Palynology of the Eocene Kitsilano Formation, southwest British Columbia

WILLIAM S. HOPKINS, JR.

Institute of Sedimentary and Petroleum Geology, Calgary, Alberta

Received February 5, 1969

Approximately 55 genera and 75 species of plant microfossils are illustrated and described from the Kitsilano Formation of southwestern British Columbia. The general composition of the flora suggests a humid, warm temperate climate prevailed at time of deposition. Previous work on plant megafossils indicates a late Eocene to possibly early Oligocene age. Plant microfossils recovered in this study support a probable middle to late Eocene age for the Kitsilano Formation.

Introduction

This report presents the results of a Tertiary palynological study of the Kitsilano Formation, southwestern British Columbia. This formation, probably an Eocene coastal deposit, produced a relatively large number of species of plant microfossils. The work is based on analysis of about 40 shale and coal samples collected in various Kitsilano outcrops and building excavations, as well as 14 stratigraphically located samples from an artificial excavation known as the Highbury Tunnel.

Acknowledgments

Appreciation is expressed to Dr. Glenn E. Rouse of the University of British Columbia, who supervised the Ph.D. thesis of which this is a part. Dr. Rouse also read this manuscript and offered many useful suggestions. Thanks are also due to Dr. Richard Hedlund of the Atlantic Richfield Company, who also read the manuscript at an early stage and offered numerous suggestions and improvements.

Geology

General Remarks

The Kitsilano Formation is the upper of two continental sedimentary formations which underlie the city of Vancouver, British Columbia. Both formations, the lower Burrard and the overlying Kitsilano, dip gently (ca. 10°) into the Whatcom basin, a structural and topographic low (Text-fig. 1). This basin is about 50 mi in northwest–southeast diameter with its north margin along the Coast Mountains north of Vancouver and its south margin near Bellingham, Washington. To the north, east, and south the basin is rimmed by hills and mountains composed of older and diverse rock types. To the west the Whatcom basin is open to the Strait of Georgia depression but the structural and stratigraphic connections are only imperfectly understood. Further discussion of the general geology, plus a complete list of references, can be found in Hopkins (1966). The discussion of the geology of the Kitsilano and Burrard formations is based largely on the work of Johnston (1923); little additional geologic work on either of these formations has been done since Johnston's classic studies.

Burrard Formation

The Burrard Formation was named by Johnston (1923) for a series of continental clastic rocks that underlie the city of Vancouver and which sporadically crop out along the south shore of Burrard Inlet for a distance of approximately 15 mi. Several small outcrops occur on the north shore of Burrard Inlet along the lower reaches of Capilano Canyon (Brothers Creek, Text-figs. 2 and 3).

The Burrard Formation is about 2000 ft thick, consisting of conglomerates, sandstones, and shales and a few thin interbedded lignitic seams. The base of the formation, at least to the north, rests unconformably upon the granitic rocks of the Coast Range Mountains and is exposed only in the lower canyon of the Capilano River. Within the Whatcom basin, the Burrard apparently rests on Cretaceous rocks equivalent to the Nanaimo Group. This relationship is not exposed but is documented in several well sections and will be reported on in a later paper. Beds higher up in the section are exposed from Prospect Point (Stanley Park, Text-fig. 2) more or less continuously along the

west side of Stanley Park. The general attitude of the formation appears to be a continuous south dip of 10 to 15°.

The base of the formation is marked by a 50-ft thick basal conglomerate that is composed largely of subangular granodiorite boulders up to 6 in. in diameter, accompanied by minor amounts of diorite, greenstone, chert, quartzite, and schist boulders set in a sandy, ferruginous matrix (Johnston 1923; Hughes 1946). The upper portion of the Burrard Formation consists of a coarse-grained feldspathic sandstone interbedded with sandy shale. According to Johnston, a

total of 1300 ft of strata is exposed along the west shore of Stanley Park; of this thickness, 1100 ft is sandstone and the rest shale.

Johnston placed the top of the Burrard Formation beneath a "basal conglomerate" of the overlying Kitsilano Formation. This conglomerate is not everywhere present and the similar lithologies of the two formations make distinctions difficult. A real possibility exists that this may simply be an interbedded conglomerate and may have no particular time significance, i.e. a time break here may be inconsequential (Rouse 1962).
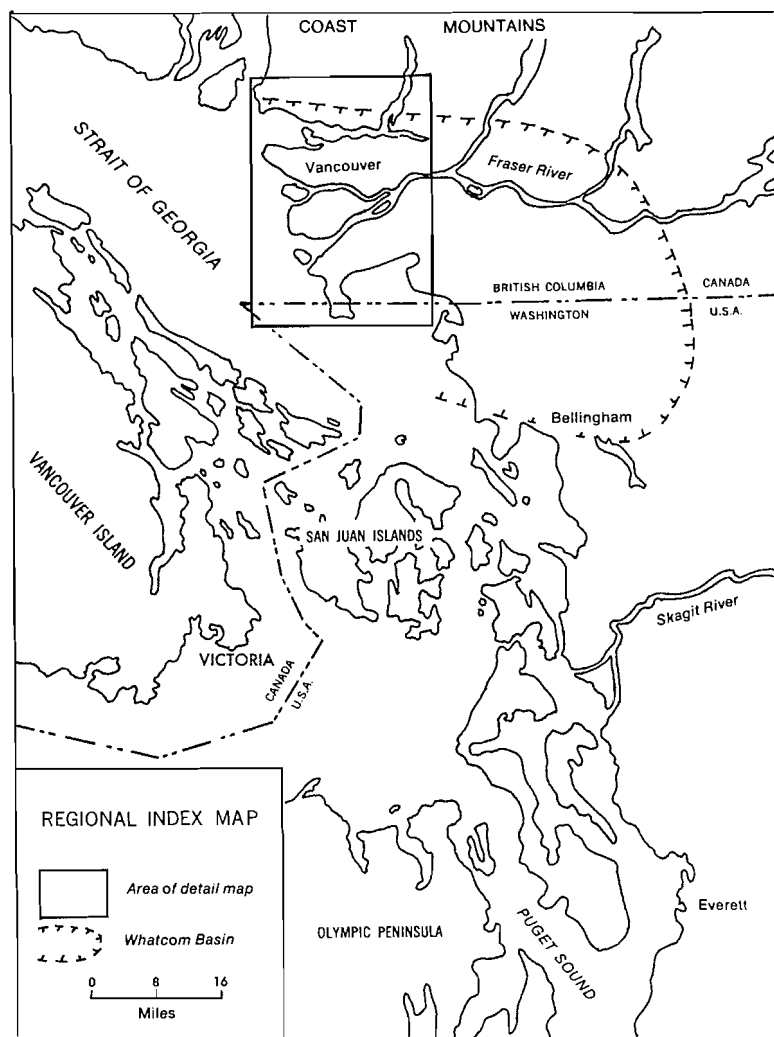
TEXT-FIG. 1. Index map of southwestern British Columbia and northwestern Washington indicating area of interest.

A number of assemblages of fossil plants have been collected and examined from the Burrard Formation. J. W. Dawson (1895) studied a collection of plant remains from the Stanley Park area along the south shore of Burrard Inlet and concluded the beds were Eocene in age. E. W. Berry, after studying a plant collection made by Johnston from the same general site, reported that the rocks were middle or upper Eocene (reported in Johnston 1923). Berry (1926) added: "There can be no question of the Eocene age of these plants, ..." Rouse (1962), after a study of the plant microfossils, concluded that the Burrard Formation south of Burrard Inlet is middle Eocene in age. He reported further that the "Burrard Formation" of the North Shore in Capilano Canyon (Brothers Creek) was considerably older, possibly Cretaceous and equivalent to part of the Upper Nanaimo Group (Text-fig. 3). The nature of the contact between the North Shore beds and the Burrard Formation to the south of the inlet is unknown because it lies below the waters of Burrard Inlet. Crickmay and Pocock (1963), using palynological techniques, suggested that the Burrard Formation was Upper Cretaceous and correlated it with the plant-bearing portions of the Nanaimo Group on Vancouver Island. According to Johnston (1923) the "Burrard Formation was deposited mostly in shallow water and in part sub-aerially on an alluvial plain under humid-warm climatic conditions and nearly at sea level. It is not a true delta deposit, at least in the landward part, but may pass into delta deposits." He suggests the possibility that all of the Georgia depression (the Strait of Georgia, to the west, and now below sea level), was an alluvial plain and that the sea did not extend into the region. Because some 2000 ft of sedimentary rock are present in the Burrard Formation, subsidence probably was active during the period of deposition.

Kitsilano Formation

The Kitsilano is a rather inadequately delimited unit overlying the Burrard Formation, and underlying the Pleistocene sediments on which the city of Vancouver is built. It crops out along Kitsilano Beach, at various places along the south shore of Burrard Inlet, and east to Burnaby Mountain. Building excavations within the northern part of the city frequently penetrate the Kitsilano (Text-fig. 2).

As suggested above, the evidence for a prolonged time break between the Burrard and Kitsilano Formations is highly uncertain at best. Indeed, even Johnston (1923) observed ". . . since both formations are in large part composed of material deposited on land or in shallow water, it is possible that the apparent break is due to contemporaneous erosion." Roddick (1965) no longer maintains the distinction between Kitsilano and Burrard formations and considers them one unit. He adds that "Armstrong (report in preparation) indicates that the subdivision should be abandoned and a new name proposed for the assemblage."

For the purpose of this report, I shall continue to use the terms Burrard and Kitsilano formations in the older sense of distinct rock units and in the sense they were defined by Johnston. Because the Kitsilano dips to the south and disappears beneath a mantle of Pleistocene outwash and till, the top of the formation is not visible. From several lines of evidence, Johnston considered a conservative estimate for the thickness of the Kitsilano Formation to be 1500 ft. However, more recent data acquired from excavation of sewer and other tunnels, as well as from water wells, suggests that a minimum thickness of 2500 ft is present. But because outcrops are limited and because we are still uncertain about the validity of the Kitsilano–Burrard contact, the actual thickness is still unknown.

The so-called Kitsilano basal conglomerate contains pebbles and boulders ranging from 1 to 10 in. in diameter. Near Second Narrows, Johnston described imbricated gravels, suggesting deposition by a westerly flowing river. The rock fragments are mostly granitic and apparently derived from the Coast Mountains. Also present are schistose rocks and pebbles of shale, the latter presumably derived from the Burrard Formation.

Sandstones and shales make up most of the middle and upper parts of the Kitsilano Formation. The sandstones are coarse-grained, frequently cross-bedded on a small scale, and occasionally contain thin lenses and irregular masses of lignitic coals. The sand grains are generally angular, contain an abundance of heavy minerals such as biotite, chlorite, hornblende, olivine, garnet, and sphene (Thomson 1958). Thomson also added that the fresh,

angular nature of the sand grains "indicates that transportation has not been great, and that conditions of rock destruction were mechanical rather than chemical." The source rocks were apparently metamorphic and igneous, also suggesting a source in the Coast Range to the north.

The shale is often blue-grey and usually sandy. Locally, both sands and shales contain remains of logs that have been altered to lignite. Stream channelling, similar to that of the Burrard Formation, is found throughout the middle and upper Kitsilano.

The Kitsilano Formation shows the same attitude as the underlying Burrard Formation and at Kitsilano Beach dips to the south at 6 to 9°. Attitudes measured south of the Kitsilano Beach outcrop, within artificially excavated tunnels are 9 to 10°. To the south, for as far as direct measurements can be made, the southerly dip is reasonably constant. What happens deeper in the Whatcom basin to the south, can only be inferred from the study of plant microfossil assemblages in wells and outcrops. The results of the well investigations will be published in a later report.
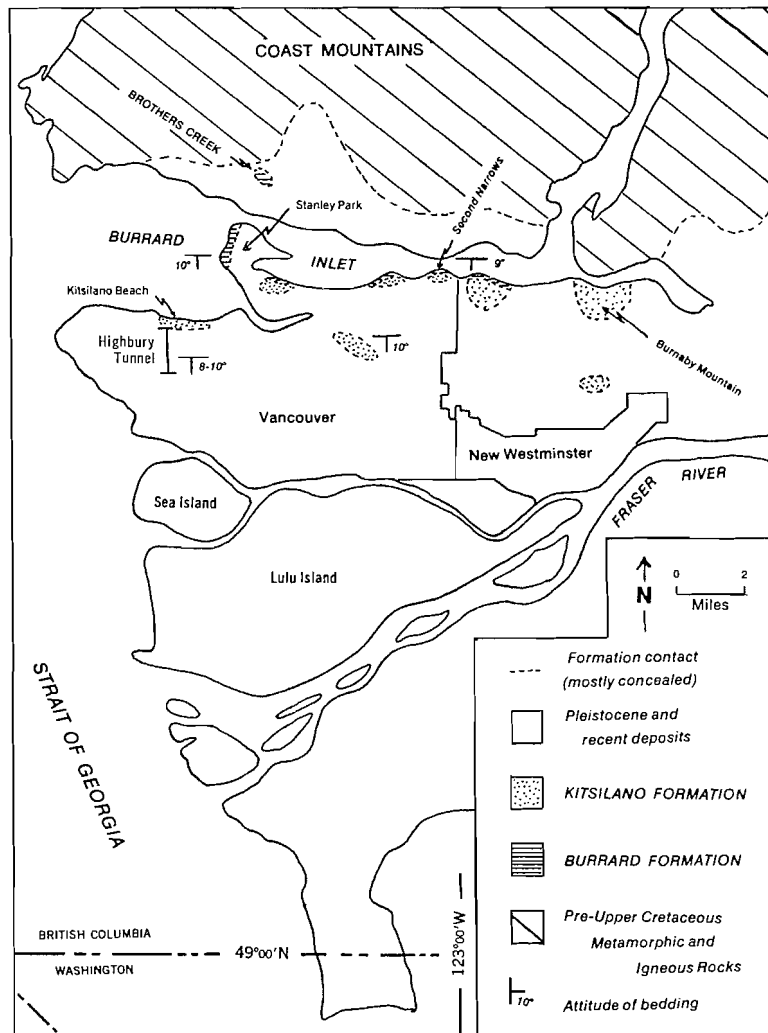
TEXT-FIG. 2. Geologic sketch map of Vancouver area showing location of Kitsilano Formation outcrops.

Plant microfossils and leaves are locally abundant in the Kitsilano Formation. A collection of leaves from exposures at Kitsilano Beach were identified and discussed by E. W. Berry. He concluded that "the general facies of the Kitsilano plants is, in my judgement, entirely Eocene and does not in the slightest degree suggest later Tertiary" (quoted by Johnston 1923). Berry, in personal communication to Johnston, goes on to say "there is no objection to considering the Burrard Inlet plants as Middle or Upper Eocene, and Kitsilano plants as Upper Eocene or Lower Oligocene." Somewhat later (1926) Berry states "the conclusion that the beds at Kitsilano are Eocene is strongly indicated . . . Just what part of the Eocene is perhaps not determinable at the present time. I would regard it as Late Eocene . . . ."

Johnston, in referring to the origin of the Kitsilano sediments, suggests they are similar to the Burrard, i.e. an alluvial plain deposit which may pass into delta sediments westward and southward. Neither formation shows any evidence of marine deposition, nor are there any

EPOCH	NORTHWESTERN WASHINGTON WELL SECTIONS	SOUTHWESTERN BRITISH COLUMBIA OUTCROPS		NORTHWESTERN WASHINGTON OUTCROPS
PLIOCENE				
MIOCENE	Unnamed Sedimentary Rocks			
OLIGOCENE				
EOCENE	KITSILANO AND BURRARD EQUIVALENTS	KITSILANO FORMATION BURRARD FORMATION	Unnamed Outcrops	Scattered Unnamed Outcrops
PALEOCENE				CHUCKANUT FORMATION (Southern Whatcom Basin)
UPPER CRETACEOUS	LOWER CHUCKANUT	Brothers Creek NANAIMO GROUP (Vancouver Island)		

TEXT-FIG. 3. Stratigraphic section showing major rock units of Vancouver area. Ages and correlations are interpretations of the author based on available geologic literature. Age revisions in the future are possible but relative stratigraphic positions are correct.

marine fossils. Channel structures, cut and fill structures, and imbricated gravels all imply an alluvial origin. Even the shales must have been deposited in shallow water because they contain abundant sand grains which probably could not have been carried far.

Age

General Comments

The Tertiary was a period of pronounced climatic and topographic change, during which floras evolved and altered their composition. Because of these changes, analysis of the floral record should be, and often is, usable as an age-dating method.

Unfortunately, however, the study of Tertiary palynology in North America has not progressed to the point where it can give absolute answers to the question of age. In fact, because of interpretive difficulties, some workers have assigned only Paleogene or Neogene ages to certain floras. The problem of the Pacific Coast Tertiary is particularly difficult because only enough has been done to be tantalizing. Many of the Alaskan and British Columbia floras have not been assigned absolute ages, but are themselves dated by floral similarities and differences. Recently MacGinitie (1966), while discussing Eocene floras of the Middle Rocky Mountains, commented on the significant vegetative variation present in Wyoming floras of essentially the same age. He added (p. 40) that "such diverse vegetation types indicate that fossil floras cannot be used as accurate age indicators on the basis of floral composition alone, unless a sequence of vegetation types is established for each separate sedimentation basin."

Further complications of interpretation are added in that definite Paleocene, Oligocene, and Pliocene floras have not been reported in the North Pacific area. In short, the typical microfossil or leaf assemblages for these time intervals have not been established. Eocene assemblages, however, are well documented from various other parts of North America, and appear to have basically similar floral elements.

Age of the Kitsilano

Rouse (1962) suggested that the Burrard Formation is most probably middle Eocene, which, if correct, indicates that the Kitsilano is middle Eocene or younger. Microfloral study of

this unit was based on samples taken from Kitsilano Beach, from transient exposures in building excavations, and a series of samples taken from the north–south Highbury sewer tunnel on Point Grey. This tunnel (Text-fig. 2), which was driven from 5th and Highbury Streets due south to the north arm of the Fraser River, penetrated about 1000 ft of Kitsilano Formation dipping 8 to 10° due south. In the vicinity of 22nd and Highbury Streets, the tunnel passed through the Kitsilano into the overlying Pleistocene outwash and till.

There is little indication of a fundamental change in either age or environment within the rocks of the Kitsilano Formation. As a result, I have considered the formation as a single unit. The microfossil assemblage is very similar to that of the underlying Burrard as described by Rouse (1962). Some of the more important genera are *Osmunda*, *Anemia*, *Cicatricosisporites*, *Lygodium*, *Pinus*, *Taxodium*, *Podocarpus*, *Salix*, *Alnus*, *Carpinus*, *Corylus*, *Castanea*, *Fagus*, *Quercus*, *Carya*, *Engelhardtia*, *Pterocarya*, *Ulmus-Zelkova*, *Tilia*, *Myrica*, and Liliaceae. A variety of fungal spores are also widely represented.

There are, however, several distinct and perhaps significant differences in the microfossil assemblages of the Burrard and Kitsilano Formations. *Tsuga* is not found in the Kitsilano but occurs in low frequency in the Burrard Formation. *Ilex* is absent in the Burrard, but is commonly present throughout the Kitsilano, becoming more abundant stratigraphically upwards. In the stratigraphically youngest Kitsilano sample, which is a carbonaceous shale, *Ilex* reaches 27% of the total pollen count. *Platycarya*, while not common, is present in the upper half of the Kitsilano but was not reported from the Burrard. Finally, *Pistillipollenites*, which locally reaches several percent in the Burrard, is present only in the lower part of the Kitsilano.

The fact that *Ilex* is present suggests either a short time break between Burrard and Kitsilano times or the establishment of *Ilex* during the early stages of Kitsilano deposition. *Platycarya* appears in the upper part of the Kitsilano, suggesting that the plant migrated into the region during Kitsilano time. Rouse (1962 and personal communication) and Hills (1965) believe that *Pistillipollenites* is most representative of the middle Eocene. However, Hedlund (1966) found

Pistillipollenites in the Cenomanian of Oklahoma and has since concluded (personal communication) that this genus is pre-Eocene in age. However, in British Columbia it is absent in Cretaceous rocks and has been found in radiometrically dated middle Eocene rocks of Interior British Columbia. *Pistillipollenites* appears to be an Eocene form of the North Pacific coast. Because of the presence of *Cicatricosisporites* and *Platycarya* I have concluded that the Kitsilano is no younger than Eocene. The former seems to have a stratigraphic range on the Pacific coast which terminates in upper Eocene or lower Oligocene, while the latter appears restricted to Eocene and older rocks throughout North America. The complete absence of exclusively Cretaceous forms suggests the Kitsilano is no older than Eocene, which is consistent with the upper Eocene age suggested by Berry (1926).

Geologic considerations also bear on the age of the Kitsilano. The lithologies of the Burrard and Kitsilano are similar, and both units apparently were formed under the same depositional environment. No clear-cut formational contact appears between them except for a discontinuous conglomerate which has been assumed to be a basal conglomerate. No real evidence has been presented to show that this is anything more than a local conglomeratic lens, without regional or temporal significance.

The lack of a conspicuous break between the formations; the lithologic, textural, and structural similarities; and the floral similarities lead me to conclude that the Kitsilano is not really a distinct unit differentiated from the Burrard, but that both represent a continued period of locally discontinuous deposition. Perhaps local disastems occur within the Burrard–Kitsilano, but they are not of sufficient magnitude to be called unconformities. If this is so, the formational names Burrard and Kitsilano should be discarded and an all-encompassing name applied to both.

In summary the Burrard Formation has been established as probably middle Eocene age (Berry 1926; Rouse 1962); the Kitsilano Formation contains a microflora which appears to be characteristically coastal middle to upper Eocene; and the two formations are probably conformable. Therefore, I have concluded that the Kitsilano is middle to late Eocene in age.

Paleoecological Interpretations
General Considerations

Ideally, plants are the most sensitive of the terrestrial ecological indicators. Animals can roam and move about if climatic conditions become unfavorable, but plants are rooted to one spot and must tolerate the environment in which they grow. Furthermore, the tolerance in their environmental requirements is less than for most animals. Because the most critical stage in a plant's entire growth cycle is at germination, a changing environment will allow survival of the reproductive propagules only if they fall in a favorable site. Because of this, a changing climate can markedly alter the flora in a comparatively few years. As a consequence, analysis of fossil floras should provide data on climatic conditions at the time of growth.

And indeed they do, but several problems loom large. In palynology, as in all paleontology, a generally accepted truism is the old saw, "the present is the key to the past." In paleoecologic interpretations it must be assumed that organisms, whether plant or animal, reacted to a given environment in much the same way as do their modern counterparts. In other words, an alder and an elm would have had the same ecologic requirement in the Miocene as they do today. The practical problem with this assumption is that ecologists are not really familiar with the complete ecological requirements and the range of tolerance of most genera and species of plants. This is true with temperate species, and is even more so with tropical and subtropical species. Furthermore, within any given genus the range of variability may be (and usually is) high, with each species requiring slightly different conditions. However, in virtually all studies where plant microfossils are used to interpret paleoecology, palynologists are not dealing with natural species but only with natural genera. The species of microfossils or other plant parts are artificial, at least in rocks older than Pliocene, and are based on various morphological differences which may or may not have significance in reflecting natural (or phylogenetic) relationships. In any event, in very few cases can they be equated to modern species. It is usually best to take the total range of variables within a genus, and use as many genera as possible to interpret paleoecology. Hopefully, a large microfossil assemblage will give a qualitative estimate

TABLE I

Range and ecological requirements of modern genera whose fossil counterparts have been
identified from the Kitsilano Formation (modified after Rouse (1962), Hills (1965) with
additions from Bailey (1949), Lawrence (1951), Graham (1965), Smiley (1966),
and Willis (1966)

Genus	Habitat and geographic range	Climate
Isoetes	Moist areas to aquatic, cosmopolitan	Temperate to tropical
Lycopodium	Most are mesophytic, cosmopolitan	Temperate to tropical
Osmunda	Swamps, shaded moist woodland, mainly Northern Hemisphere	Temperate to tropical
Anemia	Wet lowlands and rain forests; particularly in tropical America	Subtropical to tropical
Lygodium	Swamps, shaded moist areas, Southern Hemisphere	Subtropical to tropical
Gleichenia	Swamps, shaded moist areas, mainly Southern Hemisphere	Tropical to subtropical
Azolla	Quiet lake and pond waters	Warm temperate to tropical
Ginkgo	Open stands, well-drained areas, west China	Warm temperate, 40–60 in. precipitation
Cedrus	Dense forests, northern Africa, southern Asia	Temperate to subtropical
Keteleeria	Dense forests, China	Warm temperate
Larix	Marshes to woodlands, mainly Northern Hemisphere	Cool temperate to boreal
Picea	Moist soils, mainly Northern Hemisphere	Cool temperate, generally high altitude
Pinus	Swamps to rocky highlands, predominantly dry sites, Northern Hemisphere	Variable
Glyptostrobus	Associated with evergreen oak forest, generally moist to swampy habitats, southeast China	Warm temperate to subtropical, 50–60 in. precipitation
Metasequoia	Wet ravines in mountains, central China	
Taxodium	Swamps and flood plains of southeastern United States and Mexico	Warm temperate to subtropical, 50–60 in. precipitation
Podocarpus	Moist woodlands and mountains of the Southern Hemisphere, Caribbean, and South America	Warm temperate
Taxus	Northern Hemisphere, mostly small trees in woodlands	Temperate
Magnoliaceae	Trees and shrubs, some climbing, cosmopolitan	Warm temperate, subtropical to tropical
Salix	Damp thickets, swamps, cool woods, cosmopolitan	Variable
Alnus	Swamps, wet woods, stream margins, cosmopolitan	Variable
Betula	Uplands to bog and wooded swamp, Northern Hemisphere	Cool temperate
Carpinus	Upland woodlands to coastal swamps, Northern Hemisphere	Cool temperate
Corylus	Thickets, woodlands, Northern Hemisphere	Temperate
Castanea	Dry woods, thickets, Northern Hemisphere	Cool to warm temperate
Fagus	Forms homogeneous, Northern Hemisphere	Temperate
Quercus	Wide range of habitats, Northern Hemisphere, mountains of the tropics	Variable
Carya	Variable habitats, China, southeast Asia, eastern North America	Cool temperate to subtropical
Juglans	Woods and river terraces, southeastern United States, South America, southeastern Europe, Asia	Warm temperate to subtropical
Platycarya	Japan and northern China	
Pterocarya	Northern Hemisphere of old world	Temperate
Tilia	Low slopes and along streams, Northern Hemisphere	Temperate
Acer	Variable habitats, Northern Hemisphere	Cool to warm temperate
Aesculus	Woods, bottomlands and stream borders and thickets, Northern Hemisphere, and South America	Temperate

TABLE I (Concluded)

Genus	Habitat and geographic range	Climate
Ilex	Bogs, moist depressions, cosmopolitan	Warm temperate to subtropical
Proteaceae	Mostly xerophytic, restricted to Southern Hemisphere	Tropical; most indicate long annual dry season
Myrica	Variable habitats, cosmopolitan	Temperate to subtropical
Sabal	Lowlands, river bottoms, coastal plains, southeastern United States, Caribbean, Columbia	Subtropical to tropical
Typha	Marshes, along river banks, cosmopolitan, except south of equator in Africa	Temperate to tropical
Potamogeton	Herbaceous in streams and ponds, a few along sea margin	Cool temperate to subtropical

of the climatic conditions at the site of deposition while the particular flora was in existence.

Another problem is whether a given sample is truly representative of the extant flora at the time of deposition. Several considerations must be borne in mind while evaluating the data. Differential preservation is always a factor— some pollen grains survive bacterial and fungal attack, oxidation, hydrolysis, and rock diagenesis more readily than others. Certain pollen grains are thin-walled and fragile (i.e. *Thuja* and *Populus*) and easily destroyed. Others are attacked by bacterial action (i.e. *Acer*) and may be underrepresented. Others, because of their exceptionally durable nature (i.e. fungal spores and many spores of the Pterophyta) may be overrepresented. Furthermore, pollen and spores are produced in vastly different quantities by different genera. For example, a 10-year-old branch system of beech has been estimated to produce 28 million pollen grains per year, while an equivalent branch system of pine may produce 350 million grains (Faegri and Iverson 1964). This difference will obviously be reflected in the quantities of pollen grains obtained from maceration of rock samples and used in slide counts.

The method of pollen dispersal also reflects relative quantities. Wind pollinated species (i.e. *Pinus*) which usually produce pollen in enormous quantities will be abundant in the fossil record, whereas insect pollinated plants (i.e. *Acer*) produce relatively few pollen grains. As a result, *Acer* may be underrepresented in a microfossil spectrum and its importance in the assemblage may be underrated. In the case of *Acer*, a pollen grain which is also easily destroyed, the combination of low relative productivity and com-

parative fragility may result in its absence entirely from the pollen record.

Factors such as these undoubtedly lead to complications of interpretation and must always be borne in mind when arriving at ecological conclusions. However, if floras are taken as a whole, and if adequate consideration is given to the various modifying factors, a fairly reliable analysis of surrounding vegetation is possible.

Discussion of Kitsilano Paleoecology

The Kitsilano microfossil assemblage is largely composed of genera whose modern components are warm temperate to subtropical (see Table I). Most of the genera, such as *Anemia, Taxodium, Salix, Alnus, Ilex, Sabal,* and *Typha* are now characteristic of low, moist, and poorly drained coastal areas. The presence of *Azalla* and *Potamogeton,* which presently inhabit ponds and (or) lakes, indicate the presence of standing water on this lowland.

Other microfossils which suggest a more upland habitat are present. These include *Pinus, Picea, Podocarpus, Carya, Corylus,* and *Quercus.* How far these trees were growing from the site of deposition is uncertain, but their low frequency of occurrence would suggest it was some distance away. *Pinus* and *Picea,* whose pollen is produced in prolific amounts, are not common microfossils in any of the Kitsilano rocks. The few bladdered conifer grains that are present are seldom well preserved, are often physically broken, and are almost inevitably corroded. The implication is that their habitat was a considerable distance away, probably to the north, east, or south. Transport to the depositional site was probably largely by streams, which accounts for the poor physical preservation.

The lithologies, insofar as they are visible in the Kitsilano and Burrard Formations, as well as in other Eocene outcrops, bear out this interpretation of a lowland environment. Sands and shales predominate, river and stream channels are common, and thin coal seams are present, as are occasional cross-beds. Together these characteristics indicate the existence of lowlands and swamps. The picture that emerges is similar to that proposed by Johnston (1923) of a low, swampy coastal plain, spotted with small lakes, ponds, and swamps, and traversed by generally slow-moving, meandering streams flowing westward to their junction with the sea.

In summary, the Eocene in the area of the Whatcom basin appears to have been warmer and more humid than at present, but probably not truly subtropical. Highlands must have surrounded the basin of deposition, but relief was far less than at present. Precipitation was moderately high, probably 50 to 60 in. annually and was more or less uniformly distributed throughout the year.

Palynology

General Taxonomic Considerations

As every palynologist knows, the classification and description of plant microfossils is in a chaotic state with no uniform system acceptable to all workers. There are, however, two broad schemes in use, each with its advantages, i.e. a natural classification and a morphologic classification.

In this work I have elected to use the system which is commonly applied by many Tertiary palynologists, i.e. a combination of these two broad systems. This involves identification to an extant genus wherever possible, and in some cases assignment to a form species in that genus. However, I have generally been conservative in my approach to subdividing a genus into species. It is often the practice in paleontology to subdivide or to split into ever smaller units, often on dubious grounds. If, within a given genus there are two or more forms which are clear cut, distinct, and easily recognized, a subdivision into form species is more useful in stratigraphic studies. If, however, as appears to be more often the case, subdivisions are based on end products of evolution showing intergradations of form or on idefinite and vague criteria, little

but confusion results, and comparisons between microfossil assemblages become difficult. Besides, this leads to unnecessary and meaningless proliferation of specific names. For palynomorphs which cannot be assigned to modern genera I have used form generic names. At times, I have suggested possible or probable botanical affiliations, but this is often only an opinion and in some cases cannot be substantiated.

A section in the taxonomy called "Frequency" gives a rough measure of the abundance of the palynomorph. "Rare" indicates that the given palynomorph occurs as less than 1% of the total spore and pollen count, exclusive of fungal spores. "Occasional" indicates 1 to 5%. "Common" indicates 6 to 10% while "Abundant" refers to grain occurrence in excess of 10% of the total count.

Because of the variation in application and definition of various textural and sculptural terms, I have followed closely the terminology suggested by Faegri and Iverson (1964). The plant taxonomic classification employed is the system outlined in Scagel et al. (1965).

In the following section I have described microfossils representing approximately 55 genera and 75 species from the Kitsilano Formation, whose occurrence ranges from abundant in nearly all samples to a single occurrence in one sample.

Division EUMYCOTA
Class FUNGI IMPERFECTI
Form Genus *Dyadosporonites* Elsik 1968

Dyadosporonites sp. 1
Fig. 1

DESCRIPTION: Spores bilocular, 35 to 74 μ long, elliptical, aperture characteristics questionable, but apical and presumably circular. Central septum simple and 2–3 μ thick. Wall psilate.

REMARKS: Similar fungal spores have been recorded in Upper Cretaceous, Eocene, and Pliocene beds.

BOTANICAL AFFINITY: Probably spores of a rust.

FREQUENCY: Rare.

Dyadosporonites sp. 2
Figs. 2–3

DESCRIPTION: Spores elliptical, biporate, and bicellular, size 55 to 75 μ. Pores large, circular,

slightly aspidate, some subwall thickening. Large thickened septum through middle of grain, apparently dividing grain into two cells, each with an apical pore. Wall thick (ca. 2 μ) and heavy.

REMARKS: This grain is referred to the genus *Dyadosporonites* as redefined by Elsik (1968). It differs from *Dyadosporonites* sp. 1 in having a heavier and less well-defined septum as well as larger and more distinct apical pores.

FREQUENCY: Rare.

Form Genus *Pleuricellaesporites* Hammen ex Clarke 1965

Pleuricellaesporites psilatus Clarke 1965
Figs. 4–6

DESCRIPTION: Uniseriate fungal spores with individuals consisting of several to many cells. The width varies from 12 to 25 μ and the length may be in excess of 100 μ, depending upon the number of component cells. Length of individual cells 6 to 12 μ. A 0.5 to 1.0 μ diameter aperture occurs in each septum. Thickenings on one side of the septum appear as adjacent triangles with the aperture occurring between them. Cell walls psilate.

REMARKS: These spores are identical in all respects with those described by Clarke (1965). They are particularly common in many early Tertiary horizons of Arctic and Western Canada. They are also common in numerous outcrop samples from Eocene and Oligocene rocks of coastal Oregon and Washington.

BOTANICAL AFFINITY: Spores of a fungus.

FREQUENCY: Common.

Pleuricellaesporites sp.
Fig. 7

DESCRIPTION: Spores 35 to 50 μ long with a length:width ratio of about 2:1, multicellular, usually with three perforate cross walls. There is a suggestion of a pore at either end, but ruptured ends leave this unclear. Thickening on one side of the septum appears as two adjacent triangles.

REMARKS: The pattern of thickened septa which appear triangular suggests strongly that this particular fungal spore should be assigned to the genus *Pleuricellaesporites*. Possibly this form is identical with *P. psilatus* but is more mature, developed by constriction of every third cell. However, these spores always have

four cells separated by three septa; furthermore, no intermediate stages were recognized. Consequently assignment to a separate species is tentative.

FREQUENCY: Rare.

Fungal Hyphae
Fig. 8

DESCRIPTION: Segmented and germinating fungal hyphae, overall length 150 μ, average thickness of hypha is 7 μ.

REMARKS: Although of no known diagnostic value, this is a common fossil in the Kitsilano Formation. Of interest are the young budding hypha and widely spaced and perforate septa shown on Fig. 8.

FREQUENCY: Abundant.

Division LYCOPODOPHYTA
Order ISOETALES
Family ISOETACEAE
Genus *Isoetes* L.

?*Isoetes* sp.
Figs. 9–10

DESCRIPTION: Small (17 to 23 μ) monolete microspore (pollen?). Characteristically the sulcate furrow extends about two-thirds length of grain, in some gaping slightly, in others tightly closed. Sculpture scabrate.

REMARKS: Assignment of this microfossil to *Isoetes* remains highly tentative, but it closely resembles the illustration and descriptions given by Erdtman (1943) for *Isoetes* microspores.

FREQUENCY: Rare.

Order LYCOPODIALES
Family LYCOPODIACEAE
Genus *Lycopodium* L.

Lycopodium annotinioides (Krutzsch)
Martin and Rouse 1966
Fig. 11

DESCRIPTION: Trilete spore, 30 to 35 μ, with moderately distinct laesurae reaching from pole to equator. Subcircular in polar view; distal surface and equatorial area of proximal surface covered with a reticulum of narrow muri and wide lumina. Reticulum 4 to 6 μ between muri; muri up to 2 μ high. Exine thin.

REMARKS: These specimens are identical with those found by Martin and Rouse (1966) from the Miocene or Pliocene Skonun Formation of

the Queen Charlotte Islands, British Columbia. Their extremely thin exine makes them rather inconspicuous and difficult to photograph.

FREQUENCY: Rare.

Division PTEROPHYTA
Order FILICALES
Family OSMUNDACEAE
Genus *Osmunda* L.

Osmunda regalites Martin and Rouse 1966
Fig. 12

DESCRIPTION: "Trilete spores, spherical in outline. Laesurae simple, usually gaping slightly, and ranging from 18 to 22 μ in length. A thin but distinct margo borders the commissure. The wall is about 1 μ thick and appears to be rigid, as little folding has been observed. The ornamentation is characteristically rugulate with the rugulae short and thick, and packed close together. Individual rugulae range to 3 μ in length but rarely exceed 0.5 μ in height" (Martin and Rouse 1966).

FREQUENCY: Abundant.

Osmunda irregulites Martin and Rouse 1966
Figs. 13–14

DESCRIPTION: "Trilete spores, sub-circular in outline but usually folded or split open. Laesurae distinct, with a thin margo, and measuring about 17–22 μ in length. The ornamentation consists of bacula 1.5–2.5 μ long, 0.5–2.0 μ wide, and spaced 1–3 μ apart. The bacula are usually straight, occasionally clavate. There are no rugulate thickenings subtending the bacula. The most diagnostic feature is the complete irregularity of the width of the bacula; delicate, slender bacula are randomly mixed with stout-stump like bacula and with all grades in between. Size range 41–57 μ." (Martin and Rouse 1966).

FREQUENCY: Rare, but see "Remarks" under *Osmunda* sp. 2.

Osmunda sp. 1
Figs. 15–17

DESCRIPTION: Trilete spore showing considerable variation in shape. Trilete mark usually not distinct, but laesurae extend to equator. Ornamentation varies slightly from definitely baculate to weakly vermiculobaculate; bacula closely spaced, ranging from 1 to 3 μ in height. The wall is comparatively thin, which probably accounts for the wide variation in shape, ranging from prolate to spherical to irregular. Observed size range is 42 to 60 μ.

REMARKS: These microfossils differ from *O. irregulites* in the smaller and more densely packed bacula.

BOTANICAL AFFINITY: This spore type appears almost identical with modern *O. claytonia*.

FREQUENCY: Common, but see "Remarks" under *Osmunda* sp. 2.

Osmunda sp. 2
Figs. 18–20

DESCRIPTION: Subspherical, echinate, trilete spore, laesurae sharp and distinct, tapering to a point at the equator; wall thin, covered with short spines less than 1 μ high which are widely spaced over the entire surface. Size range 45 to 55 μ.

REMARKS: This form differs from *Osmunda* sp. 1 in having much more widely spaced projections. Furthermore, the ornamentation appears to be much more spiny than is characteristic of the three preceding species. Occasional blunt bacula are observed but on the whole the ornamentation is echinate.

Although four different species of *Osmunda* are described here, these are in reality probably end products of a continuum. Attempts to count *Osmunda* were continuously frustrated by uncertainty about which of the four groups particular specimens should be assigned. I feel at this time it would be unwise to assume that these grains represent four different species. All that can be said with certainty is that *Osmunda* was a common genus of fern throughout the time interval represented by Kitsilano deposition.

FREQUENCY: Occasional, but see above.

Family SCHIZAECEAE
Genus *Anemia* Swartz

Anemia poolensis Chandler 1955
Figs. 21–23

DESCRIPTION: These trilete spores are identical in all respects with those described by Chandler. Size range is 34 to 58 μ with most approximately 52 μ.

REMARKS: Kitsilano specimens are identical with those described by Rouse (1962) from the Burrard Formation and by Hills (1965) from

the middle Eocene strata of interior British Columbia.

FREQUENCY: Abundant.

Form genus *Cicatricosisporites* Potonié and Gelletich

Cicatricosisporites intersectus Rouse 1962
Figs. 24–27

REMARKS: Specimens from the Kitsilano Formation are identical with those described by Rouse (1962) from the Burrard Formation. *Cicatricosisporites intersectus* has not been found to date in the middle Eocene beds from the interior of British Columbia. Apparently it is an Eocene–?Oligocene species restricted to coastal lowlands. This species appears identical with *C. dorogensis* Potonié and Gelletich except that *C. intersectus* has ribbing over the entire proximal surface.

BOTANICAL AFFILIATION: *Cicatricosisporites* is a form genus with very definite schizaeceous affinities, resembling certain species of *Mohria* and *Anemia*.

FREQUENCY: Abundant.

Genus *Lygodium* Swartz

Lygodium reticulosporites Rouse 1962
Fig. 28

REMARKS: The grains of this species agree with those described by Rouse (1962) with an observed size range of 55 to 70 μ.

BOTANICAL AFFILIATION: Rouse comments (1962, p. 197) that "spores of this species resemble those of the living *Lygodium japonicum* Swartz and *L. kerstenii* Kuhn very closely."

FREQUENCY: Rare, but present in all Kitsilano samples.

Family GLEICHENACEAE
Genus *Gleichenia* Smith

Gleichenia sp.
Figs. 29–30

DESCRIPTION: Sharply triangular, laevigate, trilete spores, 25 to 30 μ in diameter. Rounded to pointed corners, weakly to strongly concave interradial areas. Wall thickens near proximal pole in interradial area, the thickenings extend toward the angles so that the trilete mark is enclosed by thickenings.

REMARKS: Very few specimens were found, and these could not, with confidence, be placed in an established species. Several specimens bear a resemblance to *G. triangula* Stanley 1965; however, for a discussion of fossil gleicheniaceous spores, see Skarby (1964).

FREQUENCY: Rare.

Family POLYPODIACEAE
Form genus *Laevigatosporites* (Ibrahim) Schopf, Wilson and Bentall

Laevigatosporites discordatus Thompson and Pflug 1953
Figs. 31–32

DESCRIPTION: Spores generally bean-shaped, monolete, laesurae short, wall laevigate, although some appear to be nearly circular; size range 40 to 80 μ.

BOTANICAL AFFILIATION: Rouse (1962) states "the closest affiliation appears to be with *Dryopteris*, particularly *D. latifrons*."

FREQUENCY: Common to abundant.

Laevigatosporites albertensis Rouse 1962
Fig. 33

DESCRIPTION: Kidney-shaped, monolete spores, with a weakly defined suture, always occurring along the concave crest. Ornamentation weakly punctate. Size range 32 to 36 μ.

BOTANICAL AFFILIATION: Rouse (1962) described this species from the Burrard Formation, suggesting that it is most likely related to *Dryopteris* or *Asplenites*, both of which have been reported as leaves in the Burrard.

FREQUENCY: Rare.

Laevigatosporites ovatus Wilson and Webster 1946
Not illustrated

DESCRIPTION: Monolete, bean-shaped spores, length 33 to 37 μ, smooth wall, simply monolete suture.

BOTANICAL AFFINITY: See *L. gracilis*.

FREQUENCY: Rare.

Laevigatosporites gracilis Wilson and Webster 1946
Not illustrated

DESCRIPTION: Bean-shaped monolete spores, laevigate, simple monolete suture on concave side, length 25 to 32 μ.

BOTANICAL AFFILIATION: Wilson and Webster (1946) remark that *L. gracilis* and *L. ovatus*

probably belong to *Thelypteris, Asplenium, Athyrium, Aspidium,* or *Blechnum.*

FREQUENCY: Rare.

Families DENNSTAEDTIACEAE–POLYPODIACEAE
Figs. 34–39

REMARKS: Martin and Rouse (1966) have discussed the difficulties in classifying the large reticulate–verrucate–warty monolete spores which are abundant in the Miocene and (or) Pliocene Skonun Formation. This spore pattern occurs in several different fern genera in at least two families, viz. Polypodiaceae and Dennstaedtiaceae, and sufficient gradation of ornamentation exists to defy generic identification. Potonié (1956) employed three form genera to include these three spore types, i.e. *Polypodiisporites, Polypodiites,* and *Verrucatosporites.* However, the fossil spores encountered in the Skonun Formation could not be assigned even to form genera. As a result, Martin and Rouse elected to use "non-committal form designates" for the three main forms.

In the present work I encountered identical problems of classifying these monolete spores— gradations from one morphological form to another occur. As a result, I have used the system suggested by Martin and Rouse. Forms 1, 2, and 3 are illustrated but not described. They are identical in all respects with the descriptions given by Martin and Rouse (1966, pp. 187–188).

FREQUENCY: Rare to common. One, two, or three of the forms may occur in the same sample.

Order SALVINIALES
Family SALVINIACEAE
Genus *Azolla* Lamarck

Azolla sp.
Fig. 40

DESCRIPTION: Only isolated anchor-shaped glochidia of *Azolla* were found in this study. The massulae and microspores were not encountered; the reason for their absence is not known. The glochidia are about 20 μ long, and 8 μ across the barbs.

REMARKS: *Azolla* appears to be especially common in Eocene rocks in the interior of British Columbia (Hills 1965) but has also been reported from Upper Cretaceous and rocks of other Tertiary epochs.

FREQUENCY: Rare.

Division GINKGOPHYTA
Order GINKGOALES
Family GINKGOACEAE
Genus *Ginkgo* L.

?*Ginkgo* sp.
Figs. 41–43

DESCRIPTION: Pollen monosulcate, shape oblate to peroblate, sulcus broad, generally closed in the middle and gaping at the ends. Sculpture psilate to lightly scabrate. Length 28–34 μ.

REMARKS: Comparison with modern *Ginkgo biloba* strongly suggests affiliation with *Ginkgo.* Similar grains have been reported as *Cycadopites* Wodehouse 1933 and *Cycadopites follicularis* Wilson and Webster 1946. Various other names have been applied to similar monocolpate grains found in Mesozoic rocks.

FREQUENCY: Rare.

Division CONIFEROPHYTA
Order CONIFERALES
Family PINACEAE
Genus *Cedrus* Link

?*Cedrus* sp.
Fig. 44

DESCRIPTION: The two grains found from the Kitsilano appear to be that of *Cedrus*; both are about 65 μ in diameter. The bladders are moderately large and tend to enclose the body, except at the leptoma, which slightly separates the bladders. Sculpture of the body is finely reticulate, whereas the bladders are somewhat more coarsely reticulate.

REMARKS: Only two grains of this form were found. Preservation is only fair and many of the finer details are not clear. As a result it is only tentatively assigned to *Cedrus* sp. on the basis of comparisons made with modern *Cedrus* pollen. However, *Dacrydium* (Podocarpaceae) is superficially similar in that it has a body enclosed by bladders with a narrow cleft leptoma.

There have been very few reports of *Cedrus* in North American Tertiary rocks, the most recent documented occurrence being in the Miocene/Pliocene of the Queen Charlotte Islands (Martin and Rouse 1966).

FREQUENCY: Two grains only found.

Genus *Keteleeria* Carr.

Keteleeria sp.
Figs. 45–46

DESCRIPTION: Bisaccate grains, large, body

oval, 85 by 65 µ; bladders nearly subspherical, 55 by 45 µ. The body appears to be scabrate to minutely punctate, cap thin. Bladders are finely reticulate, attached discretely to body and directed distally. Structure and dimensions of leptoma obscured by bladders.

REMARKS: The character of this grain fits closely those of *Keteleeria davidana* as illustrated in Erdtman (1943) and Macko (1957). However, Macko gives overall dimensions of up to 200 µ while Erdtman gives dimensions of 102 to 161 µ. Because only a few of these grains were found, I have no satisfactory range of sizes and it may be the average size is higher.

The only other grain which resembles this is *Pseudolarix*, which is considerably smaller. According to Wodehouse (1935) *Pseudolarix* ranges from 51 to 53 µ.

At the present time *Keteleeria* is restricted to central China where it grows in damp lowland forests and lower belts of mountain forests up to 8000 ft above sea level.

FREQUENCY: Rare.

Genus *Larix* Miller

Larix plicatipollenites Rouse 1962
Figs. 47–48

REMARKS: These grains appear to be identical with those reported by Rouse (1962) from the Burrard Formation. However, a number are smaller, with the observed size range for the present specimens being 50 to 70 µ. They clearly agree in size with the *L. plicatipollenites* reported by Hills (1962) from the Princeton Basin of interior British Columbia. Their small size suggests affiliation with *Larix* rather than *Pseudotsuga*. Wodehouse (1935) states that *Larix* pollen ranges in size from 62.5 to 90.2 µ, while *Pseudotsuga* lies within the comparatively narrow range of 90 to 100 µ.

FREQUENCY: Rare to common.

Genus *Picea* Dietrich

Picea grandivescipites Wodehouse 1933
Figs. 49–50

REMARKS: Although poorly preserved, this bisaccate pollen appears essentially identical with that described by Wodehouse (1933) and Rouse (1957, 1962). The observed range of body size is 25 to 80 µ.

FREQUENCY: Rare.

Genus *Pinus* L.

Pinus strobipites Wodehouse 1933
Figs. 51–52

REMARKS: Although preservation is invariably poor, there is little doubt that this is the same specimen described by Wodehouse (1933) from the Eocene Green River Formation. It has also been reported from the Eocene Burrard Formation by Rouse (1962).

FREQUENCY: Although more common than other saccate pollen grains *P. strobipites* is relatively rare.

Pinus sp. *haploxylon*-type
Figs. 53–54

DESCRIPTION: Bisaccate pollen grain with bladders attached to lateral equatorial extremities of body, bladders larger than body, body circular and finely reticulate; bladders moderately coarsely reticulate, becoming finer toward bladder roots. Leptoma broad, straight-margined, and finely granular. Body ranges from 40 to 50 µ, bladders slightly larger.

REMARKS: Thompson and Pflug (1953) refer this species to the form species *Pityosporites microalatus*, which, they say, belongs to the *Pinus haploxylon* group of Rudolph (1935).

FREQUENCY: Rare.

Pinus sp.
Fig. 55

DESCRIPTION: Bisaccate pollen grain with bladders about equal in size or slightly smaller than body. The body is essentially spherical with exine coarsely granular proximally. Lightly reticulate sculpture on both bladders and distal portion of body. Cap thick. The bladder connection at the proximal root is well defined, and at the distal root the contact is sharp and distinct. Leptoma indistinct, but smooth to fine granulate. Observed body diameter 50 to 55 µ.

BOTANICAL AFFILIATION: This pollen grain is almost identical with that of the extant *Pinus strobus*.

FREQUENCY: Rare to occasional.

Family CUPRESSACEAE
Figs. 56–57

DESCRIPTION: Pollen grains subspherical, although in some cases deformed by folding. Inaperturate, size range 20 to 40 µ. Exine thin, transparent, invariably with surface folds, occasionally ruptured. Surface of exine covered

with small flecks that are slightly more stained than exine. No evidence of pores, colpae, or papillae. Irregular area of thinning is commonly present which may represent a leptoma.

BOTANICAL AFFINITY: This pollen appears to be that of *Juniperus*. However, other genera of the Cupressaceae have similar pollen, and differentiation is difficult or impossible. As a result, I have placed grains of this morphology and size in the family Cupressaceae, recognizing that one or more genera may be represented.

FREQUENCY: Common to abundant.

Family CUPRESSACEAE, TAXODIACEAE, or PINACEAE
Figs. 58–59

DESCRIPTION: Usually subcircular, inaperturate, laevigate pollen grains, identical with those of *Larix*, except smaller. Observed size range 22 to 42 μ.

BOTANICAL AFFINITY: These grains would be assignable to *Larix* except for their small size. They also bear a marked resemblance in size and form to modern species of *Thuja*. At this time it is not possible to classify them more closely than probably affiliated to one or more of the above families.

FREQUENCY: Rare.

Family TAXODIACEAE
Genus *Glyptostrobus* Endlicher

Glyptostrobus vacuipites Wodehouse 1933
Figs. 60–61

DESCRIPTION: According to Wodehouse (1933) "the case skins of pollen grains split into two approximately equal halves. Exine in life apparently stiff and under mechanical strain so that, in separating, the two halves buckle with the formation of longitudinal folds. Outer surface dotted with small flecks openly and irregularly spaced. Length of halves 37.6 μ."

Martin and Rouse (1966) add that the "pollen grains usually split into two valves, with the wall folded parallel to the split edges. Size range 27–30 μ, wall thickness about 0.5 μ and the ornamentation decidedly scabrate."

The specimens in this study correspond closely to the above descriptions except that the length of the split halves ranges from 30 to 33 μ.

REMARKS: Although *Glyptostrobus* is now confined to southeastern China, it appears to

have been widespread in the late Mesozoic and Tertiary of western North America.

FREQUENCY: Rare.

Genus *Metasequoia* Miki ex Hu and Cheng

Metasequoia papillapollenites Rouse 1962
Fig. 62

REMARKS: The few grains of *Metasequoia* encountered appear to be identical with those described by Rouse (1962) from the Burrard Formation and by Hills (1962) from the Eocene Princeton coal fields.

FREQUENCY: *Metasequoia* is frequently difficult to distinguish from *Taxodium* and so the apparent frequency may be less than it is in reality. Definitely identifiable *Metasequoia* is rare.

Genus *Sciadopitys* Siebold and Zuccarini

?*Sciadopitys* sp.
Fig. 63

DESCRIPTION: Pollen grains large (78 and 75 μ), spherical, covered with large warts, 3 to 6 μ in diameter, usually lower than broad. Although a distinct aperture is not visible, there is a distinct leptoma that is usually psilate to granulate, but covered with warty projections in some specimens.

REMARKS: Although this grain closely resembles the single extant species *Sciadopitys verticillata*, as figured and described by Erdtman (1934) and Van Campo (1951), it is considerably larger. *S. verticillata*, both in modern reference slides and in the above literature, appears to have a size range of 28 to 44 μ, with most being 35 to 40 μ. Morphologically this grain is also very similar to *S. serratus* as described by Martin and Rouse (1966) but again is much larger. *S. serratus* has an observed size range of 29 to 41 μ.

There is also a similarity to *Verrucosisporites obscurilaesuratus* Pockock 1962. However, the Kitsilano form never shows a trilete mark and is somewhat larger.

Although size is not always a critical criterion, the discrepancies mentioned here are enough to cast some doubt on the generic assignment.

FREQUENCY: Rare.

Genus *Taxodium* Richard

Taxodium hiatipites Wodehouse 1933
Fig. 64

REMARKS: Some specimens appear to be identical with those described by Wodehouse (1933), Wilson and Webster (1946), Rouse (1962), and Hills (1962). It is quite possible that some grains are *Metasequoia* because of the frequent difficulty in distinguishing the two species except under conditions of exceptional preservation.

FREQUENCY: Common.

Family PODOCARPACEAE
Genus *Podocarpus* L'Heritier ex Persoon

Podocarpus sp.
Figs. 65–66

DESCRIPTION: Bisaccate grain, body circular, 28 to 33 μ in diameter. Bladders large and irregular. Body sculpture scabrate, bladders finely reticulate.

REMARKS: Only a few grains referable to *Podocarpus* were found in this study and all are poorly preserved. As a result, no attempt has been made to assign them to particular species.

Superficially these grains appear similar to *Podocarpidites microreticuloidatus* Cookson. Hills (1962, 1965) reported *Podocarpus* from the Eocene rocks of interior British Columbia. Rouse (1962) found a single grain of *Podocarpus* from the middle Eocene Burrard Formation.

FREQUENCY: Rare.

Family TAXACEAE
Genus *Taxus* L.

?*Taxus* sp.
Figs. 67–68

DESCRIPTION: Spherical pollen grains, 18 to 21 μ in diameter. In most specimens a leptoma appears to have ruptured to form a large irregular opening. Exine psilate to faintly scabrate.

BOTANICAL AFFINITY: Lack of definite and diagnostic features makes assignment of this form to *Taxus* somewhat tenuous. However, morphologically it appears identical with grains of the western yew, *Taxus brevifolia*. The Kitsilano specimens average about 5 μ smaller than extant pollen.

FREQUENCY: Rare.

Division GNETOPHYTA
Order EPHEDRALES
Family GNETACEAE
Genus *Ephedra* L.

?*Ephedra* sp.
Fig. 69

DESCRIPTION: Large (80 μ), elliptical pollen grains. Exine thick, heavy, and provided with broad, low, and irregular ridges that are subparallel to the long axis of the grain. Ridges appear to bifurcate and anastomose in an irregular pattern. No furrows or pores are apparent.

REMARKS: It is with the greatest uncertainty that I assign this grain to *Ephedra*, which, in extant forms, ranges from 35 to 55 μ in length. It is much larger than modern members of this genus, but is similar in morphology to *Ephedripites* Bolkhovitina 1953 as illustrated in Potonié (1958).

FREQUENCY: Rare.

Division ANTHOPHYTA
Class DICOTYLEDONAE
Order MAGNOLIALES

Family MAGNOLIACEAE
Fig. 70

DESCRIPTION: Ellipsoidal, monocolpate grains ranging from 46 to 56 μ in polar length. A single furrow extends from end to end of the grain, usually gaping slightly at the ends. Margins of the furrow are closed and slightly wavy, and are not thickened along margins. Exine moderately thick and slightly roughened.

REMARKS: Except for the roughened exine, this pollen is identical with that of *Liriodendron psilopites* reported by Wodehouse (1933) from the Eocene Green River Formation.

FREQUENCY: Rare.

Order ARALIALES
Family CORNACEAE
Genus *Nyssa* Gronovius ex L.

?*Nyssa* sp.
Fig. 71

DESCRIPTION: Large (45 to 50 μ equatorial diameter) tricolporate pollen grains. Outline essentially circular, colpae long and tapering, becoming wider at the equator. Each colpus contains a deeply sunken, pronounced slightly

elliptical pore. Exine finely but distinctly granulate.

REMARKS: Morphologically these grains appear to be affiliated with *Nyssa* but are generally larger than extant pollen. Also the shoulders of the wall surrounding the colpae are sloping rather than right-angled as in extant pollen of *Nyssa*.

FREQUENCY: Rare.

Order SALICALES
Family SALICACEAE
Genus *Salix* L.

Salix discoloripites Wodehouse 1933
Figs. 72–73

REMARKS: The grains found in this investigation are identical with those described by Wodehouse except for a more restricted size range of 15 to 19 μ.

FREQUENCY: Rare.

?*Salix* sp.
Figs. 74–75

DESCRIPTION: Tricolpate, mostly oblate with colpae extending almost from pole to pole. Furrows closed, with a slight internal marginal thickening.

Sculpture minutely reticulate to punctate, maintained right up to the margins of the colpae. Reticulations about 1 μ. Length of grain 25 to 30 μ, equatorial diameter 15 to 20 μ.

REMARKS: This grain is only tentatively assigned to *Salix* because of the lack of conclusive and diagnostic features. Tricolpate, reticulate pollen grains are abundant in various families and their identification is always an uncertain procedure.

FREQUENCY: Rare.

Order FAGALES
Family BETULACEAE
Genus *Alnus* Miller

Alnus verus (Potonié) Martin and Rouse 1966
Figs. 76–83

REMARKS: This genus and species include all the various pollen of alder described in the past (see synonyms in Martin and Rouse 1966, pp. 196–197). Pore number can vary from three to seven but four- and five-pored pollen is markedly more common.

FREQUENCY: Occasional to abundant. Six-pored pollen grains are never as common as the four- and five-pored types, but are often associated with them. Six-pored grains occasionally make up several percent of the total alder count in the Kitsilano.

Genus *Betula* L.

Betula cf *B. claripites* Wodehouse 1933
Figs. 84–85

REMARKS: Pollen grains assignable to *Betula* are very rare in rocks from this formation. The several grains found seem to fit the description of *B. claripites* as given by Wodehouse (1933).

Betula pollen is a widespread and common element in Tertiary rocks throughout North America. Among the numerous localities where it has been found are the Paleocene Fort Union Formation, the Eocene Green River Formation, the middle Eocene of interior British Columbia, and the middle to late Miocene (?early Pliocene) Latah Formation.

FREQUENCY: Rare.

Genus *Carpinus* Rafinesque

cf. *Carpinus* sp.
Figs. 86–87

DESCRIPTION: A number of grains were found which suggest definite affinities with *Carpinus*. Generally they fit the description of *Carpinus ancipites* Wodehouse 1933 but many are considerably smaller. The size range of the present specimens are 20 to 37 μ, whereas Wodehouse reports a range of 27.4 to 44.5 μ. The only modern *Carpinus* pollen available for reference was *C. betulus*, with a size averaging 35 μ.

REMARKS: *Carpinus* was once much more widespread than it is at present, and appears to have been a common element in many of the North American Tertiary floras.

FREQUENCY: Rare to occasional.

Genus *Corylus* L.

Corylus tripollenites Rouse 1962
Figs. 88–89

REMARKS: *Corylus* encountered in this study is morphologically identical with the forms described by Rouse, but tend to be smaller with a minimum size of 18 μ and an average of about 24 μ.

Corylus has been reported locally from the Burrard Formation and the Miocene or Pliocene Skonun Formation.

FREQUENCY: Rare to occasional.

Family FAGACEAE
Genus *Castanea* Miller

?Castanea sp.
Figs. 90–91

DESCRIPTION: Grains small (16–20 µ), tricolporate, with colpae extending from pole to pole. Small circular pore, situated in short transverse furrow, lies in the center of each colpus. The exine is psilate to very faintly granular.

REMARKS: These specimens look much like pollen of the modern species *Castanea dentata* but are slightly larger. However, pollen of the genus *Castanopsis* looks much like that of *Castanea*. In fact, pollen of *Castanopsis chrysophylla* is virtually identical with that of *Castanea dentata*. For this reason assignment to *Castanea* is questionable.

Castanea-type pollen has been described from numerous Tertiary rocks ranging in age from Eocene to Pliocene. Rouse (1957) and Couper (1960) have also reported *Castanea*-type pollen from Upper Cretaceous rocks.

FREQUENCY: Occasional.

Genus *Fagus* L.

Fagus granulata Martin and Rouse 1966
Figs. 92–94

REMARKS: These specimens appear identical with those described by Martin and Rouse (1966) from the Miocene/Pliocene of the Queen Charlotte Islands. They go on to say that this species probably represents "either an extinct or extant Asiatic species."

FREQUENCY: Rare.

Fagus sp.
Figs. 95–96

DESCRIPTION: Subspherical and tricolpate, 30 to 34 µ in diameter. Colpae one-half to two-thirds total grain length. Conspicuous margo bordering colpae; small, slightly elliptical pores in center of each colpus. Exine finely scabrate, becoming much finer on the margo.

REMARKS: This form differs from *F. granulata* mainly in having shorter colpae, but also appears to have consistently smaller pores. This probably represents an undescribed species, but there is little doubt that it is *Fagus*, probably an extinct form.

FREQUENCY: Rare.

Genus *Quercus* L.

Quercus explanata Anderson 1960
Figs. 97–98

REMARKS: This form is identical with that described by Anderson from Paleocene rocks of New Mexico.

FREQUENCY: Rare.

Quercus sp. 1
Figs. 99–100

DESCRIPTION: Prolate tricolpate pollen grains with furrows extending nearly from pole to pole. Occasionally a weak margo flanks colpae. Pores absent but the middle of the furrow sometimes gapes slightly. A tectate–collumnellate exine suggests a reticulate pattern which appears slightly coarser at the poles. Polar axis varies from 33 to 40 µ, width 23–30 µ.

REMARKS: This grain resembles *Quercus longicanalis* Traverse 1955. See "Remarks" under *Quercus* sp. 4.

Quercus sp. 2
Figs. 101–102

DESCRIPTION: Fairly large (29–35 µ polar diameter), tricolpate grain, nearly circular in polar and equatorial views. Colpae two-thirds to three-fourths length of grain, usually tightly closed. No subexinous thickenings along colpae. Sculpture scabrate.

REMARKS: See "Remarks" under *Quercus* sp. 4.
FREQUENCY: Rare.

Quercus sp. 3
Figs. 103–104

DESCRIPTION: Tricolpate grain, 20 to 24 µ long, prolate. Closed colpae extending from end to end of grain. Weak subexinous thickenings beneath colpae margins. Sculpture frequently scabrate.

REMARKS: This grain, although somewhat smaller, superficially resembles *Quercus virginiana* Mill as described by Macko 1957.

REMARKS: See "Remarks" under *Quercus* sp. 4.
FREQUENCY: Rare to common.

Quercus sp. 4
Fig. 105

DESCRIPTION: Tricolpate grain with the same size and same morphology as *Quercus* sp. 3. The sculpture, however, is psilate rather than scabrate.

REMARKS: During the Tertiary *Quercus* appears to have been a major constituent of northern hemisphere floras, and now is a widespread genus consisting of over 300 species. It seems probable that the pollen found in the Kitsilano Formation represent more than four species, but these would be impossible to subdivide meaningfully. The four main morphological types found in the Kitsilano rocks are illustrated but no attempt is made to assign them to species.

FREQUENCY: Rare, but see above.

Order JUGLANDALES
Family JUGLANDACEAE
Genus *Carya* Nuttall

Carya juxtaporites (Wodehouse, 1933)
Rouse 1962
Figs. 106–109

DESCRIPTION: Circular to subtriangular triporate grains, 24 to 36 μ in diameter. Pores usually circular, 1½ to 2 μ in diameter, occasionally slightly oval. Pores on one hemisphere, slightly offset from equator. Ornamentation ranges widely from psilate to distinctly granulate.

REMARKS: The Kitsilano Formation specimens appear identical with the *Hicoria juxtaporites* Wodehouse 1933 and with *Carya juxtaporites* (Wodehouse 1933) Rouse 1962. The size range given by Rouse (23 to 29 μ) is slightly less than that given above but in all other respects they appear identical. The average size of the specimens encountered in this study is 30 μ and the range in ornamentation is pronounced.

Possibly more than one species is included under this designation but the gradational nature of the ornamentation makes it difficult to draw definite conclusions. Wodehouse (1933) in his original description of this species included psilate to granular forms and I have followed the same procedure in this study.

Carya is a common fossil, both as leaves and pollen, in North American Tertiary rocks.

FREQUENCY: Common.

Genus *Engelhardtia* Leschen. ex Bl. corr. Bl.

Engelhardtia cf. *E. granulata* Simpson 1961
Figs. 110–111

DESCRIPTION: Pollen grains 22 to 26 μ in diameter, profile in polar view triarcuate; three pores, close to circular, slightly aspidate; on most specimens there is a narrow and often inconspicuous collar, sculpture slightly scabrate. On proximal hemisphere, between pores, there are three subcircular areas of exine thinning; a broad indefinite triradiate mark is present on proximal surface.

REMARKS: These forms appear very similar to those described by Simpson (1961) from Lower Tertiary rocks of Scotland. See "Remarks" under *Engelhardtia* sp.

FREQUENCY: Rare.

Engelhardtia sp.
Figs. 112–113

DESCRIPTION: Pollen grains in this group are similar to those of *E. granulata* but differ in two respects: (1) there is no area of thinning in the interpolar areas and (2) the exine is laevigate to faintly scabrate.

REMARKS: This grain appears similar to *Engelhardtia corylipites* Wodehouse 1933.

It is with some uncertainty that I assign the grains encountered here to two fossil species of *Engelhardtia*. Modern *Engelhardtia* pollen can be distinguished from *Myrica* and *Corylus* mainly on the basis of size, but it is only supposition that this relationship held throughout the Tertiary. Because these forms are smaller than typical *Myrica*, and because the pores are not set precisely on the equator, which is a characteristic of the Juglandaceae, I have concluded that these grains are those of *Engelhardtia*.

FREQUENCY: Rare.

Genus *Platycarya* Sieb. and Zucc.

Platycarya sp.
Figs. 114–116

DESCRIPTION: Small (14 to 17 μ), triporate pollen grains. More or less distinctly triangular; sharp, slit-like pores at each angle. Pores are reported by several authors Wodehouse (1933); Thiergart (1940) to have a characteristic *Corylus* pattern. Pores are characteristically slightly offset from the equator in the Juglandaceous fashion. Exine is faintly scabrate and always marked by at least two crossed folds (splits?).

REMARKS: Although to my knowledge it is not published, the unofficial feeling among Tertiary palynologists is that *Platycarya* is restricted to Eocene rocks. However, as a number of writers have mentioned, the dis-

tinction between *Platycarya* and *Engelhardtia* and certain members of the Betulaceae can at times be difficult. I have not had access to modern *Platycarya* or *Engelhardtia* pollen but have compared descriptions and illustrations and can see how difficulties of differentiation might occur. As a result of this potential confusion it seems possible that *Platycarya* might be more long ranging than commonly thought, simply because it has not been identified.

I have assigned these grains with some confidence because of their small size, their slit-like pores, and characteristic crossfolds (splits?).

FREQUENCY: Rare.

Genus *Juglans* L.

Juglans periporites Martin and Rouse 1966
Figs. 117–118

DESCRIPTION: These forms are essentially morphologically identical with those described by Martin and Rouse. However, the size range can be expanded because forms from the Kitsilano Formation range from 26 to 35 μ. Martin and Rouse give an annulus diameter of 8 to 10 μ, which is somewhat higher than shown in their illustrations. The annulus of the present specimens ranges from 5 to 6 μ with pore diameters, in different specimens, varying from 1.5 to 4 μ.

REMARKS: *Juglans* pollen has been found in numerous Tertiary floras, including the Eocene Green River Formation (Wodehouse 1933) and the Oligocene–Miocene of Alaska (Wolfe *et al.* 1966). Wodehouse (1933) states "*Juglans* is an ancient group, with a history dating back to the Upper Cretaceous. In the Tertiary is was represented by many different species and is a conspicuous feature of most of the Tertiary floras, particularly those of the more northerly and colder climates . . . ."

FREQUENCY: Rare to common.

Juglans sp.
Figs. 119–121

DESCRIPTION: Polyporate pollen grain, 28 to 35 μ, subrounded. Number of pores highly variable but usually around 12. Most located near the equator, the rest located on one hemisphere. Pores generally small (1 to 2 μ in diameter), circular to slightly elliptical, annulus weak or absent altogether. Sculpture is weakly scabrate.

REMARKS: The closest species appears to be *Juglans periporites* Martin and Rouse 1966, but these have a more pronounced annulus. This type of *Juglans* pollen from the Kitsilano Formation is similar to that of the modern *J. nigra*.

FREQUENCY: Rare.

Genus *Pterocarya Kunth*

Pterocarya stellatus Martin and Rouse 1966
Figs. 122–124

DESCRIPTION: Polyporate grain with five to eight subcircular to circular pores, located at or near the equator. Pores vary from 5 to 7 μ in diameter, most grains having six pores. Grains definitely angular with the number of side dependent on the number of pores. Subexinous thickenings beneath the pores shallow. Almost invariably the surface is creased with one or more folds. Surface sculpture ranges from psilate to faintly scabrate. Size range 28 to 37 μ.

REMARKS: No obvious morphological difference appears to exist between fossil and extant *Pterocarya* pollen.

FREQUENCY: Infrequent to frequent.

Order ?URTICALES
Family ?ULMACEAE
Form genus *Momipites* Wodehouse

Momipites tenuipolis Anderson 1960
Figs. 125–127

REMARKS: These grains are identical with those described by Anderson (1960); size range 14 to 17 μ.

Stanley (1965) describes what appears to be *M. tenuipolis* from the Paleocene of South Dakota, and calls it *Engelhardtia microfovealata*. He does not refer to Anderson's species, nor does he comment on polar exine thinning which characterizes *M. tenuipolus*, but his illustrations appear to show this thinning.

BOTANICAL AFFILIATION: Ecologically it is unfortunate that this grain cannot be assigned to the natural classification. It is locally very abundant and apparently was a major constitutent of the Kitsilano flora. Possibly it belongs to the family Juglandaceae; possibly related to *Engelhardtia* or *Pterocarya*. On the other hand it may belong to the family Ulmaceae. *Momipites*

shows a marked resemblance to the modern genus *Momisia*.

FREQUENCY: Occasional to abundant.

Order URTICALES
Family ULMACEAE

Genus *Ulmus* L. or Genus *Zelkova* Spach.
Figs. 128–129

DESCRIPTION: Square to subrectangular; 28 to 37 µ in diameter. Four pores are the rule, although three and five have been observed; they are somewhat elliptical, 3 to 4 µ in length. As a rule, pores are located on the angles of the grain, but as in modern *Ulmus*, they may be all on one hemisphere, adjacent to the equator. Slight, subexinous thickenings do occur. Exine characteristically laevigate with a rugulate to reticulate pattern impressed into it. Wodehouse (1935) has remarked that these undulations are due to "internal thickenings."

REMARKS: *Ulmus* and *Zelkova* cannot be distinguished on the basis of pollen, even in modern pollen grains, so I have not attempted to separate them here. This form is quite different from the *U. granopollenites* described by Rouse from the Burrard Formation. It looks much like the modern *U. americana* but according to Wodehouse (1935), *U. americana* characteristically has five pores. The *Ulmus* described here is dominantly four-pored.

FREQUENCY: Rare.

Genus *Planera* Gmel.

Planera sp.
Fig. 130

DESCRIPTION: Morphologically, *Planera* is identical with *Ulmus–Zelkova* already described, but has the addition of arci or curved linear thickenings reaching from pore to pore. A description of *Planera* given by Simpson (1961) fits these grains almost exactly. Wodehouse (1935), commenting on the arci of *Planera*, states that arci are more than adequate to differentiate *Planera* from *Ulmus*.

REMARKS: I feel there is little doubt that these are truly *Planera*. The difference in these grains to those referred to as *Ulmus–Zelkova* is striking and consistent. Leaves of *Planera* have been found in the Burrard Formation.

FREQUENCY: Rare.

Order TILIALES
Family TILIACEAE
Genus *Tilia* L.

?*Tilia* cf. *T. vescipites* Wodehouse 1933
Figs. 131–133

DESCRIPTION: Circular to rounded subtriangular, 24 to 34 µ, tricolporate, pores more or less deeply sunk. Very little subexinous thickening around pores. This form is similar to *T. vescipites* although reticulation is somewhat coarser.

REMARKS: This particular species shows a variation in external form from the circular (Fig. 131) to the triangular with broadly rounded angles (Figs. 132–133). The latter two forms approach in morphology several genera of the Bombacaceae, which with the Tiliaceae, comprise the order Tiliales. Differentiation of these two families along with the Malvaceae has long been controversial. Erdtman (1952) expressed doubt about the validity of elevating Bombacaceae to family rank. Fuchs (1967) feels sufficient evidence is now available to distinguish these families. but additional work is necessary before the present confusion can be settled.

FREQUENCY: Common to abundant.

Tilia sp.
Fig. 134

DESCRIPTION: Small (21 to 24 µ), tricolporate grain, invariably subcircular. Pores circular and deeply sunken, forming pits. Subexinous thickening around pores is considerable and always conspicuous. Exine is pitted to minutely reticulate.

REMARKS: This grain differs from *T. vescipites* in its smaller size, in the punctate rather than reticulate sculpture, and in the pronounced thickenings around the pores.

FREQUENCY: Rare.

Family ?TILIACEAE
Fig. 135

DESCRIPTION: Elliptical pollen grain, 22 to 26 µ, markedly pointed polar ends. Tricolporate, colpae extending from end to end of grain. Marked subexinous thickenings. Small circular pore located in short, shallow, transverse furrow. Exine is fine granular with a suggestion that alignment or ornamentation is parallel to long axis of grain.

REMARKS: Assignment to the Tiliaceae is tentative, but the morphologic resemblance to the modern *Grewia* is pronounced. See Erdtman (1952, 1966).

FREQUENCY: Rare.

Order SAPINDALES
Family ACERACEAE
Genus *Acer* L.

Acer sp.
Figs. 136–137

DESCRIPTION: Grains predominantly oblate, 24 to 30 µ long, 10 to 20 µ in width. Colpae extend from pole to pole, usually closed; where gaping slightly, the colpa floor is faintly granular. No thickening of colpae margins. The exine is always distinctly granulate; almost always the granules are arranged in rows, giving a striate appearance. Frequently the striations are weakly developed.

REMARKS: Wodehouse (1935) and Simpson (1961) both remark on the diagnostic value of the granular striations. Among modern forms only *Acer negundo* fails to show this striate appearance. As a consequence I have identified as *Acer* only those grains which show this feature. Tricolpate grains are common in many diverse groups in the Dicotyledonae, and I am convinced that many misidentifications are found in the literature. As a result I have decided to err on the conservative side and assign to *Acer* only those grains which show the characteristic striations. This undoubtedly has resulted in *Acer* appearing in lesser percentage than it did originally.

FREQUENCY: Rare to occasional.

Family HIPPOCASTANACEAE
Genus *Aesculus* L.

Aesculus sp.
Fig. 138

DESCRIPTION: Prolate, tricolpate grain, 20 to 26 µ in polar diameter. Colpae short, each containing a small elliptical pore in the center. Exine faintly scabrate.

FREQUENCY: Only two grains found.

Order ?CONTORTAE
Family ?GENTIANACEAE
Form Genus *Pistillipollenites* Rouse

Pistillipollenites mcgregorii Rouse 1962
Figs. 139–142

REMARKS: This form is identical with that described by Rouse (1962). *P. mcgregorii* has been reported from rocks as old as Cenomanian (Hedlund 1966) and as young as Eocene (Rouse 1962). R. W. Hedlund (personal communication) states that *Pistillipollenites* occurs only in Paleocene and older rocks of the United States Gulf Coast. However, it has been found in rocks of Eocene age in interior British Columbia which are well dated radiometrically and by fossil mammal bones (Rouse and Mathews 1961; Hills 1962, 1965).

BOTANICAL AFFINITY: Rouse (1962 suggested) affinity with the modern monotypic genus *Rusbyanthus*, a member of the family Gentianaceae.

FREQUENCY: Frequent in lower Kitsilano, absent in upper Kitsilano.

Family AQUIFOLIACEAE
Genus *Ilex* L.

Ilex sp.
Figs. 143–148

DESCRIPTION: Tricolpate pollen grains, subprolate to prolate. Some grains show the colpae distinctly, others with the colpae barely visible. All specimens show a clavate sculptured ektexine. Clavae vary from 1.5 to 3.5 µ in diameter, markedly expanded, and rounded on distal ends. Most specimens have equal-sized clavae, others have slight variations. No clavae present on furrows. Size range (excluding ornaments) 25 to 37 µ in polar length.

REMARKS: At the present time there are 400 species of *Ilex* (Willis 1966) and many of these undoubtedly exhibit slight variation in pollen morphology. Presumably considerable multiplicity of species was present in the Tertiary, as several different forms of *Ilex* are reported from Tertiary floras. Differences in the pollen of *Ilex* in the Kitsilano Formation are slight and do not lend themselves to meaningful subdivision. Considerable overlap of form exists, and it is difficult and arbitrary to assign most of the grains to any particular species. Traverse (1955) has created five fossil species, but here this would have little value. Gradation and overlap of morphological forms precludes

meaningful assignment to species. As a result I have simply placed all forms in *Ilex* sp. and illustrated some of the minor variations present.

FREQUENCY: Common to abundant.

Order PROTEALES
Family PROTEACEAE
Form genus *Proteacidites* (Cookson) Couper

Proteacidites thalmani Anderson 1960
Figs. 149–151

DESCRIPTION: Triporate, triangular pollen grain about 22 to 30 μ in diameter. Rounded corners, slightly convex interradial areas. Pores at angles, somewhat variable in character, generally appear elliptical and notchlike. Annulus usually pronounced around pores. Exine is rather coarsely reticulate near equator, becoming finer toward poles.

REMARKS: *Proteacidites* is difficult to break into species because of the transitional nature of the pollen grain morphology. However, the present specimens appear identical with *P. thalmanii* Anderson 1960.

Available evidence indicates that *Proteacidites* is restricted to Upper Cretaceous in New Mexico (Anderson 1960). Stanley (1965) found *Proteacidites retusus* Anderson (1960) restricted to Upper Cretaceous in northwestern South Dakota. Rouse (1962) states that two species, *P. terrazus* Rouse and *P. marginus* Rouse 1962, are restricted to Upper Cretaceous rocks in British Columbia. However, the stratigraphic range of *Proteacidites* in North America is still uncertain. I have seen them in various Eocene rocks of western Oregon and Washington with no especial evidence that they were reworked. However, they are seldom abundant in rocks younger than Cretaceous and the real possibility exists that they were reworked into the Kitsilano rocks.

FREQUENCY: Rare.

Proteacidites sp.
Fig. 152

DESCRIPTION: Rather sharply triangular grain, abruptly rounded angles, straight to slightly concave sides. Size about 28 μ. Pores indistinct but appear notch-like, no particular thickening of exine around pores. Sculpture is wart-like at equator grading to reticulate and punctate at poles.

REMARKS: This grain appears similar to *Proteacidites terrazus* Rouse 1962 but is rather poorly preserved.

FREQUENCY: Only one specimen found, probably contamination from underlying Cretaceous.

Order MYRICALES
Family MYRICACEAE
Genus *Myrica* L.

Myrica annulites Martin and Rouse 1966
Figs. 153–154

REMARKS: Triporate grains, 26 to 33 μ in diameter. Species from the Kitsilano appear very similar to those found in the Skonun Formation of the Queen Charlotte Islands. Wodehouse (1933) has stated "*Myrica* is one of the most abundant and widely distributed genera of the Tertiary occurring in practically all of the floras of the epoch." It was also present in the Upper Cretaceous and is still widely distributed although greatly reduced in number of species.

FREQUENCY: Rare.

Class MONOCOTYLEDONAE
Order LILIALES
Family LILIACEAE
Form genus *Liliacidites* Couper

Liliacidites sp.
Figs. 155–156

DESCRIPTION: Monocolpate pollen grains, prolate to perprolate, 14 to 45 μ in polar length. Furrow extending to extremities of grain, usually not gaping but well defined; some grains show a slight margo. Sculpture reticulate, becoming finer toward the furrow and end of grain. Lumina irregular and angular in shape.

REMARKS: These grains are morphologically similar to those of *Liliacidites leei* Anderson 1960 but many are 5 to 10 μ shorter in polar diameter. They are also similar to *Aponogeton* but because this is strictly an African genus it seems unlikely it was ever native to North America.

FREQUENCY: Rare.

Order PALMALES
Family PALMAE
Genus *Sabal* Adams

Sabal granopollenites Rouse 1962
Figs. 157–158

DESCRIPTION: "Pollen monocolpate, fusiform in outline, coarsely granulate to weakly reticu-

late. The single colpae is long and narrow with weak margins. Size range 28 to 32 μ." (Rouse 1962).

REMARKS: *Sabal granopollenites* has been reported from Eocene Burrard Formation (Rouse 1962), the middle Eocene Allenby Formation (Hills 1965), and the Paleocene(?) Chuckanut Formation (Griggs 1965).

FREQUENCY: Rare.

Order PANDANALES
Family TYPHACEAE
Genus *Typha* L.

Typha sp.
Figs. 159–160

DESCRIPTION: Pollen grains small (18 to 25 μ), irregularly spheroidal. Single germ pore which is often not distinct, but usually occurs as a rather irregular hole. Exine is thin and covered with a fine, foam-like reticulation.

REMARKS: These grains appear identical with those of the extant *Typha latifolia* which grows in marshes throughout temperate North America, sometimes abundantly.

FREQUENCY: Rare.

Order NAJADALES
Family POTAMOGETONACEAE
Genus *Potamogeton* L.

Potamogeton hollickipites Wodehouse 1933
Fig. 161

DESCRIPTION: According to Wodehouse these grains are "spheroidal, somewhat ellipsoidal or variously irregular, 16 to 27.4 μ in diameter. Exine rather thin and conspicuously reticulate with a coarse network of beaded ridges. Without pores or furrows or vestiges of them."

REMARKS: The specimens here are similar to those described by Wodehouse from the Eocene Green River Formation except that the upper size limit is 32 μ. The Kitsilano specimens are identical with those described by Hills (1965) from the Eocene Allenby Formation, Princeton Basin, interior British Columbia.

Wodehouse (1933) remarked: "It is not known for certain whether they (*Potamogeton* pollen) have a germ pore or not, the absence of which is the only character which distinguishes these grains from those of *Sparganium* and some

species of *Typha*." However, detailed examination of the reticulate ornamentation indicates that the muri of modern *Sparganium* pollen are not always closed, while *Potamogeton* appears to always have closed muri. Furthermore, *Typha* has a much finer and more delicate reticulum than either *Sparganium* or *Potamogeton* and usually has a conspicuous germ pore. Because a germ pore is never present and the muri are always closed, I have assigned these grains to the genus *Potamogeton*.

Potamogeton has been described from a number of Tertiary formations, including the Eocene Green River (Wodehouse 1933), the middle Eocene Allenby Formation of interior British Columbia (Hills 1962), and the Miocene – lower Pliocene Latah Formation of the Columbia Plateau (Chaney and Axelrod 1959).

FREQUENCY: Occasional.

Incertae sedis

Trilites solidus (Potonié) Krutzsch 1959
Figs. 162–163

DESCRIPTION: Moderate-sized (35 to 50 μ) trilete spore, subangular, rounded angles. Slightly concave to slightly convex interradial areas. Trilete mark distinct, extending from pole almost to equator. Ornamentation coarsely warty rugulate.

REMARKS: Krutzsch (1959) states this spore occurs in the Eocene of Germany, but its overall stratigraphic range is unknown.

FREQUENCY: Two specimens only found.

Deltoidospora sp. 1
Fig. 164

DESCRIPTION: Small (22 to 28 μ), trilete spore. Subtriangular, broadly rounded angles, straight to slightly concave interradial areas. Trilete mark weakly developed, extending about two-thirds of distance toward equator. Exine very weakly and minutely punctate.

REMARKS: This spore is similar to *Deltoidospora microforma* Rouse 1962, but these grains do not have the generally gaping laesurae which Rouse describes. In size and shape it is more like *D. rhytisma* Rouse 1962 but does not often have the concave interradial areas which characterize Rouse's illustrations.

FREQUENCY: Rare.

Deltoidospora sp. 2
Fig. 165

DESCRIPTION: Small (20 to 22 μ) trilete spore. Subtriangular in shape, broadly rounded angles, straight to weakly concave interradial areas. Trilete mark weak, extends to spore equator. Sculpture scabrate.

REMARKS: This grain is similar to *Deltoidospora taenia* Rouse 1962, but is considerably smaller. Rouse gives a size range for this species of 26 to 35 μ.

FREQUENCY: Rare.

Monoporate A
Figs. 166–167

DESCRIPTION: Almost spherical spore, 16 to 17 μ, with one very slightly aspidate pore. Exine about 3 μ thick with no thickening about the pore. Exine psilate.

BOTANICAL AFFILIATION: Fungal spore.

FREQUENCY: Rare.

Monoporate B
Fig. 168

DESCRIPTION: Spherical to oval, 17 to 20 μ, monoporate spore. Pore very minute, surrounded by slight subexinous thickenings, nonaspidate. Exine psilate.

BOTANICAL AFFILIATION: Fungal spore.

FREQUENCY: Rare.

Monoporate C
Fig. 169

DESCRIPTION: Small (15 to 16 μ), oval, monoporate spore. Pore located at one end, circular, showing slight thickening of the exine of pore margins. Exine psilate.

BOTANICAL AFFILIATION: Fungal spore.

FREQUENCY: Rare.

Fusiformisporites microstriatus n. sp.
Fig. 170

DIAGNOSIS: Oval spore, 42 to 49 μ in length. Grain divided into two cells by a septum in middle of grain. Fine longitudinal ribs extend from the poles to the equatorial septum (which is very slightly constricted). Most of these ribs terminate at the equator, although occasionally several may be continuous across it. The wall is thick and appears granular.

REMARKS: This form is placed in the genus *Fusiformisporites* Rouse 1962 but has much finer ribs and grooves than *F. crabbii* Rouse 1962.

BOTANICAL AFFINITY: Probably fungal spore.

HOLOTYPE: In writers collection, slide 14–5–65–3–1, Leitz ortholux coordinates 25.2 × 118.0.

FREQUENCY: Rare.

Punctodiporites harrisii Varma & Rawat 1963
Figs. 171–172

REMARKS: Specimens from the Kitsilano Formation are identical with those described by Varma and Rawat, with a size range of 50 to 65 μ.

BOTANICAL AFFILIATION: Probably a fungal or algal spore, although it bears resemblance to certain forms in the family Onagraceae, especially the diporate forms of *Fuchsia*.

FREQUENCY: Rare.

Diporisporites (Hammen) Elsik 1968

Diporisporites sp.
Fig. 173

DESCRIPTION: Elongate spore or pollen grain elliptical to fusiform in outline, 55 to 60 μ in length. Biporate, pores opposed, slightly aspidate. Poral costae prominent with exine thinner toward pores. Exine psilate.

BOTANICAL AFFINITY: Probably a fungal or algal spore.

FREQUENCY: Rare.

Diporate A
Fig. 174

DESCRIPTION: Large (63 to 68 μ), irregularly oval pollen(?) grain. Diporate, pores are small, circular, and surrounded by a narrow zone of subexinous thickening. Pores are always on the same surface, but not always in the same place. Wall is thin and always creased with a number of folds. Sculpture minutely scabrate.

BOTANICAL AFFINITY: Unknown.

FREQUENCY: Rare in Kitsilano Formation, abundant in lignite layers of equivalent age in northwest Washington.

Diporate C
Fig. 175

DESCRIPTION: Large (75 to 85 μ), oval, diporate. Circular, slightly aspidate pore at each end. Subexinous thickening around each pore. Grain divided into four cells by three moderately thick but simple septa. No pores apparent in septa. Walls psilate.

BOTANICAL AFFINITY: Probably fungal spores.

FREQUENCY: Rare.

Tricolpate A
Figs. 176–177

DESCRIPTION: Large (40 to 44 μ), tricolpate pollen grain. Colpae about three-fourths total length of grain, somewhat wavy and tending to gape in middle. Exine coarsely reticulate, becoming slightly coarser at poles and finer toward the colpae.

BOTANICAL AFFINITY: Unknown, but I have seen this form in various Tertiary rocks of western Washington.

FREQUENCY: Rare.

Tricolpate B
Fig. 178

DESCRIPTION: Prolate, tricolpate pollen grain, 26 to 28 μ in polar diameter. Colpae sharp and tightly closed, extending about three-fourths length of grain. Exine laevigate.

FREQUENCY: Two grains found.

Tricolpate C
Fig. 179

DESCRIPTION: Small (15 to 19 μ, prolate, tricolpate pollen grain. Colpae extending almost from end to end of grain, always tightly closed and showing no subexinous thickening. Exine moderately thick, scabrate to minutely granular.

FREQUENCY: Rare.

Tricolporate A
Fig. 180

DESCRIPTION: Tricolporate pollen grain, prolate, 23 to 28 μ long. Three colpae extend almost from pole to pole. Circular protruding pore in center of each colpae. Weak subexinous thickenings along margins of colpae. Exine scabrate.

FREQUENCY: Rare.

Triporate A
Figs. 181–182

DESCRIPTION: Triporate pollen grain, 26 to 38 μ in diameter. Pores moderately aspidate, but nature of exine around pores is not clear; there does not appear to be any thickening of exine around pores. Exine finely and irregularly striate.

BOTANICAL AFFINITY: Only two species, both illustrated, were found, both in upper part of the Kitsilano Formation. These two forms may not be the same species, botanical affiliation unknown.

FREQUENCY: Two grains only were found.

Fungal Spore
Fig. 183

DESCRIPTION: Uniseriate fungal spores with individual spores consisting of several to many cells. The width varies from 12 to 25 μ and the length may be in excess of 100 μ, depending upon the number of component cells. Length of individual cells 6 to 12 μ. A minute, slit-like aperture occurs in each septum.

FREQUENCY: Occasional to abundant.

Asterina sp.
Fig. 184

REMARKS: These structures, which range from 65 to 85 μ in diameter, are identical with the cylindrical plates of cells described by Dilchner (1963). He found them in Eocene clay deposits of Tennessee and assigned them to the epiphyllous fungi family Microthyraceae. Similar structures are illustrated but not described by Hills (1965) from the Eocene of interior British Columbia. Martin and Rouse (1966) found them in the Miocene–Pliocene of the Queen Charlotte Islands.

Unidentified
Figs. 185–186

DESCRIPTION: Large (75 to 80 μ), circular organic body of unknown origin.

FREQUENCY: Rare.

ANDERSON, R. Y. 1960. Cretaceous–Tertiary palynology, eastern side of the San Juan basin, New Mexico. N. Mex. Bureau Mines Mineral Resources, Mem. 6.

AXELROD, D. I. 1949. Eocene and Oligocene formations in the Western Great Basin. Geol. Soc. Amer. Bull. 60: 1935–1936A.

——— 1950. Studies in Late Tertiary paleobotany. Carnegie Inst. Wash. Publ. 590.

BAILEY, L. H. 1949. Manual of cultivated plants. 9th ed. The Macmillan Co., New York.

BARGHOORN, E. S. 1951. Age and environment; a survey of North American Tertiary floras in relation to paleoecology. J. Paleontol. 25: 736–744.

BARGHOORN, E. S. and SPACKMAN, W. 1950. Geological and botanical study of the Brandon lignite and its significance in coal petrology. Econ. Geol. 45: 344–357.

BELL, W. A. 1949. Uppermost Cretaceous and Paleocene floras of western Alberta. Geol. Surv. Can., Bull. 13.

BERRY, E. W. 1926. Tertiary floras from British Columbia. Geol. Surv. Can., Bull. 42, pp. 91–116.

BRADLEY, W. H. 1931. Origin of the microfossils of the oil shales of the Green River Formation of Colorado and Utah. U.S. Geol. Surv. Prof. Pap. 168.

——— 1964. Geology of the Green River Formation and associated Eocene rocks in southwestern Wyoming and adjacent parts of Colorado and Utah. U.S. Geol. Surv. Prof. Pap. 496A, pp. A1–A86.

CAMP, W. H. 1947. Distribution patterns in modern plants and problems of ancient dispersals. Ecol. Monogr. 17: 159–183.

CHANDLER, M. E. J. 1955. The Schizaeaceae of the south of England in Early Tertiary times. Bull. Brit. Mus. (Natur. Hist.) 2, No. 7: 291–314.

CHANEY, R. W. 1936. Plant distribution as a guide to age determination. Wash. Acad. Sci. 26: 313–324.

——— 1940. Tertiary forests and continental history. Geol. Soc. Amer. Bull. 51: 469–488.

——— 1948. The bearing of the living Metasequoia on problems of Tertiary paleobotany. Nat. Acad. Sci. Proc. 34: 503–515.

——— 1951. A revision of fossil Sequoia and Taxodium in western North America based on the recent discoveries of Metasequoia. Amer. Phil. Soc. Trans., new ser., 40(3): 171–239.

CHANEY, R. W. and AXELROD, D. I. 1959. Miocene floras of the Columbia Plateau. Pt. 1 and 2. Carnegie Inst. Wash. Publ. 617.

CLARKE, R. T. 1965. Fungal spores from Vermejo Formation coal beds (Upper Cretaceous) of central Colorado. The Mountain Geol. 2: 85–93.

COUPER, R. A. 1953. Upper Mesozoic and Cainozoic spores and pollen grains from New Zealand. N.Z. Geol. Surv., Paleontological Bull. 22.

——— 1960. New Zealand Mesozoic and Cainozoic plant microfossils. N.Z. Geol. Surv., Paleontological Bull. 32.

COX, R. L. 1962. Age and correlation of the Sooke Formation with a section on its palynology. Unpublished M.Sc. Thesis, Univ. of British Columbia, Vancouver.

CRICKMAY, C. H. and POCOCK, S. A. J. 1963. Cretaceous of Vancouver, British Columbia, Canada. Amer. Ass. Petrol. Geol. Bull. 47: 1928–1942.

DAWSON, J. W. 1895. On collections of Tertiary plants from the vicinity of the city of Vancouver, B.C. Roy. Soc. Can. Trans., Ser. 2, 1(4): 137–161.

DILCHER, D. L. 1963. Eocene epiphyllous fungi. Science, 42: 667–669.

ELSIK, W. C. 1968. Palynology of a Paleocene Rockdale Lignite, Milam County, Texas. 1. Morphology and taxonomy. Pollen Spores, 10: 263–314.

ERDTMAN, G. 1943. An introduction to pollen analysis. Chronica Botanica Co., Waltham, Mass.

——— 1952. Pollen morphology and plant taxonomy; angiosperms (An introduction to palynology, 1). Chronica Botanica Co., Waltham, Mass.

——— 1957. Pollen and spore morphology/plant taxonomy; gymnospermae, pteridophyta, bryophyta. The Ronald Press Co., New York.

——— 1966. Pollen morphology and plant taxonomy; Angiosperms. Hafner Pub. Co., New York.

EVERNDEN, J. F. and JAMES, G. T. 1964. Potassium argon dates and the Tertiary floras of North America. Amer. J. Sci. 262: 945–974.

FAEGRI, K. and IVERSON, J. 1964. Textbook of pollen analysis. 2nd ed. Hafner Publishing Co., New York.

FELIX, C. J. 1965. Neogene Tasmanites and leiospheres from southern Louisiana, U.S.A. Paleontology, 8(1): 16–26.

FUCHS, H. P. 1967. Pollen morphology of the family Bombacaceae. Rev. Palaeobotan. Palynol. 3: 119–132.

GRAHAM, A. 1965. The Sucker Creek and Trout Creek Miocene floras of southeastern Oregon. Kent State Univ. Bull., Res. Ser., 9.

GRIGGS, P. H. 1965. Stratigraphic significance of fossil pollen and spores of the Chuckanut Formation, northwest Washington. Unpublished M.Sc. Thesis, Michigan State Univ.

HAMMEN, TH. VAN DER. 1954. El desarrolo de la flora Colombiana en los periodos geologicos. Bogotá, Bol. Geológico, 2: 49–106.

——— 1956a. A palynological systematic nomenclature. Bogotá, Bol. Geológico, 4: 63–101.

——— 1956b. Description of some genera and species of fossil pollen and spores. Bogotá, Bol. Geológico, 4: 111–117.

HEDLUND, R. W. 1966. Palynology of the Red Branch Member (Woodbine Formation). Okla. Geol. Surv. Bull. 112.

HILLS, L. V. 1962. Glaciation, stratigraphy, structure and micropaleontology of the Princeton coalfield, British Columbia. Unpublished M.Sc. Thesis, Univ. of British Columbia, Vancouver.

——— 1965. Palynology and age of early Tertiary basins, interior British Columbia. Unpublished Ph.D. Thesis, Univ. of Alberta.

HOLLAND, S. S. 1964. Landforms of British Columbia—A physiographic outline. Brit. Columbia Dept. Mines Petrol. Resources, Bull. 48.

HOPKINS, W. S. 1966. Palynology of Tertiary rocks of the Whatcom basin, southwestern British Columbia and northwestern Washington. Unpublished Ph.D. Thesis, Univ. of British Columbia, Vancouver.

——— 1968. Subsurface miocene rocks, British Columbia–Washington, a palynological investigation. Geol. Soc. Amer. Bull. 79: 763–768.

HUGHES, R. 1946. Fraser River Tertiary. Unpublished B.A. Thesis, Univ. of British Columbia, Vancouver.

JOHNSTON, W. A. 1923. Geology of the Fraser River Delta map area. Geol. Surv. Can., Mem. 135.

KRAJINA, V. J. 1959. Bioclimatic zones of British Columbia. Univ. of British Columbia, Botanical Ser. No. 1.

——— 1965. Biogeoclimatic zones and classification of British Columbia. In Ecology of North America. Vol. 1. pp. 1–17. University of British Columbia, Dept. Botany.

KREMP, G. O. W. 1965. Morphologic encyclopedia of palynology. Univ. of Arizona Press, Tucson, Arizona.

KREMP, G. O. W. and GERHARD, J. E. 1960. Pollen and spores from the Lower Tertiary of North and South Dakota and some taxonomic problems concerning their designation. Pa. State Univ. College Min. Industries. Contrib. 58–64, pp. 257–269.

KRUTZSCH, W. 1957. Sporen- und pollengruppen aus der Oberkreide und dem Tertiar Mitteleuropas und ihre stratigraphische verteilung. Z. Angew. Geol. Bd. 3, Heft 11/12, S. 490–588.

——— 1959a. Mikropalontologische (Sporenpalaeontologische) untersuchungen in der Braunkohle des Geiseltales. Akad.-Verlag-Berlin, Nr. 21–22, Jahrgang 8, S. 1–425.

——— 1959b. Einige neue formgattungen und -arten von sporen und pollen aus der Mitteleuropaischen Oberkreide und dem Tertiar. Paleontogr., Bd. 105, S. 105–157.

——— 1962. Atlas der Mittel- und Juntertiaren dispersen sporen- und pollen sowie der mikroplanktonformen des nordlichen Mitteleuropas (in three parts). Veb Deutcher verlag der Wissenschaften, Berlin.

LAWRENCE, G. M. 1951. Taxonomy of vascular plants. Macmillan Co., New York.

MACGINITIE, H. D. 1941. A Middle Eocene flora from the central Sierra Nevada. Carnegie Inst. Wash. Publ. 534.

——— 1966. Some vegetation types in Eocene of Middle Rocky Mountains. Geol. Soc. Amer. abstracts for 1966 annual meetings at Las Vegas, Nevada, pp. 40–41A.

MACKO, S. 1957. Lower Miocene pollen flora from the valley of Klodnica near Gliwice (Upper Silesia). Trav. Soc. Sciences Lettres Wroclaw, Ser. B, Nr. 88, pp. 5–314.

—— 1959. Pollen grains and spores from Miocene brown coals in Lower Silesia, 1. Trav. Soc. Lettres Wroclaw, Ser. B. Nr. 96, pp. 5–178.

—— 1963. Sporomorphs from Upper Cretaceous near Opole (Silesia) and from the London clays. Trav. Soc. Sciences Lettres Wroclaw, Ser. B, Nr. 106, pp. 5–136.

MARTIN, H. A. and ROUSE, G. E. 1966. Palynology of Late Tertiary sediments from Queen Charlotte Islands, British Columbia. Can. J. Bot. **44**: 171–208.

MULLER, J. 1959. Palynology of the Recent Orinoco delta and shelf sediments. Micropaleontology, **5**: 1–32.

NEWMAN, K. R. 1965. Upper Cretaceous–Paleocene guide palynomorphs from northwestern Colorado. Univ. of Colorado, Ser. in Earth Sciences No. 2.

NOREM. W. L. 1955. Pollen, spores, and other organic microfossils from the Eocene of Venezuela. Micropaleontology, **1**: 261–268.

POTONIÉ, R. 1951. Pollen- und sporeformen als leitfossilien des Tertiars. Sonderdruck aus Mikroscopie, Bd. 6, Heft 9/10, S. 272–283.

—— 1956. Synopsis der gattungen der sporae dispersae, 1 Teil, sporites. Beih. Geol. Jahrb., Hannover, Heft 23, 103 S.

—— 1958. Synopsis der gattungen der sporae dispersae, 2 Teil, sporites (nachtrage), saccites, aletes, praceolpates, monocolpates. Beih. Geol. Jahrb., Hannover, Heft 31, S. 1–114.

—— 1960. Synopsis der gattungen der sporae dispersae, 3 Teil, nachtrage sporites, fortsetzung pollenites mit general register zu Teil 1–3. Beih. Geol. Jahrb., Hannover, Heft 39, S. 1–187.

RODDICK, J. A. 1965. Vancouver north, Coquitlam and Pitt Lake map-area, British Columbia. Geol. Surv. Can., Mem. 335.

ROUSE, G. E. 1957. The application of a new nomenclatural approach to Upper Cretaceous plant microfossils from western Canada. Can. J. Bot. **35**: 349–375.

—— 1962. Plant microfossils from the Burrard Formation of western British Columbia. Micropaleontology, **8**: 187–218.

ROUSE, G. E. and MATHEWS, W. H. 1961. Radioactive dating of Tertiary plant-bearing deposits. Science, **133**: 1079–1080.

RUDOLPH, K. 1935. Mikrofloristische Untersuchungen Tertiarer Ablagerungen im nordlichen Bohmen. Bech. Bot. Cbl. **54**: 244–328.

SCAGEL, R. F., BANDONI, R. J., ROUSE, G. E., SCHOFIELD, W. B., STEIN, J. R., and TAYLOR, T. M. C. 1965. An evolutionary survey of the plant kingdom. Wadsworth Publishing Co., Belmont, California.

SIMPSON. J. B. 1961. The Tertiary pollen-flora of Mull and Ardnamurchan. Trans. Roy. Soc. Edinburgh, **64**.

SKARBY, A. 1964. Revision of *Gleicheniidites senonicus* Ross. Acta Univ. Stockholmiensis, Stockholm Contrib. Geol. **11**: 59–77.

SMILEY, C. J. 1966. Cretaceous floras from Kuk River area, Alaska; stratigraphic and climatic interpretations. Geol. Soc. Amer. Bull. **77**: 1–14.

SNAVELY, P. D. and WAGNER, H. C. 1963. Tertiary geologic history of western Oregon and Washington. Wash. Div. Mines Geol. Rep. Inv. 22.

STANLEY, E. A. 1965. Upper Cretaceous and Paleocene plant microfossils and Paleocene dinoflagellates and hystrichosphaerids from northwestern South Dakota. Bull. Amer. Paleontol. **49**: 179–384.

THIERGART, F. 1940. Die mikropalaontologie als pollenanalyses im dienst der Braunkohlenforschung. Von Ferdinand Enke, Stuttgart, 13 Heft.

THOMSON, P. W. and PFLUG, H. 1953. Pollen und sporen des Mitteleuropaischen Tertiars. Palaeontogr. **94**, Pt. B: 1–138.

THOMSON, R. V. 1958. Petrographic and sedimentary comparison of sandstones of the Kitsilano and Burrard Formation. Unpublished B.A. Thesis, Univ. of British Columbia, Vancouver.

TRAVERSE, A. 1955. Pollen analysis of the Brandon lignite of Vermont. U.S. Bur. Mines Rep. Inv. 5151.

VAN CAMPO-DUPLAN, M. 1951. Recherches sur la phylogenie des Taxodiacees d'apres leurs grains de pollen. Trav. Lab. Forest. Univ. Toulouse, **4**, Art. 2: 1–14.

VARMA, C. P. and ROWAT, M. S. 1963. A note on some diporate grains recovered from Tertiary horizons of India and their potential marker value. Grana Palynologica, **4**: 130–139.

WHITE, W. H. 1959. Cordilleran tectonics in British Columbia. Amer. Ass. Petrol. Geol. **43**: 60–100.

WILLIS, J. C. 1966. A dictionary of the flowering plants and ferns. 7th ed. Cambridge Univ. Press, England.

WILSON. L. F. 1956. Composite micropaleontology and its application to Tertiary and near Recent stratigraphy. Micropaleontology, **2**: 1–6.

WILSON, L. R. and WEBSTER, R. M. 1946. Plant microfossils from a Fort Union coal of Montana. Amer. J. Bot **33**: 271–278.

WODEHOUSE, R. P. 1933. Tertiary pollen −2; the oil shales of the Green River Formation. Torrey Bot. Club Bull. **60**: 479–524.

—— 1935. Pollen grains, their structure, identification and significance in science and medicine. McGraw-Hill Book Co.. Inc., N.Y.

WOLFE, J. A. and BARGHOORN, E. S. 1960. Generic change in Tertiary floras in relation to age. Amer. J. Sci., Bradley Vol. **258A**: 388–399.

WOLFE, J. A., GOWER, H. D., and VINE, J. D. 1961. Age and correlation of the Puget Group in King County, Washington. U.S. Geol. Surv. Prof. Pap. 424–C, Art. 232, pp. C230–232.

WOLFE, J. A., HOPKINS, D. M., and LEOPOLD, E. B. 1966. Tertiary stratigraphy and paleobotany of the Cook Inlet region, Alaska. U.S. Geol. Surv. Prof. Pap. 398–A, p. A1–A29.

EXPLANATION OF FIGS. 1–186

FIG. 1. *Dyadosporonites* sp. 1 (× 1000).

FIGS. 2–3. *Dyadosporonites* sp. 2 (× 500).

FIGS. 4–6. *Pleuricellaesporites psilatus* Hammen ex Clarke 1965 (× 500).

FIG. 7. *Pleuricellaesporites* sp. (× 1000).

FIG. 8. Fungal hyphae (× 500).

FIGS. 9–10. ?*Isoetes* sp. (× 1000).

FIG. 11. *Lycopodium annotinioides* (Krutzsch) Martin & Rouse 1966 (× 1000).

FIG. 12. *Osmunda regalites* Martin & Rouse 1966 (× 1000).

FIGS. 13–14. *Osmunda irregulites* Martin & Rouse 1966 (× 1000).

FIGS. 15–17. *Osmunda* sp. 1 (× 1000).

FIG. 18. *Osmunda* sp. 2 (× 1000).

FIG. 19. *Osmunda* sp. 2 (× 500).
FIG. 20. *Osmunda* sp. 2 (× 1000).
FIGS. 21–23. *Anemia poolensis* Chandler 1955 (× 1000).
FIG. 24. *Cicatricosisporites intersectus* Rouse 1962 (× 1000).
FIG. 25. *Cicatricosisporites intersectus* Rouse 1962 (× 500).
FIGS. 26–27. *Cicatricosisporites intersectus* Rouse 1962 (× 1000).
FIG. 28. *Lygodium reticulosporites* Rouse 1962 (× 1000).
FIGS. 29–30. *Gleichenia* sp. (× 1000).
FIGS. 31–32. *Laevigatosporites discordatus* Thompson & Pflug 1953 (× 1000).
FIG. 33. *Laevigatosporites albertensis* Rouse 1962 (× 1000).
FIG. 34. *Dennstaedtiaceae–Polypodiaceae* form 1 (× 1000).
FIGS. 35–36. *Dennstaedtiaceae–Polypodiaceae* form 2 (× 1000).
FIGS. 37–38. *Dennstaedtiaceae–Polypodiaceae* form 2 (× 1000).
FIG. 39. *Dennstaedtiaceae–Polypodiaceae* form 3 (× 1000).
FIG. 40. *Azolla* glochidia (× 1000).
FIGS. 41–43. ?*Ginkgo* sp. (× 1000).
FIG. 44. ?*Cedrus* sp. (× 1000).
FIG. 45. *Keteleeria* sp. (× 1000).
FIG. 46. *Keteleeria* sp. (× 750).
FIGS. 47–48. *Larix plicatipollenites* Rouse 1962 (× 1000).
FIGS. 49–50. *Picea grandivescipites* Wodehouse 1933 (× 750).
FIGS. 51–52. *Pinus strobipites* Wodehouse 1933 (× 750).
FIGS. 53–54. *Pinus* sp. *haploxylon*-type (× 750).
FIG. 55. *Pinus* sp. (× 750).
FIGS. 56–57. Cupressaceae (× 1000).
FIGS. 58–59. Cupressaceae, Taxodiaceae, or Pinaceae (× 1000).
FIGS. 60–61. *Glyptostrobus vacuipites* Wodehouse 1933 (× 1000).
FIG. 62. *Metasequoia papillapollenites* Rouse 1962 (× 1000).
FIG. 63. ?*Sciadopitys* sp. (× 750).
FIG. 64. *Taxodium hiatipites* Wodehouse 1933 (× 1000).
FIGS. 65–66. *Podocarpus* sp. (× 1000).
FIGS. 67–68. ?*Taxus* sp. (× 1000).
FIG. 69. ?*Ephedra* sp. (× 1000).
FIG. 70. *Magnoliacea* (× 1000).
FIG. 71. ?*Nyssa* sp. (× 1000).
FIGS. 72–73. *Salix discoloripites* Wodehouse 1933 (× 1000).
FIGS. 74–75. ?*Salix* sp. (× 1000).
FIGS. 76–83. *Alnus verus* (Potonié) Martin & Rouse 1966 (× 1000).
FIGS. 84–85. *Betula* cf. *B. claripites* Wodehouse 1933 (× 1000).
FIGS. 86–87. cf. *Carpinus* sp. (× 1000).
FIGS. 88–89. *Corylus tripollenites* Rouse 1962 (× 1000).
FIGS. 90–91. ?*Castanea* sp. (× 1000).
FIGS. 92–94. *Fagus granulata* Martin & Rouse 1966
FIGS. 95–96. *Fagus* sp. (× 1000).
FIGS. 97–98. *Quercus explanata* Anderson 1960 (× 1000).
FIGS. 99–100. *Quercus* sp. 1 (× 1000).
FIGS. 100–102. *Quercus* sp. 2 (× 1000).
FIGS. 103–104. *Quercus* sp. 3 (× 1000).
FIG. 105. *Quercus* sp. 4 (× 1000).
FIGS. 106–109. *Carya juxtaporites* (Wodehouse) Rouse 1962 (× 1000).
FIGS. 110–111. *Engelhardtia* cf. *E. granulata* Simpson 1961 (× 1000).
FIGS. 112–113. *Engelhardtia* sp. (× 1000).
FIGS. 114–116. *Platycarya* sp. (× 1000).
FIGS. 117–118. *Juglans periporites* Martin & Rouse 1966 (× 1000).
FIGS. 119–121. *Juglans* sp. (× 1000).
FIGS. 122–124. *Pterocarya stellatus* Martin & Rouse 1966 (× 1000).
FIGS. 125–127. *Momipites tenuipolis* Anderson 1960.
FIGS. 128–129. *Ulmus* sp. or *Zelkova* sp. (× 1000).
FIG. 130. *Planera* sp. (× 1000).
FIGS. 131–133. ?*Tilia* cf. *T. vescipites* Wodehouse 1933 (× 1000).
FIG. 134 *Tilia* sp. (× 1000).
FIG. 135. ?Tiliaceae.
FIGS. 136–137. *Acer* sp. (× 1000).
FIG. 138. *Aesculus* sp. (× 1000).
FIGS. 139–142. *Pistillipollenites mcgregorii* Rouse 1962 (× 1000).
FIGS. 143–148. *Ilex* sp. (× 1000).
FIGS. 149–151. *Proteacidites thalmani* Anderson 1960 (× 1000).
FIG. 152. *Proteacidites* sp. (× 1000).
FIGS. 153–154. *Myrica annulites* Martin & Rouse 1966 (× 1000).
FIGS. 155–156. *Liliacidites* sp. (× 1000).
FIGS. 157–158. *Sabal granopollenites* Rouse 1962 (× 1000).
FIGS. 159–160. *Typha* sp. (× 1000).

FIG. 161. *Potamogeton hollickipites* Wodehouse 1933 (× 1000).
FIGS. 162–163. *Triletes solidus* (Potonie) Krutzsch 1959 (× 1000).
FIG. 164. *Deltoidospora* sp. 1 (× 1000).
FIG. 165. *Deltoidospora* sp. 2 (× 1000).
FIGS. 166–167. Monoporate A (× 1000).
FIG. 168. Monoporate B (× 1000).
FIG. 169. Monoporate C (× 1000).
FIG. 170. *Fusiformisporites microstriatus* n. sp. (× 1000).
FIGS. 171–172. *Punctodiporites harrisii* Varma and Rawat 1963 (× 750).
FIG. 173. *Diporisporites* sp. (× 500).
FIG. 174. Diporate A (× 1000).
FIG. 175. Diporate C (× 500).
FIGS. 176–177. Tricolpate A (× 1000).
FIG. 178. Tricolpate B (× 1000).
FIG. 179. Tricolpate C (× 1000).
FIG. 180. Tricolporate A (× 1000).
FIGS. 181–182. Triporate A (× 1000).
FIG. 183. Fungal spore (× 1000).
FIG. 184. *Asterina* sp. (× 500).
FIGS. 185–186. Unidentified (× 500).

NOTE: Figs. 1–186 follow.

PLATE I
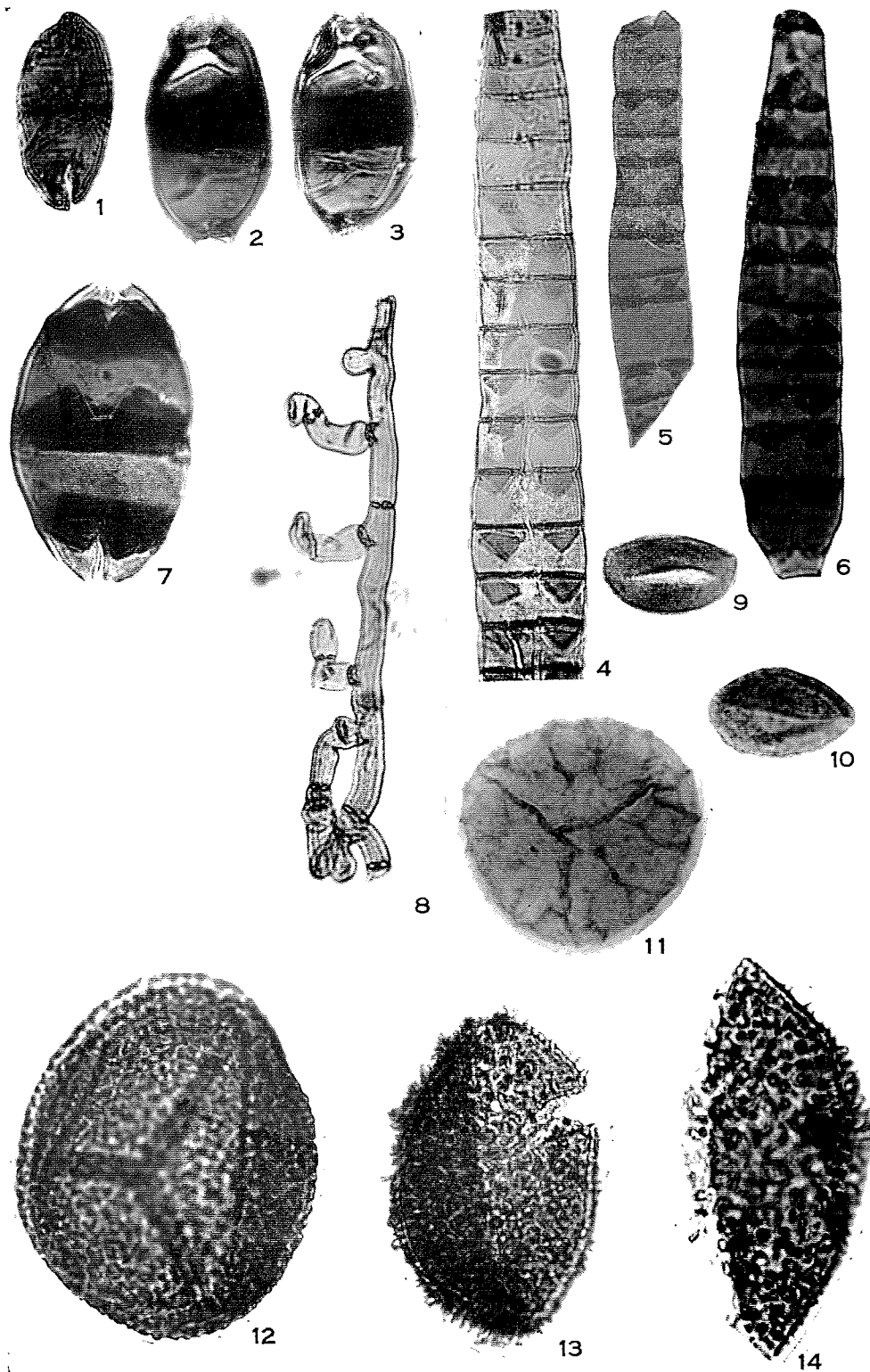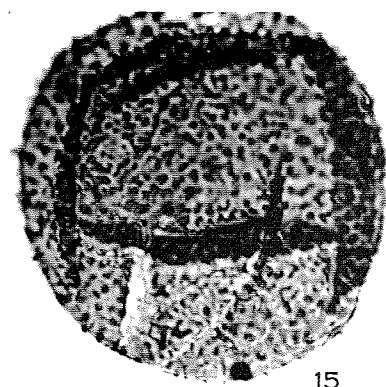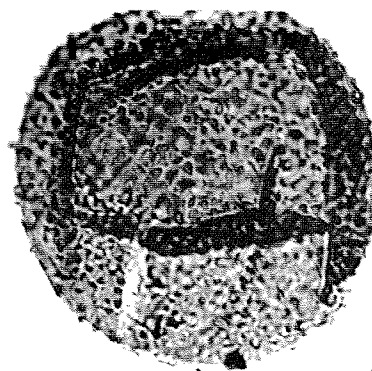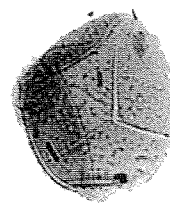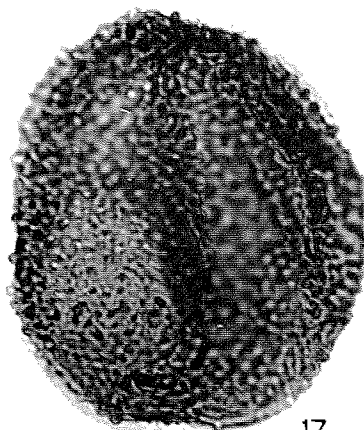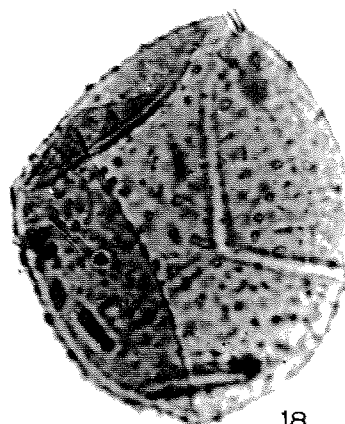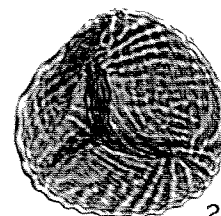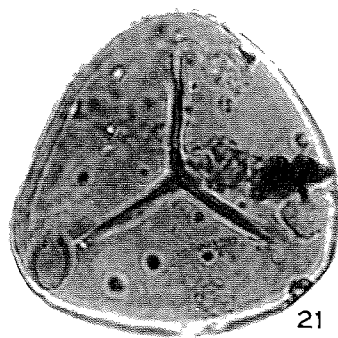
PLATE II

15

16

19

17

18

20

25

21
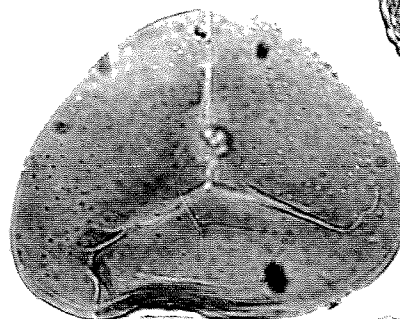
22
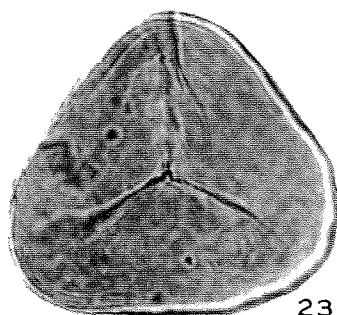
23
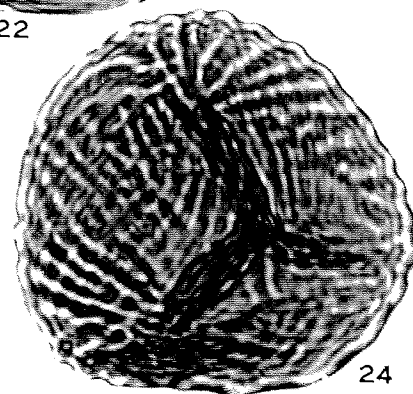
24
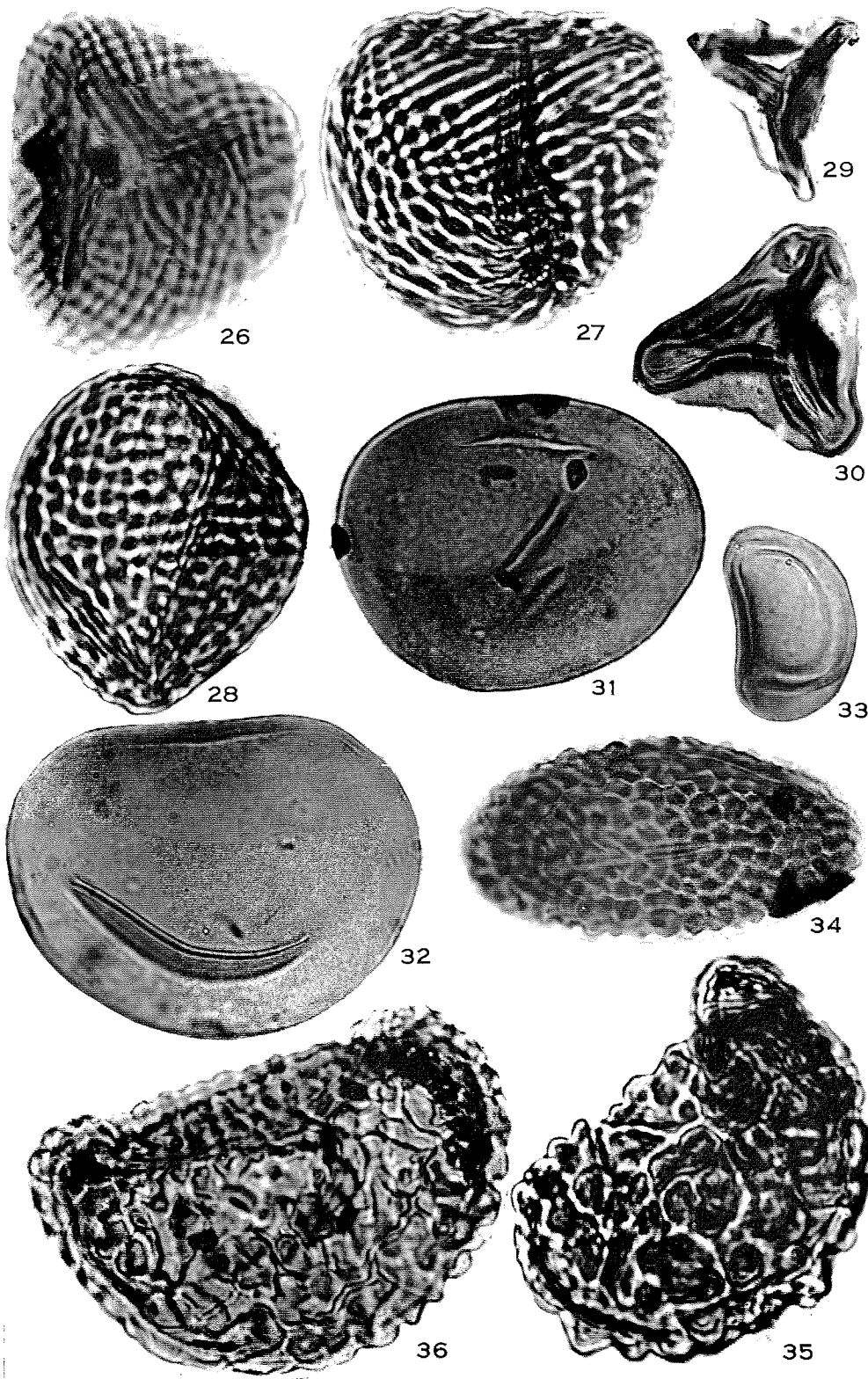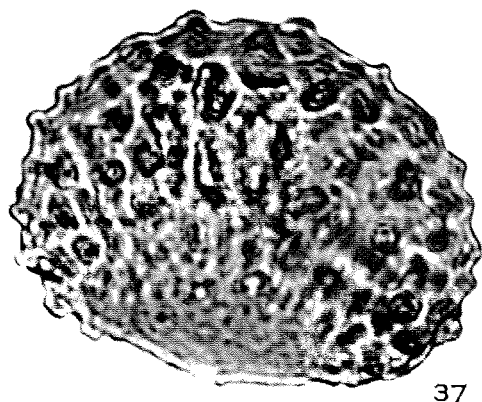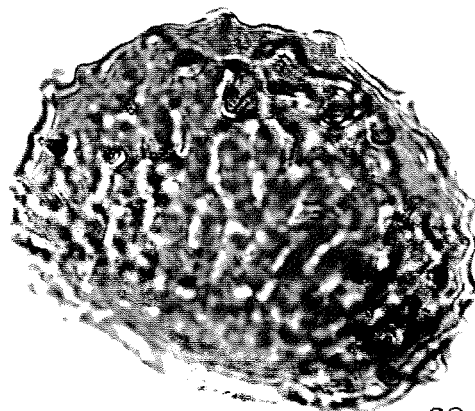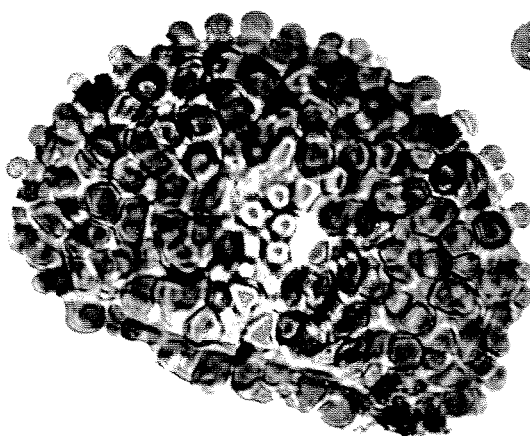
PLATE III

PLATE IV

37

38

40

41

39

42

43

44

45

PLATE V

46

47

48

49

50

51

52

PLATE VI

53

54

55

56

57

58

59

60

61

62

63

64

65

66

67

68

PLATE VII

PLATE VIII

95

96

97

98

99

100

101

102

103

104

105

106

107

108

109

110

111

112

113

114

115

116

PLATE IX

117

118

119

120

121

122

123

124

125

126

127

128

129

130

131

132

133

134

135

PLATE X

136   137   138   139   140

141   142   143   144

145   146   147   148

149   150   151   152

153   154   155   156

PLATE XI

157

158

159

160

161

162

163

164

165

166

167

168

169

170

171

172

173
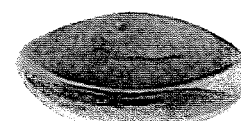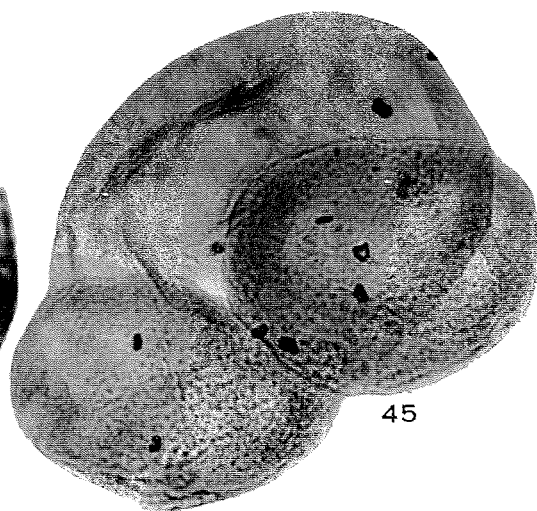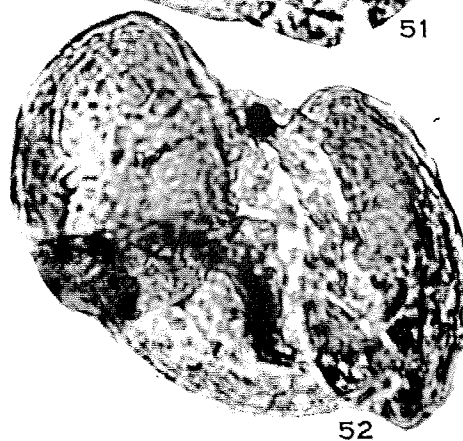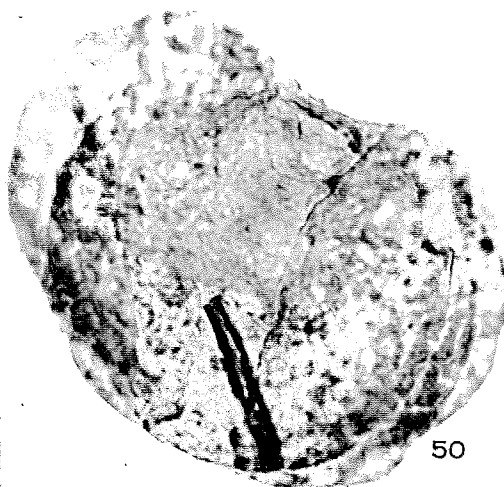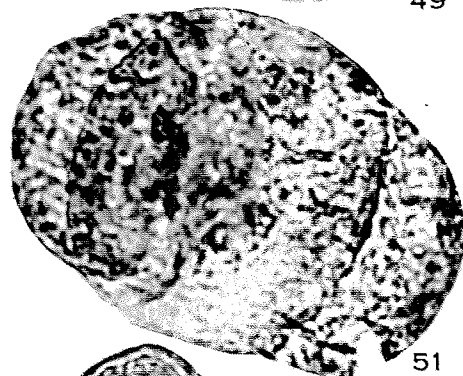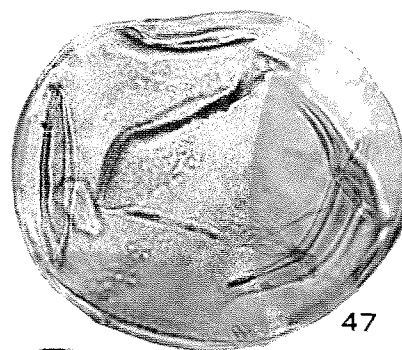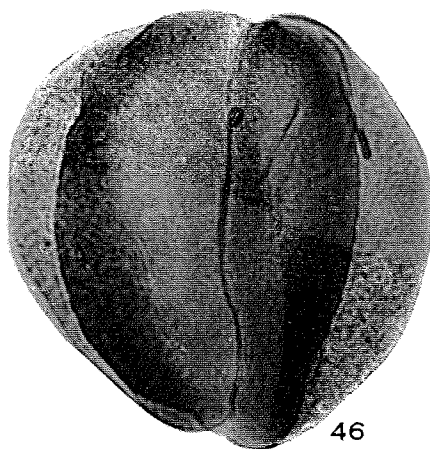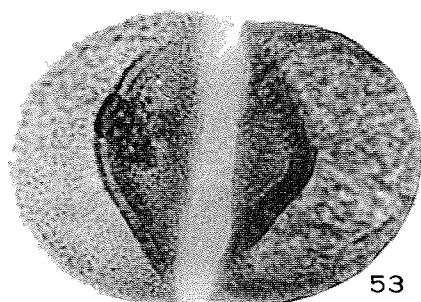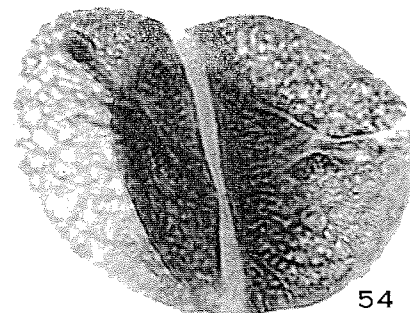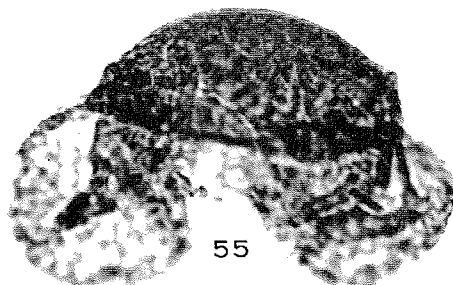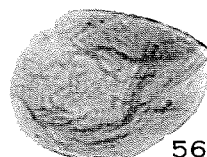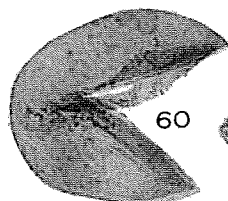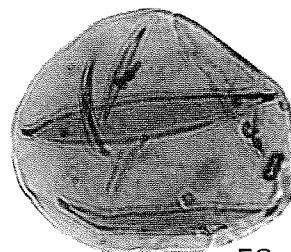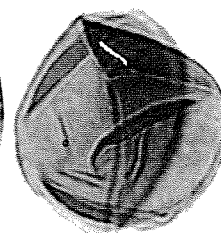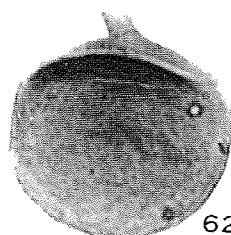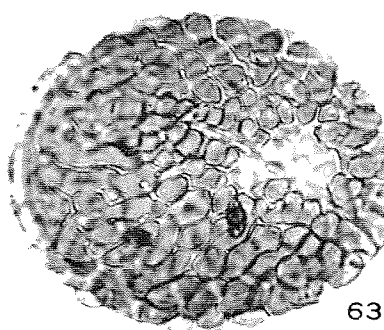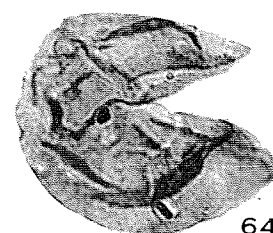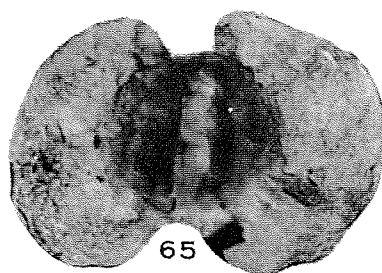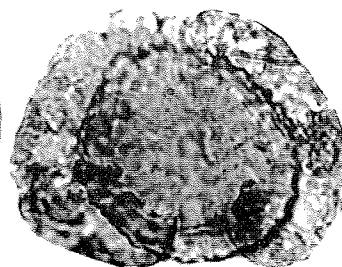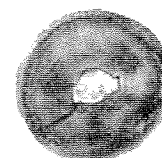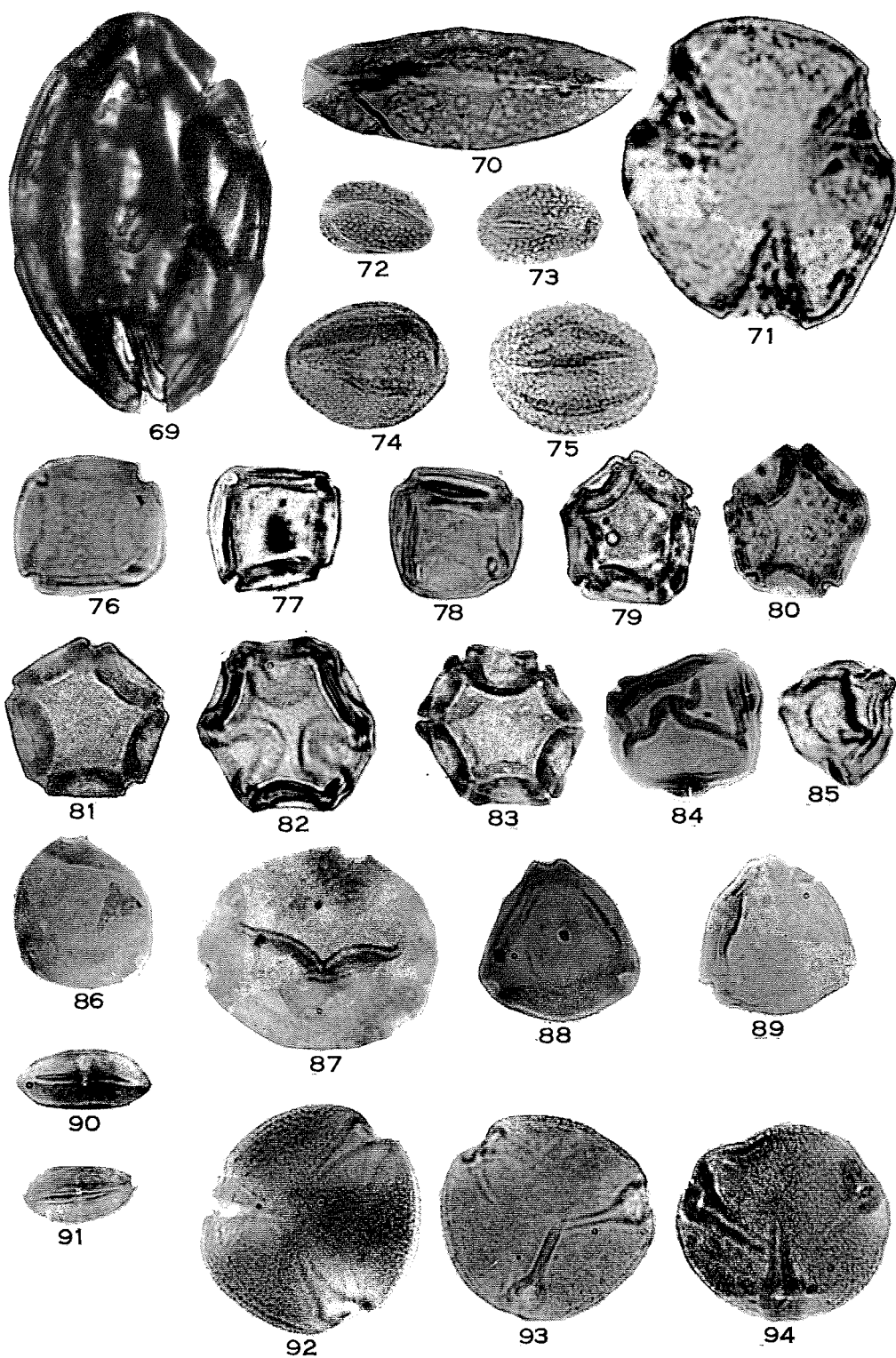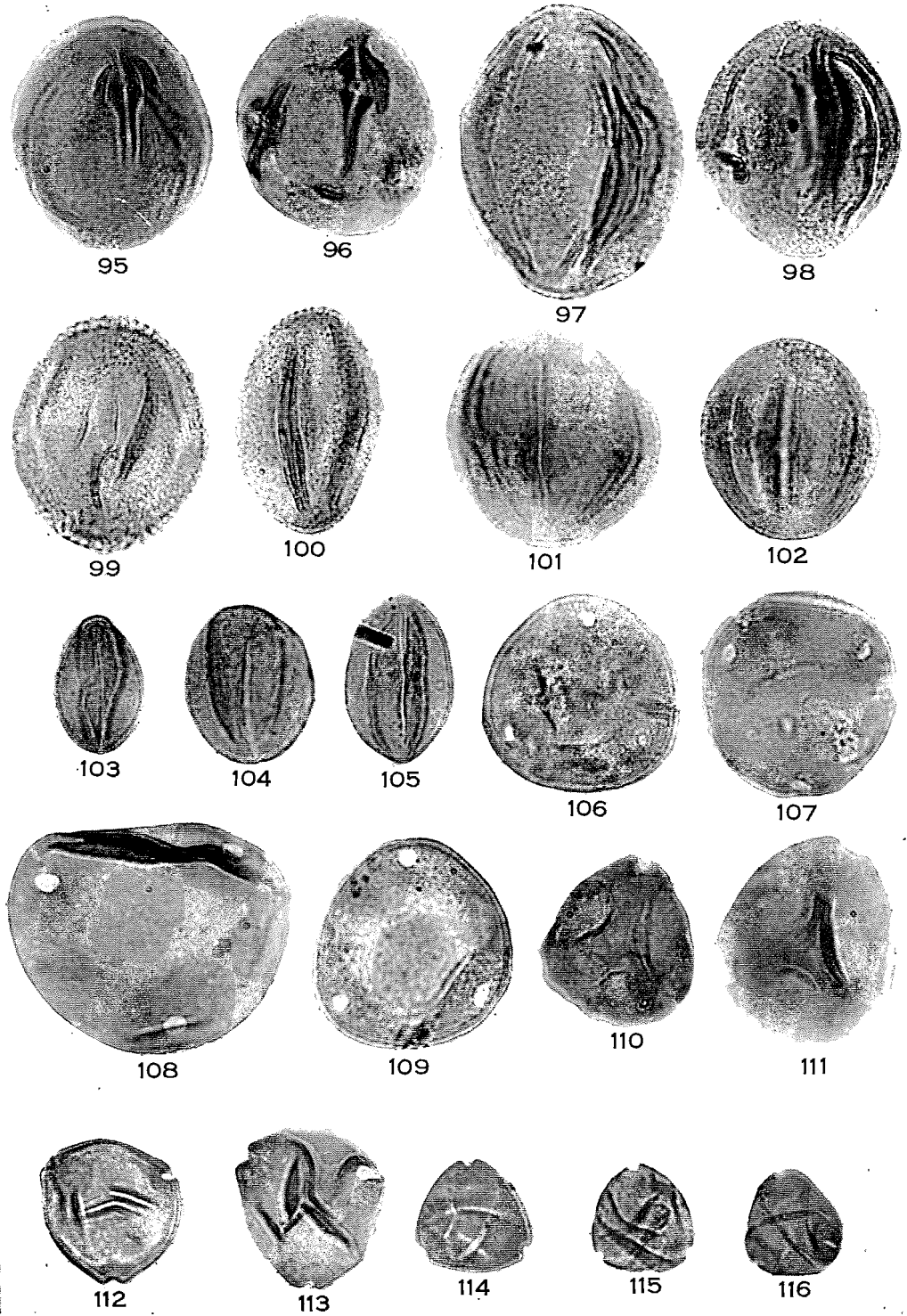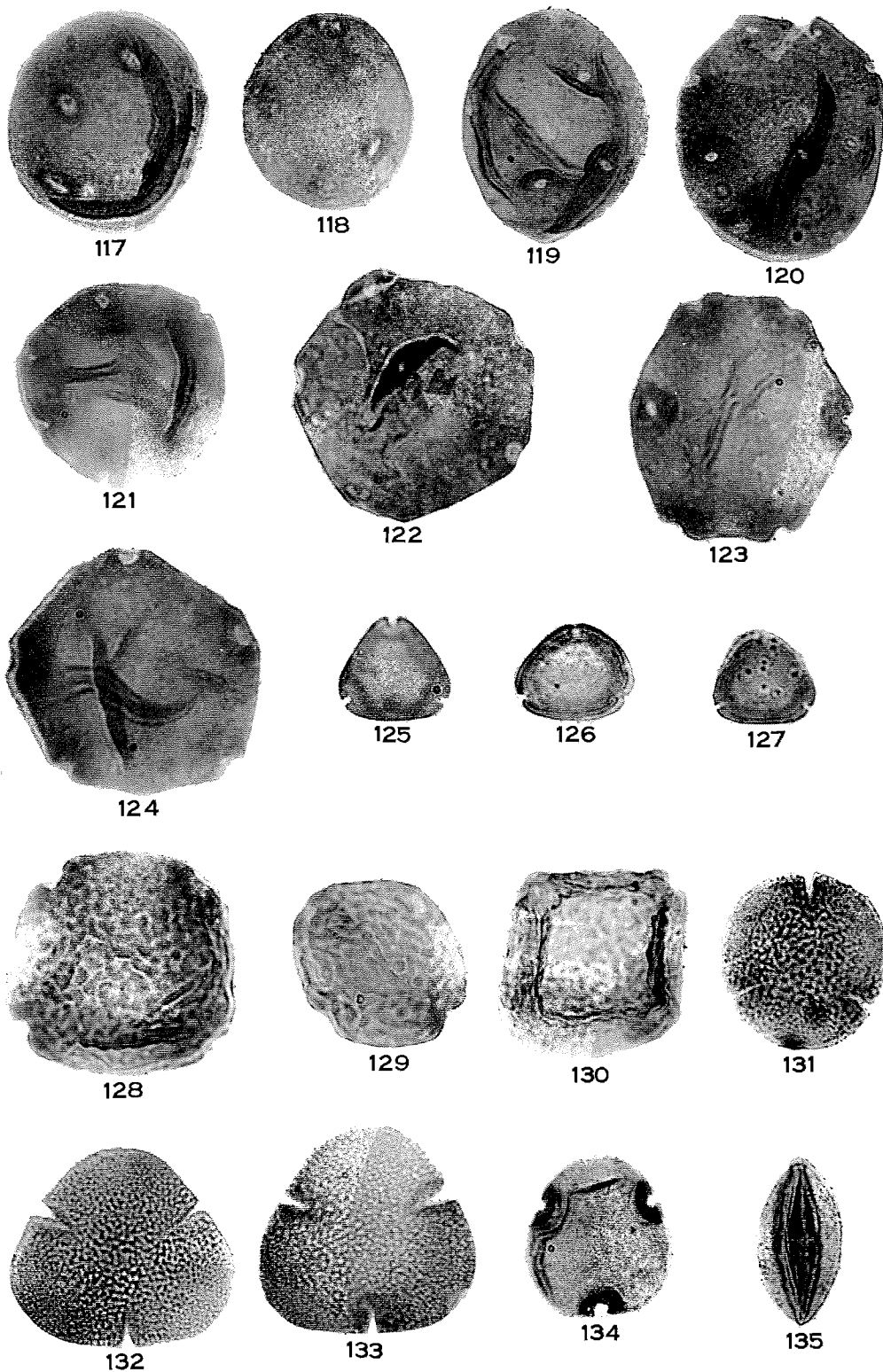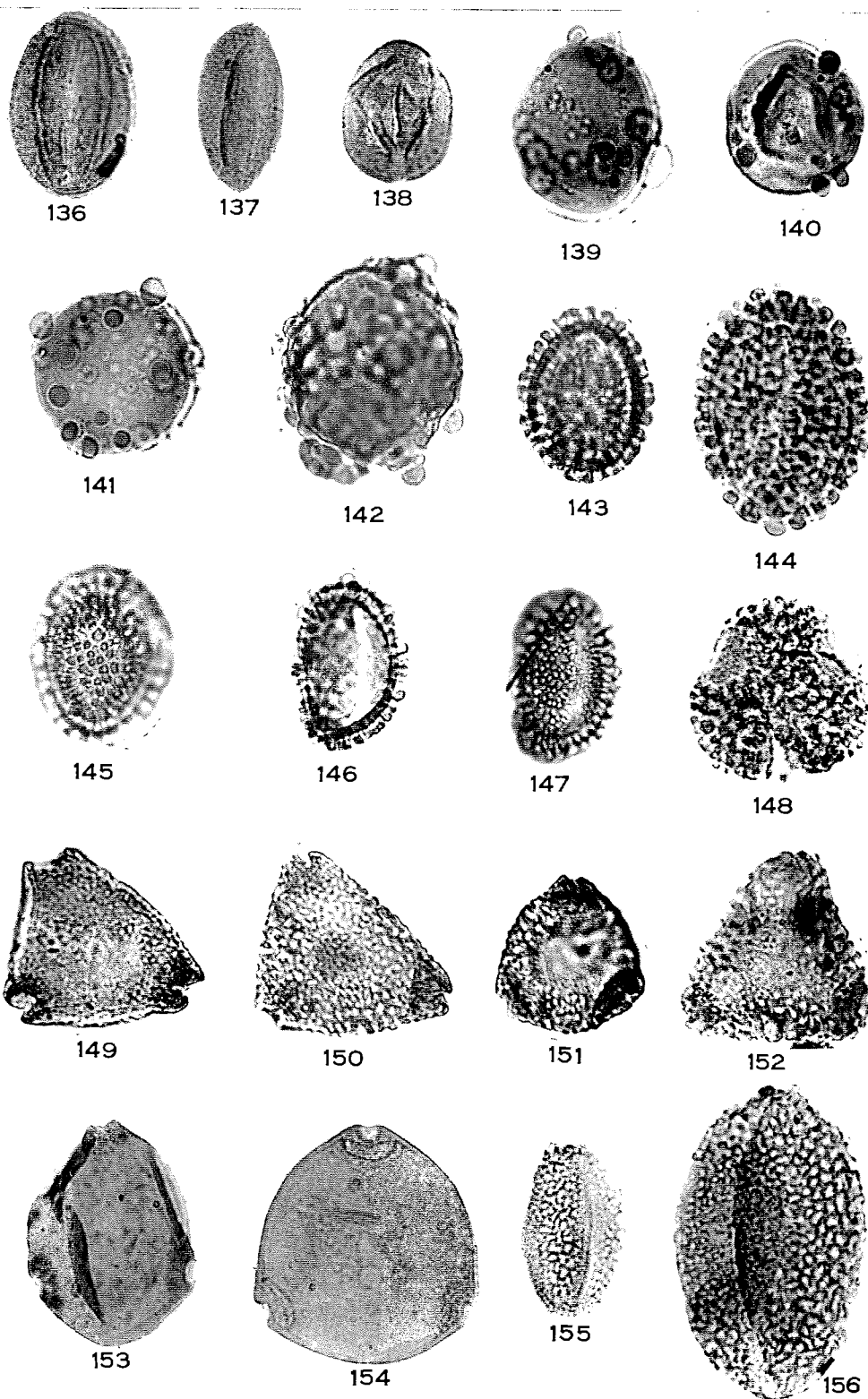
PLATE XII
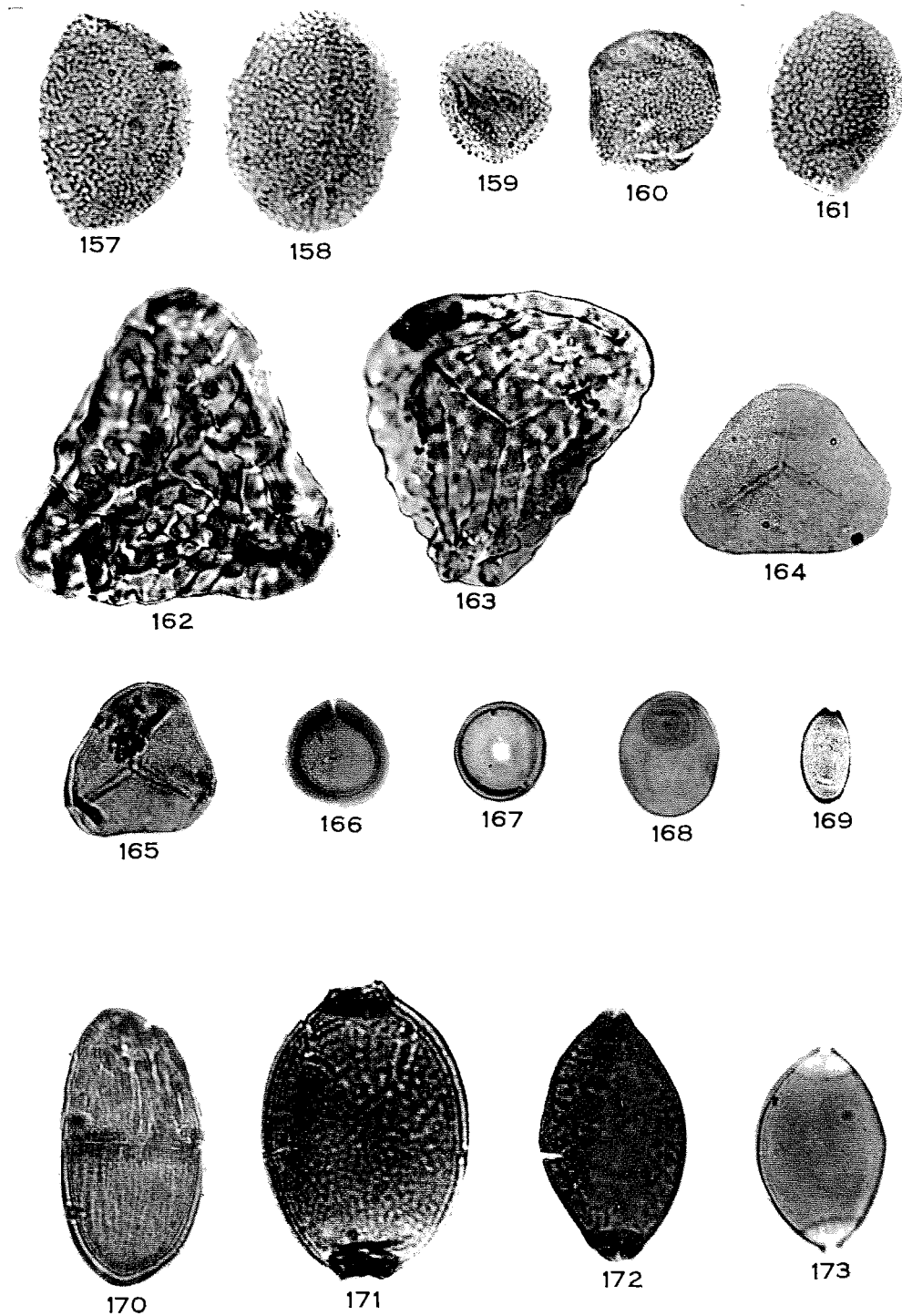
174
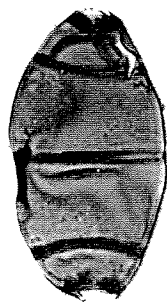
175
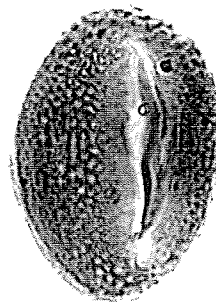
176
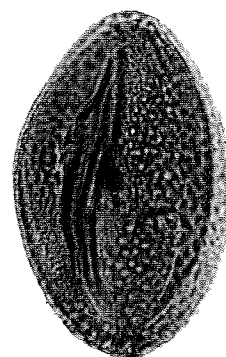
177
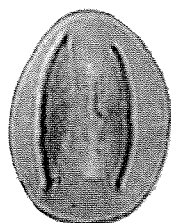
178

179
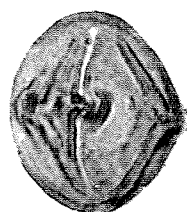
180

181

182

183

184

185

186