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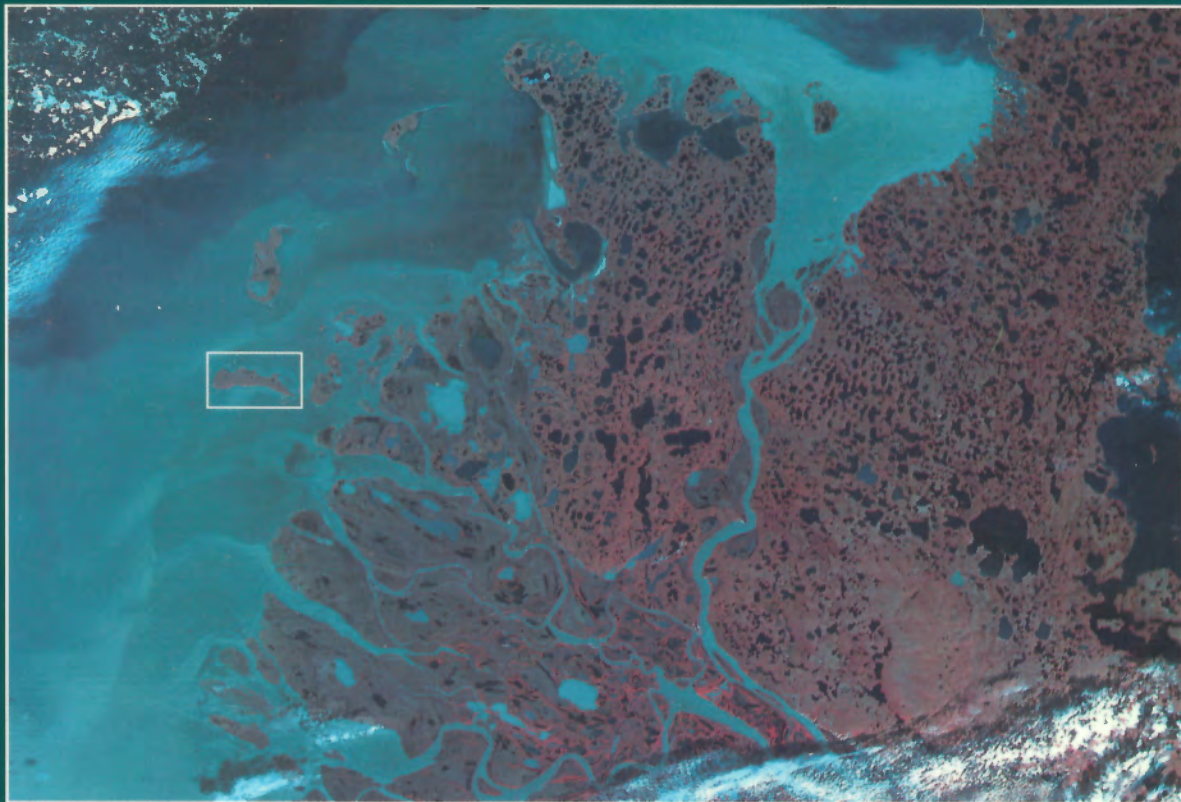
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GEOLOGICAL SURVEY OF CANADA  
BULLETIN 523

**PALEOCENE-PLIOCENE DELTAIC TO INNER SHELF  
PALYNOSTRATIGRAPHIC ZONATION, DEPOSITIONAL  
ENVIRONMENTS AND PALEOCLIMATES IN THE IMPERIAL  
ADGO F-28 WELL, BEAUFORT-MACKENZIE BASIN**

G. Norris



1997



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Photo from part of LANDSAT 5-TM (band 2, 3, 4) showing location of ADGO F-28 well (outlined in white). Scene ID: 50874-200259; photo acquired July 23, 1986. Distributed with the authorization of the Canada Centre for Remote Sensing.

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## **PREFACE**

The Mackenzie River delta in northwestern Canada contains a thick sequence of Tertiary sedimentary rocks, which because of their hydrocarbon content, are of significant interest. One of the tools used to subdivide and correlate the succession is palynology – the study of plant and other organic microfossils. This bulletin describes the results of a study contracted by the Geological Survey of Canada to document the palynological record in a hydrocarbon exploration well that penetrated 3200 m of sediments. The result is a distribution analysis that will serve as a standard for Tertiary sequences anywhere in arctic and subarctic regions of the world. More than 200 species were analyzed to produce this zonation. These fossils also provide invaluable information about the environments in which the deltaic and associated marine shelf sediments were deposited, and record the progressively cooling climatic conditions. Some of the species illustrated are new to science, and some of them new to the area; thus this bulletin is an important contribution to our knowledge of the paleontology and geology of northwestern Canada, and as well, an aid to the petroleum geologist.

M.D. Everell  
Assistant Deputy Minister  
Earth Sciences Sector

## **PRÉFACE**

Le delta du fleuve Mackenzie, dans le nord-ouest du Canada, renferme une épaisse séquence de roches sédimentaires du Tertiaire qui affichent un intérêt particulier en raison de leur contenu en hydrocarbures. Afin d'établir des subdivisions et des corrélations à l'intérieur de cette séquence, on a notamment eu recours à la palynologie - l'étude des microfossiles organiques d'origine végétale et autre. Le présent bulletin décrit les résultats d'une étude sous contrat réalisée par la Commission géologique du Canada dans le but de fournir une description détaillée des données palynologiques recueillies dans un sondage de recherche d'hydrocarbures ayant traversé 3 200 m de roches sédimentaires. Une analyse de répartition a été élaborée à partir de ces données; celle-ci aura une valeur normative pour les séquences tertiaires de l'ensemble des régions arctiques et subarctiques du globe. Plus de 200 espèces ont été analysées afin d'élaborer le schéma de zonation palynologique. Les palynomorphes livrent en outre des renseignements fort utiles sur les milieux de dépôt des sédiments deltaïques et des sédiments de plate-forme continentale interne associés de ce sondage, tout en fournissant des indications sur le refroidissement progressif du climat. Certaines des espèces décrites n'avaient jamais été observées auparavant et d'autres n'avaient jamais été notées dans la région. Ce bulletin apporte ainsi une contribution importante à nos connaissances sur la paléontologie et la géologie du nord-ouest du Canada. Il constitue également un guide pour le géologue pétrolier.

M.D. Everell  
Sous-ministre adjoint  
Secteur des sciences de la Terre



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# PALEOCENE-PLIOCENE DELTAIC TO INNER SHELF PALYNOSTRATIGRAPHIC ZONATION, DEPOSITIONAL ENVIRONMENTS AND PALEOCLIMATES IN THE IMPERIAL ADGO F-28 WELL, BEAUFORT-MACKENZIE BASIN

## *Abstract*

The Imperial Adgo F-28 well (lat. 69°30'N, long. 135°45'W) penetrates more than 10 000 ft (3200 m) of Cenozoic deltaic and delta-front clastic sediments representing transgressive-regressive cycles. Stratigraphic ranges of more than 200 species of palynomorphs in the Pliocene through upper Paleocene interval are documented based on cuttings samples composited over 100-foot intervals. An interval zonation for the well is established based on last appearance datums (stratigraphic range tops) of selected terrestrial species supplemented by other palynomorph assemblage information. The zonation is correlated with other sections in the Beaufort-Mackenzie Basin and Arctic Archipelago and ages are determined by comparison with biostratigraphic data from Cenozoic sections within and outside the basin.

The Iperk Sequence (Late Pliocene) is characterized by the *Laevigatosporites* Zone and the upper part of the *Chenopodipollis* Zone. The subjacent Mackenzie Bay Sequence (Early-Middle Miocene) is characterized by the *Tsugaepollenites* Zone. At approximately 2800 ft, Miocene sediments rest on the late Eocene *Integricarpus* Zone (Richards Sequence). Below this are more than 7000 ft (2130 m) of Taglu Sequence (latest Paleocene-Middle Eocene) and Aklak Sequence (Late Paleocene). These two sequences are divided into six interval zones (from top to bottom, the *Pesavis tagluensis*, *Punctodiporites*, *Paraalnipollenites*, *Fusiformisporites*, *Ctenosporites*, and *Multicellaesporites-Pluricellaesporites* zones). The Paleocene-Eocene boundary occurs within the *Ctenosporites* Zone near the bottom of the Taglu Sequence.

Scattered intervals within the Taglu Sequence and lower part of the Richards Sequence (spanning collectively Lower through Upper Eocene) are characterized by dinoflagellate cyst assemblages of low diversity indicating sporadic marine to hyposaline incursions consistent with a fluctuating inner shelf/prodelta/delta-front depositional environment. Some of the Eocene dinoflagellate flora appear to be endemic to the basin, but other species indicate connections with lower latitude assemblages.

Upper Paleocene spore-pollen floras are of low diversity and contrast with the rich Eocene palynofloras. The highly diverse Lower through Upper Eocene terrestrial palynofloras in general indicate warm temperate climates. Warm temperate climates may have recurred in the early Miocene. Cool temperate climates are indicated for the late Miocene and Pliocene, possibly becoming boreal at the end of Pliocene times.

Fungal palynomorphs and embryophyte spores and pollen new to the area are illustrated and listed taxonomically. These include 8 new species, 16 species described in open nomenclature, 6 new combinations, and an additional 45 species new to the area but previously described from outside the Beaufort-Mackenzie Basin.



## Résumé

Le sondage Imperial Adgo F-28 (lat. 69°30'N, long. 135°45'W) traverse plus de 10 000 pieds (3 200 m) de roches sédimentaires clastiques du Cénozoïque, qui se sont déposées dans des milieux deltaïque et frontodeltaïque et qui témoignent de cycles de transgression-régression. Dans l'intervalle du Pliocène au Paléocène supérieur, des échantillons composites de déblais de forage recueillis sur des intervalles de 100 pieds ont servi à établir les extensions stratigraphiques de plus de 200 espèces de palynomorphes. Dans la coupe fournie par ce sondage, les niveaux de dernière présence (sommets de l'extension stratigraphique) d'espèces continentales choisies ont permis de définir des zones d'intervalle; le schéma de zonation qui se dégage de celles-ci a été complété à l'aide d'autres informations sur les associations de palynomorphes. Les zones définies dans cette coupe ont permis des corrélations avec d'autres coupes du bassin de Beaufort-Mackenzie et de l'archipel Arctique; les âges de celles-ci ont été déterminés par comparaison avec des données biostratigraphiques provenant de coupes du Cénozoïque à l'intérieur et à l'extérieur du bassin.

La Séquence d'Iperk (Pliocène supérieur) renferme la Zone à *Laevigatosporites* et la partie supérieure de la Zone à *Chenopodipollis*. La Séquence de Mackenzie Bay (Miocène inférieur-moyen) sous-jacente se distingue par la Zone à *Tsugaepollenites*. À 2 800 pieds (850 m) environ, les roches sédimentaires du Miocène surmontent la Zone à *Integricorpus* de l'Éocène tardif (Séquence de Richards). Sous ce niveau, le sondage a recoupé plus de 7 000 pieds (2 130 m) de roches sédimentaires attribuées à la Séquence de Taglu (Paléocène sommital-Éocène moyen) et à la Séquence d'Aklak (Paléocène supérieur). Six zones d'intervalle ont été définies dans ces deux séquences (de haut en bas, ce sont les zones à *Pesavis tagluensis*, à *Punctodiporites*, à *Paraalnipollenites*, à *Fusiformisporites*, à *Ctenosporites* et à *Multicellaesporites-Pluricellaesporites*). La limite Paléocène-Éocène se trouve au sein de la Zone à *Ctenosporites*, près de la base de la Séquence de Taglu.

Dans la Séquence de Taglu et la partie inférieure de la Séquence de Richards (qui s'étendent collectivement de l'Éocène inférieur à l'Éocène supérieur), des intervalles dispersés sont caractérisés par des associations de kystes de dinoflagellés affichant une faible diversité qui témoignent d'incursions sporadiques d'eaux marines à saumâtres; cela indique que le dépôt des sédiments s'est effectué dans des milieux de plate-forme continentale interne, de prodelta et de front de delta aux limites fluctuantes. Une partie de la flore de dinoflagellés de l'Éocène paraît endémique au bassin, mais d'autres espèces montrent des affinités avec des associations de plus basse latitude.

Les flores de spores et de pollens du Paléocène tardif présentent une faible diversité et font contraste avec les riches palynoflores de l'Éocène. Les palynoflores continentales très variées de l'Éocène précoce à l'Éocène tardif attestent en général de climats tempérés chauds. Il est possible que de tels climats soient réapparus au début du Miocène. Le climat, qui était du type tempéré frais au Miocène tardif et au Pliocène, est peut-être devenu boréal à la fin du Pliocène.

Les palynomorphes fongiques et les spores et les pollens d'embryophytes identifiés pour la première fois dans la région sont illustrés et énumérés selon leur taxonomie. Figurent notamment 8 espèces nouvelles, 16 espèces décrites dans des nomenclatures provisoires, 6 nouvelles combinaisons et 45 espèces non observées jusqu'ici dans la région mais déjà décrites à l'extérieur du bassin de Beaufort-Mackenzie.

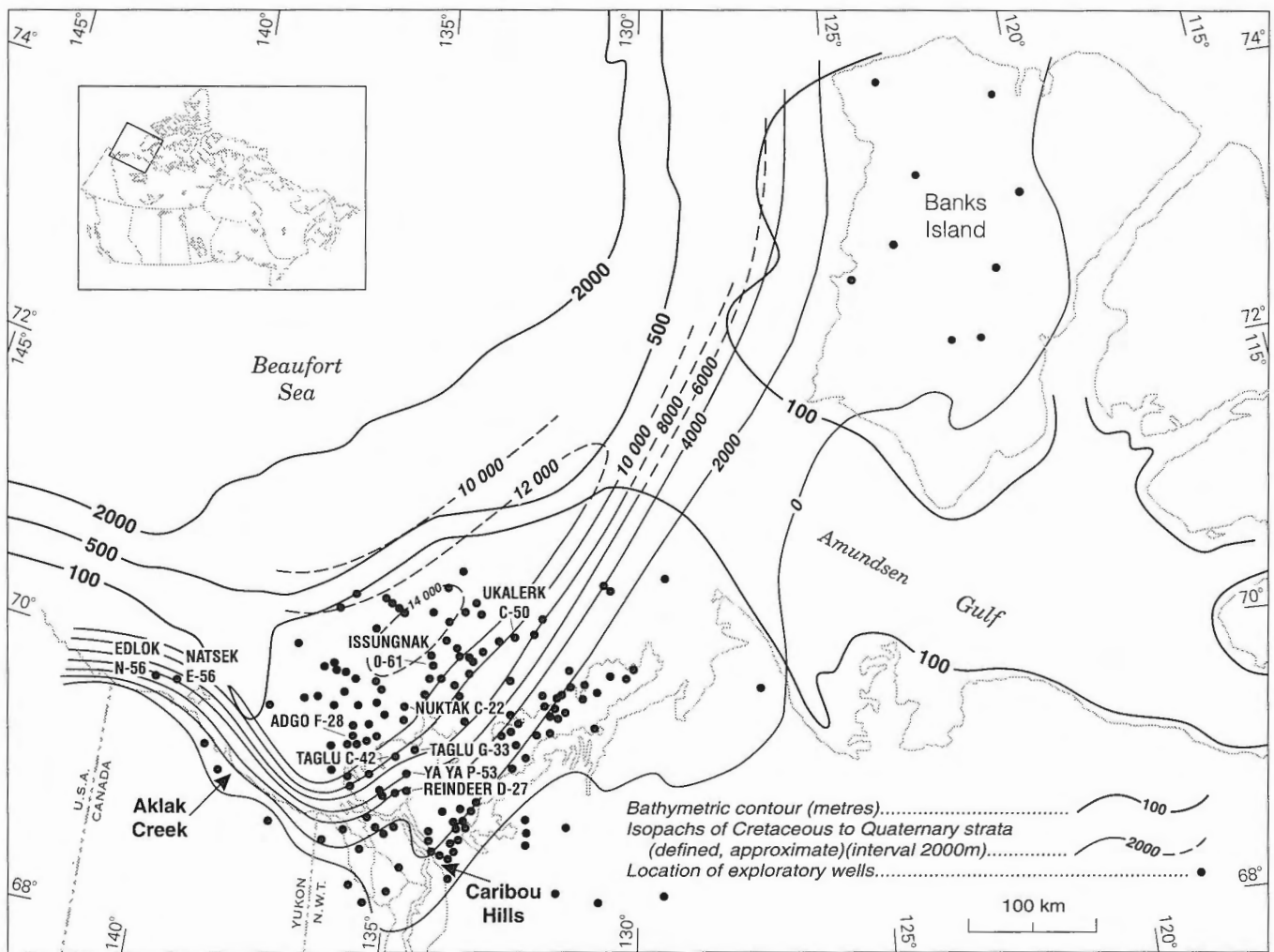
# INTRODUCTION

## Background

The Beaufort-Mackenzie Basin contains a Cenozoic sedimentary fill dominated by terrigenous, clastic sediments that accumulated on the relatively narrow continental margin of the Beaufort Sea. Total estimated thickness of these sediments is about 12 km in the basin depocentre, located offshore and north of the Mackenzie Delta (Fig. 1). Nine depositional, transgressive-regressive sequences, spanning the interval from uppermost Cretaceous through Pleistocene, have been recognized in this basin (Fig. 2), based on integrated seismostratigraphy and lithostratigraphy (Dietrich et al., 1985; Dixon and Dietrich, 1988; Dietrich et al., 1989; Dixon et al., 1992). Major unconformities within the Paleogene and Neogene have

been attributed to both tectonism near the basin margins and changes in relative sea level. Industry interest in the petroleum potential of these strata has focused on Paleocene, Eocene, and Oligocene clastic units, and their hydrocarbon accumulations are known to be related to both structural relations and lithofacies variations. Fundamental to a proper understanding of all these approaches has been the continuing development of a sound biostratigraphic framework on which to base both chronostratigraphic and facies analyses of sedimentary units.

Earlier biostratigraphic studies concentrated on foraminifers (McNeil, 1985, 1989, 1990a; Dixon et al., 1985). The introduction of the Frontier Geoscience Program by the Geological Survey of Canada in 1984 provided the impetus and necessary resources to integrate earlier studies into a regional foraminiferal



**Figure 1.** Location map of Adgo F-28 well and other wells and localities mentioned in the text. Isopachs of Upper Cretaceous through Quaternary strata shown as 2000 m contours (after Dixon et al., 1992, Fig. 15). Selected wells are identified. Location of other exploratory wells indicated by dots.

AUTHORS AGE	DIXON ET AL. (1992)	WILLUMSEN AND CÔTÉ (1982)	YOUNG AND McNEIL (1982)	LANE AND JACKSON (1980)	HEA ET AL. (1980)
	QUATERNARY	SHALLOW BAY SEQ.	BEAUFORT DELTA	Recent deposits HERSCHEL I. FM	
PLIOCENE	I PERK SEQUENCE		NUKTAK FORMATION		BEAUFORT FORMATION
MIOCENE	L AKPAK SEQUENCE	AKPAK DELTA		BEAUFORT SEQUENCE	
	M E MACKENZIE BAY SEQUENCE		BEAUFORT FORMATION		
			MACKENZIE BAY FM		
OLIGOCENE	L KUGMALLIT SEQUENCE	PULLEN DELTA	KUGMALLIT FORMATION		Shale
	E			MACKENZIE SEQUENCE	Pullen sand
EOCENE	L RICHARDS SEQUENCE	Unnamed Eocene shale	RICHARDS FORMATION	KUGMALLIT SEQUENCE	Unnamed shale
	M TAGLU SEQUENCE	TAGLU DELTA	REINDEER FORMATION	REINDEER SEQUENCE	REINDEER FORMATION
	E AKLAK SEQUENCE				
PALEOCENE	L				
	E FISH RIVER SEQUENCE	MOOSE CHANNEL DELTA	FISH RIVER GROUP MOOSE CHANNEL FM	FISH RIVER SEQUENCE	MOOSE CHANNEL FM
MAASTRICHTIAN		No named units	TENT ISLAND FM	No named units	TENT ISLAND FM
CAMPANIAN	SMOKING HILLS SEQUENCE				

Figure 2. Campanian through Quaternary stratigraphic nomenclature and ages for the Beaufort-Mackenzie Basin employed by various authors (redrawn from Dixon et al., 1992; references cited in that publication). Hachured areas indicate missing sections.

zonation that included much of the Cenozoic marine strata (McNeil, 1989). Palynological studies of the Beaufort Mackenzie Basin were slower to start, but a good summary by Staplin (1976) of industry initiatives led to a number of subsequent studies that refined and expanded earlier palynostratigraphic ideas (Brideaux and Myhr, 1976; Ioannides and McIntyre, 1980; McNeil et al. 1982; Dixon et al., 1985; McIntyre, 1985; Norris, 1986; Dietrich et al., 1989; White, 1989). Concomitant studies on morphological and taxonomic features of parts of the palynofloras, as reviewed in more detail later in this paper, contributed to the building of a soundly analyzed database. To date, however, no comprehensive overview of regional palynostratigraphy has been attempted comparable to that achieved by McNeil et al. (op. cit.).

The importance of palynology to a proper understanding of Cenozoic stratigraphy and structures in the Mackenzie Delta region cannot be over-emphasized. Throughout the latest Cretaceous and Cenozoic, the basin was dominated by major wave-modified, river-dominant deltas that profoundly influenced the biota, and led to extreme biofacies gradients which commonly extinguished marine faunas when progradation or river discharge, or both, were at a maximum. Significantly large intervals are nonmarine and therefore contain no foraminifers or other marine fauna, making it essential to use the terrestrial palynofloras for biostratigraphic control, both within single facies and across different facies. The ability of certain components of a palynoflora to cross facies boundaries on a predictable basis is paleontologically unique and enormously important to a comprehensive synthesis of stratigraphic relations within a basin with complex facies associations such as the Beaufort-Mackenzie.

Previous palynological studies can be categorized as follows:

- i. morphology and systematics (Elsik and Jansonius, 1974)
- ii. palynostratigraphy (Ioannides and McIntyre, 1980)
- iii. paleoecology and paleoenvironmental (Norris, 1982)
- iv. multidisciplinary; integrating palynology with other paleontological and stratigraphic approaches (Dietrich et al., 1989)

Several publications contain some or all of the above approaches.

There has been considerable variation in palynostratigraphic methodology. Different authors have concentrated on analysis of specific intervals, entire sections or wells, different taxonomic groups,

elucidation of assemblages, or recognition of a variety of zones, with or without the designation of formalized taxa or formalized biostratigraphic units. Complications arise when comparing data insofar as different authors subscribe to different taxonomic and nomenclatural procedures. The latter generally either base taxa on extant comparable genera and species, or utilize a morphographic approach to establish palynological taxa on fossil material alone. Although there are some notable examples of extant taxa being unequivocally documented in the fossil record, a very large proportion of Cenozoic palynomorphs are apparently not comparable to modern genera and species. This is not surprising considering the evolutionary potential of all groups over the more than 60 million years of history of the Beaufort-Mackenzie Basin. Therefore, the present author favours a morphographic approach, as successfully used in a previous palynostratigraphic study of Cenozoic strata in the Mackenzie Delta (Norris, 1986) and widely employed by many other workers in industry and other institutions. Taxa recognized using this approach can thus be easily categorized to form a useful and consistent database, and may also be compared botanically to extant taxa at various levels. A more detailed discussion of these topics is presented elsewhere in this paper.

The purposes of the present study are:

- i. using the Adgo F-28 well, to expand the palynostratigraphic scheme as outlined by Norris (1986) for the Pliocene to Middle Eocene interval into the Lower Eocene and possibly the Upper Paleocene, and to integrate this with other palynological studies in the basin and elsewhere;
- ii. to provide systematic information on terrestrial and marine palynomorphs;
- iii. to correlate palynological assemblages and zones with other sections in the Beaufort-Mackenzie Basin;
- iv. to establish age and facies relations of the palynologic successions, where possible, and to relate them to seismostratigraphic units established by others within the Cenozoic of the basin.

## Materials and methods

The Imperial Adgo F-28 well was drilled in 1973 from an artificial island offshore of Mackenzie Delta (Fig. 1). It resulted in the first offshore oil/gas discovery in the basin.

The samples for this study were provided by the Geological Survey of Canada (Calgary). Cuttings samples were composited over 100-foot (30.5 m)

intervals starting at 100 ft and terminating at TD at 10 528 ft (3208.9 m). Imperial units are used throughout this paper to refer to samples from wells drilled prior to metric conversion in Canada.

The samples were macerated for palynomorphs using standard acid oxidation procedures and mounted in cellosize-elvacite as strew mounts without screening. Two slides of each sample were examined, scanning with 25x and 40x interference contrast objectives. Photographs were taken using a 100x interference contrast objective and Ilford Pan F film. Red filters were used when photographing the dark brown fungal palynomorphs.

Palynomorphs were identified to species level. Several new species were identified and described; other species, which may be new but are not represented by enough specimens to ascertain infraspecific variability remain in open nomenclature. All terrestrial embryophyte and fungal palynomorphs have been constrained taxonomically in this paper, and the new species – or newly reported species – have been described and illustrated. Dinoflagellates generally occur less commonly and are less well preserved than are terrestrial palynomorphs in the Adgo F-28 well. Therefore, they have been identified as closely as possible but the apparently new dinoflagellate species have been left in open nomenclature and illustrated only.

All species were assigned unique species numbers to facilitate entry in a database used to generate species distribution charts through PAZ Graphics Strat/Range Charter and Claris MacDraw II software. Some of these unique numbers are used to identify species in open nomenclature, but most species are referred to legitimate and validly published names in accord with the International Code of Botanical Nomenclature.

Species distribution (Fig. 3) is plotted with emphasis on the last appearance datums (LADs), in view of the fact that the samples are cuttings and subject to caving, which tends to extend the base of a species range downhole (i.e., the first appearance datum may be higher than indicated by the lowest occurrence of a species). This type of data set is best handled by division into interval zones, as defined by the International Stratigraphic Guide (Hedberg, 1976). However, the palynostratigraphic data seem to be well constrained in some intervals and not greatly affected by caving; therefore, in certain cases it is possible to develop information on assemblage zonations, always bearing in mind that the precise first appearance datums (FADs) cannot be known with certainty without additional information from core material, which was not available from Adgo F-28. The

palynostratigraphic data are presented in their entirety to facilitate future use in numerical biostratigraphic methods.

### Stratigraphy

The first comprehensive account of the Cenozoic lithostratigraphy of the Beaufort-Mackenzie Basin was published by Young and McNeil (1984). Their work has subsequently been updated and placed within the context of regionally recognized sequences (Fig. 2) by Dietrich et al. (1985), Dixon and Dietrich (1988), Dietrich et al. (1989), and Dixon, et al. (1992), and within the context of foraminiferal biostratigraphy and biofacies by McNeil (1989, 1990a). Of the nine transgressive-regressive sequences now recognized in the Cenozoic and uppermost Maastrichtian of the Beaufort-Mackenzie Basin, the following are present in Adgo F-28 (Dixon, 1990, modified by J. Dixon, pers. comm., March 1991):

Sequence	Sequence top (ft)
Iperk	24
Mackenzie Bay	1690
Richards	2805
Taglu	3560
Aklak	9250 (TD 10 528)

Earlier work on the lithostratigraphy of this well had indicated the presence of the Moose Channel Formation below about 8570 ft (2612.1 m) or “Lower Reindeer Sequence” below 9250 ft (2819.4 m) (see Dixon et al., 1987) but this was incorrect (see Dixon, 1990; Dixon et al., 1992, fig. 21). The entire lower part of this well is now known to represent only the upper part of the Aklak Sequence (i.e., Reindeer Formation) and does not include the lower part of the sequence as implied in Figures 4 and 5 of Norris (1986), in the interval labelled erroneously “Moose Channel Formation”.

Classification of the sequence stratigraphy was further modified by Dixon et al. (1992, fig. 21), the most notable difference being the placement of the Mackenzie Bay interval between 480 ft and 1690 ft. On the basis of palynostratigraphy, the present author believes it is more likely that the Mackenzie Bay interval occurs between about 1690 ft (515.1 m) and 2805 ft (855 m), an interval containing Neogene floras correlative with the Mackenzie Bay sequence in the Imperial Nuktak C-22 well (see Norris, 1986, figs. 4, 5). If this is the case, the Iperk Sequence would occupy the interval between 24 ft and 1690 ft in the Adgo F-28 well. There is no palynological evidence to suggest the presence of Late Miocene marine strata with the

characteristic dinoflagellates reported from the Akpak Sequence farther north (Bujak and Davies, 1981; Dixon et al., 1984).

On the basis of foraminiferal studies, McNeil (1989, 1990a), Dietrich et al. (1989), and Dixon et al. (1992) provided the following maximum age determinations for these sequences for the basin as a whole:

- Iperk - Pliocene and Pleistocene
- Mackenzie Bay - very Late Oligocene, Early and Middle Miocene
- Richards - latest Middle and Late Eocene
- Taglu - late Early and Middle Eocene
- Aklak - Late Paleocene and earliest Early Eocene.

Palynological studies as reported herein and by others (e.g., Dixon et al., 1985) broadly agree with these determinations, although sequences in the Adgo F-28 well do not represent total maximum ranges for each sequence across the entire basin.

In the southern part of the Beaufort-Mackenzie Basin, the Aklak Sequence consists of delta-plain, dominantly arenaceous strata, composed of fining-upward sedimentary cycles with coals. These gradually pass northward into coarsening-upward units of the prodelta and delta-front regime. The overlying Taglu Sequence is dominated by coarsening-upward units, representing crevasse and delta-front clastics of widely varying thickness (Dixon et al., 1985). The Richards Sequence, by contrast, is mudstone-dominated and represents a succession of prodelta and slope deposits, with local coarser grained beds interpreted as debris-flow deposits. A considerable hiatus separates the Richards Sequence from the superjacent Mackenzie Bay Sequence, which is dominated by mudstone and siltstone. The Iperk Sequence unconformably overlies the Mackenzie Bay Sequence in this area. It comprises arenaceous and higher energy, fluvio-deltaic depositional complexes.

### PALYNOSTRATIGRAPHY

The interval zones described below are based on range tops (last - i.e., youngest - appearance datums or LADs) of selected palynomorph species because the primary material from the well is derived from cuttings samples, which may contain cavings from higher horizons. In some instances, it is possible to integrate the interval zonation with data on assemblages when cavings appear to be minimal. This interval zonation builds on that developed by Norris (1986) using the Imperial Nuktak C-22 well, and partially overlaps it. Preliminary correlations between the two wells were indicated by Norris (1986; figs. 4 and 5) but are refined

in the present paper. Distribution of palynomorph species in the Adgo F-28 well are shown in Figure 3. A summary of the zones and age determinations are shown in Figure 4.

SEQUENCE	PALYNOLOGICAL ZONE	AGE
IPERK 24 ft	200 ft <i>Laevigatosporites</i>	LATE PIOCENE
	1300 ft <i>Chenopodipollis</i>	
MACKENZIE BAY 1690 ft	2000 ft <i>Tsugaepollenites</i>	EARLY to MIDDLE MIOCENE
RICHARDS 2805 ft	2800 ft <i>Integricorpus</i>	LATE EOCENE
TAGLU 3560 ft	3300 ft <i>Pesavis tagluensis</i>	MIDDLE EOCENE
	4000 ft <i>Punctodiporites</i>	EARLY EOCENE to MIDDLE EOCENE
	5100 ft <i>Paraalnipollenites</i>	EARLY EOCENE
	6000 ft <i>Fusiformisporites</i>	
6600 ft 7400 ft <i>Ctenosporites</i>	EARLY EOCENE to LATE PALEOCENE	
AKLAK 9250 ft T.D. 10 528 ft	9100 ft <i>Multicellaesporites-Pluricellaesporites</i> T.D. 10 528 ft	LATE PALEOCENE

Figure 4. Palynological interval zones, age determinations, and stratigraphic sequences of the Adgo F-28 well. Tops of sequences and zones are indicated in feet.

#### *Laevigatosporites* Zone (200–1200 ft; 61–365.8 m)

This zone is defined by the LAD for *Laevigatosporites novus*, and its base determined by the top of the underlying zone. The following species occur commonly in this zone but all also occur in the underlying Neogene:

- Polyvestibulopollenites verus*
- Trivestibulopollenites claripites*
- Salixpollenites discoloripites*
- Stereisporites minor*
- Stereisporites stereoides*

*Piceapollenites grandivescipites*  
*Pinuspollenites* sp. A  
Fungal hypha type C

Also present in this zone and in the remainder of the Neogene is *Sigmopollenites psilatus*, a possible algal or aquatic fungal microfossil of uncertain environmental significance. Scattered occurrences of *Pyxidiella* sp. A also characterize this zone but they may represent a recycled dinoflagellate from the Upper Cretaceous. Recycled material is commonly present throughout the Neogene interval in this and other wells in the Beaufort-Mackenzie Basin.

Only one sample, at 100 ft (30.5 m) was taken above the *Laevigatosporites* Zone. It contains a flora of six species (all of which are common in the *Laevigatosporites* zone) and is presumably late Neogene.

### Age

The *Laevigatosporites* Zone was originally assigned tentatively to the Pliocene on the basis of its impoverished flora and presence of some species unknown in the Quaternary (Norris, 1986). It occupies the upper part of the Iperk Sequence, approximately coincident with the *Criboelphidium ustulatum* foraminiferal interval zone (McNeil, 1989). This foraminiferal zone is widespread in arctic regions and represents a period of arctic glacial fluctuations; the impoverished palynoflora is consistent with this interpretation. The *C. ustulatum* zone is underlain by the *Cibicides rossus* interval zone, the upper limit of which McNeil (1990a) believes to be coincident with the onset of widespread glacial conditions at approximately 2.4 Ma. A Late Pliocene age for the *Laevigatosporites* Zone is supported by the immediately adjacent Late Pliocene *Chenopodipollis* Zone.

### Correlation and depositional environment

The *Laevigatosporites* Zone characterizes the Iperk Sequence, which in the Adgo F-28 well consists primarily of fluviodeltaic arenaceous and rudaceous facies (Dixon et al., 1992). The impoverished terrestrial assemblages represented by spores and pollen with affinities to *Pinus*, *Picea*, *Alnus*, *Sphagnum*, *Betula*, *Salix*, and Polypodiaceae (Norris, 1986), have similarities to the boreal assemblages described by Ritchie (1974, 1984). The complete absence, however, of certain herbs in the *Laevigatosporites* Zone, in contrast to those that characterize the modern pollen spectra of the Mackenzie Delta, may be the result of the Adgo F-28 samples representing different

depositional environments (as compared to the low-energy surface environments (lakes, bogs) studied by Ritchie) as much as to any possible climatic differences. If *Sigmopollis* is a freshwater algal cyst (Zippi, 1992; see also the review in Head, 1993), its presence in this and the subjacent zones may be indicative of lacustrine depositional environments associated with ponding on the Iperk Delta. Recycled palynomorphs from Paleogene, Cretaceous, and Upper Paleozoic sources are common in this zone and are probably a result of the dominant fluvial environments and river systems discharging into the very large Iperk Delta centered over the eastern Beaufort Sea.

The Iperk Sequence is named after the Iperk Group, which has its type section in the Dome Gulf et al. Ukalerk C-50 well (Jones et al., 1980). The palynology of the Iperk interval in this well (2000–5208 ft: 609.6–1587.4 m) has been briefly discussed by McNeil et al. (1982). The *Laevigatosporites* Zone occupies the upper part of the interval and broadly conforms with the zonal characteristics as described in the Nuktak C-22 well by Norris (1986). It is underlain in the Ukalerk well below 3700 ft (1127.8 m) by an interval containing compositacean pollen, which is probably attributable to the *Chenopodipollis* Zone (McNeil et al., 1982; Norris, 1986).

The Worth Point Formation outcrops on Banks Island below glacial deposits and may correlate with the Iperk Sequence (Dixon et al., 1992; Vincent et al., 1983; Matthews, 1989).

### *Chenopodipollis* Zone (1300–1900 ft; 396.2–579.1 m)

The top of this zone is defined by the LAD for *Chenopodipollis nuktakensis*, a species confined to this zone together with *Graminiidites* sp. A and *Retitriletes annotinioides*. The base of the zone is defined by the top of the underlying zone. Four other species have LADs at the top of this zone but are also present lower in the Neogene:

*Carpinipites* cf. *spackmaniana*  
*Fractisporonites* cf. *canalis*  
*Deltoidospora hallei*  
*Taxodiaceapollenites hiatus*

*Myricipites annulites* and *Retitriletes* cf. *oligogenicus* occur in the *Chenopodipollis* Zone and do not range lower than the underlying *Tsugaepollenites* Zone. The lower part of the *Chenopodipollis* Zone contains the following species, which appear to range into the *Tsugaepollenites* Zone and also occur in the Paleogene:

*Osmundacidites wellmanii*  
*Quercoidites* sp. A  
*Quercoidites microhenrica*  
*Polyatriopollenites stellatus*  
*Ericipites compactipollinatus*  
*Corsinipollenites triangulatus*  
*Cyathidites minor*  
*Pinuspollenites labdacus*  
*Laevigatosporites ovatus*

It is uncertain whether the occurrence of *Ericipites compactipollinatus* in the uppermost Paleogene is in situ or due to cavings from the Neogene.

### Age

The *Chenopodipollis* Zone was assigned by Norris (1986) to the Pliocene on the basis of the impoverished flora and lack of temperate taxa. This zone in the Imperial Nuktak C-22 well occurs in the lower part of the Iperk Sequence and is approximately coincident with the *Cibicides grossus* foraminiferal interval zone of McNeil (1989), which is dated as early Pliocene to earliest Late Pliocene (McNeil, 1989, 1990a) – immediately prior to the onset of widespread glacial conditions at about 2.4 Ma. The lack of *Tsugaepollenites* pollen in this zone is noteworthy, in view of the probable elimination of *Tsuga* from western Alaska (Wolfe, 1972) and the Beaufort-Mackenzie Basin (White, 1989) after the Middle Pliocene. This may support a Late Pliocene age assignment for the *Chenopodipollis* Zone.

### Correlation and depositional environment

The *Chenopodipollis* Zone occupies the lower part of the Iperk Sequence and appears to extend into the uppermost part of the Mackenzie Bay Sequence. However, its extension into the Mackenzie Bay Sequence is most certainly due either to cavings or an incorrectly chosen base of the Iperk Sequence. Its fluviodeltaic depositional environment is broadly similar to that of the overlying *Laevigatosporites* Zone. The palynofloras are two or three times richer in species than in the overlying zone, chiefly because of the presence of a variety of angiosperm herbs and trees, and more diverse pteridophytes. The chenopod and ericaceous pollen suggests open ground or dry soils, but the climate may have been warmer than the overlying boreal zone judging from the deciduous tree and shrub pollen also present (*Carpinipites*, *Myricipites*, *Quercoidites*, *Polyatriopollenites*). The latter may, however, be recycled in whole or in part from older Cenozoic strata (see White, 1989, for a discussion of the Neogene recycling problem in the

Beaufort-Mackenzie Basin). This zone was first described from the Nuktak C-22 well where it is comparably developed (Norris, 1986).

Dietrich et al. (1989, fig. 5) reported an impoverished palynofloral assemblage from basal Iperk strata in the Natsek E-56 well in the western Beaufort Sea. This assemblage contains Chenopodiaceae and Gramineae but lacks *Tsugaepollenites*, suggesting a correlation with the *Chenopodipollis* Zone.

Terrestrial palynomorph assemblages documented by White (1989) from the lower part of the Iperk Group in the Issungnak O-61 well contain *Tsugaepollenites*. These assemblages are therefore likely older than those from the lowest Iperk strata in the Adgo F-28 and Natsek E-56 wells because *Tsuga* probably does not occur above the Middle Pliocene in Alaska and the Beaufort-Mackenzie Basin (Wolfe, 1972; White, 1989).

Assemblages from the lower part of the Iperk Sequence in the Ukalerk C-50 well, between 3700 ft (1127.8 m) and 5200 ft (1585 m) contain composite pollen, *Sigmopollis*, and an associated impoverished terrestrial palynoflora, suggesting to McNeil et al. (1982, p. 8) a correlation with the *Chenopodipollis* Zone. The sporadic occurrence of *Tsugaepollenites*, however, indicates that this interval may be older for the reasons cited above. Furthermore, in the adjacent Ukalerk 2C-50 well, the last appearance of *Asterigerina staeschei* marks the Middle/Upper Miocene boundary (McNeil, 1989, fig. 3) at 5206 ft (1586.8 m) which is putatively overlain by the Iperk Sequence (Dixon et al., 1992, fig. 22b). It is possible that some Upper Miocene to Middle Pliocene strata are preserved above this horizon, judging from the presence of *Tsugaepollenites*. It is not yet known whether the Akpak Sequence is present at the Ukalerk locality, but it is noteworthy that it is present in adjacent wells (McNeil, 1989; Dixon et al., 1992). The lack of the characteristic species of the *Cibicidioides* sp. 800 interval zone in the Ukalerk wells may be the result of more restricted marine depositional conditions, but a correlation with the Akpak Sequence remains to be demonstrated.

### *Tsugaepollenites* Zone

(2000–2700 ft: 609.6–823 m)

This top of this zone is recognized by the LADs of *Tsugaepollenites viridifluminipites* and *Tsugaepollenites igniculus*, and at the base by the top of the underlying zone. The two species of *Tsugaepollenites* may be confined to this zone and therefore their occurrences in



the underlying Paleogene would be attributed to cavings. Cored sections would be needed to verify this possibility. The following species are also present throughout most of this interval:

*Baculatisporites comaumensis*  
*Baculatisporites crassiprimarius*  
*Baculatisporites quintus* (apparently confined to this zone)  
*Biretisporites potoniaei*  
*Dyadosporites oblongatus*  
*Ilexpollenites microiliaceus*  
*Monoporisorites singularis*  
*Monoporisorites abruptus*  
*Obtusisporis* sp. (apparently confined to this zone)  
*Sparganiaceapollenites neogenicus*  
*Trivestibulopollenites betuloides*  
*Ulmipollenites undulosus*  
*Lacrimasporonites globulosus*

The lower part of the *Tsugaepollenites* Zone in this well is characterized by the following species, which also occur in the Paleogene:

*Lonicerapollis gallwitzii*  
*Intratropipollenites crassipites*  
*Ulmoideipites tricostatus*  
*Cupuliferoidaepollenites oviformis*  
*Annutripipollenites tripollenites*  
*Echinatisporis* sp. A

All palynomorphs in this zone are terrestrial, with the exception of *Sigmopollis psilatus* and *Horologinella* sp. A, which may be aquatic.

## Age

The *Tsugaepollenites* Zone is coincident with the Mackenzie Bay Sequence and was originally dated by Norris (1986) as Miocene with the possibility of extension to the latest Oligocene. Foraminiferal work by McNeil (1989) indicates that the Mackenzie Bay Sequence is characterized by the *Asterigerina staeschei* interval zone, which correlates with Lower and Middle Miocene in northwest Europe and suggests relatively warm water conditions at this time, up to the Middle/Upper Miocene boundary (10.4 Ma). The eponymous species may, however, have first entered the Beaufort-Mackenzie Basin in the latest Oligocene (McNeil, 1990a). The palynofloras characteristically contain thermophylic elements typical of the Miocene floras around the Pacific rim of China, Japan, and the west coast of North America (White 1989; Norris, 1986; Martin and Rouse, 1966).

A hiatus occurs in the Adgo F-28 well, with the superjacent Akpak Sequence missing. In other parts of the basin, the Akpak Sequence contains Late Miocene foraminifera (McNeil, 1989) and Late Miocene dinoflagellates (Bujak and Davies, 1981; Dixon et al., 1984), and also contains terrestrial palynomorphs indicative of slightly cooler climates compared with the underlying zone (White, 1989).

## Correlation and depositional environment

The *Tsugaepollenites* Zone was first described by Norris (1986) from the Mackenzie Bay Formation in the Nuktak C-22 well. It characterizes all but the uppermost part of the Mackenzie Bay Sequence, which, at Adgo F-28, consists of shale-dominant, mid-shelf deposits (Dixon et al., 1992, fig. 61). The lower contact of the sequence is erosional with the Eocene, and is indicated by pronounced palynofloral changes at 2700 ft (823 m) in the Adgo F-28 well. It is noteworthy that in spite of the marine mid-shelf paleoenvironment, and the presence of foraminifera of the *Cibicidioides* Assemblage Zone (McNeil, 1989), no dinoflagellates have been recovered from this interval in the Adgo F-28 well in the Mackenzie Bay Sequence nor from coeval strata in the Nuktak C-22 well, which was deposited in a similar depositional and paleobathymetric environment (Norris, 1986). Salinity, temperature, photoperiod, and turbidity may be controlling factors that precluded the growth of both auxotrophic and heterotrophic dinoflagellates in the area at that time. However, in the Ukalerk C-50 well, which penetrates a deep-water facies of the Mackenzie Bay Formation (McNeil et al., 1982; Dixon et al., 1992, fig. 61) the following dinoflagellates occur in the interval: *Lingulodinium machaerophorum*, *Spiniferites ramosus*, *Operculodinium centrocarpum*, and *Palaecocystodinium*. In the Issungnak O-61 well, in which Mackenzie Bay strata represent an outer shelf environment (Dixon et al., 1992, figs. 60, 61), dinoflagellates are present (White, 1989) but specific identifications were not made and it is uncertain how many might be recycled. In any event, the species-poor assemblages of marine dinoflagellates in this interval are in marked contrast to coeval, very diverse, Miocene assemblages from lower latitudes and normal seawater salinities (e.g., Bujak, 1984; Duffield and Stein, 1986; Head et al., 1989; Stover, 1977). This suggests that some environmental constraints were in operation in the area during the Early and Middle Miocene. Particularly noteworthy is the complete lack of the heterotrophic protoperidiniacean (congruentidiacean of Fensome et al., 1993) dinoflagellate cysts, which are characteristic of the Neogene elsewhere (De Verteuil and Norris, 1992).

The spore-pollen floras are more diverse than in the higher intervals and contain notable numbers of thermophilic taxa (see Norris, 1982, 1986; Norris and Head, 1985) that do not occur higher in the section. Species with a possible affinity to extant taxa (indicated in parentheses) include:

*Tsugaepollenites* (*Tsuga*)  
*Carpinipites* (*Carpinus*)  
*Ulmipollenites* and *Ulmoideipites* (*Ulmus*)  
*Ilexpollenites* (*Ilex*)  
*Intratropipollenites* (*Tilia*, *Craigia*)  
*Polyatriopollenites* (*Pterocarya*)  
*Retitriletes* (*Lycopodium*)  
*Osmundacidites* (*Osmunda*)  
*Lonicerapollis* (*Lonicera*)

Source vegetation from temperate woodlands is indicated.

### ***Integricorpus* Zone**

(2800–3200 ft: 853.4–975.4 m)

The top of this zone is recognized by the LAD of either *Ericipites antecurseroides* or *Integricorpus* sp. A. Also present at the top of this zone are:

*Juglanspollenites verus*  
*Piceapollenites* sp. A  
*Sequoiapollenites polyformosus*  
Fungal hypha type G  
*Multicellaesporites compactilis*  
*Hypoxylonites pirozynskioides*  
*Dyadosporites* sp. A  
Fungal hyphae type G

The following species have LADs within this zone:

*Caryapollenites inelegans* (recycled)  
*Caryapollenites veripites*  
*Cupuliferoideaepollenites pusillus*  
*Intratropipollenites minimus*  
*Momipites waltmanensis* (recycled)  
*Momipites wyomingensis* (recycled)  
*Tricolpites hians*  
*Verrucatosporites favus*  
*Retitriletes* cf. *novomexicanum*  
*Multicellaesporites margaritus*  
*Aceripollenites tener*  
*Montanapollis* cf. *globosiporus*

It is probable that most or all of the occurrences of *Caryapollenites inelegans*, *Momipites waltmanensis*, and *M. wyomingensis* within this zone are the result of

recycling from the Paleocene, or perhaps contamination from Paleocene drilling mud. The Paleocene-Eocene boundary is believed to occur in the *Ctenosporites* Zone at about 7400 ft (687.5 m) as discussed below, therefore all occurrences of specimens of these species in the zones above this depth are allochthonous.

Several other species are common components of assemblages in this zone but are not restricted to this zone:

*Polyvestibulopollenites verus*  
*Quercoidites microhenrica*  
*Ulmipollenites undulosus*  
*Piceapollenites grandivescipites*  
*Pinuspollenites labdacus*  
*Taxodiaceapollenites hiatus*  
*Stereisporites minor*  
*Cyathidites minor*  
*Laevigatosporites ovatus*  
*Multicellaesporites margaritus*

Some other species occur sporadically in this zone but are more common in the subjacent zone (see discussion below).

It is uncertain whether the presence of *Ericipites compactipollinatus* and the two species of *Tsugaepollenites* in the upper 300 ft (91.4 m) of this zone is due to cavings from above the regional unconformity or whether they are part of the in situ assemblages.

The occurrence in the lower part of this zone of *Palaeoperidinium ariadnae*, less common *Palaeoperidinium* sp. 367, and a single occurrence of *Wetzeliella* cf. *hampdenensis* shows a weak marine or estuarine influence.

### **Age**

The *Integricorpus* Zone was originally reported from the Imperial Nuktak C-22 well in the lower part of the Richards Sequence (Norris, 1986) and was dated as Late Eocene, possibly extending into Early Oligocene. Foraminiferal studies by McNeil (1989) indicate that the Richards Sequence is characterized by the *Haplophragmoides* sp. 2000 interval zone, which is endemic to the basin (McNeil, 1990a) and consistent with a Late Eocene age. The presence of *Wetzeliella* and other dinoflagellates in the lower part of the *Integricorpus* Zone also points to a largely Late Eocene age. In the Adgo F-28 well, however, the *Integricorpus*

Zone is truncated and does not preserve the Eocene/Oligocene transition and the accompanying drop in floral diversity due to climatic cooling, which is recorded elsewhere in the basin (Norris, 1982). In lower latitudes, *Integricorpus* sp. is reported (as *Parviprojectus*) to be associated with Lower Oligocene titanotheres (Rouse and Mathews, 1979) but also overlaps with the range of *Pesavis tagluensis*. Diachronism is, therefore, a possibility (Rouse, 1977).

The presence of species of *Momipites* and *Caryapollenites* in this zone may be the result of recycling of Paleocene material into this Late Eocene zone (D. J. McIntyre, pers. comm.). However, species of these genera are known to show strong latitudinal zoning and diachronism (Pocknall, 1987; Demchuk, 1990) and it may be premature to unequivocally exclude the possibility that some of these occurrences may be in situ.

### *Correlation and depositional environment*

The *Integricorpus* Zone is truncated in the Adgo F-28 well by the pre-Mackenzie Bay unconformity but in the Nuktak C-22 well, where it was originally identified and is probably not truncated (Norris, 1986), it comprises more than 2500 ft (762 m) in the bottom part of the Richards Sequence. Both wells penetrate the Richards Sequence in its prodelta/shelf depositional facies, according to Dixon et al. (1992, fig. 52), but only a sparse dinoflagellate flora is known in the lower part of the *Integricorpus* Zone (*Palaeoperidinium*, *Wetzeliella*, *Dioxya*), suggesting restricted marine or low salinity conditions. However, environmental controls on dinoflagellate distribution at high latitudes are not fully understood and it is therefore possible that low-diversity dinoflagellate floras are typical of normal marine salinities if the foraminiferal interpretations are correct (McNeil, 1990a; McNeil et al., 1990). The report by McNeil (1990a, b) of abundant diatoms in the shale facies of the Richards Sequence is indicative of nutrient-rich upwelling onto the shelf from the bathyal parts of the Arctic Ocean. Heterotrophic dinoflagellates would be anticipated in such an environment, but the congruentidians (protoperidinians), which in the Neogene typically occur in these conditions, are unknown in the Paleogene. It is possible that these heterotrophs may have existed in the free-living stage but that their cyst walls were of a composition unsuitable for preservation in sediments.

In the western Beaufort Sea, the Edlok N-56 well penetrates a nearshore facies of the Richards Sequence (Dixon et al., 1992, fig. 52) consisting of interbedded mudstone and sandstone. The lower half of the

sequence at this locality contains Middle or Upper Eocene foraminifera and also is characterized by the chorate dinoflagellate *Cordosphaeridium inodes* (Klumpp) Eisenack emend. Morgenroth, and Peridinioid sp. A (Dietrich et al., 1989). The latter appears to be a group of species, some of which (Dietrich et al., 1989, Pl. 2, fig. 6) are comparable to *Palaeoperidinium ariadnae* Norris, which occurs in the Richards Sequence elsewhere. The upper part of the Richards Sequence in the Edlok well is barren of foraminifera and dinoflagellates but contains a pollen flora identified only to the genus level by comparison with extant hardwood and softwood taxa. The pollen appear to be similar to elements of the *Integricorpus* Zone but without the eponymous genus.

The Natsek E-56 well, approximately 20 km east of the Edlok well, contains a diverse dinoflagellate flora in the uppermost 500 m of the Taglu Sequence, above the LAD for *Pesavis tagluensis* (Dietrich et al., 1989, fig. 5), which is presumably correlative with the *Integricorpus* Zone. The dinoflagellate flora comprises species of *Ceratiopsis*, *Kisselovia*, *Glaphyrocysta*, *Apectodinium*, *Wetzeliella*, *Thalassiphora*, *Dioxya*, *Phthanoperidinium*, *Cordosphaeridium*, and *Spinidinium*. All these genera also occur lower in the subjacent zones of the Eocene. The Taglu Sequence is truncated by a Neogene erosion surface in the Natsek E-56 well at about 200 m, significantly above the LAD for *P. tagluensis*. Diachronism of the Taglu/Richards sequence boundary is therefore a distinct possibility between the western Beaufort Sea and the eastern Mackenzie Delta.

The terrestrial flora in the *Integricorpus* Zone comprises more than 60 taxa in the Adgo F-28 well, including many thermophilic hardwood taxa. The latter suggest a climate similar to that in modern mid-latitudes (Norris, 1982).

### *Pesavis tagluensis* Zone (3300–3900 ft: 1005.8–1188.7 m)

The top of this interval zone is recognized by the LAD of *Pesavis tagluensis* and by the top of the subjacent zone at its base. The following additional species also have LADs concurrent with *Pesavis tagluensis* in this locality:

*Tricolpopollenites sculptus*  
*Didymosporisporonites ovatus*  
*Diporicellaesporites* cf. *bellulus*  
*Multicellaesporites leptaleus*  
*Dicellaesporites popovii*  
*Brachysporisporites* cf. *cotalis* (also has a single occurrence in the superjacent zone)

Several species terminate their ranges in the middle or lower part of this zone, including:

*Periporopollenites stigmaticus*  
*Pistillipollenites mcgregorii*  
*Striadiporites sanctaebarae*  
*Dicellisporites obnixus*  
*Inapertisporites* cf. *vittatus*  
*Brachysporisporites cotalis*  
*Brachysporisporites opimus*

Weak marine or estuarine influence in much of this zone is indicated by the persistent occurrence in low numbers of *Palaeoperidinium ariadnae*, *Palaeoperidinium* sp. 367, and *Wetzeliella* cf. *hampdenensis*. The following also occur very sporadically in low numbers:

*Apectodinium hyperacanthum*  
*Cerodinium* cf. *striatum*  
*Glaphyrocysta ordinata*  
*Maduradinium turpis*

All of these dinoflagellates, with the exception of *Wetzeliella* cf. *hampdenensis*, also occur in the subjacent *Punctodiporites* Zone and *Paraalnipollenites* Zone.

The assemblages in the *Pesavis tagluensis* Zone are diverse. The following species have LADs in the interval but occur only sporadically:

*Inapertisporites circularis*  
*Callimothallus pertusus*  
*Dyadosporites* cf. *schwabii*  
*Diporicellaesporites bellulus*  
*Diporicellaesporites* cf. *laevigatiformis*  
*Fractisporonites* sp. A  
*Fractisporonites* sp. B  
*Fusiformisporites microstriatus*  
*Multicellaesporites* cf. *lanceolatus*  
*Multicellaesporites conspicuus*  
*Plochmopeltinites masonii*  
*Spirotremesporites* cf. *clinatus*  
*Staphlosporites delumbus*  
*Striadiporites multistriatus*  
*Azolla* sp.  
*Stereisporites microgranulus*  
*Psilastephanocolpites* cf. *marginatus*  
*Celtispollenites tschudyi*  
*Intratriporopollenites* sp. A  
*Juglanspollenites tetraporus*  
*Myrtacidites parvus*  
*Plicapollis pseudoexcelsus*  
*Rhoipites* sp.  
*Caryophyllidites* sp.

A number of other species occur in these assemblages but have more extensive ranges:

*Annutriporites tripollenites*  
*Caryapollenites veripites*  
*Cupuliferoideaepollenites pusillus*  
*Intratriporopollenites crassipites*  
*Intratriporopollenites minimus*  
*Polyatriopollenites stellatus*  
*Polyvestibulopollenites verus*  
*Quercoidites microhenrica*  
*Quercoidites* sp. A  
*Ulmipollenites undulosus*  
*Piceaepollenites grandivescipites*  
*Taxodiaceaeapollenites hiatus*  
*Laevigatosporites ovatus*  
*Fractisporonites* cf. *canalis*  
*Lacrimasporonites* sp. A  
*Monoporisporites singularis*

## Age

The *Pesavis tagluensis* Zone was originally described from the upper part of the Taglu Sequence in the Imperial Nuktak C-22 well and dated as Middle Eocene by comparison with marine dinoflagellates from the Caribou Hills and offshore eastern Canada (Norris, 1986). Foraminifera are less useful in the interval between the base of the Richards Sequence and the Paleocene-Maastrichtian boundary in the Beaufort-Mackenzie Basin (McNeil 1989) because of the presence of thick, nonmarine sections that do not yield mineralized microfossils. Available foraminiferal data are, however, consistent with a Middle Eocene age for the *Pesavis tagluensis* Zone. In lower latitudes, *Pesavis tagluensis* may have a longer range and extend into the Lower Oligocene (Rouse, 1977; Rouse and Mathews, 1979).

## Correlation and depositional environment

The *Pesavis tagluensis* Zone occupies the top of the Taglu Sequence in the Adgo F-28 well and also in the Nuktak C-22 well, where it was first defined (Norris, 1986). The Taglu Sequence in both these wells developed as delta-front facies at the time of maximum progradation (Dixon et al., 1992, fig. 49). Foraminifera are unknown in this interval, but the zone contains a limited assemblage of dinoflagellates (*Palaeoperidinium*, *Wetzeliella*, *Apectodinium*, *Cerodinium*, *Glaphyrocysta*, *Maduradinium*, *Distatodinium*, *Cordosphaeridium*, *Spinidinium*, *Senoniasphaera*), indicating marine shelf conditions. In the Adgo F-28 well, the assemblages are low in numbers and sparse in species, suggesting restricted-

marine or possibly brackish water conditions, whereas more open-marine conditions may have prevailed in the Nuktak C-22 well. In the western Beaufort Sea, correlative assemblages in the upper part of the Taglu Sequence in the Natsek E-56 well (Dietrich et al., 1989; Norris et al., 1991) contain species of *Operculodinium*, *Nematosphaeropsis*, *Ceratiopsis*, *Kisselovia*, *Glaphyrocysta*, *Apectodinium*, *Wetzeliella*, *Thallasiphora*, *Dioxya*, *Palaeoperidinium* sp. A (of Norris), *Phthanoperidinium*, *Cordosphaeridium*, and *Spinidinium*, suggesting open-marine shelf conditions. This is in accord with the outer shelf environment for this locality indicated by Dixon et al. (1992, fig. 49) but it is noteworthy that this interval does not contain any foraminifers (Dietrich et al., 1989).

The terrestrial floral elements in this zone are diverse and probably represent warm temperate climatic conditions (Norris, 1982; 1986).

### ***Punctodiporites* Zone** (4000–5000 ft: 1219.2–1524 m)

This interval zone is defined on the basis of the LAD of *Punctodiporites granulatus*. This event is accompanied by LADs of the following species in this well:

*Platycaryapollenites shandongensis*  
*Diporisorites pisciculatus*  
*Monoporisorites* sp. A  
*Involutisporonites putus*  
*Multicellaesporites dongyingensis*

Two other species in this zone have LADs at the sample immediately underlying the LAD for *Punctodiporites granulatus*:

*Mediocolpopollis alitandus*  
*Margocolporites stenosus*

The base of the zone is defined by the top of the subjacent zone in this well.

Scattered occurrences of the following dinoflagellates suggest some marine influence, but abundance and diversity are low, indicating possible hypersalinity:

*Micrhystridium fraseri*  
*Distatodinium* sp. A  
*Morkallacysta* sp. 375  
*Senegalinium* cf. *microgranulatum*  
*Achomosphaera ramulifera*  
*Palaeoperidinium* sp. 367, *Wetzeliella* cf. *hampdenensis*, *Maduradinium turpis*, and *Glaphyro-*

*cysta ordinata* occur in this interval but are also known from higher horizons in this well.

Other LADs near the top of the *Punctodiporites* Zone include:

*Phragmothyrites* (?) sp. A  
*Phragmothyrites* cf. *eocaenicus*  
*Ailanthipites* cf. *berryi*  
*Dicellaesporites* cf. *akyolli*  
*Acanthacidites* sp.  
*Tetracolporopollenites* sp. A  
*Striadiporites inflexus*  
*Desmidiospora willoughbyi*

The following species have their top occurrences in the lower part of this zone:

*Polyadosporites enormis*  
*Ericipites* aff. *ericeus*  
*Diporicellaesporites* cf. *liaoningensis*  
*Podocarpidites maximus*  
*Caprifoliipites incertigrandis*  
*Rhoipites* cf. *microreticulatus*  
*Reduviasporonites* cf. *catenulatus*  
*Psilastephanocolporites* sp.  
*Platycaryapollenites shandongensis*

Commonly occurring components of the highly diverse assemblages in this zone include the following species, which have total ranges extending beyond the *Punctodiporites* Zone:

*Annutriporites tripollenites*  
*Caryapollenites veripites*  
*Cupuliferoideaepollenites oviformis*  
*Cupuliferoideaepollenites pusillus*  
*Intratriporopollenites crassipites*  
*Polyatriopollenites stellatus*  
*Polyvestibulopollenites verus*  
*Quercoidites microhenrica*  
*Ulmipollenites undulosus*  
*Piceaepollenites grandivescipites*  
*Taxodiaceaeepollenites hiatus*  
*Cyathidites minor*  
*Laevigatosporites ovatus*  
*Osmundacidites wellmanii*  
*Brachysporisorites* cf. *cotalis*  
*Brachysporisorites cotalis*  
*Callimothallus pertusus*  
*Dicellaesporites obnixus*  
*Fractisporonites* sp. B  
Fungal hypha type C  
*Lacrimasporonites* sp.  
*Monoporisorites abruptus*  
*Monoporisorites singularis*  
*Multicellaesporites compactilis*

*Multicellaesporites conspicuus*  
*Multicellaesporites leptaleus*  
*Multicellaesporites margaritus*  
*Pesavis tagluensis*  
*Striadiporites sanctaebabarbarae*

A few species that range above the *Punctodiporites* Zone appear to have lower limits within this zone, although the effect of cavings on these datums is unknown:

*Pluricellaesporites* cf. *conspicuus*  
*Juglanspollenites verus*  
*Ilexpollenites microiliaceus*  
*Quercoidites* sp. A

### Age

*Platycaryapollenites* occurs in the *Punctodiporites* Zone and has been noted by Dietrich et al. (1989) and Wing (1984) to be indicative of the Early Eocene in this region. Furthermore, *Intratropipollenites crassipites* is common in this zone and has been documented by Pocknall (1987) in sediments no younger than Eocene in Wyoming. This species is believed to have a similar distribution in the Canadian Arctic (McIntyre and Ricketts, 1989). An Early Eocene age for the *Punctodiporites* Zone would be consistent with ages for the overlying and underlying zones. Dinoflagellates in this zone include species of *Wetzeliella*, *Maduradinium*, and *Glaphyrocysta*, which occur elsewhere in the Lower and Middle Eocene. This zone characterizes the top of the Taglu Sequence in the Adgo F-28 well. The Taglu Sequence contains foraminifera of the lower part of the *Haplophragmoides* sp. 2000 interval zone and the *Portatrochammina* sp. 2850 interval zone (McNeil et al., 1990), which together range through the Early and Middle Eocene. These ages are consistent with the diverse dinoflagellate assemblages present in coeval strata in the Natsek E-56 well (Dietrich et al., 1989).

### Correlation and depositional environment

The *Punctodiporites* Zone is difficult to correlate because palynofloras from probable coeval strata in the basin have not been thoroughly documented at the species level. It is noteworthy, however, that *Platycaryapollenites* is confined to this zone – albeit sparsely – and that pollen of *Platycarya* has been reported by Dietrich et al. (1989) to be confined to a narrow interval in Lower Eocene strata of the Natsek E-56 well in the western Beaufort Sea. The *Punctodiporites* Zone occurs in the upper part of the Taglu Sequence, several thousand feet above the top of

the Aklak Sequence in the Adgo F-28 well, whereas *Platycarya* pollen is confined to an interval mapped as the top of the Aklak Sequence in the Natsek well. In both areas, *Platycarya* is associated with bisaccate pollen, *Caryapollenites*, *Intratropipollenites*, and *Pesavis tagluensis* (Dixon et al., 1985).

The zone contains highly diverse palynofloras with many thermophylic elements, fungal spores, and pteridophytes (Dixon et al., 1985), suggesting warm temperate conditions, as discussed above for the *Pesavis tagluensis* Zone. Rouse (1977) suggests that the Early Eocene floras in the arctic may be warm temperate to subtropical on the basis of the presence of pollen species with tropical or subtropical parent plants that appear to have migrated from lower latitudes in the Middle and Late Paleocene and Early Eocene. In the northern parts of northeast Siberia (the Yana-Indigirka Lowland), Eocene palynofloras with a high proportion of thermophylic hardwoods and have been interpreted as indicative of a subtropical climate (Kulkova, 1973, p. 109). Warm temperate climates are also indicated for the Eocene in Spitsbergen (Norris and Head, 1985).

Scattered occurrences of *Micrhystridium fraseri*, *Distatodinium* sp. A, *Morkallacysta*, *Senegalinium* cf. *microgranulatum*, *Achomosphaera ramulifera*, *Palaeoperidinium*, *Wetzeliella* cf. *hampdenensis*, *Maduradinium turpis*, and *Glaphyrocysta ordinata* in the *Punctodiporites* Zone suggest marine conditions, but their low abundance and diversity indicate possible abnormal salinity. This would be in accord with a paleogeographic position of the Adgo well in a delta-front environment (Dixon et al., 1992, fig. 49).

### *Paraalnipollenites* Zone

(5100–5900 ft: 1554.8–1798.3 m)

The following LADs define the top of this zone:

*Paraalnipollenites alterniporus*  
*Tropipollenites mullensis*  
*Brachysporisporites* cf. *conicus*  
*Brachysporisporites fustitudinus*

*Staphlosporites* sp. A terminates locally at the top of this zone but is known to occur higher elsewhere (Norris, 1986). The base of this zone is defined by the top of the subjacent zone in this well. *Palaeoperidinium* sp. 367 is common but not abundant. The following dinoflagellates occur sporadically:

*Spinidinium* cf. *sagittulum*  
*Apectodinium quinquelatum*  
*Apectodinium homomorphum*

*Geiselodinium* sp. 371  
*Gochtodinium simplex*

Other species with LADs high in this zone are:

*Foveosporites* sp.  
*Pesavis parva*  
*Platanoides* (?) cf. *ipelensis*  
*Momipites leffingwelli* (recycled)  
*Diporisporites elegans*  
*Diporisporites oblongatus*  
*Spirotremesporites recklawensis*

A large number of longer ranging species are common components of assemblages within this zone; for example:

*Caryapollenites inelegans* (recycled)  
*Caryapollenites veripites*  
*Cupuliferoideaepollenites oviformis*  
*Intratropollenites crassipites*  
*Piceapollenites grandivescipites*  
*Polyatripollenites stellatus*  
*Polyvestibulopollenites verus*  
*Quercoidites microhenrica*  
*Ulmipollenites undulosus*  
*Sequoiapollenites polyformosus*  
*Taxodiaceapollenites hiatus*  
*Laevigatosporites ovatus*  
*Osmundacidites wellmanii*  
*Brachysporisporites* cf. *cotalis*  
*Brachysporisporites cotalis*  
*Callimothallus pertusus*  
*Dicellaesporites obnixus*  
*Dyadosporites* sp. A  
*Fractisporonites* cf. *canalis*  
*Fractisporonites* sp. A  
*Fractisporonites* sp. B  
Fungal hypha type C  
*Inapertisporites* cf. *vittatus*  
*Lacrimasporonites* sp. A  
*Monoporisporites abruptus*  
*Monoporisporites singularis*  
*Multicellaesporites compactilis*  
*Multicellaesporites conspicuus*  
*Multicellaesporites dongyingensis*  
*Multicellaesporites leptaleus*  
*Punctodiporites granulatus*  
*Staphlosporonites delumbus*  
*Striadiporites sanctaebabarbae*

## Age

The *Paraalnipollenites* Zone is characterized by the last appearance of *Paraalnipollenites alterniporus*, which Ioannides and McIntyre (1980) recorded from

Paleocene into Lower Eocene strata in the Caribou Hills. McIntyre and Ricketts (1989) confirmed similar ranges for this species in Cornwall and Amund Ringnes islands. *Paraalnipollenites confusus* and *Triporopollenites mullensis* occur together in this zone and are also recorded together in Late Paleocene assemblages from Somerset Island (McIntyre 1989) and from the North Slope of Alaska (Frederiksen et al., 1988). The presence in this zone of *Caryapollenites inelegans*, *Caryapollenites veripites*, and *Momipites leffingwellii*, which occur in the Paleocene of Wyoming (Nichols and Ott, 1978) and Alberta (Demchuk, 1990), is attributed to recycling or possibly to contamination from drilling mud. The common presence of *Intratropollenites crassipites* in this zone indicates an Early Eocene age (see discussion for the superjacent *Punctodiporites* Zone), which may mean that occurrences of *Triporopollenites mullensis* in this zone are the result of recycling from Paleocene sources. *Pesavis parva* occurs in this zone, a species believed by Kalgutkar and Sweet (1988) to occur in western and northern Canada no higher than the Lower Paleocene. The present study indicates that *P. parva* ranges into the Lower Eocene but these occurrences may also be the result of recycling. The sporadic occurrence of the marine dinoflagellates *Apectodinium quinquelatum* and *Apectodinium homomorphum* in this zone concur with a latest Paleocene or earliest Eocene age for the zone (Williams and Bujak, 1985; Köthe, 1990; Powell, 1992). A single occurrence of *Gochtodinium simplex* in the zone is interpreted as caving from a higher interval because in northwest Europe this species has a lowest reported range in highest Middle Eocene strata (Bujak, 1979; Powell, 1992) and the overwhelming evidence from this and adjacent intervals suggests an Early Eocene age.

## Correlation and depositional environment

The *Paraalnipollenites* Zone occupies the middle of the Taglu Sequence in the Adgo F-28 well. The LAD of the eponymous genus can be matched in the Natsek E-56 well, about 100 m below the LAD of *Platycarya* pollen and near the top of the Aklak Sequence (Dietrich et al., 1989). This zone appears also to correlate with Zone C of the Reindeer Formation outcropping in the Caribou Hills immediately east of the Mackenzie Delta (Ioannides and McIntyre, 1980), as indicated by the co-occurrence of *Paraalnipollenites alterniporus*, *Punctodiporites granulatus*, and *Apectodinium homomorphum*, together with several other characteristic Early Eocene angiosperms and dinoflagellates. The latter facilitate correlation to the more diverse and better known Eocene marine basins in mid latitudes (Norris et al., 1991; Parsons and Norris, 1992). In the eastern Arctic, the LAD for

*Paraalnipollenites* has not been determined precisely, but the genus is known to occur in an unnamed Eocene sandstone on Cornwall Island (McIntyre and Ricketts, 1989). However, its co-occurrence with *Aquila-pollenites tumanganicus* in this sandstone unit suggests that this locality might not represent its LAD but rather be correlative with the subjacent *Ctenosporites* Zone, as discussed below. Rouse (1977) reported that the last appearance of *Paraalnipollenites* occurs in the lower part of the Eureka Sound Group on Banks and Ellesmere islands in his Zone P-4, which he dated as Late Paleocene but which is probably Early Eocene, based on more recent work on *Paraalnipollenites* (see previous section). A similar co-occurrence of *Paraalnipollenites* and *Aquilapollenites* is implied by Staplin (1976, p. 127) for the bottom part of the Paleogene section in the onshore delta area, between the Taglu, Ya Ya, and Reindeer wells, sections now assigned to the Taglu Sequence for the Taglu wells and the Aklak Sequence for Ya Ya P-53 and Reindeer D-27 wells (Dixon, 1990).

Sporadic occurrences of *Spinidinium*, *Palaeoperidinium*, *Apectodinium*, *Geiselodinium*, and *Gochtodinium* suggest marine influence in some horizons and would accord with a delta-front environment for the Taglu Sequence in this well, as suggested by Dixon et al. (1992). Diverse fungal and embryophyte floras, some with distinct thermophilic preferences, suggest a warm temperate climate (see Rouse 1977; Norris, 1982).

### ***Fusiformisporites* Zone** (6000–6500 ft: 1828.8–1981.2 m)

This interval zone is defined at the top of the LADs of the following species:

*Biporisporites rotundus*  
*Novemprojectus traversii*  
*Fusiformisporites crabbii*  
*Dyadosporites solidus*  
*Striadiporites anceps*

Its base is defined by the top of the subjacent zone.

*Fusiformisporites annafrancescae* and *Punctodiporites foedus* also have their LADs high in this zone. Lower in this zone, *Biporisporites praestigiatus* and *Plochmopeltinites* sp. A have their top occurrences.

The assemblages are moderately diverse in terrestrial species, with the following being common components:

*Caryapollenites inelegans* (recycled)  
*Caryapollenites veripites*

*Cupuliferoideapollenites oviformis*  
*Intratropopollenites crassipites*  
*Polyatriopollenites stellatus*  
*Polyvestibulopollenites verus*  
*Quercoidites microhenrica*  
*Ulmipollenites undulosus*  
*Piceapollenites grandivescipites*  
*Taxodiaceapollenites hiatus*  
*Laevigatosporites ovatus*  
*Osmundacidites wellmanii*  
*Brachysporisporites* cf. *cotalis*  
*Callimothallus pertusus*  
*Brachysporisporites fustitudinus*  
*Dyadosporites* sp. A  
*Fractisporonites* cf. *canalis*  
*Fractisporonites* sp. A  
*Fractisporonites* sp. B  
Fungal hypha type C  
*Monoporisporites abruptus*  
*Monoporisporites singularis*  
*Multicellaesporites compactilis*  
*Punctodiporites granulatus*  
*Striadiporites sanctaebabarbarae*

In addition, the following dinoflagellates occur sporadically in this zone:

*Melitasphaeridium pseudorecurvatum*  
*Lentinia* sp. 373  
Dinoflagellate sp. S-1

Rare occurrences of longer ranging dinoflagellate taxa are also recorded in the *Fusiformisporites* Zone, as indicated in the distribution chart.

### *Age*

The presence of *Melitasphaeridium pseudorecurvatum* in the *Fusiformisporites* Zone accords with a latest Paleocene or earliest Eocene age (Williams and Bujak, 1985; Köthe, 1990). *Novemprojectus traversii* is confined to this zone and in the eastern Arctic it is believed to be an Early Eocene species (Choi, 1984; D.J. McIntyre, pers. comin.). An Early Eocene age for the zone is suggested also by the common presence of *Intratropopollenites crassipites* for reasons discussed earlier. The presence of *Biporisporites rotundus* in, and its restriction to, the *Fusiformisporites* Zone is noteworthy but of little help for age assignment in view of the miscalibration of the Paleogene in east China and its offshore region, where the Shahejie Formation, which contains this species, is putatively Oligocene (Ke et Shi, 1978). Almost certainly this age assignment for the Chinese strata is wrong. Thus an Early Eocene age for the *Fusiformisporites* Zone is favoured. The presence of *Caryapollenites inelegans* in this zone is



believed to be attributable to recycling or to drilling mud contamination.

### *Correlation and depositional environment*

The *Fusiformisporites* Zone occurs near the middle of the Taglu Sequence. *Fusiformisporites crabbii*, which has a single occurrence in the *Fusiformisporites* Zone, also occurs in the Burrard Formation in the Vancouver area which Rouse (1962) considers to be Middle Eocene with "carry-overs" from the Paleocene. *Novem-projectus traversii* has been reported by Choi (1984) from the lower part of the Eureka Sound Group in the eastern Arctic Archipelago. The associated assemblages were correlated by McIntyre (1989) with zones in the Strand Bay and Iceberg Bay formations and elsewhere in the Eureka Sound Group of Ellesmere and Banks islands (Rouse, 1977; Doerenkamp et al., 1976), and the lower part of Interval B of the Reindeer Formation in the Mackenzie Delta (Ioannides and McIntyre, 1980).

Spore-pollen assemblages in the *Fusiformisporites* Zone are diverse and suggest a warm temperate climate during the Early Eocene, as discussed for the overlying zones. Scattered occurrences of a small number of dinoflagellate species (*Lentinia*, *Melitasphaeridium*) suggest hyposaline marine conditions, as would be anticipated for a delta-front environment postulated by Dixon et al. (1992) for the Taglu Sequence in the Adgo area.

### ***Ctenosporites* Zone** (6600–9000 ft: 2011.7–2743.2 m)

The top of this zone is defined by the LAD of *Ctenosporites wolfei* and at the base by the top of the subjacent zone. In addition, the top of the zone is characterized by a number of species with LADs as follows:

*Cicatricosisporites intersectus*  
*Phragmothyrites* (?) sp. B  
*Ctenosporites eskerensis*  
*Fractisporonites* sp. C  
*Anatolinites* sp.  
*Microthyrites* sp. B  
*Plochmopeltinites* sp. B  
*Striadiporites* cf. *bistriatus*

Most of the above-listed species appear to be confined to the *Ctenosporites* Zone, the exceptions being *Anatolinites* sp. and *Plochmopeltinites* sp. A.

At lower horizons in the *Ctenosporites* Zone, the following species are sporadically distributed with restricted ranges:

*Anacolosidites* sp.  
*Aquilapollenites tumanganicus*  
*Dyadosporites ellipsus*  
*Polyadosporites* cf. *conoideus*  
*Diporicellaesporites* sp. B  
*Diporicellaesporites liaoningensis*

The assemblages occurring within this zone are highly diverse, particularly in the upper part of the zone (believed to be in Lower Eocene strata - see later discussion). Below approximately 7000 ft (2133.6 m), there is a progressive attenuation of species richness downhole in the Upper Paleocene strata. The following species are characteristic of assemblages in the *Ctenosporites* Zone:

*Annutriporites tripollenites*  
*Caryapollenites inelegans*  
*Caryapollenites veripites*  
*Cupuliferoideapollenites oviformis*  
*Cupuliferoideapollenites pusillus*  
*Intratriporopollenites crassipites*  
*Pistillipollenites mcgregorii*  
*Polyatripollenites stellatus*  
*Polyvestibulopollenites verus*  
*Quercoidites microhenrica*  
*Triporopollenites mullensis*  
*Ulmipollenites undulosus*  
*Piceapollenites grandivescipites*  
*Pinuspollenites labdacus*  
*Sequoiapollenites polyformosus*  
*Taxodiaceapollenites hiatus*  
*Baculatisporites crassiprimarius*  
*Cyathidites minor*  
*Deltoidospora hallei*  
*Laevigatosporites ovatus*  
*Osmundacidites wellmanii*  
*Brachysporisporites* cf. *cotalis*  
*Brachysporisporites cotalis*  
*Brachysporisporites opimus*  
*Dicellaesporites obnixus*  
*Dicellaesporites popovii*  
*Diporicellaesporites bellulus*  
*Diporicellaesporites laevigatiformis*  
*Dyadosporites* sp. A  
*Fractisporonites* cf. *canalis*  
*Fractisporonites* sp. A  
*Fractisporonites* sp. B  
Fungal hypha type A  
Fungal hypha type C  
*Fusiformisporites microstriatus*

*Inapertisporites* cf. *vittatus*  
*Inapertisporites* cf. *elongatus*  
*Lacrimasporites* sp. A  
*Monoporisporites* *singularis*  
*Multicellaesporites* *compactilis*  
*Multicellaesporites* *leptaleus*  
*Multicellaesporites* *margaritus*  
*Pesavis* *parva*  
*Pesavis* *tagluensis*  
*Punctodiporites* *granulatus*  
*Staphlosporites* *delumbus*  
*Striadiporites* *sanctaebarbarae*  
*Striadiporites* *anceps*  
*Trichothyrites* sp. A

Below 7300 ft (2225 m), *Caryapollenites inelegans*, *Momipites wyomingensis*, and *Momipites leffingwelli* are interpreted as occurring in place in the *Ctenosporites* Zone.

In addition, small numbers of dinoflagellates and acritarchs occur sporadically in this zone, the first two with LADs near the top of the zone:

*Phelodinium* sp. 377  
*Lentinia serrata*  
*Micrhystridium fraseri*  
*Wetzeliella* cf. *hampdenensis*

## Age

*Aquilapollenites tumanganicus* is restricted to an interval in the upper part of the *Ctenosporites* Zone, and in the eastern Arctic occurs in Upper Paleocene and Lower Eocene strata (McIntyre and Ricketts, 1989). Occurrences of *Momipites wyomingensis*, *Momipites leffingwelli*, and *Caryapollenites inelegans* below approximately 7300 ft (2225 m) are interpreted as being in situ and therefore indicative of a Late Paleocene age (see Nichols and Ott, 1978; Demchuk, 1990; McIntyre in Ricketts, 1991). Above this horizon, occurrences of *Intratropipollenites crassipites* are interpreted as Eocene (see Pocknall, 1987; McIntyre and Ricketts, 1989). Therefore, on the basis of spore-pollen evidence, the Paleocene/Eocene boundary may occur somewhere in the upper part of the *Ctenosporites* Zone, although its precise placement awaits evaluation of the effects of recycling and/or caving on these palynofloras.

Further evidence for the presence of the Paleocene/Eocene boundary in this zone is provided by the identification of a foraminiferal interval in the Adgo F-28 well by McNeil (1989, fig. 4). Foraminifera

recovered from 2588-2699 m (8490-8854 ft) in this well, very low in the *Ctenosporites* Zone, represent the *Verneuilina* sp. 2700 neritic biofacies, which is part of the *Portatrochammina* Assemblage Zone. According to McNeil, the Paleocene-Eocene boundary occurs low in this assemblage zone, as was determined biostratigraphically in outcrop of the Aklak Member, Reindeer Formation, in Aklak Creek, in the lower part of the *Portatrochammina* sp. 2850 interval zone. However, the foraminiferal biofacies are diachronous, and precise correlation of the Paleocene-Eocene boundary from Aklak Creek to the Adgo F-28 well has not yet been achieved.

The combined evidence from foraminifera and palynomorphs indicates that the Paleocene/Eocene boundary falls somewhere within the *Ctenosporites* Zone. Interpretation of the distribution of species of *Momipites* and *Caryapollenites* (both with juglandaceous affinities) has been made on the conventional assumption that these are absent in the Eocene in northern Canada (D.J. McIntyre, pers. comm.), but that *Intratropipollenites* species (*Tilia* of some authors) enter the stratigraphic record in the early Eocene. The Juglandaceae have a complex Late Cretaceous and Cenozoic phytogeographic history (Manchester, 1987); the tribe Engelhardieae (Middle Eocene-Recent) produces *Momipites* pollen and the tribe Hicoreae (Upper Paleocene-Recent) produces *Caryapollenites* pollen, although similar pollen types were produced by antecedents of these tribes in the Paleocene and latest Cretaceous. Both tribes diversified and radiated to Asia and to higher latitudes from an origin in mid-latitude North America during the Paleogene and Neogene. These considerations suggest that the occurrences of *Caryapollenites* and *Momipites* species in Eocene and some younger strata in northern Canada may require re-evaluation. Thermophylic taxa are known to have responded to climatic warming trends in high latitude Eocene and Miocene sites (e.g., Norris, 1982). It is possible that this climatic effect – and not exclusively recycling – may be responsible for some Eocene occurrences of *Momipites* and *Caryapollenites* in northern Canada.

The presence of *Lentinia serrata* in the *Ctenosporites* Zone is puzzling to the extent that its reported range elsewhere is higher in the Eocene (Williams and Bujak, 1985). This conflicts with the bulk of the biostratigraphic evidence here; and points to a correlation of the *Ctenosporites* Zone close to the Paleocene-Eocene boundary. Downward caving of this species from higher in the section is possible but *L. serrata* has yet to be reported from Middle Eocene marine intervals in the Beaufort-Mackenzie Basin.

## *Correlation and depositional environment*

The *Ctenosporites* Zone occurs in the lowest part of the Taglu Sequence. The eponymous genus has a longer range than in the Adgo F-28 well (Elsik and Jansonius, 1974), but its association with several other species of restricted range (e.g., *Cicatricosisporites intersectus*, *Aquilapollenites tumanganicus*, etc.) uniquely define the zone. Staplin (1976, p. 126 and fig. 4) reported the restriction of *Aquilapollenites tumanganicus* (as their pollen type EC-16-3) to Zone T-1 and illustrated its restriction to an interval in the Taglu G-33 well, subsequently interpreted by Dixon (1990) as the upper, approximately 457 m, of the Taglu Sequence. Illustrations presented by Staplin (1976, figs. 4, 5), suggest that this interval can be correlated with the upper Taglu Sequence in the Taglu C-42 well, the lower Taglu and perhaps upper Aklak sequences in the Ya Ya P-53 well, and the lower part of the Taglu Sequence in the Reindeer D-27 well. In the eastern Arctic, *A. tumanganicus* occurs sporadically in an unnamed sandstone unit unconformably overlying folded Mesozoic basement on Cornwall Island (McIntyre and Ricketts, 1989), and has previously been recorded from the Paleocene of the Sea of Japan (Bolotnikova, 1973), the early Eocene of the Gulf of Bohai (Sung et al., 1978), and from the Eureka Sound Group of Ellesmere and Axel Heiberg islands by Choi in an unpublished thesis (fide McIntyre and Ricketts, 1989). McIntyre (*in* Ricketts, 1991) confirmed its presence in Upper Paleocene to Lower Eocene strata of Axel Heiberg Island. Triprojectate pollen from apparently coeval strata in the Norwegian Sea and adjacent sites in Greenland and the British Isles is spinose but poorly preserved and not identifiable to the species level from the available illustrations (Boulter and Manum, 1989). This *Aquilapollenites* species is, however, associated with *Apectodinium* species, *Lentinia*, *Caryapollenites*, and *Cicatricosisporites*, suggesting a correlation of the intra-basaltic sediments in the Norwegian Sea with the *Ctenosporites* Zone. Dinoflagellate assemblages reported by Manum and Thronsdén (1986) from Spitsbergen suggest the *Ctenosporites* Zone might be present in the Gilsonryggen Formation based on the presence of *Apectodinium homomorphum* and associated species of this plexus (Harland, 1979).

Assemblages in this zone are highly diverse, comprising embryophytes with affinities to warm temperate taxa and some genera with distributions centred in subtropical areas, e.g., *Anacolosidites*, *Cicatricosisporites*. Fungal elements are diverse but of unknown climatic significance at the present time, other than as indicators of moisture or humidity. A few dinoflagellate species in low abundance occur sporadically in the *Ctenosporites* Zone and suggest a

marine influence, as discussed for the higher zones in the Taglu Sequence. A deep-water neritic foraminiferal biofacies was reported by McNeil (1989) in the Adgo F-28 well, occupying a position near the bottom of the *Ctenosporites* Zone, but this interval contains no dinoflagellates.

## ***Multicellaesporites-Pluricellaesporites* Zone** (9100–10 528 ft: 2773.7–3208.9 m TD)

This interval zone is defined by the LAD for *Multicellaesporites* cf. *vermiculatus*. The LADs for *Pluricellaesporites* sp. and *Spirotremesporites* cf. *reklawensis* occur lower in this zone. The zonal base is arbitrarily defined at the total depth for the well at 10 528 ft (3208.9 m).

The assemblages in this zone are generally less diverse than those from the zones higher in the Paleogene. The following occur commonly in assemblages in this zone, along with other, more sporadically occurring species:

*Piceapollenites grandivescipites*  
*Taxodiaceapollenites hiatus*  
*Brachysporisporites* cf. *cotalis*  
*Brachysporisporites cotalis*  
*Brachysporisporites opimus*  
*Dicellaesporites obnixus*  
*Dicellaesporites popovii*  
*Fractisporonites* cf. *canalis*  
*Fractisporonites* sp. A  
*Fractisporonites* sp. B  
Fungal hypha type C  
*Inapertisporites* cf. *vittatus*  
*Multicellaesporites compactilis*  
*Multicellaesporites leptaleus*  
*Pesavis tagluensis*  
*Tripoporipollenites mullensis*

*Lentinia serrata* occurs rarely in this zone and may be derived from cavings from higher horizons. No other dinoflagellates are known from this zone.

## *Age*

*Pesavis tagluensis* is a consistent constituent of palynofloras in the *Multicellaesporites-Pluricellaesporites* Zone, suggesting that the zone is no older than Late Paleocene (Kalgutkar and Sweet, 1988). This age assignment is consistent with the placement of the Paleocene–Eocene boundary in the superjacent *Ctenosporites* Zone (see discussion above). LADs in this zone are for terrestrial species not previously reported, and therefore of no assistance in further

refining an age. Other species occurring in the zone also occur higher in the section and may, in part, be due to cavings from above. The *Multicellaesporites-Pluricellaesporites* Zone characterizes the top of the Aklak Sequence, which is dated by foraminifers and associated palynomorphs as Late Paleocene-Early Eocene (McNeil, 1989; Dixon et al., 1992).

### Correlation and depositional environment

Correlation of the *Multicellaesporites-Pluricellaesporites* Zone, which occupies the top of the Aklak Sequence in the Adgo F-28 well, is very difficult because the species confined to this zone have not been previously reported. Based on the arguments presented above for the distribution of *Aquilapollenites tumanganicus*, which occurs in the superjacent zone, this zone is presumably present near the bottom of Staplin's (1976) Zone T-1. The sparse terrestrial palynofloras reported by Dietrich et al. (1989, fig. 5) in the lower half of the Aklak Sequence in the Natsek E-56 well may be correlative with the *Multicellaesporites-Pluricellaesporites* Zone. However this supposition awaits confirmation from careful analysis of the fungal elements in this interval, which has not yet been done. The Adgo well occupies a position in the Aklak Sequence near the prodelta/delta-front boundary (Dixon et al., 1992, fig. 46). The virtual absence of dinoflagellates in this zone is consistent with a nonmarine environment of deposition. The low diversity spore-pollen assemblages in this zone contrast with the highly diverse, warm temperate assemblages in the overlying Lower Eocene zones, and may suggest relatively cooler climatic conditions.

## TAXONOMY

### Taxonomic species lists

In the following list, the number preceding the Latin binomial is the unique number assigned to the species in the database from which the Distribution Chart (Fig. 3) was generated. These data are on file at the Geological Survey of Canada (Calgary) and in the Palynology Laboratory in the Department of Geology, University of Toronto, and are freely available on request. Note that the numbers associated with the dinoflagellates and other aquatic palynomorphs are prefixed with the letter "M". Numbers without a prefix refer to spores and pollen of embryophytes and fungi, and other associated microfossils of presumed terrestrial origin, e.g., fungal fruiting bodies or hyphae. Plate and figure numbers are indicated for species illustrated in this paper; those for new species are in boldface type. Holotypes for new species and all

other illustrated specimens are deposited in the palynology type collection of the Geological Survey of Canada (Calgary).

## Fungal palynomorphs

### Monocellate fungal spores

- 1008 *Biporisporites rotundus* Ke et Shi ex Sung et al. (Pl. 1, figs. 26-31)
- 711 *Diporisporites communis* Ke et Shi ex Sung et al.
- 980 *Diporisporites elegans* Ke et Shi ex Sung et al. (Pl. 1, fig. 42)
- 949 *Diporisporites oblongatus* Ke et Shi ex Sung et al. Pl. 1, figs. 43, 44)
- 969 *Diporisporites pisciculatus* sp. nov. (**Pl. 2, figs. 1-8**)
- 996 *Hypoxylonites pirozynskioides* Elsik (Pl. 1, figs. 11, 12)
- 1014 *Hypoxylonites vicksbergensis* Elsik (Pl. 1, fig. 10)
- 854 *Inapertisporites circularis* Sheffy and Dilcher
- 961 *Inapertisporites elongatus* Rouse (Pl. 1, figs. 6, 7)
- 727 *Inapertisporites* sp. cf. *I. subovoideus* Sheffy and Dilcher
- 579 *Inapertisporites* sp. cf. *I. vitattatus* Sheffy and Dilcher
- 1010 *Inapertisporites* sp. cf. *I. elongatus* Rouse (Pl. 1, figs. 1, 2)
- 1023 *Lacrimasporonites globulosus* (Rouse) comb. nov. (Pl. 1, figs. 3, 4)
- 759 *Monoporisporites abruptus* Sheffy and Dilcher (Pl. 1, fig. 8)
- 860 *Monoporisporites singularis* Sheffy and Dilcher (Pl. 1, fig. 5)
- 751 *Monoporisporites* sp. A Norris
- 707 *Monoporisporites* sp. cf. *M. cupuliformis* Sheffy and Dilcher
- 1002 *Spirotremesporites recklawensis* Elsik (Pl. 1, fig. 13)
- 1001 *Spirotremesporites* sp. cf. *S. clinatus* Elsik (Pl. 1, figs. 14, 15)
- 1015 *Spirotremesporites* sp. cf. *recklawensis* Elsik (Pl. 1, fig. 9)
- 685 *Striadiporites inflexus* (Ke et Shi ex Sung et al.) Norris (Pl. 1, figs. 17, 18)
- 859 *Striadiporites multistriatus* (Ke et Shi ex Sung et al.) Norris
- 391 *Striadiporites sanctaebarae* Elsik and Jansonius (Pl. 1, fig. 19)
- 988 *Striadiporites* sp. cf. *bistriatus* Ke et Shi ex Sung et al. (Pl. 1, fig. 16)

- 550 *Biporisporites praestigiatus* Norris sp. nov. (Pl. 1, figs. 32-41)  
 1008 *Biporisporites rotundus* Ke et Shi ex Sung et al. (Pl. 1, figs. 26-31)  
 551 *Striadiporites anceps* sp. nov. (Pl. 1, figs. 20-25)  
 608 *Triporisporonites verus* (Ke et Shi ex Sung et al.) Norris

#### Dicellate fungal spores

- 683 *Dicellaesporites aculeolatus* Sheffy and Dilcher  
 732 *Dicellaesporites obnixus* Norris (Pl. 2, fig. 30)  
 686 *Dicellaesporites popovii* Elsik (Pl. 2, fig. 29)  
 1004 *Dicellaesporites* sp. cf. *D. akyolii* Ediger and Alison (Pl. 2, figs. 9-11)  
 754 *Didymosporisporonites ovatus* Ke et Shi ex Sung et al. (Pl. 2, figs. 33, 43)  
 758 *Dyadosporites oblongatus* (Ke et Shi ex Sung et al.) Norris (Pl. 2, fig. 34)  
 601 *Dyadosporites* sp. A Norris (Pl. 2, fig. 32)  
 731 *Dyadosporites* sp. cf. *D. schwabii* (Elsik) Norris  
 986 *Dyadosporites* sp. cf. *D. solidus* Ke et Shi ex Sung et al.  
 533 *Dyadosporites* sp. cf. *D. ellipsus* Clarke  
 528 *Fusiformisporites microstriatus* Hopkins (Pl. 2, figs. 35, 36)  
 761 *Fusiformisporites* sp. A Norris  
 548 *Fusiformisporites annafrancescae* sp. nov. (Pl. 2, figs. 12-14)  
 981 *Fusiformisporites crabbii* Rouse (Pl. 2, fig. 15)

#### Multicellate fungal spores

- 848 *Diporicellaesporites bellulus* Ke et Shi ex Sung et al. (Pl. 2, fig. 31)  
 692 *Diporicellaesporites laevigatiformis* Ke et Shi ex Sung et al. (Pl. 2, fig. 23)  
 947 *Diporicellaesporites liaoningensis* Ke et Shi ex Sung et al. (Pl. 2, figs. 16, 17)  
 992 *Diporicellaesporites* sp. A (Pl. 2, fig. 18)  
 999 *Diporicellaesporites* sp. B (Pl. 2, figs. 27, 28)  
 753 *Diporicellaesporites* sp. cf. *D. bellulus* Ke et Shi ex Sung et al.  
 845 *Diporicellaesporites* sp. cf. *D. liaoningensis* Ke et Shi ex Sung et al. (Pl. 2, fig. 19)  
 546 *Punctodiporites granulatus* (Rouse) comb. nov. (Pl. 2, figs. 20-22)  
 1009 *Punctodiporites foedus* sp. nov. (Pl. 2, figs. 24-26)  
 1016 *Pluricellaesporites* sp. (Pl. 2, figs. 37-40)

- 998 *Pluricellaesporites* sp. cf. *P. conspicuus* (Ke et Shi ex Sung et al.) comb. nov. (Pl. 2, figs. 41, 42)  
 392 *Brachysporisporites cotalis* (Elsik and Jansonius) Norris  
 684 *Brachysporisporites opimus* (Elsik and Jansonius) Norris (Pl. 2, fig. 44)  
 374 *Brachysporisporites* sp. cf. *B. cotalis* (Elsik and Jansonius) Norris  
 1007 *Brachysporisporites fustitudinus* sp. nov. (Pl. 3, figs. 1-5)  
 698 *Anatolinites* sp. (herein) (Pl. 3, figs. 8-11)  
 866 *Anatolinites dongyingensis* (Ke et Shi ex Sung et al.) Elsik, Ediger, & Bati (Pl. 3, fig. 7)  
 378 *Fractisporonites* sp. cf. *F. canalis* Clarke  
 549 *Fractisporonites* sp. A Norris  
 760 *Fractisporonites* sp. B (Pl. 3, figs. 20, 21)  
 1003 *Fractisporonites* sp. C (Pl. 3, figs. 17-19)  
 946 *Involutisporonites* sp. cf. *I. putus* Ke et Shi ex Sung et al. (Pl. 3, figs. 12-16)  
 1011 *Multicellaesporites cingulatus* Ke et Shi ex Sung et al.  
 687 *Multicellaesporites compactilis* Ke et Shi ex Sung et al. (Pl. 3, fig. 6)  
 944 *Multicellaesporites conspicuus* Ke et Shi ex Sung et al. (Pl. 2, figs. 45-47)  
 856 *Multicellaesporites lanceolatus* Ke et Shi ex Sung et al.  
 752 *Multicellaesporites leptaleus* Ke et Shi ex Sung et al.  
 749 *Multicellaesporites margaritus* Ke et Shi ex Sung et al.  
 942 *Multicellaesporites oculus* Ke et Shi ex Sung et al. (Pl. 3, fig. 22)  
 855 *Multicellaesporites* sp. cf. *M. conicus* Ke et Shi ex Sung et al. (Pl. 2, fig. 48)  
 999 *Multicellaesporites* sp. cf. *M. lanceolatus* Ke et Shi ex Sung et al.  
 954 *Multicellaesporites* sp. cf. *M. obscurus* Ke et Shi ex Sung et al. (Pl. 3, fig. 23)  
 1022 *Multicellaesporites* sp. cf. *M. oculus* Ke et Shi ex Sung et al. (Pl. 3, fig. 24)  
 941 *Multicellaesporites* sp. cf. *M. vermiculatus* Ke et Shi ex Sung et al. (Pl. 3, figs. 25, 26)  
 1006 *Reticellites* sp. (Pl. 3, fig. 27)  
 987 *Polyadosporites enormis* Ediger (Pl. 3, figs. 28, 29)  
 400 *Pesavis tagluensis* Elsik and Jansonius (Pl. 3, figs. 31-33)  
 556 *Pesavis parva* Kalgutkar and Sweet (Pl. 3, figs. 34-36)  
 532 *Ctenosporites eskerensis* Elsik and Jansonius  
 555 *Ctenosporites wolfei* Elsik and Jansonius (Pl. 3, fig. 37)  
 728 *Centonites* sp. A Norris

- 721 *Reduviasporonites anangus* Norris  
 726 *Reduviasporonites* sp. cf. *R. catenulatus*  
 Wilson  
 580 *Staphlosporonites delumbus* Norris  
 725 *Staphlosporonites* sp. A Norris  
 858 *Staphlosporonites* sp. cf. *S. conoideus*  
 Sheffy and Dilcher (Pl. 3, fig. 30)

### *Mycelial hyphae*

- 715 Fungal hypha type A Norris  
 717 Fungal hypha type B Norris  
 718 Fungal hypha type C Norris  
 729 Fungal hypha type D Norris  
 733 Fungal hypha type E Norris  
 738 Fungal hypha type G Norris

### *Fungal fruiting bodies*

- 599 *Desmidiospora willoughbyi* (Bradley)  
 Etheridge Glass et al. (Pl. 3, figs. 38-40)  
 739 *Plochmopeltinities masonii* Cookson (Pl. 4,  
 figs. 14, 15)  
 975 *Plochmopeltinities* sp. A (Pl. 4, figs. 1-4)  
 991 *Trichopeltinities* (?) sp. A (Pl. 4, figs. 5-7)  
 740 *Phragmothyrites* sp. cf. *P. eocaenicus*  
 Edwards (Pl. 4, fig. 13)  
 840 *Phragmothyrites* (?) sp. A (Pl. 4, figs. 8, 9)  
 867 *Phragmothyrites* (?) sp. B (Pl. 4, figs. 10,  
 11)  
 985 *Microthyrites* (?) sp. (Pl. 5, figs. 2, 3)  
 764 *Callimothallus pertusus* Dilcher (Pl. 4,  
 fig. 12)  
 747 *Microthallites* sp. cf. *M. lutosus* Dilcher  
 742 *Trichothyrites* sp. A Norris

### *Embryophyte spores and pollen*

#### *Turma Triletes*

- 367 *Azolla* sp.  
 183 *Baculatisporites comaumensis* (Cookson)  
 Potonie  
 722 *Baculatisporites crassiprimarius* (Krutzsch)  
 Norris  
 724 *Baculatisporites quintus* (Thomson and  
 Pflug) Krutzsch  
 52 *Biretisporites potoniaei* Delcourt and  
 Sprumont  
 405 *Cicatricosisporites dorogensis* Potonie and  
 Gelletich (Pl. 5, fig. 13)  
 22 *Cyathidites minor* Couper  
 16 *Deltoidospora hallei* Miner  
 615 *Echinatisporis* sp. A Norris

- 542 *Foveosporites* sp. (Pl. 5, figs. 4-8)  
 1000 *Obtusisporis* sp. (Pl. 5, figs. 11, 12)  
 19 *Osmundacidites wellmanii* Couper  
 570 *Retitriletes annotinioides* Krutzsch  
 412 *Retitriletes* sp. cf. *R. novomexicanus*  
 (Anderson) Norris  
 36 *Retitriletes* sp. cf. *R. oligocenicus* Krutzsch  
 413 *Stereisporites microgranulus* Krutzsch  
 1 *Stereisporites minor* (Raatz) Krutzsch  
 409 *Stereisporites stereoides* (Potonie and  
 Venitz) Pflug in Thomson and Pflug

#### *Turma Monoletes*

- 34 *Laevigatosporites ovatus* Wilson and  
 Webster  
 407 *Laevigatosporites novus* Norris (Pl. 5,  
 fig. 10)  
 418 *Verrucatosporites favus* (Potonie) Thomson  
 and Pflug (Pl. 5, fig. 9)

#### *Turma Saccites*

- 401 *Piceapollenites grandivescipites*  
 (Wodehouse) Norris  
 411 *Piceapollenites* sp. A Norris  
 719 *Pinuspollenites labdacus* (Potonie) Raatz ex  
 Potonie  
 326 *Pinuspollenites* sp. A Norris  
 327 *Podocarpidites maximus* (Stanley) comb.  
 nov. (Pl. 5, fig. 14)  
 597 *Tsugaepollenites igniculus* (Potonie)  
 Potonie and Venitz  
 371 *Tsugaepollenites viridifluminipites*  
 (Wodehouse) Norris

#### *Turma Aletes*

- 239 *Sequoiapollenites polyformosus* Thiergart  
 (Pl. 5, fig. 16)  
 245 *Sigmopollis psilatus* Piel (Pl. 7, fig. 33)  
 2 *Taxodiaceapollenites hiatus* Potonie ex  
 Potonie

#### *Turma Plicates*

#### Tricolpate

- 978 *Tricolpopollenites sculptus* Takahashi  
 (Pl. 5, figs. 17, 18, 24, 25)  
 997 *Aceripollenites tener* Samoiloitch) comb.  
 nov. (Pl. 5, figs. 22, 23)  
 291 *Tricolpites hians* Stanley

- 524 *Ilexpollenites microiliaceus* (Pflug and Thomson) Ke et Shi ex Sung et al.  
 422 *Integricarpus* sp. A Norris (Pl. 5, figs. 19-21)  
 935 *Aquilapollenites tumanganicus* Bolotnikova (Pl. 5, figs. 32-34)  
 982 *Novemprojectus traversii* Choi (Pl. 6, figs. 1-4)  
 381 *Quercoidites microhenrica* (Potonie) Potonie  
 736 *Quercoidites* sp. A Norris

#### Polycolpate

- 964 *Psilastephanocolpites* sp. cf. *P. marginatus* Gonzales Guzman (Pl. 6, fig. 34)

#### Tricolporate

- 850 *Platanoides* (?) sp. cf. *Platanus ipelensis* (Pacltova) emend. Pacltova comb. nov. (Pl. 6, figs. 9-11)  
 536 *Ailanthipites fluens* sp. nov. (Pl. 6, figs. 21-27)  
 973 *Rhoipites* sp. cf. *R. microreticulatus* (Pflug and Thomson) Takahashi and Jux (Pl. 5, figs. 26-28)  
 965 *Rhoipites* sp. (Pl. 5, figs. 29-31)  
 974 *Caprifoliipites incertigrandis* Frederiksen (Pl. 5, figs. 35-27)  
 539 *Acanthacidites* (?) sp. (Pl. 6, figs. 12-16)  
 544 *Mediocolpopollis alitandus* sp. nov. (Pl. 6, figs. 17-20)  
 416 *Ericipites antecursoroides* Norris (Pl. 6, fig. 5)  
 971 *Ericipites* sp. cf. *E. ericeus* (Potonie) Potonie (Pl. 6, figs. 7, 8)  
 377 *Ericipites compactipollinatus* (Traverse) Norris  
 976 *Faguspollenites* sp. (Pl. 6, figs. 28, 29)  
 962 *Myrtacidites parvus* Cookson and Pike (Pl. 6, figs. 35-37)  
 834 *Lonicerapollis gallwitzii* Krutzsch (Pl. 6, figs. 30-32)  
 626 *Montanapollis* cf. *globosiporus* (Samoilovich) Srivastava (Pl. 6, figs. 38-40)  
 373 *Cupuliferoideaepollenites pusillus* (Potonie) Potonie  
 399 *Cupuliferoideaepollenites oviformis* (Potonie) Potonie  
 389 *Margocolporites stenosus* Ke et Shi ex Sung et al.

#### Polycolporate

- 552 *Psilastephanocolporites* sp. (Pl. 6, fig. 33)  
 970 *Tetracolporopollenites* sp. (Pl. 7, fig. 1)

#### Turma Poroses

#### Monoporate

- 640 *Graminidites* sp. A Norris  
 525 *Sparganiaceapollenites neogenicus* Krutzsch (Pl. 5, fig. 15)

#### Triporate

- 1017 *Caryapollenites inelegans* Nichols and Ott (Pl. 7, figs. 2, 3)  
 282 *Caryapollenites veripites* (Wilson and Webster) Nichols and Ott (Pl. 7, figs. 5-7)  
 1019 *Momipites annellus* Nichols and Ott (Pl. 7, figs. 11, 12)  
 1021 *Momipites leffingwelli* Nichols and Ott (Pl. 7, fig. 10)  
 1018 *Momipites waltmanensis* Nichols and Ott (Pl. 7, fig. 9)  
 1020 *Momipites wyomingensis* Nichols and Ott (Pl. 7, figs. 4, 8)  
 952 *Triporopollenites mullensis* (Simpson) Rouse and Srivastava (Pl. 7, figs. 13, 14)  
 979 *Bombacacidites* sp. (Pl. 7, fig. 18)  
 972 *Platycaryapollenites* sp. cf. *P. shandongensis* Ke et Shi ex Sung et al. (Pl. 7, figs. 15-17)  
 864 *Plicapollis* sp. cf. *P. spatiosa* Frederiksen (Pl. 6, figs. 41, 42)  
 849 *Paraalnipollenites alterniporus* (Simpson) Srivastava (Pl. 7, figs. 23, 24)  
 368 *Corsinipollenites triangulatus* (Zaklinskaya) Ke et Shi ex Sung et al.  
 370 *Intratriporopollenites crassipites* (Wodehouse) Norris (Pl. 7, figs. 21, 22)  
 397 *Intratriporopollenites minimus* Mai (Pl. 7, figs. 19, 20)  
 943 *Intratriporopollenites* sp. A Rouse  
 394 *Myricipites annulites* (Martin and Rouse) Norris  
 330 *Pistillipollenites mcgregorii* Rouse  
 959 *Proteacidites verruciformis* Ke et Shi  
 936 *Scabiosapollis intrabaculus* Wang  
 220 *Trivestibulopollenites claripites* (Wodehouse) Norris  
 714 *Trivestibulopollenites betuloides* Pflug in Thomson and Pflug

- 755 *Annutriporites* sp. A Norris  
 324 *Annutriporites tripollenites* (Rouse) Norris  
 395 *Carpinipites* sp. *C. spackmaniana*  
 (Traverse) Zhou

#### Polyporate and polyfovate

- 1012 *Anacolosidites* sp. (Pl. 7, fig. 32)  
 966 *Caryophyllidites* sp. (Pl. 7, figs. 25, 26)  
 967 *Celtispollenites tschudyii* (Elsik) comb. nov.  
 (Pl. 7, figs. 28, 29)  
 940 *Juglanspollenites tetraporus* Sung and Tsao  
 (Pl. 7, fig. 27)  
 995 *Juglanspollenites verus* Raatz (Pl. 7, fig. 30)  
 950 *Periporopollenites stigmus* (Potonie)  
 Thomson and Pflug (Pl. 7, fig. 35)  
 408 *Chenopodipollis nuktakensis* Norris (Pl. 7,  
 fig. 31)  
 323 *Polyatriopollenites stellatus* (Potonie) Pflug  
 (Pl. 7, fig. 36)  
 287 *Polyvestibulopollenites verus* (Potonie)  
 Thomson and Pflug  
 360 *Polyvestibulopollenites trinus* (Stanley)  
 Norris  
 1005 *Ulmipollenites minor* Groot and Grott  
 320 *Ulmipollenites undulosus* Wolff (Pl. 7,  
 fig. 37)  
 720 *Ulmoideipites tricostatus* Anderson

#### Dinoflagellates

- M369 *Achomosphaera ramulifera* (Deflandre)  
 Evitt  
 M259 *Apectodinium homomorphum* (Deflandre  
 and Cookson) Lentin and Williams  
 M260 *Apectodinium hyperacanthum* (Cookson  
 and Eisenack) Lentin and Williams  
 (Pl. 7, fig. 48)  
 M255 *Apectodinium quinquelatum* (Williams and  
 Downie) Costa and Downie  
 M368 *Cerodinium* cf. *striatum* (Drugg) Lentin and  
 Williams (Pl. 7, fig. 49)  
 M372 Dinoflagellate sp. S-1 (Pl. 7, fig. 40)  
 M292 *Distatodinium* sp. A  
 M371 *Geiselodinium* sp. 371 (Pl. 7, fig. 44)  
 M230 *Glaphyrocysta ordinata* (Williams and  
 Downie) Stover and Evitt  
 M370 *Gochtodinium simplex* Bujak  
 M233 *Horologinella* sp. A  
 M378 *Lentinia serrata* Bujak (Pl. 7, fig. 50)  
 M373 *Lentinia* sp. 373 (Pl. 7, fig. 41)  
 M246 *Maduradinium turpis* Norris (Pl. 7, fig. 51)  
 M349 *Melitasphaeridium pseudorecurvatum*  
 (Morgenroth) Bujak et al. (Pl. 7, fig. 42)

- M374 *Micrhystridium fraseri* Piel (Pl. 7, fig. 38)  
 M375 *Morkallacysta* sp. 375 (Pl. 7, fig. 39)  
 M244 *Palaeoperidinium ariadnae* Norris  
 M367 *Palaeoperidinium* sp. 367 (Pl. 7, figs. 52,  
 53)  
 M377 *Phelodinium* sp. 377 (Pl. 7, fig. 45)  
 M242 *Pyxidiella* sp. A  
 M376 *Senegalinium* cf. *microgranulatum* (Stanley)  
 (Pl. 7, figs. 46, 47)  
 M291 *Spinidinium* cf. *sagittulum* (Drugg) Lentin  
 and Williams (Pl. 7, fig. 34)  
 M229 *Wetzeliella* cf. *hampdenensis* Wilson

#### SYSTEMATIC DESCRIPTIONS

The spore-pollen species treated below include only new species – either formally named or left in open nomenclature – and previously described species which are newly reported from the Beaufort-Mackenzie Basin. Also included are species reported previously from this area, principally in biostratigraphic studies, but which require more formal taxonomic treatment.

Full details of literature citations for genera may be found in the Jansonius and Hills Genera File of Fossil Spores (Jansonius and Hills, 1976 et seq.) and are not repeated in the list of references.

Species have been consistently assigned to form genera that are objectively defined palynomorph entities based on fossil material. Use of extant genera has been avoided in the systematic part of this work to separate the conceptually distinct endeavour of assessing botanical affinities of dispersed organs of plants.

Synonymies are not intended to be exhaustive but rather to highlight salient taxa, basionyms, and recombinations, together with selected citations of records of taxa of special interest to this study.

The section on “Distribution” for each species is intended as a general guide only; full details of distribution in the Adgo F-28 well are provided in the biostratigraphic part of this work. In the following section, occurrence of each species in the sequences studied is indicated. Each sequence cited is followed by its age range (e.g., Paleocene-Eocene), but this is not intended to indicate the range of the species. For more precise information on ranges of individual taxa, refer to the discussion in the biostratigraphic section on the age and correlation of the zones. Note in particular that the Taglu Sequence embraces the Paleocene-Eocene boundary; approximately only the basal one third of this sequence is Paleocene in age.



## Fungal palynomorphs

### Monocellate fungal spores

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

*Inapertisporites* cf. *I. elongatus* Rouse

Plate 1, figures 1, 2

1962 (cf.) *Inapertisporites elongatus* Rouse, p. 208,  
Pl. 5, figs. 14-16.

*Description.* Fungal spores monocellate, inaperturate, isopolar, equilateral, elongated in outline with rounded ends, and with slightly inflated apices indicated by clusters of arcuate folds in the wall. Spore wall levigate, 0.25  $\mu\text{m}$  thick. Spore length 30-32  $\mu\text{m}$ ; spore width 12-15  $\mu\text{m}$ .

*Remarks.* Distinguished from *I. elongatus* Rouse by its larger size, thinner spore wall, and lack of apertures, and from *I. subcapsularis* Sheffy and Dilcher by its equilateral outline.

*Distribution.* Taglu Sequence (Paleocene-Eocene).

**Genus** *Lacrimasporonites* (Clarke) Elsik

*Lacrimasporonites globulosus* (Rouse)  
comb. nov.

Plate 1, figures 3, 4

1962 *Inapertisporites globulosus* Rouse, p. 208, Pl. 5,  
figs. 12, 13.

1968 *Lacrimasporonites globulosus* (Rouse 1962) Elsik  
(nomen nudum), p. 273.

*Distribution.* Mackenzie Bay, Richards, and Taglu sequences (Paleocene-Miocene). Eocene of British Columbia (Rouse 1962).

**Genus** *Hypoxylonites* Elsik

*Hypoxylonites pirozynskioides* Elsik

Plate 1, figures 11, 12

1974 cf. *Hypoxylon* sp., Elsik and Dilcher, p. 71,  
Pl. 27, fig. 24.

1990 *Hypoxylonites pirozynskioides* Elsik, p. 155,  
Pl. 2, figs. 66, 83.

*Distribution.* Richards Sequence (Middle Eocene). Middle Eocene, Tennessee (Elsik, 1990).

**Genus** *Spirotremesporites* Duenas 1979  
emend. Elsik 1990

*Spirotremesporites* sp. cf. *S. clinatus* Elsik

Plate 1, figures 14, 15

1990 (cf.) *Spirotremesporites clinatus* Elsik, p. 162,  
Pl. 1, figs. 24, 48.

*Description.* Fungal spores monocellate, isopolar, equilateral, with a short, straight furrow set at an angle to the apical line. Spore wall levigate, 0.5-1.0  $\mu\text{m}$  thick, thickening up to 1.5  $\mu\text{m}$  at the apices. Spore length 11-15  $\mu\text{m}$ ; spore width 6-10  $\mu\text{m}$ ; furrow 4-6  $\mu\text{m}$  long.

*Remarks.* Distinguished from *S. clinatus* Elsik and *S. obliquus* Elsik by its much smaller size. *Distribution.* Upper part of the Taglu Sequence (Paleocene-Eocene).

*Spirotremesporites reklawensis* Elsik

Plate 1, figure 13

1990 *Spirotremesporites reklawensis* Elsik, p. 164,  
Pl. 1, fig. 41.

*Distribution.* Taglu Sequence (Paleocene-Eocene). Middle Eocene, Texas (Elsik, 1990).

*Spirotremesporites* sp. cf. *S. reklawensis* Elsik

Plate 1, figure 9

1990 (cf.) *Spirotremesporites reklawensis* Elsik, p. 164,  
Pl. 1, fig. 41.

*Description.* Fungal spores monocellate, isopolar, equilateral, with rounded apices and a short, slightly sigmoidal furrow crossing the apical line at an angle. Spore wall levigate, 0.25-0.5  $\mu\text{m}$  thick. Spore length 9  $\mu\text{m}$ ; spore width 4  $\mu\text{m}$ ; furrow 5  $\mu\text{m}$  long.

*Remarks.* Distinguished from *S. reklawensis* Elsik by its much smaller size.

*Distribution.* Aklak Sequence (Paleocene).

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

*Striadiporites* sp. cf. *S. bistriatus* (Ke  
et Shi ex Sung et al.) Norris

Plate 1, figure 16

1986 (cf.) *Striadiporites bistriatus* (Ke et Shi ex Sung  
et al.) Norris, p. 20, Pl. 1, figs. 32-34.

1978 (cf.) *Striadiporites bistriatus* Ke et Shi ex Sung  
et al., p. 47, Pl. 4, figs. 32, 33.

**Description.** Fungal spores unicellate, isopolar, equilateral, diporate, with a fusiform outline and sharply rounded apices. Spore wall 0.5  $\mu\text{m}$  thick, with 4 or 5 ribs running meridionally from apex to apex. Ribs 1-2  $\mu\text{m}$  wide, spaced up to 4  $\mu\text{m}$  apart, converging and becoming narrower towards the pores where they may fuse to form a sub-apical annulus or disappear against the pore. Spore length 40-49  $\mu\text{m}$ ; spore width 21-24  $\mu\text{m}$ ; pores 2-3  $\mu\text{m}$  wide.

**Remarks.** Distinguished from *S. bistriatus* by the narrower, more numerous, and more closely spaced ribs, and by the more sharply rounded rather than truncated apices.

**Distribution.** Taglu Sequence (Paleocene-Eocene).

*Striadiporites anceps* sp. nov.

Plate 1, figures 20-25

**Holotype.** GSC holotype 111967 from Imperial Adgo F-28 well, NWT, 6000 ft (1828.8 m), Pl. 1, figs. 21, 22.

**Derivation of name.** Latin *anceps*, two-headed, in allusion to the double annular thickenings beneath the apices.

**Diagnosis.** Fungal spores unicellular, diporate, isopolar, equilateral or slightly inequilateral, oval to fusiform in shape. Spore wall striate with meridionally disposed, subparallel ribs converging and partially fusing with a pair of sub-apical annular thickenings that surround each apical pore.

**Description.** Spore wall 0.5  $\mu\text{m}$  thick, thinning over the apical pores. Ribs 5 to 8 in number, up to 1  $\mu\text{m}$  wide, not well defined and presumably not markedly thicker than the spore wall, becoming narrower approaching the apices, spaced up to 3  $\mu\text{m}$  apart. The two annular thickenings below each apex are 1-2  $\mu\text{m}$  wide and

spaced 2-4  $\mu\text{m}$  apart from one another. Some of the ribs fuse with the annular thickenings while others pass across them towards the apices. Pores circular, 1-2  $\mu\text{m}$  in diameter, protruding beyond the subjacent annular thickenings. Spore length 37-46  $\mu\text{m}$ ; spore width 20-26  $\mu\text{m}$ .

**Remarks.** This species is distinguished from other species of *Striadiporites* by the double annulus at each apex.

**Distribution.** Taglu Sequence (Paleocene-Eocene).

**Genus *Biporisporites*** Ke et Shi ex  
Sung et al. 1978, emend. herein

**Type Species:** *Biporisporites rotundus* Ke et Shi ex Sung et al., 1978, p. 45, Pl. 4, figs. 19, 20.

**Emended Diagnosis.** Fungal spore-like bodies, unicellate, equilateral, heteropolar, oblate, circular to oval in shape, one end (defined as apical) with a central boss-like thickening flanked by two pores at its proximal end and prominent lumina in the spore wall laterally adjacent to the constricted median part of the boss. Lateral arm-like thickenings arise from the distal end of the boss. Spore wall smooth, single-layered, unornamented or bearing variable ornament in the form of concentric or reticulate thickenings that become subdued in the area immediately surrounding the central boss.

**Remarks.** Sung et al. diagnosed this monotypic genus as follows (translation in Jansonius and Hills, 1979, card 3537): "Single cell, spherical. Two pores, situated at one end of spore. Wall of medium thickness, surface smooth or roughened." The type species was described: "22-30  $\mu\text{m}$ ; single cell (sub)spherical, flattened at end with pores; pores round or oval, 5  $\mu\text{m}$  across; wall two-layered, outer layer thicker than inner one, surface smooth."

The following species are now attributed to this genus and allow a more precise diagnosis differing in significant respects from the original provided by Sung et al:

*Biporisporites rotundus* Ke et Shi ex Sung et al., 1978, p. 45, Pl. 4, figs. 19, 20. Oligocene, China (re-described below from Canadian material).

*Biporisporites* sp. (syn. *Striadiporites* cf. *sanctaebarbarae* auct. non Elsik and Jansonius, Ediger and Alisan 1989, p. 141, Pl. 3. figs. 1, 2). Paleogene, Turkey.

*Biporisporites praestigiatus* sp. nov. Eocene, northern Canada (described below).

In the genus *Biporisporites*, the cell is clearly oblate rather than spherical, flattening in a plane encompassing both the apical and antapical ends. Sung et al.'s type species is relatively unornamented, but their photographs clearly show diffuse concentric thickenings on the spore wall. The other two species described have more prominent reticulate and concentric ornament. A distinctive feature of this genus is the central boss at the apical end, which in all the described species is developed with a median constriction emphasized by flanking subcircular lumina in the spore wall. The pores occur immediately adjacent to the proximal end of the boss. Furthermore, in all three species, the distal portion of the boss gives rise to lateral pairs of arm-like thickenings in the spore wall, which further emphasize the lumina flanking the median constriction of the boss. When these lateral thickenings are perfectly superimposed, the impression is of a tricellate organization, as shown in Jansonius and Hills' apparently erroneous reillustration of the type species (1979, Card 3537).

Although the species in this genus are attributed a spore-like structure, it is not entirely certain that these unique structures are spores. Their deep brown colour suggests a fungal affinity, but they may possibly be fruiting bodies. *Pesavis* shows a similar heteropolar organization but its multicellular and multiseriate structure is clearly quite different.

*Biporisporites rotundus* Ke et Shi ex Sung et al.

Plate 1, figures 26-31

1978 p. 45, Pl. 4, figs. 19, 20.

*Description.* Fungal spore-like bodies, unicellate, oblate, flattened, equilateral, heteropolar, subcircular to oval in outline (broader than long or longer than broad), with two pore-like structures flanking the proximal end of a central opaque boss with a flattened and somewhat indented proximal end, a rounded distal end, a constricted median portion, and tending to project slightly from the amb at the apex. Spore wall single-layered, levigate, except for two lumina 3-5  $\mu\text{m}$  in diameter located beneath and partly confluent with the apical pores and which flank the constricted part of the central boss, being subtended also by two pairs of lateral, more or less rectilinear, inwardly projecting muri. Muri approximately 0.25  $\mu\text{m}$  wide, not sharply delimited, extending from near the distal end of the central boss and connecting across to the spore amb. A diffuse thinner zone in the spore wall may surround the

distal end of the central boss but this is not consistently developed. Spore wall 0.25-1  $\mu\text{m}$  thick, single layered, thinner over the pores, which are 1-2  $\mu\text{m}$  wide and merge with the subjacent lumina, both tending to rupture. Central boss 9-11  $\mu\text{m}$  long, 6-11  $\mu\text{m}$  wide, but narrowing in the median part. Spore length (parallel to boss from apex to antapex), 19-32  $\mu\text{m}$ ; spore width, 27-34  $\mu\text{m}$ .

*Distribution.* Taglu Sequence (Paleocene-Eocene). Oligocene, China (Sung et al., 1978).

*Biporisporites praestigiatus* sp. nov.

Plate 1, figures 32-41

*Holotype.* GSC holotype 111979 from Imperial Adgo F-28 well, NWT, 6400 ft (1950.7 m), Pl. 1, figs. 36, 37.

*Derivation of name.* Latin *praestigiator*, a juggler, in allusion to the central boss resembling a figure with arms extended and with objects in orbit above the head (viz., the antapically directed, subconcentric ornament).

*Diagnosis.* Fungal spore-like bodies, unicellate, oblate, equilateral, heteropolar, subcircular to oval in outline with two pore-like structures flanking proximally beneath the apex a central opaque boss with a median constriction. Spore wall with subconcentric and reticulate thickenings on the antapical half, which extend apically as progressively narrower areas converging towards the proximal end of the central boss. The boss projects subhemispherically beyond the amb. The proximal part of the boss is a unified structure but may split distally into two parts, confluent with the upper and lower surfaces of the spore. Two pairs of lateral, more or less rectilinear, inwardly projecting muri extend from near the distal end of the central boss and connect laterally across the spore amb. Two pairs of lumina in the spore wall flank the constricted part of the central boss. Pores are circular, immediately adjacent to the central boss, located on the amb, the thinner pore wall merging imperceptibly with the foveae of the ornamented areas.

*Description.* Spore wall single-layered, approximately 1  $\mu\text{m}$  thick, thinner over the pores and up to 2  $\mu\text{m}$  thick over the ornament. Central boss 11-15  $\mu\text{m}$  long, 6-10  $\mu\text{m}$  wide but narrower at the constriction. Ornamental muri on wall 1-4  $\mu\text{m}$  wide, commonly connected into an elongated reticulum with rounded lumina 5-15  $\mu\text{m}$  in diameter. Two or three muri are more prominent and follow subconcentric paths subparallel to the amb, the innermost delimiting a central area surrounding the boss, which is largely

devoid of ornament. The pairs of lateral thickenings diverging from the boss are inwardly thickened, sharply to poorly delimited, and up to 1  $\mu\text{m}$  wide. Pores 1-2  $\mu\text{m}$  in diameter, merging with the adjacent lumina. Spore length (parallel to boss from apex to antapex) 31-45  $\mu\text{m}$ ; spore width 32-37  $\mu\text{m}$ .

*Remarks.* *Biporisporites* sp. of Ediger and Alison (1989) is similar to *B. praestigiatus* but has coarser and more angular muri that project further at the amb and enclose smaller polygonal lumina.

*Distribution.* Taglu Sequence (Paleocene-Eocene).

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

*Diporisporites elegans* Ke et Shi ex Sung et al.

Plate 1, figure 42

1978 p. 46, Pl. 4, fig. 21.

*Distribution.* Taglu Sequence (Paleocene-Eocene).  
Oligocene of China (Sung et al., 1978).

*Diporisporites oblongatus* Ke et Shi ex Sung et al.

Plate 1, figures 43, 44

1978 p. 46, Pl. 4, figs. 24-26.

*Remarks.* Apices slightly more blunt than the Chinese specimens.

*Distribution.* Taglu Sequence (Paleocene-Eocene).  
Upper Eocene-Lower Oligocene, China (Sung et al., 1978).

*Diporisporites pisciculatus* sp. nov.

Plate 2, figures 1-8

*Holotype.* GSC holotype 111989 from Imperial Adgo F-28 well, NWT, 7600 ft (2316.5 m), Pl. 2, figs. 2, 3.

*Derivation of name.* From the Latin *pisciculus*, a little fish, referring to the fin-like projections of the wall.

*Diagnosis.* Fungal spores monocellate, diporate, equilateral, isopolar, oval, with a thick opaque or translucent wall surrounded by a diaphanous folded membrane that projects at the amb.

*Description.* Spore wall 2-4  $\mu\text{m}$  thick, levigate, thinning at the pores, and commonly split. Diaphanous membrane up to 0.25  $\mu\text{m}$  thick, levigate or scabrate, projecting 1-5  $\mu\text{m}$  beyond the amb of the inner spore wall, strongly folded along rectilinear and curvilinear lines. Pores 1-4  $\mu\text{m}$  in diameter, circular, sometimes circumscribed by an atrium-like modification of the spore wall forming a chamber up to 4  $\mu\text{m}$  deep beneath the pores. Overall spore length 29-37  $\mu\text{m}$ ; width 18-29  $\mu\text{m}$ .

*Remarks.* The presence of a hyaline, perine-like membrane is distinctive but can be overlooked in view of the extreme density contrast between it and the inner wall. *Lacrimasporonites stoughii* Elsik (1968) and *Multicellaesporites cingulatus* Ke et Shi ex Sung et al. (1978) both have wall structures similar to *Diporisporites pisciculatus* sp. nov., but are otherwise distinctly different.

*Distribution.* Taglu Sequence (Paleocene-Eocene).

## Dicellate fungal spores

**Genus** *Dicellaesporites* Elsik emend. Norris 1986

*Dicellaesporites* sp. cf. *D. akyolii*  
Ediger and Alison

Plate 1, figures 9-11

1989 (cf.) *Dicellaesporites akyolii* Ediger and Alison,  
p. 155, Pl. 3, figs. 10, 11.

*Description.* Fungal spores dicellate, isopolar, equilateral, oval with sharply rounded apices, and no pre-formed aperture. Spore wall 0.25-0.5  $\mu\text{m}$  thick, densely covered with grana approximately 0.25  $\mu\text{m}$  in diameter and 0.25  $\mu\text{m}$  high, spaced approximately 0.5  $\mu\text{m}$  apart. Septum 0.5-1.0  $\mu\text{m}$  thick, apparently aperforate. An annular zone, 2-3  $\mu\text{m}$  wide, may be developed around each cell approximately halfway between the septum and the apex where the spore wall is reduced in thickness. Spore length 28-41  $\mu\text{m}$ ; spore width 12-15  $\mu\text{m}$ .

*Remarks.* Distinguished from *D. akyolii* by its larger size, more elongate shape, and finer, denser ornament.

*Distribution.* Taglu Sequence (Paleocene-Eocene).

**Genus** *Dyadosporites* Van der Hammen  
ex Clarke 1965

*Dyadosporites* sp. cf. *D. solidus* Ke et Shi ex Sung et al.

Plate 1, figure 45

1979 (cf.) *Dyadosporites solidus* Ke et Shi ex Sung et al., p. 49, Pl. 5, fig. 10.

*Description.* Fungal spores dicellate, equilateral, isopolar, fusiform, with a pore at each apex. Spore wall up to 1  $\mu\text{m}$  thick, scabrate to subgranular; granules up to 0.5  $\mu\text{m}$  in diameter, projecting up to 0.25  $\mu\text{m}$  at amb, spaced 0.25-1  $\mu\text{m}$  apart. Spore wall thickened and darker in colour in an annular zone 2-5  $\mu\text{m}$  wide on each side of the septum. Septum 1-2  $\mu\text{m}$  thick, perforate; locus of septal insertion slightly indented at amb. Pores marked by thinning of the wall at the apices. Spore length, 52  $\mu\text{m}$ ; spore width, 26  $\mu\text{m}$ .

*Remarks.* Distinguished from *D. solidus* Ke et Shi ex Sung et al. by its slightly smaller size, its lack of furrows, and its distinctive wall structure and ornament.

*Distribution.* Taglu Sequence (Paleocene-Eocene).

*Dyadosporites* sp. cf. *D. ellipsus* Clarke

Plate 1, figure 46

1965 (cf.) *Dyadosporites ellipsus* Clarke, p. 90, Pl. 1, figs. 13, 14.

*Description.* Fungal spores dicellate, isopolar, equilateral, diporate, fusiform. Spore wall 0.5  $\mu\text{m}$  thick, scabrate. Septum 0.5-1  $\mu\text{m}$  thick, perforate. Cells slightly constricted at the locus of septal insertion. Pores at each apex up to 2  $\mu\text{m}$  in diameter, splitting irregularly along lines subparallel to the apical line. Spore length 56  $\mu\text{m}$ ; spore width 14-15  $\mu\text{m}$ .

*Remarks.* Distinguished from *Dyadosporites ellipsus* Clarke by its more fusiform shape, thinner exine, and smaller pores, and from *Dicellaesporites volubilis* Ke et Shi ex Sung et al. by the possession of pores and the constricted locus of septal insertion. *Dyadosporites solidus* Ke et Shi ex Sung et al. is wider, thicker walled, and has distinctive wall structure near the pores.

*Distribution.* Taglu Sequence (Paleocene-Eocene).

Genus *Fusiformisporites* Rouse emend. Elsik 1968

*Fusiformisporites annafrancescae* sp. nov.

Plate 2, figures 12-14

*Holotype.* GSC holotype 111996 from Imperial Adgo F-28 well, NWT. 7000 ft (2133.6 m), Pl. 2, fig. 12.

*Derivation of name.* For my wife, Anne Frances Norris.

*Diagnosis.* Fungal spores dicellate, equilateral, isopolar, fusiform in outline, without preformed apertures. Each cell with subparallel striae in a zone adjacent to the septum and with smooth to scabrate apical areas divided by meridionally disposed arcuate muri into faceted sectors.

*Description.* Spore wall 0.25-0.5  $\mu\text{m}$  thick except at the apices, where arcuate muri cross the amb and at the locus of septal insertion where the wall thickens up to 1  $\mu\text{m}$ . Septum 1-2  $\mu\text{m}$  thick, apparently aperforate. Striate zone occupies slightly more than half of each cell and comprises subparallel, occasionally bifurcating muri 0.25-0.5  $\mu\text{m}$  wide, spaced 0.5-1  $\mu\text{m}$  apart, oriented parallel to the apical line. The muri terminate adapically at an annular curvilinear murus that is confluent with a meridional murus; the latter passes across the apex from one side of the annular murus to the other. The spore wall in the sectors created by the curvilinear muri is levigate, scabrate or subgranular; the granules are up to 0.5  $\mu\text{m}$  in diameter.

*Remarks.* Distinguished from *Fusiformisporites* sp. A Norris 1986 by the smooth to scabrate rather than microreticulate spore wall in the apical areas.

*Distribution.* Taglu Sequence (Paleocene-Eocene).

*Fusiformisporites crabbii* Rouse

Plate 2, figure 15

1962 p. 210, Pl. 4, figs. 27-29.

*Description.* Fungal spores dicellate, isopolar, equilateral, fusiform, with prominent striae parallel to the apical line and converging at the apices. Locus of septal insertion marked by a distinct V-shaped furrow about 1  $\mu\text{m}$  wide and 1  $\mu\text{m}$  deep. Spore wall 0.25  $\mu\text{m}$

thick in between muri, increasing to up to 2  $\mu\text{m}$  at the apices. Muri 1.5-2  $\mu\text{m}$  wide near the septum, up to 1.5  $\mu\text{m}$  thick, becoming narrower towards the apices where they fuse into a thickened apical cap. The muri are spaced up to 3  $\mu\text{m}$  apart at the septum and, although apparently confluent between the cells, can be slightly offset across the septum and may also be slightly constricted at this point. Cells open by dehiscence between some of the muri. Spore length 44  $\mu\text{m}$ ; spore width 24  $\mu\text{m}$ .

*Remarks.* The above description augments Rouse's original description with further details.

*Distribution.* Taglu Sequence (Paleocene-Eocene). Eocene of British Columbia (Rouse, 1962).

### Multicellate fungal spores

**Genus** *Diporicellaesporites* Elsik 1968

*Diporicellaesporites liaoningensis* Ke et Shi ex Sung et al.

Plate 2, figures 16, 17

1978 p. 50, Pl. 5, figs. 7-9.

*Distribution.* Taglu Sequence (Paleocene-Eocene). Eocene and Oligocene of China (Sung et al., 1978).

*Diporicellaesporites* sp. A

Plate 2, figure 18

*Description.* Fungal spores with 8 cells, diporate, isopolar, equilateral, fusiform. Spore wall 2  $\mu\text{m}$  thick, progressively thinner in the penultimate and ultimate cells, smooth but provided with narrow sinuous fissures roughly aligned to the apical line, some of which are split open, perhaps as a result of compression. Pores 5-6  $\mu\text{m}$  in diameter, truncating the ultimate cells. Septa 2  $\mu\text{m}$  thick, perforate, denticulate. Loci of septal insertion slightly and broadly constricted. Spore length 154  $\mu\text{m}$ ; spore width 45  $\mu\text{m}$ .

*Distribution.* Taglu Sequence (Paleocene-Eocene).

*Diporicellaesporites* sp. B

Plate 2, figures 27, 28

*Description.* Fungal spores multicellate, uniseriate, equilateral, anisopolar, diporate, with 10-16 cells that are wider than long and are larger at one end of the spore, becoming narrower towards the apices. Septa perforate, in some cases dentate. Pores 2-3  $\mu\text{m}$  in diameter, of irregular shape on the blunt end of the apical cells. Spore wall 0.25-0.5  $\mu\text{m}$  thick, levigate. Spore length 45-82  $\mu\text{m}$ ; maximum spore width 11-14  $\mu\text{m}$ .

*Remarks.* Similar to *Diporicellaesporites* sp. Elsik and Dilcher (1974, p. 72, Pl. 27, fig. 42 only) which, however, has relatively longer cells. *Multicellaesporites lanceolatus* Ke et Shi ex Sung et al. is similar in overall shape but has fewer cells and is said to be inaperturate.

*Distribution.* Taglu Sequence (Paleocene-Eocene).

**Genus** *Punctodiporites* Varma and Rawat 1963

*Punctodiporites granulatus* (Rouse) comb. nov.

Plate 2, figures 20-22

1962 *Diporites granulatus* Rouse, p. 212, Pl. 5, figs. 5, 6.

1977 *Punctodiporites* A, Rouse, p. 64, Pl. 2, figs. 44, 45.

1980 *Punctodiporites* sp. Ioannides and McIntyre, p. 206, Pl. 31.5, fig. 18.

*Description.* Fungal spores with one large cell flanked by two pore-bearing smaller cells, fusiform, isopolar, equilateral. Spore wall on the main cell 0.25-0.5  $\mu\text{m}$  thick, with prominent, internally directed, microreticulate ornament. Muri of the microreticulum up to 0.25  $\mu\text{m}$  wide, separated by rounded lumina 0.5  $\mu\text{m}$  or less in diameter. Flanking cells are levigate; the spore wall reaches up to 1  $\mu\text{m}$  in thickness. Pores circular, 2-4  $\mu\text{m}$  in diameter, terminating the flanking cells, which are 3-5  $\mu\text{m}$  in length and 5-6  $\mu\text{m}$  wide at the base.

*Distribution.* Taglu Sequence (Paleocene-Eocene). Eocene of British Columbia and the eastern Arctic (Rouse, 1977).

*Remarks.* This species was originally attributed by Rouse to onagracean pollen, but it clearly has fungal affinities. *Punctodiporites harrisii* Varma and Rawat has a greater size range, thicker wall, and larger pores.

*Diporisorites granulatus* Ke et Shi ex Sung et al. is larger and has a thicker wall and wider pores. Sung et al.'s species clearly belongs to *Punctodiporites* but is a junior homonym of *P. granulatus* (Rouse) comb. nov. Consequently, it is here named *Punctodiporites keshii* sp. nov. (basionym *Diporisorites granulatus* Ke et Shi ex Sung et al., 1978, p. 46, Pl. 3, figs. 19, 20; holotype Sung et al.'s Pl. 3, fig. 20). The name (Ke et Shi) is derived by Latinization of the "collective name" adopted by Sung, Cao, Zhou, Guan, and Wang, which, at the time, was in China a requirement for taxonomic work produced during the Great Proletarian Cultural Revolution (Sung et al., 1978, p. v-vi). This collective name was derived from the second syllable of Nanjing (Nanking) and the first syllable of Shengli oil field (according to Sung Zhichen, Nanking Institute of Paleontology, pers. comm., 1979). *Diporicellaesporites endogranulosus* Kemp 1978 is larger, has two flanking cells on each side, and is internally granulate.

*Punctodiporites foedus* sp. nov.

Plate 2, figures 24-26

*Derivation of name.* From Latin *foedus*, foul, horrible.

*Holotype.* GSC holotype 112009 from Imperial Adgo F-28 well, NWT. 6300 ft (1920.2 m), Pl. 2, fig. 25.

*Diagnosis.* Fungal spores isopolar, fusiform, equilateral or slightly inequilateral, with a main cell flanked by two pore-bearing smaller cells. Spore wall with internally directed irregular granular ornament separated by irregular fossulae on the main cell, and thickened into a basal annulus on the flanking cells.

*Description.* Fungal wall 1.5-2.5  $\mu\text{m}$  thick. Internally directed granules 1-3  $\mu\text{m}$  in diameter, approximately 1  $\mu\text{m}$  high, irregular, rounded-polygonal, or elongate in shape, in places fusing into larger areas of thickened exine. Fossulae 0.25-0.5  $\mu\text{m}$  wide, sometimes split open. Flanking cells triangular, attached to the main cell without constriction, 8-11  $\mu\text{m}$  in basal diameter, 6-11  $\mu\text{m}$  long, tapering to the pore which is 1-2  $\mu\text{m}$  in diameter. The approximately basal one third of the flanking cells is distinctly thickened into a levigate annulus, which contrasts with the ornamented main cell wall. The upper part of the flanking cell is hyaline, and the spore wall is 0.25  $\mu\text{m}$  or less in thickness and susceptible to decay or damage. Spore length 44-56  $\mu\text{m}$ ; spore width 23-31  $\mu\text{m}$ .

*Remarks.* Distinguished from other species of *Punctodiporites* by the distinctive irregular granular and fossulate ornament on the inner surface of the main cell wall.

*Distribution.* Taglu Sequence (Paleocene-Eocene).

**Genus *Pluricellaesporites*** Van der Hammen  
emend. Elsik and Jansonius 1974

*Pluricellaesporites* sp.

Plate 2, figures 37-40

1980 *Pluricellaesporites* sp. 2, Sepulveda, p. 264, Pl. 2, fig. 4; Textfig. 28.

1989 *P. cf. vermiculus* Ediger; Ediger and Alisan p. 141, Pl. 3, fig. 19.

*Description.* Fungal spores, three- to four-celled, anisopolar, equilateral, monoporate. Basal two cells thicker and commonly the only ones preserved; together they are hemispherical or slightly elongated-hemispherical with straight sides. Upper two cells lighter in colour, thinner walled, slightly tapering to a terminal pore 8-12  $\mu\text{m}$  in diameter. Spore wall levigate, up to 1  $\mu\text{m}$  thick in the basal cells, thinner in the upper cells. Septa are thick and opaque, forming distinct annular bands up to 10  $\mu\text{m}$  wide, perforate, dentate. Spore length 25-37  $\mu\text{m}$ ; spore width 20-33  $\mu\text{m}$ .

*Remarks.* The large, more or less hemispherical, basal two cells and large diameter pore distinguish this species from other species of *Pluricellaesporites*. It is distinguished from *Granatisporites catinus* Elsik and Jansonius by its less tapered outline in the upper cells and by its smaller basal cell. *Brachysporisorites opimus* (Elsik and Jansonius) Norris has similar basal cells but shows very strong tapering to the pore, which may be covered by a pore cell. *Pluricellaesporites delicatus* Ke et Shi ex Sung et al. is similar but has a narrower pore with an annulus.

The present specimens show a large range of sizes, which may indicate a means of discriminating more than one species when further material becomes available.

*Distribution.* Aklak Sequence (Paleocene).

*Pluricellaesporites* sp. cf. *P. conspicuus*  
(Ke et Shi ex Sung et al.) comb. nov.

Plate 2, figures 41, 42

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

1981 *Pluricellaesporites vermiculus* Ediger, p. 92, Pl. 2, figs. 9, 11 (only).

1989 *Pluricellaesporites vermiculus* Ediger and Alisan auct. non Ediger 1981, p. 141, Pl. 3, figs. 16-18.

**Description.** Fungal spores four-celled, anisopolar, equilateral, monoporate. Lower three cells thick-walled, broader than long, tapering slightly towards pore cell. Upper cell usually thinner walled, tapering to the pore, which is 2-4  $\mu\text{m}$  in diameter. Spore wall levigate, 2-3  $\mu\text{m}$  thick on lower three cells, 1  $\mu\text{m}$  or less in thickness on the upper cell. Spore length, 25-31  $\mu\text{m}$ ; spore width, 13-16  $\mu\text{m}$ .

**Remarks.** Distinguished from *Pluricellaesporites conspicuus* (Ke et Shi ex Sung et al.) comb. nov. (herein) by its smaller size, larger number of comparatively wider cells, and thicker spore wall. *Pluricellaesporites vermiculus* described by Ediger in 1981 appears to be a species of *Involutispora*. Other specimens attributed to *P. vermiculus* and illustrated by Ediger (1981) and Ediger and Alisan (1989) appear to be *P. cf. P. conspicuus*.

**Distribution.** Richards, Taglu, and Aklak sequences (Middle Eocene-Upper Paleocene). Lower Tertiary of Turkey (Ediger and Alisan, 1989).

#### Genus *Brachysporisporites* Lange and Smith 1971

*Brachysporisporites fustitudinus* sp. nov.

Plate 3, figures 1-5

**Holotype.** GSC holotype 112032 from Imperial Adgo F-28 well, NWT. 5100 ft (1554.5 m), Pl. 3, fig. 1.

**Derivation of name.** From the Latin *fustitudinus*: cudgel-walloping.

**Diagnosis.** Fungal spores six-celled or more, equilateral, anisopolar, monoporate, with a sharply rounded basal cell, upper cells strongly tapered towards the pore, and curvilinear septa concave towards the nearest pole.

**Description.** Spore wall 0.5  $\mu\text{m}$  or less in thickness, thinner towards the pore cell, levigate or scabrate, with scattered small foveae 0.25  $\mu\text{m}$  in diameter. Basal cell approximately one third the spore length, tapering towards a sharply rounded apex; next two cells slightly shorter than the basal cell, broader than long, occupying the widest part of the cell; upper three cells much smaller, tapering strongly to a blunt tip, which

may be the pore or may be the broken end of the pore cell. Pore 4-5  $\mu\text{m}$  in diameter. Septa perforate, distinctly concave, their concavities in opposing directions either side of the line marking the maximum spore width. Spore length 45-60  $\mu\text{m}$ ; spore width 23-31  $\mu\text{m}$ .

**Remarks.** Distinguished from *Brachysporisporites* sp. 1 Sepulveda (1980) by its larger size, larger number of cells, and thinner spore wall.

**Distribution.** Taglu Sequence (Paleocene-Eocene).

*Brachysporisporites* sp. cf. *Brachysporisporites conicus* Ke et Shi ex Sung et al. comb. nov.

Plate 2, figure 48

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

**Remarks.** Similar to *B. conicus* but distinguished by the thinner wall and the uncurved narrow end. *Brachysporisporites catinus* (Elsik and Jansonius) comb. nov. (basonym *Granatisporites catinus* Elsik and Jansonius 1974, p. 954, fig. 15) is smaller, with a strongly thickened basal cell.

**Distribution.** Taglu Sequence (Paleocene-Eocene).

#### Genus *Anatolinites* Elsik, Ediger, and Bati 1990

*Anatolinites dongyingensis* (Ke et Shi ex Sung et al.) Elsik, Ediger, and Bati

Plate 3, figure 7

1978 *Multicellaesporites dongyingensis* Ke et Shi ex Sung et al., p. 36, Pl. 1, figs. 22-25.

1978 *Multicellaesporites maximus* Ke et Shi ex Sung et al., p. 38, Pl. 3, fig. 21.

1981 *Brachysporites thraceus* Ediger, p. 93, Pl. 2, figs. 15-18; Pl. 3, fig. 1.

1990 *Anatolinites dongyingensis* (Ke & Shi 1978) Elsik, Ediger, and Bati, p. 96, Pl. 1, figs. 1-23; Pl. 2, figs. 1-8; Pl. 3, figs. 1-4; Textfig. 2.

**Distribution.** Taglu Sequence (Paleocene-Eocene). Paleocene to ?Miocene of Europe, China, and North America (see Elsik, Ediger, and Bati, 1990).



Plate 3, figures 8-11

*Involutisporonites* sp. cf. *I. putus*

Ke et Shi ex Sung et al.

**Description.** Fungal spores four- or five-celled, anisopolar, equilateral, biporate. The larger, distal cell, which is one third to one half the total spore length, has a distinct acuminate outline with a pointed apex supporting a minute distal pore surrounded by an annulus. The cells become smaller and narrower proximally, terminating with a pore up to 0.5  $\mu\text{m}$  in diameter on the rounded apex. Spore wall levigate or scabrate, 0.25-0.5  $\mu\text{m}$  thick, increasing to approximately 1  $\mu\text{m}$  thick around the distal pore, which is 0.25  $\mu\text{m}$  or less in diameter and difficult to observe. Septa perforate, some dentate, up to 1  $\mu\text{m}$  thick. Spore length, 35-45  $\mu\text{m}$ ; spore width, 18-24  $\mu\text{m}$ .

Plate 3, figures 12-16

1978 (cf.) *Involutisporonites putus* Ke et Shi ex Sung et al., p. 45, Pl. 4, fig. 18.

**Description.** Fungal spores monoporate, multicellate (5-7 cells), uniseriate, anisopolar, curved, with three or four cells at the pore-bearing end slightly to strongly curved, and with the opposite apex supported on two or three rectilinear cells. Spore wall 0.5-1.0  $\mu\text{m}$  thick, thinner on the pore cell, levigate. Septa perforate, usually dentate, up to 1  $\mu\text{m}$  thick. Spore length, 29-45  $\mu\text{m}$ ; spore width, 14-21  $\mu\text{m}$ , the cells gradually increasing in width from the pore cell to the hemispherical cell at the opposite apex.

**Remarks.** Distinguished from other species of *Anatolinites* described by Elsik et al. (1990) by its distinctly acuminate distal apex. *Pluricellaesporites informis* Ke et Shi ex Sung et al. has a conical terminal cell but it is seven-celled, with a wide and distinctly annulate pore at the opposite apex.

**Remarks.** Distinguished from the holotype of *Pluricellaesporites vermiculus* Ediger by the thinner spore wall. The present specimens show a greater size range than the type material of *I. putus*, but are otherwise similar.

**Distribution.** Taglu and Aklak sequences (Paleocene-Eocene).

**Distribution.** Taglu Sequence (Paleocene-Eocene). Oligocene, China (Sung et al., 1978).

Genus *Fractisporonites* Clarke 1965

*Fractisporonites* sp. C

Plate 3, figures 17-19

**Description.** Fungal spores multicellular, uniseriate, equilateral, comprising many cells with slight constriction at the locus of septal insertion, giving the interior of the cells a distinctly sub-spheroidal, beaded appearance. Cells equidimensional or slightly elongate; cell width 5-7  $\mu\text{m}$ ; cell length 5-10  $\mu\text{m}$ . Cell wall 0.5-1  $\mu\text{m}$  thick, levigate. Septa perforate, dentate, up to 1  $\mu\text{m}$  thick. Spore fragments up to approximately 100  $\mu\text{m}$  long, straight or slightly curvilinear, with the cell width consistent along the spore length.

Genus *Multicellaesporites* Elsik emend.

Sheffy and Dilcher 1971

*Multicellaesporites* sp. cf. *M. obscurus*

Ke et Shi ex Sung et al.

Plate 3, figure 23

1978 (cf.) *Multicellaesporites obscurus* Ke et Shi ex Sung et al., p. 38, Pl. 3, figs. 9-11.

**Description.** Spores tetracellate, isopolar, equilateral, inaperturate, with a distinct constriction 2-4  $\mu\text{m}$  deep in the equatorial amb at the locus of septal insertion between the inner cells. Inner cells thick walled (1-3  $\mu\text{m}$  thick), levigate; apical cells much smaller and thinner walled (up to 0.25  $\mu\text{m}$  thick), levigate. Septa 2-6  $\mu\text{m}$  thick, thickest between the inner cells. Spore length, 50-60  $\mu\text{m}$ ; spore width, 22-23  $\mu\text{m}$ .

**Remarks.** Distinguished from *Fractisporonites* cf. *canalis* Clarke sensu Norris (1986) by the smaller, beaded cells. "Hyphae Type III" of Ediger and Alison 1989 (Pl. 8, figs. 6-8) is similar but has thinner-walled cells that do not have such a beaded appearance.

**Remarks.** Distinguished from *M. obscurus* by the smooth spore wall.

**Distribution.** Taglu Sequence (Paleocene-Eocene).

*Distribution.* Lower Taglu and Aklak sequences (Paleocene).

*Multicellaesporites oculus* Ke et  
Shi ex Sung et al.

Plate 3, figure 22

1978 p. 38, Pl. 3, fig. 22.

*Distribution.* Taglu Sequence (Paleocene-Eocene).  
Oligocene of China (Sung et al., 1978).

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

Plate 3, figure 24

1978 (cf.) *Multicellaesporites oculus* Ke et Shi ex Sung  
et al., p. 38, Pl. 3, fig. 22.

*Remarks.* Distinguished from *M. oculus* by its smaller  
size (spore length 35-44  $\mu\text{m}$ ; spore width 26-35  $\mu\text{m}$ ) and  
thinner wall (1-3  $\mu\text{m}$ ).

*Distribution.* Taglu Sequence (Paleocene-Eocene).

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

Plate 3, figures 25, 26

1978 (cf.) *Multicellaesporites vermiculatus* Ke et Shi  
ex Sung et al., p. 40, Pl. 2, fig. 16.

*Remarks.* Distinguished from *Multicellaesporites*  
*vermiculatus* by its relatively shorter cells, thinner  
exine, and less constricted loci of septal insertion. It is  
superficially similar to *Diporicellaesporites* sp. B  
which, however, is diporate and thinner walled.

*Distribution.* Aklak Sequence (Paleocene).

**Genus** *Reticellites* Glass, Brown, and Elsik 1987

*Reticellites* sp.

Plate 3, figure 27

*Description.* Fungal spores oval in outline, tricellate,  
equilateral, anisopolar, monoporate, cells of unequal

size, slightly indented at the loci of septal insertion.  
Spore wall up to 4  $\mu\text{m}$  thick, sculptured with coarse,  
irregular rugulae up to 5  $\mu\text{m}$  wide and 15  $\mu\text{m}$  long,  
which may fuse into an imperfect reticulum, separated  
by narrow fossulae up to 0.5  $\mu\text{m}$  wide. The smaller cell  
is thinner walled (approximately 1  $\mu\text{m}$ ) and bears a  
pore at the apex approximately 5  $\mu\text{m}$  in diameter and  
which tends to split open. Spore length, 82  $\mu\text{m}$ ; spore  
width, 57  $\mu\text{m}$ .

*Distribution.* Taglu Sequence (Paleocene-Eocene).

**Genus** *Polyadosporites* van der Hammen  
emend. Ediger 1981

*Polyadosporites enormis* Ediger

Plate 3, figures 28, 29

1981 p. 95, Pl. 3, figs. 12-15.

*Distribution.* Taglu Sequence (Paleocene-Eocene).  
Paleogene, Turkey (Ediger, 1981).

*Polyadosporites* sp. cf. *P. conoideus*  
(Sheffy and Dilcher) Ediger

Plate 3, figure 30

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

1981 (cf.) *Polyadosporites conoideus* (Sheffy and  
Dilcher) Ediger p. 95.

1986 *Staphlosporonites* sp. cf. *S. conoideus* Sheffy and  
Dilcher. Norris, p. 26, Pl. 3, figs. 23, 27.

*Distribution.* Taglu Sequence (Paleocene-Eocene).  
Norris (1986) reported this species from the Eocene  
Richards Formation in the Beaufort Mackenzie Basin.

**Genus** *Pesavis* Elsik and Jansonius 1974

*Pesavis parva* Kalgutkar and Sweet

Plate 3, figures 34-36

1974 *Pesavis tagluensis* auct non Elsik and Jansonius;  
Elsik and Jansonius, Pl. 1, fig. 10 (only).

1976 *Pesavis* "parva" Jansonius, p. 132, Pl. 1, fig. 2.

1980 *Pesavis* sp. Ioannides and McIntyre, Pl. 31.5, fig. 15 (only).

1988 *Pesavis parva* Kalgutkar and Sweet, p. 123, Pl. 6.1, figs. 1-16.

*Remarks.* *Staphlosporonites discitypicus* Ke et Shi ex Sung et al. (1978, p. 51, Pl. 5, fig. 20) is similar to *Pesavis parva* but its description is lacking in enough critical detail to make a closer comparison.

*Distribution.* Taglu and Aklak sequences (Paleocene-Eocene). Maastrichtian to Eocene of western and northern Canada and Britain (Kalgutkar and Sweet, 1988).

### Fruiting bodies

#### Genus *Desmidiospora*

*Desmidiospora willoughbyi* (Bradley)  
Ethridge Glass et al.

Plate 3, figures 38-40

1967 *Endophlyctis willoughbyi* Bradley, p. 579, Figs. 1-7, 9.

1976 microthyriaceous germling PS-21-12, Staplin, p. 130, Pl. 2, fig. 17.

1978 Microthyriaceous germling, Kemp, p. 75, Pl. 1, figs. 1-5.

1986 *Desmidiospora willoughbyi* (Bradley) Ethridge Glass, Brown, and Elsik, p. 408, Pl. 2, fig. 1.

1989 Epiphyllous fungal germling, Guan et al., p. 135, Pl. 5, fig. 17 (only).

*Distribution.* Taglu Sequence (Paleocene-Eocene; see also Staplin, 1976). Eocene of Texas and Wyoming (Ethridge Glass et al., 1986; Bradley, 1967); Eocene-Oligocene, Indian Ocean (Kemp, 1978); Neogene, China (Guan et al., 1989).

#### Genus *Plochmopeltinites* Cookson 1947

*Plochmopeltinites* sp. A

Plate 4, figures 1-4

*Description.* Fungal fruiting bodies peltate, with irregular margin, ostiolate, with distinctly raised and thickened ost collar comprising six ranks of cells.

Prosenchyma around ostiole comprises irregularly radial hyphae with thickened cell walls, which pass centrifugally into a zone of sinuous and thinner walled hyphae, which in turn merge with a zone of peripheral tissue with little or no distinct hyphal structure. Ostiole 5-12  $\mu\text{m}$  in diameter, oval in shape, sometimes with a thin-walled, scabrate covering membrane present in entirety or only at the edges. Hyphae comprising ost collar up to 2  $\mu\text{m}$  wide with more or less isodiametric cells except at the base of the collar where the cells tend to be elongated tangentially. Cell walls in the ost margin approximately 1.5  $\mu\text{m}$  thick, the thickening imparting a rounded shape to the cell lumina. The thickened hyphae form a prominent annular zone surrounding the ostiole from 5-12  $\mu\text{m}$  wide and up to 30  $\mu\text{m}$  in diameter. Hyphae in the zone surrounding the annular thickened zone are thinner walled, irregularly sinuous, occasionally branching, up to 3  $\mu\text{m}$  wide, merging into granular tissue with no definite hyphal structure.

*Remarks.* Distinguished from *Plochmopeltinites masonii* Cookson emend Selkirk by the irregular shape of the margin and the virtual lack of distinct hyphae away from the ost margin. *Trichothyrites* sp. B of Smith (1980, p. 21, Textfig. 4C and D) has a similar ostiole and ost margin on its upper wall, but by implication also has a lower wall of cells, the latter being absent in *Plochmopeltinites* sp. A. In addition, the peripheral prosenchyma in *Trichothyrites* has a definite radial structure that is continuous to the margin, whereas in *Plochmopeltinites* the hyphae in the peripheral area are sinuous and may become indistinct near the margin.

*Plochmopeltinites* sp. A may occur embedded in and confluent with what appears to be cuticular tissue. More frequently, only the ost collar and fragments of the peripheral zone are preserved in palynology residues.

*Distribution.* Lower part of Taglu Sequence (Paleocene-?Eocene).

#### Genus *Trichopeltinites* Cookson

*Trichopeltinites* (?) sp. A

Plate 4, figures 5-7

*Description.* Fungal fruiting bodies, elongate, non-ostiolate, with irregularly rounded margin, dimension 150-240  $\mu\text{m}$ . Stroma single-layered, comprising a central denser pseudoparenchymatous zone surrounded by a peripheral prosenchymatous zone of radiating hyphae. Central pseudoparenchyma

composed of thickened rugulate or irregularly granulate elements 2-3  $\mu\text{m}$  wide and 4-8  $\mu\text{m}$  long, irregularly arranged except near the border with the prosenchyma where the elements thin and become radially aligned to the hyphae. Prosenchyma composed of radiating hyphae, 2-3  $\mu\text{m}$  wide and with thickened walls and slightly elongate cells 3-4  $\mu\text{m}$  long. Hyphal walls 0.5-1  $\mu\text{m}$  thick delimiting somewhat rounded cell lumina.

*Remarks.* Generic attribution of this species is uncertain because no dehiscence features have been observed; such features characterize the type species, *T. pulcher* Cookson.

*Distribution.* Basal part of the Taglu Sequence (Paleocene-?Eocene).

### Genus *Phragmothyrites* Edwards

Plate 4, figures 8, 9

*Description.* Fungal fruiting bodies peltate, circular, 45-70  $\mu\text{m}$  in diameter, comprising a single layer of radially arranged bifurcating hyphae that are connected through most of their length, surrounding a central slightly raised area of up to four approximately equidimensional cells. Hyphae 2-4  $\mu\text{m}$  wide, divided by septa into square or trapezoidal cells that appear to be raised above the connecting prosenchymatous tissue. Hyphal walls 0.25-0.5  $\mu\text{m}$  thick, levigate or scabrate. Individual cells have a tendency to split along radial or tangential lines delimited by the hyphal walls and septa. Distally the hyphae merge with structureless, scabrate or sub-granular tissue with an irregular margin.

*Remarks.* Generic attribution is uncertain because the hyphae have, in places, the appearance of being free and unconnected, although this might be a secondary or preservational feature. The raised nature of the hyphal cells made this species distinctive. The peripheral tissue surrounding the distal ends of the hyphae might be leaf cuticle.

*Distribution.* Taglu and Aklak sequences (Paleocene-Eocene).

### *Phragmothyrites* (?) sp. B

Plate 4, figures 10, 11

*Description.* Fungal fruiting bodies, non-ostiolate, circular, 56-70  $\mu\text{m}$  in diameter, with radiating hyphae on one surface, no regular structural features on the

other, and a peripheral zone thickened with large, rounded lumina merging into a structureless rim of tissue. Hyphae 1-2  $\mu\text{m}$  at centre of stroma, tapering and merging proximally into a central confluent structure, and expanding distally up to 7  $\mu\text{m}$  wide near the peripheral zone. A few hyphae bifurcate near the peripheral zone. Hyphae divided into almost square or trapezoidal cells up to 6  $\mu\text{m}$  long. Hyphal walls not distinct but the cells and hyphae are defined by narrow lines of thinner exine or incipient separation. Peripheral zone one third to one half the radius of the stroma in width, comprising a dark limbus up to 5  $\mu\text{m}$  wide with a series of rounded lumina on the inside edge and an irregular rime of scabrate or subgranular tissue on the outside. Lumina up to 5  $\mu\text{m}$  in diameter giving a scalloped appearance to the peripheral zone.

*Remarks.* Generic attribution is uncertain because of the distinctive narrow lines of thinning or incipient separation between the hyphae. The peripheral scalloped zone distinguishes this species from *Phragmothyrites* (?) sp. A.

*Distribution.* Basal Taglu Sequence (Paleocene?-Eocene).

### Genus *Microthyrites* Pampaloni

*Microthyrites* (?) sp.

Plate 5, figures 2, 3

*Description.* Fungal fruiting bodies, discoidal, non-ostiolate, 120-150  $\mu\text{m}$  in diameter and 10-15  $\mu\text{m}$  thick. Stroma two-layered, comprising prosenchyma of tangled rugulate and granulate elements of irregular shape with a few straight or bifurcating elements, all presumably hyphae in various stages of fusion. Hyphal elements 1-2  $\mu\text{m}$  wide and up to 15  $\mu\text{m}$  long where discernable, all apparently aseptate. Overall shape of stroma is circular but the periphery is irregularly lobed and marked in places by angular or sub-angular protuberances of lighter colour or thinner structure.

*Remarks.* Generic attribution is uncertain because of the obscure structure of the stroma which, however, appears to be composed of aseptate hyphae. The genus *Microthyrites*, according to the original diagnosis, is a non-ostiolate fruiting body of irregular shape and composed of small, concentric, polygonal cells, or, according to Elsik (1977, 1978), of rounded cells of irregular arrangement.

*Distribution.* Lower part of Taglu Sequence (Paleocene-Eocene).

## Embryophyte palynomorphs

### Trilete spores

**Genus** *Obtusisporis* (Krutzsch) Pocock

*Obtusisporis* sp.

Plate 5, figures 11, 12.

1989 *Obtusisporis* sp. Guan et al., p. 38, Pl. 7, figs. 1, 2.

*Distribution.* Mackenzie Bay Sequence (Miocene). Neogene of China (Guan et al., 1989).

**Genus** *Foveosporites* Balme 1957

*Foveosporites* sp.

Plate 5, figures 4-8

*Description.* Spores trilete with long, labiate laesurae reaching the equator, a straight-sided triangular amb, prominent foveolate or foveoreticulate sculpture on the distal and proximal surfaces, and thick exine reaching up to 5  $\mu\text{m}$  thick at the equator. Distal foveae up to 2  $\mu\text{m}$  in diameter, irregularly connected by narrow fossulae delimiting irregular rugulae 2-3  $\mu\text{m}$  wide. Proximal exine similarly but less prominently sculptured, the sculptural elements coalescing around the laesurae into labiae 4-6  $\mu\text{m}$  in total width. Exine two-layered, the exine distinctly thicker (2-4  $\mu\text{m}$ ) than the endexine (approximately 0.5  $\mu\text{m}$ ). Equatorial diameter, 37-45  $\mu\text{m}$ .

*Remarks.* *Verrucingulatisporites solox* Frederiksen et al. (1983) is similar but has a distinct equatorial cingulum and is more distinctly reticulate rather than foveolate.

*Distribution.* Taglu Sequence (Paleocene-Eocene).

**Genus** *Cicatricosisporites* Potonie and Gelletich emend. Potonie

*Cicatricosisporites dorogensis* Potonie and Gelletich

Plate 5, figure 13

1933 *Cicatricosisporites dorogensis* Potonie and Gelletich, p. 522, Pl. 1, figs. 1-5.

*Distribution.* Taglu Sequence (Paleocene-Eocene). Eocene, southern USA (Frederiksen, 1980).

### Saccate pollen

**Genus** *Podocarpidites* Cookson ex Couper emend. Potonie 1958

*Podocarpidites maximus* Stanley comb. nov.

Plate 5, figure 14

1965 *Podocarpus maximus* Stanley, p. 281, Pl. 41, figs. 1-8.

1980 *Podocarpus maximus* Stanley. Frederiksen, p. 35, Pl. 4, fig. 16.

*Distribution.* Taglu Sequence (Paleocene-Eocene). Paleocene and Eocene of USA (Stanley, 1965; Frederiksen, 1980).

### Tricolpate pollen

**Genus** *Tricolpopollenites* Pflug in Thomson and Pflug 1953

*Tricolpopollenites sculptus* Takahashi

Plate 5, figures 17, 18, 24, 25

1957 p. 219, Pl. 38, figs. 50-51; Pl. 39, figs. 33-34.

1982 *Tricolpopollenites sculptus* Takahashi, Takahashi and Jux, p. 44, Pl. 5, figs. 8, 9.

*Distribution.* Richards and Taglu sequences (Paleocene-Eocene). Paleogene of Europe and Japan (Takahashi and Jux, 1982).

**Genus** *Aceripollenites* Nagy 1969

*Aceripollenites tener* (Samoilovitch) comb. nov.

Plate 5, figures 22, 23

1965 *Acer tener* Samoilovitch, p. 122, Pl. 50, fig. 1.

1978 *Striatridolpites* (sic) *tener* (Samoil.) Ke et Shi ex Sung et al., p. 131, Pl. 44, figs. 30-32.

*Distribution.* Richards and Taglu sequences (Paleocene-Eocene). Upper Cretaceous, Siberia (Samoilovitch, 1965). Upper Eocene-Lower Oligocene, China (Sung et al., 1978).

**Genus *Aquilapollenites* Rouse 1957**

*Aquilapollenites tumanganicus* Bolotnikova

Plate 5, figures 32-34

1973 *Aquilapollenites tumanganicus* Bolotnikova, p. 99, Pl. 25, figs. 1-3.

1976 *Aquilapollenites* sp. Staplin et al., p. 130, Pl. 2, fig. 25.

1978 *Aquilapollenites spinulosus* Sung et al. auct. non Funkhouser, p. 157, Pl. 58, figs. 11-25; Pl. 61, figs. 5, 6.

*Distribution.* Lower Taglu Sequence (Paleocene). Paleocene, Mackenzie Delta (Staplin, 1976). Paleocene, western coast of Sea of Japan (Bolotnikova, 1973). Lower Eocene, China (Sung et al., 1978). Upper Paleocene-Lower Eocene, eastern Canadian Arctic (McIntyre and Ricketts, 1989; McIntyre in Ricketts, 1991).

**Genus *Novemprojectus* Choi 1984**

*Novemprojectus traversii* Choi

Plate 6, figures 1-4

1984 p. 338, Pl. 1, fig. 1.

*Distribution.* Taglu Sequence (Paleocene-Eocene). Eocene of Arctic Islands (Choi 1984; McIntyre and Ricketts, 1989; McIntyre in Ricketts, 1991). Jansonius (in Jansonius and Hills, 1985, card 4302) indicated that this species is reworked from the Upper Cretaceous. The present occurrences do not support this, and the work of D.J. McIntyre (pers. comm.) in the eastern Arctic further supports an Early Eocene age for *N. traversii*.

***Polycolpate* pollen**

**Genus *Psilastephanocolpites* Leidelmeyer 1966**

*Psilastephanocolpites* sp. cf. *P. marginatus*  
Gonzales Guzman

Plate 6, figure 34

1967 (cf.) *Psilastephanocolpites marginatus* Gonzales Guzman, p. 43, Pl. 13, figs. 3, 3a.

*Description.* Pollen grains four-colpate, spheroidal to subprolate, colpi narrow with thickened margins, not reaching poles. Exine 1  $\mu\text{m}$  thick, columellate, scabrate, nexine approximately one third total exine thickness. Colpi 0.5  $\mu\text{m}$  wide, about one half polar axis in length, bordered by areas of thicker exine up to 2  $\mu\text{m}$  wide. Polar axis, 24  $\mu\text{m}$ ; equatorial diameter, 19  $\mu\text{m}$ .

*Remarks.* Distinguished from *P. marginatus* Gonzales Guzman by its less prolate shape and shorter colpi.

*Distribution.* Taglu Sequence (Paleocene-Eocene).

***Tricolporate* pollen**

**Genus *Platanoidites* Potonie, Thomson, and Thiergart 1951 ex Potonie 1960**

*Remarks on the genus.* *Platanus*-like pollen has been reported from Santonian through upper Cenozoic strata and is closely comparable to modern *Platanus* (Pacltova, 1982). It has also been described in association with platanoid leaves and reproductive structures (Crane et al., 1988). The species described below is comparable to *Platanus* pollen but is referred to *Platanoidites* to conform with the practice adopted herein of using form genera for dispersed fossil grains.

However, the genus *Platanoidites* was not particularly well described by Potonie (1960) and may need revision in the light of Pacltova's subsequent work, which used techniques of both light and scanning electron microscopy on the palynology of *Platanus* and relatives (Pacltova, 1961; 1966; 1978; 1982; 1987). These later works clearly demonstrated the complex nature of the *Platanus* endogerminal, which in some modern grains comprises three raised pores on the nexine lying beneath the sexinal colpus membrane and visible using an SEM. These pores are not clearly visible, however, using optical microscopy. They are presumably related to the multiple lobate splitting of the endogerminal, characteristically visible under an optical microscope as segmented pairs separated by up to four pairs of short slits inserted at each endogerminal and parallel to the equator. Recently, Crane et al. (1990, p. 22), described some exceptionally well preserved silicified internal and external molds of pollen from platanaceous inflorescences from the Upper Paleocene of North Dakota. His SEM illustrations of the internal molds clearly show the shape of the endogerminals (op. cit., fig. 14D) and the paired slits in the nexine (op. cit., fig. 14C).

Potonie's diagnosis of *Platanoidites* mentions the presence of a geniculus on each colpus. Stanley and Kremp's (1959) careful examination of *Quercus* using an optical microscope clearly shows that this geniculus – a raised thinner area of nexine beneath the colpus membrane – is morphologically similar to the endopores of *Platanus*, illustrated in SEM photographs by Pacltova (1982, Pl. 7, fig. 2, which is the unnumbered photograph at the lower left of the plate). Until the type material of *Platanoidites* is reexamined, it would be highly speculative to pursue further the possible morphological similarities of this genus with *Platanus*. Meanwhile, the species described below is tentatively assigned to *Platanoidites* which, in terms of exine stratification and pilate structure, as well as the presence of three geniculate sinuaperturate colpi, resembles to some extent modern *Platanus* pollen and fossil platanaceous pollen (Crane et al., 1990).

*Platanoidites* (?) sp. cf. *Platanus ipelensis*  
(Pacltova) emend. Pacltova, comb. nov.

Plate 6, figures 9-11

1966 (cf.) *Tricolporopollenites ipelensis* Pacltova,  
p. 61, Pl. 19, figs. 14-19.

1982 (cf.) *Platanus ipelensis* Pacltova 1966 n. emend.  
Pacltova, p. 374, Pl. 4, figs. 1-7; Pl. 5, figs. 1-12;  
Textfig. 7.

**Description.** Pollen grains prolate-spheroidal to subprolate, sinuaperturate, tricolpate with complex segmented endogerminal and with pilate, scabrate exine. Exine 0.75-1.25  $\mu\text{m}$  thick, nexine one fifth or less the total thickness. Sexine outside the colpi indistinctly pilate, the capita either just visible as a roughened edge in optical section at the limits of optical resolution, or not at all. Bacula usually visible in optical section as striations in the sexine. Colpi long, reaching within 2-3  $\mu\text{m}$  of poles, 1-2  $\mu\text{m}$  wide at the equator and gradually tapering polewards, situated in slight depressions commonly marked by flanking arcuate folds in the exine. Sexine on the colpus slightly thinner and clearly delimited because of suppression of the capita of the pila and replacement by very low, irregularly shaped, granules 0.25-1  $\mu\text{m}$  in diameter, giving a distinctive patchy pattern to the colp membrane, which may be ruptured or missing. Endogerminals aligned beneath each colpus but shorter and narrower, less than 1  $\mu\text{m}$  wide but commonly split open along a ragged edge or marked by a fold of overlapping nexine. Up to four pairs of nexinal slits, 2-3  $\mu\text{m}$  long, are developed at right angles to the length of the endogerminal (viz., they are parallel to the equator) and are confluent with the open germinal but

are also visible flanking the closed germinals. These paired slits flanking the endogerminal give each grain a distinctive segmented shape, strongly reminiscent of an agnostid trilobite in which the poles represent the cephalon and pygidium respectively, the equatorial region represents the segmented thorax, and the germinal plus colpus represents the axial furrow. Polar axis, 14-20  $\mu\text{m}$ ; equatorial diameter, 10-17  $\mu\text{m}$ ; P:E ratio, 1.07-1.2  $\mu\text{m}$ .

**Remarks.** Distinguished from *Platanus ipelensis* by the possession of more finely sculptured and structured exine, and of thinner nexine.

**Distribution.** Taglu Sequence (Paleocene-Eocene).

### Genus *Ailanthipites* Wodehouse 1933

*Ailanthipites fluens* sp. nov.

Plate 6, figures 21-27

**Holotype.** Imperial Adgo F-28 well, NWT. 4500 ft (1371.6 m), Pl. 6, figs. 21, 22.

**Derivation of name.** From Latin *fluo*, to flow, referring to the mesocolpia having the appearance of flow lines.

**Diagnosis.** Pollen grains prolate, tricolporate, reticulate or retistriate (elongated to the polar axis) in the mesocolpia, with almost circular ora and long colpi with distinctly thickened margins widest at the equator and flanked by levigate areas.

**Description.** Ora circular or very slightly lalongate, 1-3  $\mu\text{m}$  in diameter. Colpi very narrow (0.5-1.0  $\mu\text{m}$ ) extending almost to the poles, bordered by distinctly thickened margins 5-10  $\mu\text{m}$  wide at the equator, but tapering strongly towards the poles and flanked by levigate or very sparsely foveolate areas approximately 5  $\mu\text{m}$  wide. Nexine 0.25-0.5  $\mu\text{m}$  thick. Sexine 0.5-1.5  $\mu\text{m}$  thick, sometimes slightly thickened at the poles, comprising elongated (sometimes teardrop-shaped) foveae 0.5-2  $\mu\text{m}$  in diameter, wider in the mesocolpia, becoming smaller nearer the unornamented areas flanking the colpi, spaced 0.5-1  $\mu\text{m}$  apart, forming a reticulate or retistriate pattern. The exine is indistinctly columellate, its outer surface perforated by the foveae. Polar axis, 41-49  $\mu\text{m}$ ; equatorial diameter, 22-31  $\mu\text{m}$ ; P:E ratio, 1.3-2.1.

**Remarks.** Distinguished from *Ailanthipites marginatus* Frederiksen (1983) by the indistinctly columellate exine with coarser sculpture and by the circular or almost circular ora; and from *Ailanthipites berryi* Wodehouse

(1933) by its larger size and coarser sculpture. *Simpsonipollis mullensis* (Simpson) Srivastava 1975 has similar but finer retistriate mesocolpia, the ora are a different shape, and the colpi are not flanked by levigate areas.

*Distribution.* Taglu Sequence (Paleocene-Eocene).

**Genus *Rhoipites* Wodehouse 1933**

*Rhoipites* sp. cf. *R. microreticulatus* (Pflug and Thomson) Takahashi and Jux

Plate 5, figures 26-28

1953 (cf.) *Tricolporopollenites microreticulatus* Pflug and Thomson, p. 106, Pl. 14, figs. 27-42.

1986 (cf.) *Rhoipites microreticulatus* (Pflug and Thomson in Thomson and Pflug) Takahashi and Jux, p. 164, Pl. 26, figs. 18-20.

*Description.* Pollen grains prolate-spheroidal to prolate, tricolporate, microreticulate, with long narrow colpi flanked by unornamented thickened margins and more or less circular ora, each with a distinct endannulus. Exine 1-1.5  $\mu\text{m}$  thick, microreticulate, columellate, nexine less than one quarter total exine thickness. Lumina of reticulum less than 1  $\mu\text{m}$  in diameter, slightly elongate but randomly oriented, becoming smaller closer to the colpal margins, which are levigate. Muri of reticulum up to 1  $\mu\text{m}$  high and up to 0.5  $\mu\text{m}$  wide. Colpi almost reach poles, up to 0.5  $\mu\text{m}$  wide, with thickened margins up to 2  $\mu\text{m}$  wide at the equator and tapering to the poles. Ora are 1.5-2.5  $\mu\text{m}$  in diameter, circular or slightly lalongate, each with an endannulus up to 2  $\mu\text{m}$  thick and 1  $\mu\text{m}$  broad. Polar axis, 20-22  $\mu\text{m}$ ; equatorial diameter, 12-20  $\mu\text{m}$ ; P:E ratio, 1.12-1.6.

*Remarks.* Distinguished from *R. microreticulatus* by the thinner exine, lalongate ora, more prominent, unornamented colpal margins, and the columellate but not baculate exine structure. *Rhoipites* sp. 2 of Frederiksen (1983) is larger and has less prominent endannuli than *R. cf. microreticulatus*.

*Distribution.* Taglu Sequence (Paleocene-Eocene).

*Rhoipites* sp.

Plate 5, figures 29-31

1983 *Rhoipites* sp. 3 Frederiksen, p. 72, Pl. 19, figs. 42-43; Pl. 20, figs. 1-3.

*Description.* Pollen grains subprolate to prolate, tricolporate, microreticulate, with long, narrow colpi flanked by slightly thickened and moderately ornamented margins, and with lalongate ora, each with distinct endannulus. Exine 1.5-2.5  $\mu\text{m}$  thick, microreticulate with clavate muri in optical section, and with very thin nexine less than 0.25  $\mu\text{m}$  thick. Lumina of reticulum 1-2  $\mu\text{m}$  in diameter, equidimensional without preferred orientation, but slightly smaller nearer colpi; muri up to 2  $\mu\text{m}$  high and 0.25-0.5  $\mu\text{m}$  wide, randomly oriented, slightly smaller nearer the colpi. Colpi long but do not reach poles, narrow and slit-like, with thickened margins up to 2  $\mu\text{m}$  wide at equator, tapering gradually towards poles. Ora distinctly lalongate, 1-2  $\mu\text{m}$  high and 5-7  $\mu\text{m}$  wide, with distinct endannulus 1.5-2  $\mu\text{m}$  thick and approximately 2  $\mu\text{m}$  wide. Polar axis, 32-34  $\mu\text{m}$ ; equatorial diameter, 25-26  $\mu\text{m}$ ; P:E ratio, 1.23-1.35.

*Remarks.* Slightly larger and less coarsely reticulate than the specimens described by Frederiksen (1983), but otherwise identical.

*Distribution.* Taglu Sequence (Paleocene-Eocene). Middle Eocene, California (Frederiksen, 1983).

**Genus *Caprifoliipites* Wodehouse 1933**

*Caprifoliipites incertigrandis* Frederiksen

Plate 5, figures 35-37

1977 *Caprifoliipites* B Rouse, p. 62, Pl. 1, fig. 24.

1980 *Caprifoliipites incertigrandis* Frederiksen p. 57, Pl. 13, figs. 26-29.

*Distribution.* Taglu Sequence (Paleocene-Eocene). Eocene of Arctic Islands and British Columbia (Rouse, 1977) and of southern USA (Frederiksen, 1980).

**Genus *Acanthacidites* Sah 1967**

*Acanthacidites* (?) sp.

Plate 6, figures 12-16

1971 Tricolporate C Piel, p. 1916, Figs. 138-140.

1977 Cf. Acanthaceae Rouse, p. 64, Pl. 2, figs. 32, 33.

*Description.* Pollen grains tricolpoidorate, prolate with well-rounded poles, with strongly granular colpoids almost reaching the poles, and with well-defined circular ora bordered by an inwardly thickened



annulus. Exine tectate, 0.5-1  $\mu\text{m}$  thick, nexine and sexine of approximately equal thickness, levigate except on the colpoid areas that have grana 0.25-0.5  $\mu\text{m}$  in diameter, spaced 1-2  $\mu\text{m}$  apart, and some are arranged in linear groups. Mesocolpoid areas thinner than colpoids and delimited by the linear edge of the thickened colpoids or by the bordering linear groups of grana. Ora circular, equatorial or slightly sub-equatorial, 2-3  $\mu\text{m}$  in diameter, with a distinct annulus approximately 1  $\mu\text{m}$  wide and projecting inward up to 1  $\mu\text{m}$ , merging gradually with the colpoid exine. Colpoids up to 3  $\mu\text{m}$  wide at the equator, tapering to, but not quite reaching the poles. Polar axis, 11-20  $\mu\text{m}$ ; equatorial diameter, 7-14  $\mu\text{m}$ ; P:E ratio, 1.4-1.6.

*Remarks.* This species is questionably assigned to *Acanthacidites* because the type species is two-aperturate, although the generic diagnosis includes three-aperturate species. A similar colpoid area in the type species is described as a "band-shaped sulcoid depression which is ornamented by low verrucae and a few baculae" (Jansonius and Hills, 1976, card 20).

*Distribution.* Taglu Sequence (Paleocene-Eocene). Lower to Upper Eocene of eastern Arctic Canada but Upper Eocene to Lower Oligocene in south-central British Columbia according to Rouse (1977).

#### Genus *Mediocolpopollis* Krutzsch 1959

*Mediocolpopollis alitandus* sp. nov.

Plate 6, figures 17-20

*Holotype.* GSC holotype 112125 from Imperial Adgo F-28 well, NWT. 4800 ft (1463 m), Pl. 6, fig. 20.

*Derivation of name.* From Latin *ales*, winged or bird, referring to the characteristic shape of the crossed apertures.

*Diagnosis.* Pollen grains subprolate to spheroidal, tricolporate or tricolpoidate, with prominent annulate, alongate ora, and narrow colpi or colpoids of similar dimensions to ora (approximately one third of the polar axis) with thickened margins in the equatorial region. Exine columellate, scabrate to microreticulate.

*Description.* Exospores and endospores approximately the same size, but with a tendency for the exospores to be slightly smaller and less clearly delimited than the endospores, 0.5-1  $\mu\text{m}$  long, 8-10  $\mu\text{m}$  wide, with slightly tapering to rounded ends. Annulus 1-1.5  $\mu\text{m}$  thick 1-2  $\mu\text{m}$  wide, circumscribes the ora but widest near the

intersection with the colpoid that indents it. Colpoids 0.5-1.0  $\mu\text{m}$  wide, 10-15  $\mu\text{m}$  long, parallel sided at subequatorial position but slightly constricted on the equator, clearly demarked across the equatorial region but tapering and becoming less clearly defined polewards. The colpoids are flanked by slightly thickened margins (viz., caverna), 1-2  $\mu\text{m}$  wide, which are meridional extensions of the annulus and are particularly prominent in the quadrants formed by the intersection of the colpoid and its superjacent and subjacent ora. Exine 0.5-1.0  $\mu\text{m}$  thick, nexine representing one quarter to one third of the total thickness, obscurely columellate, with scabrate to microreticulate surface pattern. Polar axis, 21-25  $\mu\text{m}$ ; equatorial diameter, 20-24  $\mu\text{m}$ ; P:E ratio, 1.05-1.1.

*Remarks.* The colpoids appear to conform to the concept of "medio colpus" as defined by Krutzsch in the generic diagnosis (see Jansonius and Hills, 1976, card 1618), representing an elongated space between nexine and sexine. However, some specimens show the meridionally elongate areas of thinner exine delimited by distinct margins at the equator, which may be indentations in the sexine (and therefore related to a colpus), or may be margins of the caverna marking separation of nexine and sexine (and therefore a medio colpus).

*Distribution.* Taglu Sequence (Paleocene-Eocene).

#### Genus *Ericipites* Wodehouse 1933

*Ericipites* sp. cf. *E. ericeus* (Potonie) Potonie

Plate 6, figures 7, 8

1931 (cf.) *Pollenites ericeus* Potonie, p. 329, Pl. 2, fig. 25 (*vide* Potonie, 1960).

1960 (cf.) *Ericipites* (al. *Pollenites*) *ericeus* (R. Pot. 1931) Potonie, p. 138.

*Remarks.* This species has a greater overall size range (25-37  $\mu\text{m}$ ) than *E. ericeus* but is otherwise similar.

*Distribution.* Taglu Sequence (Paleocene-Eocene).

#### Genus *Faguspollenites* (Raatz) Nagy 1969

*Faguspollenites* sp.

Plate 6, figures 28, 29

1969 *Fagus* sp. Hopkins, p. 1119, Figs. 95, 96.

*Distribution.* Taglu Sequence (Paleocene-Eocene). Eocene of British Columbia (Hopkins, 1969).

**Genus *Myrtaceidites* Cookson and Pike 1954**

*Myrtaceidites parvus* Cookson and Pike

Plate 6, figures 35-37

1954 p. 206, Pl. 1, figs. 27-31.

1969 *Cupanieidites parvus* (Cookson and Pike) Krutzsch, p. 403.

1970 *Cupanieidites* sp. Tschudy and Van Loenen, Pl. 4, figs. 23-24.

1978 (syn) *Myrtaceidites verus* Ke et Shi ex Sung et al., p. 135, Pl. 46, figs. 5-7.

1983 *Myrtaceidites parvus* Cookson and Pike. Frederiksen, p. 60, Pl. 17, figs. 16-18.

*Distribution.* Taglu Sequence (Paleocene-Eocene). Eocene of USA (Frederiksen, 1980, 1983). Upper Eocene-Oligocene, China (Sung et al., 1978).

**Genus *Lonicerapollis* Krutzsch 1962**

*Lonicerapollis gallwitzii* Krutzsch

Plate 6, figures 30-32

1962 p. 275, Pl. 5, figs. 1-6.

1978 *Lonicerapollis interospinosus* Zhou in Sung et al., p. 145, Pl. 52, figs. 3-9.

*Distribution.* Mackenzie Bay and Richards sequences (Eocene to Miocene). Eocene and Oligocene of China (Sung et al., 1978). Neogene of Europe (Krutzsch, 1962). Eocene of California (Frederiksen, 1983).

**Genus *Montanapollis* Tschudy 1971**

*Montanapollis* sp. cf. *M. globosiporus* (Sam.) Srivastava

Plate 6, figures 38-40

1991 Onagraceous pollen, McIntyre, Pl. 1, fig. 6.

1975 (cf.) *Montanapollis globosiporus* (Samoilovitch in Samoilovitch and Mchedlishvili) Srivastava, p. 140, Pl. 9, figs. 5-7.

*Distribution.* Richards and Taglu sequences (Paleocene-Eocene). Eocene, Axel Heiberg Island (McIntyre, 1991). The compared species occurs in the Maastrichtian of Siberia and Scotland (Srivastava, 1975).

*Remarks.* Identical pollen was illustrated, but not described, by McIntyre (1991) from sediments associated with the fossil forest of Axel Heiberg Island, and was left in open nomenclature and attributed an onagraceous affinity. Although the present material is attributed to *Montanapollis*, this genus is typically Cretaceous. The pore and wall structure of the Paleogene pollen is similar to the Cretaceous form but differs in detail. Caprifoliaceous pollen attributed to *Diervilla* (a modern genus) was also illustrated by McIntyre (1991, Pl. 4, figs. 1-2) and shows some resemblance to *Montanapollis* cf. *M. globosiporus* but it has not been found in the Adgo F-28 well. Final generic attribution of this species awaits a complete taxonomic review of these triporate pollen types.

***Polycolporate pollen***

*Psilastephanocolporites* sp.

Plate 6, figure 33

*Description.* Pollen grains prolate, five-colporate, long narrow colpi, and lalongate ora with distinct endannuli. Exine 0.5-1.0  $\mu\text{m}$  thick, scabrate, with thin nexine and obscure structure, presumably finely columellate. Colpi approximately 0.25  $\mu\text{m}$  wide, almost reaching the poles. Ora 1-2  $\mu\text{m}$  in diameter, lalongate, each with an endannulus approximately 1  $\mu\text{m}$  thick and 1  $\mu\text{m}$  wide, tending to merge laterally with adjacent annuli to form a semicontinuous equatorial thickening. Polar axis, 17  $\mu\text{m}$ ; equatorial diameter, 14  $\mu\text{m}$ .

*Remarks.* *Tetracolporopollenites* A Rouse (1977) is larger and has distinct colpal margins.

*Distribution.* Taglu Sequence (Paleocene-Eocene).

**Genus *Tetracolporopollenites* Pflug and Thomson in Thomson and Pflug**

*Tetracolporopollenites* sp.

Plate 7, figure 1

1977 *Tetracolporopollenites* A, Rouse, p. 64, Pl. 2, fig. 34.

*Distribution.* Taglu Sequence (Paleocene-Eocene). Eocene-Oligocene of British Columbia (Rouse, 1977).

*Triporate pollen*

**Genus** *Caryapollenites* Raatz ex Potonie  
emend. Krutzsch 1961

*Caryapollenites inelegans* Nichols and Ott

Plate 7 figures 2, 3

1978 p. 105, Pl. 2, figs. 7-8.

*Distribution.* Richards and Taglu sequences (Paleocene-Eocene), recycled above the Paleocene. Paleocene, Wyoming (Nichols and Ott, 1978). Upper Paleocene, Arctic Islands (Doerenkamp et al., 1976; McIntyre, 1989).

**Genus** *Intratropopollenites* Pflug and Thomson  
*in Thomson and Pflug 1953*

*Notes on the genus*

Three species are assigned to this genus: *Intratropopollenites* sp. A Rouse (not illustrated herein); *I. minimus* Mai (Pl. 7, figs. 19, 20), and *I. crassipites* (Wodehouse) Norris (Pl. 7, figs. 21, 22). The use of the extant genus, *Tilia*, for pollen of these types is rejected for the following reasons. First, as explained in the introductory comments to this paper, a morphographic approach to spore-pollen taxonomy is favoured for Cenozoic studies. Second, evolution of plant organs has often proceeded at different rates, and this is manifested in tiliaceous plants. Thus, modern *Tilia* from Europe and North America produces pollen similar to Tertiary *Intratropopollenites*, but so do modern species of *Craigia* (= *Burretiodendron*), the latter belonging to the tiliaceous subfamily Excentrodendroideae and currently restricted in distribution to southern China (Kvacek et al., 1991). Furthermore, the fossil fruit *Pteleaecarpum* Weyland is identical to the tiliaceous *Craigia* (Buzek et al., 1989; Kvacek et al., 1991). *Pteleaecarpum* dispersed rapidly across Asian and North American high latitudes in the Eocene and Oligocene, migrating to Europe in the

Oligocene, where it continued into the Late Miocene and Early Pliocene. It is possible that *Pteleaecarpum* is present as early as Paleocene in the western interior of the U.S.A. (S. Manchester, pers. comm.). Therefore, dispersed *Intratropopollenites* pollen could be related to several extant and extinct genera; assignment to any one of these genera would be unwarranted and misleading.

A critical restudy of species of *Intratropopollenites* in the North American Cenozoic is needed in view of the confusion surrounding the species formulated by Wodehouse (1933) in his early study of the Eocene of Colorado and Utah. He instituted two species of *Tilia* that were inadequately described and were illustrated by line drawings lacking some detail. In this work and in Norris (1986), Wodehouse's species *crassipites* is used for distinctly reticulate pollen which, however, may grade into the slightly smaller and more finely reticulate species *vescipites*. Others (e.g., Nichols and Ott, 1978, Pl. 2, fig. 17; McIntyre, 1991, Pl. 3, figs. 11-13) use different limits to distinguish these two species. Clearly, in view of its stratigraphic importance, dispersed tiliaceous pollen warrants critical reappraisal from well constrained outcrop and subsurface material.

**Genus** *Momipites* Wodehouse  
emend. Nichols 1973

*Momipites wyomingensis* Nichols and Ott

Plate 7, figures 4, 8

1978 p. 100, Pl. 1, figs. 1-4.

*Distribution.* Richards, Taglu and Aklak sequences (Paleocene-Eocene), recycled above the Paleocene. Paleocene, Wyoming (Nichols and Ott, 1978). Paleocene, Alberta (Demchuk, 1990). Upper Paleocene, Arctic Islands (McIntyre, 1989).

*Momipites waltmanensis* Nichols and Ott

Plate 7, figure 9

1978 p. 102, Pl. 1, figs. 5-8.

1991 *Engelhardtia*, McIntyre, Pl. 3, fig. 7, 8.

*Distribution.* Richards and Taglu sequences (Paleocene-Eocene), possibly recycled above the Paleocene. Paleocene, Wyoming (Nichols and Ott, 1978). Paleocene, Alberta (Demchuk, 1990). Eocene (?recycled), Axel Heiberg Island (McIntyre, 1991).

*Momipites annellus* Nichols and Ott

Plate 7, figures 11, 12

1978 p. 103, Pl. 1, figs. 22-25.

*Distribution.* Taglu Sequence (Paleocene-Eocene), recycled above the Paleocene. Paleocene, Wyoming (Nichols and Ott, 1978). Paleocene, Alberta (Demchuk, 1990). Upper Paleocene, Arctic Islands (McIntyre 1989).

*Momipites leffingwellii* Nichols and Ott

Plate 7, figure 10

1978 p. 103, Pl. 1, figs. 27-30.

*Distribution.* Taglu Sequence (Paleocene-Eocene), recycled above the Paleocene. Paleocene, Wyoming (Nichols and Ott, 1978). Paleocene, Alberta (Demchuk, 1990).

**Genus** *Triporopollenites* Pflug and Thomson emend. Potonie 1960

*Triporopollenites mullensis* (Simpson)  
Rouse and Srivastava

Plate 7, figures 13, 14

1961 *Corylus mullensis* Simpson, p. 444, Pl. 13, figs. 13-16.

1972 *Triporopollenites mullensis* (Simpson) Rouse and Srivastava, p. 1179, fig. 61.

1984 *Triporopollenites mullensis*. Riediger et al., p. 1290, Fig. 7(i).

1988 *Triporopollenites mullensis* (Simpson) Rouse and Srivastava. Frederiksen et al., p. 520, Pl. 1, fig. 2.

1989 *Triporopollenites mullensis*. McIntyre, p. 195, Pl. 2, fig. 11.

1989 *Triporopollenites mullensis* (Simpson) Rouse and Srivastava. Dietrich et al., p. 152, Pl. 3, fig. 5.

*Distribution.* Taglu and Aklak sequences (Paleocene-Eocene), possibly recycled in the upper part of the Taglu Sequence. Aklak and Fish River sequences, western Beaufort Sea (Dietrich et al., 1989).

Maastrichtian, Paleocene, and Eocene of Yukon, NWT, and Scotland (Rouse and Srivastava, 1972; Srivastava, 1975).

**Genus** *Bombacacidites* Couper 1960

*Bombacacidites* sp.

Plate 7, figure 18

1983 *Bombacacidites* sp. 1 Frederiksen, p. 76, Pl. 21, figs. 6-7.

*Distribution.* Taglu Sequence (Paleocene-Eocene). Eocene, California (Frederiksen, 1983).

**Genus** *Platycaryapollenites* Nagy emend. Frederiksen and Christopher 1978

*Remarks on the genus.* The original diagnosis by Nagy (1969) was inadequate, although clearly the type material resembled modern *Platycarya* in its possession of long curvilinear areas of folded and possibly thinned exine. Frederiksen and Christopher (1978) emended the genus and provided more precision in defining it. At the same time, they removed from the genus any taxa that show the "true" pseudocolpi of modern *Platycarya*, which according to them, are two pairs of long narrow troughs (one pair on each hemisphere) formed primarily by thinning of both ecto- and endosexine and by invagination. In contrast, the species assigned to *Platycaryapollenites* are believed to have fewer curvilinear features on each hemisphere, and there is considerable doubt as to the exact nature of these features in the type species; they may be thinned areas of exine or they may be merely folds (Frederiksen and Christopher, 1978, p. 136). Furthermore, in assigning three fossil species to the genus *Platycarya* Sieb. and Zucc., Frederiksen and Christopher clearly indicated that significant features also include a prominent atrium beneath each pore, but amb shape was variable, ranging from strongly convex to straight, to concave sides on a triangular plan.

In view of the uncertainties outlined above, and in conformity with the practice adopted in this paper of assigning fossil species to form genera, the species described below is assigned to *Platycaryapollenites*. Some of the features described may warrant further emendations to the definition of *Platycaryapollenites* and relatives, but in view of the extreme rarity of material available in this study, formal changes are not proposed at this time.

*Platycaryapollenites* sp. cf. *P. shandongensis*  
Ke et Shi ex Sung et al.

Plate 7, figures 15-17

1978 (cf.) *Platycaryapollenites shandongensis* Ke et Shi  
ex Sung et al., p. 106, Pl. 34, fig. 33 (only).

1989 *Platycarya* sp., Dietrich et al., p. 150, Pl. 2,  
figs. 12 and 13 (but not fig. 17 as indicated in the  
plate explanation).

**Description.** Pollen grains oblate with rounded, triangular amb, triporate with slightly centripetal annulus and infrapunctate atrium, with two or more curvilinear pseudocolpi distributed on both hemispheres. Exine 1-1.5  $\mu\text{m}$  thick except over apertures; nexine 0.25  $\mu\text{m}$  or less in thickness; sexine with no discernable structure between the apertures. Pores 0.5-1  $\mu\text{m}$  in diameter, indented at the amb, with pore exine less than 0.5  $\mu\text{m}$  thick; surrounded by a shallow aspidote annulus 1-2  $\mu\text{m}$  wide and projecting 0.25-0.5  $\mu\text{m}$  beyond the amb. Atrium 5-7  $\mu\text{m}$  in diameter, infrapunctate, formed by thinning and irregular corrosion of the nexine; most clearly developed at the equator with punctae up to 1  $\mu\text{m}$  in diameter, less strongly developed above and below the equatorial plane where punctae are smaller, sparse, or absent. At least one pseudocolpus is developed on each hemisphere, and may be accompanied by a second, each comprising a long, curvilinear, narrow area of thinner sexine, 0.25-1  $\mu\text{m}$  wide, but varying along the length, usually flanked by parallel exinal folds on each side, the entire feature totalling 2-3  $\mu\text{m}$  in width. Each pseudocolpus appears to arise in the sexine near the edge of an atrium and pass across the polar region as if following the path of a great circle to terminate in the sexine above the furthest edge of an adjacent atrium. Equatorial diameter 19  $\mu\text{m}$ .

**Remarks.** The holotype of *P. shandongensis* (Sung et al., 1978, Pl. 34, figs. 31, 32) does not show the slight thickenings at the pore mentioned in the original description on p. 106, but the other illustrated specimen (Pl. 34, fig. 33) does show this feature, as well as an indication of an indistinct atrium, the latter feature not being present in the holotype or mentioned in the description. It is possible, therefore, that the two specimens belong to different species, the one in Plate 34, figure 33, being closest to the material described from the Beaufort-Mackenzie Basin, and the holotype closer to the *Platycarya* pollen described and illustrated by Hopkins (1969) from the Eocene of British Columbia (p. 1120, Pl. 8, figs. 114, 115, but not fig. 116, which might be *Platycaryapollenites*

*dongyingensis* Ke et Shi ex Sung et al.). Neither specimen is comparable to *Triatriopollenites coryphaeus* subsp. *punctatus* Thomson and Pflug 1953, selected specimens of which having been erroneously included in *P. shandongensis* by Sung et al. (1978, p. 106). *T. coryphaeus punctatus* has been synonymized with *Platycarya platycaryoides* (Roche) by Frederiksen and Christopher (1978), a species characterized, in part, by large featureless atria and finely granulate exine.

**Distribution.** Taglu Sequence (Paleocene-Eocene). Aklak Sequence in the western Beaufort Sea (Dietrich et al., 1989). *Platycaryapollenites shandongensis* Ke et Shi ex Sung et al. (1978) occurs in the Eocene of China.

### Genus *Plicapollis* Pflug

*Plicapollis* sp. cf. *P. spatiosa* Frederiksen

Plate 6, figures 41, 42

1973 (cf.) *Plicapollis spatiosa* Frederiksen, p. 75, Pl. 2,  
fig. 15-18.

**Description.** Pollen grains oblate, triporate, vestibulate, plicate, with a rounded triangular amb and slight labrum at each apex. Pores slightly lalongate, 1  $\mu\text{m}$  wide, with a symmetrically or slightly centripetally developed annulus 2-3  $\mu\text{m}$  wide and 1-1.5  $\mu\text{m}$  thick. Exine stratification only visible at the apices, where the nexine is recurved at the edge of the vestibulum enclosing an endopore 5-7  $\mu\text{m}$  in diameter. The vestibulum is 1-2.5  $\mu\text{m}$  in depth, in the form of a low equilateral triangle. In some specimens, the nexine is split again to form a postvestibulum. Exine 0.5  $\mu\text{m}$  thick interradially, thickening up to 1.5  $\mu\text{m}$  at the locus of separation of nexine and sexine, scabrate except on the inner surface of the vestibulum, which is distinctly foveolate and granulate, the elements being approximately 0.25  $\mu\text{m}$  in diameter. Plicae about 1  $\mu\text{m}$  wide, originating as pairs near the bases of the atria and curving parallel to each other and adjacent plicae over the polar area to the neighbouring atria. Equatorial diameter 23-26  $\mu\text{m}$ .

**Remarks.** This species is distinguished from *P. spatiosa* Frederiksen by the convex sides, wider endopores, different vestibula, and less heavily ornamented inner surfaces of vestibula.

**Distribution.** Taglu Sequence (Paleocene-Eocene).

**Genus *Paraalnipollenites* Hills and Wallace 1969**

*Paraalnipollenites alterniporus*  
(Simpson) Srivastava

Plate 7, figures 23, 24

1961 *Alnus alternipora* Simpson, p. 443, Pl. 13, fig. 5.

1963 *Triatrio-pollenites confusus* Zaklinskaya, p. 232, Pl. 34, fig. 7 (only).

1969 *Paraalnipollenites confusus* (Zaklinskaya) Hills and Wallace, p. 141, Pl. 17, figs. 1-8.

1975 *Paraalnipollenites alterniporus* (Simpson) Srivastava, p. 140.

1980 *Paraalnipollenites alterniporus* (Simpson) Srivastava, Ioannides and McIntyre, p. 204, Pl. 31.4, fig. 16.

1984 *Paraalnipollenites confusus*. Riediger et al., p. 1290, Fig. 7(g).

1989 *Paraalnipollenites alterniporus*. McIntyre, p. 195, Pl. 2, fig. 5.

1989 *Paraalnipollenites alterniporus*. Dietrich et al., p. 152, Pl. 3, fig. 2.

1991 *Paraalnipollenites alterniporus*. Kalgutkar and McIntyre, p. 368, Pl. 2, fig. 11.

*Distribution.* Taglu Sequence (Paleocene-Eocene). Maastrichtian to Paleocene of Canada, Scotland, and USSR (Zaklinskaya, 1963; Rouse and Srivastava, 1972; Srivastava, 1975). Paleocene to Lower Eocene, Caribou Hills (Ioannides and McIntyre, 1980).

***Polyporate and polyfovate pollen***

**Genus *Anacolosidites* Cookson and Pike**

*Anacolosidites* sp.

Plate 7, figure 32

*Description.* Pollen grains oblate, triangular with slightly concave sides, tridiplofovate. Foramina positioned approximately 5  $\mu\text{m}$  from the equator, 2-4  $\mu\text{m}$  in diameter, slightly elongate, indented, surrounded by a diffuse slightly thickened annulate area up to 10  $\mu\text{m}$  in diameter. Exine 1.5-2  $\mu\text{m}$  thick, obscurely columellate, striate, with nexine less than 0.25  $\mu\text{m}$  thick. Muri 0.25  $\mu\text{m}$  wide, up to 0.5  $\mu\text{m}$  high,

more prominent interradially, spaced up to 1  $\mu\text{m}$  apart, branching, and partly imbricate, arranged at right angles to the interradiation but passing across the apical amb at a shallow angle.

*Remarks.* Distinguished from *Anacolosidites* cf. *acutulus* Cookson and Pike (Zaklinskaya 1963) by its larger size and possession of a striate exine, and from *Anacolosidites reklawensis* Elsik 1974 by the striate rather than microreticulate exine and larger size. *A.* cf. *reklawensis* Elsik (McIntyre, 1991) is similar but not identical; McIntyre's species from the Lower Eocene of Axel Heiberg Island awaits description of the fine detail of the exine. McIntyre (pers. comm.) believes that the species from the Adgo F-28 well may be the result of recycling from an Upper Cretaceous source.

*Distribution.* Taglu Sequence (Paleocene-Eocene).

**Genus *Caryophyllidites* Couper**

*Caryophyllidites* sp.

Plate 7, figures 25, 26

*Description.* Pollen grains spheroidal oblate, polyfovate, with thick, complexly stratified scabrate exine. Foramina 12-15 in number, distributed evenly and globally, elliptical in outline, 4-6  $\mu\text{m}$  long, 1.5  $\mu\text{m}$  wide, clearly delimited by sexinal thinning and depression of the outer exine. Exine 2.5-3  $\mu\text{m}$  thick (1-1.5  $\mu\text{m}$  thick over foramina). Nexine approximately 0.25  $\mu\text{m}$  thick. Sexine with a prominent sub-granular tegillum, up to 0.75  $\mu\text{m}$  thick (absent or reduced over apertures). Enedexine 0.75-1.25  $\mu\text{m}$  thick, separated from the tegillum by a less dense, obscurely columellate layer. Equatorial diameter 27  $\mu\text{m}$ .

*Remarks.* Distinguished from *Caryophyllidites* sp. of Takahashi and Jux (1986) by the possession of thicker, less strongly granular exine. *Miocaenipollis miocaenicus* Krutzsch 1966 is similar but the apertures are distinctly atriate. Specimens attributed erroneously by Ollivier-Pierre (1980) to *Orapollis potsdamensis* Krutzsch are similar to *Caryophyllidites* sp. but have a thinner exine.

*Distribution.* Taglu Sequence (Paleocene-Eocene).

**Genus *Celtispollenites* Ke et Shi ex  
Sung et al. 1978**

*Celtispollenites tschudyi* (Elsik) comb. nov.

Plate 7, figures 28, 29

1964 *Pollenites anulus* Engelhardt auct. non Potonie, p. 79, Pl. 5, figs. 60, 61.

1970 *Juglanspollenites* sp. Tschudy and Van Loenen, Pl. 3, figs. 29, 30.

1973 *Multiporopollenites* spp. Tschudy, p. B15, Pl. 3, figs. 20-22.

1974a *Nothofagus tschudyi* Elsik, p. 290, Pl. 1, figs. 1-5; Pl. 2, figs. 1-9.

1974b Cf. *Nothofagus Dombeyi* Type, Elsik, p. 96, Pl. 2, fig. 44.

1980 *Celtis tschudyi* (Elsik) Frederiksen, p. 43, Pl. 8, figs. 23-25.

*Distribution.* Taglu Sequence (Paleocene-Eocene). Eocene of the Gulf of Mexico (Frederiksen 1980).

#### Genus *Juglanspollenites* Raatz 1939

##### *Juglanspollenites verus* Raatz

Plate 7, figure 30

1937 p. 18, Pl. 1, fig. 9.

*Distribution.* Richards and Upper Taglu sequences (Eocene). Upper Cretaceous and Tertiary of Europe, Asia, and China (Sung et al., 1978).

##### *Juglanspollenites tetraporus* Sung and Tsao ex Sung et al.

Plate 7, figure 27

1978 *Juglanspollenites tetraporus* Sung and Tsao 1973 (MS), in Sung et al., p. 104, Pl. 34, figs. 11-15.

*Distribution.* Taglu Sequence (Paleocene-Eocene). Upper Eocene and Oligocene of China (Sung et al., 1978).

#### Genus *Periporopollenites* Pflug and Thomson in Thomson and Pflug 1953

*Comments on the genus.* *Liquidambar*-type pollen is accommodated in this genus. The genus *Liquidambarpollenites* Raatz ex Potonie is a junior synonym of *Periporopollenites* (Jansonius and Hills, 1976, card no. 1962).

#### *Periporopollenites stigosus* (Potonie) Thomson and Pflug

Plate 7, figure 35

1931 *Pollenites stigosus* Potonie, p. 332, Pl. 2, fig. 1 (*vide* Potonie, 1960).

1953 *Periporopollenites stigosus* Thomson and Pflug, p. 111, Pl. 15, fig. 58.

1971 *Liquidambar* sp., Piel, p. 1912, figs. 123, 124.

1980 *Liquidambarpollenites* sp., Ioannides and McIntyre, p. 204, Pl. 31.4, fig. 18.

1989 *Liquidambar* sp., Dietrich et al., p. 152, Pl. 3, fig. 11.

*Distribution.* Taglu Sequence (Paleocene-Eocene) – see also Dietrich et al. (1989) report of *Liquidambar* pollen in the Taglu Sequence of the western Beaufort Sea. *Liquidambar*-type pollen has also been reported, but not described or illustrated, by White (1989) as high as the Mackenzie Bay Sequence in the Esso et al. Issungnak 0-61 well in the Beaufort Sea. Oligocene of British Columbia (Piel, 1971). Tertiary of Europe (Thomson and Pflug, 1953). Upper Eocene-Oligocene of China (Sung et al., 1978).

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## APPENDIX 1

### Alphabetical checklist of palynomorph species

The names of species identified in the Adgo F-28 well are listed below in alphabetical order and preceded by their unique species number as used in the database for the University of Toronto Beaufort-Mackenzie Basin project.

#### *Terrestrial palynomorphs*

- |      |  |      |  |
|------|--|------|--|
| 539  | <i>Acanthacidites</i> (?) sp.  | 405  | <i>Cicatricosisporites dorogensis</i> Potonie and Gelletich                          |
| 997  | <i>Aceripollenites tener</i> (Samoilovitch) comb. nov.                             | 368  | <i>Corsinipollenites triangulatus</i> (Zaklinskaya) Ke et Shi ex Sung et al.         |
| 536  | <i>Ailanthipites fluens</i> sp. nov.   | 532  | <i>Ctenosporites eskerensis</i> Elsik and Jansonius                                  |
| 1012 | <i>Anacolosidites</i> sp.  | 555  | <i>Ctenosporites wolfei</i> Elsik and Jansonius                                      |
| 866  | <i>Anatolinites dongyingensis</i> (Ke et Shi ex Sung et al.) Elsik, Ediger, & Bati | 399  | <i>Cupuliferoideaepollenites oviformis</i> (Potonie) Potonie                         |
| 698  | <i>Anatolinites</i> sp.  | 373  | <i>Cupuliferoideaepollenites pusillus</i> (Potonie) Potonie                          |
| 755  | <i>Annutriporites</i> sp. A Norris   | 22   | <i>Cyathidites minor</i> Couper  |
| 324  | <i>Annutriporites tripollenites</i> (Rouse) Norris                                 | 16   | <i>Deltoidospora hallei</i> Miner  |
| 935  | <i>Aquilapollenites tumanganicus</i> Bolotnikova                                   | 599  | <i>Desmidiospora willoughbyi</i> (Bradley) Etheridge Glass et al.                    |
| 367  | <i>Azolla</i> sp.  | 683  | <i>Dicellaesporites aculeolatus</i> Sheffy and Dilcher                               |
| 183  | <i>Baculatisporites comaumensis</i> (Cookson) Potonie                              | 732  | <i>Dicellaesporites obnixus</i> Norris   |
| 722  | <i>Baculatisporites crassiprimarius</i> (Krutzsch) Norris                          | 686  | <i>Dicellaesporites popovii</i> Elsik  |
| 724  | <i>Baculatisporites quintus</i> (Thomson and Pflug) Krutzsch                       | 1004 | <i>Dicellaesporites</i> sp. cf. <i>D. akyolii</i> Ediger and Alison                  |
| 550  | <i>Biporisporites praestigiatus</i> sp. nov.                                       | 754  | <i>Didymosporisporonites ovatus</i> Ke et Shi ex Sung et al.                         |
| 1008 | <i>Biporisporites rotundus</i> Ke et Shi ex Sung et al.                            | 848  | <i>Diporicellaesporites bellulus</i> Ke et Shi ex Sung et al.                        |
| 52   | <i>Biretisporites potoniaei</i> Delcourt and Sprumont                              | 692  | <i>Diporicellaesporites laevigatiformis</i> Ke et Shi ex Sung et al.                 |
| 979  | <i>Bombacacidites</i> sp.  | 947  | <i>Diporicellaesporites liaoningensis</i> Ke et Shi ex Sung et al.                   |
| 855  | <i>Brachysporisporites</i> sp. cf. <i>M. conicus</i> Ke et Shi ex Sung et al.      | 992  | <i>Diporicellaesporites</i> sp. A Norris   |
| 392  | <i>Brachysporisporites cotalis</i> (Elsik and Jansonius) Norris                    | 999  | <i>Diporicellaesporites</i> sp. B Norris   |
| 1007 | <i>Brachysporisporites fustitudinus</i> sp. nov.                                   | 753  | <i>Diporicellaesporites</i> sp. cf. <i>D. bellulus</i> Ke et Shi ex Sung et al.      |
| 684  | <i>Brachysporisporites opimus</i> (Elsik and Jansonius) Norris                     | 845  | <i>Diporicellaesporites</i> sp. cf. <i>D. liaoningensis</i> Ke et Shi ex Sung et al. |
| 374  | <i>Brachysporisporites</i> sp. cf. <i>B. cotalis</i> (Elsik and Jansonius) Norris  | 711  | <i>Diporisporites communis</i> Ke et Shi ex Sung et al.                              |
| 764  | <i>Callimothallus pertusus</i> Dilcher   | 980  | <i>Diporisporites elegans</i> Ke et Shi ex Sung et al.                               |
| 974  | <i>Caprifoliipites incertigrandis</i> Frederiksen                                  | 949  | <i>Diporisporites oblongatus</i> Ke et Shi ex Sung et al.                            |
| 395  | <i>Carpinipites</i> sp. cf. <i>C. spackmaniana</i> (Traverse) Zhou                 | 969  | <i>Diporisporites pisciculatus</i> sp. nov.  |
| 1017 | <i>Caryapollenites inelegans</i> Nichols and Ott                                   | 758  | <i>Dyadosporites oblongatus</i> (Ke et Shi ex Sung et al.) Norris                    |
| 282  | <i>Caryapollenites veripites</i> (Wilson and Webster) Nichols and Ott              | 601  | <i>Dyadosporites</i> sp. A Norris  |
| 966  | <i>Caryophyllidites</i> sp.  | 533  | <i>Dyadosporites</i> sp. cf. <i>D. ellipsus</i> Clarke                               |
| 967  | <i>Celtispollenites tschudyii</i> (Elsik) comb. nov.                               | 731  | <i>Dyadosporites</i> sp. cf. <i>D. schwabii</i> (Elsik) Norris                       |
| 728  | <i>Centonites</i> sp. A Norris   | 986  | <i>Dyadosporites</i> sp. cf. <i>D. solidus</i> Ke et Shi ex Sung et al.              |
| 408  | <i>Chenopodipollis nuktakensis</i> Norris  | 615  | <i>Echinatisporis</i> sp. A Norris   |

- 416 *Ericipites antecursoroides* Norris  
377 *Ericipites compactipollinatus* (Traverse) Norris  
971 *Ericipites* sp. cf. *E. ericeus* (Potonie) Potonie  
976 *Faguspollenites* sp.  
542 *Foveosporites* sp.  
549 *Fractisporonites* sp. A Norris  
760 *Fractisporonites* sp. B Norris  
1003 *Fractisporonites* sp. C (herein)  
378 *Fractisporonites* sp. cf. *F. canalis* Clarke  
715 Fungal hypha type A Norris  
717 Fungal hypha type B Norris  
718 Fungal hypha type C Norris  
729 Fungal hypha type D Norris  
733 Fungal hypha type E Norris  
738 Fungal hypha type G Norris  
548 *Fusiformisporites annafrancescae* sp. nov.  
981 *Fusiformisporites crabbii* Rouse  
528 *Fusiformisporites microstriatus* Hopkins  
761 *Fusiformisporites* sp. A Norris  
640 *Graminidites* sp. A Norris  
996 *Hypoxylonites pirozynskioides* Elsik  
1014 *Hypoxylonites vicksbergensis* Elsik  
524 *Ilexpollenites microiliaceus* (Pflug and Thomson) Ke et Shi ex Sung et al.  
1010 *Inapertisporites* sp. cf. *I. elongatus* Rouse  
854 *Inapertisporites circularis* Sheffy and Dilcher  
961 *Inapertisporites elongatus* Rouse  
727 *Inapertisporites* sp. cf. *I. subovoideus* Sheffy and Dilcher  
579 *Inapertisporites* sp. cf. *I. vitattatus* Sheffy and Dilcher  
422 *Integricorpus* sp. A Norris  
370 *Intratripoporipollenites crassipites* (Wodehouse) Norris  
397 *Intratripoporipollenites minimus* Mai  
943 *Intratripoporipollenites* sp. A Rouse  
946 *Involutisporonites* sp. cf. *I. putus* Ke et Shi ex Sung et al.  
940 *Juglanspollenites tetraporus* Sung and Tsao  
995 *Juglanspollenites verus* Raatz  
617 *Lacrimasporonites* sp. A Norris  
407 *Laevigatosporites novus* Norris  
34 *Laevigatosporites ovatus* Wilson and Webster  
834 *Loniceraepollis gallwitzii* Krutzsch  
389 *Margocolporites stenosus* Ke et Shi ex Sung et al.  
544 *Mediocolpopollis alitandus* sp. nov.  
747 *Microthallites* sp. cf. *M. lutosus* Dilcher  
985 *Microthyrites*(?) sp.  
1019 *Momipites annellus* Nichols and Ott  
1021 *Momipites leffingwelli* Nichols and Ott  
1018 *Momipites waltmanensis* Nichols and Ott  
1020 *Momipites wyomingensis* Nichols and Ott  
759 *Monoporisporites abruptus* Sheffy and Dilcher  
860 *Monoporisporites singularis* Sheffy and Dilcher  
751 *Monoporisporites* sp. A Norris  
707 *Monoporisporites* sp. cf. *M. cupuliformis* Sheffy and Dilcher  
626 *Montanapollis* cf. *globosiporus* (Samoilovich) Srivastava  
1011 *Multicellaesporites cingulatus* Ke et Shi ex Sung et al.  
687 *Multicellaesporites compactilis* Ke et Shi ex Sung et al.  
944 *Multicellaesporites conspicuus* Ke et Shi ex Sung et al.  
856 *Multicellaesporites lanceolatus* Ke et Shi ex Sung et al.  
752 *Multicellaesporites leptaleus* Ke et Shi ex Sung et al.  
749 *Multicellaesporites margaritus* Ke et Shi ex Sung et al.  
942 *Multicellaesporites oculus* Ke et Shi ex Sung et al.  
999 *Multicellaesporites* sp. cf. *M. lanceolatus* Ke et Shi ex Sung et al.  
954 *Multicellaesporites* sp. cf. *M. obscurus* Ke et Shi ex Sung et al.  
1022 *Multicellaesporites* sp. cf. *M. oculus* Ke et Shi ex Sung et al.  
941 *Multicellaesporites* sp. cf. *M. vermiculatus* Ke et Shi ex Sung et al.  
394 *Myricipites annulites* (Martin and Rouse) Norris  
962 *Myrtaceidites parvus* Cookson and Pike  
982 *Novemprojectus traversii* Choi  
1000 *Obtusisporis* sp.  
19 *Osmundacidites wellmanii* Couper  
849 *Paraalnipollenites alterniporus* (Simpson) Srivastava  
950 *Periporopollenites stigmosus* (Potonie) Thomson and Pflug  
556 *Pesavis parva* Kalgutkar and Sweet  
400 *Pesavis tagluensis* Elsik and Jansonius  
840 *Phragmothyrites* (?) sp. A  
867 *Phragmothyrites* (?) sp. B  
740 *Phragmothyrites* sp. cf. *P. eocaenicus* Edwards  
401 *Piceaepollenites grandivescipites* (Wodehouse) Norris  
411 *Piceaepollenites* sp. A Norris  
719 *Pinuspollenites labdacus* (Potonie) Raatz ex Potonie  
326 *Pinuspollenites* sp. A Norris  
330 *Pistillipollenites mcgregorii* Rouse  
850 *Platanoides* (?) sp. cf. *Platanus ipelensis* (Pacltova) emend. Pacltova comb. nov.  
972 *Platycaryapollenites* sp. cf. *P. shandongensis* Ke et Shi ex Sung et al.  
864 *Plicapollis* sp. cf. *C. spatiosa* Frederiksen  
739 *Plochmopeltinites masonii* Cookson  
975 *Plochmopeltinites* sp. A  
1016 *Pluricellaesporites* sp.

- 998 *Pluricellaesporites* sp. cf. *P. conspicuus* (Ke et Shi ex Sung et al.) comb. nov.
- 327 *Podocarpidites maximus* (Stanley) comb. nov.
- 987 *Polyadosporites enormis* Ediger
- 858 *Polyadosporites* sp. cf. *P. conoideus* (Sheffy and Dilcher) Ediger
- 323 *Polyatriopollenites stellatus* (Potonie) Pflug
- 360 *Polyvestibulopollenites trinus* (Stanley) Norris
- 287 *Polyvestibulopollenites verus* (Potonie) Thomson and Pflug
- 959 *Proteacidites verruciformis* Ke et Shi
- 964 *Psilastephanocolpites* sp. cf. *P. marginatus* Gonzales Guzma
- 552 *Psilastephanocolporites* sp.
- 1009 *Punctodiporites foedus* sp. nov.
- 546 *Punctodiporites granulatus* (Rouse) comb. nov.
- 381 *Quercoidites microhenrica* (Potonie) Potonie
- 736 *Quercoidites* sp. A Norris
- 721 *Reduviasporonites anangus* Norris
- 726 *Reduviasporonites* sp. cf. *R. catenulatus* Wilson
- 1006 *Reticellites* sp. (herein)
- 570 *Retitriteles annotinioides* Krutzsch
- 412 *Retitriteles* sp. cf. *R. novomexicanus* (Anderson) Norris
- 36 *Retitriteles* sp. cf. *R. oligocenicus* Krutzsch
- 965 *Rhoipites* sp.
- 973 *Rhoipites* sp. cf. *R. microreticulatus* (Pflug and Thomson) Takahashi and Jux
- 239 *Sequoiapollenites polyformosus* Thiergart
- 245 *Sigmopollis psilatus* Piel
- 525 *Sparganiaceapollenites neogenicus* Krutzsch
- 1002 *Spirotremesporites recklawensis* Elsik
- 1015 *Spirotremesporites* sp. cf. *recklawensis* Elsik
- 1001 *Spirotremesporites* sp. cf. *S. clinatus* Elsik
- 580 *Staphlosporonites delumbus* Norris
- 725 *Staphlosporonites* sp. A Norris
- 413 *Stereisporites microgranulus* Krutzsch
- 1 *Stereisporites minor* (Raatz) Krutzsch
- 409 *Stereisporites stereoides* (Potonie and Venitz) Pflug in Thomson and Pflug
- 551 *Striadiporites anceps* sp. nov.
- 685 *Striadiporites inflexus* (Ke et Shi ex Sung et al.) Norris
- 859 *Striadiporites multistriatus* (Ke et Shi ex Sung et al.) Norris
- 391 *Striadiporites sanctaebarae* Elsik and Jansonius
- 988 *Striadiporites* sp. cf. *bistriatus* Ke et Shi ex Sung et al.
- 2 *Taxodiaceapollenites hiatus* Potonie ex Potonie
- 970 *Tetracolporopollenites* sp.
- 991 *Trichopeltinites* (?) sp. A
- 742 *Trichothyrites* sp. A Norris
- 291 *Tricolpites hians* Stanley
- 978 *Tricolpopollenites sculptus* Takahashi
- 608 *Triporisporonites verus* (Ke et Shi ex Sung et al.) Norris
- 952 *Triporopollenites mullensis* (Simpson) Rouse and Srivastava
- 714 *Trivestibulopollenites betuloides* Pflug in Thomson and Pflug
- 220 *Trivestibulopollenites claripites* (Wodehouse) Norris
- 597 *Tsugaepollenites igniculus* (Potonie) Potonie and Venitz
- 371 *Tsugaepollenites viridifluminipites* (Wodehouse) Norris
- 1005 *Ulmipollenites minor* Groot and Groot
- 320 *Ulmipollenites undulosus* Wolff
- 720 *Ulmoideipites tricostratus* Anderson
- 418 *Verrucatosporites favus* (Potonie) Thomson and Pflug

### Dinoflagellates

- M369 *Achomosphaera ramulifera* (Deflandre) Evitt
- M259 *Apectodinium homomorphum* (Deflandre and Cookson) Lentin and Williams
- M260 *Apectodinium hyperacanthum* (Cookson and Eisenack) Lentin and Williams
- M255 *Apectodinium quinquelatum* (Williams and Downie) Costa and Downie
- M368 *Cerodinium* cf. *striatum* (Drugg) Lentin and Williams
- M372 Dinoflagellate sp. S-1
- M292 *Distatodinium* sp. A
- M371 *Geiselodinium* sp. 371
- M230 *Glaphyrocysta ordinata* (Williams and Downie) Stover and Evitt
- M370 *Gochtodinium simplex* Bujak
- M233 *Horologinella* sp. A
- M378 *Lentinia serrata* Bujak
- M373 *Lentinia* sp. 373
- M246 *Maduradinium turpis* Norris
- M349 *Melitasphaeridium pseudorecurvatum* (Morgenroth) Bujak et al.
- M374 *Micrhystridium fraseri* Piel
- M375 *Morkallacysta* sp. 375
- M24 *Palaeoperidinium ariadnae* Norris
- M367 *Palaeoperidinium* sp. 367
- M377 *Phelodinium* sp. 377
- M242 *Pyxidiella* sp. A
- M376 *Senegalinium* cf. *microgranulatum* (Stanley)
- M291 *Spinidinium* cf. *sagittulum* (Drugg) Lentin and Williams
- M229 *Wetzeliella* cf. *hampdenensis* Wilson



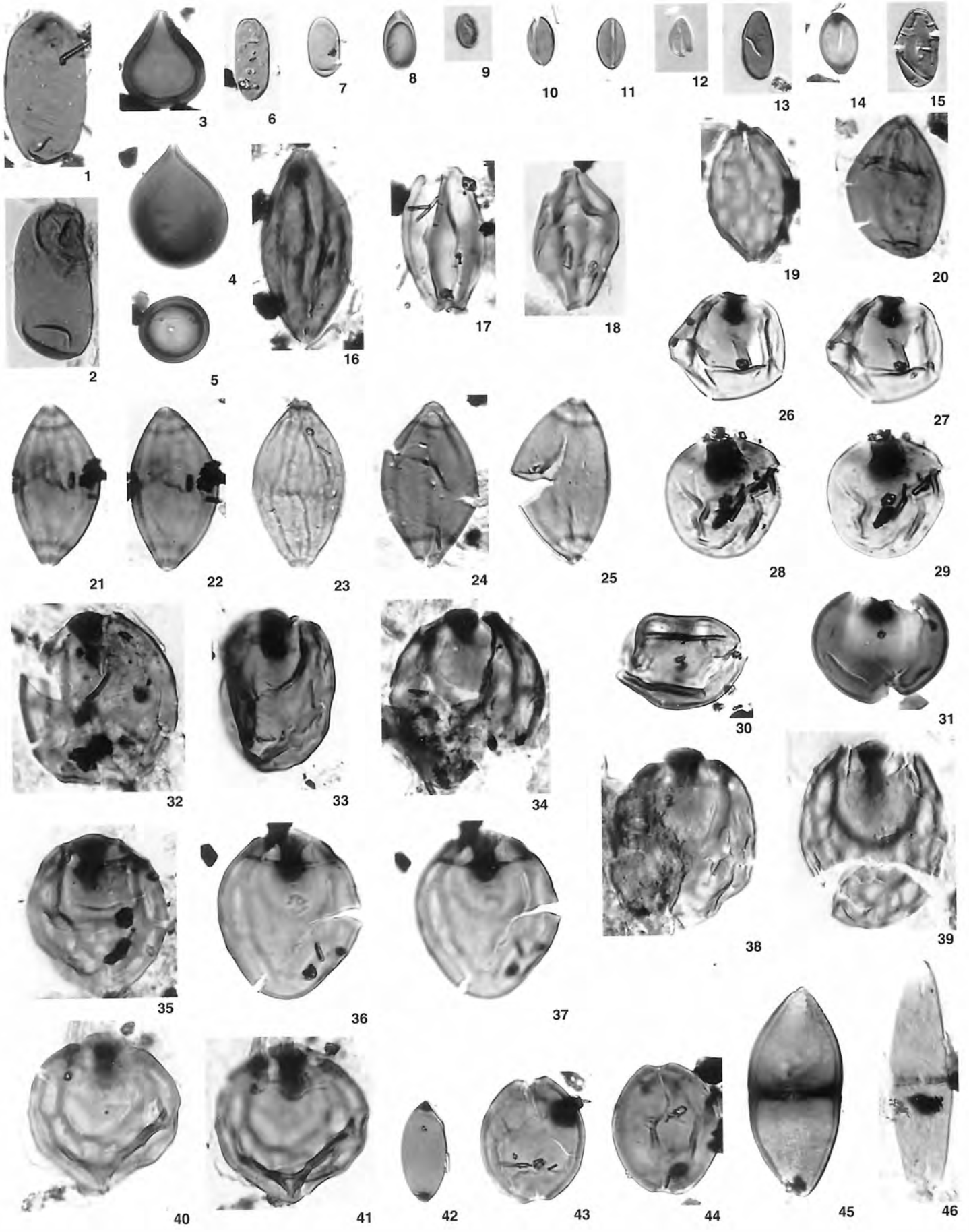
## PLATES

All specimens are identified with GSC figured specimen numbers, followed by the microscope slide number (indicating depth in feet) and the suffix A or B for the slide containing the specimen. Coordinates are for a Leitz Orthoplan microscope. All specimens are from the Imperial Adgo F-28 well (lat. 69°27'17"N, long. 135°51'16"W) (GSC loc. C-48824). They are stored in the Type Collection of Invertebrate and Plant Fossils of the Geological Survey of Canada (Calgary).

### PLATE 1

All figures 800x, at mid-focus with interference contrast illumination, unless otherwise specified

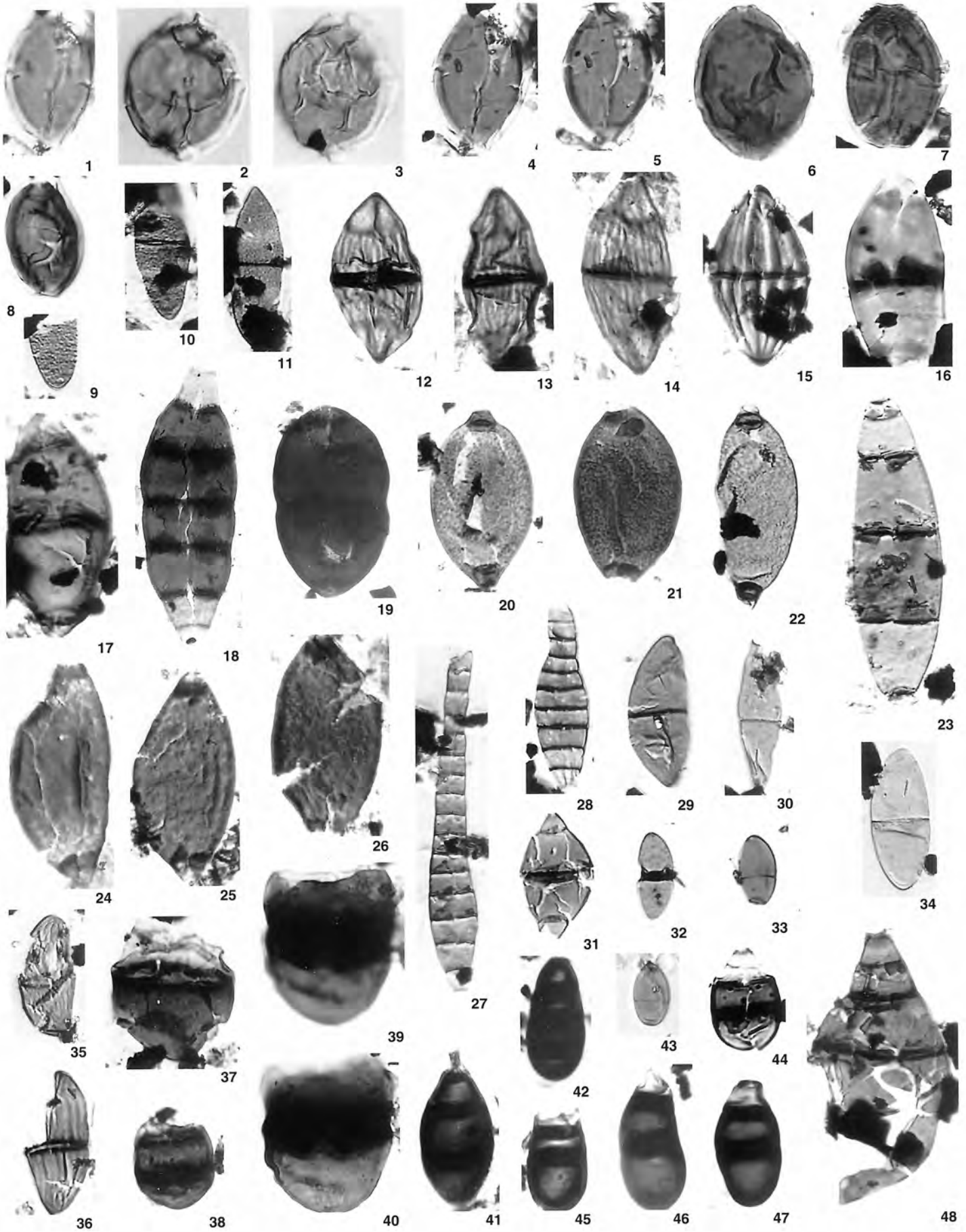
- Figures 1, 2. *Inapertisporites cf. elongatus* Rouse  
1. Figured specimen GSC 111947/7000B; 49.4 x 99.5; mid-focus  
2. Figured specimen GSC 111948/6800B; 43.1 x 95.4
- Figures 3, 4. *Lacrimasporonites globulosus* (Rouse) comb. nov.  
3. Figured specimen GSC 111949/5200A; 51.7 x 96.8  
4. Figured specimen GSC 111950/5100A; 36.6 x 112.3
- Figure 5. *Monoporisporites singularis* Sheffy and Dilcher  
Figured specimen GSC 111951/3500B; 48.5 x 103.7
- Figure 6, 7. *Inapertisporites elongatus* Rouse  
6. Figured specimen GSC 111952/3500A; 40.8 x 92.5  
7. Figured specimen GSC 111953/3500A; 34.0 x 109.8
- Figure 8. *Monoporisporites abruptus* Sheffy and Dilcher  
Figured specimen GSC 111954/3500B; 48.5 x 96.6
- Figure 9. *Spirotremesporites cf. reklawensis* Elsik  
Figured specimen GSC 111955/10,000B; 49.8 x 97.7
- Figure 10. *Hypoxylonites vicksbergensis* Elsik  
Figured specimen GSC 111956/4800B; 42.2 x 100.9
- Figures 11, 12. *Hypoxylonites pirozynskioides* Elsik  
11. Figured specimen GSC 111957/5000A; 47.3 x 104.4  
12. Figured specimen GSC 111958/2800B; 50.3 x 98.4
- Figure 13. *Spirotremesporites reklawensis* Elsik  
Figured specimen GSC 111959/5300B; 46.0 x 111.5
- Figures 14, 15. *Spirotremesporites cf. clinatus* Elsik  
14. Figured specimen GSC 111960/3700B; 41.3 x 101.7  
15. Figured specimen GSC 111961/3800B; 46.2 x 106.7
- Figure 16. *Striadiporites cf. bistriatus* Ke et Shi ex Sung et al.  
Figured specimen GSC 111962/7100A; 34.3 x 106.4
- Figures 17, 18. *Striadiporites inflexus* (Ke et Shi ex Sung et al.) Norris  
17. Figured specimen GSC 111963/6500B; 43.7 x 111.8  
18. Figured specimen GSC 111964/7700A; 41.4 x 106.6
- Figure 19. *Striadiporites sanctaebabarbarae* Elsik and Jansonius  
Figured specimen GSC 111965/3500A; 41.6 x 94.2
- Figures 20-25. *Striadiporites anceps* sp nov.  
20. Figured specimen GSC 111966. C-48824/6700B; 40.5 x 97.8  
21, 22. Figured specimen GSC 111967/6000B; holotype; 33.7 x 95.4; high focus and mid-focus, respectively  
23. Figured specimen GSC 111968/6000A; 34.6 x 112.4  
24. Figured specimen GSC 111969/6700B; 34.9 x 92.9  
25. Figured specimen GSC 111970/6100B; 49.8 x 105.1
- Figures 26-31. *Biporisporites rotundus* Ke et Shi ex Sung et al.  
26, 27. Figured specimen GSC 111971/6000B; 38.0 x 91.0; high and low focus, respectively  
28, 29. Figured specimen GSC 111972/6000B; 45.9 x 94.4; low and high focus, respectively  
30. Figured specimen GSC 111973/4900B; 45.0 x 101.4  
31. Figured specimen GSC 111974/6700B; 40.9 x 96.3
- Figures 32-41. *Biporisporites praestigiatus* sp nov.  
32. Figured specimen GSC 111975/7000B; 49.9 x 95.1  
33. Figured specimen GSC 111976/6800B; 36.8 x 113.6  
34. Figured specimen GSC 111977/45.8 x 111.8.  
35. Figured specimen GSC 111978/7400A; 32.8 x 103.7  
36, 37. Figured specimen GSC 111979/6400B; holotype; 35.8 x 99.0; high and low focus, respectively  
38. Figured specimen GSC 111980/6800A; 31.1 x 110.3  
39. Figured specimen GSC 111981/8000B; 49.2 x 104.4.  
40, 41. Figured specimen GSC 111982/8000B; 46.3 x 97.9; high and low focus, respectively
- Figure 42. *Diporisporites elegans* Ke et Shi ex Sung et al.  
Figured specimen GSC 111983/5200A; 53.2 x 108.5
- Figures 43, 44. *Diporisporites oblongatus* Ke et Shi ex Sung et al.  
43. Figured specimen GSC 111984/5300B; 44.6 x 100.6  
44. Figured specimen GSC 111985/5300A; 40.9 x 108.1
- Figure 45. *Dyadosporites cf. solidus* Ke et Shi ex Sung et al.  
Figured specimen GSC 111986/7300B; 40.6 x 102.2
- Figure 46. *Dyadosporites cf. ellipsus* Clarke  
Figured specimen GSC 111987/7600B; 47.1 x 105.2



## PLATE 2

All figures 800x, at mid-focus with interference contrast illumination, unless otherwise specified

- Figures 1-8. *Diporisporites pisciculatus* sp. nov.  
1, 4, 5. Figured specimen GSC 111988/4400A; 42.1 x 94.7 high, mid-, and low focus, respectively  
2, 3. Figured specimen GSC 111989/7600B; holotype; 47.9 x 110.0; mid-, and high focus, respectively  
6. Figured specimen GSC 111990/6800A; 45.1 x 112.2; high focus  
7. Figured specimen GSC 111991/4400B; 48.6 x 98.7; high focus  
8. Figured specimen GSC 111992/5100A; 39.6 x 96.2; high focus
- Figures 9-11. *Dicellaesporites* cf. *akyolli* Ediger and Alison  
9. Figured specimen GSC 111993/4400A; 41.9 x 94.7  
10. Figured specimen GSC 111994/5400B; 45.5 x 93.5  
11. Figured specimen GSC 111995/4800B; 45.5 x 104.9
- Figures 12-14. *Fusiformisporites annafrancescae* sp. nov.  
12. Figured specimen GSC 111996/7000B; holotype; 38.1 x 107.2  
13. Figured specimen GSC 111997/6700B; 35.0 x 99.1  
14. Figured specimen GSC 111998/6800B; 47.9 x 107.6
- Figure 15. *Fusiformisporites crabbi* Rouse  
Figured specimen GSC 111999/6000A; 49.2 x 103.1
- Figures 16, 17. *Diporicellaesporites liaoningensis* Ke et Shi ex Sung et al.  
16. Figured specimen GSC 112000/6000A; 47.3 x 102.0  
17. Figured specimen GSC 112001/5000B; 43.4 x 101.3
- Figure 18. *Diporicellaesporites* sp. A Norris  
Figured specimen GSC 112002/8300A; 48.8 x 100.1
- Figure 19. *Diporicellaesporites* cf. *liaoningensis* Ke et Shi ex Sung et al.  
Figured specimen GSC 112003/8400B; 41.0 x 100.8
- Figures 20-22. *Punctodiporites granulatus* (Rouse) comb. nov.  
20. Figured specimen GSC 112004/4800A; 35.9 x 97.8  
21. Figured specimen GSC 112005/6400A; 43.8 x 100.0  
22. Figured specimen GSC 112006/4900A; 41.0 x 93.0
- Figure 23. *Diporicellaesporites laevigatiformis* Ke et Shi ex Sung et al.  
Figured specimen GSC 112007/6000B; 42.8 x 102.8
- Figures 24-26. *Punctodiporites foedus* sp. nov.  
24. Figured specimen GSC 112008/6800A; 52.6 x 93.7  
25. Figured specimen GSC 112009/6300A; holotype; 34.7 x 105.7  
26. Figured specimen GSC 112010/6800B; 52.7 x 99.3
- Figures 27, 28. *Diporicellaesporites* sp. B Norris  
27. Figured specimen GSC 112011/3500B; 48.7 x 96.9  
28. Figured specimen GSC 112012/4500B; 39.7 x 103.7
- Figure 29. *Dicellaesporites popovii* Elsik  
Figured specimen GSC 112013/4000A; 41.4 x 103.6
- Figure 30. *Dicellaesporites obnixus* Norris  
Figured specimen GSC 112014/3700B; 51.7 x 107.1
- Figure 31. *Diporicellaesporites bellulus* Ke et Shi ex Sung et al.  
Figured specimen GSC 112015/4700B; 48.6 x 113.5
- Figure 32. *Dyadosporites* sp. A Norris  
Figured specimen GSC 112016/4900A; 33.9 x 106.3
- Figures 33, 43. *Didymosporisporonites ovatus* Ke et Shi ex Sung et al.  
33. Figured specimen GSC 112017/3800A; 34.5 x 104.1  
43. Figured specimen GSC 112026/3300B; 46.2 x 102.8
- Figure 34. *Dyadosporites oblongatus* (Ke et Shi ex Sung et al.) Norris  
Figured specimen GSC 112018/3900B; 47.1 x 108.5
- Figures 35, 36. *Fusiformisporites microstriatus* Hopkins  
35. Figured specimen GSC 112019/4000B; 39.7 x 106.1  
36. Figured specimen GSC 112020/4800A; 36.4 x 97.5
- Figures 37-40. *Pluricellaesporites* sp.  
37. Figured specimen GSC 112021/10200B; 43.6 x 103.4  
38. Figured specimen GSC 112022/9900B; 42.5 x 99.7  
39, 40. Figured specimen GSC 112023/10200B; 47.6 x 107.0; low and high focus, respectively
- Figures 41, 42. *Pluricellaesporites* cf. *conspicuus* (Ke et Shi ex Sung et al.) comb. nov.  
41. Figured specimen GSC 112024/4900A; 46.4 x 93.2  
42. Figured specimen GSC 112025/3600B; 43.0 x 109.6
- Figure 44. *Brachysporisporites opimus* (Elsik and Jansonius) Norris  
Figured specimen GSC 112027/4900A; 47.8 x 106.3
- Figures 45-47. *Multicellaesporites conspicuus* Ke et Shi ex Sung et al.  
45. Figured specimen GSC 112028/5000A; 42.7 x 93.1  
46. Figured specimen GSC 112029/5400A; 50.3 x 98.9  
47. Figured specimen GSC 112030/8100B; 39.6 x 101.9
- Figure 48. *Brachysporisporites* cf. *conicus* Ke et Shi ex Sung et al.  
Figured specimen GSC 112031/5200B; 40.1 x 95.5



### PLATE 3

All figures 800x, at mid-focus with interference contrast illumination, unless otherwise specified

Figures 1-5. *Brachysporisporites fustitudinus* sp. nov.

1. Figured specimen GSC 112032/5100B; holotype; 47.7 x 94.1
2. Figured specimen GSC 112033/6900B; 43.9 x 111.0
3. Figured specimen GSC 112034/7000B; 48.1 x 102.9
4. Figured specimen GSC 112035/6100B; 49.6 x 95.0
5. Figured specimen GSC 112036/6400B; 45.9 x 94.4

Figure 6. *Multicellaesporites compactilis* Ke et Shi ex Sung et al.  
Figured specimen GSC 112037/3300B; 41.7 x 97.8

Figure 7. *Anatolinites dongyingensis* (Ke et Shi ex Sung et al.)  
Elsik, Ediger, and Bati  
Figured specimen GSC 112038/4000A; 51.3 x 99.0

Figures 8-11. *Anatolinites* sp.

8. Figured specimen GSC 112039/7900B; 45.7 x 98.3
9. Figured specimen GSC 112040/6700B; 48.2 x 104.0
10. Figured specimen GSC 112041/7500B; 47.1 x 101.0
11. Figured specimen GSC 112042/8400B; 50.1 x 109.7

Figures 12-16. *Involutisporonites* cf. *putus* Ke et Shi ex Sung et al.

12. Figured specimen GSC 112043/7400A; 36.6 x 103.8
13. Figured specimen GSC 112044/7200B; 47.1 x 96.7
14. Figured specimen GSC 112045/9600B; 47.2 x 103.7
15. Figured specimen GSC 112046/4400A; 47.0 x 111.8
16. Figured specimen GSC 112047/7300A; 48.4 x 111.9

Figures 17-19. *Fractisporonites* sp. C

17. Figured specimen GSC 112048/6900B; 47.1 x 110.9
18. Figured specimen GSC 112049/7000B; 56.0 x 110.2
19. Figured specimen GSC 112050/7100B; 48.9 x 97.9 or 46.5 x 98.6

Figures 20, 21. *Fractisporonites* sp. B Norris

20. Figured specimen GSC 112051/5000A; 32.6 x 99.6
21. Figured specimen GSC 112051/5000A; 32.1 x 99.5 (same specimen as Figure 20)

Figure 22. *Multicellisporites oculus* Ke et Shi ex Sung et al.  
Figured specimen GSC 112052/5000B; 43.9 x 105.6

Figure 23. *Multicellaesporites* cf. *obscurus* Ke et Shi ex Sung et al.  
Figured specimen GSC 112053/9700A; 49.7 x 100.2

Figure 24. *Multicellaesporites* cf. *oculus* Ke et Shi ex Sung et al.  
Figured specimen GSC 112054/5900B; 34.5 x 100.8

Figures 25, 26. *Multicellaesporites* cf. *vermiculatus* Ke et Shi ex Sung et al.

25. Figured specimen GSC 112055/9900B; 47.3 x 99.8
26. Figured specimen GSC 112056/9900B; 36.4 x 107.0

Figure 27. *Reticellites* sp.

Figured specimen GSC 112057/6100B; 52.5 x 102.5

Figures 28, 29. *Polyadosporites enormis* Ediger

28. Figured specimen GSC 112058/7000A; 40.8 x 110.6
29. Figured specimen GSC 112059/4600B; 45.6 x 95.6

Figure 30. *Polyadosporites* cf. *conoideus* (Sheffy and Dilcher)  
Ediger

Figured specimen GSC 112060/8400B; 49.9 x 98.9

Figures 31-33. *Pesavis tagluensis* Elsik and Jansonius

31. Figured specimen GSC 112061/6700B; 45.1 x 95.4
32. Figured specimen GSC 112062/7600A; 41.4 x 95.9
33. Figured specimen GSC 112063/6600A; 50.4 x 105.0

Figures 34-36. *Pesavis parva* Kalgutkar and Sweet

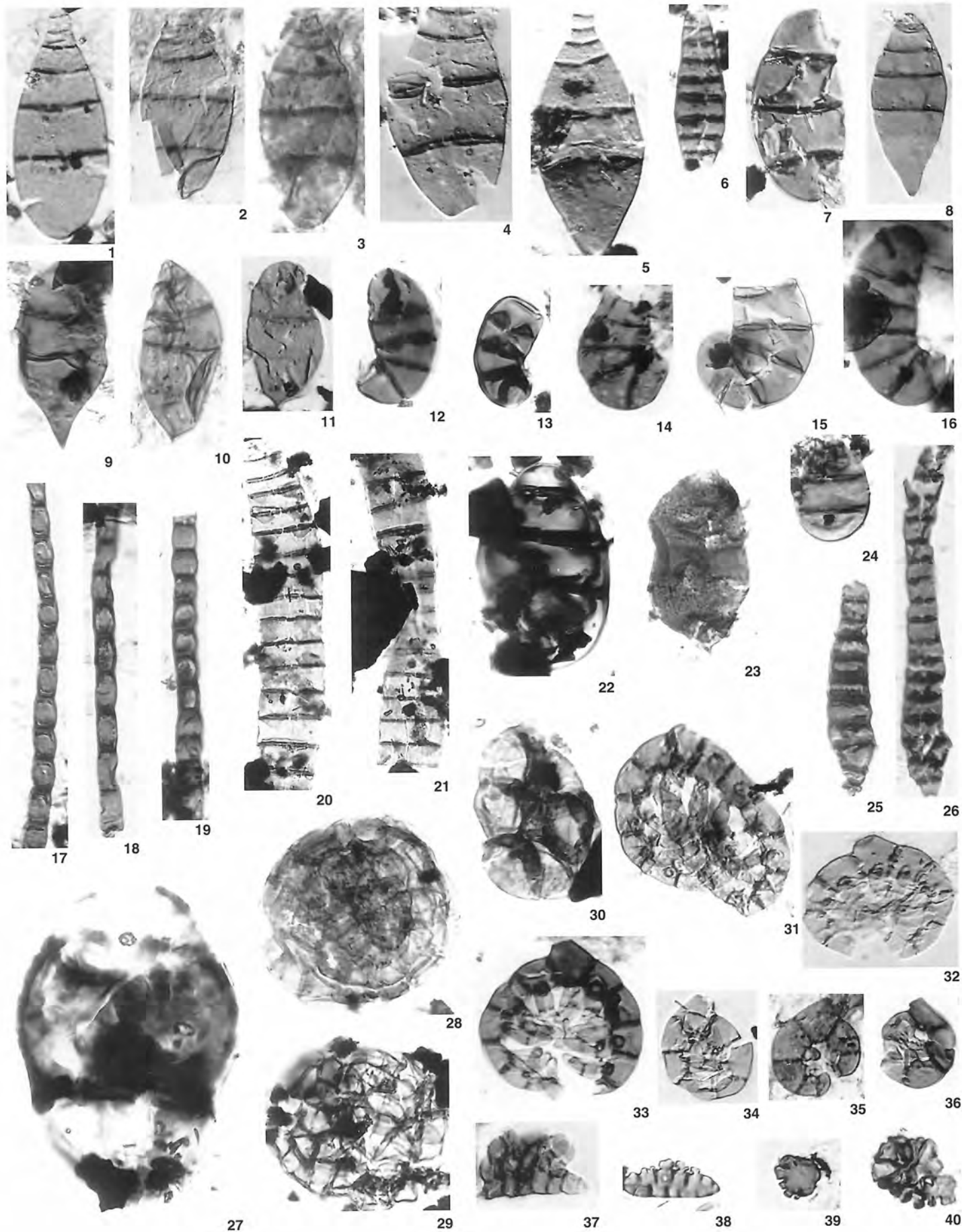
34. Figured specimen GSC 112064/6000A; 46.1 x 95.2
35. Figured specimen GSC 112065/6700A; 42.6 x 110.9
36. Figured specimen GSC 112066/5400A; 48.6 x 98.5

Figure 37. *Ctenosporites wolfei* Elsik and Jansonius

Figured specimen GSC 112067/7900B; 39.4 x 108.4

Figures 38-40. *Desmidiospora willoughbyi* (Bradley) Etheridge  
Glass et al.

38. Figured specimen GSC 112068/4500B; 27.5 x 94.7
39. Figured specimen GSC 112069/4800A; 42.1 x 105.6
40. Figured specimen GSC 112070/6100B; 46.2 x 94.8



## PLATE 4

All figures 800x, at mid-focus with interference contrast illumination, unless otherwise specified

### Figures 1-4. *Plochmopeltinites* sp. A

1. Figured specimen GSC 112071/6800A; 37.1 x 110.4
2. Figured specimen GSC 112072/7000B; 53.5 x 112.3
3. Figured specimen GSC 112073/6800A; 40.6 x 103.9
4. Figured specimen GSC 112074/7000B; 53.3 x 112.1

### Figures 5-7. *Trichopeltinites* (?) sp. A

5. Figured specimen GSC 112075/8100A; 35.1 x 102.9; (400x)
- 6, 7. Figured specimen GSC 112076/7100B; 49.1 x 102.2; Fig. 6, 400x; Fig. 7, 800x

### Figures 8, 9. *Phragmothyrites* (?) sp. A

8. Figured specimen GSC 112077/4200B; 47.5 x 104.9
9. Figured specimen GSC 112078/6100B; 52.7 x 96.5

### Figures 10, 11. *Phragmothyrites* (?) sp. B

Figured specimen GSC 112079/7300B; 46.1 x 94.7; low and mid-focus, respectively

### Figure 12. *Callimothallus pertusus* Dilcher

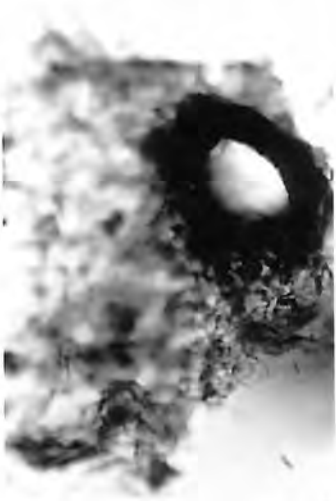
Figured specimen GSC 112080/7000A; 45.4 x 111.8

### Figure 13. *Phragmothyrites* cf. *eocaenicus* Edwards

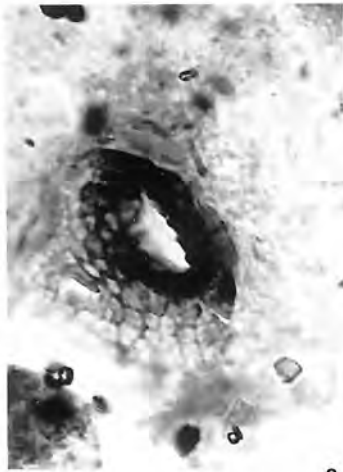
Figured specimen GSC 112081/9700B; 45.3 x 104.5

### Figures 14, 15. *Plochmopeltinites masonii* Cookson

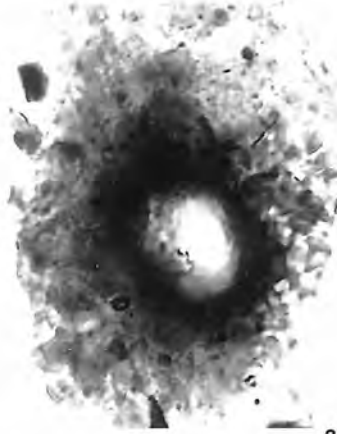
Figured specimen GSC 112082/6400B; 38.9 x 102.8; 400x and 800x respectively



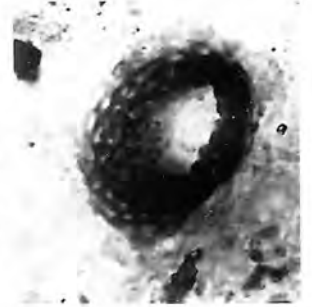
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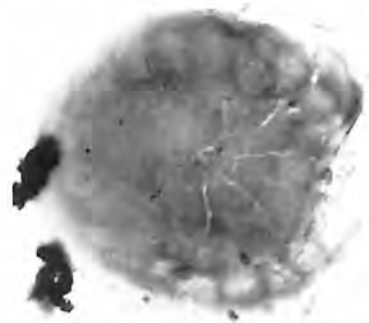
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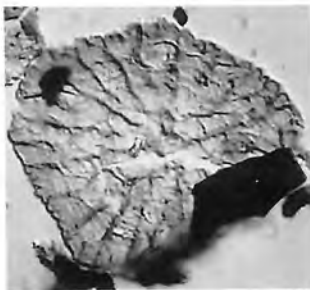
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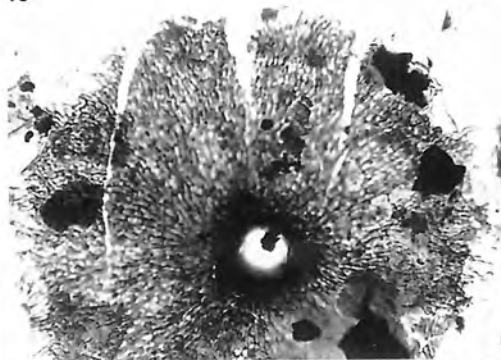
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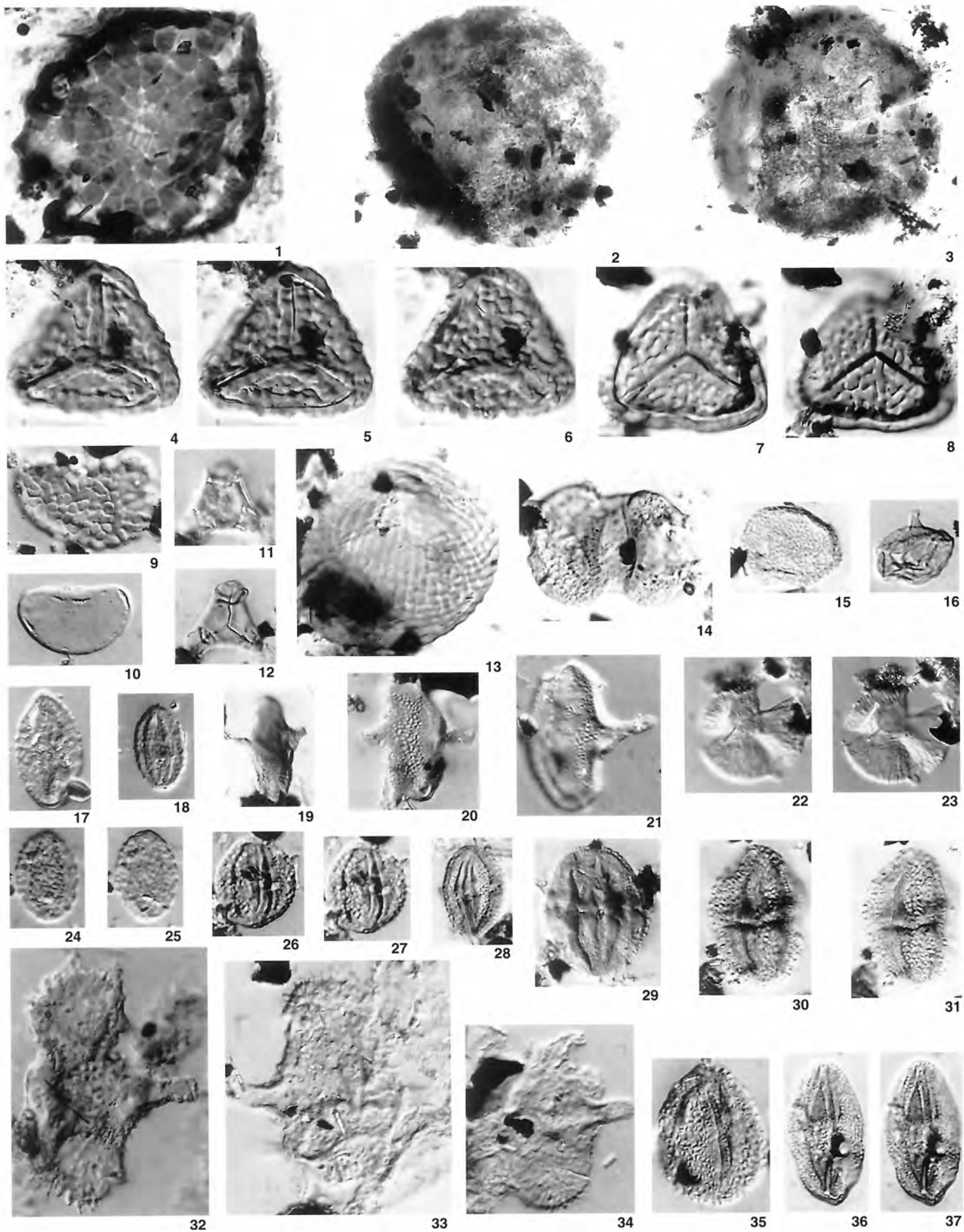
15



## PLATE 5

All figures 800x, at mid-focus with interference contrast illumination, unless otherwise specified

- Figure 1. *Phragmothyrites* (?) sp. B  
Figured specimen GSC 112083/7100B; 35.9 x 96.0
- Figures 2, 3. *Microthyrites* (?) sp.  
2. Figured specimen GSC 112084/6700B; 38.1 x 108.5; (400x)  
3. Figured specimen GSC 112085/52.5 x 109.4; (400x)
- Figures 4-8. *Foveosporites* sp.  
4-6. Figured specimen GSC 112086/5400A; 50.0 x 103.1; high, mid-, and low focus, respectively  
7, 8. Figured specimen GSC 112087/5200A; 45.7 x 106.6; low focus dorsal and high focus proximal views, respectively
- Figure 9. *Verrucatosporites favus* (Potonie) Thomson and Pflug  
Figured specimen GSC 112088/3500A; 47.4 x 104.4
- Figure 10. *Laevigatosporites novus* Norris  
Figured specimen GSC 112089/1700B; 48.4 x 94.3
- Figures 11, 12. *Obtusisporis* sp.  
Figured specimen GSC 112090/2200B; 48.1 x 100.7; mid-, and high focus proximal views, respectively
- Figure 13. *Cicatricosisporites dorogensis* Potonie and Gelletich  
Figured specimen GSC 112091/6900B; 30.2 x 108.8
- Figure 14. *Podocarpidites maximus* (Stanley) comb. nov.  
Figured specimen GSC 112092/4800B; 41.8 x 102.9
- Figure 15. *Sparganiaceapollenites neogenicus* Krutzsch  
Figured specimen GSC 112093/4900A; 33.9 x 109.5
- Figure 16. *Sequoiapollenites polyformosus* Thiergart  
Figured specimen GSC 112094/4900A; 42.9 x 109.6
- Figures 17, 18, 24, 25. *Tricolpopollenites sculptus* Takahashi  
17. Figured specimen GSC 112095/3700B; 44.3 x 110.9  
18. Figured specimen GSC 112096/3800B; 41.6 x 91.6  
24, 25. Figured specimen GSC 112101/3400A; 41.2 x 94.9
- Figures 19-21. *Integricorpus* sp. A Norris  
19. Figured specimen GSC 112097/3700B; 41.1 x 104.6  
20. Figured specimen GSC 112098/5400B; 46.1 x 104.6  
21. Figured specimen GSC 112099/2900A; 47.3 x 98.1
- Figures 22, 23. *Aceripollenites tener* (Samoilovitch) comb. nov.  
Figured specimen GSC 112100/2900B; 49.9 x 96.9
- Figures 26-28. *Rhoipites* cf. *microreticulatus* (Pflug and Thomson) Takahashi and Jux  
26, 27. Figured specimen GSC 112102/4700A; 47.3 x 105.1  
28. Figured specimen GSC 112103/5100A; 38.8 x 105.3
- Figures 29-31. *Rhoipites* sp.  
29. Figured specimen GSC 112104/4400A; 45.5 x 100.1  
30, 31. Figured specimen GSC 112105/3800A; 44.1 x 95.4; mid-, and high focus, respectively
- Figures 32-34. *Aquilapollenites tumanganicus* Bolotnikova  
32. Figured specimen GSC 112106/7500B; 40.2 x 104.1  
33. Figured specimen GSC 112107/7300A; 33.1 x 111.5  
34. Figured specimen GSC 112108/7300A; 40.5 x 101.8
- Figures 35-37. *Caprifoliipites incertigrandis* Frederiksen  
35. Figured specimen GSC 112109/5300B; 37.8 x 109.9  
36, 37. Figured specimen GSC 112110/4700A; 37.4 x 98.8; high and mid-focus, respectively



## PLATE 6

All figures 800x, at mid-focus with interference contrast illumination, unless otherwise specified

Figures 1-4. *Novemprojectus traversii* Choi

- 1, 2. Figured specimen GSC 112111/6000B; 32.7 x 93.5; high and low focus, respectively
- 3, 4. Figured specimen GSC 112112/6100B; 51.5 x 111.8; low and high focus, respectively

Figure 5. *Ericipites antecursoroides* Norris

Figured specimen GSC 112113/2800A; 37.4 x 103.2

Figure 6. *Salixpollenites discoloripites* (Wodehouse) Srivastava

Figured specimen GSC 112114/4600B; 48.7 x 110.8

Figures 7, 8. *Ericipites cf. ericeus* (Potonie) Potonie

7. Figured specimen GSC 112115/5800A; 52.8 x 102.8
8. Figured specimen GSC 112116/4900A; 46.4 x 94.1

Figures 9-11. *Platanoides* (?) cf. *Platanus ipelensis* (Pacltova) emend Pacltova comb. nov.

- 9, 10. Figured specimen GSC 112117/8200B; 40.4 x 105.8; high and low focus, respectively of a group of four grains
11. Figured specimen GSC 112118/6500B; 47.7 x 110.9

Figures 12-16. *Acanthacidites* (?) sp.

12. Figured specimen GSC 112119/5500B; 41.4 x 91.8
- 13, 14. Figured specimen GSC 112120/4600B; 44.3 x 103.2; mid-, and high focus, respectively
- 15, 16. Figured specimen GSC 112121/4400B; 46.4 x 97.9; low and high focus, respectively

Figures 17-20. *Mediocolpopollis alitandus* sp. nov.

17. Figured specimen GSC 112122/4800B; 32.9 x 101.6
18. Figured specimen GSC 112123/4800B; 41.5 x 111.9
19. Figured specimen GSC 112124/4800A; 42.3 x 109.2
20. Figured specimen GSC 112125/4800B; holotype; 48.8 x 104.1

Figures 21-27. *Ailanthipites fluens* sp. nov.

- 21, 22. Figured specimen GSC 112126/4500A; holotype; 34.7 x 107.9; low and high focus, respectively

23. Figured specimen GSC 112127/5300A; 42.1 x 101.4

24, 25. Figured specimen GSC 112128/5200A; 42.1 x 96.7; high and low focus, respectively

26, 27. Figured specimen GSC 112129/4800B; 37.3 x 103.9; low and high focus, respectively

Figures 28, 29. *Faguspollenites* sp.

28. Figured specimen GSC 112130/6700B; 32.8 x 94.9

29. Figured specimen GSC 112131/4800A; 42.3 x 109.3

Figures 30-32. *Lonicerapollis gallwitzii* Krutzsch

30. Figured specimen GSC 112132/2400A; 39.9 x 109.3

31, 32. Figured specimen GSC 112133/2400B; 46.9 x 101.4; mid-, and low focus, respectively

Figure 33. *Psilastephanocolporites* sp.

Figured specimen GSC 112134/5200B; 43.3 x 93.6

Figure 34. *Psilastephanocolpites cf. marginatus* Gonzales Gusman

Figured specimen GSC 112135/3700A; 43.7 x 112.1

Figures 35-37. *Myrtaceidites parvus* Cookson and Pike

35. Figured specimen GSC 112136/4800A; 53.7 x 103.6

36. Figured specimen GSC 112137/3700A; 39.8 x 104.7

37. Figured specimen GSC 112138/3600A; 42.8 x 96.9

Figures 38-40. *Montanapollis cf. globosiporus* (Samoilovich) Srivastava

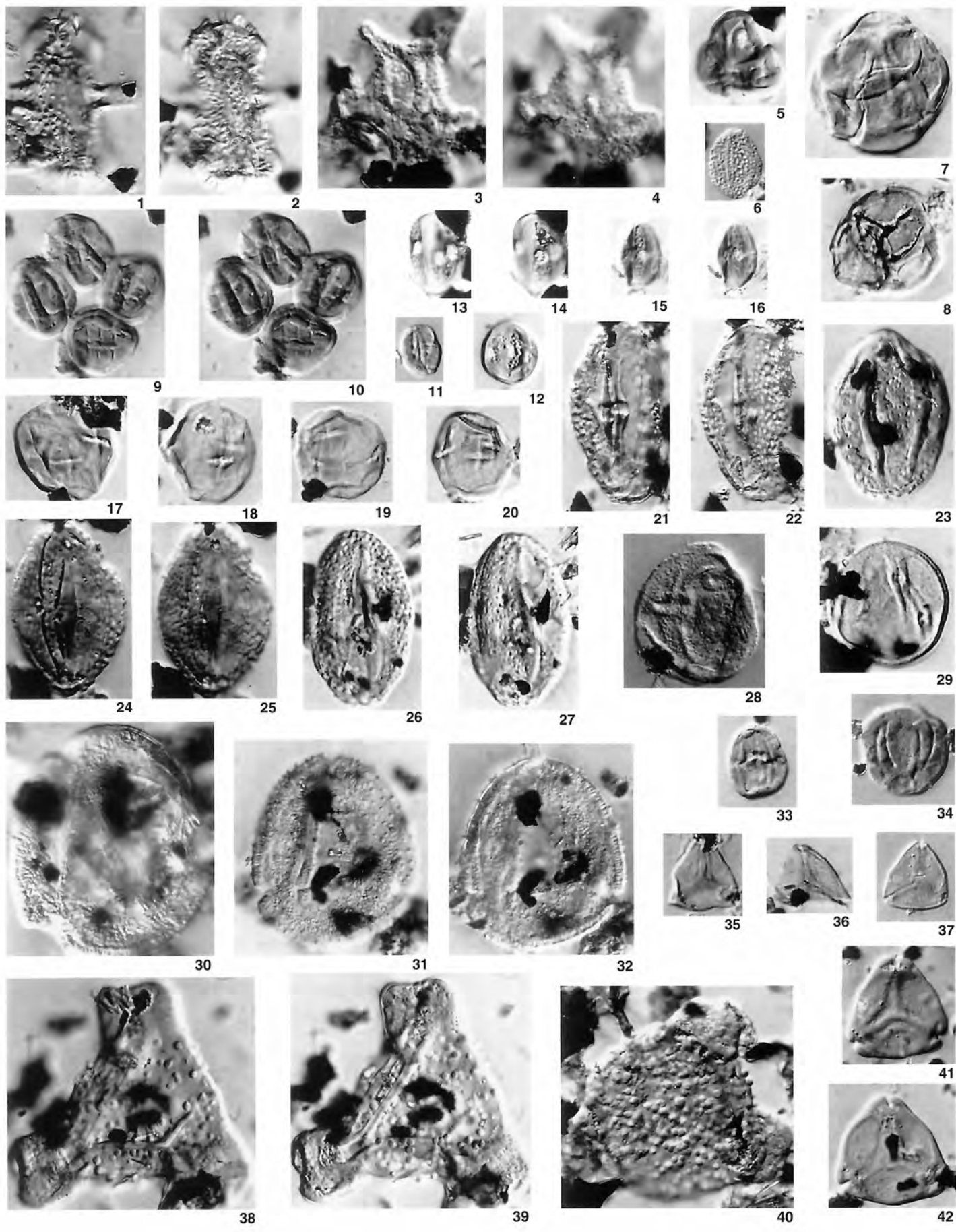
38, 39. Figured specimen GSC 112139/5200A; 45.9 x 106.5

40. Figured specimen GSC 112140/6900B; 33.7 x 104.6; high focus

Figures 41, 42. *Plicapollis cf. spatiosa* Frederiksen

41. Figured specimen GSC 112141/3400B; 30.1 x 95.2

42. Figured specimen GSC 112142/3400A; 35.7 x 107.8



## PLATE 7

All figures 800x, at mid-focus with interference contrast illumination, unless otherwise specified

- Figure 1. *Tetracolporopollenites* sp.  
Figured specimen GSC 112143/5300B; 39.5 x 101.3
- Figures 2, 3. *Caryapollenites inelegans* Nichols and Ott  
2. Figured specimen GSC 112144/5600B; 50.1 x 92.  
3. Figured specimen GSC 112145/6800A; 38.1 x 102.1
- Figure 4, 8. *Momipites wyomingensis* Nichols and Ott  
4. Figured specimen GSC 112146/7400A; 47.1 x 91.5  
8. Figured specimen GSC 112147/4800B; 36.0 x 101.8
- Figures 5-7. *Caryapollenites veripites* (Wilson and Webster) Nichols and Ott  
5. Figured specimen GSC 112148/6500B; 37.6 x 92.9  
6. Figured specimen GSC 112149/6300A; 46.3 x 104.6  
7. Figured specimen GSC 112150/3400B; 46.6 x 102.7
- Figure 9. *Momipites waltmanensis* Nichols and Ott  
Figured specimen GSC 112151/3300A; 37.9 x 102.4
- Figure 10. *Momipites leffingwelli* Nichols and Ott  
Figured specimen GSC 112152/5200A; 41.8 x 96.9
- Figures 11, 12. *Momipites annellus* Nichols and Ott  
Figured specimen GSC 112153/4600B; 37.0 x 101.7; mid- and low focus, respectively
- Figures 13, 14. *Tripoporopollenites mullensis* (Simpson) Rouse and Srivastava  
13. Figured specimen GSC 112154/6700B; 40.2 x 99.1; low focus  
14. Figured specimen GSC 112155/7100B; 49.7 x 111.8
- Figures 15-17. *Platycaryapollenites* sp. cf. *P. shandongensis* Ke et Shi ex Sung et al.  
15. Figured specimen GSC 112156/4000B; 56.2 x 102.2  
16, 17. Figured specimen GSC 112157/4700A; 50.0 x 104.8; high and low focus, respectively
- Figure 18. *Bombacacidites* sp.  
Figured specimen GSC 112158/4800A; 36.9 x 96.8
- Figures 19, 20. *Intratripoporopollenites minimus* Mai  
19. Figured specimen GSC 112159/3500A; 40.1 x 106.9  
20. Figured specimen GSC 112160/3400A; 49.6 x 105.6
- Figures 21, 22. *Intratripoporopollenites crassipites* (Wodehouse) Norris  
21. Figured specimen GSC 112161/4500A; 35.5 x 100.8  
22. Figured specimen GSC 112162/4500A; 35.6 x 94.6
- Figures 23, 24. *Paraalnipollenites alterniporus* (Simpson) Srivastava  
23. Figured specimen GSC 112163/5100A; 37.5 x 112.4  
24. Figured specimen GSC 112164/5300A; 42.1 x 98.3
- Figures 25, 26. *Caryophyllidites* sp.  
Figured specimen GSC 112165/3800B; 35.7 x 94.5; mid- and low focus, respectively
- Figure 27. *Juglanspollenites tetraporus* Sung and Tsao  
Figured specimen GSC 112166/3500A; 29.7 x 110.4
- Figures 28, 29. *Celtispollenites tschudyii* (Elsik) comb. nov.  
28. Figured specimen GSC 112167/3900A; 38.4 x 103.1  
29. Figured specimen GSC 112168/4000A; 35.1 x 104.9
- Figure 30. *Juglanspollenites verus* Raatz  
Figured specimen GSC 112169/3600B; 45.1 x 105.6
- Figure 31. *Chenopodiipollis nuktakensis* Norris  
Figured specimen GSC 112170/1300B; 45.7 x 106.5
- Figure 32. *Anacolosidites* sp.  
Figured specimen GSC 112171/7900B; 39.3 x 104.7; low focus
- Figure 33. *Sigmopollis psilatus* Piel  
Figured specimen GSC 112172/600A; 44.8 x 96.4
- Figure 34. *Spinidinium* cf. *sagittulum* (Drugg) Lentin and Williams  
Figured specimen GSC 112173/5300B; 42.9 x 106.7 (400x)
- Figure 35. *Periporopollenites stigmosus* (Potonie) Thomson and Pflug  
Figured specimen GSC 112174/3700B; 47.6 x 103.9
- Figure 36. *Polyatriopollenites stellatus* (Potonie) Pflug  
Figured specimen GSC 112175/6800A; 41.6 x 93.5
- Figure 37. *Ulmipollenites undulosus* Wolff  
Figured specimen GSC 112176/4200B; 43.6 x 99.0
- Figure 38. *Micrhystridium fraseri* Piel  
Figured specimen GSC 112177/6800A; 37.9 x 102.1
- Figure 39. *Morkallacysta* sp. 375  
Figured specimen GSC 112178/6000B; 34.0 x 104.9 (400x)
- Figure 40. Dinoflagellate sp. S-1  
Figured specimen GSC 112179/6100A; 46.4 x 101.9 (400x)
- Figure 41. *Lentinia* sp. 373  
Figured specimen GSC 112180/6000B; 41.9 x 99.1 (400x)
- Figure 42. *Melittasphaeridium pseudorecurvatum* (Morgenroth) Bujak et al.  
Figured specimen GSC 112181/5900B; 46.0 x 101.4 (400x)
- Figure 43. *Homotryblum tenuispinosum* Davey and Williams  
Figured specimen GSC 112182/7200B; 40.8 x 102.9 (400x)
- Figure 44. *Geiselodinium* sp. 371  
Figured specimen GSC 112183/5600B; 56.9 x 109.5 (400x)
- Figure 45. *Phelodinium* sp. 377  
Figured specimen GSC 112184/6500B; 46.2 x 106.7 (400x)
- Figures 46, 47. *Sengalinium* cf. *microgranulatum* (Stanley)  
46. Figured specimen GSC 112185/4700B; 48.7 x 97.8 (400x)  
47. Figured specimen GSC 112186/4700B; 51.5 x 105.6 (400x)
- Figure 48. *Apectodinium hyperacanthum* (Cookson and Eisenack) Lentin and Williams  
Figured specimen GSC 112187/5000A; 33.9 x 107.2 (400x)
- Figure 49. *Cerodinium* cf. *striatum* (Drugg) Lentin and Williams  
Figured specimen GSC 112188/3900A; 34.1 x 101.1 (400x)
- Figure 50. *Lentinia serrata* Bujak  
Figured specimen GSC 112189/8900B; 44.0 x 97.9 (400x)
- Figure 51. *Maduradinium turpis* Norris  
Figured specimen GSC 112190/4500B; 27.2 x 92.4 (400x)
- Figures 52, 53. *Palaeoperidinium* sp. 367  
52. Figured specimen GSC 112191/5800B; 33.8 x 100.7 (400x)  
53. Figured specimen GSC 112192/5800B; 50.8 x 97.4 (400x)

