Palynology of the Eocene Kitsilano Formation, southwest British Columbia

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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-serially 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

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<table>
<thead>
<tr>
<th>EPOCH</th>
<th>NORTHWESTERN WASHINGTON WELL SECTIONS</th>
<th>SOUTHWESTERN BRITISH COLUMBIA OUTCROPS</th>
<th>NORTHWESTERN WASHINGTON OUTCROPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLEISTOCENE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MIOCENE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oligocene</td>
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<td></td>
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<tr>
<td>Eocene</td>
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</tr>
<tr>
<td>Paleogene</td>
<td></td>
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</tr>
<tr>
<td>Upper Cretaceous</td>
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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 Burrrard 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 Burrrard as described by Rouse (1962). Some of the more important genera are Osmunda, Anemia, Cicutricissporites, Lygodium, Pinus, Taxodium, Fodocarpus, Salix, Alnus, Carpinus, Corylus, Castanea, Fagus, Quercus, Caryya, Engelharditia, 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 Burrrard and Kitsilano Formations. Tsuga is not found in the Kitsilano but occurs in low frequency in the Burrrard Formation. Ilex is absent in the Burrrard, 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. Pityocarya, while not common, is present in the upper half of the Kitsilano but was not reported from the Burrrard. Finally, Pistillipollenites, which locally reaches several percent in the Burrrard, is present only in the lower part of the Kitsilano.

The fact that Ilex is present suggests either a short time break between Burrrard and Kitsilano times or the establishment of Ilex during the early stages of Kitsilano deposition. Pityocarya 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 Burrrard and Kitsilano are similar, and both units apparently were formed under the same depositional environment. No clear-cut formalional 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 Burrrard, but that both represent a continued period of locally discontinuous deposition. Perhaps local disastems occur within the Burrrard-Kitsilano, but they are not of sufficient magnitude to be called unconformities. If this is so, the formalional names Burrrard and Kitsilano should be discarded and an all-encompassing name applied to both.

In summary the Burrrard 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))

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

TABLE I (Concluded)

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

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-
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 indefinite 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\(\mu\)) 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

**DESCRIPTION:** Uniseriate fungal spores with individuals consisting of several to many cells. The width varies from 12 to 25\(\mu\) and the length may be in excess of 100\(\mu\), depending upon the number of component cells. Length of individual cells 6 to 12\(\mu\). A 0.5 to 1.0\(\mu\) 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.

**DESCRIPTION:** Spores 35 to 50\(\mu\) 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

**DESCRIPTION:** Segmented and germinating fungal hyphae, overall length 150\(\mu\), average thickness of hypha is 7\(\mu\).

**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 Zsoetes**

*Zsoetes?* sp.

**DESCRIPTION:** Small (17 to 23\(\mu\)) 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 *Zsoetes* remains highly tentative, but it closely resembles the illustration and descriptions given by Erdtman (1943) for *Isotes* microspores.

**FREQUENCY:** Rare.

**ORDER Lycopodiaceae**

**FAMILY Lycopodiaceae**

**GENUS Lycopodium**

*Lycopodium annotinioides* (Krutzsch) Martin and Rouse 1966

**DESCRIPTION:** Trilete spore, 30 to 35\(\mu\), 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\(\mu\) between muri; muri up to 2\(\mu\) 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. Laeaeurae 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. Laeaeurae 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:** 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 laeaeurae extend to equator. Ornamentation varies slightly from definitely baculate to weakly vermiculobaculate; bacula closely spaced, ranging from 1 to 3 μ in length. 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.

**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
Fig. 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 schizaceous 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.

Fig. 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 thickenings 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 gleichenaceous spores, see Skarby (1964).

FREQUENCY: Rare.

Family POLYPODIACEAE

Laevigatosporites 

*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

**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. Polyodiaceae 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. *Polypodisporites*, *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 \( \mu \); bladders nearly subspherical, 55 by 45 \( \mu \). 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 clavulata* as illustrated in Erdtman (1943) and Macko (1957). However, Macko gives overall dimensions of up to 200 \( \mu \) while Erdtman gives dimensions of 102 to 161 \( \mu \). 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 \( \mu \).

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 Burrrad Formation. However, a number are smaller, with the observed size range for the present specimens being 50 to 70 \( \mu \). 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 \( \mu \), while *Pseudotsuga* lies within the comparatively narrow range of 90 to 100 \( \mu \).

**FREQUENCY:** Rare to common.

**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 Burrrad Formation by Rouse (1962).

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

**Genus 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 \( \mu \), bladders slightly larger.

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

**FREQUENCY:** Rare.

**Genus 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 \( \mu \).

**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 \( \mu \). 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**

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 obscurilaeusuratus* 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 micoreticuloidatus* 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 sub-parallel 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.

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

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.

Moreover, other grains were assigned to the following genera and species:

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 is 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. betuloides, 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 Burrrard Formation and the Miocene or Pliocene Skonum 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 trirporate 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.

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), trirporate 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 it is 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 stellata* 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 Monipites Wodehouse**

*Monipites tenuipolus* 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. tenuipolus* from the Paleocene of South Dakota, and calls it *Engelhardtia microfoveolata*. 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 constituent 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. *Monipites*
shows a marked resemblance to the modern
genus Moinisia.

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 \( \mu \) in diameter. Four pores are the rule,
although three and five have been observed;
they are somewhat elliptical, 3 to 4 \( \mu \) 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 dis-
tinguished 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 \( T. \) granopollenites described by Rouse
from the Burrard Formation. It looks much
like the modern \( T. \) americana but according to
Wodehouse (1935), \( T. \) americana character-
istically 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 subtriang-
ular, 24 to 34 \( \mu \), 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, com-
prise 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 Bom-
bacaceae to family rank. Fuchs (1967) feels
sufficient evidence is now available to dis-
tinguish 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 \( \mu \)), tricolporate
grain, invariably subcircular. Pores circular and
deeply sunken, forming pits. Subexinous thick-
ening around pores is considerable and always
conspicuous. Exine is pitted to minutely reticu-
late.

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 \( \mu \), markedly pointed polar ends. Tricol-
porate, colpae extending from end to end of
grain. Marked subexinous thickenings. Small
circular pore located in short, shallow, trans-
verse furrow. Exine is fine granular with a sug-
gestion 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 Rusbyaenathus, 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

**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 notch-like. 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. thalmani* 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.

**Order Myrionales**

Family Myricaceae

Genus Myrica L.

*Myrica annulites* Martin and Rouse 1966

**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.

**Class Monocotyledonae**

**Order Liliales**

Family Liliaceae

Form genus Liliacidites Couper

*Liliacidites sp.*

**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

**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

**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.

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*Fusiformisporites* microstriatus n. sp.

**Description:** 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. crabbi* 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.

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*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.

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*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 Affiliation:** Probably a fungal or algal spore.

**Frequency:** Rare.

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*Diporisporites* sp.

**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 Affiliation:** Unknown.

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

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*Diporisporites* sp.

**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 Affiliation:** Probably fungal spores.

**Frequency:** Rare.
Tricolporate 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. 

Tricolporate 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. 

Tricolporate C  
Fig. 179  
**DESCRIPTION:** Small (15 to 19 μ), 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. 

Uniseriate Fungal Spores  
Figs. 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. 


Fig. 161. *Potamogeton hollickipites* Wodehouse 1933 (× 1000).
Fig. 164. *Deltoidospora* sp. 1 (× 1000).
Fig. 165. *Deltoidospora* sp. 2 (× 1000).
Fig. 168. Monoporate B (× 1000).
Fig. 169. Monoporate C (× 1000).
Fig. 170. *Punctoidosporites microstriatus* n. sp. (× 1000).
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. Tricolorporate 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.