaternary of the Beaufort-Mackenzie Basin (Harland et al., 1980).

Laevigatosporites Zone (upper part of the Nuktak Formation)

None of the species in this zone appear to have restricted ranges useful for age determinations nor have any been reported previously. The *Laevigatosporites* Zone is distinguished from the subjacent, probably Pliocene, *Chenopodipollis* Zone principally on the basis of a lack of *Chenopodipollis* spp.

The impoverished terrestrial assemblages contain taxa such as *Pinus*, *Picea*, *Alnus*, *Sphagnum*, *Betula*, and *Salix*, which might be expected in the Quaternary of this region, but in addition have *Sigmopollis psilatus*, *Laevigatosporites novus*, and *Rhizophagites cerasiformis*, which have not been reported in the Quaternary. Consequently, the *Laevigatosporites* Zone is probably Pliocene.

CORRELATION WITH OTHER TERTIARY SECTIONS IN NORTHERN CANADA

The Tertiary palynofloral zones recognized in the Imperial Nuktak C-22 well can be recognized in part in the Imperial Adgo F-28 well, about 30 miles (48 km) to the southwest. An informal palynologic zonation of this well is available in Geological Survey of Canada Open File Report No. 484 (1979). A correlation between the two wells appears in Figure 4, clearly showing the uplift and bevelling of the Richards Formation beneath the Neogene unconformity at 2800 feet (853 m) in the Adgo well, which is on the north flank of the Langley High (Fig. 1). The top of the Reindeer Formation, in the Adgo well, may be correlated with the bottom part of the Richards Formation, in the Nuktak well, on the basis of the *Pesavis* Zone. The *Integricorpus* Zone is developed in the lowest part of the Richards Formation in the Adgo well, whereas this zone spans the middle part of the Richards Formation in the Nuktak well. The Sapotaceae Zone, *Punctodiporites* Zone, *Striadiporites* Zone, and *Leptolepidites* cf. *tenuis* Zone span the lower part of the Reindeer Formation and the Moose Channel Formation in the Adgo well, but are unknown in the Nuktak well. These early Eocene and Paleocene zones occur elsewhere in the subsurface of the Mackenzie Delta (writer's unpublished data) and their existance is, to a large extent, based on the presence of fungal spores. Published research on fungal spores of the Richards Island Basin and adjacent regions is lacking. Consequently, it is not possible to make unequivocal correlations at this time on the basis solely of embryophyte spores and pollen.

Correlations between the C-22 well and sections in the Caribou Hills and the Banks Basin are shown in Figure 5. These correlations are based on age determinations of floras described for the Richards Island Basin in this paper, for the Caribou Hills by Ioannides and McIntyre (1980), and for the Banks Basin by Doerenkamp et al. (1976).

The *Pesavis* Zone appears to be present in the lower half of Interval C of the Reindeer Formation but *Pistillipollenites mcgregorii* ranges into the upper half. The

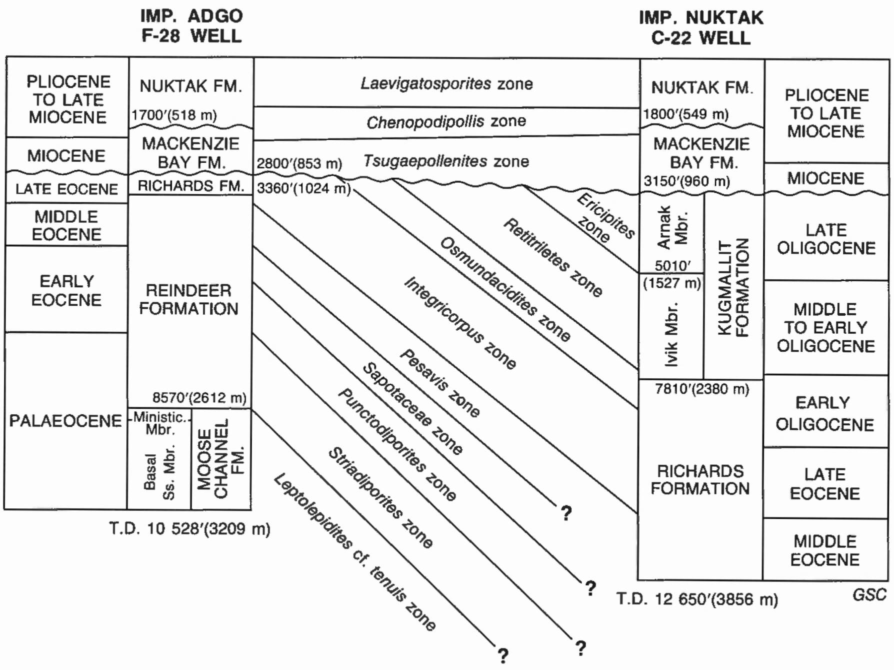

Figure 4. *Palynological correlation between Adgo F-28 and Nuktak C-22 wells.*

presence of *Punctodiporites* sp. and other fungal spores in the lower one third of Interval C indicates the presence of Early Eocene strata, an age assignment confirmed by a distinctive assemblage of marine dinoflagellates, including species of *Apectodinium*, *Wetzeliella*, *Cordosphaeridium*, and *Glaphyrocysta* (Ioannides and McIntyre, 1980). The underlying Interval B is judged to be Late Paleocene on the basis of the presence of ***Pistillipollenites mcgregorii***, ***Azolla stanleyi***, ***Nudopollis*** sp., and other distinctive elements recovered from the Paleocene Bonnet Plume Formation of northeast Yukon (Rouse and Srivistava, 1972) and Paleocene strata from mid-latitudes. Thus, Interval B of the Reindeer Formation of the Caribou Hills is Late Paleocene, and is correlated with the Moose Channel Formation of Imperial Adgo F-28 well; Interval C of the Caribou Hills is early and Middle Eocene and is correlated with the Reindeer Formation of the Imperial Adgo F-28 well. The top of Interval C is correlated with the lower part of the Richards Formation of the Nuktak C-22 well.

Interval D of the Reindeer Formation was judged to be Oligocene by Ioannides and McIntyre (1980) and compares closely with the Oligocene of British Columbia. Notable elements present include ***Boisduvalia clavatites*** and ***Diervilla echinata***, ***Saxonipollis saxonicus***, ***Fisheripollis undulatus***, and species of ***Juglanspollenites*** and ***Liquidambarpollenites***, none of which have been found in the C-22 well. Assuming there is no hiatus between Interval C and Interval D, the latter may be correlated with some part of the upper Richards Formation. It is shown in Figure 5 as Late Eocene, but, if the Oligocene age assigned to Interval D by Ioannides and McIntyre is correct, then a hiatus spanning the Late Eocene presumably occurs in the Caribou Hills.

Overlying Interval D in the Caribou Hills section is a conglomeratic unit that was originally assigned as an upper member of the Reindeer Formation (Mountjoy, 1967). It has been now tentatively reassigned to the Beaufort Formation by Young et al. (1976), who suggested it was probably Neogene. Doerenkamp et al. (1976) described an assemblage of arborescent and herbaceous angiosperm pollens from this unit (*Quercus*, *Corylus*, with chenopods, Compositae, grass pollen, and Geraniaceae appearing in the uppermost horizons), and questionably assigned it to the Miocene-Pleistocene interval. On this basis, a correlation with the Beaufort-Mackenzie Bay formations and the Nuktak Formation in the subsurface of the Richards Island Basin is suggested, but confirmation must await more detailed study of this interval.

Palynofloras from the Eureka Sound Formation of northern Banks Island have been described by Doerenkamp et al. (1976). Palynologic Zone T II from the upper member of the Eureka Sound Formation is characterized by ***Pistillipollenites mcgregorii***, ***Nudopollis*** sp., ***Extratriporopollenites*** sp., and other embryophytes as well as the dinoflagellates ***Apectodinium***, ***Wetzeliella***, ***Hystrichokolpoma***, and ***Achomosphaera***. This zone appears to be Late Paleocene in age and, therefore, is correlated with Interval B of the lower Reindeer Formation of the Caribou Hills and with the Moose Channel Formation of the Richards Island Basin.

These correlations are necessarily tentative until such time as more detailed analytical results are available from the sections in question, including precise information on the fungal palynomorph components of the microfloras.

SYSTEMATIC DESCRIPTIONS

All species are systematically listed, most are illustrated, and some are described if new (or if new features require documentation).

Generic citations of miospores and relevant references are to be found in the "Genera File of Fossil Spores and Pollen" by Jansonius and Hills (1976, 1979). Citations of literature for genera are, therefore, not given unless the genus is not cited by Jansonius and Hills (*op. cit.*) or if new information is given. Generic citations and literature references for dinoflagellate cysts are to be found in Lentin and Williams (1977), Stover and Evitt (1978) and Artzner et al. (1979).

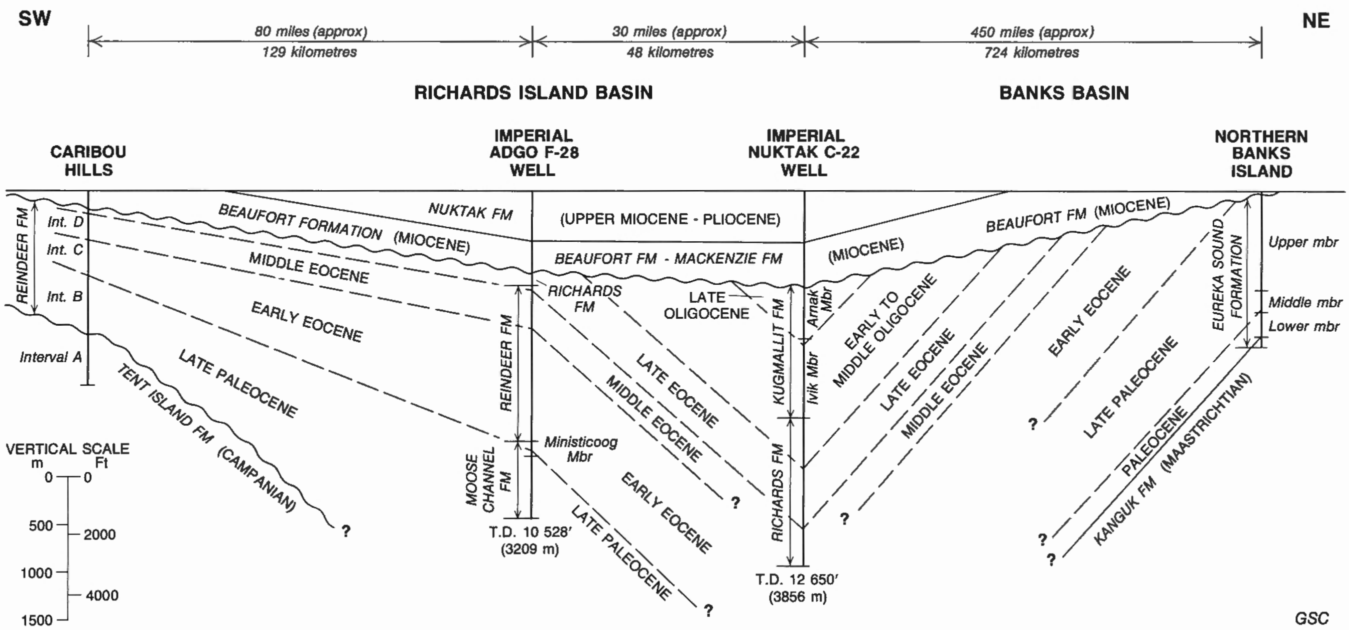

Figure 5. *Palynological correlation between Mackenzie Delta surface and subsurface sections.*

The systematic section is divided into three parts:

(i) Fungal palynomorphs
(ii) Embryophyte spores and pollen
(iii) Dinoflagellate cysts

Distribution of each species is summarized from the paleo-log (see Fig. 7). The "range" indicated is taken from the probable age of each formation discussed earlier, together with information available from other studies. Only leading references are given for these previous studies.

Spore-pollen taxonomy

(a) Fungal palynomorphs

Fungal Spores

Remarks on morphology and terminology

No comprehensive body of terms is currently available for description of fungal spores. Consequently, the following terms have been adopted for descriptions, and are illustrated in Figure 6. Dr. W. Elsik (pers. comm.) currently is preparing a comprehensive treatment of fungal spore morphology.

Fungal spores may be regarded as comprising one or more cells (monocellate, dicellate etc.); each cell is surrounded by a spore wall and delimited from other cells by septa. Apertures may be present, usually in the form of pores (Fig. 6B, D, E, F, H), and less frequently as furrows (Fig. 6G). The number of apertures distinguishes inaperturate (Fig. 6A), monoporate (Fig. 6B), diporate (Fig. 6D, H), and other groups. In addition to these structural apertures, the fungal spore may exhibit germinals of irregular shape and position that are difficult to distinguish from extraneous damage or corrosion.

Fungal spores may be circular (Fig. 6A) or elongated in shape (Fig. 6B-K). Elongated spores may exhibit equally developed ends or apices (except for apertures) and are referred to as isopolar (Fig. 6C, D, G, H) or may have different shaped ends and be referred to as heteropolar (Fig. 6B, E, F, J, K).

The imaginary straight line connecting the ends or apices of a fungal spore is referred to as the apical line. The imaginary line connecting the ends or apices and passing through the centre of the septa is the median line. Both these lines are straight and coincident in equilateral spores (Fig. 6L). Inequilateral spores have an arcuate median line (Fig. 6M). Curved spores have an arcuate median line and a straight apical line, the latter running outside the spore (Fig. 6N).

Many fungal spores are uniserial (Fig. 6E, F, G, H, I) but some are biserial (Fig. 6J) or multi-branched (Fig. 6K).

Cells are delimited by septa in spores comprising more than one cell. Septa may be penetrated by centrally located septal pores. Dentate septa are the result of facultative response to compression. Their precise morphology and development have no apparent taxonomic utility and are best understood by reference to the so-called "Dixie-cup" effect as follows: make a hole in the base of a styrofoam or paper beverage cup with a pencil, and compress strongly in a lateral direction to develop projecting folded or torn edges surrounding the hole, which simulate a dentate septum. Shadow bands are diffuse, annular thickenings of the spore wall and may or may not be remnants of a septum.

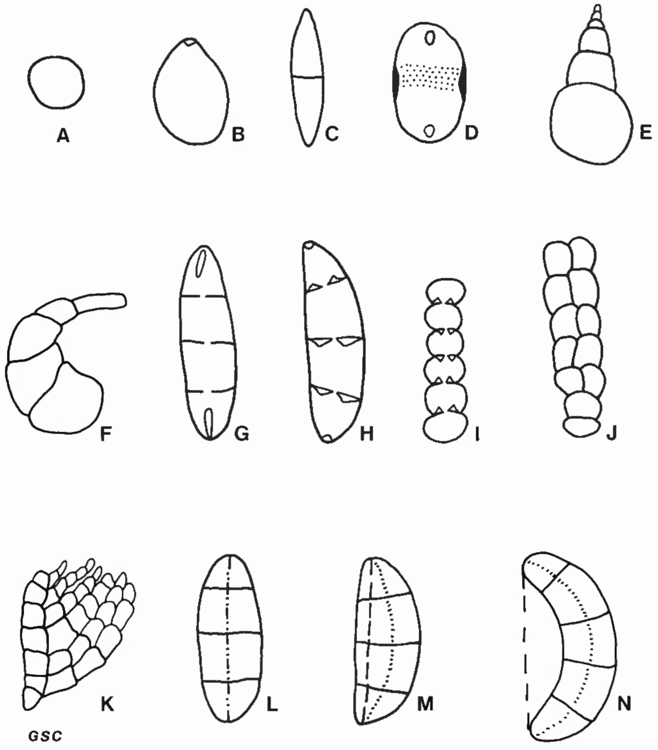

Figure 6. *Schematic illustrations of fungal spores.*

Classification

It is not yet clear which features are taxonomically significant at the supra-generic level. Rueda-Gaxiola (1969) proposed a scheme utilizing groups based on the number of cells as the primary, and the number of apertures as the secondary criteria.

A formal scheme will not be used in this paper. Rather, fungal spores will be grouped into broad categories of monocellate, dicellate, tricellate, and multicellate species. The relative importance for classification of cell number, shape and size, aperture type and number, ornament of spore wall, colour or composition for classification is not known at present.

Monocellate fungal spores

Genus *Inapertisporites* Van der Hammen emend. Sheffy and Dilcher 1971

Type species. *Inapertisporites pseudoreticulatis* Rouse, 1959

"*Inapertisporites*" sp. cf. *I. vittatus* Sheffy and Dilcher

Plate 1, figures 1, 2

1971 (cf.) *Inapertisporites vittatus* Sheffy and Dilcher, p. 39; Pl. 13, fig. 13; Pl. 15 fig. 13.

Description. Fungal spores monocellate, oval outline, with a fissure on one side, partially encroaching onto the other side. Spore wall 0.5 µm thick, levigate. Length 18-26 µm; width 10-12 µm.

Distribution. Sporadic in the lower part of the Richards Formation.

Range. Eocene.

Remarks. No genus is available currently to accommodate unicellate, fissured, fungal spores. Insufficient material was available in the present study to allow precise circumscription of a new taxon. Sheffy and Dilcher's compared species has a differentially thickened wall.

Inapertisporites circularis Sheffy and Dilcher

Plate 1, figures 3, 4

1971 *Inapertisporites circularis* Sheffy and Dilcher, p. 38; Pl. 13, fig. 2; Pl. 15, fig. 2.

Distribution. Sporadic in the Kugmallit and upper part of the Richards Formation; common in the lower part of the Richards Formation. Occurs in the Eocene of Tennessee (Sheffy and Dilcher, 1971).

Range. Eocene to Oligocene.

Inapertisporites sp. cf. *I. subovoideus* Sheffy and Dilcher

Plate 1, figure 5

1971 (cf.) *Inapertisporites subovoideus* Sheffy and Dilcher, p. 38; Pl. 13, fig. 7; Pl. 15, fig. 7.

Description. Fungal spores, monocellate, inaperturate, heteropolar, slightly elongated (12 µm long, 9-10 µm wide) with one apex flattened and the other rounded. Spore wall levigate, 0.25-0.5 µm thick.

Distribution. Rare in the lower part of the Richards Formation.

Range. Eocene.

Remarks. Distinguished from *I. subovoideus* Sheffy and Dilcher by the smaller size and less elongated cell.

"*Inapertisporites*" sp. A

Plate 1, figures 9, 10

Description. Fungal spore monocellate, inaperturate, oval in outline, isopolar, equilateral, with striae concentric about each apex, and a narrow equatorial zone of low rugulae. Striae approximately 0.25 µm wide, projecting externally with rounded tops, occasionally bifurcate, spaced about 0.25 µm apart. Equatorial rugulae up to 2 µm long, sinuous. Spore wall approximately 0.5 µm thick including sculpture. Spore length 38 µm; spore width 22 µm. Apparently lacking apertures but split at the equator.

Distribution. Rare in the middle part of the Richards Formation.

Range. Eocene.

Remarks. Only one specimen encountered. No genus is available currently to accommodate distinctive spores of this type. Formal taxonomic treatment awaits collection of more material. *Fusiformisporites* Rouse is dicellate with meridionally arranged striae.

Genus *Monoporisporites* van der Hammen 1954 emend. Scheffy and Dilcher, 1971

Type species. *Monoporisporites minutus* van der Hammen, 1954

Monoporisporites abruptus Scheffy and Dilcher

Plate 1, figures 11-13

1971 *Monoporisporites abruptus* Sheffy and Dilcher, p. 41; Pl. 13, fig. 24; Pl. 15, fig. 24.

Distribution. Sporadic in the lower part of the Richards Formation. Middle Eocene, Tennessee (Sheffy and Dilcher, 1971).

Range. Middle Eocene.

Monoporisporites singularis Sheffy and Dilcher

Plate 1, figures 6-8

1971 *Monoporisporites singularis* Sheffy and Dilcher, p. 40; Pl. 13, fig. 22; Pl. 15, fig. 22.

Distribution. Sporadic in the Mackenzie Bay Formation and upper part of the Kugmallit Formation. Eocene, Tennessee (Sheffy and Dilcher, 1971).

Range. Eocene to Oligocene.

Monoporisporites sp. A

Plate 1, figures 21, 22

Description. Monoporate, unicellate, isopolar fungal spores. Spore wall levigate, up to 1 µm thick. Cell prolate with broadly rounded apices. Cell length 22-33 µm; cell width 15-24 µm. Pore centrally positioned, up to 2 µm in diameter.

Distribution. Sporadic in the Kugmallit and Richards formations.

Range. Eocene to Oligocene.

Remarks. Distinguished from other species of *Monoporisporites* by greater dimensions of cell and pore.

Monoporisporites sp. cf. *M. cupuliformis* Sheffy and Dilcher

Plate 1, figures 16, 17

1971 (cf.) *Monoporisporites cupuliformis* Sheffy and Dilcher, p. 40; Pl. 13, fig. 23; Pl. 15, fig. 23.

Description. Fungal spores monocellate, monoporate, heteropolar, elongate with one end flattened and the opposite apex bearing a 1 µm diameter pore. Spore wall levigate, 0.25 µm thick, except at the flattened end which is approximately twice as thick. Cell length 15-16 µm; width 9-10 µm.

Distribution. Rare in the Kugmallit Formation.

Range; Oligocene.

Genus *Lacrimasporonites* Clarke, 1965

Type species. *Lacrimasporonites levis* Clarke, 1965

Lacrimasporonites sp. A

Plate 1, figure 14

Description. Monoporate, unicellate, heteropolar fungal spores. Distal half of cell broadly rounded (almost hemispherical). Proximal end of cell tapers toward the pore (1-2 µm in diameter), which is centrally positioned, and bluntly terminates the proximal end. Spore wall 1.5 µm thick, levigate, usually very dark brown. Cell length 24 µm; cell width 17 µm.

Distribution. Rare in the Richards Formation.

Range. Eocene.

Remarks. Distinguished from *L. levis* Clarke by the broader, bluntly-terminated proximal end.

Genus *Triporisporonites* Sheffy and Dilcher, 1971

Type species. *Triporisporonites ovalis* Sheffy and Dilcher, 1971

Triporisporonites verus (Ke et Shi ex Sung et al.) comb. nov.

Plate 1, figure 15

1978 *Multicellaesporites verus* Ke et Shi ex Sung et al., p. 40; Pl. 2, fig. 1.

Distribution. Rare in the Kugmallit Formation and sporadic in the Richards Formation. Paleogene of northeast China (Sung et al., 1978).

Range. Eocene to Oligocene.

Genus *Rhizophagites* Rosendahl, 1943

Type species. *Rhizophagites butleri* Rosendahl, 1943

Rhizophagites cerasiformis sp. nov.

Plate 1, figures 23-27

Holotype. GSC 67877; Slide P-2154-2d, 27.2 x 109.2; Nuktak Formation, Imperial Nuktak C-22 well; GSC loc. C-48831/600-700; depth 600-700 feet (182.8-213.4 m). The holotype is attached to another cell illustrated in Pl. 1, fig. 27.

Diagnosis. Fungal spore unicellate, heteropolar with a levigate cell wall and an irregular ellipsoidal outline, attached to an aseptate filament by a short neck, which may be slightly thickened.

Description. Neck 3-6 µm wide, narrowing to and confluent with an aseptate, more or less parallel-sided filament 2-5 µm wide. Cell wall 0.5-2 µm thick, except at the neck which may be thickened up to 3 µm. Filament wall usually slightly thinner than cell wall. Cell wall may be penetrated by irregular pores 1-3 µm wide. Filament up to 100 µm long but usually broken; it may be joined to another filament in a dichotomous fashion.

Dimensions. Cell diameter 30-60 µm (holotype 36 µm).

Distribution. Sporadic in the Nuktak Formation. A few specimens occur in the Kugmallit and Richards formations but may be the result of caving.

Range. Pliocene to possibly Paleogene.

Remarks. Distinguished from the type species by the smaller cell diameter and narrower filaments and from *R. acinus* Srivastava by the thinner, single-layered cell wall and smaller cell diameter.

Genus *Diporisporites* van der Hammen emend. Elsik, 1968

Type species. *Diporisporites elongatus* van der Hammen, 1954

Diporisporites communis Ke et Shi ex Sung et al.

Plate 1, figures 18, 19

1978 *Diporisporites communis* Ke et Shi ex Sung et al., p. 46; Pl. 4, figs. 22, 23.

Distribution. Sporadic in the Richards and Kugmallit formations. Oligocene, northeast China (Sung et al., 1978).

Range. Eocene to Oligocene.

Diporisporites sp. A

Plate 1, figure 20

Description. Diporate, monocellate, isopolar fungal spores with an equatorially placed furrow encircling the inner surface of the spore wall. Pores 1 µm in diameter, subapical displaced 1-2 µm from the apices. Spore outline ovoidal with sharply rounded apices. Spore length 34 µm, width 17 µm.

Distribution. Rare in the upper part of the Richards Formation.

Range. Eocene.

Remarks. The lack of a septum distinguishes this from species of *Dyadosporites*.

Genus *Striadiporites* Varma and Rawat 1963
emend. Elsik and Jansonius, 1974.

Type species. *Striadiporites reticulatus* Varma and Row, 1963

syn. *Stridiporosporites* Ke et Shi ex Sung et al., 1978

Striadiporites bistriatus (Ke et Shi ex Sung et al.) comb. nov.

Plate 1, figures 32-34

1978 *Stridiporosporites bistriatus* Ke et Shi ex Sung et al., p. 47; Pl. 4, figs. 32, 33.

Distribution. Sporadic in the lower part of the Richards Formation. Paleogene of northeast China (Sung et al., 1978).

Range. Paleogene.

Striadiporites multistriatus (Ke et Shi ex Sung et al.) comb. nov.

Plate 1, figures 36, 37

1978 *Stridiporosporites multistriatus* Ke et Shi ex Sung et al., p. 48; Pl. 4, figs. 38, 39.

Distribution. Sporadic in the lower part of the Richards Formation. Upper Oligocene of northeast China (Sung et al, 1978).

Range. Eocene to Oligocene.

Striadiporites sanctaebarbarae Elsik and Jansonius

Plate 1, figures 28, 29

1974 *Striadiporites sanctaebarbarae* Elsik and Jansonius, p. 955; figs. 18-20.

1978 *Stridiporosporites retistriatus* Ke et Shi ex Sung et al., p. 48; Pl. 4, figs. 34-37.

Distribution. Sporadic to common in the lower part of the Richards Formation. Upper Eocene and Oligocene of California (Elsik and Jansonius, 1974); Oligocene of northeast China (Sung et al., 1978).

Range. Eocene to Oligocene.

Striadiporites inflexus (Ke et Shi ex Sung et al.) comb. nov.

Plate 1, figs. 30, 31, 35

1978 *Stridiporosporites inflexus* Ke et Shi ex Sung et al., p. 48; Pl. 4, figs. 30, 31.

Distribution. Common in the middle part of the Richards Formation. Oligocene of northeast China (Sung et al., 1978).

Range. Oligocene.

Dicellate fungal spores

Genus *Dicellaesporites* Elsik, 1968 emend.

Type species. *Dicellaesporites popovii* Elsik, 1968

Emended diagnosis. Dicellate, inaperturate, isopolar, equilateral fungal spores. Spore wall levigate to scabrate.

Remarks. Both Elsik (1968, p. 269) and Sheffy and Dilcher (1971, p. 41) mentioned the shape of *Dicellaesporites* as "variable". This imprecision is unacceptable in view of current knowledge of fungal spore morphology. The emended diagnosis restricts this genus to those dicellate aporate spores with isopolar, equilateral cells.

Dicellaesporites popovii Elsik

Plate 2, figures 1, 2

1968 *Dicellaesporites popovii* Elsik, p. 269; Pl. 2, fig. 9.

Distribution. Sporadic to rare in the Kugmallit and Richards formations. Paleocene of Texas (Elsik, 1968). Eocene-Oligocene of northeast China (Sung et al., 1978).

Range. Paleocene to Oligocene.

Dicellaesporites obnixus sp. nov.

Plate 2, figure 3-7

Holotype. GSC 67894; Slide P-2154-67b, 20.8 x 111.0; Richards Formation, Imperial Nuktak C-22 well; GSC loc. C-48831/12 000-12 100, depth 12 000-12 100 feet (3657 to 3688 m).

Diagnosis and Description. Dicellate, inaperturate, isopolar, equilateral fungal spores with sharply rounded apices on each cell. Septum 0.5 µm thick, apparently aporate. Spore wall 0.5 µm thick or less, levigate and slightly thickened at the apex of each cell. The cells may rupture irregularly but there appears to be no predetermined aperture or aperture shape. Spore length 33-57 µm (holotype 45 µm); spore width 10-16 µm (holotype 15 µm).

Distribution. Sporadic in the lowest part of the Richards Formation.

Range. Eocene.

Remarks. Distinguished from *Dicellaesporites volubilis* Ke et Shi ex Sung et al. by the more pointed apices and the slight apical thickenings of the spore wall.

Dicellaesporites aculeolatus Sheffy and Dilcher

Plate 2, figure 8

1971 *Dicellaesporites aculeolatus* Sheffy and Dilcher, p. 41; Pl. 13, fig. 26; Pl. 15, fig. 26.

Distribution. Rare in the lower part of the Richards Formation. Eocene of Tennessee (Sheffy and Dilcher, 1971). Eocene-Oligocene of northeast China (Sung et al., 1978).

Range. Eocene to Oligocene.

Genus *Fusiformisporites* Rouse emend. Elsik, 1968

Type species. *Fusiformisporites crabbii* Rouse, 1962

Fusiformisporites sp. A

Plate 2, figure 11

Description. Dicellate, inaperturate, equilateral, isopolar fungal spores with striate spore wall approximately 0.25 µm thick, except at apices where it reaches 1 µm in thickness. Ornament striate on approximately two thirds of each cell adjacent to the septum. Striae up to 0.5 µm thick and spaced a similar distance apart, but irregular in width, and on some specimens bifurcating. Approximately one third of each cell surrounding each apex ornamented with an irregular, imperfect reticulum (muri 0.25 µm wide; lumina up to 0.5 µm in diameter), separated from the striate ornament by a shadow band 2-3 µm wide. Spore length 40 µm; spore width 18 µm.

Distribution. Rare in the lower part of the Richards Formation.

Range. Eocene.

Remarks. Other published species of *Fusiformisporites* do not show the narrow ornamental elements and differentiation at the apices present in *Fusiformisporites* sp. A.

Fusiformisporites microstriatus Hopkins

Plate 2, figure 10

1969 *Fusiformisporites microstriatus* Hopkins, p. 1126; Pl. 11, fig. 170.

Distribution. Rare in the lower part of the Richards Formation. Middle-Upper Eocene, southwest British Columbia (Hopkins, 1969).

Range. Eocene.

Remarks. Slightly smaller (32 µm long) than Hopkins' specimens but otherwise identical, including the apical thickenings of the spore wall up to approximately 1 µm thick, illustrated but not described by Hopkins.

Genus *Dyadosporites* Van der Hammen ex Clarke, 1965

Type species. *Dyadosporites ellipsus* Clarke, 1965

syn. *Dyadosporonites* Elsik, 1968.

Dyadosporites sp. cf. *D. schwabii* (Elsik) comb. nov.

Plate 2, figure 9

1968 (cf.) *Dyadosporonites schwabii* Elsik, p. 279; Pl. 2, fig. 30.

Description. Essentially the same as *D. schwabii* except for its smaller size (length 12 µm, width 5 µm) and more centrally located pores.

Remarks. Its much smaller size distinguishes it from *Dyadosporites oblongatus* (Ke et Shi ex Sung et al.) comb. nov. and *Dyadosporites solidus* (Ke et Shi ex Sung et al.) comb. nov. (basionym: *Dyadosporonites solidus* Ke et Shi ex Sung et al., 1978, p. 49, Pl. 5, fig. 10).

Distribution. Rare in the Richards and Kugmallit formations.

Range. Eocene to Oligocene.

Dyadosporites oblongatus (Ke et Shi ex Sung et al.) comb. nov.

Plate 2, figures 12-16

1978 *Dyadosporonites oblongatus* Ke et Shi ex Sung et al., p. 48; Pl. 5, fig. 6.

Distribution. Sporadic in the lower part of the Richards Formation and the upper part of the Kugmallit Formation. Lower Tertiary, northeast China (Sung et al., 1978).

Range. Eocene to Oligocene.

Dyadosporites sp. A

Plate 2, figures 17-19

Description. Fungal spores, dicellate, diporate, isopolar, slightly inequilateral, constricted up to 3 µm at the locus of septal insertion. Apices sharply rounded. Pores located sub-apically 4-8 µm, almost on apical line. Each cell is widest approximately one third its length from the septum. Septum apparently aporate. Spore wall levigate, 0.25 µm thick. Spore length 19-27 µm; width 12-13 µm.

Distribution. Rare in the middle part of the Richards Formation.

Range. Eocene to (?)Oligocene.

Genus *Imprimospora* gen nov.

Type species. *Imprimospora tankensis* sp. nov.

Generic diagnosis. Unicellate, ovoidal, equilateral, isopolar fungal spores with a central region of parallel striae or fissures parallel to the apical line. Pore or furrow present near one end of spore.

Imprimospora tankensis sp. nov.

Plate 2, figures 20-24

Holotype. GSC 67909; Slide P-2154-44b, 26.9 x 107.2; Richards Formation, Imperial Nuktak C-22 well; GSC loc. C-48831/9000-9100; depth 9000-9100 feet (2743.2-2773.7 m).

Diagnosis: A species of *Imprimospora* with an equatorial zone of parallel fissures enclosed between two shadow bands. One or two sub-apical furrows present.

Description. Unicellate, ovoidal fungal spores. Central part of cell with 7 or 8 parallel fissures up to 0.5 µm wide, extending longitudinally between two transverse, 1-2 µm wide shadow bands. Spore wall levigate, approximately 0.25-0.5 µm thick, except where thickened up to 1 µm under shadow bands. Sub-apically one or both ends of spore are ruptured irregularly or along arcuate furrows. Spore length 24-36 µm; spore width 11-17 µm.

Distribution. Sporadic in the middle part of the Richards Formation.

Range. Eocene.

Remarks. Some specimens do not show shadow bands (see Pl. 2, fig. 22) and may be an ontogenetic stage or a separate species.

Genus *Didymosporisporonites* Sheffy and Dilcher, 1971

Type species. *Didymosporisporonites psilatus* Sheffy and Dilcher, 1971

Didymosporisporonites ovatus Ke et Shi ex Sung et al.

Plate 2, figures 25-28

1978 *Didymosporisporonites ovatus* Ke et Shi ex Sung et al., p. 43; Pl. 4, figs. 2, 3.

Distribution. Sporadic in the Richards Formation. Lower Oligocene, northeast China (Sung et al., 1978).

Range. Eocene to Lower Oligocene.

Tricellate fungal spores

Genus *Diporicellaesporites* Elsik, 1968

Type species. *Diporicellaesporites stacyi* Elsik, 1968

Diporicellaesporites bellulus Ke et Shi ex Sung et al.

Plate 2, figures 32-34

1978 *Diporicellaesporites bellulus* Ke et Shi ex Sung et al., p. 49; Pl. 5, figs. 4, 5.

Distribution. Sporadic in the lower part of the Richards Formation and rare in the upper part of the Kugmallit Formation (possibly recycled). Eocene, northeast China (Sung et al., 1978).

Range. Eocene.

Diporicellaesporites sp. cf. *D. bellulus* Ke et Shi ex Sung et al.

Plate 2, figures 29-31

1978 (cf.) *Diporicellaesporites bellulus* Ke et Shi ex Sung et al., p. 49; Pl. 5, figs. 4, 5.

Description. Diporate, tricellate, isopolar, equilateral fungal spores with 3 cells including the terminal pore chambers. Equilateral, forming an isopolar barrel-shaped spore with levigate wall 1 µm thick. Pores 3-4 µm in diameter with ragged margins. Wall of pore chambers becomes thinner toward the pore margin. Septa less than 0.5 µm thick, variably developed, without apparent septal pore. Poorly defined shadow band 0.5 µm wide may encircle the central cell. Spore length 26-34 µm; spore width 16-18 µm.

Distribution. Sporadic in the lower part of the Richards Formation.

Range. Eocene.

Remarks. *D. bellulus* Ke et Shi ex Sung et al. is larger with narrower ends, better defined pore chambers, and porate septa.

Diporicellaesporites laevigataeformis Ke et Shi ex Sung et al.

Plate 2, figures 35, 42

1978 *Diporicellaesporites laevigataeformis* Ke et Shi ex Sung et al., p. 49; Pl. 5, fig. 11.

Distribution. Sporadic in the lower part of the Richards Formation. Lower Tertiary, northeast China (Sung et al., 1978).

Range. Eocene to (?)Oligocene.

Multicellate fungal spores

Genus *Reduviasporonites* Wilson, 1962

Type species. *Reduviasporonites catenulatus* Wilson, 1962

Reduviasporonites sp. cf. *R. catenulatus* Wilson

Plate 2, figures 40, 41, 43

1962 (cf.) *Reduviasporonites catenulatus* Wilson, p. 91; Pl. 1.

Remarks. Similar to *R. catenulatus* Wilson apart from the presence of septal pores between the cells and accompanying dentate septa. Individual cells may be circular or slightly ovoid with the major axis transverse or longitudinal.

Distribution. Common in the upper part of the Kugmallit Formation and rare in the Richards Formation.

Range. Eocene to Oligocene.

Reduviasporonites anangus sp. nov.

Plate 2, figures 36-39

Holotype. GSC 67925; Slide P-2154-18b, 44.5 x 102.1; Arnak Member, Kugmallit Formation, Imperial Nuktak C-22 well; GSC loc. C-48831/3600-3700; depth 3600-3700 feet (1097.3-1127.8 m). Maximum cell diameter 13-20 µm (holotype 13 µm).

Diagnosis. Multicellular heteropolar, equilateral fungal spore comprising almost circular or ovoidal cells in a straight uniseriate chain, which increase to a maximum size 4 to 6 cells distally from the basal cell. Septa porate. Loci of septal insertion constricted. Cell wall thin, levigate.

Description. Cells generally 5 to 8 in number and commonly folded. Basal cell 2-3 µm in diameter (approximately 0.25 maximum diameter of distal cells). Septal pores about 0.25 µm in diameter, with a narrow annulus. Septa not usually dentate. Constriction at point of septal insertion about 2-3 µm deep. Cell wall 0.25 µm or less thick.

Dimensions. Maximum cell diameter 13-20 µm (holotype 13 µm).

Distribution. Sporadic in the Arnak Member, Kugmallit Formation.

Range. Oligocene.

Reduviasporonites sp. A

Plate 2, figure 44

Description. Multicellular, heteropolar, curved fungal spore comprising irregularly ovoidal cells in a uniseriate chain on a curved axis and increasing to a maximum size 4 cells away from the basal cell. Cell wall very thin, particularly the basal cell wall, and commonly folded. Septa equally thin, equipped with a septal pore, not usually dentate. Loci of septal insertion slightly constricted (1-2 µm deep).

Dimensions. Basal cell 2-3 µm in diameter. Maximum cell diameter 15 µm.

Distribution. Sporadic in the Kugmallit and Richards formations.

Range. Eocene to Oligocene.

Remarks. Distinguished from other species of *Reduviasporonites* by the curved median line.

Genus *Brachysporisporites* Lange and Smith 1971

Type species. *Brachysporisporites pyriformis* Lange and Smith, 1971

Brachysporisporites cotalis (Elsik and Jansonius) comb. nov.

Plate 2, figures 45-47

1974 *Granatisporites cotalis* Elsik and Jansonius, p. 954, Fig. 13.

Distribution. Lower part of the Richards Formation. Paleogene, Mackenzie Delta (Elsik and Jansonius, 1974).

Range. Eocene.

Brachysporisporites sp. cf. *B. cotalis* (Elsik and Jansonius) comb. nov.

Plate 2, figures 48, 49

1971 Non-linear phragmospore 143, Lange and Smith, p. 677; Pl. 3, fig. 143.

Description. Similar to *B. cotalis* but relatively narrower (width one third to less than half total length) and tapering less strongly.

Remarks. The basionym for the compared species is cited above under the preceding species.

Dimensions. Length 22-28 µm.

Distribution. Sporadic to common in the Richards Formation. Middle Eocene, South Australia (Lange and Smith, 1971).

Range. Eocene.

Brachysporisporites opimus (Elsik and Jansonius) comb. nov.

Plate 2, figures 50, 51

1974 *Granatisporites opimus* Elsik and Jansonius, p. 954, Fig. 14.

Distribution. Common in the lower part of Richards Formation. Paleogene, Mackenzie Delta (Elsik and Jansonius, 1974).

Range. Eocene.

Genus *Multicellaesporites* Elsik 1968 emend. Sheffy and Dilcher, 1971

Type species. *Multicellaesporites nortonii* Elsik, 1968

Multicellaesporites leptaleus Ke et Shi ex Sung et al.

Plate 3, figures 1-3

1978 *Multicellaesporites leptaleus* Ke et Shi ex Sung et al., p. 37; Pl. 2, fig. 4.

Distribution. Sporadic in the lower half of the Richards Formation, becoming more common near the bottom. Eocene-Oligocene, northeast China (Sung et al., 1978).

Range. Eocene to Oligocene.

Multicellaesporites compactilis Ke et Shi ex Sung et al.

Plate 3, figures 4-6

1978 *Multicellaesporites compactilis* Ke et Shi ex Sung et al., p. 35; Pl. 2, fig. 15

Distribution. Lower part of the Richards Formation. Paleogene of northeast China (Sung et al., 1978).

Range. Eocene to Oligocene.

Multicellaesporites margaritus Ke et Shi ex Sung et al.

Plate 3, figures 7, 8

1978 *Multicellaesporites margaritus* Ke et Shi ex Sung et al., p. 37; Pl. 2, figs. 2, 3.

Distribution. Rare in the Kugmallit and Richards Formation. Paleogene, northeast China (Sung et al., 1978).

Range. Eocene to Oligocene.

Multicellaesporites sp. cf. *M. conspicuus* Ke et Shi ex Sung et al.

Plate 3, figure 12

1978 (cf.) *Multicellaesporites conspicuus* Ke et Shi ex Sung et al., p. 35; Pl. 3, fig. 1.

Description. Similar to *Multicellaesporites conspicuus* Ke et Shi ex Sung et al. but smaller (30 µm long).

Distribution. Rare in the lower part of the Richards Formation.

Range. Eocene.

Multicellaesporites sp. cf. *M. conicus* Ke et Shi ex Sung. et al.

Plate 3, figure 11

1978 (cf.) *Multicellaesporites conicus* Ke et Shi ex Sung et al., p. 35; Pl. 3, figs. 6, 7.

Description. Similar to *Multicellaesporites conicus* but with two large basal cells and several narrower cells which taper to the apex. Septa porate, approximately 0.25 µm thick. Spore length 48 µm; width 15 µm.

Distribution. Rare in the lower part of the Richards Formation.

Range. Eocene.

Multicellaesporites lanceolatus Ke et Shi ex Sung et al.

Plate 3, figure 10

1978 *Multicellaesporites lanceolatus* Ke et Shi ex Sung et al., p. 37; Pl. 2, figs. 17, 18.

Distribution. Sporadic in the lower part of the Richards Formation. Upper Eocene, northeast China (Sung et al., 1978).

Range. Eocene.

"*Multicellaesporites*" sp. A

Plate 3, figure 13

Description. Fungal spore, multicellular, isopolar, bipyriform, diporate, equilateral. Cells bulge between loci of septal insertion, 7 or 8 in number; centre cells thicker walled (approximately 1 µm) than more distal ones. Cell wall levigate, 0.25-1 µm thick. Septa of same thickness as cell wall, porate, dentate. Pores terminal, central, 3 µm in diameter.

Remarks. This species does not belong strictly to *Multicellaesporites* because its apertures are pores and not furrows. No genus is currently available to accept this spore type.

Distribution. Rare in the Arnak Member, Kugmallit Formation.

Range. Oligocene.

Genus *Fractisporonites* Clarke, 1965

Type species. *Fractisporonites canalis* Clarke, 1965

Fractisporonites sp. cf. *F. canalis* Clarke

Plate 3, figure 9

1965 (cf.) *Fractisporonites canalis* Clarke, p. 92; Pl. 1, fig. 6.

Description. Fungal spores, uniseriate, equilateral, comprising many parallel-sided cells separated by dentate septa. Cells 7-15 µm wide, generally wider than long, occasionally square. Cell wall, levigate, approximately 1 µm thick. Septa also about 1 µm thick, with prominent central or sub-central pore. No constriction present at the locus of septal insertion. Spore fragments up to 100 µm approximately in length, commonly tapering slightly.

Distribution. Sporadic in the Nuktak and Mackenzie Bay formations, and upper part of the Kugmallit Formation. Common in the Richards Formation.

Range. Eocene to Pliocene.

Remarks. This species is distinguished from *F. canalis* Clarke by the smaller cells, thinner septa, and lack of a tubular channel connecting the cells.

Fractisporonites sp. A

Plate 3, figures 15, 16, 28

Description. Fungal spores, multicellular, uniseriate, equilateral, comprising many large cells, with slight constrictions at the locus of septal insertion. Septa 0.5 to 1.0 µm thick, apparently aporate and non-dentate. Cells 24-36 µm wide, 36-45 µm long, generally longer than wide. Cell wall 0.25-0.5 µm thick, levigate, with irregularly distributed punctae. Spore fragments commonly in excess of 200 µm, irregular in overall shape.

Distribution. Lowest part of the Richards Formation.

Range. Eocene.

Fractisporonites sp. B.

Plate 3, figure 14

Description. Fungal spores, multicellular, uniseriate, equilateral or irregular, comprising many parallel-sided cells that are wider than long. Septa 1 µm thick, dentate. Cells 15-20 µm wide, 5-8 µm long, except at occasional points on the spore where the chain is constricted or bent. Spore wall 1 µm thick, levigate except for sporadically distributed punctae. Spore fragments about 100 µm long.

Distribution. Rare in the lower part of the Richards Formation.

Range. Eocene.

Genus *Staphlosporonites* Sheffy and Dilcher, 1971

Type species. *Staphlosporonites conoideus* Sheffy and Dilcher, 1971

Staphlosporonites delumbus sp. nov.

Plate 3, figures 17-20

Holotype. GSC 67958; Slide P-2154-17b, 36.8 x 111.6; Arnak Member, Kugmallit Formation, Imperial Nuktak C-22 well; GSC loc. C-48831/3500-3600, depth 3500-3600 feet (1066.8-1097.3 m).

Diagnosis. Multicellular, linear, uni-, bi-, and tri-serial, inaperturate, fungal spores. Spore wall thin and levigate. Cells rounded proximally becoming polygonal and thinner walled distally.

Description. Basal cell 5-10 µm in diameter giving rise to biserial cells within 2 cells of basal cell, and to triserial cells within 4 or 5 cells of basal cell. Triserial cells partly overlapping. Spore wall approximately 0.25 µm thick in basal cell, becoming progressively thinner distally. Septa about 0.25 µm thick, porate, and dentate in some specimens. Loci of septal insertion constricted, 1-2 µm in the uniserial part of the spore, becoming less constricted distally. Cells increase in diameter up to 15 µm distally. Spores comprise 6-11 rows of cells and may occur in pairs with overlapping distal ends and opposing basal cells.

Dimensions. Total length 60-150 µm (holotype 105 µm).

Distribution. Sporadic in the Arnak Member, Kugmallit Formation. Rare in the Richards Formation.

Range. Eocene to Oligocene.

Staphlosporonites sp. A

Plate 3, figure 21

Description. Fungal spores, multicellular, uni-, bi-, and tri-serial, linear, inaperturate. Basal cell 10 µm in diameter. First row of cells biserial; subsequent row triserial. Cell wall scabrate, 0.25 µm thick. Cells angular in outline. Septa thickened up to 2 µm, no pores visible. Amb concave between loci of septal insertion. Distal end of spore bluntly terminated.

Dimensions. 8 rows of cells: total length 100 µm; total width 42 µm.

Distribution. Rare in the Kugmallit Formation.

Range. Oligocene.

Staphlosporonites sp. cf. *S. conoideus* Sheffy and Dilcher

Plate 3, figures 23, 27

1971 (cf.) *Staphlosporonites conoideus* Sheffy and Dilcher, p. 48; Pl. 14, fig. 77; Pl. 16, fig. 77.

1978 *Staphlosporonites* cf. *conoideus* Sheffy and Dilcher. Sung et al., p. 51; Pl. 5, fig. 19.

Distribution. Rare in the middle part of the Richards Formation. Oligocene, northeast China (Sung et al., 1978).

Range. Oligocene.

Genus *Pesavis* Elsik and Jansonius, 1974

Type species. *Pesavis tagluensis* Elsik and Jansonius, 1974

Pesavis tagluensis Elsik and Jansonius

Plate 3, figures 24, 25

1974 *Pesavis tagluensis* Elsik and Jansonius, p. 956; Pl. 1, figs. 5-8, 9, 11 (non fig. 10).

Distribution. Common in the lower part and sporadic in the middle part of the Richards Formation. Paleocene-Eocene of Washington, British Columbia, Alaska, and Northwest Territories (Elsik and Jansonius, 1974). According to Rouse (1977, Text-fig. 3), *P. tagluensis* ranges into the late Eocene in British Columbia but does not range as high in the Arctic.

Range. Paleocene to Eocene.

Genus *Ctenosporites* Elsik and Jansonius, 1974

Type species. *Ctenosporites eskerensis* Elsik and Jansonius, 1974

Ctenosporites wolfei Elsik and Jansonius

Plate 3, figure 22

1974 *Ctenosporites wolfei* Elsik and Jansonius, p. 957; Pl. 1, figs. 2-4.

Distribution. Sporadic in the lowest part of the Richards Formation. Middle Eocene of Northwest Territories, Alaska, and British Columbia (Elsik and Jansonius, 1974). Rouse (1977, Text-fig. 3) indicated Lower, Middle, and Upper Eocene distribution in the Arctic compared with an extended range into the Lower Oligocene of south-central British Columbia.

Range. Eocene to (?)Lower Oligocene.

Genus *Centonites* Peppers, 1964

Type species. *Centonites symmetricus* Peppers, 1964

Centonites sp. A

Plate 3, figure 26

Description. Multicellular, inaperturate, fungal spore, comprising a central cell surrounded by a ring of 6 cells. Cell wall amb slightly bulging between loci of septal insertion. Cell wall up to 0.5 µm thick, foveo-reticulate; muri and lumina up to 1 µm wide. Septa up to 1 µm thick, porate.

Dimensions. Total diameter 31 x 20 µm. Cells 7-9 µm in diameter.

Distribution. A single occurrence in the upper part of the Arnak Member, Kugmallit Formation.

Range. Oligocene.

Remarks. Distinguished from *Staphlosporonites discitypicus* Ke et Shi ex Sung et al. by the smaller number of cells and the lack of a basal cell.

Mycelial hyphae

Several distinctive types of fungal hyphae occur with restricted ranges in the Tertiary of the Mackenzie Delta. They may be distinctive species or they may represent ontogenetic stages. Pending assessment of their genotypic or phenotypic significance, they are described here informally as types of fungal hyphae. Fungal hyphae are distinguished somewhat arbitrarily from fungal spores with elongate cells on the basis of the cell length:width ratio being greater than four (Elsik, 1968).

Fungal Hyphae Type A

Plate 4, figures 1-5

Description. Hyphae varying in width from 5-10 µm, slightly constricted or narrowed at points of septal insertion, yielding a bulbous outline to the cells. Cells 12-30 µm long, some with L-shaped lateral branches or hemispherical protrusions up to 6 µm wide. Hyphal wall less than 1 µm wide, levigate. Septa slightly thicker than hyphal wall, with a septal pore approximately 0.25 µm in diameter.

Distribution. Sporadic in the Richards, Kugmallit, Mackenzie Bay, and Nuktak formations.

Range. Eocene to Pliocene.

Fungal Hyphae Type B

Plate 4, figures 6-8

Description. Hyphae 2-4 µm wide, more or less parallel-sided except at locus of septal insertion, which might be slightly or strongly constricted. The constricted portions of the hyphae are 1-2 µm wide and may extend 1-2 µm beyond the locus of septal insertion. Lateral branches develop at right angles to the main axis of the cell.

Distribution. Sporadic in the upper part of the Kugmallit and Mackenzie Bay formations, rare below.

Range. Oligocene.

Fungal Hyphae Type C

Plate 4, figures 9, 10

Description. Hyphae 3-6 µm wide, of more or less constant width except for a very slight constriction (if any) at the locus of septal insertion. Cells 15-100 µm long. Hyphal wall levigate, approximately 0.25 µm thick. Septa 0.5-1.0 µm wide with a minute pore that is scarcely visible. Lateral branches inserted at right angles to main axis of cell, comprising cells of smaller dimensions than the main hypha.

Distribution. Sporadic in the Richards Formation and Ivik Member, Kugmallit Formation. Common in the Arnak Member, Kugmallit Formation. The single occurrence in the Nuktak Member may be due to recycling.

Range. Eocene to Oligocene (and possibly to Pliocene).

Fungal Hyphae Type D

Plate 4, figures 11-14

Description. Hyphae 3-6 µm wide, with a gradual constriction toward the locus of septal insertion. Cells 40-50 µm long. Hyphal wall 0.5 µm thick with external granules up to 1 µm in diameter and spaced irregularly 1-3 µm apart or in rows parallel to the cell axis. Septa of similar thickness to hyphal wall; no pore visible. Terminal cell 6 µm in diameter, irregularly ellipsoidal in shape. Lateral branches emerge abruptly at right angles from main hypha without any constriction at the point of insertion.

Distribution. Sporadic in Arnak Member, Kugmallit Formation.

Range: Oligocene.

Fungal Hyphae Type E

Plate 4, figures 15, 16

Description. Hyphae 4-6 µm wide, parallel sides straight or sinuous, with slight constriction at locus of septal insertion. Cells 12-30 µm long; hyphal wall levigate, very thin. Septa of same width as hyphal wall, usually strongly dentate; minute septal pore up to 0.25 µm in diameter. Some cells have lateral balloon-shaped cells emerging at right angles, up to 6 µm in maximum diameter but constricted to approximately 3 µm at point of insertion, equipped with a septal pore 0.5 µm in diameter.

Distribution. Restricted to the middle part of the Arnak Member, Kugmallit Formation.

Range. Upper Oligocene.

Fungal Hyphae Type F

Plate 4, figure 17

Description. Hyphae 3-5 µm wide, slightly irregular in width and slightly constricted at locus of septal insertion. Hyphal wall 0.25 µm wide, levigate. Cell length very irregular, varying from 5-40 µm. Septa same thickness as hyphal wall, strongly denticulate. Some septa appear as "ghosts" perhaps due to resorption.

Distribution. Rare in the middle part of the Arnak Member, Kugallit Formation.

Range. Upper Oligocene.

Fungal Hyphae Type G

Plate 4, figures 18-22

Description. Hyphae apparently aseptate, parallel-sided, or slightly tapering to a rounded termination, 6-15 µm wide. Hyphal wall up to 2 µm thick, bearing internally directed, irregularly-shaped granules 1-4 µm in diameter, closely-spaced and partially coalescent, forming an imperfect areolation.

Distribution. Sporadic in the Ivik Member and lower part of the Arnak Member, Kugmallit Formation, and in the Richards Formation.

Range. Eocene to Oligocene.

Fungal fruiting bodies

Genus *Plochmopeltinites* Cookson 1947 emend. Selkirk, 1975

Type species. *Plochmopeltinites masonii* Cookson, 1974

Plochmopeltinites masonii Cookson

Plate 5, figures 1-3

1947 *Plochmopeltinites masonii* Cookson, p. 212; Pl. 13, figs. 14, 15.

Distribution. Sporadic in the lower part of the Kugmallit Formation and the Richards Formation. Upper Oligocene, Kerguelen Island; Oligocene-Miocene of southern Australia (Cookson, 1947).

Range. Eocene to Miocene.

Genus *Phragmothyrites* Edwards, 1922

Type species. *Phragmothyrites eocaenicus* Edwards, 1922

Phragmothyrites sp. cf. *P. eocaenicus* Edwards

Plate 5, figures 4, 5

1922 (cf.) *Phragmothyrites eocaenicus* Edwards, p. 69; Pl. 8, figs. 1-4.

Description. Similar to the thyriothecia described by Edwards (1922) for *Phragmothyrites eocaenicus*, but the hyphae expand up to 5 or 6 µm at the periphery. Fruiting bodies 45-60 µm in diameter.

Distribution. Sporadic in the Ivik Member, Kugmallit Formation and in the lower part of the Richards Formation.

Range. Eocene to Lower Oligocene. The compared species was described from the Lower Eocene of Scotland (Edwards, 1922).

Genus *Microthyriacites* Cookson, 1947

Type species. *Microthyriacites grandis* Cookson, 1947 [designated by Jansonius and Hills, 1976; Venkatachala and Kar (1969) did not actually designate a type species].

Microthyriacites sp. A

Plate 5, figures 6, 7

Description. Fungal fruiting body, a low cone or flattened oblate spheroid in shape, astomate, margin entire, amb circular to oval. Apex of cone on the proximal side with a central cell surrounded by a circular thickened ring 6-10 µm in diameter and 1-2 µm wide. Proximal hyphae radiate out from the ring, 1-2 µm wide at the centre, increasing to 4-6 µm at the margin, completely united, divided by septa into cells up to 10 µm long. Distal surface broken irregularly, flat or slightly concave, comprising united hyphae that are continuations of the proximal hyphae. Distal hyphae 3-5 µm wide, more or less parallel-sided, radially arranged, slightly thicker walled than proximal hyphae, divided by septa into cells 5-20 µm long (longer toward the margin).

Dimensions. Total diameter 79-96 µm.

Distribution. Rare in the lower part of the Ivik Member, Kugmallit Formation and Richards Formation.

Range. Eocene to Oligocene.

Genus *Trichothyrites* Rosendahl, 1943

Type species. *Trichothyrites pleistocaenicus* Rosendahl, 1943

Trichothyrites sp. A

Plate 6, figures 1, 2

Description: Fungal fruiting body, peltate, osteolate, margin entire. Osteole on proximal surface supported by a neck about 8 µm high, irregularly octagonal in shape. Proximal hyphae radiate out from neck, increasing from 2 µm to 4 µm in width at the margin, completely united, with walls up to 1 µm thick. Distal hyphae similar to proximal hyphae. Transverse septa divide hyphae into cells 5-10 µm long. Cells comprising neck with thicker walls about 1-2 µm thick. Parts of the proximal or distal surface may lose the hyphal structure by thickening or solution of the hyphae.

Dimensions. Total diameter 72-130 µm.

Distribution. Rare in the lower part of the Ivik Member, Kugmallit Formation and in the Richards Formation.

Range. Eocene to Oligocene.

Genus *Microthallites* Dilcher, 1965

Type species. *Microthallites lutosus* Dilcher, 1965

Microthallites sp. cf. *M. lutosus* Dilcher

Plate 6, figure 5

1965 (cf.) *Microthallites lutosus* Dilcher, p. 16; Pl. 10, figs. 84, 85.

Remarks. A single specimen comprising only part of the proximal side of the peltate fruiting body conforms to Dilcher's description. The margin, however, is not preserved and so definite identity cannot be established.

Distribution. A single occurrence in the middle of the Richards Formation.

Range. Eocene. The compared species was described from the Eocene of Tennessee.

Genus *Microthyrites* Pampaloni, 1902

Type species. *Microthyrites disodilis* Pampaloni, 1902

Microthyrites sp. A

Plate 6, figure 3

Description. Fungal fruiting body, amb irregularly circular with indentations, margin entire, astomate, saucer shaped. Proximal and distal surfaces similar, comprising cells 4-8 µm in diameter, rounded or irregular in shape. Cells slightly larger at amb. Cell wall 0.25 µm thick, slightly thicker (or cells more densely packed) in a peripheral zone 5-8 µm wide situated about 5 µm inside margin.

Dimensions. Maximum diameter 77 µm.

Distribution. A single occurrence in the Richards Formation.

Range. Eocene.

Genus *Callimothallus* Dilcher, 1965

Type species. *Callimothallus pertusus* Dilcher, 1965

Callimothallus pertusus Dilcher

Plate 6, figures 4, 6-9

1965 *Callimothallus pertusus* Dilcher, p. 13; Pl. 6, fig. 45.

Distribution. Common in the lowest part of the Richards Formation. Eocene of Tennessee (Dilcher, 1965)

Range. Eocene.

Indeterminate peltate fruiting bodies

Plate 6, figures 10, 11

Remarks. Fragments of cellular, presumably peltate, fruiting bodies are identifiable in certain samples but, due to their fragmentary nature, cannot be identified more closely.

Distribution. Lower part of the Richards Formation.

Range. Eocene.

(b) Embryophyte spores and pollen

The Potonié morphographic system of classification is employed in this section with modifications introduced by Dettmann (1963).

Turma Triletes Reinsch emend. Dettmann

Suprasubturma Acavatitriletes Dettmann

Subturma Azonotriletes Luber emend. Dettmann

Infraturma Laevigati Bennie and Kidston emend. Potonié

Genus *Stereisporites* Pflug in Thomson and Pflug, 1953

Type species. *Stereisporites stereoides* (Potonié and Venitz, 1934) Pflug in Thomson and Pflug, 1953

Stereisporites stereoides (Potonié and Venitz) Pflug in Thomson and Pflug

Plate 7, figures 1, 2

1934 *Sporites stereoides* Potonié and Venitz, p. 11; Pl. 1, fig. 4.

1953 *Stereisporites stereoides* (Potonié and Venitz) Pflug in Thomson and Pflug, p. 53.

Distribution. Common in the lower part of the Nuktak Formation, Mackenzie Bay Formation, and Arnak Member, Kugmallit Formation. Sporadic in the Ivik Member, Kugmallit Formation, and Richards Formation. Tertiary of Europe (e.g. Thomson and Pflug, 1953; Krutzsch, 1963).

Range. Tertiary.

Stereisporites minor (Raatz) Krutzsch

Plate 7, figures 3, 4

1937 *Sphagnumsporites minor* Raatz, p. 9; Pl. 1, fig. 5 (holotype re-illustrated in Krutzsch 1963, p. 36; Pl. 1, figs. 1, 2).

1953 *Stereisporites stereoides* Thomson and Pflug auct. non Potonié and Venitz, p. 53; Pl. 1, fig. 67 (only).

1959 *Stereisporites (Stereisporites) minor* (Raatz) Krutzsch, p. 73.

1959 (syn.) *Stereisporites apsilatus* Krutzsch, p. 73 (fide Krutzsch, 1963, p. 36).

Distribution. Common throughout the Richards, Kugmallit, Mackenzie Bay and Nuktak formations. Tertiary of Europe (Krutzsch, 1963).

Range. Tertiary.

Stereisporites micrograndulus Krutzsch

Plate 7, figures 5-7

1963 *Stereisporites (Stereigranisporis) micrograndulus* Krutzsch, p. 86; Pl. 24, figs. 1-4.

Distribution. Sporadic in the Mackenzie Bay and Kugmallit formations. Miocene of Germany (Krutzsch, 1963).

Range. Oligocene to Miocene.

Genus *Cyathidites* Couper, 1953

Type species. *Cyathidites australis* Couper, 1953

Cyathidites minor Couper.

Plate 7, figure 8

1953 *Cyathidites minor* Couper, p. 28; Pl. 2, fig. 13.

Distribution. Sporadic in the Richards and Kugmallit formations, and lower part of the Mackenzie Bay Formation.

Range. Mesozoic to Cenozoic.

Genus *Deltoidospora* Miner, 1935

Type species. *Deltoidospora hallii* Miner, 1935

Deltoidospora hallii Miner

Plate 7, figure 9

1935 *Deltoidospora hallii* Miner, p. 618; Pl. 24, fig. 7.

Distribution. Sporadic in the Mackenzie Bay, Kugmallit and Richards formations.

Range. Mesozoic to Cenozoic.

Genus *Biretisporites* Delcourt and Sprumont, 1955

Type species. *Biretisporites potoniaei* Delcourt and Sprumont, 1955

Biretisporites potoniaei Delcourt and Sprumont

Plate 7, figure 10

1955 *Biretisporites potoniaei* Delcourt and Sprumont, p. 40; Fig. 10.

Distribution. Rare in the Kugmallit and Richards formations.

Range. Mesozoic to Cenozoic.

Infraturma Apiculati Bennie and Kidston emend. Potonié

Genus *Osmundacidites* Couper, 1953

Type species. *Osmundacidites wellmanii* Couper, 1953

Osmundacidites wellmanii Couper

Plate 7, figure 11

1953 *Osmundacidites wellmanii* Couper, p. 20; Pl. 1, fig. 5.

Distribution. Common in the Richards, Kugmallit and Mackenzie Bay formations.

Range. Mesozoic to Cenozoic.

Remarks on the the holotype. In view of the putative similar morphology of *Baculatisporites* (q.v.) and the suggestion of Krutzsch (1967, p. 6, 7) to merge *Osmundacidites* with *Baculatisporites*, the holotype of *Osmundacidites wellmanii* Couper was re-examined. The following is a description: spore trilete, with an irregular, circular amb, partly folded; laesurae simple, almost reaching equator; distal surface granulate; granules circular to irregular in outline, about 1.0 µm in diameter and 0.5-1 µm high, spaced 0.25-1.0 µm apart and distributed irregularly; proximal surface also granulate with a possible slight reduction in density and a tendency toward rugulae; exine 1 µm thick.

Thus the ornament is different from that proposed by Krutzsch as diagnostic of *Baculatisporites*, viz. weakly echinoid single bacula, to flatly-rugulate or sinuous muri and warts.

It is proposed to retain *Osmundacidites* for clearly granulate species without baculae or echinoid sculpture.

Osmundacidites richardsii sp. nov.

Plate 7, figures 12-14, 17, 18

Holotype. GSC 68018; Slide P-2154-52b, 35.4 x 107.4; Richards Formation, Imperial Nuktak C-22 well; GSC loc. C-48831/10 100-10 200; depth 10 100-10 200 feet (3078.5-3109.0 m).

Diagnosis. Spore trilete with circular amb. Laesurae simple, or with narrow lips, almost reaching equator. Exine granulate-verrucate proximally and distally. Granules and small verrucae mostly 1-3 µm in diameter, up to 1 µm approximately in average height, hemispherical or nearly so, a few coalescent; densely packed on equator, less dense on poles. Ornament reduced in height on contact areas.

Description. Sculptural elements circular or slightly irregular in outline, spaced less than 1 µm apart with a few granules, 0.5 µm or less in diameter, interspersed with the larger elements. Most granules and verrucae are round-topped but a few are somewhat truncated with rounded corners. A few elements, particularly in the equatorial region, are coalescent. Proximal sculpture similar in character to the distal sculpture, but apparently somewhat smaller or lower. Exine without sculpture about 1 µm thick.

Dimensions. Equatorial diameter 30-45 µm (holotype 40 µm).

Distribution. Sporadic in the Richards Formation above 10 300 feet (3139.4 m) and in the lowest part of the Ivik Member, Kugmallit Formation.

Range. Upper Eocene to Lower Oligocene.

Remarks. Distinguished from *Osmundacidites wellmanii* Couper on the basis of smaller size, larger sculptural elements, and differential distribution of sculpture.

Genus *Leptolepidites* Couper emend. Norris, 1968

Type species. *Leptolepidites verrucatus* Couper, 1953

Leptolepidites sp. A

Plate 7, figure 22

1978 *Leptolepidites* sp. Sung et al, p. 64; Pl. 10, fig. 10.

Description. Spores rounded, triangular, trilete, verrucate. Verrucae on distal surface 2-3 µm in diameter, circular or slightly irregular, round-topped (less than hemispherical), approximately 1-2 µm high, spaced 0.25-1 µm apart, locally coalescent. Proximal surface levigate with some verrucae encroaching near the equator. Laesurae simple, almost reaching equator.

Distribution. Sporadic in the middle part of the Richards Formation. Paleogene of northeast China (Sung et al., 1978).

Range. Eocene to Oligocene.

Genus *Baculatisporites* Pflug in Thomson and Pflug, 1953

Type species. *Baculatisporites primarius* (Wolff) Pflug in Thomson and Pflug, 1953

Baculatisporites crassiprimarius (Krutzsch) comb. and stat. nov.

Plate 7, figures 16, 19-21

1967 *Baculatisporites primarius crassiprimarius* Krutzsch, p. 58; Pl. 111, figs. 1-9.

1978 *Osmundacidites crassiprimarius* (Krutzsch) Ke et Shi ex Sung et al., p. 55.

Distribution. Common in the Arnak Member of the Kugmallit Formation and in the middle part of the Richards Formation. Rare in the Ivik Member of the Kugmallit Formation. Eocene to Pliocene of Europe (Krutzsch, 1967). Eocene of northeast China (Sung. et al., 1978).

Range. Eocene to Pliocene.

Baculatisporites comaumensis (Cookson) Potonié

Plate 7, figure 15

1953 *Trilites comaumensis* Cookson, p. 470; Pl. 2, figs. 27, 28.

1956 *Baculatisporites comaumensis* (Cookson) Potonié, p. 33.

Distribution. Common in the lower part of the Richards Formation. Sporadic in the upper part of the Richards Formation, Kugmallit Formation, and lower part of the Mackenzie Bay Formation.

Range. Mesozoic to Cenozoic.

Baculatisporites quintus (Thomson and Pflug) Krutzsch

Plate 7, figures 23, 24

1953 *Rugulatisporites quintus* Pflug and Thomson in Thomson and Pflug, p. 56; Pl. 2, figs. 44-47.

1959 *Verrucosisporites quintus* (Thomson and Pflug) Krutzsch, p. 144.

1967 *Baculatisporites quintus* (Thomson and Pflug) Krutzsch, p. 48.

Distribution. Sporadic in the upper part of the Arnak Member, Kugmallit Formation. Middle and Upper Tertiary of Germany (Krutzsch 1967).

Range. Oligocene to Pliocene.

Genus *Echinatisporis* Krutzsch, 1959

Type species. *Echinatisporis longechinus* Krutzsch, 1959

Echinatisporis sp. A

Plate 7, figures 27-30

1957 *Selaginella selaginoides* (L.) Link. - type. Macko, p. 111; Pl. LXI, figs. 1-17.

Description. Spores trilete, amb rounded-triangular. Laesurae 0.5-1.0 µm wide, raised, reaching equator. Proximal surface scabrate. Distal surface scabrate with spines 3-7 µm long, spaced 3-7 µm apart, some having bifurcate tips.

Dimensions. Equatorial diameter (overall) 33-36 µm; without spines 24-26 µm.

Distribution. Rare in the Nuktak and Kugmallit formations. Miocene of Poland (Macko, 1957).

Range. Oligocene to Miocene.

Infraturma Murornati Potonié and Kremp

Genus *Retitriletes* van der Hammen ex Pierce emend. Döring et al. in Krutzsch, 1963

Type species. *Retitriletes globosus* Pierce, 1961

Retitriletes sp. cf. *R. oligocenicus* Krutzsch

Plate 7, figures 25, 26; Plate 8, figure 6

1978 *Lycopodiumsporites* cf. *oligocenicus* (Krutzsch) Ke et Shi ex Sung et al., p. 54; Pl. 6, figs. 6-9.

Distribution. Sporadic in the lower part of the Mackenzie Bay and Kugmallit formations. Common in the Richards Formation. Paleocene of north-east China (Sung. et al., 1978).

Range. Eocene to Miocene.

Retitriletes sp. cf. *R. novomexicanus* (Anderson) comb. nov.

Plate 8, figures 1-5

1960 (cf.) *Lycopodium novomexicanum* Anderson, p. 14; Pl. 1, fig. 2; Pl. 8, fig. 1.

1967 (cf.) *Lycopodiumsporites novomexicanum* (sic) (Anderson) Drugg, p. 40.

1971 (cf.) *Zlivisporis novamexicanum* (sic) (Anderson) Leffingwell, p. 25.

Description. Similar to *R. novomexicanus* (Anderson, 1960) comb. nov., apart from overall smaller size (equatorial diameter 35-45 µm) and more prominent laesurae.

Distribution. Sporadic in the Ivik Member, Kugmallit Formation. Common in the upper 2000 feet (609.6 m) of the Richards Formation.

Range. Eocene to Oligocene.

Retitriletes annotinioides Krutzsch

Plate 7, figures 31, 32

1963 *Retitriletes annotinioides* Krutzsch, p. 76; Pl. 19, figs. 1-14.

1966 *Lycopodium annotinioides* (Krutzsch), Martin and Rouse, p. 184.

Distribution. Sporadic in the lower part of the Mackenzie Bay and upper part of the Kugmallit Formation. Eocene, Oligocene, Miocene, and Pliocene of British Columbia (Martin and Rouse, 1966; Hopkins, 1969; Piel, 1971).

Range. Eocene to Pliocene.

Genus *Azolla* Meyen

Type species. *Azolla teschiana* Florschutz, 1945

Azolla sp. A

Plate 8, figure 7

Description. Fragments of massulae up to 100 µm in diameter with indefinite numbers of glochidia attached, apparently randomly. Glochidia with ribbon-like shafts and anchor-shaped terminations approximately 2 µm wide at proximal end, expanding to terminations about 4 µm wide.

Distribution. Sporadic in the lower part of the Richards Formation.

Range. Eocene.

Turma Monoletes Ibrahim

Suprasubturma Acavatomonoletes Dettmann

Subturma Azonomonoletes Luber

Infraturma Laevigatomonoleti Dybova and Jachowicz

Genus *Laevigatosporites* Ibrahim, 1933

Type species. *Laevigatosporites vulgaris* (Ibrahim) Ibrahim, 1933

Laevigatosporites novus sp. nov.

Plate 8, figures 8-10

Holotype. GSC 68042; Slide P-2154-4g, 39.4 x 98.5; Nuktak Formation, Imperial Nuktak C-22 well; GSC loc. C-48831/1100-1200; depth 1100-1200 feet (335.3-365.8 m).

Diagnosis. Monolete spore, laevigate, 15-20 µm long, proximal side concave, polar axis approximately 50-70% of length.

Description. Laesurae approximately two thirds the length of the grains, simple or raised up to 1 µm. Proximal face concave to almost flat. Distal face moderately to strongly convex. Exine 1 µm or less in thickness, a few with concentric folds running parallel to the distal face.

Dimensions. 21-30 µm in length (holotype 21 µm).

Distribution. Sporadic in Arnak Member of Kugmallit Formation; more common in Mackenzie Bay and Nuktak formations.

Range. Oligocene to Pliocene.

Remarks. The small size and relatively long polar axis distinguish this species from others assigned to *Laevigatosporites*.

Laevigatosporites ovatus Wilson and Webster

Plate 8, figure 13

1946 *Laevigatosporites ovatus* Wilson and Webster, p. 273, Fig. 5.

Distribution. Fairly common in the lower part of the Mackenzie Bay Formation, common in the Arnak Member and fairly common in the Ivik Member of the Kugmallit Formation and in the Richards Formation.

Range. Upper Paleozoic to Cenozoic.

Infraturma Sculptatomonoleti Dybova and Jachowicz

Genus *Verrucatosporites* Pflug in Thomson and Pflug 1953

Type species. *Verrucatosporites alienus* (Potonié) Thomson and Pflug, 1953

Verrucatosporites favus (Potonié) Thomson and Pflug.

Plate 8, figures 11, 12

1931 *Polypodii* (?) - *sporonites favus* Potonié, p. 56; Fig. 3.

1953 *Verrucatosporites favus* (Potonié) Thomson and Pflug, p. 60.

1956 *Polypodii* (?) *sporites favus* Potonié, p. 78.

1978 *Polypodiisporites favus* Potonié, Sung et al., p. 70.

Distribution. Sporadic in the middle part of the Richards Formation. Tertiary of Europe (Thomson and Pflug, 1953; Krutzsch, 1967); Lower Oligocene of northeast China (Sung et al., 1978).

Range. Eocene to Pliocene.

Anteturma Pollenites Potonié

Turma Saccites Erdtman

Subturma Monnosaccites Chitaley emend. Potonie and Kremp

Infraturma Saccizonati Bhardwaj

Genus *Tsugaepollenites* Potonié and Venitz ex. Potonié, 1958

Type species. *Tsugaepollenites igniculus* (Potonié) Potonié and Venitz, 1934

Tsugaepollenites igniculus (Potonié) Potonié and Venitz

Plate 9, figure 6

1931 *Sporonites igniculus* Potonié, p. 556, Fig. 2.

1934 *Tsugaepollenites igniculus* (Potonié) Potonié and Venitz, p. 17.

Distribution. Rare in the uppermost part of the Kugmallit Formation and in the Mackenzie Bay Formation. Middle and Upper Tertiary of Germany (Thomson and Pflug, 1953).

Range. Oligocene to Miocene.

Tsugaepollenites viridifluminipites (Wodehouse) comb. nov.

Plate 8, figure 27; Plate 9, figure 3

1933 *Tsuga viridifluminipites* Wodehouse, p. 489, Fig. 14.

1953 *Zonalapollenites viridifluminipites* (Wodehouse) Thomson and Pflug, p. 67.

Distribution. Common in the Mackenzie Bay, Kugmallit and Richards formations.

Range. Eocene to Oligocene. Previously recorded from the Eocene of British Columbia and U.S. western interior (Rouse 1962; Wodehouse 1933) and the middle and upper Tertiary of Germany (Thomson and Pflug, 1953).

Subturma Disaccites Cookson

Genus *Pinuspollenites* Raatz ex Potonié, 1958

Type species. *Pinuspollenites labdacus* (Potonié) Raatz ex. Potonié

Pinuspollenites labdacus (Potonié) Raatz ex Potonié, 1958

Plate 8, figure 14, 15

1931 *Pollenites labdacus* Potonié, p. 5, Fig. 32.

1958 *Pinuspollenites labdacus* (Potonié) Raatz ex Potonié, p. 62.

Distribution. Fairly common to common in the Kugmallit and Richards formations. Tertiary of Europe (e.g. Krutzsch, 1971).

Range. Tertiary.

Pinuspollenites sp. A.

Plate 8, figures 16, 17

Description. Bisaccate pollen; sacci slightly constricted at roots, displaced distally. Sacci with imperfect, irregular, internally directed reticulum; lumina 1-3 µm in diameter; muri up to 3 µm high, commonly split at the base to form a smaller-meshed reticulum near the surface of the sacci. Proximal cap approximately 1 µm thick, columellate, with a scabrate-punctate pattern in surface view. Leptoma between distal roots 3-5 µm wide, with parallel or slightly convex sides.

Dimensions. Overall width 42-60 µm. Length 30-35 µm.

Distribution. Kugmallit, Mackenzie Bay, and Nuktak formations. It also occurs rarely in cores in the top 200 feet (61 m) of the Richards Formation.

Range. Oligocene to Pliocene.

Remarks. This species is similar to post-glacial and recent pollen of *Pinus* Section Diploxlyon (*Pinus banksiana*, *P. resinosa*, *P. rigida*) described and illustrated by McAndrews et al. (1973, figs. 3G-J).

Genus *Piceaepollenites* Potonié, 1931

Type species. *Piceaepollenites alatus* Potonié, 1931

Piceaepollenites grandivescipites (Wodehouse) comb. nov.

Plate 8, figures 24, 26; Plate 9, figure 1

1933 *Picea grandivescipites* Wodehouse, p. 488; Fig. 10.

Distribution. Common in the Richards Formation. Less common or sporadic in the Kugmallit, Mackenzie Bay, and Nuktak formations. Eocene of British Columbia (Rouse, 1962; Hopkins, 1969) and U.S. western interior (Wodehouse, 1933).

Range. Eocene to Pliocene.

Piceaepollenites sp. A.

Plate 9, figure 2; Plate 9, figures 4, 5

1971 *Picea* sp. 2, Piel, p. 1902; Fig. 52.

Distribution. Common in the Richards Formation, less common in the Ivik Member, and sporadic in the Arnak Member of the Kugmallit Formation. Oligocene, British Columbia (Piel, 1971).

Range. Eocene to Oligocene.

Turma Aletes Ibrahim

Subturma Azonaletes Luber emend. Potonié and Kremp

Infraturma Psilonapiti Erdtman

Genus *Taxodiaceaepollenites* Kremp ex Potonié, 1958

Type species. *Taxodiaceaepollenites hiatus* Potonié ex Potonié, 1958

Taxodiaceaepollenites hiatus Potonié ex Potonié

Plate 8, figure 23

1932 *Pollenites hiatus* Potonié, p. 5; Fig. 27.

1949 *Taxodiaceae - Pollenites hiatus* Potonié in Kremp, p. 59.

1958 *Taxodiaceaepollenites hiatus* Potonié ex Potonié, p. 78.

Distribution. Common throughout the Richards, Kugmallit, Mackenzie Bay, and Nuktak formations.

Range. Mesozoic to Cenozoic.

Infraturma Tuberini

Genus *Sequoiapollenites* Thiergart, 1937

Type species. *Sequoiapollenites polyformosus* Thiergart, 1938

Sequoiapollenites polyformosus Thiergart

Plate 8, figures 18-20

1937 *Sequoiapollenites polyformosus* Thiergart, p. 301; Pl. 23, fig. 6.

1953 *Inaperturopollenites polyformosus* (Thiergart) Thomson and Pflug, p. 65.

1962 *Metasequoia papillapollenites* Rouse, p. 201; Pl. 2, fig. 5.

Distribution. Sporadic in the Mackenzie Bay, Kugmallit and Richards formations. Eocene and Oligocene of British Columbia (Rouse, 1962; Hopkins, 1969; Piel, 1971). Oligocene to Pliocene of Europe (Krutzsch, 1971). Eocene and Oligocene of northeast China (Sung et al., 1978).

Range. Eocene to Pliocene.

Genus *Sigmopollis* Hedlund, 1965

Type species. *Sigmopollis hispidus* Hedlund, 1965

Sigmopollis psilatus Piel

Plate 8, figures 21, 22

1957 unnamed species, Macko, Pl. B, figs. 9-12.

1971 *Sigmopollis psilatus* Piel, p. 1897; figs. 7, 8.

Distribution. Common in the Nuktak and Mackenzie Bay formations. Sporadic in the Kugmallit Formation. Oligocene, British Columbia (Piel, 1971). Lower Miocene, Poland (Macko, 1957).

Range. Oligocene to Pliocene.

Remarks. Although included as a pollen grain, the affinities of this species are uncertain. It is possible that *Sigmopollis* is an algal cyst (Staplin, 1976).

Turma Plicates Naumova emend. Potonié

Subturma Triptyches Naumova

Genus *Tricolpites* Cookson ex Couper, 1953

Type species. *Tricolpites reticulata* Cookson ex Couper, 1953

Tricolpites hians Stanley

Plate 9, figures 7, 8

1965 *Tricolpites hians* Stanley, p. 321; Pl. 47, figs. 24-27.

Distribution. Sporadic in the Richards and Kugmallit formations. Paleocene of South Dakota (Stanley, 1965).

Range. Paleocene to Oligocene.

Genus *Salixipollenites* Srivastava, 1966

Type species. *Salixipollenites discoloripites* (Wodehouse) Srivastava, 1966

Salixipollenites discoloripites (Wodehouse) Srivastava

Plate 9, figure 9

1933 *Salix discoloripites* Wodehouse, p. 506; figs. 34, 35.

1966 *Salixipollenites discoloripites* (Wodehouse) Srivastava, p. 529.

Distribution. Arnak Member, Kugmallit Formation. Also occurs rarely in the Nuktak Formation where it might be recycled. Previously recorded from the Eocene (Wodehouse, 1933; Hopkins, 1969).

Range. Eocene to Oligocene and possibly Pliocene.

Genus *Quercoidites* Potonié, Thomson and Thiergart ex Potonié, 1960

Type species. *Quercoidites henrica* (Potonié) Potonié, 1960

Quercoidites microhenrica (Potonié) Potonié

Plate 9, figure 10

1931 *Pollenites microhenrica* Potonié p. 26; Pl. 1, fig. 192.

1950 *Quercoidites microhenrica* (Potonié) Potonié, p. 55.

1953 *Tricolpopollenites microhenrica* Thomson and Pflug, p. 96.

Distribution. Rare in the Kugmallit and Richards formations. Tertiary of Europe (Thomson and Pflug, 1953) and northeast China (Sung et al., 1978).

Range. Lower Tertiary to Pliocene.

Quercoidites sp. A

Plate 9, figure 11

1969 *Quercus* sp. 3, Hopkins, p. 1119; figs. 103-104.

Description. Pollen grains prolate, tricolpate, with tectate exine and weak scabrate ornament which is scarcely visible. Colpi extend from pole to pole and are bordered by narrow thickenings or folds which are interrupted or thinner in the equatorial region. Exine 0.75 µm thick.

Dimensions. Equatorial diameter 11-12 µm. Length 17-20 µm.

Remarks. Hopkins specimens are slightly longer.

Distribution. Rare in the Kugmallit and Richards formations. Eocene of British Columbia (Hopkins, 1969).

Range. Eocene to Oligocene.

Genus *Integricorpus* Mtchedlishvili 1961 emend. Stanley, 1970

syn. *Parviprojectus* Mtchedlishvili (see Stanley, 1970, p. 13)

Type species. *Integricorpus bellum* Mtchedlishvili, 1961

Integricorpus sp. A

Plate 9, figures 12-14

1976 *Parviprojectus* sp. PJ-1. Staplin, p. 128; Pl. 1, figs. 9, 10.

1977 *Parviprojectus* A. Rouse, p. 64; Pl. 2, fig. 31.

Description. Pollen grains tricolpate, prolate, isopolar, microreticulate, with three relatively small, equatorial projections. Exine 1-1.5 µm thick with a microreticulate surface sculpture (lumina approximately 0.25-0.5 µm in diameter, subangular, irregular). Nexine less than 0.5 µm thick. Exine on equatorial projections becomes thinner and scabrate distally. Colpi narrow, 2-3 µm long, located at distal ends of equatorial projections. Polar axis 31-35 µm; equatorial diameter 12-19 µm (excluding equatorial projections); equatorial projections 8-12 µm long, 4-5 µm wide at base, tapering to 1-2 µm at distal end.

Distribution. Sporadic in the lower part of Richards Formation. Middle Eocene to Oligocene, Mackenzie Delta (Staplin, 1976). Lower Oligocene, Canadian Arctic and south-central British Columbia (Rouse, 1977).

Range. Middle Eocene to Oligocene.

Subturma Ptychotriporines Naumova

Genus *Cupuliferoipollenites* Potonié ex Potonié, 1960

Type species. *Cupuliferoipollenites pusillus* (Potonié) Potonié

Cupuliferoipollenites pusillus (Potonié) Potonié

Plate 9, figures 15, 16

1934 *Pollenites quisqualis pusillus* Potonié, p. 71; Pl. 3, fig. 21.

1953 *Tricolporopollenites cinqulum pusillus* Thomson and Pflug, p. 100.

1960 *Cupuliferoipollenites pusillus* (Potonié) Potonié, p. 98.

Distribution. Sporadic in the Richards Formation. Tertiary of Europe (Thomson and Pflug, 1953); Upper Eocene and Lower and Middle Oligocene, northeast China (Sung et al., 1978).

Range. Eocene to Pliocene.

Cupuliferoipollenites oviformis (Potonié) Potonié

Plate 9, figures 17-19

1931 *Pollenites oviformis* Potonié, p. 328; Pl. 1, fig. 20.

1951 *Cupuliferoipollenites oviformis* (Potonié) Potonié, p. 145.

1953 *Tricolporopollenites cingulum* subsp. *oviformis* (Potonié) Thomson and Pflug, p. 100.

1969 *Castanea* sp., Fairchild and Elsik, p. 83; Fig. 6.

1969 (?) *Castanea* sp., Hopkins, p. 1119; figs. 90, 91.

1971 *Castanea* sp., Piel, p. 1911; Fig. 110.

Distribution. Sporadic in the Kugmallit Formation and more common in the Richards Formation. Eocene to Pliocene of Europe (Thomson and Pflug, 1953); Eocene (Hopkins, 1969) and Oligocene (Piel, 1971) of British Columbia; Lower and Middle Oligocene of northeast China (Sung et al., 1978); Paleocene and Eocene of Texas and Louisiana (Fairchild and Elsik, 1969).

Range. Paleocene to Pliocene.

Remarks. Some of the larger grains included in this species reach up to 18 µm in length and border on the lower size limit for *Cupuliferoipollenites pusillus* (Potonié) Potonié which is similar, except in other than size, to *C. oviformis*.

Genus *Margocolporites* Ramnujam ex Srivastava, 1969

Type species. *Margocolporites tsukadai* Ramnugam, 1966

Margocolporites stenosus Ke et Shi ex Sung et al.

Plate 10, figures 3, 4

1978 *Margocolporites stenosus* Ke et Shi ex Sung et al., p. 123; Pl. 57, fig. 17.

Distribution. Rare in the Arnak Member, Kugmallit Formation. Paleogene of northeast China (Sung et al., 1978).

Range. Paleogene.

Genus *Lonicerapollis* Krutzsch, 1962

Type species. *Lonicerapollis qalliwitzii* Krutzsch, 1962

Lonicerapollis spiniformis (Ke et Shi ex Sung et al.) comb. nov.

Plate 10, figures 1, 2

1978 *Proteacidites spiniformis* Ke et Shi ex Sung et al., p. 177; Pl. 38, figs. 12-18; Pl. 60, figs. 3, 5, 6.

Remarks. The brevitricolporate nature of this species is clearly shown in the original illustrations and excludes it from *Proteacidites* Cookson ex Couper as emended by Martin and Harris (1975, p. 109). *Diervilla echinata* Piel from the Oligocene of British Columbia is similar but larger.

Distribution. Rare in the Arnak Member, Kugmallit Formation. Oligocene of northeast China (Sung et al., 1978).

Range. Oligocene.

Genus *Striacolporites* Sah and Kar, 1970

Type species. *Striacolporites striatus* Sah and Kar, 1970

Striacolporites sp. A

Plate 10, figure 5

Description. Pollen grain prolate, tricolporate. Exine 0.75 µm thick with striato-reticulate sculpture. Muri and lumina less than 0.25 µm wide and developed on outer sexinal surface. Sexine thicker than nexine. Colpi about 3/4 length of grain, 1 µm wide. Pores lalongate, 3 µm wide, 2 µm long. Aperture membranes scabrate.

Dimensions. (1 specimen). Equatorial diameter 22 µm; length 26 µm.

Distribution. Rare at the top of the Arnak Member, Kugmallit Formation.

Range. Oligocene.

Genus *Ericipites* Wodehouse, 1933

Type species. *Ericipites longisulcatus* Wodehouse, 1933

Ericipites compactipolliniatus (Traverse) comb. nov.

Plate 10, figures 6, 7

1955 *Vaccinium compactipolliniatum* Traverse, p. 69, figs. 12-116.

Distribution. Common in the Mackenzie Bay Formation and in the Arnak Member, Kugmallit Formation. Rare occurrences below this, may be due to caving. Upper Oligocene, Vermont (Travers, 1955).

Range. Oligocene (possibly Upper Eocene).

Ericipites antecursoroides sp. nov.

Plate 10, figures 8-13

Holotype. GSC 68087; Slide P-2154-44b; 16.1 x 98.8; Richards Formation, Imperial Nuktak C-22 well; GSC loc. C-48831/9000-9100; depth 9000-9100 feet (2743.2-2773.7 m).

Diagnosis. Tricolporate pollen in obligate tetrahedral tetrads. Exine levigate, up to 3 µm thick. Colpi slit-like, visible with difficulty. Grains compressed in the tetrad giving it a triangular outline.

Description. Tetrads usually strongly triangular in outline with only slight indentation between the grains. Grains tightly compressed in the tetrad with angular proximal contacts between grains and strongly rounded distal poles Nexine about 1 µm thick and may be separated in places from the sexine giving a distinctive "lined" appearance to the tetrad. Levigate exine may be slightly undulose and may be ornamented with irregular short furrows or fovea. Apertures not always visible. Colpi very narrow, about 10 µm long. Pores are presumed to lie between the contacts of the grain but not observed.

Dimensions. Overall tetrad diameter 18-32 µm (holotype 24 µm). Equatorial diameter of individual grains 13-20 µm (holotype 15 µm).

Remarks. Distinguished from *Tetradopollenites ericeus* (Potonié) Thomson and Pflug by smaller size, levigate exine, stronger compression of grains in the tetrad, and relatively thicker exine.

Distribution. Common in the middle part of the Richards Formation.

Range. Eocene.

Subturma Ptychopolyporines Naumova emend. Potonié

Genus *Polybrevicolporites* Venkatachala and Kar, 1969

Type species. *Polybrevicolporites cephalus* Venkatachala and Kar, 1969

Polybrevicolporites sp. A

Plate 10, figures 15, 16

Description. Pollen 5-brevicolporate, angulaperturate, annulate. Exine 0.5 µm thick, punctuate, columellate. Sexine thickening up to 2 µm around colpi, thickenings extending meridionally beyond colpi. Nexine 0.25 µm thick, separating from sexine and forming a small vestibulum at the apertures. Colpi 0.5 µm wide and 2-3 µm long. Endopores lalongate, of similar dimensions to colpi but oriented at right angles to them.

Dimensions. Equatorial diameter 24 µm (one specimen).

Distribution. A single occurrence in the lower part of the Ivik Member, Kugmallit Formation.

Range. Upper Eocene or Lower Oligocene.

Turma Poroses Naumova emend. Potonié

Subturma Monoporines Naumova

Genus *Sparganiaceaepollenites* Thiergart, 1937

Type species. *Sparganiaceaepollenites polygonalis* Thiergart, 1937

Sparganiaceaepollenites neogenicus Krutzsch

Plate 10, figures 14, 17

1970 *Sparganiaceaepollenites neogenicus* Krutzsch, p. 82; Pl. 13, figs. 1-13.

Distribution. Rare in the lowest part of the Mackenzie Bay Formation and in the Arnak Member, Kugmallit Formation. Lower Oligocene to Middle Miocene, Europe (Krutzsch, 1970).

Range. Lower Oligocene to Middle Miocene.

Genus *Graminidites* Cookson 1947 ex Potonié, 1960

Type species. *Graminidites media* Cookson ex Potonié, 1960

Graminidites sp. A

Plate 10, figures 18, 19

1978 *Graminidites* sp., Sung et al., p. 150; Pl. 55, fig. 20.

Distribution. Rare in the upper part of the Kugmallit Formation and the Nuktak Formation. Oligocene, northeast China (Sung et al., 1978).

Range. Oligocene to Pliocene.

Subturma Triporines Naumova emend. Potonié

Genus *Annutriporites* Gonzalez Guzman, 1967

Type species. *Annutriporites iversenii* (van der Hammen) ex Gonzalez Guzman, 1967

Annutriporites tripollenites (Rouse) comb. nov.

Plate 10, figures 20-23

1962 *Corylus tripollenites* Rouse, p. 202; Pl. 2, figs. 11, 12, 15, 17.

1978 *Momipites coryloides* Sung et al., auct. non Wodehouse, p. 110.

Remarks. This species is characterized by an annulus up to 1.5 µm thick and about 5 µm in diameter. No atrium is present, a feature described by Nichols (1973) as characterizing *Momipites coryloides* Wodehouse. Rouse (1962) discussed the possibility of conspecificity between *A. tripollenites* and *M. coryloides* and noted only a difference in size range. His illustrations, however, indicate that *tripollenites* is annulate but not atriate, thus clearly placing it outside the circumscription of *Momipites*. Specimens of *M. coryloides* illustrated by Sung et al. (1978) also appear to be non-atriate but clearly annulate.

Distribution. Common in the Kugmallit and Richards formations. Eocene of British Columbia. Eocene to Oligocene of northeast China (Sung et al., 1978).

Range. Eocene to Oligocene.

Annutriporites sp. A

Plate 10, figures 24-27

Description. Pollen grains triporate, oblate, with rounded, triangular amb. Exine levigate to scabrate, less than 0.5 µm thick, except where thickened up to 1.5 µm as annuli around pores which protrude as aspides. Pores circular, 0.5 µm diameter, indenting the amb. Equatorial diameter 15-21 µm.

Distribution. Common in the lower part of the Richards Formation.

Range. Eocene.

Genus *Momipites* Wodehouse emend. Nichols, 1973

Type species. *Momipites coryloides* Wodehouse, 1933

Momipites tenuipolus Anderson

Plate 10, figures 28, 29

1960 *Momipites tenuipolus* Anderson, p. 25; Pl. 7, fig. 14; Pl. 8, figs. 14, 15.

1971 *Maceopolipollenites tenuipolus* (Anderson) Leffingwell, p. 31.

1971 *Engelhardtia* sp. cf. *E. chrysolepis* Hance, Piel, p. 1909.

Distribution. Rare in the Arnak Member, Kugmallit Formation. Paleocene of U.S. western interior (Anderson, 1960; Leffingwell, 1971); Eocene and Oligocene of British Columbia (Hopkins, 1969; Piel, 1971).

Range. Paleocene to Oligocene.

Genus *Myricipites* Wodehouse, 1933

Type species. *Myricipites dubius* Wodehouse, 1933

Myricipites annulites (Martin and Rouse) comb. nov.

Plate 10, figures 30, 34

1966 *Myrica annulites* Martin and Rouse, p. 195, figs. 91, 92.

Distribution. Rare in the Arnak Member, and in the Kugmallit and Mackenzie Bay formations. Eocene and Oligocene, British Columbia (Martin and Rouse, 1966; Hopkins, 1969; Piel, 1971).

Range. Eocene to Oligocene.

Genus *Carpinipites* Srivastava, 1966

Type species. *Carpinipites ancipites* (Wodehouse) Srivastava, 1966

Carpinipites sp. cf. *Carpinipites spackmaniana* (Traverse) Zhou

Plate 10, figures 31-33

1955 (cf.) *Engelhardtia spackmaniana* Traverse, p. 44; Fig. 9 (27).

1970 (cf.) *Triporopollenites spackmanii* (Traverse) Kedves, p. 86.

1975 (cf.) *Carpinipites spackmanii* (Traverse) Zhou, Pl. 34, fig. 13, fide Sung et al., 1978, p. 109.

Description. Similar to *Carpinipites spackmaniana* (Traverse) Zhou but with a thinner exine (approx. 1 µm) which is levigate or finely scabrate (not papillate sensu Traverse, 1955).

Distribution. Common in the lower part of the Mackenzie Bay Formation and in the Arnak Member of the Kugmallit Formation. Sporadic in the lower part of the Kugmallit Formation and Richards Formation.

Range. Eocene to Miocene.

Genus *Ostryoipollenites* Potonié ex Potonié, 1960

Type species. *Ostryoipollenites rhenanus* (Thomson) Potonié ex Potonié, 1960.

Ostryoipollenites sp. cf. *O. rhenanus* (Thomas) Potonié ex Potonié

Plate 10, figures 35-37

1950 (cf.) *Ostrya* (?) - *Pollenites granifer rhenanus* Thomson in Potonié, Thomson and Thiergart, p. 52; Pl. B, fig. 10.

1951 (cf.) *Ostryoipollenites rhenanus* (Thomson) Potonié, p. 91 (nom. nud.).

1953 (cf.) *Triporopollenites rhenanus* (Thomson) Thomson and Pflug, p. 84.

1960 (cf.) *Ostryoipollenites rhenanus* (Thomson) Potonié ex Potonié, p. 116.

Remarks. A weak annulus may be developed in some specimens. The exine is slightly thinner (0.5-1.0 µm) than in *P. rhenanus* (Thomson) Potonié ex Potonié and may show a scabrate or subgranular ornament partly related to weak columellate structure and partly to supra-tegillar sculpture.

Distribution. Sporadic in the Arnak Member, Kugmallit Formation.

Range. Oligocene.

Corsinipollenites Nakoman, 1965

1967 (syn.) *Jussitriporites* Gonzales Guzman

Type species. *Corsinipollenites oculusnoctis* (Thiergart) Nakoman, 1965

Corsinipollenites triangulatus (Zaklinskaya) Ke et Shi ex Sung et al.

Plate 10, figures 54-56

1956 *Chamaenerites triangula* Zaklinskaya, Pl. 17, figs. 1-4.

1971 *Jussiaea* sp. Piel, p. 1914, figs. 152, 153.

1978 *Corsinipollenites triangulus* Ke et Shi ex Sung et al., p. 139.

Distribution. Rare in the Nuktak and Kugmallit formations. Previously recorded from the Oligocene of British Columbia (Piel, 1971), and Oligocene of northeast China (Sung et al., 1978). The occurrence in the Nuktak Formation may be the result of recycling.

Range. Oligocene to (?) Pliocene.

Genus *Trivestibulopollenites* Pflug in Thomson and Pflug, 1953

syn. *Betulaceoipollenites* Potonié ex Potonié, 1960.

Type species. *Trivestibulopollenites betuloides* Pflug in Thomson and Pflug, 1953

Trivestibulopollenites betuloides Pflug, in Thomson and Pflug

Plate 10, figures 38-42

1953 *Trivestibulopollenites betuloides* Pflug in Thomson and Pflug, p. 85; Pl. 9, figs. 25-34.

Distribution. Common in the Arnak member, Kugmallit Formation, and in the Mackenzie Bay and Nuktak formations. European Tertiary, becoming abundant in the Pliocene (Thomson and Pflug, 1953).

Range. Paleogene and Neogene.

Trivestibulopollenites claripites (Wodehouse) comb. nov.

Plate 10, figures 47-49

1933 *Betula claripites* Wodehouse, p. 509; Fig. 41.

Distribution. Common in the Nuktak and Mackenzie Bay formations, less common to rare in the Kugmallit and Richards formations.

Range. Eocene to Pliocene.

Remarks. *T. claripites* (Wodehouse) comb. nov. is distinguished from *T. betuloides* Pflug in possessing a triangular outline, a thicker lightly sculptured exine and small endopore. *Betula infrequens* Stanley is similar but appears to have a stronger sculpture on the exine and a more robust annulus.

Genus *Intratriporopollenites* Pflug and Thomson in Thomson and Pflug, 1953

Type species. *Intratriporopollenites instructus* (Potonié) Thomson and Pflug, 1953

Remarks on the genus. *Intratriporopollenites* is a synonym of *Tiliaepollenites* Potonié, 1931. The latter genus, however, is based on a recent pollen grain of *Tilia* and is, therefore,itself a junior synomym of *Tilia* (Krutzsch 1961, p. 312). *Tiliapollenites* Raatz, 1938, was not provided with a generic diagnosis and is an obligate junior synomym of *Intratriporopollenites* because of the identical type species. *Intratriporopollenites* is, therefore, the earliest available valid published name for dispersed pollen of tiliaceous aspect.

Intratriporopollenites crassipites (Wodehouse) comb. nov.

Plate 10, figures 43-45, 50

1933 *Tilia crassipites* Wodehouse, p. 515; Fig. 48.

1971 *Tilia crassipites* Wodehouse, in Piel (expanded description), p. 1914; Fig. 127.

1978 *Tiliaepollenites microreticulatus* (Mai) Ke et Shi ex Sung et al., p. 136; Pl. 46, figs. 24, 25.

Distribution. Sporadic in the Kugmallit and Richards formations (more common in the lower part of the Richards Formation than in the higher part) Eocene of U.S. western interior (Wodehouse, 1933); Oligocene of British Columbia (Piel, 1971); Oligocene of northeast China (Sung et al,, 1978).

Range. Eocene to Oligocene.

Intratriporopollenites minimus Mai

Plate 10, figures 51, 52

1962 *Intratriporopollenites minimus* Mai, p. 65; Pl. 10, figs. 10-15.

1978 *Tiliaepollenites minimus* Wang in Sung et al., p. 136.

Distribution. Sporadic in the lower part of the Richards Formation. Eocene to Oligocene of northeast China (Sung et al., 1978). Middle Tertiary of Europe.

Range. Eocene to Oligocene.

Genus *Caryapollenites* Raatz ex Potonié 1960 emend. Krutzsch, 1961

Type species. *Caryapollenites simplex* (Potonié) Raatz, 1937

Caryapollenites veripites (Wilson and Webster) Nichols and Ott

Plate 10, figure 58

1946 *Carya veripites* Wilson and Webster, p. 276; Fig. 14.

1978 *Caryapollenites veripites* (Wilson and Webster) Nichols and Ott, p. 106.

Distribution. Sporadic in the lower part of the Richards Formation. Paleocene of Wyoming and Montana (Nichols and Ott, 1978). Lower Eocene to Lower Oligocene, south-central British Columbia; Middle Paleocene to Lower Oligocene, Arctic Canada (Rouse, 1977).

Range. Paleocene to Oligocene.

Genus *Pistillipollenites* Rouse, 1962

Type species. *Pistillipollenites mcgregorii* Rouse, 1962

Pistillipollenites mcgregorii Rouse

Plate 10, figure 57

1962 *Pistillipollenites mcgregorii* Rouse, p. 206; Pl. 1, figs. 10, 12.

Distribution. Rare in the lower part of the Richards Formation. Upper Paleocene to Middle Eocene, Canadian Arctic (Rouse, 1977). Lower to Middle Eocene, south-central British Columbia (Rouse 1977); Paleocene, Gulf of Mexico (Hedlund in Hopkins, 1969).

Range. Paleocene to Middle Eocene.

Subturma Polyporines Naumova emend. Potonié

Infraturma Stephanoporiti van der Hammen

Genus *Polyvestibulopollenites* Pflug in Thomson and Pflug, 1953

syn. *Alnipollenites* Potonié ex Potonié *Alnuspollenites* Raatz

Type species. *Polyvestibulopollenites verus* (Potonié) Thomson and Pflug, 1953

Polyvestibulopollenites verus (Potonié) Thomson and Pflug

Plate 11, figures 3, 4

1931 *Pollenites verus* Potonié, p. 332; Pl. 2, fig. 40.

1953 *Polyvestibulopollenites verus* (Potonié), Thomson and Pflug, p. 90.

Distribution. Common throughout the Richards, Kugmallit, Mackenzie Bay, and Nuktak formations.

Range. Cenozoic.

Remarks. This species usually exhibits 5 pores. Stanley (1965) recognized a 4-pored taxon as *Alnus quaternaria* Stanley.

Polyvestibulopollenites trinus (Stanley) comb. nov.

Plate 10, figures 46, 53

1965 *Alnus trina* Stanley, p. 289; Pl. 43, figs. 4-6.

Occurrence. Rare in the Mackenzie Bay Formation and Arnak Member, Kugmallit Formation. Previously reported from the Paleocene of North Dakota (Stanley, 1965).

Range. Paleocene to Miocene.

Genus *Polyatriopollenites* Pflug, 1953

Type species. *Polyatriopollenites stellatus* (Potonié) Pflug, 1953

syn. *Pterocaryapollenites* Raatz ex Potonié, 1960

Polyatriopollenites stellatus (Potonié) Pflug

Plate 11, figures 5-7

1931 *Pollenites stellatus* Potonié, p. 28, Pl. 2.

1938 *Pterocaryapollenites stellatus* (Potonié) Raatz, p. 18.

1953 *Polyatriopollenites stellatus* (Potonié) Pflug, p. 115.

1966 *Pterocarya stellatus* (Potonié) Martin and Rouse, p. 196.

Distribution. Common in the lower part of the Ivik Member, Kugmallit Formation and lower part of the Richards Formation, sporadic in the Arnak Member, Kugmallit Formation. Eocene, Oligocene, Miocene and Pliocene of British Columbia (Martin and Rouse, 1966; Hopkins, 1969; Piel, 1971). Upper Eocene or Lower Oligocene, northeast China (Sung et al., 1978). Tertiary of Europe.

Range. Eocene to Pliocene.

Genus *Ulmoideipites* Anderson, 1960

Type species. *Ulmoideipites krempii* Anderson

Ulmoideipites tricostatus Anderson, 1960

Plate 11, figures 1, 2

1960 *Ulmoideipites tricostatus* Anderson, p. 21; Pl. 4, figs. 9-11; Pl. 6, figs. 4, 5; Pl. 7, fig. 8; Pl. 8, figs. 8, 9.

Distribution. Sporadic in the Arnak Member, Kugmallit Formation. Paleocene, New Mexico (Anderson, 1960). Eocene to Oligocene, northeast China (Sung et al., 1978.

Range. Paleocene to Oligocene.

Genus *Ulmipollenites* Wolff, 1934

Type species. *Ulmipollenites undulosus* Wolff, 1934

Ulmipollenites undulosus Wolff

Plate 11, figures 8, 9

1934 *Ulmipollenites undulosus* Wolff, p. 75; Pl. 5, fig. 25.

1953 *Polyporopollenites undulosus* (Wolff) Thomson and Pflug, p. 90.

Distribution. Sporadic in the Mackenzie Bay and Kugmallit formations; rare in the Richards Formation. Middle and upper Tertiary, Europe (Thomson and Pflug, 1953).

Range. Eocene to Miocene or younger.

Infraturma Periporiti van der Hammen emend. Potonié

Genus *Chenopodipollis* Krutzsch, 1966

Type species. *Chenopodipollis multiplex* (Weyland and Pflug) Krutzsch, 1966

Chenopodipollis nuktakensis sp. nov.

Plate 11, figures 10-12

Holotype. GSC 68140; Slide P-2154-22b, 46.1 x 105.5; Nuktak Formation, Imperial Nuktak C-22 well; GSC loc. C-48831/4100-4200; depth 4100-4200 feet (1249.7-1280.2 m).

Diagnosis. Pollen periporate, aproximately 20 µm in diameter. Pores circular, scabrate, approximately 15 in number. Exine thick, columellate.

Description. Pores circular, 2-3 µm in diameter, with a scabrate pore membrane, spaced up to 5 µm apart. Nexine 0.25 µm thick. Sexine 1-2 µm thick, densely columellate (less dense immediately above nexine), markedly thinned over pores, infrapunctuate in surface view.

Dimensions. Equatorial diameter 16-24 µm (holotype 19 µm).

Distribution. Sporadically distributed in the upper part of the Nuktak Formation and lower part of the Mackenzie Bay Formation. Rare lower occurrences may be the result of caving.

Range. Miocene to Pliocene.

Chenopodipollis sp. A

Plate 11, figures 13-16

Description. Pollen periporate; pores circular, 1 µm in diameter, spaced approximately 1 µm apart, in excess of 50 in number. Exine 0.5-1.0 µm thick, no stratification visible, levigate or very finely scabrate.

Dimension. 15-17 µm in equatorial diameter.

Distribution. Rare in the lower part of the Nuktak Formation and in the Mackenzie Bay Formation.

Range. Miocene to Pliocene.

Chenopodipollis sp. B.

Plate 11, figures 17-19

Description. Pollen periporate; pores circular, 0.5-1 µm in diameter, spaced approximately 3 µm apart, approximately 30 in number. Exine 2 µm thick, levigate, with very thin nexine visible.

Dimensions. 14-16 µm in equatorial diameter.

Distribution. Rare in the lower part of the Nuktak Formation.

Range. Pliocene.

Dinoflagellate cyst taxonomy

The comprehensive works by Lentin and Williams (1977) and Stover and Evitt (1978) on dinoflagellate genera and species have been used as a nomenclatural and conceptual base. The supra-generic classification of dinoflagellate cysts summarized in Artzner et al. (1979) has been used at the family and higher levels. Citations of literature relevant to dinoflagellate taxa may be found in the above works. Bujak and Davies' (1983) revision of the sub-order Peridiniinae has been followed.

Terminology generally follows that advocated in Norris (1978) with supplementary terms defined in Williams et al. (1978), Stover and Evitt (1978), and Artzner et al. (1979).

Division PYRRHOPHYTA Pascher

Class DINOPHYCEAE Fritsch

Order PERIDINIALES Haeckel

Suborder GONYAULACYSTINEAE Norris

Family CORDOSPHAERIDIACEAE Sarjeant and Downie emend. Norris

Genus *Cordosphaeridium* Eisenack emend. Davey, 1969

Type species. *Cordosphaeridium inodes* (Klumpp) Eisenack, 1963

Cordosphaeridium gracile (Eisenack) Davey and Williams.

Plate 11, figure 21

1938 (cf.) *Hystrichosphaera ramosa* (Ehr.) Eisenack, p. 186; Text-fig. 1.

1954 *Hystrichosphaeridium inodes* var. *gracile* Eisenack, p. 66; Pl. 3, fig. 17; Pl. 10, figs. 3-8; Pl. 12, figs.7, 21.

1963 *Cordosphaeridium inodes* subsp. *gracile* (Eisenack) Eisenack, p. 261.

1966 *Cordosphaeridium gracilis* (sic.) (Eisenack) Davey and Williams in Davey et al., p. 84.

1977 *Cordosphaeridium gracile* (Eisenack) Davey and Williams, Lentin and Williams, p. 32.

Distribution. Sporadic in the lower part of the Richards Formation. Eocene of England (Davey et al., 1966; Eaton, 1976). Lower Oligocene, Germany (Eisenack, 1954; Gerlach, 1961). Upper Paleocene and Eocene, offshore eastern Canada (Williams, 1975).

Range. Upper Paleocene to Lower Oligocene.

Suborder HYSTRICHOSPHAERIDIINEAE Norris

Family HYSTRICHOSPHAERIDIACEAE Evitt emend. Norris

Genus *Distatodinium* Eaton, 1976

Type species. *Distatodinium craterum* Eaton, 1976

Distatodinium sp. A

Plate 11, figure 20

Description. Cysts skolochorate with elongate ellipsoidal body and flattened, solid, intratabular processes with aculeate distal termination. Autophragm 1 µm thick with vesicles less than 0.25 µm in diameter, giving a spongy texture. Processes up to 25 µm long, 2-3 µm wide at base, tapering to approximately 1 µm distally, with slightly vesicular texture and faint striations along length; distal terminations 4-7 µm in diameter, aculeate, reflexed. Processes intratabular, inserted in apical, precingular, postcingular, and antapical series (none on cingulum). Details of tabulation not discernible. Main body length 89 µm, width 41 µm; total length 101 µm, total width 78 µm.

Distribution. Sporadic in the lower part of the Richards Formation.

Range. Eocene.

Remarks. Distinguished from other species of *Distatodinium* by the solid processes and vesicular autophragm. The archeopyle is not visible in *Distatodinium* sp. A.

Family AREOLIGERACEAE Evitt emend. Sarjeant and Downie

Genus *Glaphyrocysta* Stover and Evitt, 1978

Type species. *Glaphyrocysta retiintexta* (Cookson) Stover and Evitt, 1978

Glaphyrocysta ordinata (Williams and Downie) Stover and Evitt

Plate 11, figure 22; Plate 12, figure 1

1966 *Cyclonephelium ordinatum* Williams and Downie in Davey et al., p. 225; Pl. 25, fig. 3; Text-fig. 62.

1978 *Glaphyrocysta ordinata* (Williams and Downie in Davey et al.) Stover and Evitt, p. 50.

Distribution. Common in the lower part of the Richards Formation. Eocene, England (Davey et al., 1966). Middle-Upper Eocene, Scotian Shelf, Grand Banks, Labrador Shelf (Williams, 1975; Gradstein and Williams, 1976).

Range. Eocene.

Family SENONIASPHAERACEAE Norris, 1978

Genus *Senoniasphaera* Clarke and Verdier, 1967

Type species. *Senoniasphaera protrusa* Clarke and Verdier, 1967

Senoniasphaera sp. A

Plate 11, figures 23, 24; Plate 12, figures 2-4

Description. Cysts proximate, bicavate, with prominent apical and two antapical horns and (tA) archeopyle. Periphragm less than 0.25 µm thick, levigate to scabrate; endophragm less than 0.25 µm thick. Apical horn 10-12 µm long; antapical horns 12-16 µm long, equal in length, about 10 µm wide at base, separated by a deep cleft which reaches or almost reaches to the endocyst. Cingulum 3-4 µm wide, faintly marked by narrow ridges, slightly indented. Archeopyle margin a fastigiate suture. Details of tabulation uncertain, presumably gonyaulacacean. Total length 44-67 µm; width 33-48 µm. Logogram: Pc; ap 2aa; (tA); abs; pcin; (?) gon.

Distribution. Rare in the lowest part of the Richards Formation.

Range. Eocene.

Suborder PERIDINIINAE Fott emend. Bujak and Davies

Family DEFLANDREACEAE Eisenack emend. Bujak and Davies

Subfamily DEFLANDREOIDEAE Bujak and Davies

Genus *Spinidinium* Cookson and Eisenack emend. Lentin and Williams, 1976

Type species. *Spinidinium styloniferum* Cookson and Eisenack, 1962

Spinidinium sp. cf. *S. sagittulum* (Drugg) Lentin and Williams

Plate 12, figures 5, 7-9

1970 (cf.) *Deflandrea sagittula* Drugg, p. 809; Fig. 1A-C.

1976 (cf.) *Spinidinium sagittulum* (Drugg) Lentin and Williams, p. 64.

1976 *Pseudodeflandrea* sp. cf. *sagittula* Drugg, Staplin, p. 128; Pl. 1, figs. 8, 12.

Description. Cysts apteate, cornucavate, with prominent apical and two antapical horns and nontabular spines on the periphragm. Spine 0.5 µm in diameter, 1 µm long, spaced irregularly 1-5 µm apart. Apical horn about 8 µm long, 5 µm wide at base; antapical horns 13-16 µm long, slightly unequal in development. Cingulum helicoid, 3 µm wide, flanked by well developed sutural ridges 1 µm wide and 1-2 µm high. periphragm and endophragm total 0.25-0.5 µm in thickness. Archeopyle not discernible, presumably intercalary. Total length 77 µm; width 41 µm. Logogram: Ap; ap 2aa; (?)I; non; (?)per.

Distribution. Rare in the lower part of the Richards Formation. Paleogene Zone T-2, Mackenzie Delta (Staplin, 1976).

Range. Eocene.

Remarks. Distinguished from *Spinidinium sagittulum* (Drugg) Lentin and Williams by smaller size and pointed shorter processes.

Genus *Maduradinium* Cookson and Eisenack, 1970

Type species. *Maduradinium pentagonum* Cookson and Eisenack, 1970

Maduradinium turpis sp. nov.

Plate 13, figure 7; Plate 14, figures 1-4

Holotype. GSC 68167; Slide P-2154-73b, 24.0 x 104.8; Richards Formation, Imperial Nuktak C-22 well; GSC loc. C-48831/12 600-12 650; depth 12 600-12 650 feet (3840.5-3855.7 m).

Diagnosis. Cysts proximate with a short apical and two antapical horns. Autophragm with dense nontabular foveae on the inner surface passing into fossulae in the cardinal positions and along the cingulum. Archeopyle I. Logogram: Pa; ap 2aa; I; non; per.

Description. Apical horn 2-3 µm long; antapical horns up to 6 µm long but the left horn strongly reduced. Autophragm 0.5 µm thick except on the apical horn where it is 1 µm thick. Inner surface of autophragm with randomly distributed foveae up to 0.25 µm in diameter and spaced 0.25-1 µm apart. Outer surface of autophragm with very sparsely distributed tiny granules. Internal foveae larger and coalescent into fosulae beneath the horns and along the cingulum. Cingulum 4-6 µm wide, slightly raised and flanked by 1 µm high ridges. Archeopyle intercalary, probably standard hexa 2a, but otherwise no indication of tabulation.

Dimensions. Total length 43-65 µm; width 41-58 µm.

Holotype. 65 µm long; 58 µm.

Distribution. Common in the lowest part of the Richards Formation.

Range. Eocene.

Remarks. Stover and Evitt (1978) doubt the validity of *Maduradinium*, particularly the taxonomically dubious criterion of a "readily detachable apical horn" cited by Cookson and Eisenack (1970). The differentially thickened autophragm, however, distinguishes this genus from *Lejeunecysta* which it resembles in some aspects.

Maduradinium turpis sp nov. is distinguished from *Maduradinium spatiosum* (Morgenroth) Lentin and Williams by the internally foveolate autophragm and generally smaller dimensions.

Subfamily PALAEOPERIDINIOIDEAE (Vozzhenikova) Bujak and Davies

Genus *Palaeoperidinium* Deflandre emend Lentin and Williams, 1976

Type species. *Palaeoperidinium pyrophorum* (Ehrenberg) Deflandre emend. Sarjeant, 1967

Palaeoperidinium ariadnae sp. nov.

Plate 12, figures 10-12; Plate 13, figures 1-4

Holotype. GSC 68162; Slide P-2154-54f, 27.1 x 110.9; Richards Formation, Imperial Nuktak C-22 well; GSC loc. C-48831/10 500-10 600; depth 10 500-10 600 feet (3200.4-3230.9 m).

Diagnosis. Cysts proximate, slightly cornucavate, peridinioid outline, commonly broader than long. Antapical horns of unequal length, separated by a broad concavity. Periphragm scabrate, with sutural ridges along cingulum. Transapical sutures define archeopyle type (AtI3P). Logogram Pc; ap 2aa; (AIP); sut; pcin; per.

Description. The pericoels are 5-8 µm long and are discernible only with difficulty in most specimens. Cingulum helicoid, approximately 5 µm wide, delimited by low ridges, divides cyst into larger epicyst and smaller hypocyst. Narrow quasi-tabular ridges radiate out below the apex and are approximately 5 µm in length.

Dimensions. Length 44-63 µm; width 45-65 µm.

Holotype. 44 µm x 45 µm.

Distribution. Common in the lower part of the Richards Formation.

Range. Eocene.

Remarks. Distinguished from other species of *Palaeoperidinium* by its relatively small size, relatively wider dimensions, broadly separated antapical horns, and small hypocyst.

Palaeoperidinium sp. A

Plate 13, figures 5, 6

1976 (?) Dinoflagellate sp. S-1 Staplin, p. 128; Fig. 14 (only).

Description. Cysts proximate, cornucavate, with one apical and two antapical horns and a regularly microreticulate periphragm. Archeopyle opens by a transapical suture (probably (AtIP)). Cingulum about 10 µm wide, slightly raised, bordered by an anterior sutural ridge about 1 µm wide and a more prominent posterior sutural ridge. Sulcus very wide, occupying approximately half the pericyst width, flanked by raised crests which may be folded and run from the centre of the epicyst, flare out across the hypocyst, and merge with the antapical horns. Periphragm and endophragm together total approximately 3 µm in thickness; nontabular microreticulum on periphragm comprises muri 1-2 µm wide, enclosing lumina approximately 1 µm wide and elongated along lines running from apex to antapex. Apical horn 10-15 µm long; antapical horns slightly smaller, the right antapical horn larger than the left. Cyst length (including horns) 67-84 µm; width 48-60 µm. Logogram: Pc; ap; 2aa; (AIP); non; per.

Distribution. Sporadic in the lower part of the Richards Formation. Early to Middle Eocene, Mackenzie Delta region (Staplin, 1976).

Range. Eocene.

Remarks. *Palaeoperidinium* sp. A is distinctive because of its microreticulate periphragm and also its characteristic darker brown colour compared with other dinoflagellate cysts in the same interval. Dinoflagellate S-1 illustrated by Staplin (1976) appears to be a heterogeneous group of which the specimen illustrated in his Figure 14 may be conspecific with *Palaeoperidinium* sp. A, but this cannot be confirmed without a detailed description.

Subfamily WETZELIELLOIDEAE (Vozzhenikova) Bujak and Davies

Genus *Wetzeliella* Eisenack emend. Lentin and Wiliams, 1976

Type species. *Wetzeliella articulata* Eisenack, 1938

Wetzeliella sp. cf. *W. hampdenensis* Wilson

Plate 13, figures 10, 11

1967 (cf.) *Wetzeliella hampdenensis* Wilson, p. 480; figs. 17, 19.

1976 *Wetzeliella hampdenensis* Staplin auct. non Wilson, Pl. 1, fig. 16.

1980 *Wetzeliella* sp. Ioannides and McIntyre, figs. 2, 4-9.

Description. Similar to *Wetzeliella hampdenensis* Wilson, but distinguished by the following:

(i) Overall greater dimensions (overall length 134-165 µm; overall width 130-142 µm).

(ii) Areolations of the endophragm in a zone approximately 5 µm wide at the edge of the endocyst, becoming particularly prominent beneath the horns.

(iii) The processes are apparently nontabular and are aculeate, but some appear to retain remnants of ectophragm draped over them and connecting to adjacent processes.

(iv) The hypopericyst and hypoendocyst have straight or distinctly concave sides and are relatively longer.

(v) The lateral horns project up to 25 µm from the endocyst and are relatively more slender.

Distribution. Lower part of the Richards Formation. Lower part of Paleogene Zone T2, Mackenzie Delta (Staplin, 1976). Eocene, Caribou Hills (Ioannides and McIntyre, 1980).

Remarks. The specimens illustrated by Ioannides and McIntyre (1980) are somewhat smaller and show process tabulation (N.S. Ioannides, pers. comm.).

Range. Eocene.

Subfamily PALAEOCYSTODINIOIDEAE
Bujak and Davies

Genus *Pyxidiella* Cookson and Eisenack, 1958

Type species. *Pyxidiella pandora* Cookson and Eisenack, 1958

Pyxidiella sp. A

Plate 14, figures 5-7

1976 Dinoflagellate cyst DI-264 Staplin, p. 130; Pl. 2, fig. 1.

Description. Cysts proximate, ovoidal, with a broadly rounded antapex and sharply rounded apex. Autophragm levigate to minutely subgranular, less than 0.25 µm thick, except at the apex, which is slightly thickened or bears small granules. Archeopyle type I, tending to open first at the anterior end; otherwise no sutural features. Length 80-85 µm; width 60-64 µm.

Distribution. Sporadic in the Nuktak Formation and highest Mackenzie Bay Formation. Zones T4 and upper Zone T3 (Neogene, possibly highest Paleocene), IOE Taglu G-33 Well, Mackenzie Delta (Staplin et al., 1976).

Range. Neogene, possibly highest Paleogene.

Remarks. Superficially similar to "ovoidal cysts" illustrated by Ioannides and McIntyre (1980) from the Campanian of the Caribou Hills, but *Pyxidiella* sp. A is larger and has a more sharply rounded and thickened apex. Ioannides and McIntyre (pers. comm.) suspect that this species is recycled.

Subfamily INCERTA

Genus *Dioxya* Cookson and Eisenack emend. Morgan, 1977

Type species. *Dioxya armata* Cookson and Eisenack, 1958

Dioxya (?) *pignerata* sp. nov.

Plate 14, figures 8-14

1976 Dinoflagellate sp. J-7 Staplin, p. 128; Pl. 1, fig. 11.

Holotype. GSC 68183; Slide P-2154-53b, 31.7 x 111.4; Richards Formation, Imperial Nuktak C-22 well; GSC loc. C-48831/10 300-10 400; depth 10 300-10 400 feet (3139.4-3169.9 m).

Diagnosis. Cysts apteate, ovoidal, with broadly rounded apex and antapex. Autophragm scabrate with solid, nontabular processes with narrow, sinuous shafts and recurved, cauliflorate, distal terminations. Archeopyle obscure, apparently involving apical and intercalary plates. Logogram: Ap; 0ap 0aa; AI; non; (?)per.

Description. Processes 9-11 µm long, spaced 2-5 µm apart, less than 0.25 µm wide along the entire length except for the distal terminations, which consist of a cluster of 3 or 4 granules (some granules born on a 0.25 µm long recurved stalk), with a total diameter of approximately 1 µm. Archeopyle comprises some apical and intercalary plates but its development is variable and details obscure. Cyst length 60-90 µm (excluding processes, 45-83 µm); width 53-78 µm (excluding processes 30-53 µm). Total dimensions of holotype 70 x 60 µm).

Distribution. Restricted to part of the lower Richards Formation. Paleogene, Mackenzie Delta (Staplin, 1976).

Range. Eocene.

Remarks. The processes superficially resemble the glochidia of *Azollopsis* and *Azolla* but are more delicate. The placement of this species in *Dioxya* is provisional due to the uncertain nature of the archeopyle. *Dioxya* is characterized by a standard hexa intercalary archeopyle (Morgan, 1977). *D.* (?) *pignerata* sp. nov. appears to have a combination AI archeopyle, the details of which remain uncertain.

Acritarcha

Genus *Horologinella* Cookson and Eisenack, 1962

Type species. *Horologinella lineata* Cookson and Eisenack, 1962

"*Horologinella*" sp. A

Plate 13, figures 8, 9

Description. Organic-walled microfossils, roughly hourglass-shaped, with smooth but irregulary folded wall. Constriction in equatorial region roughly keyhole-shaped, giving the terminal expansions an anchor-shaped appearance. One of the terminal expansions is slightly larger than the other. No openings in the wall discernible. Total length 48-60 µm; width of terminal expansions 41-51 µm; width of constricted equatorial zone 12-17 µm.

Distribution. Sporadic in the Kugmallit Formation.

Range. Oligocene.

Remarks. *Hologinella* is a dinoflagellate cyst; species other than the type species assigned to this genus by Cookson and Eisenack (1962) are acritarchs (Stover and Evitt, 1978, p. 53-54) and are being transferred to a new genus by Stover and Evitt. Meanwhile, "*Horologinella*" sp. A is left in open nomenclature. It differs from *H. incurvata* Cookson and Eisenack (possibly an algal aplanospore) in its larger size and anchor-shaped terminal expansions.

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1976: Geology of the Beaufort-Mackenzie Basin; Geological Survey of Canada, Paper 76-11, 65 p.

APPENDIX 1

OCCURRENCES OF MIOSPORES AND DINOFLAGELLATES

Palynomorph assemblages are described in descending order because the majority are from cutting samples, which yield reliable information only on tops of taxon ranges. Thus, the formations and zones are described as being characterized by range tops (extinction or emigration events). Less reliable information is available on bottoms of taxon range unless core samples are available. Nevertheless, certain species appear to have restricted ranges and are described with these distinctive distributions even though the exact bottom of a range is impossible to determine unequivocally from the samples available.

Nuktak Formation (0-1800 ft; 0-549 m)

This interval is characterized by an impoverished indigenous flora, although recycled Lower Tertiary, Mesozoic, and Paleozoic palynomorphs are common or dominant. The following species occur throughout the formation:

Bryophytes

Stereisporites minor

Pteridophytes

Laevigatosporites novus

Gymnosperms

Piceaepollenites grandivescipites
Pinuspollenites sp. A.
Taxodiaceaepollenites hiatus

Angiosperms

Polyvestibulopollenites verus
Trivestibulopollenites betuloides
Trivestibulopollenites claripites

The presence of *Salixpollenites discoloripites* may be the result of Paleogene recycling although this is not certain. The disjunction between the occurrences in the Nuktak Formation and other occurrences of *Salixpollenites discoloripites* lower in the Paleogene is notable. A single occurrence of *Corsinipollenites triangulatus* was noted at 400 feet (122 m).

Between 600 and 1800 feet (183-548.6 m) in the Nuktak Formation, the following species occur:

Fungi

Fractisporonites sp. cf. *F. canalis*
Fungal hyphae type A
Fungal hyphae type C
Rhizophagites cerasiformis

Bryophytes

Stereisporites stereoides

Pteriodophytes

Echinatisporis sp. A

Angiosperms

Chenopodipollis nuktakensis
Chenopodipollis sp. A
Chenopodipollis sp. B
Graminidites sp. A
Sigmopollis psilatus

The lowest 400 feet (122 m) of the Nuktak Formation contains *Pyxidiella* sp. A, a presumed marine dinoflagellate.

Mackenzie Bay Formation (1800-3150 ft; 549-960 m)

Recycled material is common in this formation but a greater variety of indigenous spores and pollen is present. The following occur throughout the Mackenzie Bay Formation:

Bryophytes

Stereisporites microgranulus
Stereisporites minor
Stereisporites stereoides

Pteridophytes

Baculatisporites comaumensis
Laevigatosporites novus

Gymnosperms

Piceaepollenites grandivescipites
Pinuspollenites sp. A
Taxodiaceaepollenites hiatus
Tsugaepollenites igniculus

Angiosperms

Chenopodipollis nuktakensis
Chenopodipollis sp. A.
Myricipites annulites
Polyvestibulopollenites trinus
Polyvestibulopollenites verus
Sigmopollis psilatus
Trivestibulopollenites betuloides
Trivestibulopollenites claripites

The lower half of the Mackenzie Bay Formation contains, in addition, the following species:

Fungi

Fungal hyphae type B

Pteriodphytes

Cyathidites minor
Deltoidspora hallii
Laevigatosporites ovatus
Osmundacidites wellmanii
Retitriletes annotinioides
Retitriletes sp. cf. *R. oligocenicus*

Gymnosperms

Tsugaepollenites viridifluminipites

Angiosperms

Carpinipites sp. cf. *C. spackmaniana*
Ulmipollenites undulosus
No dinoflagellates are present in the Mackenzie Bay Formation.

The presence at 2400 feet (731 m) of *Ericipites compactipollinatus* and *Baculatisporites crassiprimarius* is interpreted as being due to recycling, because a stratigraphic disjunction of at least 600 feet (183 m) exists between these high occurrences and the main part of their ranges below the Paleogene-Neogene unconformity at 3000 feet (914 m).

Between 2800 feet (853 m) and the bottom of the Mackenzie Bay Formation, the following species occur and may be connected with palynofloral assemblages from the underlying Kugmallit Formation, viz. the unconformity and base of the Mackenzie Bay Formation may occur at 2800 feet (853 m) and not at 3150 feet (960 m) as indicated by Young and McNeil (1984).

Fungi

Dicellaesporites popovii
Fungal hyphae type B
Monoporisporites singularis

Pteridophytes

Cyathidites minor

Gymnosperms

Sequoiapollenites polyformosus

Angiosperms

Cupuliferoipollenites oviformis
Ericipites compactipollinatus
Intratriporopollenites crassipites
Ostryoipollenites sp. cf. *O. rhenanus*
Polyatriopollenites stellatus
Sparganiaceaepollenites neogenicus

Kugmallit Formation

(a) Arnak Member (3150-5010 ft; 960-1527 m)

The following species range down from higher intervals as substantiated by occurrences in sidewall cores taken between 4310 and 4745 feet (1314 and 1446 m).

Bryophytes

Stereisporites minor
Stereisporites stereoides

Pteridophytes

Cyathidites minor
Laevigatosporites ovatus
Osmundacidites wellmanii
Retitriletes sp. cf. *R. oligocenicus*

Gymnosperms

Pinuspollenites sp. A
Taxodiaceaepollenites hiatus
Tsugaepollenites viridifluminipites

Angiosperms

Carpinipites sp. cf. *C. spackmaniana*
Ericipites compactipollinatus
Intratriporopollenites crassipites
Polyatriopollenites stellatus
Polyvestibulopollenites verus
Sigmopollis psilatus
Trivestibulopollenites claripites
Ulmipollenites undulosus

The species below also occur in the Arnak Member and higher, but have not been recorded in Arnak core samples:

Fungi

Fractisporonites sp. cf. *F. canalis*
Fungal hyphae type A
Fungal hyphae type C
Monoporisportes singularis

Bryophytes

Stereisporites microgranulus

Pteridophytes

Baculatisporites comaumensis
Baculatisporites crassiprimarius
Deltoidospora hallii
Retitriletes annotinioides

Angiosperms

Myricipites annulites
Ostryoipollenites sp. cf. *O. rhenanus*
Polyvestibulopollenites trinus
Sparganiaceaepollenites neogenicus

The following species do not range above the top of the Arnak Member (except for possible recycling in the Neogene as indicated) and have range tops within 500 feet (152 m) of the Neogene unconformity [above 3500 feet (1067 m)]:

Fungi

Baculatisporites crassiprimarius (possibly recycled above)
Baculatisporites quintus
Biretisporites potoniaei

Gymnosperms

Pinuspollenites labdacus

Angiosperms

Annutriporites tripollenites
Ericipites compactipollinatus (possibly recycled above)
Lonicerapollis spiniformis
Ostryoipollenites sp. cf. *O. rhenanus*
Quercoidites microhenrica
Salixpollenites discoloripites (possibly recycled above)
Sparganiaceaepollenites neogenicus
Striacolporites sp. A
Tricolpite hians
Ulmoideipites tricostatus

The following species show progressively restricted ranges downwards through the lower part of the Arnak Member, below 3500 feet (1067 m):

Fungi

Centonites sp. A
Diporicellaesporites bellulus
Diporisporites communis
Dyadosporites sp. cf. *D. schwabii*
Fungal hyphae type D
Fungal hyphae type E
Fungal hyphae type F
Inapertisporites circularis
Monoporisporites sp. cf. *M. cupuliformis*
Monoporisporites sp. A
Multicellaesporites margaritus
"*Multicellaesporites*" sp. A.
Plochmopeltinites masonii
Reduviasporonites sp. cf. *R. catenulatus*
Triporisporonites verus

Gymnosperms

Piceaepollenites sp. A

Angiosperms

Margocolporites stenosus
Momipites tenuipolus
Quercoidites sp. A.

Below 4500 feet (1372 m) in the Arnak Member the acritarch "*Hurologinella*" sp. A occurs sporadically. It may have algal affinities but its paleoecological significance is unknown, and this species appears to be endemic to this region.

(b) Ivik Member (5010-7810 feet; 1527-2380 m)

The following species range down from higher horizons into the Ivik Member as is substantiated from occurrences in sidewall core samples throughout most of this interval:

Bryophytes

Stereisporites microgranulus
Stereisporites minor

Pteridophytes

Baculatisporites comaumensis
Cyathidites minor
Laevigatosporites ovatus
Osmundacidities wellmanii

Gymnosperms

Piceaepollenites sp.
Pinuspollenites labdacus
Pinuspollenites sp. A
Taxodiaceaepollenites hiatus
Tsugaepollenites viridifluminipites

Angiosperms

Annutriporites tripollenites
Carpinipites sp. cf. *C. spackmaniana*
Cupuliferoipollenites oviformis
Ericipites compactipollinatus
Intratriporopollenites crassipites
Polyatriopollenites stellatus
Polyvestibulopollenites verus
Quercoidites microhenrica
Sigmopollis psilatus
Tricolpites hians
Ulmipollenites undulosus

Other species below also occur in the Ivik Member and higher horizons but have not been recorded from Ivik cores:

Fungi

Diporisporites communis
Fractisporonites sp. cf. *F. canalis*
Fungal hyphae type A
Fungal hyphae type C
Fungal hyphae type G
Monoporisporites sp. cf. *M. cupuliformis*
Monoporisporites sp. A
Reduviasporonites anangus
Reduviasporonites sp. cf. *R. catenulatus*
Staphlosporonites delumbus

Bryophytes

Stereisporites stereoides

Pteridophytes

Baculatisporites crassiprimarius
Biretisporites potoniaei
Deltoidospora hallii
Retitriletes sp. cf. *R. oligocenicus*

Gymnosperms

Piceaepollenites grandivescipites

Angiosperms

Trivestibulopollenites claripites

The ranges of several species terminate progressively within the Ivik Member:

Fungi

Microthyriacites sp. A
Phragmothyrites sp. cf. *P. eocaenicus*
Trichothyrites sp. A

Pteridophytes

Osmundacidites richardsii
Retitriletes sp. cf. *R. novomexicanus*

Angiosperms

Cupuliferoipollenites pusillus
Polybrevicolporites sp. A

No marine palynomorphs occur in this interval. A single occurrence of the acritarch "*Hologinella*" sp. A is recorded from core at 6867 feet (2093 m) but its environmental significance is not known.

Richards Formation (7810-12650 ft; 2380-3855.7 m)

The following species occur in the top 1000 feet (305 m) of the Richards Formation and also occur in younger formations:

Fungi

Fractisporonites sp. cf. *F. canalis*

Bryophytes

Stereisporites minor

Pteridophytes

Baculatisporites comaumensis
Cyathidites minor
Laevigatosporites ovatus
Osmundacidites wellmanii
Osmundacidites richardsii
Retitriletes sp. cf. *R. novomexicanus*
Retitriletes sp. cf. *R. oligocenicus*

Gymnosperms

Piceaepollenites sp. A
Pinuspollenites labdacus
Pinuspollenites sp. A
Taxodiaceaepollenites hiatus
Tsugaepollenites viridifluminipites

Angiosperms

Annutriporites tripollenites
Carpinipites sp. cf. *C. spackmaniana*
Cupuliferoipollenites pusillus
Polyatriopollenites stellatus
Polyatriopollenites verus
Quercoidites microhenrica
Tricolpites hians

In addition, a number of species occur commonly in the Richards Formation and younger strata at the surface, but are not known from cores in the Richards Formation:

Fungi

Fungal hyphae type C
Inapertisporites circularis
Monoporisporites sp. A
Plochmopeltinites masonii

Bryophytes

Stereisporites stereoides

Pteridophytes

Deltoidospora hallii

Gymnosperms

Piceaepollenites grandivescipites

A large number of species of spores and pollen are restricted to the Richards Formation:

Fungi

Brachysporisporites cotalis
Brachysporisporites sp. cf. *B. cotalis*
Brachysporisporites opimus
Callimothallus pertusus
Ctenosporites wolfei
Dicellaesporites obnixus
Dicellaesporites aculeolatus
Didymosporonites ovatus
Diporicellaesporites cf. *D. bellulus*
Diporicellaesporites laevigatiformis
Diporisporites sp. A
Dyadosporites sp. A
Fractisporonites sp. A
Fractisporonites sp. B
Fusiformisporites sp. A
Imprimospora tankensis
"*Inapertisporites*" sp. cf. *I. vittatus*
Inapertisporites sp. cf. *I. subovoidus*
Inapertisporites sp. A
indeterminate peltate fruiting bodies
Lacrimasporonites sp. A
Microthallites sp. cf. *M. lutosus*

Microthyrites sp. A
Monoporisporites abruptus
Multicellaesporites compactilis
Multicellaesporites sp. cf. *M. conicus*
Multicellaesporites sp. cf. *M. conspicuus*
Multicellaesporites lanceolatus
Multicellaesporites leptaleus
Pesavis tagluensis
Staphlosporonites sp. cf. *S. conoideus*
Striadiporites bistriatus
Striadiporites inflexus
Striadiporites multistriatus
Striadiporites sanctaebarbarae
(see Sepulveda and Norris, 1982 for other fungal palynomorphs occurring in the Richards Formation in the C-22 well)

Pteridophytes

Azolla sp. A
Leptolepidites sp. A
Verrucatosporites favus

Angiosperms

Annutriporites sp. A
Caryapollenites veripites
Ericipites antecursoroides
Integricorpus sp. A
Intratriporopollenites minimus
Pistillipollenites mcgregorii

Between 10 000 and 11 400 feet (3048 and 3474.7 m) two dinoflagellates - *Palaeoperidinium ariadnae* and *Dioxya* (?) *pignerata* - commonly occur together, possibly indicating restricted marine, lagoonal, or brackish conditions. Between 11 400 and 12 650 feet (TD) (3474.7 and 3855.7 m) a more diverse marine dinoflagellate assemblage is found, together with *Palaeoperidinium ariadnae* and *Dioxya* (?) *pignerata* (the latter possibly being caved from above into the top of this interval):

Cordosphaeridium gracile
Distatodinium sp. A
Glaphyrocysta ordinata
Maduradinium turpis
Palaeoperidinium sp. A
Senoniasphaera sp. A
Spinidinium sp. cf. *S. sagittulum*
Wetzelliella sp. cf. *W. hampdenensis*

APPENDIX 2

NOTES – SAMPLES AND SLIDES

Samples provided by the Institute of Sedimentary and Petroleum Geology, Calgary were prepared from cuttings at 100-foot (30.5 m) intervals, as is indicated on the paleolog, except for the following intervals: 0-100 ft (0-30.5 m); 200-300 ft (61-91 m); 300-400 ft (91-122 m); 400-500 ft (122-152 m); 500-600 ft (152-183 m); 700-800 ft (213-244 m); 1000-1100 ft (305-335 m); 1600-1700 ft (488-518 m); 2000-2100 ft (610-640 m); 2200-2300 ft (671-701 m); 2500-2600 ft (762-792 m); 2600-2700 ft (792-823 m); 2700-2800 ft (823-853 m); 2900-3000 ft (884-914 m); 3200-3300 ft (975-1006 m); 3400-3500 ft (1036-1067 m); 3700-3800 ft (1128-1158 m); 5000-5100 ft (1524-1554 m); 5200-5300 ft (1585-1615 m); 5300-5400 ft (1615-1646 m); 5500-5600 ft (1676-1707 m); 5600-5700 ft (1707-1737 m); 5700-5800 ft (1737-1768 m); 5800-5900 ft (1767-1798 m); 5900-6000 ft (1798-1829 m); 6000-6100 ft (1829-1859 m); 6200-6300 ft (1890-1920 m); 6300-6400 ft (1920-1951 m); 6400-6500 ft (1951-1981 m); 6500-6600 ft (1981-2012 m); 6600-6700 ft (2012-2042 m); 6700-6800 ft (2042-2073 m); 6800-6900 ft (2073-2103 m); 6900-7000 ft (2103-2134 m); 7000-7100 ft (2134-2164 m); 7300-7400 ft (2225-2256 m); 7400-7500 ft (2256-2286 m); 7500-7600 ft (2286-2316 m); 7700-7800 ft (2347-2377 m); 8000-8100 ft (2438-2469 m); 8400-8500 ft (2560-2591 m); 8500-8600 ft (2591-2621 m); 8600-8700 ft (2621-2652 m); 9700-9800 ft (2957-2987 m); 9800-9900 ft (2987-3018 m); 9900-10 000 ft (3018-3048 m); 10 200-10 300 ft (3109-3139 m); 10 400-10 500 ft (3170-3200 m); 10 800-10 900 ft (3292-3322 m); 11 200-11 300 ft (3414-3444 m).

These samples were prepared at the Institute of Sedimentary and Petroleum Geology, Calgary, using standard techniques, including oxidation for one to five minutes, as required. Residues were stained with safranine and sieved through 45 µm mesh sieve. Analyses were performed on unsieved residues. Secondary examination of sieved residues was performed to obtain information on particular species required in taxonomic descriptions.

Palynology slides provided by Esso Resources Canada, Ltd., Calgary, comprised set number 2 of slides labelled "7062", together with a maceration number and depth. Most of these slides were prepared from cutting samples with tops of intervals spaced 90 feet (27 m) apart starting at 30 feet (9 m) and continuing downwards, 120 feet (37 m), 210 feet (64 m), 300 feet (91 m) et seq.

Thirty-two sidewall core samples were also provided by Esso Resources Canada, Ltd., and these are indicated by a suffix "C" in the paleolog (see Fig. 7).

PLATE I

All figures 750x, interference contrast illumination.

Figures 1, 2. *"Inapertisporites"* sp. cf. *I. vittatus* Sheffy and Dilcher.

1\. GSC loc. C-48831/12 300-12 400; Slide P-2154-70f; 24 x 94.6; mid-focus; GSC 67854.

2\. GSC loc. C-48831/11 700-11 800; Slide P-2154-64b; 42.9 x 104.0; mid-focus; GSC 67855.

Figures 3, 4. *Inapertisporites circularis* Sheffy and Dilcher.

3\. GSC loc. C-48831/12 400-12 500; Slide P-2154-71f; 43.6 x 100.9; mid-focus; GSC 67856.

4\. GSC loc. C-48831/12 400-12 500; Slide P-2154-71f; 34.1 x 106.0; mid-focus; GSC 67857.

Figure 5. *Inapertisporites* sp. cf. *I. subovoideus* Sheffy and Dilcher. GSC loc. C-48831/11 900-12 000; Slide P-2154-66f; 31.4 x 113.1; mid-focus; GSC 67858.

Figures 6-8. *Monoporisporites singularis* Sheffy and Dilcher.

6\. GSC loc. C-48831/3000-3100; Slide P-2154-14f; 45.3 x 100.9; mid-focus; GSC 67859.

7\. GSC loc. C-48831/2800-2900; Slide P-2154-13f; 24.9 x 96.4; mid-focus; GSC 67860.

8\. GSC loc. C-48831/3600-3700; Slide P-2154-18f; 28.0 x 100.1; mid-focus; GSC 67861.

Figures 9, 10. *"Inapertisporites"* sp. A.

9\. GSC loc. C-48831/10 600-10 700; Slide P-2154-55f; 34.0 x 99.9; mid-focus; GSC 67862.

10\. GSC loc. C-48831/ 10 600-10 700; Slide P-2154-55f; 34.0 x 99.9; high focus; GSC 67862.

Figures 11-13. *Monoporisporites abruptus* Sheffy and Dilcher.

11\. GSC loc. C-48831/9400-9500; Slide P-2154-48f; 36.4 x 101.8; GSC 67863.

12\. GSC loc. C-48831/11 900-12 000; Slide P-2154-66f; 29.0 x 110.3; GSC 67864.

13\. GSC loc. C-48831 11 800-11 900; Slide P-2154-65b; 35.6 x 112.4; mid-focus; GSC 67865.

Figure 14. *Lacrimasporonites* sp. A. GSC loc. C-48831/9000-9100; Slide P-2154-44b; 28.5 x 98.1; mid-focus; GSC 67866.

Figure 15. *Triporisporonites verus* (Ke et Shi ex Sung et al.) comb. nov. GSC loc. C-48831/12 500-12 600; Slide P-2154-72b; 43.9 x 109.9; mid-focus; GSC 67867.

Figures 16, 17. *Monoporisporites* sp. cf. *M. cupuliformis* Sheffy and Dilcher.

16\. GSC loc. C-48831/4820-4900; Slide P-2154-29f; 18.5 x 95.6; mid-focus; GSC 67868.

17\. GSC loc. C-48831/7600-7700; Slide P-2154-36f; 44.7 x 110.4; mid-focus; GSC 67869.

Figures 18, 19. *Diporisporites communis* Ke et Shi ex Sung et al.

18\. GSC loc. C-48831/7900-8000; Slide P-2154-38f; 28.1 x 94.5; mid-focus; GSC 67870.

19\. GSC loc. C-48831/10 600-10 700; Slide P-2154-55f; 44.3 x 100.1; mid-focus; GSC 67871.

Figure 20. *Diporisporites* sp. A. GSC loc. C-48831/8300-8400; Slide P-2154-41b; 31.5 x 98.9; mid-focus; GSC 67872.

Figures 21, 22. *Monoporisporites* sp. A.

21\. GSC loc. C-48831/10 100-10 200; Slide P-2154-52f; 43.1 x 93.8; mid-focus; GSC 67873.

22\. GSC loc. C-48831/9500-9600; Slide P-2154-49b; 35.5 x 104.9; mid-focus; GSC 67874.

Figures 23-27. *Rhizophagites cerasiformis* sp. nov.

23\. GSC loc. C-48831/1400-1500; Slide P-2154-6b; 44.8 x 110.7; mid-focus; GSC 67875.

24\. GSC loc. C-48831/4100-4200; Slide P-2154-22b; 27.8 x 99.3; mid-focus; GSC 67876.

25\. Holotype. GSC loc. C-48831/600-700; Slide P-2154-2d; 32.1 x 102.5; mid-focus; GSC 67877.

26\. GSC loc. C-48831/900-1000; Slide P-2154-3g; 42.7 x 99.8; mid-focus; GSC 67878.

27\. GSC loc. C-48831/600-700; Slide P-2154-2d; 32.3 x 102.5; mid-focus; GSC 67879.

Figures 28, 29. *Striadiporites sanctaebarbarae* Elsik and Jansonius.

28\. GSC loc. C-4881/11 800-11 900; Slide P-2154-65f; 37.8 x 96.5; mid-focus; GSC 67880.

29\. GSC loc. C-48831/9000-9100; Slide P-2154-44b; 15.8 x 109.7; mid-focus; GSC 67881.

Figures 30, 31, 35. *Striadiporites inflexus* (Ke et Shi ex Sung et al.) comb. nov.

30\. GSC loc. C-48831/10 300-10 400; Slide P-2154-53f; 44.0 x 110.2;, mid-focus; GSC 67882.

31\. GSC loc. C-48831/9000-9100; Slide P-2154-44f; 30.9 x 102.5; mid-focus; GSC 67883.

35\. GSC loc. C-48831/9200-9300; Slide P-2154-46f; 27.5 x 94.2; mid-focus; GSC 67884.

Figures 32-34. *Striadiporites bistriatus* (Ke et Shi ex Sung et al.) comb. nov.

32\. GSC loc. C-48831/10 600-10 700; Slide P-2154-55f; 31.5 x 104.7; mid-focus; GSC 67885.

33\. GSC loc. C-48831/9000-9100; Slide P-2154-44g; 19.5 x 98.1; high focus; GSC 67886.

34\. GSC loc. C-48831/11 500-11 600; Slide P-2154-62b; 37.9 x 95.9; mid-focus; GSC 67887.

Figures 36, 37. *Striadiporites multistriatus* (Ke et Shi ex Sung et al.) comb. nov.

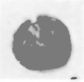
36\. GSC loc. C-48831/9200-9300; Slide P-2154-46f; 41.2 x 97.6; mid-focus; GSC 67888.

37\. GSC loc. C-48831/8900-9000; Slide P-2154-43b; 39.4 x 104.4; high focus; GSC 67889.

PLATE 1


1


2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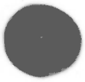
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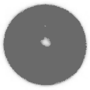
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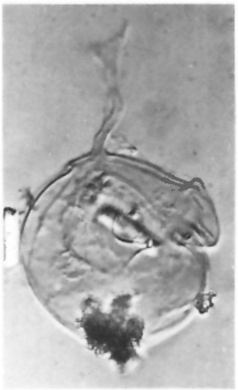
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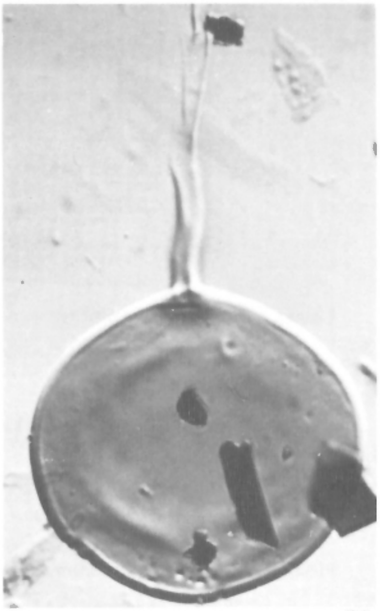
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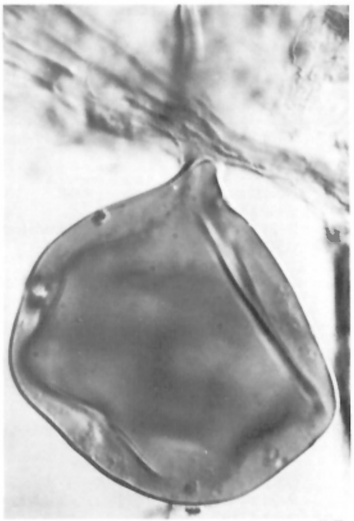
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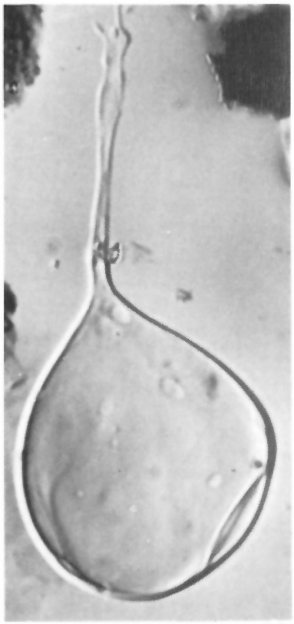
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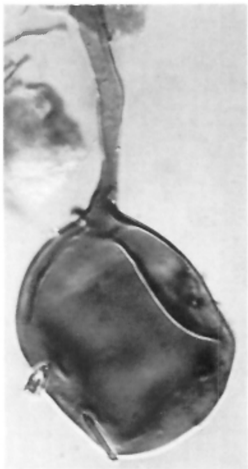
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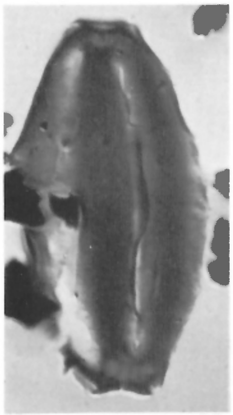
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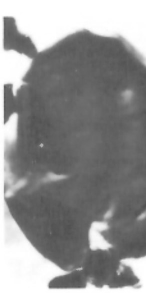
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PLATE 2

All figures 750x, interference contrast illumination.

Figures 1, 2. *Dicellaesporites popovii* Elsik.

1. GSC loc. C-48831/11 700-11 800; Slide P-2154-64f; 31.9 x 101.3; mid-focus; GSC 67890.

2. GSC loc. C-48831/12 400-12 500; Slide P-2154-71f; 35.3 x 104.5; mid-focus; GSC 67891.

Figures 3-7. *Dicellaesporites obnixus* sp. nov.

3. GSC loc. C-48831/12 400-12 500; Slide P-2154-71b; 43.4 x 97.8; mid-focus; GSC 67892.

4. GSC loc. C-48831/11 800-11 900; Slide P-2154-65b; 35.9 x 109.5; mid-focus; GSC 67893.

5. Holotype. GSC loc. C-48831/12 000-12 100; Slide P-2154-67b; 20.8 x 111.0; mid-focus; GSC 67894.

6. GSC loc. C-48831/12 400-12 500; Slide P-2154-71b; 37.4 x 94.7; mid-focus; GSC 67895.

7. GSC loc. C-48831/12 000-12 100; Slide P-2154-67b; 20.0 x 105.6; mid-focus; GSC 67896.

Figure 8. *Dicellaesporites aculeolatus* Sheffy and Dilcher.

GSC loc. C-48831/11 400-11 500; Slide P-2154-61f; 29.0 x 94.8; mid-focus; GSC 67897.

Figure 9. *Dyadosporites* sp. cf. *D. schwabii* (Elsik) comb. nov.

GSC loc. C-48831/4100-4200; Slide P-2154-22b; 38.8 x 96.8; mid-focus; GSC 67898.

Figure 10. *Fusiformisporites microstriatus* Hopkins.

GSC loc. C-48831/12 000-12 100; Slide P-2154-67f; 40.0 x 97.9; mid-focus; GSC 67899.

Figure 11. *Fusiformisporites* sp. A.

GSC loc. C-48831/11 800-11 900; Slide P-2154-65b; 41.3 x 101.6; mid-focus; GSC 67900.

Figures 12-16. *Dyadosporites oblongatus* (Ke et Shi ex Sung et al.) comb. nov.

12. GSC loc. C-48831/11 300-11 400; Slide P-2154-60f; 23.9 x 100.1; mid-focus; GSC 67901.

13. GSC loc. C-48831/9200-9300; Slide P-2154-46f; 30.2 x 106.4; mid-focus; GSC 67902.

14. GSC loc. C-48831/10 600-10 700; Slide P-2154-55b; 38.6 x 99.8; mid-focus; GSC 67903.

15. GSC loc. C-48831/11 300-13 400; Slide P-2154-60b; 23.9 x 100.1; mid-focus; GSC 67904.

16. GSC loc. C-48831/12 600-12 650; Slide P-2154-73b; 42.1 x 105.3; mid-focus; GSC 67905.

Figures 17-19. *Dyadosporites* sp. A.

17. GSC loc. C-48831/9400-9500; Slide P-2154-48f; 42.1 x 97.4; mid-focus; GSC 67906.

18. GSC loc. C-48831/9400-9500; Slide P-2154-48f; 31.9 x 93.8; mid-focus; GSC 67907.

19. GSC loc. C-48831/9300-9400; Slide P-2154-47f; 30.4 x 97.3; mid-focus; GSC 67908.

Figures 20-24. *Imprimospora tankensis* sp. nov.

20, 21. Holotype. GSC loc. C-48831/9000-9100; Slide P-2154-44b; 26.9 x 107.2; high and low focus respectively; GSC 67909.

22. GSC loc. C-48831/9200-9300; Slide P-2154-46b; 45.9 x 100.4; mid-focus; GSC 67910.

23. GSC loc. C-48831/9200-9300; Slide P-2154-46b; 27.3 x 100.1; mid-focus; GSC 67911.

24. GSC loc. C-48831/9200-9300; Slide P-2154-46g; 25.9 x 97.8; mid-focus; GSC 67912.

PLATE 2 (cont.)

Figures 25-28. *Didymosporisporonites ovatus* Ke et Shi ex Sung et al.

25. GSC loc. C-48831/9100-9200; Slide P-2154-45f; 33.5 x 100.0; mid-focus; GSC 67913.

26. GSC loc. C-48331/10 600-10 700; Slide P-2154-55f; 39.0 x 109.1; mid-focus; GSC 67914.

27. GSC loc. C-48831/10 300-10 400; Slide P-2154-53b; 40.1 x 106.8; mid-focus; GSC 67915.

28. GSC loc. C-48831/9100-9200; Slide P-2154-45f; 40.8 x 95.6; mid-focus; GSC 67916.

Figures 29-31. *Diporicellaesporites* sp. cf. *D. bellulus* Ke et Shi ex Sung et al.

29. GSC loc. C-48831/9300-9400; Slide P-2154-47f; 38.7 x 94.8; mid-focus; GSC 67917.

30. GSC loc. C-48831/11 800-11 900; Slide P-2154-65b; 25.1 x 102.4; mid-focus; GSC 67918.

31. GSC loc. C-48831/9200-9300; Slide P-2154-46g; 18.9 x 109.2; mid-focus; GSC 67919.

Figures 32-34. *Diporicellaesporites bellulus* Ke et Shi ex Sung et al.

32. GSC loc. C-48831/4000-4100; Slide P-2154-21f; 28.6 x 99.8; mid-focus; GSC 67920.

33. GSC loc. C-48831/12 600-12 650; Slide P-2154-73f; 28.9 x 93.5; mid-focus; GSC 67921.

34. GSC loc. C-48831/9200-9300; Slide P-2154-46f; 34.6 x 106.3; mid-focus; GSC 67922.

Figures 35, 42. *Diporicellaesporites laevigataeformis* Ke et Shi ex Sung et al.

35. GSC loc. C-48831/12 300-12 400; Slide P-2154-70b; 28.7 x 105.2; mid-focus; GSC 67923.

42. GSC loc. C-48831/11 700-11 800; Slide P-2154-64b; 31.1 x 102.7; mid-focus; GSC 67924.

Figures 36-39. *Reduviasporonites anangus* sp. nov.

36. Holotype. GSC loc. C-48831/3600-3700; Slide P-2154-18b; 44.5 x 102.1; mid-focus; GSC 67925.

37. GSC loc. C-48831/4700-4800; Slide P-2154-28b; 43.1 x 112.1; mid-focus; GSC 67926.

38. GSC loc. C-48831/7800-7900; Slide P-2154-37f; 12.8 x 93.5; mid-focus; GSC 67927.

39. GSC loc. C-48831/3600-3700; Slide P-2154-18b; 27.1 x 105.8; mid-focus; GSC 67928.

Figures 40, 41, 43. *Reduviasporonites* sp. cf. *R. catenulatus* Wilson.

40. GSC loc. C-48831/3600-3700; Slide P-2154-18b; 33.2 x 94.5; mid-focus; GSC 67929.

41. GSC loc. C-48831/3600-3700; Slide P-2154-18b; 40.5 x 98.5; mid-focus; GSC 67930.

43. GSC loc. C-48831/4100-4200; Slide P-2154-22f; 40.9 x 102.7; mid-focus; GSC 67931.

Figure 44. *Reduviasporonites* sp. A.

GSC loc. C-48831/3300-3400; Slide P-2154-16b; 36.4 x 108.1; mid-focus; GSC 67932.

Figures 45-47. *Brachysporisporites cotalis* (Elsik and Jansonius) comb. nov.

45. GSC loc. C-48831/11 800-11 900; Slide P-2154-65b; 28.4 x 103.4; mid-focus; GSC 67933.

46. GSC loc. C-48831/9000-9100; Slide P-2154-44b; 37.9 x 107.8; mid-focus; GSC 67934.

47. GSC loc. C-48831/12 000-12 100; Slide P-2154-67f; 33.8 x 96.5; mid-focus; GSC 67935.

Figures 48, 49. *Brachysporisporites* sp. cf. *B. cotalis* (Elsik and Jansonius) comb. nov.

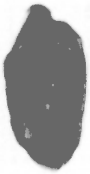
48. GSC loc. C-48831/9200-9300; Slide P-2154-46b; 29.7 x 103.7; mid-focus; GSC 67936.

49. GSC loc. C-48831/9200-9300; Slide P-2154-46g; 27.0 x 110.4; mid-focus; GSC 67937.

Figures 50, 51. *Brachysporisporites opimus* (Elsik and Jansonius) comb. nov.

50. GSC loc. C-48831/12 500-12 600; Slide P-2154-72b; 26.6 x 104.4; mid-focus; GSC 67938.

51. GSC loc. C-48831/12 200-12 300; Slide P-2154-69f; 27.9 x 106.6; mid-focus; GSC 67939.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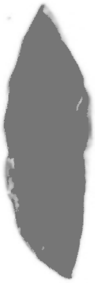
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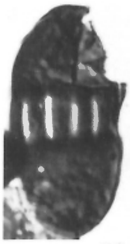
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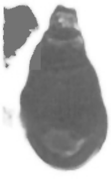
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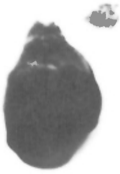
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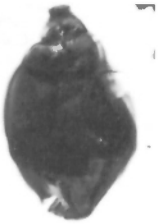
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PLATE 3

All figures 750x, interference contrast illumination.

Figures 1-3. *Multicellaesporites leptaleus* Ke et Shi ex Sung et al.

1. GSC loc. C-48831/12 000-12 100; Slide P-2154-67b; 36.3 x 98.9; mid-focus; GSC 67940.

2. GSC loc. C-48831/9200-9300; Slide P-2154-46b; 36.9 x 97.3; mid-focus; GSC 67941.

3. GSC loc. C-48831/11 900-12 000; Slide P-2154-66b; 24.7 x 96.1; mid-focus; GSC 67942.

Figures 4-6. *Multicellaesporites compactilis* Ke et Shi ex Sung et al.

4. GSC loc. C-48831/11 700-11 800; Slide P-2154-64f; 26.1 x 107.0; mid-focus; GSC 67943.

5. GSC loc. C-48831/10 600-10 700; Slide P-2154-55f; 37.3 x 104.7; mid-focus; GSC 67944.

6. GSC loc. C-48831/9200-9300; Slide P-2154-46b; 41.9 x 97.1; mid-focus; GSC 67945.

Figures 7, 8. *Multicellaesporites margaritus* Ke et Shi ex Sung et al.

7. GSC loc. C-48831/8300-8400; Slide P-2154-41f; 21.5 x 112.4; mid-focus; GSC 67946.

8. GSC loc. C-48831/9100-9200; Slide P-2154-45b; 27.8 x 95.4; mid-focus; GSC 67947.

Figure 9. *Fractisporonites* sp. cf. *F. canalis* Clarke.

GSC loc. C-48831/8800-8900; Slide P-2154-42b; 39.2 x 108.8; mid-focus; GSC 67948.

Figure 10. *Multicellaesporites lanceolatus* Ke et Shi ex Sung et al.

GSC loc. C-48831/11 500-11 600; Slide P-2154-62f; 40.3 x 107.8; mid-focus; GSC 67949.

Figure 11. *Multicellaesporites* sp. cf. *M. conicus* Ke et Shi ex Sung et al.

GSC loc. C-48831/12 400-12 500; Slide P-2154-71f; 34.1 x 109.5; mid-focus; GSC 67950.

Figure 12. *Multicellaesporites* sp. cf. *M. conspicuus* Ke et Shi ex Sung et al.

GSC loc. C-48831/12 500-12 600; Slide P-2154-72f; 37.7 x 104.9; mid-focus; GSC 67951.

Figure 13. "*Multicellaesporites*" sp. A.

GSC loc. C-48831/4500-4600; Slide P-2154-26g; 28.6 x 100.5; mid-focus; GSC 67952.

Figure 14. *Fractisporonites* sp. B.

GSC loc. C-48831/11 700-11 800; Slide P-2154-64b; 28.6 x 103.1; mid-focus; GSC 67953.

Figures 15, 16, 28. *Fractisporonites* sp. A.

15. GSC loc. C-48831/12 500-12 600; Slide P-2154-72b; 37.7 x 102.6; mid-focus; GSC 67954.

16. GSC loc. C-48831/12 600-12 650; Slide P-2154-73b; 39.1 x 106.5; mid-focus; GSC 67955.

28. GSC loc. C-48831/12 500-12 600; Slide P-2154-72b; 44.5 x 101.8; mid-focus; GSC 67956.

Figures 17-20. *Staphlosporonites delumbus* sp. nov.

17. GSC loc. C-48831/4400-4500; Slide P-2154-25b; 30.5 x 106.0; mid-focus; GSC 67957.

18. Holotype. GSC loc. C-48831/3500-3600; Slide P-2154-17b; 36.8 x 111.6; mid-focus; GSC 67958.

19. GSC loc. C-48831/9100-9200; Slide P-2154-45b; 28.9 x 106.7; mid-focus; GSC 67959.

20. GSC loc. C-48831/4700-4800; Slide P-2154-28b; 35.4 x 110.6; mid-focus; GSC 67960.

Figure 21. *Staphlosporonites* sp. A.

GSC loc. C-48831/3500-3600; Slide P-2154-17b; 33.7 x 95.6; mid-focus; GSC 67961.

Figure 22. *Ctenosporites wolfei* Elsik and Jansonius.

GSC loc. C-48831/10 300-10 400; Slide P-2154-53f; 38.2 x 99.8; mid-focus; GSC 67962.

Figures 23, 27. *Staphlosporonites* sp. cf. *S. conoideus* Sheffy and Dilcher.

23. GSC loc. C-48831/9000-9100; Slide P-2154-44g; 38.3 x 94.7; mid-focus; GSC 67963.

27. GSC loc. C-48831/8900-9000; Slide P-2154-43f; 37.3 x 111.4; mid-focus; GSC 67964.

Figures 24, 25. *Pesavis tagluensis* Elsik and Jansonius.

24. GSC loc. C-48831/9200-9300; Slide P-2154-46g; 32.7 x 104.8; mid-focus; GSC 67965.

25. GSC loc. C-48831/11 700-11 800; Slide P-2154-64f; 38.8 x 107.0; mid-focus; GSC 67966.

Figure 26. *Centonites* sp. A.

GSC loc. C-48831/3600-3700; Slide P-2154-18b; 29.9 x 97.4; mid-focus; GSC 67967.

PLATE 3


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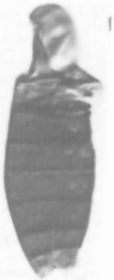
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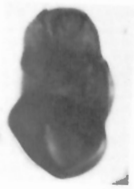
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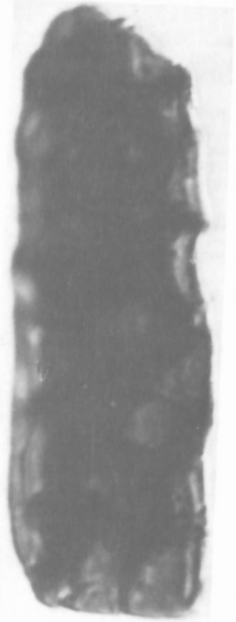
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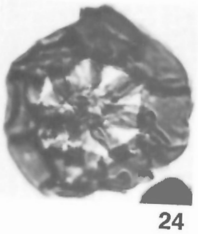
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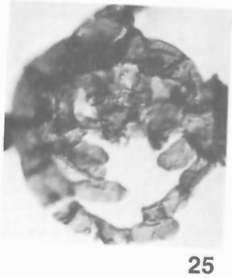
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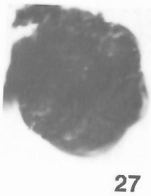
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PLATE 4

All figures 750x, interference contrast illumination.

Figures 1-5. Fungal hyphae type A.

1. GSC loc. C-48831/1700-1800; Slide P-2154-7b; 38.1 x 112.7; mid-focus; GSC 67968.

2. GSC loc. C-48831/600-700; Slide P-2154-2b; 44.6 x 104.4; mid-focus; GSC 67969.

3. GSC loc. C-48831/900-1000; Slide P-2154- 3f; 39.9 x 107.4; mid-focus; GSC 67970.

4. GSC loc. C-48831/3000-3100; Slide P-2154-14b; 37.5 x 102.0; mid-focus; GSC 67971.

5. GSC loc. C-48831/3600-3700; Slide P-2154-18b; 35.9 x 106.9; mid-focus; GSC 67972.

Figures 6-8. Fungal hyphae type B.

6. GSC loc. C-48831/2800-2900; Slide P-2154-13b; 42.8 x 96.7; mid-focus; GSC 67973.

7. GSC loc. C-48831/2800-2900; Slide P-2154-13b; 40.8 x 112.7; mid-focus; GSC 67974.

8. GSC loc. C-48831/4500-4600; Slide P-2154-26f; 32.3 x 98.6; mid-focus; GSC 67975.

Figures 9, 10. Fungal hyphae type C.

9. GSC loc. C-48831/3000-3100; Slide P-2154-14b; 42.7 x 100.9; mid-focus; GSC 67976.

10. GSC loc. C-48831/3600-3700; Slide P-2154-18b; 44.4 x 107.3; mid-focus; GSC 67977.

Figures 11-14. Fungal hyphae type D.

11. GSC loc. C-48831/3600-3700; Slide P-2154-18b; 27.7 x 103.8; mid-focus; GSC 67978.

12. GSC loc. C-48831/4200-4300; Slide P-2154-23b; 27.6 x 105.1; mid-focus; GSC 67979.

13. GSC loc. C-48831/4200-4300; Slide P-2154-23b; 27.8 x 111.8; mid-focus; GSC 67980.

14. GSC loc. C-48831/7200-7300; Slide P-2154-35b; 39.0 x 107.6; mid-focus; GSC 67981.

Figures 15, 16. Fungal hyphae type E.

15. GSC loc. C-48831/4200-4300; Slide P-2154-23b; 43.0 x 100.7; mid-focus; GSC 67982.

16. GSC loc. C-48831/4200-4300; Slide P-2154-23b; 39.6 x 105.3; mid-focus; GSC 67983.

Figure 17. Fungal hyphae type F.

GSC loc. C-48831/4200-4300, Slide P-2154-23b; 29.6 x 100.9; mid-focus; GSC 67984.

Figures 18-22. Fungal hyphae type G.

18. GSC loc. C-48831/4200-4300; Slide P-2154-23f; 43.7 x 98.1; mid-focus; GSC 67985.

19. GSC loc. C-48831/4900-5000; Slide P-2154-30b; 43.6 x 101.7; mid-focus; GSC 67986.

20. GSC loc. C-48831/4700-4800; Slide P-2154-28b; 44.0 x 112.4; mid-focus; GSC 67987 (part of same specimen illustrated in Pl. 4, fig. 22).

21. GSC loc. C-48831/4700-4800; Slide P-2154-28b; 44.9 x 110.0; mid-focus; GSC 67988.

22. GSC loc. C-48831/4700-4800; Slide P-2154-28b; 44.0 x 112.4; mid-focus; GSC 67987 (part of same specimen illustrated in Pl. 4, fig. 20).

PLATE 4


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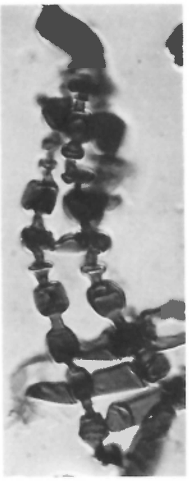
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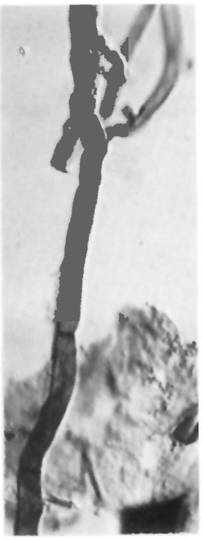
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PLATE 5

All figures 750 x, interference contrast illumination.

Figures 1-3. *Plochmopeltinites masonii* Cookson.

1. GSC loc. C-48831/4900-5000; Slide P-2154-30b; 35.3 x 99.0; mid-focus; GSC 67989.

2. GSC loc. C-48831/10 100-10 200; Slide P-2154-52b; 36.8 x 101.5; mid-focus; GSC 67990.

3. GSC loc. C-48831/12 100-12 200; Slide P-2154-68b; 39.0 x 93.6; mid-focus; GSC 67991.

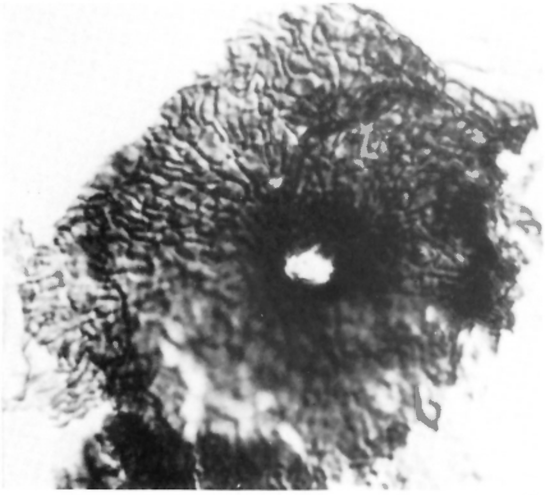
Figures 4, 5. *Phragmothyrites* sp. cf. *P. eocaenicus* Edwards.

4. GSC loc. C-48831/12 300-12 400; Slide P-2154-70b; 35.2 x 100.8; mid-focus; GSC 67992.

5. GSC loc. C-48831/11 500-11 600; Slide P-2154-62b; 42.2 x 93.5; mid-focus; GSC 67993.

Figures 6, 7. *Microthyriacites* sp. A.

GSC loc. C-48831/7200-7300; Slide P-2154-35b; 28.4 x 104.3; Fig. 6, high focus, Fig. 7; low focus; GSC 67994.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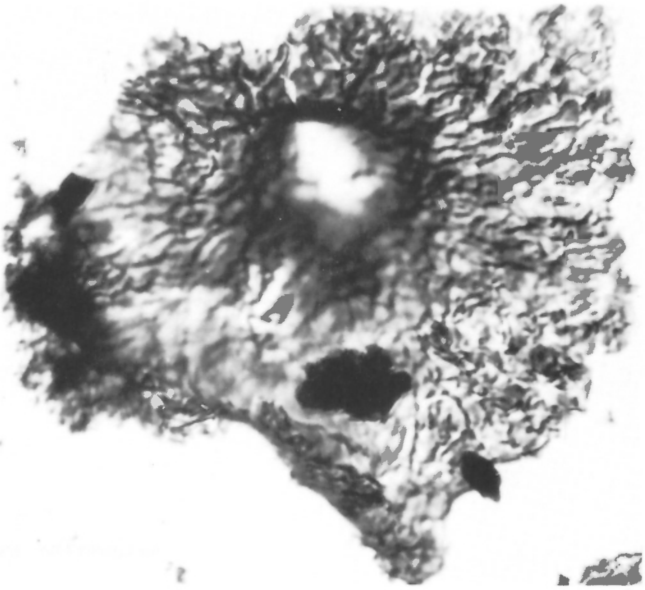
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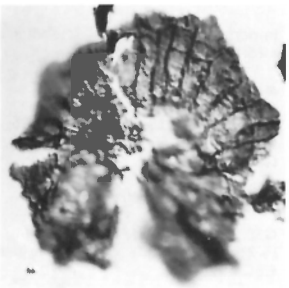
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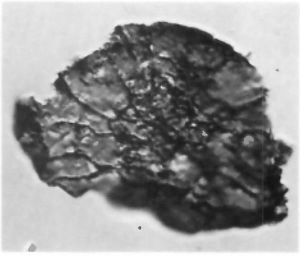
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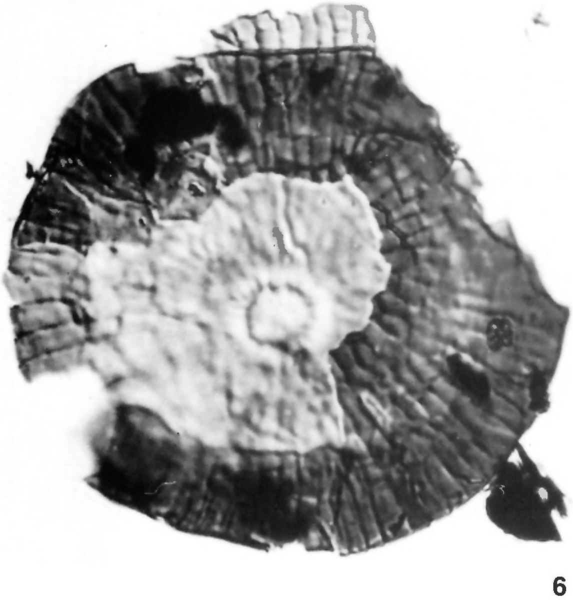
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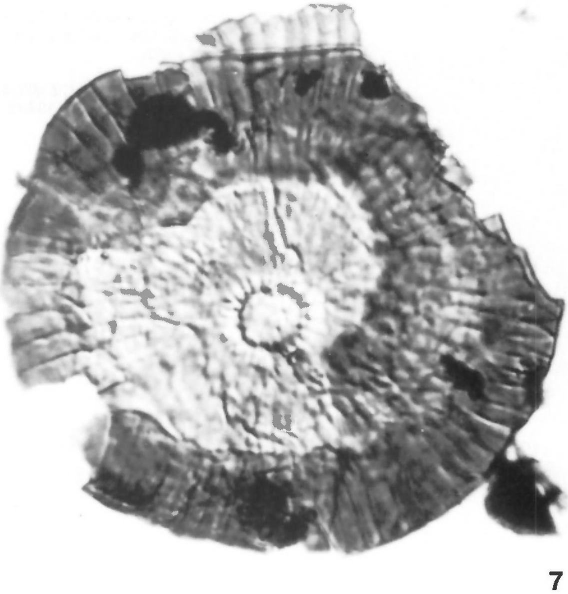
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PLATE 6

All figures 750x, interference contrast illumination.

Figures 1, 2. *Trichothyrites* sp. A.

1. GSC loc. C-48831/7600-7700; Slide P-2154-36b; 41.8 x 97.2; mid-focus; GSC 67995.

2. Imperial slide 9450, No. 1; 39.9 x 110.6; mid-focus; GSC 67996.

Figure 3. *Microthyrites* sp. A.

GSC loc. C-48831/10 300-10 400; Slide P-2154-53b; 39.1 x 99.1; mid-focus; GSC 67997.

Figures 4, 6-9. *Callimothallus pertusus* Dilcher.

4. GSC loc. C-48831/12 200-12 300; Slide P-2154-69b; 26.6 x 111.9; mid-focus; GSC 67998.

6. GSC loc. C-48831/12 000-12 100; Slide P-2154-67f; 32.7 x 111.8; mid-focus; GSC 67999.

7. GSC loc. C-48831/12 300-12 400; Slide P-2154-70f; 31.0 x 99.8; mid-focus; GSC 68000.

8. GSC loc. C-48831/11 700-11 800; Slide P-2154-65b; 36.0 x 103.3; mid-focus; GSC 68001.

9. GSC loc. C-48831/12 600-12 650; Slide P-2154-73b; 43.8 x 102.4; mid-focus; GSC 68002.

Figure 5. *Microthallites* sp. cf. *M. lutosus* Dilcher.

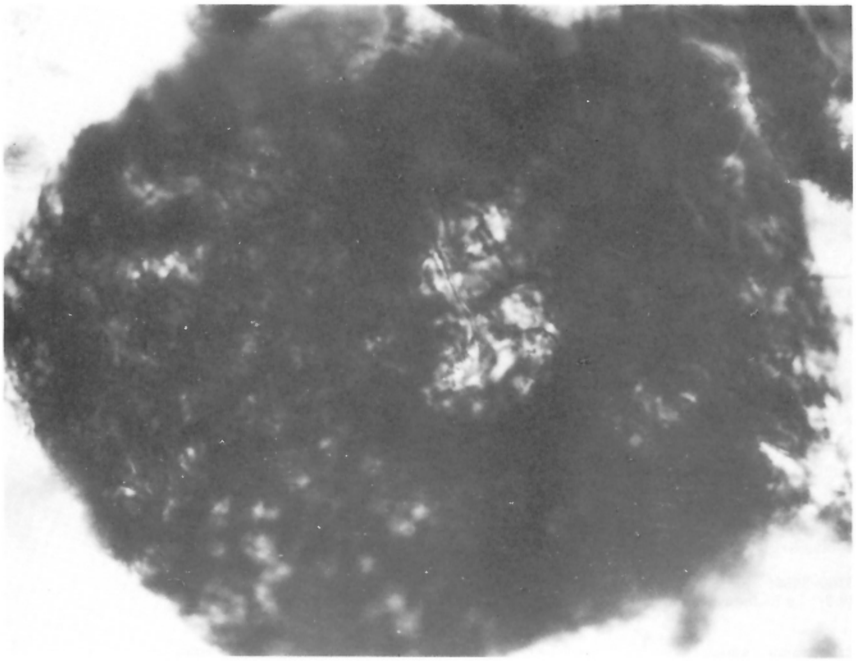
GSC loc. C-48831/9100-9200; Slide P-2154-45b; 30.5 x 111.8; mid-focus; GSC 68003.

Figures 10, 11. Indeterminate peltate fruiting bodies. A greater range of morphology is represented in this category than is illustrated.

10. GSC loc. C-48831/6100-6200; Slide P-2154-33b; 24.1 x 95.9; mid-focus; GSC 68004.

11. GSC loc. C-48831/9200-9300; Slide P-2154-46b; 20.4 x 112.1; mid-focus; GSC 68005.

PLATE 6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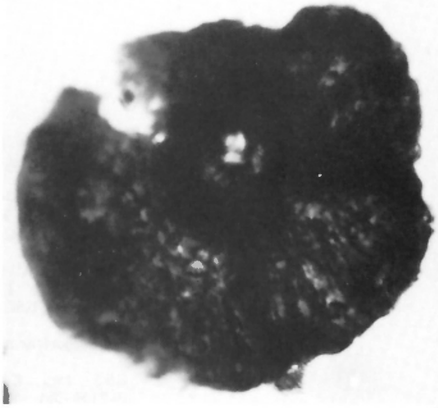
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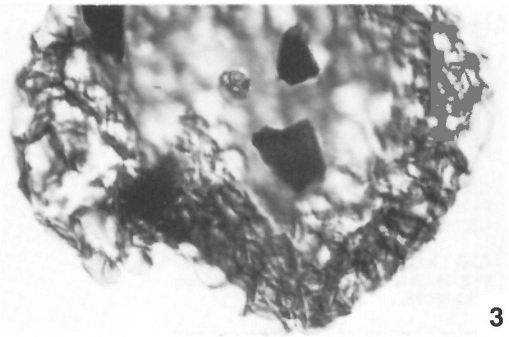
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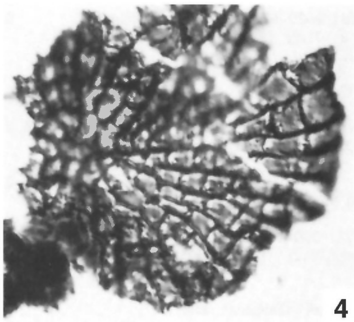
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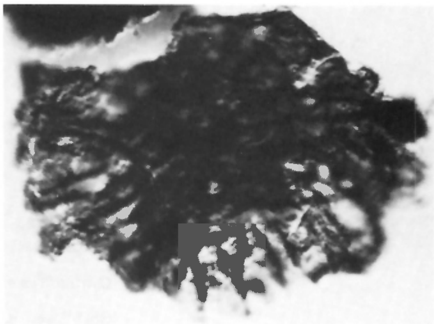
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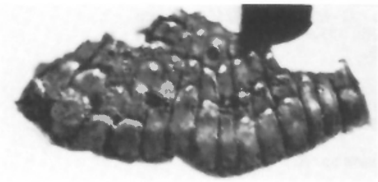
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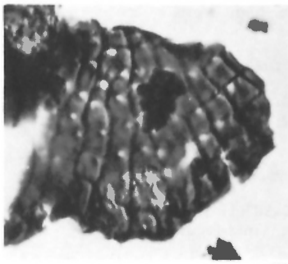
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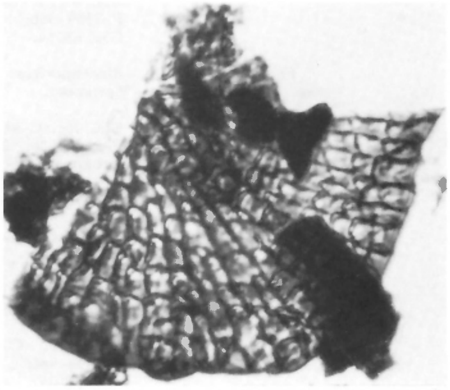
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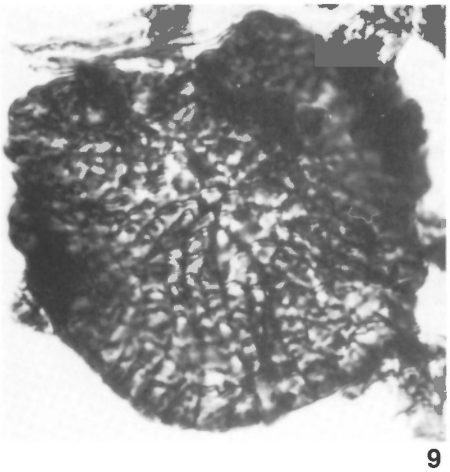
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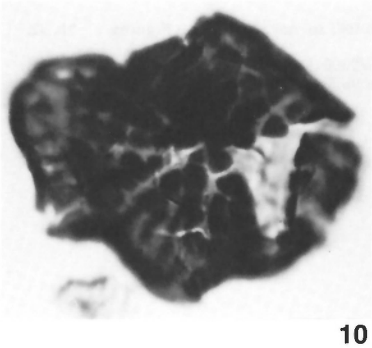
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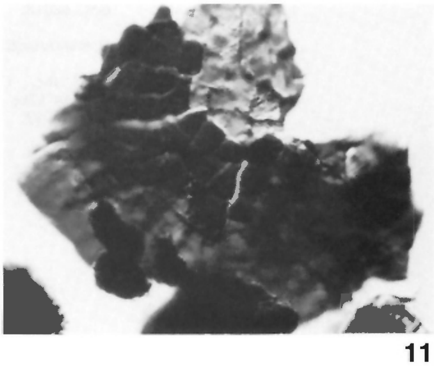
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PLATE 7

All figures 750x, interference contrast illumination.

Figures 1, 2. *Stereisporites stereoides* (Potonié and Venitz) Pflug in Thomson and Pflug.

1. GSC loc. C-48831/2400-2500; Slide P-2154-12b; 32.7 x 96.6; high focus (proximal); GSC 68006.

2. GSC loc. C-48831/3500-3600; Slide P-2154-17b; 35.8 x 101.2; high focus (proximal); GSC 68007.

Figures 3, 4. *Stereisporites minor* (Raatz) Krutzsch.

3. GSC loc. C-48831/900-1000; Slide P-2154-3g; 40.4 x 108.8; high focus (proximal); GSC 68008.

4. GSC loc. C-48831/2400-2500; Slide P-2154-12b; 37.1 x 99.4; high focus (proximal); GSC 68009.

Figures 5-7. *Stereisporites micrograndulus* Krutzsch.

5. GSC loc. C-48831/3300-3400; Slide P-2154-16f; 30.6 x 94.2; mid-focus; GSC 68010.

6. GSC loc. C-48831/4100-4200; Slide P-2154-22b; 41.1 x 103.6; low focus (distal); GSC 68011.

7. GSC loc. C-48831/4620-4700; Slide P-2154-27b; 22.1 x 101.9; high focus (distal); GSC 68012.

Figure 8. *Cyathidites minor* Couper.

GSC loc. C-48831/3000-3100; Slide P-2154-14b; 44.5 x 97.0; mid-focus; GSC 68013.

Figure 9. *Deltoidospora hallii* Miner.

GSC loc. C-48831/11 000-11 100; Slide P-2154-58b; 36.4 x 95.2; mid-focus; GSC 68014.

Figure 10. *Biretisporites potoniaei* Delcourt and Sprumont.

GSC loc. C-48831/11 000-11 100; Slide P-2154-58b; 23.7 x 101.3; high focus (proximal); GSC 68015.

Figure 11. *Osmundacidites wellmanii* Couper.

GSC loc. C-48831/3300-3400; Slide P-2154-16b; 29.6 x 106.2; mid-focus; GSC 68016.

Figures 12, 13. *Osmundacidites richardsii* sp. nov.

12. GSC loc. C-48831/8900-9000; Slide P-2154-43f; 23.9 x 95.4; mid-focus; GSC 68017.

13. Holotype. GSC loc. C-48831/10 100-10 200; Slide P-2154-52b; 35.4 x 107.4; mid-focus; GSC 68018.

Figures 14, 17, 18. *Osmundacidites richardsii* sp. nov.

14. GSC loc. C-48831/9300-9400; Slide P-2154-47b; 42.5 x 96.3; mid-focus; GSC 68019.

17, 18. GSC loc. C-48831/10 300-10 400; Slide P-2154-53b; 44.1 x 108.5; high focus (proximal) and mid-focus, respectively; GSC 68020.

Figure 15. *Baculatisporites comaumensis* (Cookson) Potonié.

GSC loc. C-48831/3300-3400; Slide P-2154-16b; 43.7 x 107.5; mid-focus; GSC 68021.

Figures 16, 19-21. *Baculatisporites crassiprimarius* (Krutzsch) comb. and stat. nov.

16. GSC loc. C-48831/8200-8300; Slide P-2154-40b; 32.0 x 103.0; mid-focus; GSC 68022.

19. GSC loc. C-48831/4100-4200; Slide P-2154-22b; 37.3 x 99.0; high focus (proximal); GSC 68023.

20. GSC loc. C-48831/9400-9500; Slide P-2154-48b; 23.4 x 99.6; mid-focus; GSC 68024.

21. GSC loc. C-48831/2400-2500; Slide P-2154-12b; 27.9 x 96.3; low-focus (proximal); GSC 68025.

Figure 22. *Leptolepidites* sp. A.

GSC loc. C-48831/9500-9600; Slide P-2154-49b; 40.0 x 96.1; mid-focus; GSC 68026.

Figures 23, 24. *Baculatisporites quintus* (Thomson and Pflug) Krutzsch.

23. GSC loc. C-48831/4000-4100; Slide P-2154-21f; 34.6 x 111.2; mid-focus; GSC 68027.

24. GSC loc. C-48831/3300-3400; Slide P-2154-16f; 37.9 x 95.1; mid-focus; GSC 68028.

Figures 25, 26. *Retitriletes* sp. cf. *R. novomexicanus* (Anderson) comb. nov.

25. GSC loc. C-48831/2400-2500; Slide P-2154-12b; 33.9 x 107.6; mid-focus; GSC 68029.

26. GSC loc. C-48831/10 000-10 100; Slide P-2154-51f; 24.1 x 95.4; mid-focus; GSC 68030.

Figures 27-30. *Echinatisporis* sp. A.

27, 28. GSC loc. C-48831/1400-1500; Slide P-2154-6b; 34.3 x 100.4; high focus (distal) and low focus (proximal), respectively; GSC 68031.

29, 30. GSC loc. C-48831/2800-2900; Slide P-2154-13f; 18.3 x 102.9; mid-focus and low focus (distal), respectively; GSC 68032.

Figures 31, 32. *Retitriletes annotinioides* Krutzsch.

31. GSC loc. C-48831/2400-2500; Slide P-2154-15b; 40.8 x 105.8; mid-focus; GSC 68033.

32. GSC loc. C-48831/2800-2900; Slide P-2154-13f; 18.3 x 99.4; high focus (distal); GSC 68034.

PLATE 7


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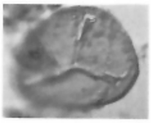
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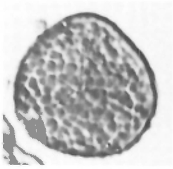
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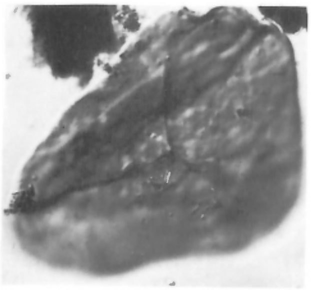
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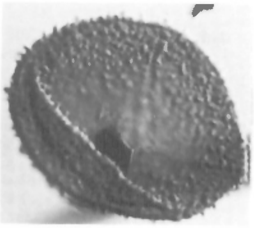
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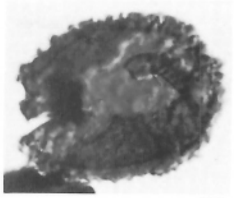
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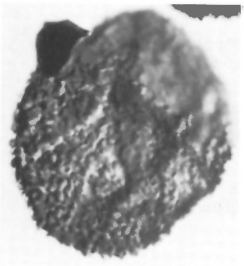
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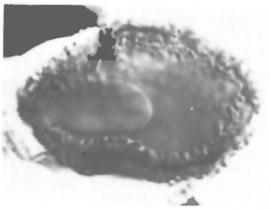
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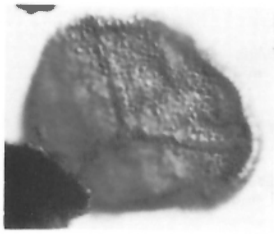
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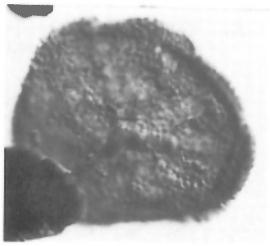
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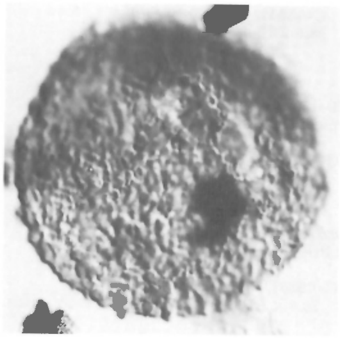
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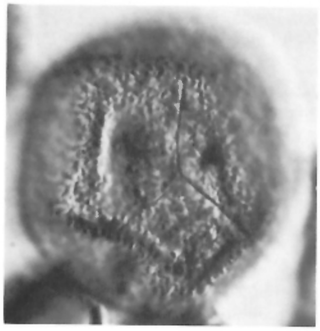
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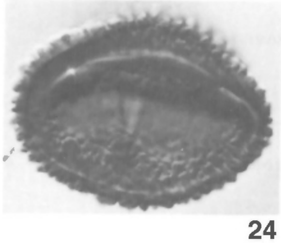
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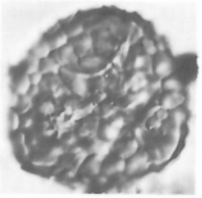
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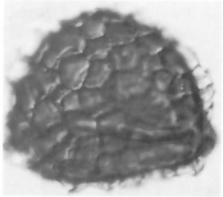
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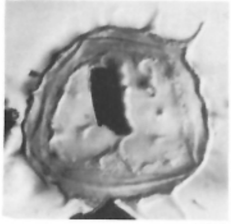
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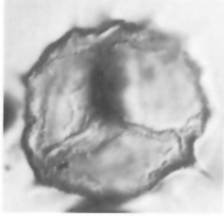
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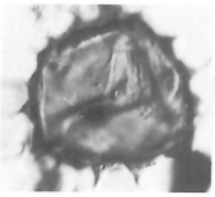
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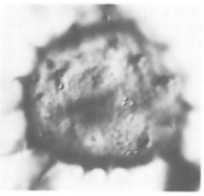
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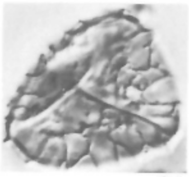
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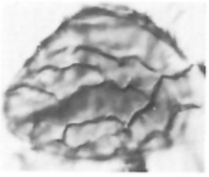
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PLATE 8

All figures 750x, interference contrast illumination.

Figures 1-5. *Retitriletes* sp. cf. *R. novomexicanus* (Anderson) comb. nov.

1, 2. GSC loc. C-48831/9500-9600; Slide P-2154-50b; 30.5 x 98.9; high focus (proximal) and low focus (distal), respectively; GSC 68035.

3. GSC loc. C-48831/7900-8000; Slide P-2154-38b; 43.0 x 104.2; high focus (distal); GSC 68036.

4. GSC loc. C-48831/10 000-10 100; Slide P-2154-51f; 34.9 x 110.6; mid-focus; GSC 68037.

5. GSC loc. C-48831/11 300-11 400; Slide P-2154-60b; 30.1 x 111.3; mid-focus; GSC 68038.

Figure 6. *Retitriletes* sp. cf. *R. oligocenicus* Krutzsch.

GSC loc. C-48831/2300-2400; Slide P-2154-11f; 36.7 x 105.2; high focus (distal); GSC 68039.

Figure 7. *Azolla* sp. A.

GSC loc. C-48831/9500-9600; Slide P-2154-49b; 43.0 x 101.3; mid-focus; GSC 68040.

Figures 8-10. *Laevigatosporites novus* sp. nov.

8. GSC loc. C-48831/600-700; Slide P-2154-2b; 38.6 x 106.3; mid-focus; GSC 68041.

9. Holotype. GSC loc. C-48831/1100-1200; Slide P-2154-4g; 39.4 x 98.5; mid-focus; GSC 68042.

10. GSC loc. C-48831/4620-4700; Slide P-2154-27f; 29.4 x 99.5; mid-focus; GSC 68043.

Figures 11, 12. *Verrucatosporites favus* (Potonié) Thomson and Pflug.

11. GSC loc. C-48831/9200-9300; Slide P-2154-46b; 26.4 x 102.9; mid-focus; GSC 68044.

12. GSC loc. C-48831/10 500-10 600; Slide P-2154-54f; 26.7 x 102.0; mid-focus; GSC 68045.

Figure 13. *Laevigatosporites ovatus* Wilson and Webster.

GSC loc. C-48831/3500-3600; Slide P-2154-17f; 46.2 x 96.6; mid-focus; GSC 68046.

Figures 14, 15. *Pinuspollenites labdacus* (Potonié) Raatz ex Potonié.

14. GSC loc. C-48831/3300-3400; Slide P-2154-16b; 42.1 x 111.4; mid-focus; GSC 68047.

15. GSC loc. C-48831/4620-4700; Slide P-2154-27b; 40.7 x 107.8; mid-focus; GSC 68048.

Figures 16, 17. *Pinuspollenites* sp. A.

16. GSC loc. C-48831/3500-3600; Slide P-2154-17f; 21.9 x 112.1; high focus (distal); GSC 68049.

17. GSC loc. C-48831/600-700; Slide P-2154-2b; 39.6 x 100.6; mid-focus; GSC 68050.

Figures 18-20. *Sequoiapollenites polyformosus* Thiergart.

18. GSC loc. C-48831/11 700-11 800; Slide P-2154-64f; 25.9 x 102.5; mid-focus; GSC 68051.

19. GSC loc. C-48831/4620-4700; Slide P-2154-27b; 22.4 x 101.4; mid-focus; GSC 68052.

20. GSC loc. C-48831/3300-3400; Slide P-2154-16b; 42.1 x 111.5; mid-focus; GSC 68053.

Figures 21, 22. *Sigmopollis psilatus* Piel.

21. GSC loc. C-48831/1400-1500; Slide P-2154-6b; 26.1 x 94.6; high focus; GSC 68054.

22. GSC loc. C-48831/3600-3700; Slide P-2154-18f; 33.7 x 103.3; mid-focus; GSC 68055.

Figure 23. *Taxodiaceaepollenites hiatus* Potonié ex Potonié.

GSC loc. C-48831/2800-2900; Slide P-2154-13b; 29.8 x 98.1; mid-focus; GSC 68056.

Figures 24-26. *Piceaepollenites grandivescipites* (Wodehouse) comb. nov.

24. GSC loc. C-48831/10 300-10 400; Slide P-2154-53b; 35.8 x 106.3; mid-focus; GSC 68057.

25. GSC loc. C-48831/600-700; Slide P-2154-53b; 39.9 x 95.6; low focus (distal); GSC 68058.

26. GSC loc. C-48831/10 300-10 400; Slide P-2154-2d; 38.9 x 94.7; mid-focus; GSC 68059.

Figure 27. *Tsugaepollenites viridifluminipites* (Wodehouse) comb. nov.

GSC loc. C-48831/10 900-11 000; Slide P-2154-57b; 44.8 x 103.6; mid-focus; GSC 68060.


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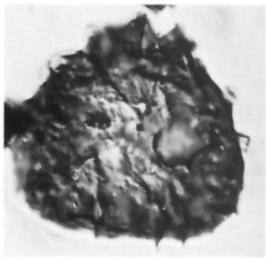
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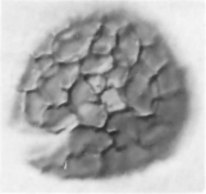
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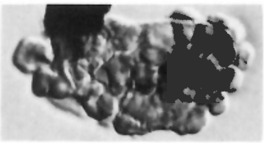
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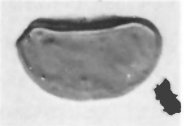
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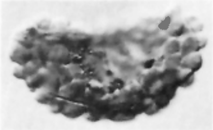
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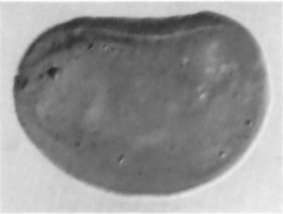
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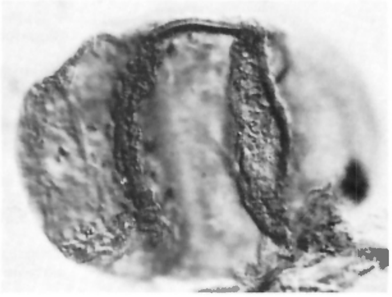
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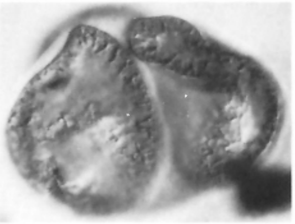
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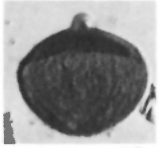
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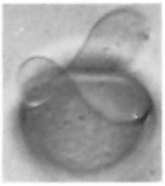
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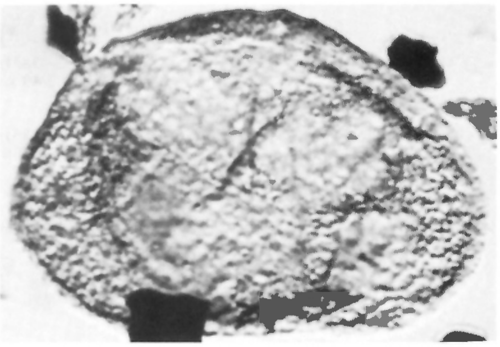
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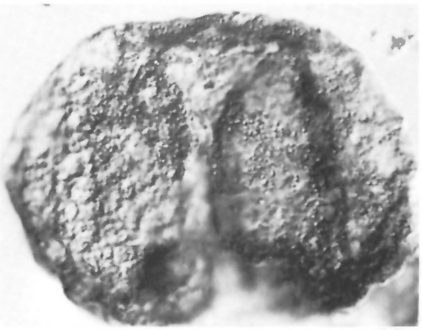
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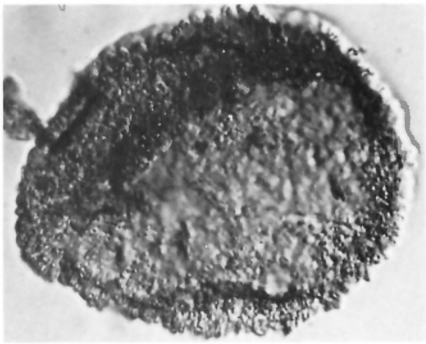
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PLATE 9

All figures 750x, interference contrast illumination.

Figure 1. *Piceaepollenites grandivescipites* (Wodehouse) comb. nov.

GSC loc. C-48831/12 600-12 650; Slide P-2154-73b; 42.1 x 106.8; mid-focus (polar view); GSC 68061.

Figures 2, 4, 5. *Piceaepollenites* sp. A.

2. GSC loc. C-48831/9000-9100; Slide P-2154-44b; 31.8 x 105.4; mid-focus (equatorial view); GSC 68062.

4. GSC loc. C-48831/9100-9200; Slide P-2154-45b; 27.8 x 98.8; mid-focus (equatorial view); GSC 68063.

5. Imperial slide 4745, SWC; 39.4 x 96.9; mid-focus (polar view); GSC 68064.

Figure 3. *Tsugaepollenites viridifluminipites* (Wodehouse) comb. nov.

GSC loc. C-48831/3000-3100; Slide P-2154-14b; 27.4 x 103.7; mid-focus; GSC 68065.

Figure 6. *Tsugaepollenites igniculus* (Potonié) Potonié and Venitz

Imperial slide 2730; 36.4 x 110.2; mid-focus; GSC 68066.

Figures 7, 8. *Tricolpites hians* Stanley.

7. GSC loc. C-48831/9500-9600; Slide P-2154-49b; 34.9 x 103.5; mid-focus; GSC 68067.

8. GSC loc. C-48831/3300-3400; Slide P-2154-16b; 29.8 x 97.4; mid-focus; GSC 68068.

Figure 9. *Salixpollenites discoloripites* (Wodehouse) Srivastava.

GSC loc. C-48831/3300-3400; Slide P-2154-16b; 35.2 x 99.6; mid-focus; GSC 68069.

Figure 10. *Quercoidites microhenrica* (Potonié) Potonié.

GSC loc. C-48831/3300-3400; Slide P-2154-16b; 38.7 x 97.7; mid-focus; GSC 68070.

Figure 11. *Quercoidites* sp. A.

GSC loc. C-48831/4500-4600; Slide P-2154-26g; 36.5 x 102.6; mid-focus; GSC 68071.

Figures 12-14. *Integricorpus* sp. A.

12. GSC loc. C-48831/9500-9600; Slide P-2154-49f; 37.5 x 102.9; mid-focus; GSC 68072.

13. GSC loc. C-48831/9300-9400; Slide P-2154-47f; 33.5 x 109.7; mid-focus; GSC 68073.

14. GSC loc. C-48831/8800-8900; Slide P-2154-42f; 28.7 x 103.4; mid-focus; GSC 68074.

Figures 15, 16. *Cupuliferoipollenites pusillus* (Potonié) Potonié.

15. GSC loc. C-48831/10 600-10 700; Slide P-2154-55b; 45.8 x 98.4; mid-focus; GSC 68075.

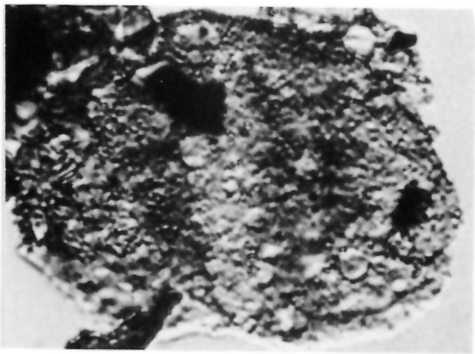
16. GSC loc. C-48831/12 500-12 600; Slide P-2154-72b; 31.4 x 99.3; mid-focus; GSC 68076.

Figures 17-19. *Cupuliferoipollenites oviformis* (Potonié) Potonié.

17. GSC loc. C-48831/11 700-11 800; Slide P-2154-64b; 28.4 x 105.4; mid-focus; GSC 68077.

18. GSC loc. C-48831/3000-3100; Slide P-2154-14f; 24.4 x 107.5; mid-focus; GSC 68078.

19. GSC loc. C-48831/11 000-11 100; Slide P-2154-58f; 35.2 x 103.2; mid-focus; GSC 68079.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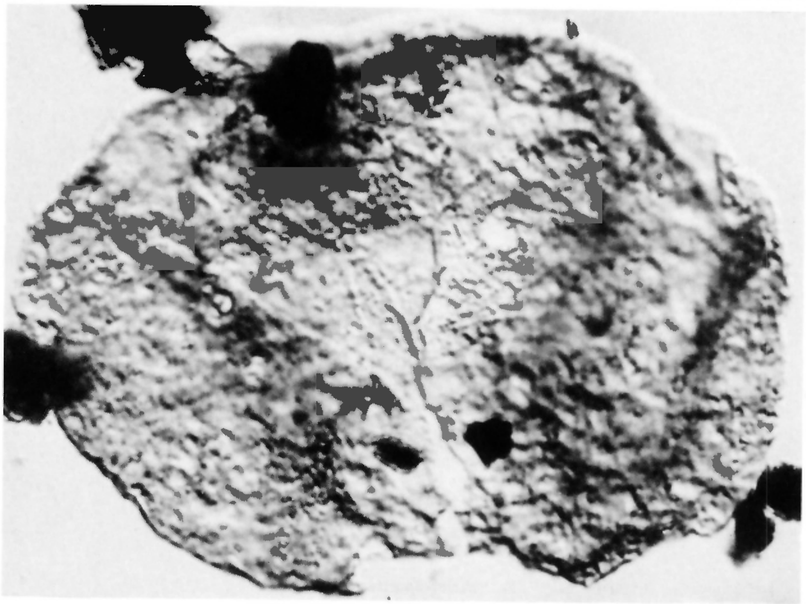
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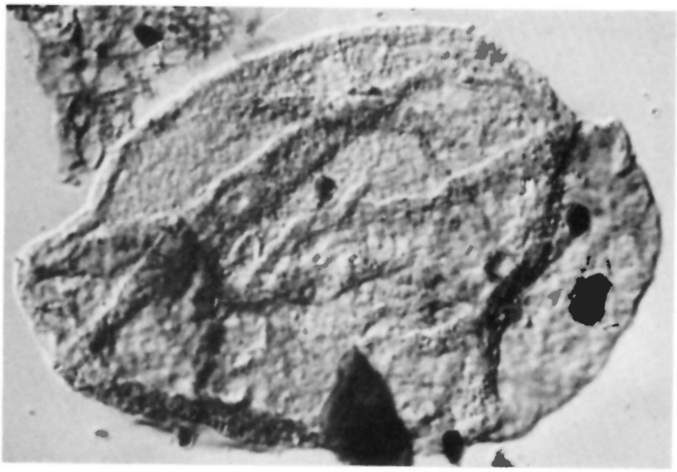
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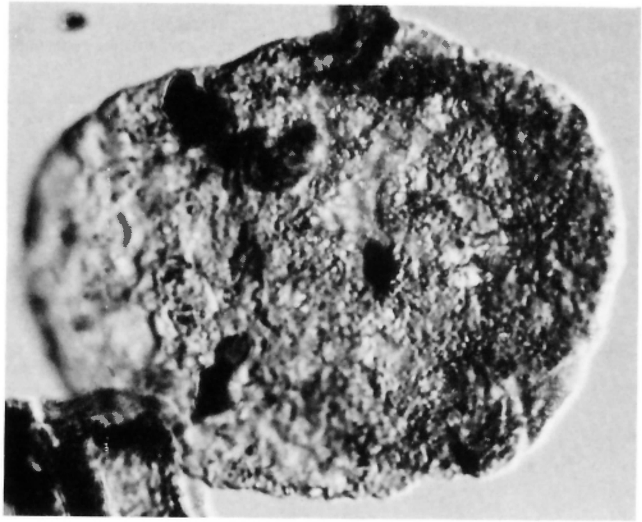
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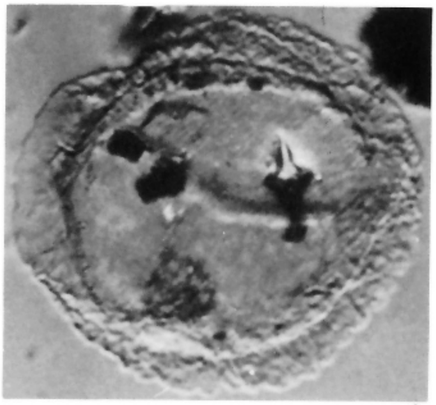
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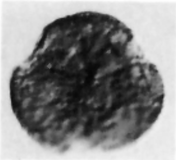
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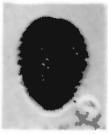
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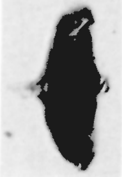
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PLATE 10

All figures 750x, interference contrast illumination.

Figures 1, 2. *Lonicerapollis spiniformis* (Ke et Shi ex Sung et al.) comb. nov.

Imperial slide 3450; 34.5 x 103.0; low focus and mid-focus, respectively; GSC 68080.

Figures 3, 4. *Margocolporites stenosus* Ke et Shi ex Sung et al.

GSC loc. C-48831/4700-4800; Slide P-2154-28b; 32.4 x 111.5; mid-focus and high focus, respectively; GSC 68081.

Figure 5. *Striacolporites* sp. A.

GSC loc. C-48831/3300-3400; Slide P-2154-16b; 35.0 x 102.8; mid-focus; GSC 68082.

Figures 6, 7. *Ericipites compactipolliniatus* (Traverse) comb. nov.

6. GSC loc. C-48831/3500-3600; Slide P-2154-17b; 42.9 x 93.0; mid-focus; GSC 68083.

7. GSC loc. C-48831/3100-3200; Slide P-2154-15f; 12.9 x 97.3; mid-focus; GSC 68084.

Figures 8-13. *Ericipites antecursoroides* sp. nov.

8. GSC loc. C-48831/9000-9100; Slide P-2154-44f; 44.3 x 104.2; mid-focus; GSC 68085.

9. GSC loc. C-48831/10 900-11 000; Slide P-2154-57f; 40.1 x 101.8; mid-focus; GSC 68086.

10, 12. Holotype. GSC loc. C-48831/9000-9100; Slide P-2154-44b; 16.1 x 98.8; low focus and high focus, respectively; GSC 68087.

11. GSC loc. C-48831/9300-9400; Slide P-2154-47b; 31.8 x 99.5; mid-focus; GSC 68088.

13. GSC loc. C-48831/10 000-10 100; Slide P-2154-51f; 20.8 x 101.8; mid-focus; GSC 68089.

Figures 14, 17. *Sparganiaceaepollenites neogenicus* Krutzsch.

14. GSC loc. C-48831/3300-3400; Slide P-2154-16b; 30.7 x 106.8; mid-focus; GSC 68090.

17. GSC loc. C-48831/3600-3700; Slide P-2154-18f; 43.5 x 95.8; mid-focus; GSC 68091.

Figures 15, 16. *Polybrevicolporites* sp. A.

Imperial slide 7485, SWC; 46.8 x 97.2; low focus and high focus, respectively; GSC 68092.

Figures 18, 19. *Graminidites* sp. A.

18. GSC loc. C-48831/3300-3400; Slide P-2154-16f; 35.2 x 104.1; mid-focus; GSC 68093.

19. GSC loc. C-48831/1400-1500; Slide P-2154-6f; 37.6 x 104.5; mid-focus; GSC 68094.

Figures 20-23. *Annutriporites tripollenites* (Rouse) comb. nov.

20. GSC loc. C-48831/11 300-11 400; Slide P-2154-60f; 10.0 x 103.0; mid-focus; GSC 68095.

21. GSC loc. C-48831/3300-3400; Slide P-2154-38f; 30.7 x 96.5; mid-focus; GSC 68096.

22. GSC loc. C-48831/9200-9300; Slide P-2154-46b; 36.4 x 107.0; mid-focus; GSC 68097.

23. GSC loc. C-48831/7900-8000; Slide P-2154-16b; 39.1 x 99.2; mid-focus; GSC 68098.

Figures 24-27. *Annutriporites* sp. A.

24. GSC loc. C-48831/10 000-10 100; Slide P-2154-51f; 34.3 x 93.1; mid-focus; GSC 68099.

25. GSC loc. C-48831/9600-9700; Slide P-2154-50b; 24.9 x 110.4; mid-focus; GSC 68100.

26. GSC loc. C-48831/9300-9400; Slide P-2154-47b; 40.2 x 104.4; mid-focus; GSC 68101.

27. GSC loc. C-48831/10 300-10 400; Slide P-2154-53b; 44.0 x 103.4; mid-focus; GSC 68102.

Figures 28, 29. *Momipites tenuipolus* Anderson.

Imperial slide 4602, SWC; 44.7 x 99.6; high focus and low focus, respectively; GSC 68103.

Figures 30, 34. *Myricipites annulites* (Martin and Rouse) comb. nov.

30. GSC loc. C-48831/4300-4400; Slide P-2154-24b; 34.4 x 99.0; mid-focus; GSC 68104.

PLATE 10 (cont.)

34\. GSC loc. C-48831/4200-4300; Slide P-2154-23f; 34.9 x 99.7; mid-focus; GSC 68105.

Figures 31-33. *Carpinipites* sp. cf. *Carpinipites spackmaniana* (Traverse) Zhou.

31\. GSC loc. C-48831/4500-4600; Slide P-2154-26g; 28.4 x 103.5; mid-focus; GSC 68106.

32\. GSC loc. C-48831/12 500-12 600; Slide P-2154-72b; 38.8 x 108.4; mid-focus; GSC 68107.

33\. GSC loc. C-48831/3600-3700; Slide P-2154-18b; 35.2 x 107.8; mid-focus; GSC 68108.

Figures 35-37. *Ostryoipollenites* sp. cf. *O. rhenanus* (Thomson) Potonié ex Potonié

35\. GSC loc. C-48831/3000-3100; Slide P-2154-14f; 28.0 x 109.5; mid-focus; GSC 68109.

36\. GSC loc. C-48831/3500-3600; Slide P-2154-17b; 28.9 x 111.2; mid-focus; GSC 68100.

37\. GSC loc. C-48831/3000-3100; Slide P-2154-14b; 39.2 x 93.6; mid-focus; GSC 68111.

Figures 38-42. *Trivestibulopollenites betuloides* Pflug in Thomson and Pflug.

38\. GSC loc. C-48831/100-200; Slide P-2154-1b; 38.4 x 96.1; mid-focus; GSC 68112.

39\. GSC loc. C-48831/2300-2400; Slide P-2154-11b; 32.6 x 98.1; mid-focus; GSC 68113.

40\. GSC loc. C-48831/2800-2900; Slide P-2154-13b; 37.4 x 105.8; mid-focus; GSC 68114.

41\. GSC loc. C-48831/2100-2200; Slide P-2154-10b; 31.8 x 107.8; mid-focus; GSC 68115.

42\. GSC loc. C-48831/2100-2200; Slide P-2154-10b; 39.5 x 102.1; mid-focus; GSC 68116.

Figures 43-45, 50. *Intratriporopollenites crassipites* (Wodehouse) comb. nov.

43, 44. GSC loc. C-48831/3000-3100, Slide P-2154-14f; 13.4 x 100.6; high focus and middle focus, respectively; GSC 68117.

45\. GSC loc. C48831/11 700-11 800; Slide P-2154-64b; 40.9 x 100.8; mid-focus; GSC 68118.

50\. GSC loc. C-48831/6100-6200; Slide P-2154-33f; 32.2 x 99.2; mid-focus; GSC 68119.

Figures 46, 53. *Polyvestibulopollenites trinus* (Stanley) comb. nov.

46\. GSC loc. C-48831/3000-3100; Slide P-2154-14b; 36.4 x 94.1; mid-focus; GSC 68120.

53\. GSC loc. C-48831/3500-3600; Slide P-2154-17f; 43.3 x 111.6; mid-focus; GSC 68121.

Figures 47-49. *Trivestibulopollenites claripites* (Wodehouse) comb. nov.

47\. GSC loc. C-48831/1200-1300; Slide P-2154-5b; 40.0 x 100.4; mid-focus; GSC 68122.

48\. GSC loc. C-48831/2400-2500; Slide P-2154-12b; 39.4 x 112.2; mid-focus; GSC 68123.

49\. GSC loc. C-48831/3300-3400; Slide P-2154-16b; 30.9 x 99.5; mid-focus; GSC 68124.

Figures 51, 52. *Intratriporopollenites minimus* Mai.

51\. GSC loc. C-48831/12 400-12 500; Slide P-2154-71b; 43.9 x 95.8; mid-focus; GSC 68125.

52\. GSC loc. C-48831/12 500-12 600; Slide P-2154-72b; 44.0 x 102.8; mid-focus; GSC 68126.

Figures 54-56. *Corsinipollenites triangulatus* (Zaklinskaya) Ke et Shi ex Sung et al.

54\. Imperial slide 3450; 36.7 x 111.5; mid-focus; GSC 68127.

55, 56. Imperial slide 6490, SWC; 49.7 x 100.5; low focus and high focus, respectively; GSC 68128.

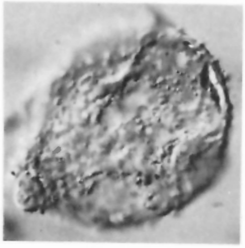
Figure 57. *Pistillipollenites mcgregorii* Rouse.

GSC loc. C-48831/11 900-12 000; Slide P-2154-66b; 39.9 x 100.2; mid-focus; GSC 68129.

Figure 58. *Caryapollenites veripites* (Wilson and Webster) Nichols and Ott.

Imperial slide 10890; 39.0 x 99.4; low focus; GSC 68130.

PLATE 10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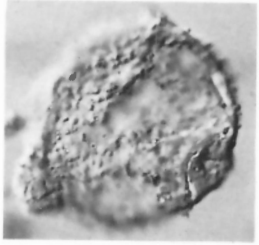
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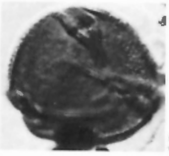
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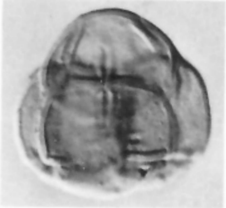
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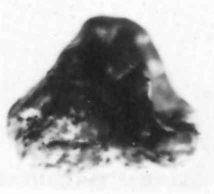
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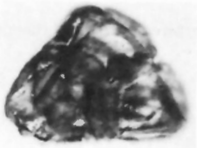
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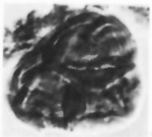
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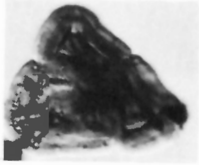
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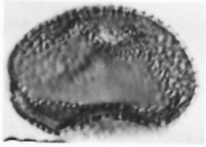
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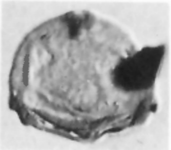
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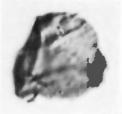
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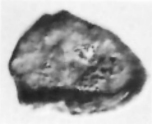
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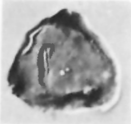
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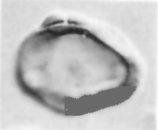
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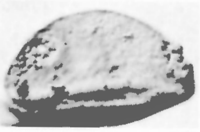
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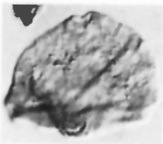
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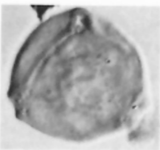
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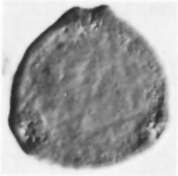
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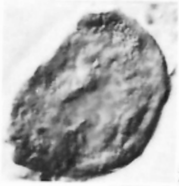
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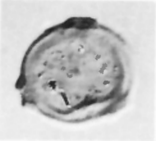
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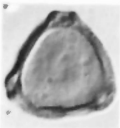
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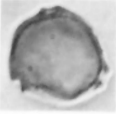
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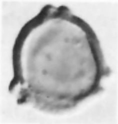
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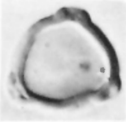
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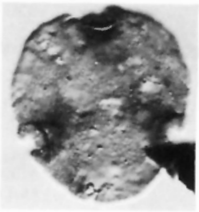
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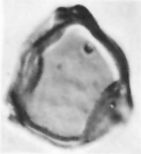
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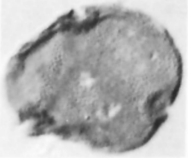
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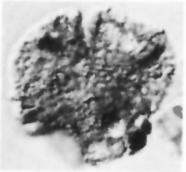
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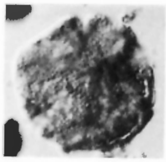
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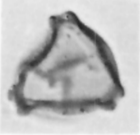
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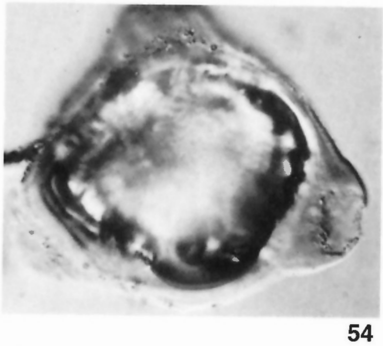
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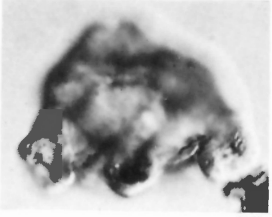
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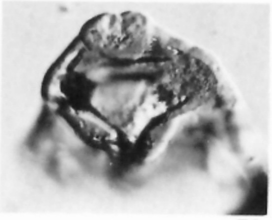
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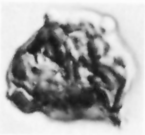
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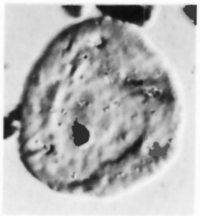
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PLATE 11

All figures 750x, interference contrast illumination.

Figures 1, 2. *Ulmoideipites tricostatus* Anderson.

GSC loc. C-48831/3300-3400; Slide P-2154-16b; 42.1 x 95.0; middle focus and low focus, respectively; GSC 68131.

Figures 3, 4. *Polyvestibulopollenites verus* (Potonié) Thomson and Pflug.

3. GSC loc. C-48831/4700-4800; Slide P-2154-28f; 40.2 x 106.5; mid-focus; GSC 68132.

4. GSC loc. C-48831/10 600-10 700; Slide P-2154-55f; 25.4 x 112.9; mid-focus; GSC 68133.

Figures 5-7. *Polyatriopollenites stellatus* (Potonié) Pflug.

5. GSC loc. C-48831/4100-4200; Slide P-2154-22b; 33.3 x 95.8; mid-focus; GSC 68134.

6. GSC loc. C-48831/10 700-10 800; Slide P-2154-56b; 27.7 x 94.5; mid-focus; GSC 68135.

7. GSC loc. C-48831/9400-9500; Slide P-2154-48b; 24.6 x 112.4; mid-focus; GSC 68136.

Figures 8, 9. *Ulmipollenites undulosus* Wolff.

8. GSC loc. C-48831/4000-4100; Slide P-2154-21b; 17.5 x 104.3; high focus; GSC 68137.

9. GSC loc. C-48831/2800-2900; Slide P-2154-13b; 27.4-98.3; mid-focus; GSC 68138.

Figures 10-12. *Chenopodipollis nuktakensis* sp. nov.

10, 11. GSC loc. C-48831/1400-1500; Slide P-2154-6b; 33.5 x 97.2; mid-focus and high focus, respectively; GSC 68139.

12. Holotype. GSC loc. C-48831/4100-4200; Slide P-2154-22b; 46.1 x 105.5; mid-focus; GSC 68140.

Figures 13-16. *Chenopodipollis* sp. A.

13. GSC loc. C-48831/2300-2400; Slide P-2154-11f; 33.1 x 105.3; high focus; GSC 68141.

14. GSC loc. C-48831/5100-5200; Slide P-2154-31f; 16.2 x 106.4; high focus; GSC 68142.

15, 16. GSC loc. C-48831/1200-1300; Slide P-2154-5b; 33.4 x 98.9; mid-focus and high focus, respectively; GSC 68143.

Figures 17-19. *Chenopodipollis* sp. B.

17. GSC loc. C-48831/1400-1500; Slide P-2154-6b; 39.8 x 98.0; high focus; GSC 68144.

18, 19. GSC loc. C-48831/1400-1500; Slide P-2154-6b; 39.8 x 98.0; high focus and mid-focus, respectively; GSC 68145.

Figure 20. *Distatodinium* sp. A.

GSC loc. C-48831/11 700-11 800; Slide P-2154-64b; 45.3 x 104.4; mid-focus; GSC 68146.

Figure 21. *Cordosphaeridium gracile* (Eisenack) Davey and Williams.

Imperial slide 11 880; 47.8 x 108.6; mid-focus; GSC 68147.

Figure 22. *Glaphyrocysta ordinata* (Williams and Downie in Davey et al.) Stover and Evitt.

GSC loc. C-48831/11 800-11 900; Slide P-2154-65d; 12.3 x 104.3; mid-focus; GSC 68149.

Figures 23, 24. *Senoniasphaera* sp. A.

23. GSC loc. C-48831/12 300-12 400; Slide P-2154-70b; 31.8 x 99.1; mid-focus; GSC 68149.

24. GSC loc. C-48831/12 400-12 500; Slide P-2154-71f; 31.5 x 102.3; high focus (dorsal); GSC 68150; (see Pl. 12, fig. 2 for ventral view of this specimen).


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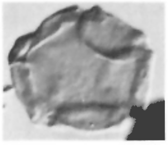
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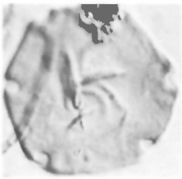
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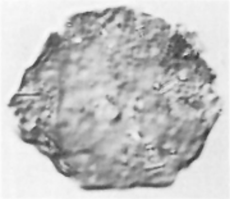
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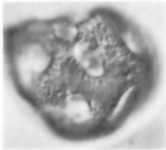
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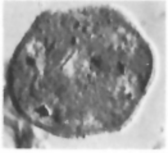
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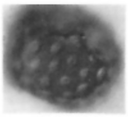
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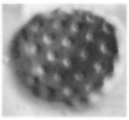
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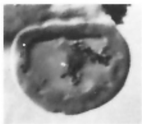
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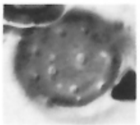
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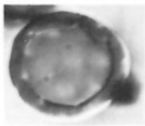
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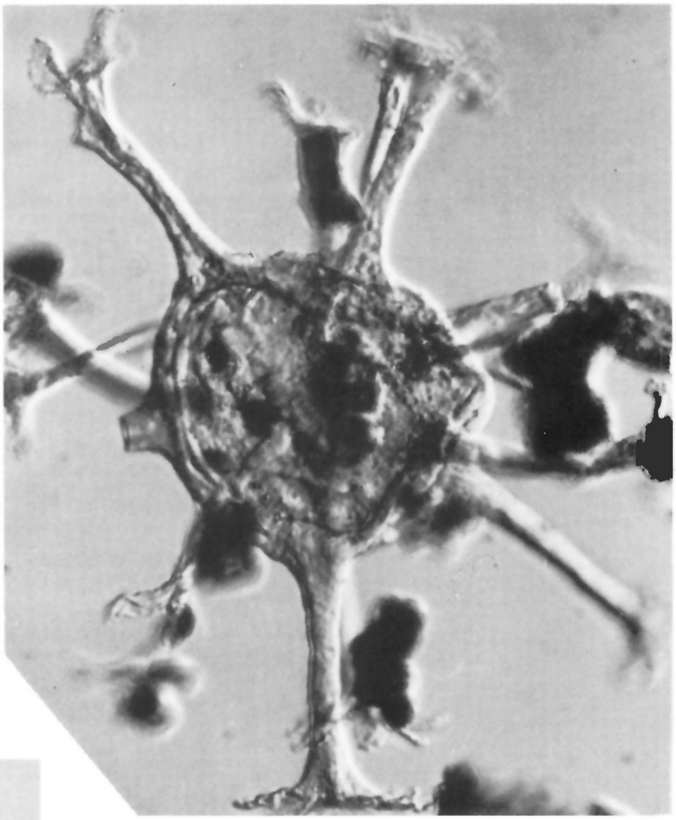
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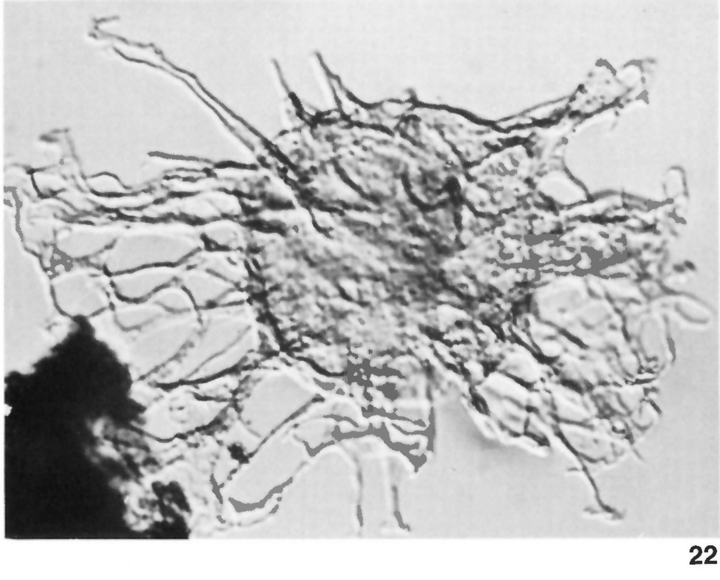
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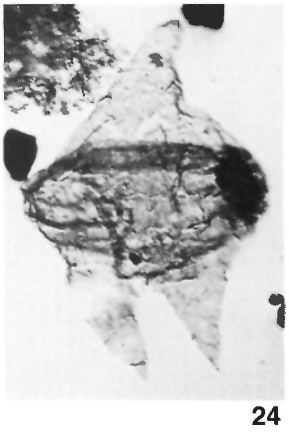
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PLATE 12

All figures 750x, interference contrast illumination.

Figures 1, 6. *Glaphyrocysta ordinata* (Williams and Downie in Davey et al.) Stover and Evitt.

1. GSC loc. C-48831/11 700-11 800; Slide P-2154-64b; 45.0 x 98.1; mid-focus; GSC 68151.

6. GSC loc. C-48831/11 800-11 900; Slide P-2154-65d; 25.7 x 102.4; mid-focus; GSC 68152.

Figures 2-4. *Senoniasphaera* sp. A.

2. GSC loc. C-48831/12 400-12 500; Slide P-2154-71f; 31.5 x 102.3; low focus (proximal); GSC 68150; (see Pl. 11, fig. 24 for dorsal view of this specimen).

3. GSC loc. C-48831/11 900-12 000; Slide P-2154-66f; 25.2 x 104.8; oblique apical view; GSC 68153.

4. GSC loc. C-48831/12 300-12 400; Slide P-2154-70b; 28.8 x 97.3; high focus (dorsal); GSC 68154.

Figures 5, 7-9. *Spinidinium* sp. cf. *S. sagittulum* (Drugg) Lentin and Williams.

5. GSC loc. C-48831/12 200-12 300; Slide P-2154-69b; 22.6 x 107.7; mid-focus; GSC 68155.

7, 8. GSC loc. C-48831/12 300-12 400; Slide P-2154-70b; 45.4 x 92.6; mid-focus and high focus (dorsal), respectively; GSC 68156.

9. GSC loc. C-48831/12 200-12 300; Slide P-2154-69b; 45.0 x 109.6; mid-focus; GSC 68157.

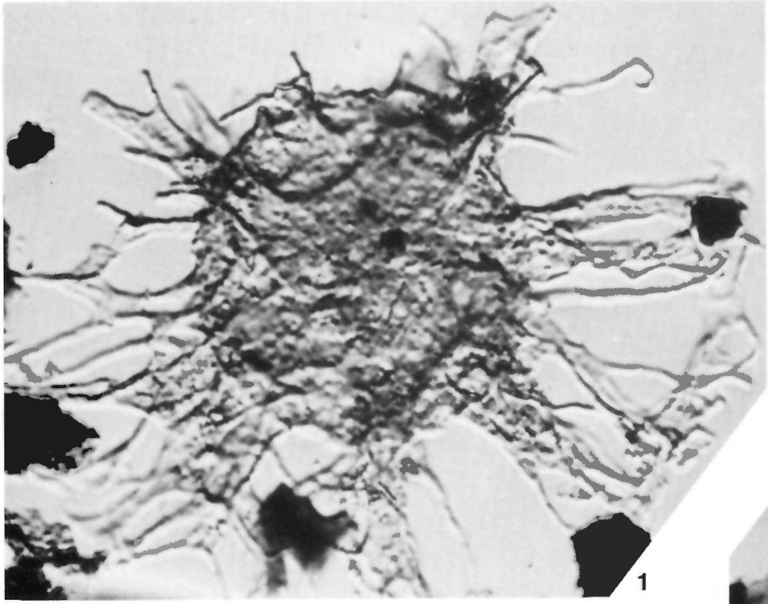
Figures 10-12. *Palaeoperidinium ariadnae* sp. nov.

10. GSC loc. C-48831/10 700-10 800; Slide P-2154-56b; 35.8 x 104.7; mid-focus; GSC 68158.

11. GSC loc. C-48831/11 700-11 800; Slide P-2154-64b; 40.9 x 93.5; mid-focus; GSC 68159.

12. GSC loc. C-48831/11 100-11 200; Slide P-2154-59b; 30.3 x 103.8; mid-focus; GSC 68160.

PLATE 12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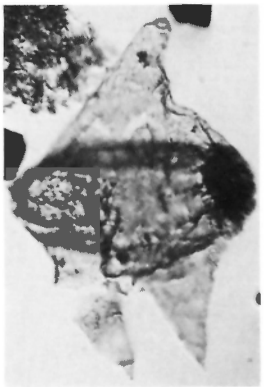
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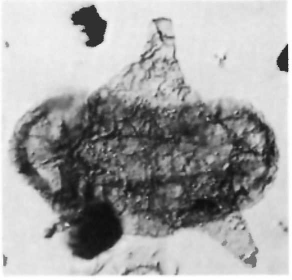
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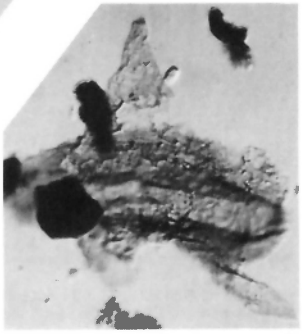
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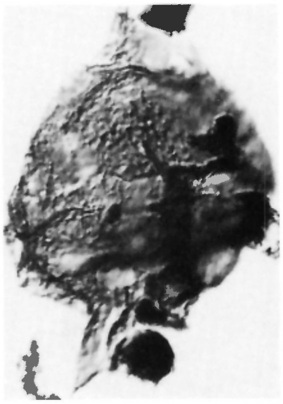
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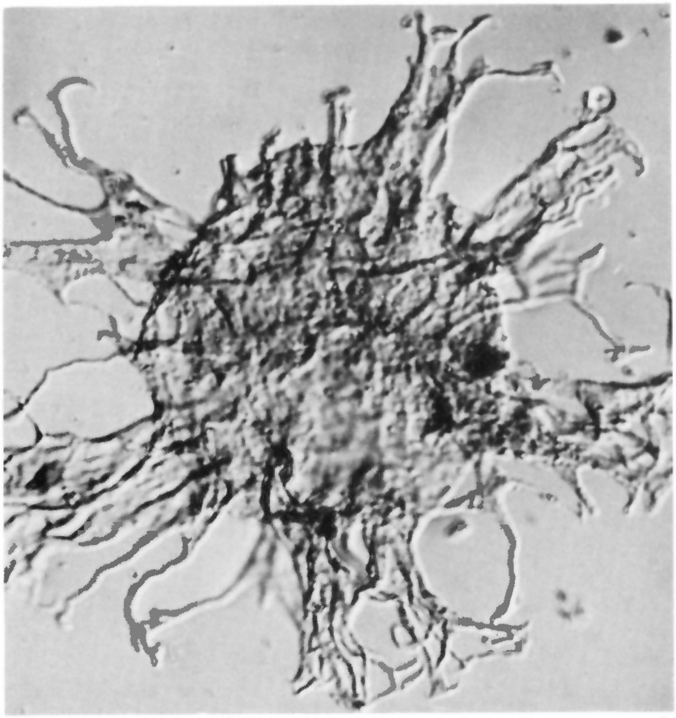
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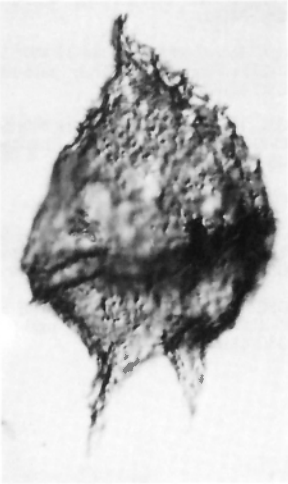
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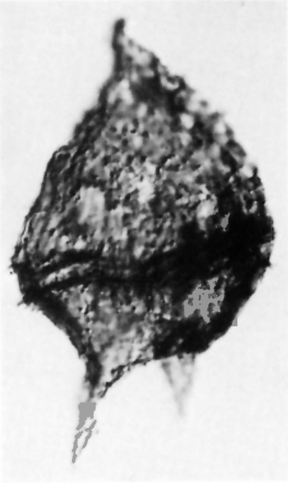
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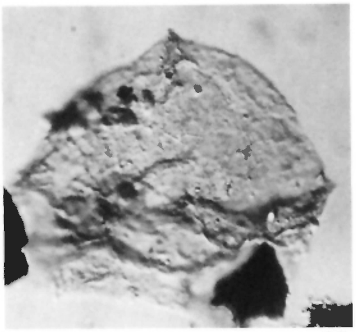
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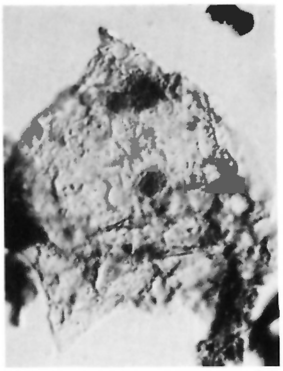
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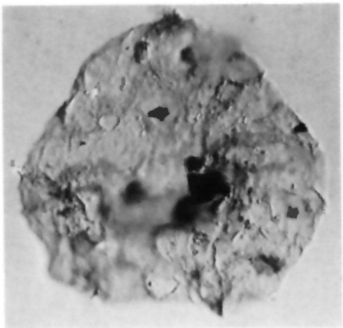
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PLATE 13

All figures 750x, interference contrast illumination.

Figures 1-4. *Palaeoperidinium ariadnae* sp. nov.

1. GSC loc. C-48831/11 800-11 900; Slide P-2154-65b; 23.9 x 98.5; low focus (ventral); GSC 68161.

2. Holotype. GSC loc. C-48831/10 500-10 600; Slide P-2154-54f; 27.1 x 110.9; mid-focus; GSC 68162.

3. GSC loc. C-48831/12 300-12 400; Slide P-2154-70b; 37.5 x 107.3; mid-focus; GSC 68163.

4. GSC loc. C-48831/12 200-12 300; Slide P-2154-69f; 41.7 x 107.8; mid-focus; GSC 68164.

Figures 5, 6. *Palaeoperidinium* sp. A.

5. GSC loc. C-48831/12 200-12 300; Slide P-2154-69b; 25.6 x 110.6; mid-focus; GSC 68165.

6. GSC loc. C-48831/11 700-11 800; Slide P-2154-64b; 43.7 x 99.6; mid-focus; GSC 68166.

Figure 7. *Maduradinium turpis* sp. nov.

Holotype. GSC loc. C-48831/12 600-12 650; Slide P-2154-73b; 24.0 x 104.8; mid-focus; GSC 68167.

Figures 8, 9 "*Horologinella*" sp. A.

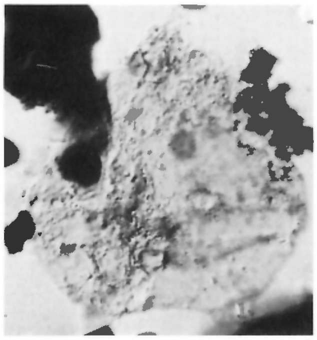
8. Imperial slide 7682, SWC; 45.4 x 94.3; mid-focus; GSC 68168.

9. Imperial slide 7291, SWC; 50.7 x 109.9; mid-focus; GSC 68169.

Figures 10, 11. *Wetzeliella* sp. cf. *W. hampdenensis* Wilson.

10. Imperial slide 12 600; 39.5 x 104.5; mid-focus; GSC 68170.

11. GSC loc. C-48831/12 400-12 500; Slide P-2154-71b; 27.8 x 95.9; mid-focus; GSC 68171.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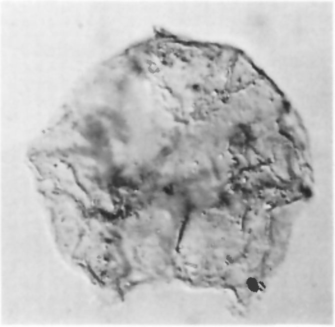
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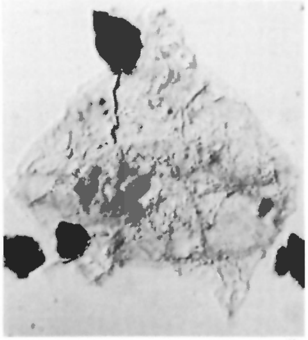
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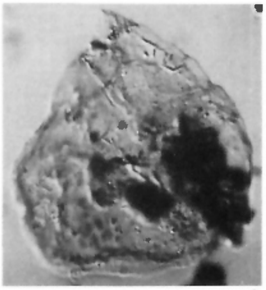
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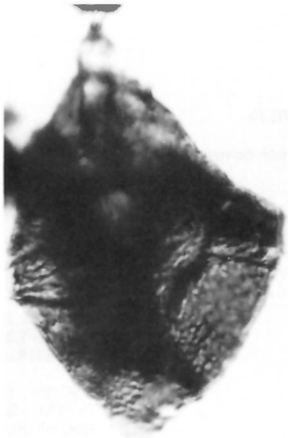
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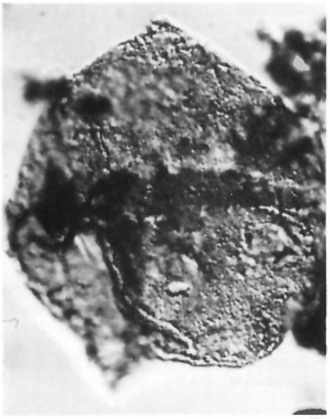
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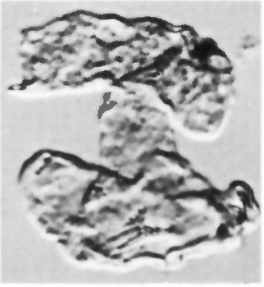
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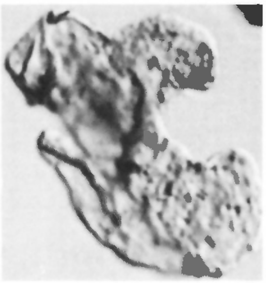
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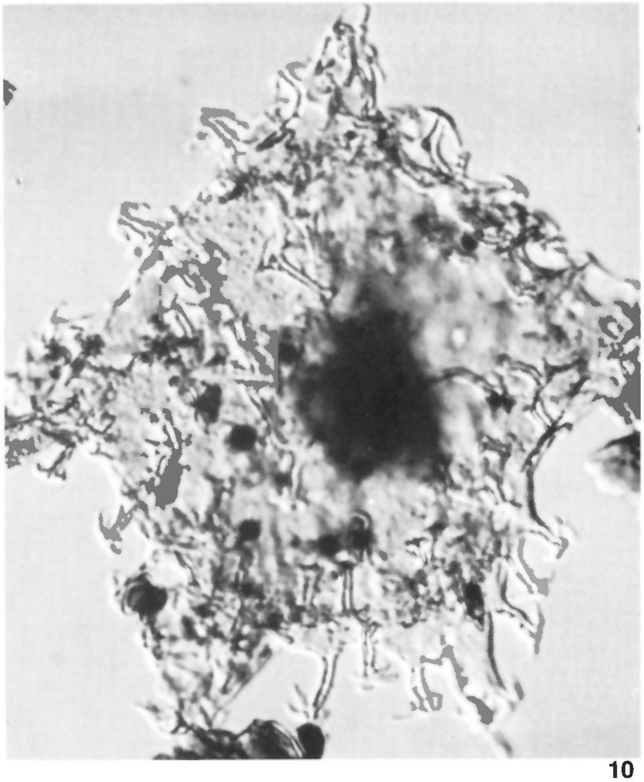
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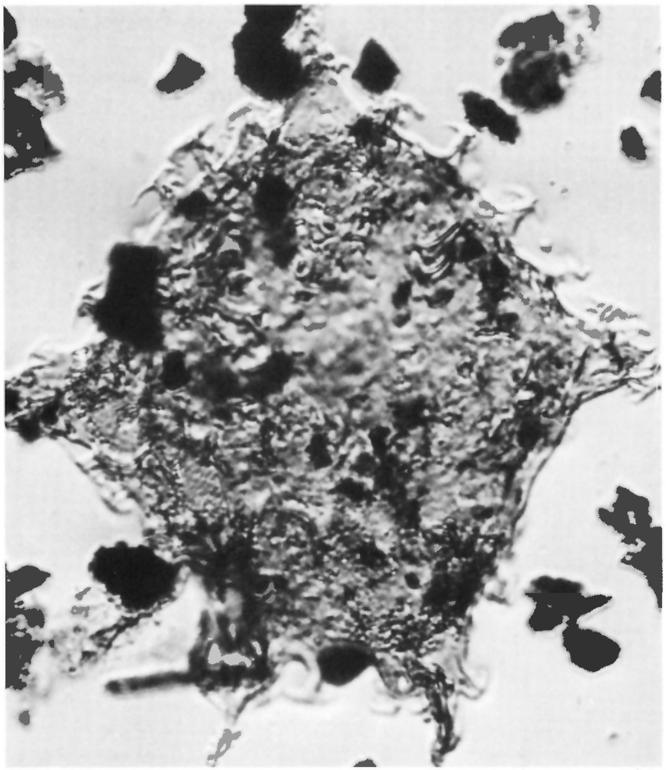
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PLATE 14

All figures 750x, interference contrast illumination.

Figures 1-4. *Maduradinium turpis* sp. nov.

1. Imperial slide 11 970; 35.9 x 102.1; high focus (dorsal); GSC 68172.

2. GSC loc. C-48831/12 300-12 400; Slide P-2154-70b; 41.9 x 109.3; mid-focus; GSC 68173.

3. Imperial slide 12 600; 30.5 x 106.3; mid-focus; GSC 68174.

4. Imperial slide 12 600; 42.8 x 98.4; mid-focus; GSC 68175.

Figures 5-7. *Pyxidiella* sp. A.

5. Imperial slide 7050; 35.7 x 109.5; mid-focus; GSC 68176.

6. Imperial slide 1650; 42.0 x 106.9; mid-focus; GSC 68177.

7. Imperial slide 7050; 37.6 x 99.7; mid-focus; GSC 68178.

Figures 8-14. *Dioxya*(?) *pignerata* sp. nov.

8. GSC loc. C-48831/10 300-10 400; Slide P-2154-53b; 30.9 x 103.0; mid-focus; GSC 68179.

9. GSC loc. C-48831/10 300-10 400; Slide P-2154-53b; 43.8 x 101.4; mid-focus; GSC 68180.

10. GSC loc. C-48831/10 600-10 700; Slide P-2154-55b; 42.6 x 100.8; mid-focus; GSC 68181.

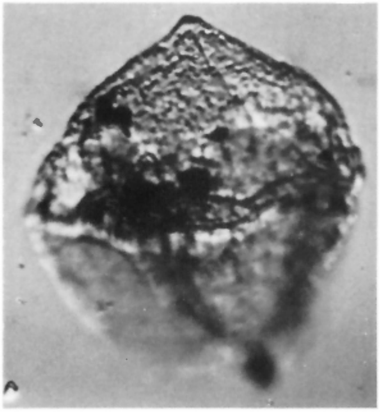
11. GSC loc. C-48831/10 300-10 400; Slide P-2154-53b; 34.8 x 110.5; mid-focus; GSC 68182.

12. Holotype. GSC loc. C-48831/10 300-10 400; Slide P-2154-53b; 31.7 x 111.4; mid-focus; GSC 68183.

13. GSC loc. C-48831/10 300-10 400; Slide P-2154-53b; 42.9 x 103.0; mid-focus; GSC 68184.

14. GSC loc. C-48831/10 300-10 400; Slide P-2154-53f; 24.3 x 104.3; mid-focus; GSC 68185.

PLATE 14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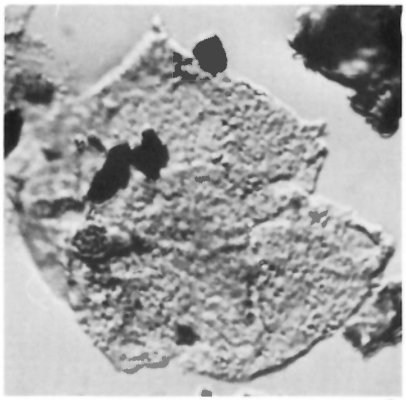
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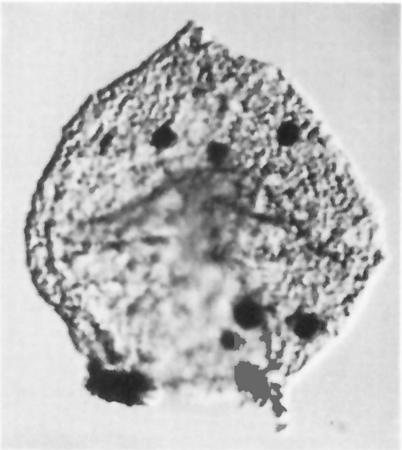
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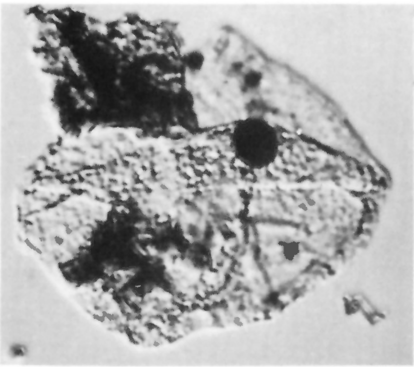
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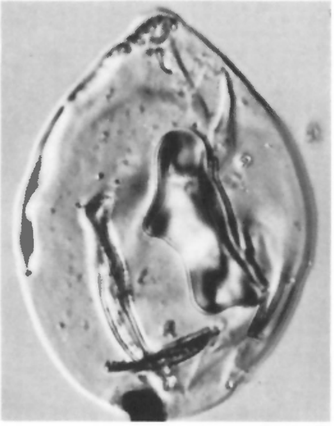
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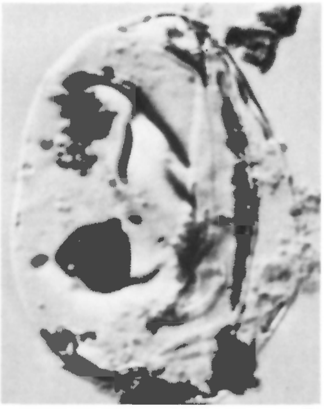
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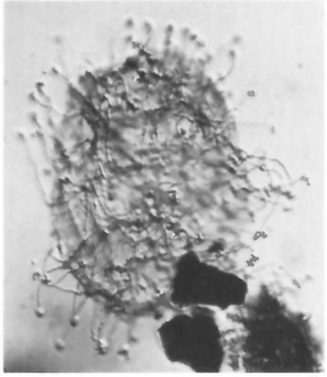
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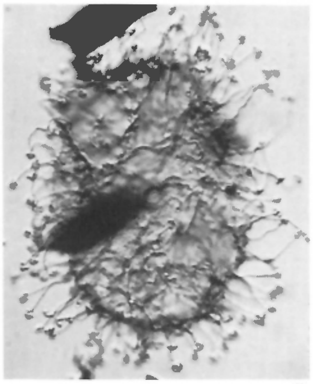
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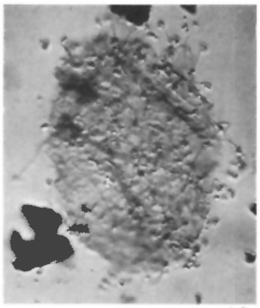
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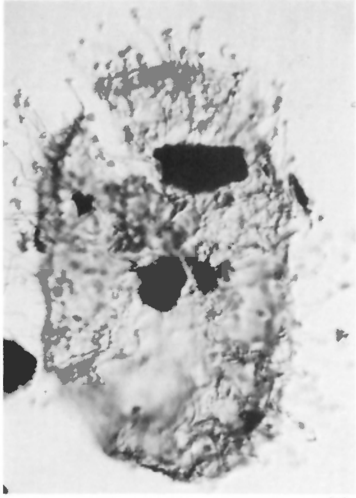
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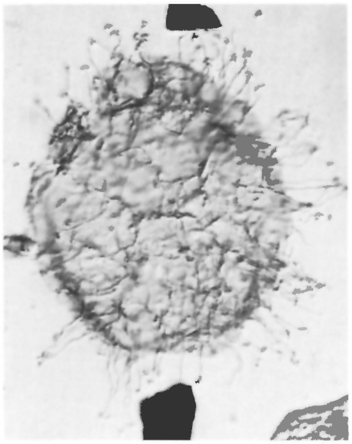
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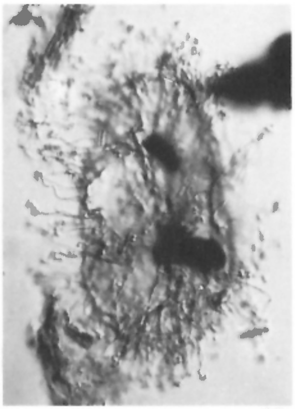
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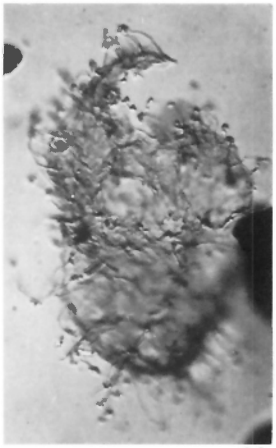
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