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Palynological Differences Between the Chuckanut and Huntingdon Formations, Northwestern Washington

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PALYNOLOGICAL DIFFERENCES BETWEEN THE CHUCKANUT AND HUNTINGDON FORMATIONS, NORTHWESTERN WASHINGTON

A Thesis

Presented to

The Faculty of

Western Washington University

In Partial Fulfillment

Of the Requirements for the Degree

Master of Science

by

Kenneth N. Reiswig

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MASTER'S THESIS

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ABSTRACT

Pollen and spore assemblages from the Tertiary coal-bearing Chuckanut and Huntingdon Formations were studied to determine the existence and location of the southern boundary of the Bellingham Basin. Ages of deposition were determined for each formation based on the flora recovered. The age of the Chuckanut Formation ranges from Middle Paleocene at its base to Late Eocene at its top. The age of the Huntingdon in northwestern Washington is Late Eocene to perhaps Earliest Oligocene. From the evidence of palynomorph ranges, no definite age breaks were found within the Chuckanut Formation, or between the Chuckanut and Huntingdon Formations. The structure of Squalicum Mountain, located near the southern boundary of the Bellingham Basin, was determined by taking numerous strikes and dips (Pevear and Reinink-Smith, unpublished data, 1980; Patrick, unpublished data, 1981). These data suggest that there is not a major angular unconformity at the southern boundary of the Bellingham Basin as previously reported. The data obtained also show that structurally, palynologically, and lithologically the Huntingdon Formation south of the Nooksack River is indistinguishable from the top of the Chuckanut Formation; therefore all of the rocks formerly mapped as Huntingdon Formation in this area should be included in the Chuckanut Formation.

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I would like to thank several people who have given invaluable help and advice during all phases of this thesis. First, I would like to thank David Pevear for suggesting this topic and for being director of this thesis. I would also like to thank Glenn Rouse for his interest in this topic and for his help in identifying many of the palynomorphs. Christopher Suczek and Charles Ross gave many helpful suggestions and provided valuable criticism of early drafts of this thesis. Their help is gratefully acknowledged. Amoco Production Company provided partial funding for this research. Their support is also gratefully acknowledged. And last, and most importantly, I would like to thank my wife for her unfailing support and patience during my master's program.

INTRODUCTION

This study examines palynomorphs from the Tertiary Chuckanut and Huntingdon Formations, northwest Washington, in order to establish their ages, to evaluate the reported unconformity between them, and to define the southern boundary of the Bellingham Basin of Miller and Misch (1963) (Figure 1). The Chuckanut and Huntingdon Formations are continental fluvial deposits which contain abundant plant fossils.

Plant macrofossils from northwestern Washington were first collected by the Wilkes Exploring Expedition in 1841. The collections were sent to John S. Newberry who published descriptions and lists of the plant species (Newberry, 1863). John Evans, United States Geologist of Oregon Territory, also collected plant macrofossils from along Bellingham Bay and from Orcas and Vancouver Islands. He gave the collections to Leo Lesquereux who published descriptions of the fossils in 1859. Lesquereux (1859) apparently confused or ignored the sources for the fossils, because he interpreted them all to be Tertiary in age (Pabst, 1968, p. 3). Newberry (1863) recognized that the specimens from Orcas and Vancouver Islands were Cretaceous and those from along Bellingham Bay were much younger; he interpreted them to be Miocene (Paleocene-Eocene of present usage). Knowlton (1902) determined the fossil-plant bearing strata near Bellingham Bay to be comparable in age with the Eocene Puget Group.

More recent studies by Pabst (1968) have concentrated on systematically sampling and zoning the Chuckanut Formation. She reported on the non-flowering plants and concluded that the flora

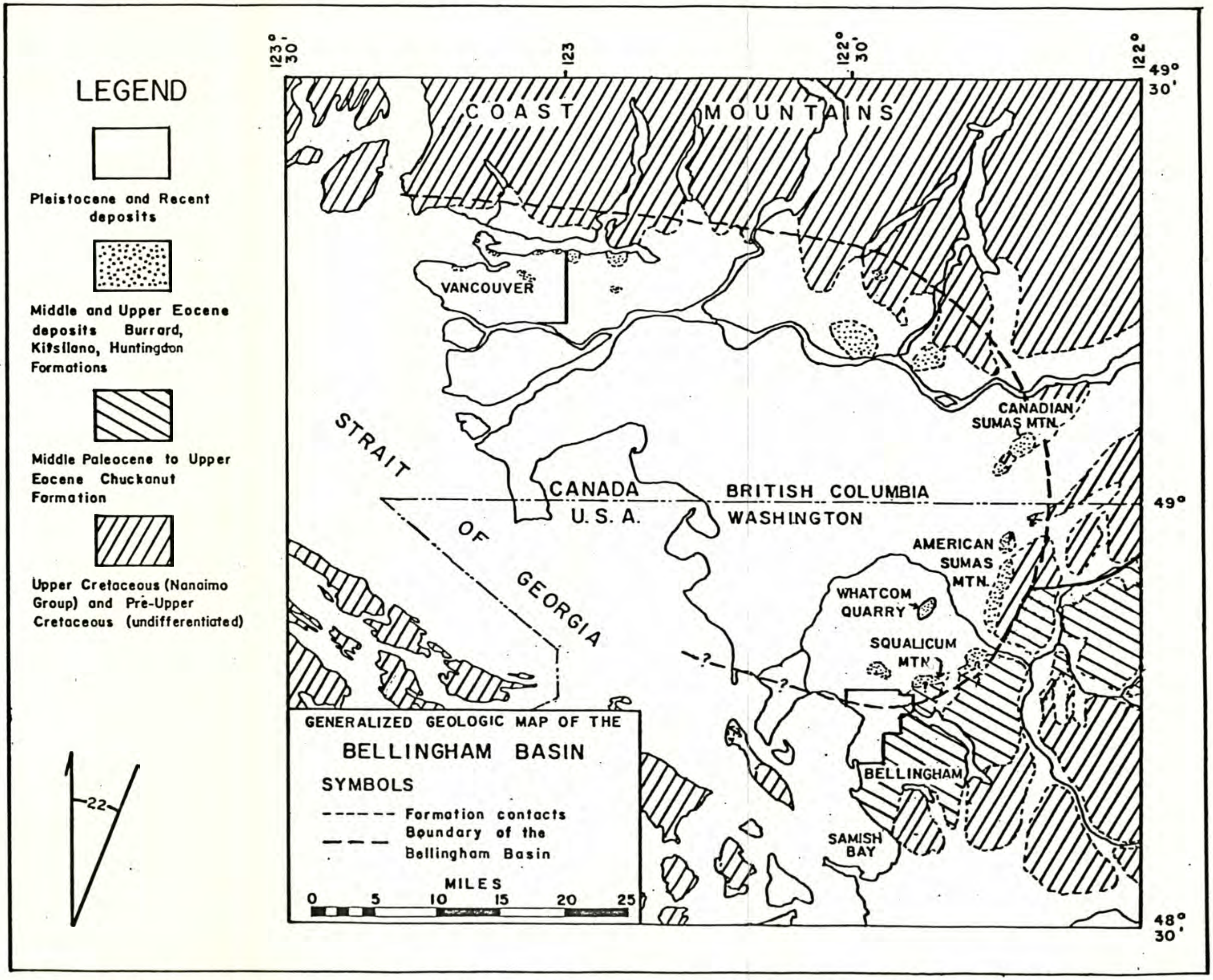


Figure 1. Generalized geologic map of the Bellingham Basin. Data modified from Miller and Misch (1963) and Hopkins (1966).

was most similar to the flora of the Fort Union Formation and therefore the rocks were Paleocene in age. However, she noted that the flora from the base of the Chuckanut compared best to the floras of the Naniamo, Denver, Mesa Verde, and Vermejo Formations, which are Late Cretaceous and Early Paleocene in age. Also the flora from the top of the Chuckanut Formation compared best to the Middle Eocene Clarno and Steel's Crossing floras. Griggs (1965) systematically studied the palynoflora of the lower 5,100 feet (1,555 m) of the Chuckanut type section located on the eastern shore of Samish Bay. Based on the palynoflora described, he concluded that the age was probably Paleocene to Early Eocene. However, he was not able to collect suitable samples for study from the lower 377 feet (115 m) of the section, and he stated that Upper Cretaceous rocks could exist in that portion.

The Huntingdon Formation was first described and named by Daly in 1912 during his examination of the geology along the 49th parallel. Daly submitted fossil leaves from the Huntingdon Formation to F.H. Knowlton; unfortunately, they were too poorly preserved to be of any diagnostic value (Daly, 1912). Hopkins (1966) studied the palynoflora of some of the Tertiary rocks of the Bellingham Basin, including outcrops of the Huntingdon Formation, and concluded that an Eocene age was indicated by the palynoflora.

Geologic and Geographic Setting

The area of the present study is in western Whatcom County, northwestern Washington (Figure 1). Miller and Misch (1963) interpret the Huntingdon Formation in this area as filling a large synclinal structural basin that extends from just north of Vancouver British Columbia, east to Canadian and American Sumas Mountains, and south to Squalicum Mountain. They interpret the southern boundary between the overlying Huntingdon Formation and the underlying Chuckanut Formation as an angular unconformity, with the location of the unconformity determined from the dips of the beds. However, because of the poor exposure, Miller and Misch (1963) question the discordance of dip between the Chuckanut and Huntingdon Formations south of the Nooksack River (note question marks on southern boundary of the basin, Figure 1).

The Chuckanut Formation crops out principally south of Bellingham, on Lummi Island, and east of American Sumas Mountain. Glover (1935) and Weaver (1937) give detailed stratigraphic descriptions of the type section along the east shore of Samish Bay. Glover states that 9,500 feet (2,896 m) of continental clastic sediments are present. Miller and Misch (1963) report 15,000 to 20,000 feet (4,572 to 6,906 m) of Chuckanut sediments east of American Sumas Mountain. The formation consists primarily of arkose with considerable amounts of shale, siltstone, and conglomerate; the few coal seams are generally confined to the upper part of the section (Glover, 1935).

Structurally the Chuckanut Formation is folded along a northwesterly trend south of Bellingham and a northeasterly trend north of the Nooksack River. This deformation is intense, and the folds are open to moderately tight. Locally there are overturned beds and evidence of minor reverse faults or overthrusts. The Boulder Creek Fault cuts the Chuckanut Formation on American Sumas Mountain (Miller and Misch, 1963). Miller and Misch (1963, p. 173) suggest that displacement is "much greater than 5,000 feet" on this fault. They also find that the northeast-southwest trending fault is overlapped on the west end by the Huntingdon Formation, which is not offset. Miller and Misch (1963) suggest that an angular unconformity exists between the Chuckanut and Huntingdon units on American Sumas Mountain.

The Huntingdon Formation type section crops out on the south end of Canadian Sumas Mountain (Daly, 1912). Post-Chuckanut rocks are also exposed on American Sumas Mountain, and Moen (1962) shows these to be part of the Huntingdon Formation. Miller and Misch (1963) map two additional areas of Post-Chuckanut rocks in the Squalicum Mountain vicinity southwest of American Sumas Mountain as Huntingdon. The structure of the Squalicum Mountain area is much less certain than that of American Sumas Mountain and has not been studied in detail. According to previous workers (Kerr, 1942; Cummings and McCammon, 1952; Horton, 1978) the lower portion of the Huntingdon Formation is deposited on a saprolitic weathering surface (paleosol) that is intensely weathered and kaolinitized. The paleosol is sufficiently weathered to form the only economically important fire-clay deposits in British Columbia (Cummings and McCammon, 1952). The total thickness of the formation is not known because neither the top nor the bottom of the section is exposed; however, Kerr (1942) measured a 1,400 foot (427 m) incomplete stratigraphic section. He states that:

> "...about 300 feet consists of clayey shales, lignite seams, gray shales, indurated grit and sandstone. The remaining 1,100 feet are made up principally of pebbly conglomerate with interbedded sandy layers and they are found on the upper slopes of the hill." (Kerr, 1942, as quoted by Hopkins (1966, p. 32).

The clasts in the conglomerate are primarily granite, diorite, quartzite, black argillite, and greenstone (Hopkins, 1966). The sands are arkoses which appear very similar to those of the Chuckanut Formation. However, Miller and Misch (1963, p. 171) state that "its degree of lithification and cementation are considerably less."

The Huntingdon Formation appears to be much less deformed than the Chuckanut Formation (Hopkins, 1966). Average dips are 10 to 15 degrees southwest with strikes of N45W (Hopkins, 1966). Dip varies locally as the result of irregular sag and differential movement during uplift (Hopkins, 1966).

Sandstones in the Huntingdon Formation are lenticular and show abundant cut and fill structures and cross-bedding features. On the other hand, shales and lignites may extend as much as 1,000 feet (305 m) along strike without any noticeable change in thickness or character (Kerr, 1942).

The typical stratigraphic column of the rocks in the Bellingham Basin is shown in Figure 2. The Chuckanut Formation unconformably overlies pre-Tertiary igneous and metamorphic rocks. On American Sumas Mountain, which I have not studied, the Chuckanut Formation is apparently unconformably overlain by the Huntingdon Formation (Moen, 1962; Miller and Misch, 1963). The Huntingdon Formation is unconformably overlain by Pleistocene and Recent deposits.

Purpose and Scope

The major purpose of this study is to substantiate the existence and location of the southern boundary of the Bellingham Basin as described by Miller and Misch (1963). Palynofloras were studied at four different localities near the reported unconformity in order to find an age

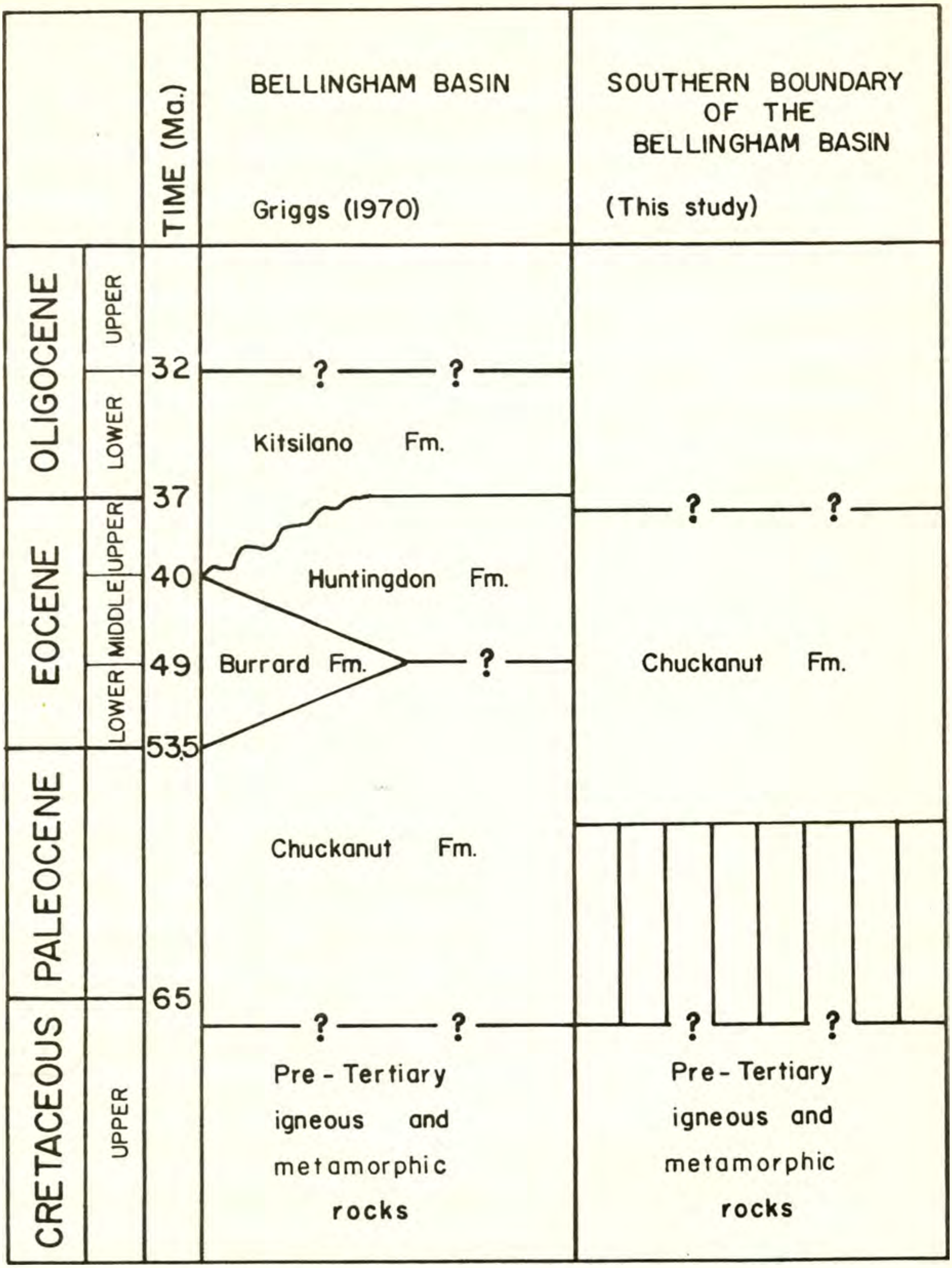


Figure 2 Generalized stratigraphic columns of the Bellingham Basin. Absolute time from Hardenbol and Berggren (1978).

difference between the two formations. Eight additional localities were sampled from the Chuckanut Formation to establish the age range for the entire formation. Overall, Chuckanut Formation samples give a Middle Paleocene to Late Eocene age and Huntingdon Formation samples give an age of Late Eocene based on the respective palynofloras sampled. In addition to the study of palynology, strikes and dips were measured to verify Miller and Misch's (1963) findings of a discordance between the Chuckanut and Huntingdon Formations and to better locate the possible unconformity (Pevear and Reinink-Smith, unpublished data, 1980; Patrick, unpublished data, 1981).

The second purpose is to determine more accurate ages for the Chuckanut and Huntingdon Formations by comparison with published stratigraphic ranges (Hopkins, 1966; Griggs, 1970; Rouse, 1977; Rouse and Mathews, 1979; Newman, 1980; Frederiksen, 1980). The age of the Chuckanut has been considerably debated, and ages ranging from Late Cretaceous to Early Eocene have been reported (Miller and Misch, 1963; Pabst, 1968; Griggs, 1970; Frizzell, 1977; Johnson, 1981). Evidence from this study indicates that abundant reworked palynomorphs are present. The reworked grains can be detected because they are preserved differently than grains that are contemporaneous with sediment deposition. Many of the reworked palynomorphs are Cretaceous in age, whereas those that are from plants living contemporaneously with sediment deposition are Paleocene to Early Eocene in age. This study gives a more reliable age for the sedimentary rocks than earlier studies, because reworked palynomorphs were excluded when age determinations were made.

A third purpose is to relate the above findings to the known regional tectonics and to further explain the deformational history of the area.

These ages may date major tectonic events. A tephra layer, located on Lookout Mountain, and several detrital rocks from the lower 50 m of the Chuckanut Formation have been dated by Joe Vance and Sam Johnson (personal communication, 1981) of the University of Washington using the zircon fission track method. Their date of 49.9 ± 1.2 ma for one tephra layer in the Chuckanut Formation, which contains a well preserved palynoflora, establishes an age for one pollen and spore flora.

MATERIALS AND METHODS

Field Sampling

The samples were collected from relatively unweathered roadcuts, kept in plastic bags to prevent contamination, and labeled. Short trenches or ditches were dug in the rock to expose unweathered material. Several of the samples had insufficient well-preserved pollen and spores and were recollected from a less weathered portion of the same outcrop or by digging a deeper trench. Several samples were provided by David Pevear.

Maceration

The maceration procedure was nearly the same for all samples; however, some modifications were made depending on the lithology of the sample. All samples were crushed to ¼" size or smaller. For coaly samples a 5-gram portion was used and for shale samples a 25-gram portion was selected. The samples were placed in a beaker with 10% hydrochloric acid for approximately 12 hours. After being washed twice with distilled water, the samples were placed in 47% hydrofluoric acid and allowed to stand, with occasional stirring, for at least 12 hours. After being washed with 10% hydrochloric acid and distilled water, the samples were placed in Schulze's solution (2:1 mixture of nitric acid and saturated aqueous potassium chlorate). The coaly samples were allowed to stand for 20 minutes to one hour, whereas the shaley samples were never allowed more than 20 minutes in Schulze's solution. All samples were then placed in a heavy-liquid solution of zinc chloride (specific gravity 1.95-2.00). This step separated the lighter organic material from the heavier rock material. The samples were then placed in a boiling mixture of 9 parts acetic anhydride and one part concentrated sulfuric acid (acetolysis mixture) to remove excess organic debris. All residues were stained with Safranin O and stored in a hydroxyethylcellulose (H.E.C.) solution.

Slide Preparation

The residues were mounted in H. E. C. on cover slips and allowed to dry. The cover slips were inverted and mounted on slides with Permount mounting media. Two to eight (generally three) slides were made from each residue.

Analytical Procedure

The collection of qualitative data involved scanning the slides thoroughly and identifying each new palynomorph encountered. The different palynomorphs identified were compared with published stratigraphic ranges (Hopkins, 1966; Griggs, 1970; Rouse 1977; Rouse and Mathews, 1979; Newman, 1980; Frederiksen, 1980), and age determinations were made. Reworked palynomorphs, not considered in the age determination, were recognized by the uneven absorption of the stain, which gave a dark yellow or yellow brown color instead of the normal red (V. E. Williams, Univ. of British Columbia, personal communication, 1980). Slides were also obtained from Michigan State University of Griggs' (1965) samples. These were used for two purposes. First, the palynomorphs found in the present study were compared to the palynomorphs found in Griggs' (1965) thesis area. Second, the palynofloras Griggs recovered were compared with published stratigraphic ranges to provide a more detailed age of deposition for the lower portion of the Chuckanut Formation.

Photography

The samples were photographed using a Zeiss Photomicroscope equipped with a Nomarski interference contrast condenser. The film used was Kodak Panatomic X and Ilford Pan F, processed in HC-110 developer. Enlargements were made on Ilford Ilfobrom number four contrast paper using Kodak Dektol developer.

RESULTS

The fossil pollen and spores obtained in this study indicate a Middle Paleocene to Late Eocene age for Chuckanut samples and a Late Eocene age for Huntingdon samples. The locations and ages determined for each sample are shown in Table 1, and all except the one from Whatcom Quarry are plotted on Figure 3. The diagnostic palynomorphs recovered in this study and their stratigraphic ranges are shown in Figure 4. The ages for each sample were determined by comparing the palynoflora recovered for that sample (Table 2) with the ranges shown on Figure 4. If, for example, a sample contained *Tilia crassipites*, *Gothanipollis* A, and *Fagus* sp., the age indicated for the sample would be Late Eocene.

Zonation of the Chuckanut and Huntingdon Formations

The rocks studied can be divided into three distinct palynozones. The first zone (P-2) is Middle to Late Paleocene in age and is characterized by *Triporopollenites mullensis*, *Momipites rotundus*, *Tricolpites reticulatus*, and abundant reworked pollen of Late Cretaceous age; also present but not common from this zone are *Rhoiipites cryptoporus*-type and *Tricolpites* A. All of Griggs' (1965) samples, the Samish Lake sample, and the sample from the southwest shore of Lake Whatcom (see Table 1) represent this zone. The second zone (E-1) is Early to Middle Eocene in age and is characterized by *Pistillipollenites mcgregorii*, *Platycarya* sp., and rarely *Holkopollenites* A and *Rhoiipites latus*. The first appearence of *Multicellaesporites* sp., *Ctenoporites wolfei*, *Tilia* sp., and *Carya* sp. occurs in zone E-1 and continues into

TABLE 1

Sample number, location and description, formation, and age of the samples analyzed in this study. Samples arranged in approximate stratigraphic order.

Sample no.	Location (TRS)	Location no. and description (Fig. 3 and as used in text)	Formation (as indicated on Fig. 1 or Fig. 3)	Age (based on palynoflora)
Pb3781	SW¼ SW¼ S9 T36N R2E	1. Griggs (1965) lowest	Chuckanut	Middle Paleocene
Pb3791	NE¼ SE¼ S25 T37N R2E	2. Griggs (1965) highest	Chuckanut	Late Paleocene to Early (?) Eocene
PP0033	SE¼ NE¼ S26 T37N R3E	3. Lake Samish	Chuckanut	Late Paleocene
PP0034	NE¼ SE¼ S20 T37N R4E	4. Southwest shore of Lake Whatcom	Chuckanut	Paleocene (?)
PP0035	NE¼ SE¼ S17 T37N R4E	5. West central shore of Lake Whatcom	Chuckanut	Early-Middle Eocene
PP0017	SE¼ SE¼ S11 T37N R3E	6. Lookout Mountain	Chuckanut	Early-Middle Eocene
PP0019	S½ SE¼ S11 T37N R3E	6. Lookout Mountain	Chuckanut	Early-Middle Eocene
PP0025	NW¼ NW¼ S25 T38N R4E	7. North shore of Lake Whatcom	Chuckanut	Late Eocene
PP0041	N½ NE¼ S1 T37N R2E	8. WWU campus	Chuckanut	Late Eocene
PP0012	SW¼ NW¼ S18 T38N R4E	9. Squalicum Mountain	Chuckanut	Late Eocene
PP0014	SW¼ NW¼ S18 T38N R4E	9. Squalicum Mountain	Chuckanut	Late Eocene
PP0028	SW¼ SW¼ S11 T38N R3E	10. Toad Lake	Huntingdon	Late Eocene
PP0011	SW¼ SE¼ S11 T39N R3E	Fig. 1. Whatcom Quarry	Huntingdon	Late Eocene
PP0037	NW¼ NW¼ S33 T39N R3E	11. Kelly Road	Huntingdon	Late Eocene
PP0038	NW¼ NW¼ S33 T39N R3E	11. Kelly Road	Huntingdon	Late Eocene
PP0039	NW¼ NW¼ S33 T39N R3E	11. Kelly Road	Huntingdon	Late Eocene

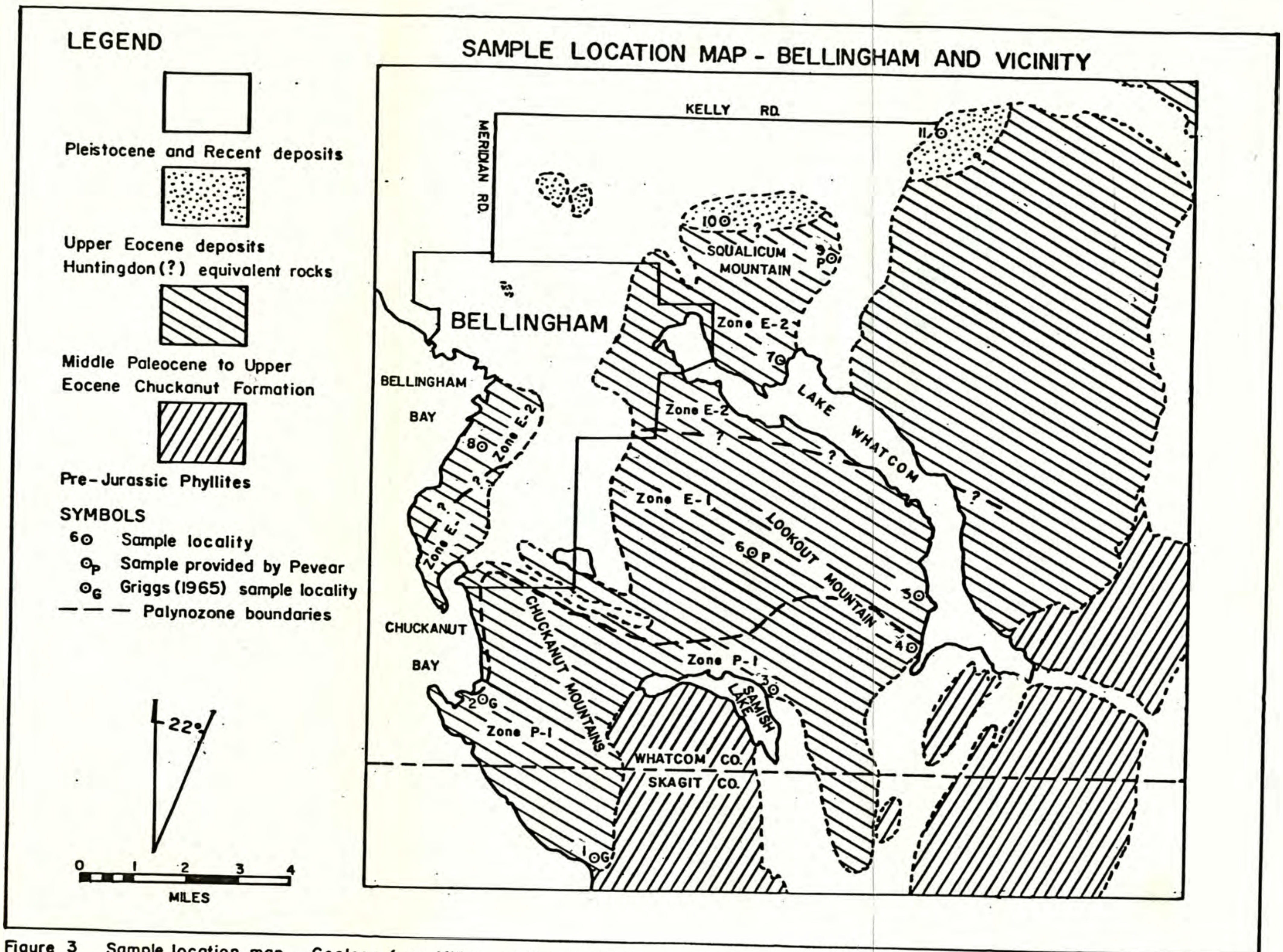


Figure 3 Sample location map. Geology from Miller and Misch (1963) and Easterbrook (1976).

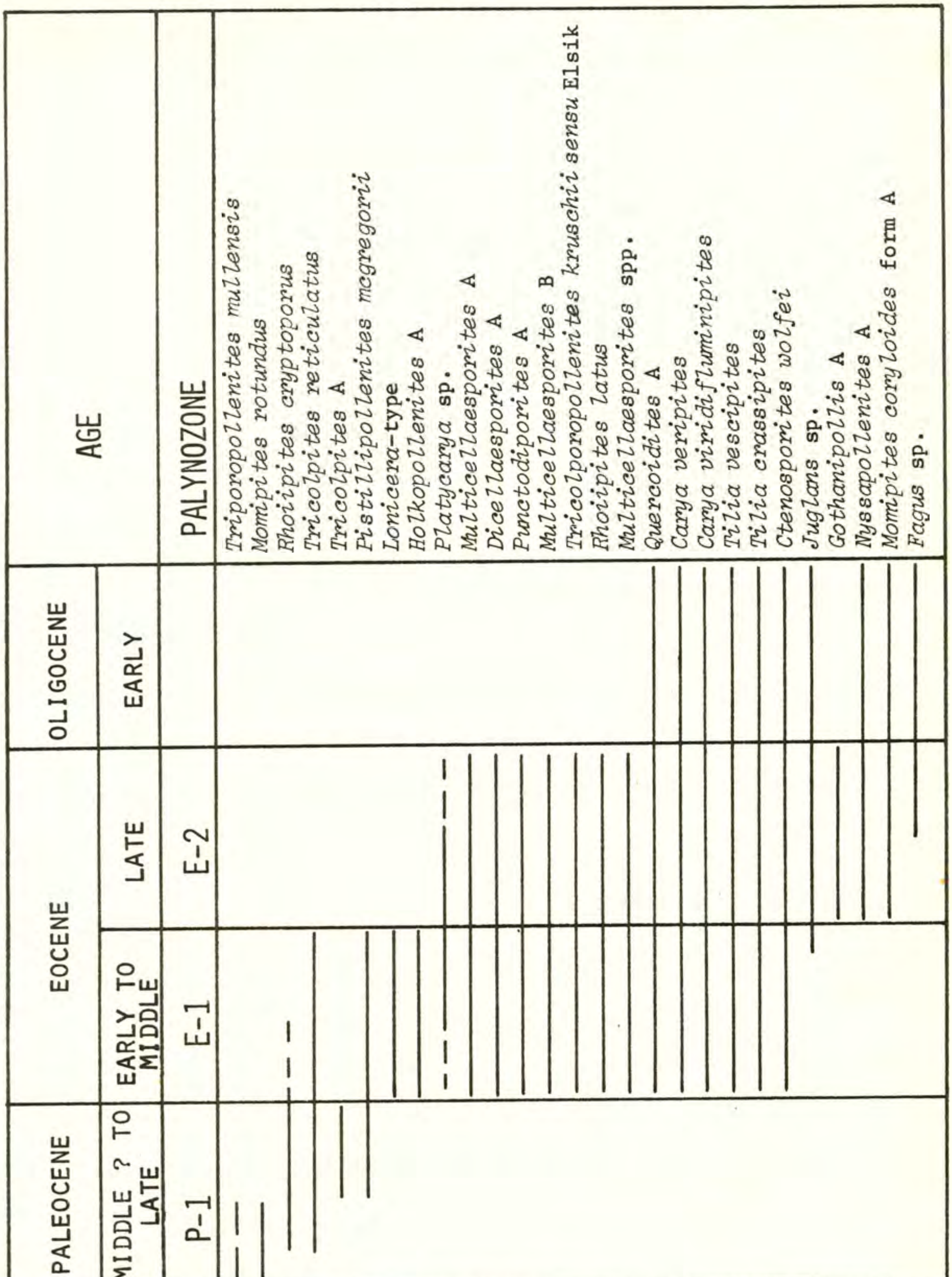


Figure 4 Chart showing the zonation of selected palynomorphs. Ranges given by Rouse (1977) and Newman (1980).

TABLE 2

Table showing the palynoflora recovered for each sample.

	PP0033	PP0034	PP0035	PP0017-19	PP0025	PP0041	PP0012, 14	PP0028	PP0011	PP0037-38
Momipites rotundus	X									
Arecipites sp.	X									
Carya sp.	X			X	X	X	X	X	X	X
pre-*Carya*	X									
Alnus sp.	X			X	X		X	X	X	X
Rhoiipites cryptoporus-type	X									
Tricolpities A	X									
Cicatricosisporites intersectus	X	X		X	X		X			
Tricolpites reticulatus	X									
Cupanieidites cf. *C. reticularis*	X									
Proteacidites cf. *P. thalmanii*	X									
cf. *Proteacidites* sp.	X			X						
Bombacacidites sp.	X			X		X	X			
Triporopollenites mullensis	X									
cf. *Holkopollenites* A	X						X			
Taxodiaceae	X	X	X	X	X	X		X		X
Pinaceae	X	X	X		X	X	X	X	X	X
Multicellaesporites A	X		X							
Dicellaesporites A	X		X							
Myrica cf. *M. annulites*	X		X	X						X
Sabal granopollenites	X	X		X						
Lonicera-type	X									
Metasequoia papillapollenites	X									
Pleuricellaesporites sp.			X			X				X
Osmunda irregulites		X		X						X
Fusiformisporites sp. 1		X								
Tilia crassipites			X		X	X	X		X	
Multicellaesporites B			X							
Momipites sp.			X	X	X					X
Tricolporopollenites kruschii (*sensu* Elsik)			X				X			
Liliacidites sp.			X			X		X		X
Nyssa sp.			X			X				
Nymphoides tripollenites			X							
Platycarya sp.			X	X	X					X
Cupanieidites sp.			X							
Fusiformisporites sp. 2				X						
Rhoiipites latus				X	X					
Pistillipollenites mcgregorii				X						
Punctodiporites A				X		X		X		
Tilia vescipites				X			X			X
Gothanipollis A					X	X	X	X	X	
Quercoidites					X	X				
Polypodiaceae					X		X			
Juglans sp.						X	X	X		
Nyssapollenites A (?)						X				X
Pterocarya sp.						X		X	X	X
Ulmus sp. or *Zelkova* sp.						X		X		
Ctenosporites wolfei						X	X			
Quercus sp.									X	X
Momipites coryloides form A						X		X		
Caprifolipites tantalus						X				
Acritarch cf. *Micrhystridium*								X		
cf. *Larix* sp.								X		X
Quercus granopollenites										X
Corylus tripollenites										X
Liquidambar sp.										X
Multicellaesporites spp.										X
Araliaceaeoipollenites cf. *A. profundus*										X
Fagus sp.										X
Pinus sp. *haploxon*-type										X
Ilex sp.										X
Typha sp.										X
Diporate A										X
Pleuricellaesporites psilatus										X
Fungal hyphae										X

the third zone (E-2). The Lookout Mountain samples and the sample from the west central shore of Lake Whatcom represent zone E-1. Zone E-2 is from Late-Middle to Late-Late Eocene in age and is characterized by *Quercus* sp., *Fagus* sp., and *Gothanipollis* A. *Momipites coryloides* and *Juglans* sp. are much less common but present in several samples from this zone. The samples from the north shore of Lake Whatcom, Western Washington University (WWU) campus, Squalicum Mountain, Toad Lake, Whatcom Quarry, and Kelly Road represent this zone.

Structure of Squalicum Mountain

The structure of Squalicum Mountain was determined by taking strikes and dips of all outcrops that could be located (Figure 5). This work was done by Dr. David Pevear and Linda Reinink-Smith (unpublished data, 1980) and Brian Patrick (unpublished data, 1981). Their studies show that there is little structural evidence for an angular unconformity located where mapped by Miller and Misch (1963) or Easterbrook (1976).

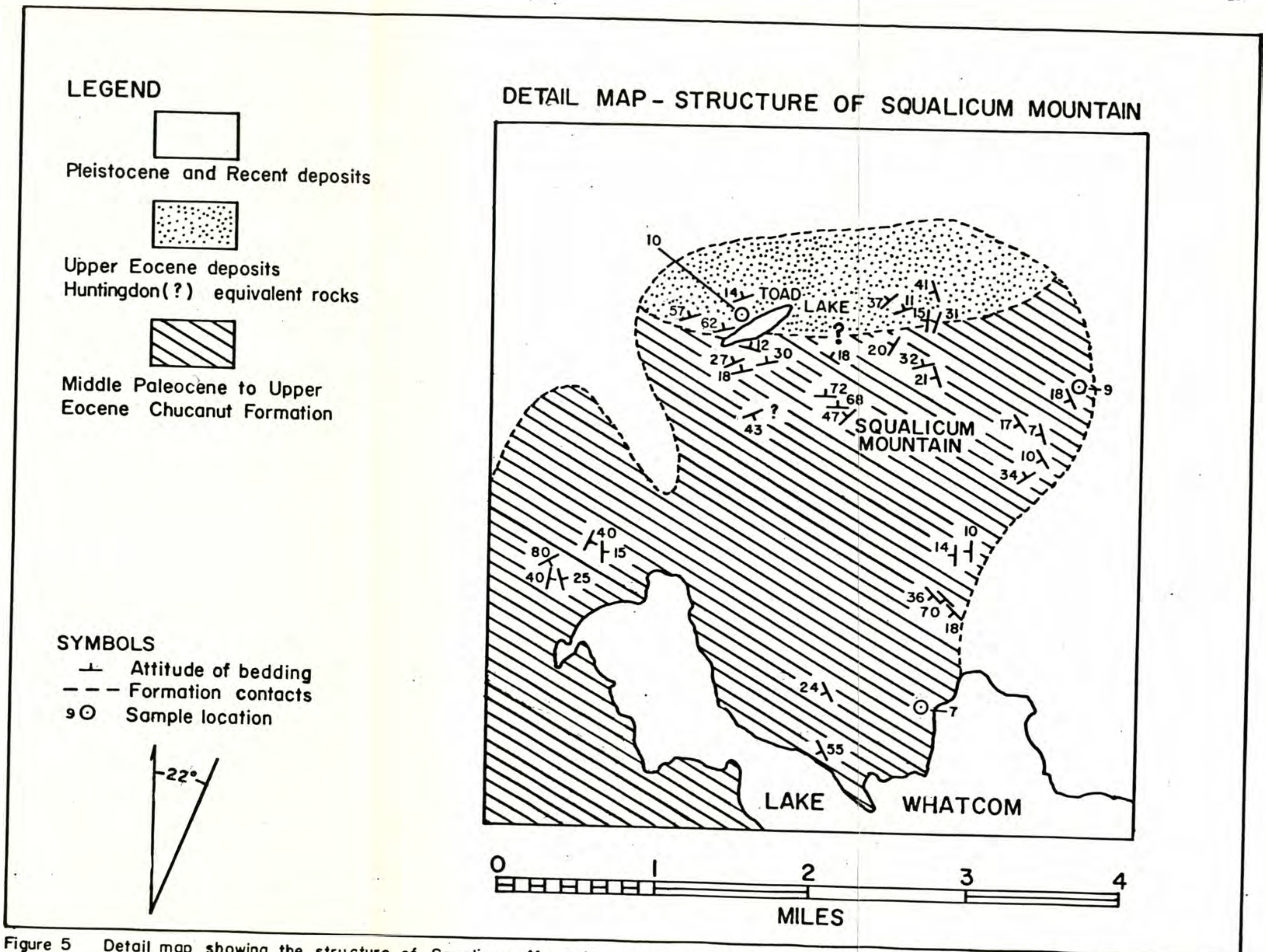


Figure 5 Detail map showing the structure of Squalicum Mountain. Geology from Miller and Misch (1963) and Easterbrook (1976). Structual data from Pevear and Reinink-Smith (unpublished data, 1980) and Patrick (unpublished data, 1981).

DISCUSSION

Microfloral studies have several advantages over the study of megafloras. Pollen and spores are small, easily transported, and readily preserved in sediments. Megafossils have the disadvantage of being much more selectively transported and preserved; thus an incomplete record of the flora is typically represented by a megafossil assemblage.

Pollen analysis, on the other hand, has a few disadvantages also. One is that differential destruction may occur. Faegri and Iversen (1975) point out that the exines (outer layer) of the remaining pollen grains will have a pitted or corroded appearance if differential destruction has occurred. Detection of such grains would mean that some of the more fragile pollen has been destroyed and quantitative results should be used with caution. If more than half the pollen grains from deciduous trees have a pitted or corroded exine, considerable differential destruction has occurred, and the samples could yield invalid results for quantitative or qualitative studies. Some differential destruction was detected in the sample from the southwest shore of Lake Whatcom. The qualitative data from this sample suggest a Paleocene age; however, because of the poor preservation, this conclusion is uncertain. All other samples contain pollen in an excellent state of preservation.

A second disadvantage to studying pollen and spores is that they can be reworked from older sediments and redeposited in a younger sequence. This appears to be a significant problem with the Chuckanut palynoflora. Reworked pollen grains were detected as described above, and this source of error was effectively eliminated. Griggs (1970) failed to recognize the presence of reworked pollen, which explains why the age he gave for the Chuckanut Formation ranged from Cretaceous to Eocene. By recognizing that abundant reworked pollen grains are present and not considering them in age determinations, a more reliable age for the Chuckanut Formation has been determined by this study. Reworked pollen is most similar to primary pollen found in the Nanaimo Group (Rouse, personal communication, 1981), suggesting that Chuckanut sediments may have been partially derived from rapid erosion of the Naniamo Group, or from other Cretaceous rocks.

A third disadvantage is that pollen grains can be transported long distances. For example, several pinaceous pollen grains were seen in the stratigraphically lower samples from this study and also by Griggs (1970). These conifers are not represented in the megafossil flora reported by Pabst (1968) and, as Griggs (1970) pointed out, are probably blown in or transported by streams from the north and northeast. Because the extraneous pollen grains are generally poorly preserved, this source of error is easily reduced by not considering the poorly preserved pollen grains when age determinations are made.

Based on the palynomorphs listed in Table 2, three palynozones are distinguished. The first zone (P-1) is Middle to Late Paleocene in age. Detrital zircons have been dated from the base of the Chuckanut Formation by the fission track method. These zircons are assumed to be derived from deeply buried igneous and metamorphic rocks that were at a temperature above the annealing temperature of zircon; these provide source-terrane uplift dates of 53.5 ma, 55-58 ma, and 100+ ma, with 10 out of 20 in the 55-58 ma range (Johnson, personal communication, 1981). These dates show that the base of the Chuckanut Formation can be no older than about 55 ma, and the wide range of dates obtained indicates that they have not been reset since Chuckanut deposition. The palynomorph data suggest an age slightly older (63-56 ma) than the fission track dates; however, the age is based on palynomorph ranges from the Canadian Arctic, since no Paleocene rocks closer to the Chuckanut have been studied in sufficient detail to provide dates. Rouse (1977) suggests that the palynofloras from the Arctic and south-central British Columbia are similar; however, the ranges in the Arctic may not be the same as those in northwest Washington.

The second zone (E-1) is Early to Middle Eocene in age. These samples are located stratigraphically above zone P-1. A tephra layer on Lookout Mountain has been dated by the zircon fission track method as 49.9 ± 1.2 ma (Johnson, personal communication, 1981). The palynoflora obtained from an adjacent stratigraphic horizon (sample locality 6) contains both *Pistillipollenites mcgregorii* and *Platycarya* sp., which indicate an age of about 49 ma (Rouse, personal communication, 1981). In this case, the fission track date and the palynoflora correlate well.

The third zone (E-2) is Late Eocene to perhaps Earliest Oligocene in age. This zone may represent the thickest sequence of rocks. There is no clear age difference among the samples of this zone which include rocks mapped as both Chuckanut and Huntingdon Formations. Hopkins (1966) analyzed samples from Toad Lake and Whatcom Quarry, which I also sampled. Hopkins (1966) reports finding *Pistillipollenites mcgregorii* from the Toad Lake sample and *Platycarya* sp. from the Whatcom Quarry sample. These data suggest an Early to Middle Eocene age for the rocks. The palynofloras that I have obtained from these same two areas do not contain either of these palynomorphs. Perhaps these palynomorphs were reworked and Hopkins (1966) failed to recognize this, or he misidentified them. The palynofloras that I have recovered from these same two areas contain an Upper Eocene palynoflora. All samples from zone E-2 except the Kelly Road sample contain *Gothanipollis* A which is an Upper Eocene indicator. The Kelly Road sample contains a noticeable increase in *Quercus* sp. and *Fagus* sp. This is the only sample that contains well preserved *Pinus* sp. pollen. The latter suggests that this is the highest stratigraphic horizon sampled and that this sample is Latest Eocene or Earliest Oligocene during which time *Quercus* sp. and *Fagus* sp. became the dominant vegetation because of a cooling and drying climatic trend (Axelrod, 1981; Wolfe, 1978).

The rocks sampled in this study do not show a major break in age. Ages from Middle Paleocene to Late Eocene have been obtained. Thus no major break in deposition at the southern boundary of the Bellingham Basin is indicated by the palynology. There could be a break in deposition of up to 7 ma that could not be detected by the palynoflora. This hiatus would provide enough time to produce the deformation suggested by Miller and Misch (1963). In addition, the structure of Squalicum Mountain was studied by Pevear and Reinink-Smith (unpublished data, 1980) and Patrick (unpublished data, 1981) in an effort to verify the findings of Miller and Misch (1963) and to better locate the southern extent of the Bellingham Basin (Figure 5). From the attitudes of the beds shown in Figure 5 there is no clear place where an angular unconformity might exist; thus there is no angular unconformity where Miller and Misch (1963) or Easterbrook (1976) mapped it. Also, the greater degree of cementation and lithification for Chuckanut rocks described by Miller and Misch (1963) was not observed in samples analyzed for this study.

In conclusion, three palynozones of different ages have been distinguished. However, there is no evidence for a major hiatus in the rocks that were examined. The structural mapping of Squalicum Mountain does not indicate an angular unconformity at the southern boundary of the Bellingham Basin; therefore, the southern boundary, as described by Miller and Misch (1963), at least on Squalicum Mountain, does not exist. Lithologically, the Chuckanut and Huntingdon Formations are so much alike that differentiating them on this basis has not been possible (Johnson, personal communication, 1981). This study shows that the top of the Chuckanut Formation and the Huntingdon Formation in the area south of American Sumas Mountain are palynologically and structurally indistinguishable from one another. Therefore, the distinction previously made should be abandoned and the rocks mapped as Huntingdon Formation around Toad Lake, at the end of the Kelly Road, and other isolated outcrops, such as Whatcom Quarry, should be included in the Chuckanut Formation.

SYSTEMATIC DESCRIPTIONS

This portion of the report contains descriptions of the sixty-three forms recovered in this study. Illustrations are provided of the most common forms (figures 1-12), and for the palynomorphs diagnostic of each recognized palynozone (Zone P-1, figures 13-20; Zone E-1, figures 21-39; Zone E-2, figures 40-57: Zone E-1 and E-2, figures 21-32). A subheading giving the ages of the diagnostic palynomorphs is provided. All others have wide stratigraphic ranges and are not useful stratigraphic indicators for the present study. Occurrence of each palynomorph is given in Table 2. The classification system used is that of Cronquist presented in Jones and Luchsinger (1979).

DIVISION EUMYCOTA

CLASS FUNGI IMPERFECTI

Pluricellaesporites psilatus Clarke, 1965

figure 12

Pluricellaesporites psilatus, Clarke, 1965, p. 90, 91, pl. 1, figs. 1-3.
Pluricellaesporites psilatus, Hopkins, 1966, p. 86, 87, pl. 1, figs. 4-6.

DESCRIPTION: Uniseriate fungal spores with individuals consisting of several to many cells. Width variable from 12 to 25 microns and the length can be in excess of 100 microns depending on the number of component cells. Thickenings on one side of the septum appear as adjacent triangles with a 0.5 to 1.0 micron aperture occurring between them. Cell walls psilate.

REMARKS: These spores are identical in all respects to those described by Clarke (1965). Hopkins (1966) states that they are common in many Early Eocene horizons of the Arctic and Western Canada and of northwestern Washington State. They were common in most of the samples analyzed.

Pluricellaesporites sp.

Not illustrated

Pluricellaesporites sp., Hopkins, 1966, p. 87, pl. 1, fig. 7.

DESCRIPTION: Spores 35 microns long and 22 microns wide, are multicellular, with four perforate cross walls. The cross walls are triangular and about 1 to 3 microns thick.

REMARKS: This specimen is similar to one described by Hopkins (1966) except that it has four septa instead of three. In all other respects it is similar to *P. psilatus* and may be a more mature form of that species. Assignment to a separate species is tentative.

Fungal Hyphae

Not illustrated

DESCRIPTION: Segmented and germinating fungal hyphae with each segment 6 to 7 microns in diameter and overall length of 90 to 100 microns.

REMARKS: This fossil has no known diagnostic value. It is present in many of the samples studied.

Multicellaesporites A Rouse, 1977

figure 22

Multicellaesporites A, Rouse, 1977, pl. 2, fig. 46.

DESCRIPTION: Uniseriate fungal spores 30 to 40 microns long and 10 to 12 microns wide. Individuals consist of several to many cells.

REMARKS: Except for the lack of triangular thickenings on the septum this form is similar to *Pluricellaesporites psilatus*. This form appears identical to the one figured by Rouse (1977).

AGE: Rouse (1977) gives a range of Eocene in south-central British Columbia for this spore.

Multicellaesporites B Rouse, 1977

Not illustrated

Multicellaesporites B, Rouse, 1977, pl. 2, fig. 40.

DESCRIPTION: Uniseriate fungal spores 40 to 50 microns long by 10 to 15 microns wide. Individuals consist of 3 to 4 cells separated by a septum with a small (0.5 to 1.0 micron) aperature.

REMARKS: These spores are similar to *M.* A and appear identical to those figured by Rouse (1977).

AGE: Rouse (1977) gives a range of Eocene in south-central British Columbia for this spore.

Multicellaesporites sp.

figure 21

Multicellaesporites sp., Rouse, 1977, pl. 2 fig. 47.

DESCRIPTION: Spores 60 microns long and a length/width ratio of 3:1. In all other respects this species is similar to *M.* A and B.

REMARKS: This spore appears identical to the one figured by Rouse (1977).

AGE: Rouse (1977) gives a range of Eocene for this spore.

DIVISION POLYPODIOPHYTA

ORDER FILICALES

FAMILY OSMUNDACEAE

Osmunda irregulites Martin and Rouse, 1966

figure 1

Osmunda irregulites, Martin and Rouse, 1966, p. 189, pl. 4, figs. 29, 30.

DESCRIPTION: Spores trilete, laesure distinct, subcircular in outline, but often folded or split open. Ornamentation baculate, 1 to 2 microns long, by 0.5 to 1.5 microns wide and randomly spaced from 1 to 2.5 microns apart. "The most diagnostic feature is the complete irregularity of the width of the bacula; delicate bacula are randomly mixed with stout, stump-like bacula, and with all grades inbetween" (Martin and Rouse, 1966, p. 189). Size range is 35 to 50 microns.

REMARKS: Specimens from this study appear identical to those described by Martin and Rouse (1966).

FAMILY SCHIZACEAE

Cicatricosisporites intersectus Rouse, 1962

figures 2 and 3

Cicatricosisporites intersectus, Rouse, 1962, p. 197, pl. 3, figs. 30, 31.

DESCRIPTION: Trilete spores, 45 to 60 microns in diameter, with two sets of parallel ribs on the spore wall. The proximal and distal ribs are oriented approximately 90 degrees to each other and thus appear as intersecting ridges.

REMARKS: This is a very common microfossil and was found in nearly all of my samples, and except for a smaller size range, these specimens appear identical to those described by Rouse (1962).

FAMILY POLYPODIACEAE

figure 4

DESCRIPTION: Spores generally bean-shaped; monolete, ornamentation variable and size range approximately 25 to 70 microns.

REMARKS: The spores of this family are quite variable but not diagnostic for stratigraphic studies; hence, no attempt has been made to classify any of these spores to generic or specific levels.

DIVISION PINOPHYTA

CLASS PINOPSIDA

FAMILY PINACEAE

Not illustrated

DESCRIPTION: Bisaccate grains, generally poorly preserved; probably referable to the genus *Pinus*.

REMARKS: Many of the samples from the stratigraphically lower part of the Chuckanut Formation contain very small amounts of poorly preserved Pinaceae pollen.

Pinus sp. *haploxon*-type

figures 40 and 41

DESCRIPTION: Bisaccate pollen with bladders attached to lateral equatorial extremities of body, bladders moderately coarsely reticulate, becoming finer toward bladder roots. Body size ranges from 40 to 50 microns, bladders slightly larger.

REMARKS: This was the only *Pinus* sp. seen in any quantity and in a good state of preservation. It was only seen in the Kelly Road sample (locality no. 11).

cf. *Larix* sp.

Not illustrated

DESCRIPTION: Pollen grains large (65 microns), often ruptured; exine thin (0.5 to 0.8 microns) and psilate.

REMARKS: *Larix* sp. and *Equisetum* sp. are difficult to distinguish from each other; these specimens are tentatively assigned to the genus *Larix*.

FAMILY TAXODIACEAE

figure 5

DESCRIPTION: Pollen grains generally granulate, circular in outline, often split open. Size range 20 to 35 microns.

REMARKS: Included here are probably pollen of *Glyptostrobus*, *Taxodium*, and *Metasequoia*. Since these genera have no stratigraphic significance in the present study, little effort has been made to separate them.

Metasequoia papillapollenites Rouse, 1962

Not illustrated

Metasequoia papillapollenites, Rouse, 1962, p. 201, pl. 2, fig. 5.

DESCRIPTION: "Pollen circular in outline with a prominent papillum ca. 3 microns in length. Ornamentation faintly and finely granulose" (Rouse 1962, p. 201). Size 24 microns in diameter.

REMARKS: This is a distinctive, but uncommon microfossil (only one seen). It has no stratigraphic significance in the present study.

DIVISION MAGNOLIOPHYTA

CLASS MAGNOLIOPSIDA (DICOTS)

ORDER HAMAMELIDALES

FAMILY HAMAMELIDACEAE

Liquidambar sp.

Not illustrated

DESCRIPTION: Spherical to irregular, polyporate pollen grains. Pores large, up to 4 by 8 microns in size. Exine very minutely reticulate to punctate. Pore membranes weakly scabrate.

REMARKS: Only one grain referable to this genus was seen and it was in the Kelly Road sample.

AGE: *Liquidambar* was most abundant in Late-Late Eocene through Miocene time. Its presence suggests a younger age for this sample compared to the other samples (i.e., Late-Late Eocene to Early Oligocene).

ORDER URTICALES

FAMILY ULMACEAE

Ulmus sp. or *Zelkova* sp.

figures 42 and 43

Ulmus or *Zelkova* sp., Hopkins, 1966, p. 133, pl. 11, figs. 134, 135.

DESCRIPTION: Square to sub-rectangular pollen grains, about 20 microns in diameter. Generally four-pored but three to five-pored specimens present as well. Exine characteristically laevigate with a rugulate to reticulate pattern impressed into it.

REMARKS: *Ulmus* and *Zelkova* cannot be distinguished on the basis of pollen, even in modern material, therefore, no attempt has been made to distinguish them here. This form is similar to that described by

Hopkins (1966). He points out that it looks like *U. americana* except *U. americana* typically has five pores. The form described here is dominately four-pored.

ORDER JUGLANDALES

FAMILY JUGLANDACEAE

Carya sp.

figure 27

Carya simplex, Frederiksen, 1980, p. 42, pl. 8, fig. 7.
Carya veripites, Frederiksen, 1980, p. 42, pl. 8, fig. 8.

DESCRIPTION: Three-pored pollen with pores on one hemisphere offset from the equator. Pores various distances from equator.

REMARKS: Frederiksen (1980) points out that two characters can be used to place *Carya* pollen in form species; one is the size of the pores and the other is the distance of the pores from the equator. For most of the *Carya* pollen encountered no attempt was made to distinguish form species, however, in the Paleocene samples a pre-*Carya* form (not illustrated) was noted which had two pores on the equator and the third pore on one hemisphere. This is a diagnostic form for the Paleocene (Rouse, personal communication, 1981).

Platycarya sp.

figures 38 and 39

DESCRIPTION: Small (14 to 17 microns) triporate pollen grains. More or less distinctly triangular; sharp, box-like pores at each angle. Exine is faintly scrabrate to granulate and is always crossed by at least two false colpi, one on each pole, giving the typical "crossed-swords" appearance.

REMARKS: When *Platycarya* is found with *Pistillipollenites mcgregorii* it indicates a Late-Early to Early-Middle Eocene age for the sediments (Rouse, personal communication, 1981).

AGE: Newman (1980) gives a range of Early to Middle Eocene for this form.

Juglans sp.

figure 44

DESCRIPTION: Polyporate pollen grains 25 to 35 microns, subrounded. Number of pores quite variable but usually about 12. Most located near the equator, the remainder located on one hemisphere. Pores generally small (1 to 2 microns in diameter) circular in outline. Sculpture very weakly scabrate.

REMARKS: This form is restricted to the stratigraphically uppermost samples and appears to be an indicator for the Late Eocene (Rouse, 1977).

AGE: Rouse (1977) gives a range of Late Eocene to Oligocene for this form.

Pterocarya sp.

figures 45 and 46

DESCRIPTION: Polyporate pollen grains with 5 to 8 circular pores, located on or near the equator. Pores vary from 2 to 5 microns in diameter. Some grains angular with the number of sides dependent on the number of pores. Grains are typically folded one or more times. Size range: 21 to 31 microns.

REMARKS: A number of these grains appear identical to *P. stellatus* described by Martin and Rouse (1966), however no attempt to identify any of the *Pterocarya* pollen to species level has been made.

Momipites rotundus (Leffingwell) Nichols, 1973

figure 14

Maceopolipollenites rotundus, Leffingwell, 1970, p. 31-36, pl. 7, fig. 7.
Momipites rotundus, Nichols, 1973, p. 108.

DESCRIPTION: Pollen triporate, 25 to 30 microns in diameter, shape oblate to rounded-triangular in polar view; pores equatorial atriate. Exine scabrate, 1 to 1.5 microns thick, thickening slightly at the pores and thinning in one or several places near one pole.

REMARKS: These pollen grains appear identical to the ones described by Leffingwell (1970).

AGE: Rouse (1977) gives a range of Middle Paleocene for this species.

Momipites coryloides Wodehouse,1933, emend. Nichols 1973;

form A Rouse, 1977

figure 47

Momipites coryloides, Wodehouse, 1933, p. 511, fig. 43.
Momipites coryloides, Nichols, 1973, p. 106-107.
Momipites coryloides form A, Rouse, 1977, pl. 1, fig. 5.

DESCRIPTION: Triporate pollen, 12 to 15 microns in diameter; pores slightly elongate meridionally, located on the equator. Exine thins slightly on one (proximal ?) pole.

REMARKS: These pollen grains appear identical to the ones figured by Rouse (1977).

AGE: This form is an indicator of the Upper Eocene to Lower Oligocene (Rouse, 1977).

Momipites sp.

figure 28

DESCRIPTION: Triporate pollen grain, 11 microns in diameter, pores slit-like. There is a thinning of the exine similar to *M. microfoveolatus* (Stanley) Nichols 1973 however, it is not as extensive, and may be due to weathering effects.

REMARKS: This grain appears similar to other species of *Momipites* and its affiliation with that genus is the most certain.

ORDER MYRICALES

FAMILY MYRICACEAE

Myrica cf. *M. annulites* Martin and Rouse, 1966

figure 6

Myrica annulites, Martin and Rouse, 1966, p. 195, pl. 9, figs. 91, 92.
Myrica annulites, Rouse and others, 1970, pl. 5, figs. 12, 13; pl. 8, figs. 9, 13; pl. 9, fig. 2.

DESCRIPTION: Triporate pollen, triangular to sub-triangular in outline. Pores located equatorially, slightly aspidate, with roughened or teeth-like projections on the vestibulum. Size range 22 to 30 microns.

REMARKS: This grain appears similar to those described by Martin and Rouse (1966). Its affiliation with *M. annulites* is the most certain.

AGE: Rouse and others (1970) include *M. annulites* as a typical component of Coastal Eocene palynofloras for southwestern British Columbia and northwestern Washington; however, its range is not restricted to the Eocene.

ORDER FAGALES

FAMILY FAGACEAE

Fagus sp.

figure 48

DESCRIPTION: Tricolporate pollen grains, broadly elliptical in shape, 30 to 35 microns in diameter, with granulate exine. Colpae about 20 microns long.

REMARKS: This form is very similar to *F. granulata* described by Martin and Rouse (1966)

AGE: *Fagus* sp. is characteristic of the Late-Late Eocene and Early Oligocene (Rouse, 1977).

Quercus granopollenites Rouse, 1962

Not illustrated

Quercus granopollenites, Rouse, 1962, p. 203, pl. 4, figs. 31, 36.

DESCRIPTION: Tricolpate pollen, elliptical in outline. Colpae are distinct and extend nearly the entire length of the grain. Ornamentation granulate. Size range 25 to 31 microns.

REMARKS: This form was found only in the Kelly Road sample where *Quercus* pollen was particularly abundant compared to the rest of the samples.

Quercoidites A Rouse, 1977

Not illustrated

Quercoidites A, Rouse, 1977, pl. 1, fig. 16.

DESCRIPTION: Tricolpate pollen, elliptical in outline, 25 to 28 microns long by 18 to 20 microns wide. Exine granulate.

REMARKS: This form appears identical to the one figured by Rouse (1977).

AGE: This palynomorph is an indicator for the Eocene to Early Oligocene (Rouse, 1977). In this study it appears to be restricted to the Late Eocene, however this could be because of insufficient sampling.

Quercus sp.

figure 49

DESCRIPTION: Tricolpate grains, size range variable (20 to 35 microns). Sculpturing of exine variable; granulate, scabrate or psilate.

REMARKS: *Quercus* is a very large genus with over 450 modern species. *Quercus* was an important element of Tertiary floras of North America beginning near the end of the Eocene (Rouse, personal communication, 1981). The samples from WWU Campus, Squalicum Mountain, and particularly the Kelly Road sample contain *Quercus* pollen. There are undoubtedly several species represented, however, *Quercus* is difficult to differentiate on the basis of pollen. All are tricolpate with few distinguishing features.

FAMILY BETULACEAE

Alnus sp.

Not illustrated

DESCRIPTION: Pollen three to six-pored. Size range 20 to 30 microns. Thickened bands (arci) connect the pores and are the most diagnostic feature.

REMARKS: Some workers have separated *Alnus* into several form species according to the number of pores present. Whereas the various forms may have some stratigraphic significance in some areas, they do not appear to in the present study. Four and five-pored *Alnus* were seen in nearly all samples. Perhaps quantitative data would show stratigraphic differences, but no quantitative data was collected and all forms of *Alnus* have been included here.

Corylus tripollenites (?) Rouse, 1962

Not illustrated

Corylus tripollenites, Rouse, 1962, p. 202, pl. 2, figs. 11, 12, 15, 17.

DESCRIPTION: Triporate pollen, sub-triangular in outline. Pores equatorial and elliptical in outline, subtended by slight bulbose expansions of the wall (see Wodehouse, 1933, text fig. 39, for *Corylus* pattern). Ornamentation weakly granulate.

REMARKS: Only one specimen of this species was seen. It was in the Kelly Road sample.

ORDER MALVALES

FAMILY TILIACEAE

Tilia vescipites Wodehouse, 1933

figure 29

Tilia vescipites, Wodehouse, 1933, p. 516, fig. 49.

DESCRIPTION: Tricolporate pollen (brevicolpate), sub-triangular in outline, pores located along sides and not at corners; pores with thickened endexine forming a collar. Ornamentation reticulate not perceptibly finer toward the edges and the pores. Polar diameter ranges from 24 to 28 microns.

REMARKS: This pollen grain appears identical with the one described by Wodehouse (1933).

AGE: This form is an indicator for the Eocene (Rouse, 1977).

Tilia crassipites Wodehouse, 1933

figures 30-32

Tilia crassipites, Wodehouse, 1933, p. 515, fig. 48.

DESCRIPTION: Except for its larger size (polar diameter of 33 to 38 microns) this species is identical to *T. vescipites*

REMARKS: These pollen grains appear identical to those described by Wodehouse (1933).

AGE: This form is an indicator of the Eocene (Rouse, 1977).

FAMILY BOMBACACEAE

Bombacacidites sp.

figure 7

DESCRIPTION: Pollen grains triangular in outline. Tricolporate; brevicolpi slit-like and located along edges and not at corners. Sculpturing reticulate, becoming decidedly finer toward the pores and corners.

REMARKS: This form is never abundant and is of little diagnostic value for dating.

ORDER PROTEALES

FAMILY PROTEACEAE

Proteacidites cf. *P. thalmannii* Anderson, 1960

Not illustrated

Proteacidites thalmannii, Anderson, 1960, p. 21, pl. 2, figs. 1-4; pl. 10, figs. 9-13.

DESCRIPTION: Triporate, triangular pollen grain 25 to 30 microns in diameter. Rounded corners, slightly convex interradial areas. Pores at the angles, generally round, annulus usually pronounced around pores. Exine is reticulate.

REMARKS: This pollen grain appears similar to that described by Anderson (1960). Also see remarks under cf. *Proteacidites* sp.

cf. *Proteacidites* sp.

figure 19

DESCRIPTION: Triporate pollen grains, triangular in outline, with convex to straight sides. Exine weakly granulate. Size range 25 to 30 microns.

REMARKS: Most proteaceous pollen appears to have been reworked from older sediments. As a result it is usually poorly preserved. (Note the missing pore on figure 19.)

ORDER CORNALES

FAMILY NYSSACEAE

Nyssa sp.

Not illustrated

Nyssa sp., Griggs, 1970, pl. 9, fig. 11.

DESCRIPTION: Tricolporate pollen, rounded to triaspidate in shape.

Ornamentation is scarbrate to microreticulate. Colpi are slit-like extending 2/3 to 3/4 the lengh of grain; ora circular and slightly protruding. Size range 35 to 45 microns.

REMARKS: These pollen grains appear similar to those described by Griggs (1970; code CP_3sm-5). This pollen grain is never abundant and its assignment here is uncertain.

Nyssapollenites A (?) Rouse, 1977

Not illustrated

Nyssapollenites A, Rouse, 1977, pl. 2, fig. 35.

DESCRIPTION: Tricolporate pollen, spherical in shape. Ornamentation scabrate to reticulate. Colpi slip-like and short (1/2 to 2/3 grain length). Ora indistinct. Size range 30 to 35 microns.

REMARKS: This pollen grain appears similar to the one figured by Rouse (1977).

AGE: Rouse (1977) gives the range of this form as Late Eocene to Early Oligocene.

ORDER CELASTRALES

FAMILY AQUIFOLIACEAE

Ilex sp.

figure 50.

DESCRIPTION: Tricolpate pollen grains, subprolate to prolate, colpae distinct. Clavate sculptured ektexine. Clavae vary from 1.5 to 3.5 microns in diameter, and are markedly expanded and rounded on the distal ends. Size about 26 microns in polar length.

REMARKS: This pollen grain is a minor component in the Late Eocene samples, and is possibly an indicator for the Late Eocene.

ORDER GENTIANALES

FAMILY GENTIANACEAE

Pistillipollenites mcgregorii Rouse, 1962

figures 36 and 37

Pistillipollenites mcgregorii, Rouse, 1962, p. 206, pl. 1, figs. 8-12.
Pistillipollenites mcgregorii, Rouse, 1977, pl. 1, fig. 8.

DESCRIPTION: Rouse (1962) describes the genus as follows: "Pollen grains circular to broadly sub-triangular in outline. Triporate (? tricolpate) with the three openings generally obscured by the club or pistil-shaped elements of ornamentation. The wall is about 2 microns thick, with no obvious division into ektexine and endexine; the presence of costae has not been confirmed because no clear view of the pores has been available. Size range 20 to 30 microns" (Rouse, 1962, p. 206).

Rouse adds to the generic description the following for the species: "The pistil shaped ornaments resemble young mushrooms emerging from the soil, i.e., they are circular to oval in shape, . . . small pores or (colpae?) which are hidden between and under the projections. . . The projections are not generally evenly distributed on the surface of the wall but tend to be concentrated on one surface. The size range is 20 to 30 microns" (Rouse, 1962, p. 206).

REMARKS: This pollen type is identical to that described by Rouse (1962).

AGE: This pollen type is an excellent marker for the Late Paleocene to Middle Eocene (Rouse, 1977) because of its easily recognizable morphology and restricted range.

Nymphoides tripollenites Rouse, 1962

Not illustrated

Nymphoides tripollenites, Rouse, 1962, p. 205, pl. 2, figs. 27, 31.

DESCRIPTION: Parasyncolpate pollen, 22 to 25 microns, sharply triangular in outline. Colpi come together at the poles to leave a triangular island in the center. Ornamentation very finely granulate.

REMARKS: This is an uncommon microfossil found only in the west central-shore of the Lake Whatcom sample.

ORDER DIPSACALES

FAMILY CAPRIFOLIACEAE

Caprifoliipites tantalus Frederiksen, 1980

figures 51 and 52

Caprifoliipites tantalus, Frederiksen, 1980, p. 57, pl. 14, figs. 1-2.
Tricolpopollenites microreticulatus, Thompson and Pflug, 1953, p. 106, pl. 14, figs. 27-42.

DESCRIPTION: Frederiksen (1980) states that except for its smaller size *C. tantalus* matches the description of *C. microreticulatus* (Pflug and Thompson in Thompson and Pflug, 1953) Potonie 1960. The size range of *C. tantalus* is 14 to 19 microns whereas the size range of *C. microreticulatus* is 18 to 30 microns.

REMARKS: This species was first reported from the Upper Eocene of Mississippi and Alabama (Frederiksen, 1980).

Rhoiipites latus Frederiksen, 1980

figure 35

Rhoiipites latus, Frederiksen, 1980, p. 55, pl. 13, figs. 9-13.

DESCRIPTION: Tricolporate pollen, 40 to 47 microns in length by

20 to 25 microns in width. Colpi deep, narrow, extending nearly full length of grain. Ora wider than colpi, distinct, and round. Exine reticulate.

REMARKS: The specimens recovered in this study are identical to those described by Frederiksen (1980).

AGE: This species is an indicator of the Eocene (Rouse, 1977).

Rhoiipites cryptoporus-type

figure 15

Rhoiipites cryptoporus, Srivastava, 1972, p. 270, pl. 21, figs. 1-11; pl. 22, figs. 1-10.

DESCRIPTION: Tricolporate pollen, prolate; colpi extending nearly from pole to pole, broader at the equator. Ora hidden. Exine reticulate. Size range 25 to 33 microns long by 18 to 25 microns wide.

REMARKS: This pollen grain appears similar to those described by Srivastava (1972) and is probably the same species.

AGE: Rouse (1977) gives a range of Middle (?) Paleocene to Early Eocene for this species.

ANGIOSPERM GENERA OF UNCERTAIN AFFINITY

Triporopollenites mullensis (Simpson) Martin and Rouse, 1966

figure 13

Corylus mullensis, Simpson, 1961, p. 444, pl. 13, figs. 13-16.
Triporopollenites mullensis, Rouse, 1977, pl. 1, fig. 3.

DESCRIPTION: Triporate pollen, 25 to 35 microns in diameter. Pores about 2 microns in diameter, slightly aspidate; collar conspicuous and broad (3 to 4 microns). Exine granulate to psilate.

REMARKS: This pollen grain appears identical to the one figured by Rouse (1977).

AGE: Rouse (1977) gives a range of Early to Middle (?) Paleocene for this palynomorph.

Tricolpites reticulatus Cookson, 1947

figure 16

Tricolpites reticulata, Cookson, 1947, p. 134, pl. 15, fig. 45.

DESCRIPTION: Tricolpate pollen, 24 to 35 microns in diameter. Furrows broad; exine distinctly reticulate.

REMARKS: This form appears identical to the one described by Cookson (1947).

AGE: This is an indicator for the Middle (?) Paleocene to Middle Eocene (Rouse, 1977).

Tricolpites A Rouse, 1977

figure 17

Tricolpites A, Rouse, 1977, pl. 1, figs. 17, 18.

DESCRIPTION: Tricolpate pollen grains 15 microns in diameter. This form is characterized by "the thin and perfectly parallel sided colpi, and the thin but distinct margo" (Rouse, 1977, p. 26).

REMARKS: This pollen grain appears identical to those figured by Rouse (1977).

AGE: The range Rouse (1977) gives for this species is Late Paleocene.

Araliaceoipollenites cf. *A. profundus* Frederiksen, 1980

Not illustrated

Araliaceoipollenites profundus, Frederiksen, 1980, p. 53, pl. 12, figs. 2-4.

DESCRIPTION: Tricolporate pollen, 32 by 18 microns. Colpi distinct, very narrow, extending nearly from pole to pole. Ora indistinct.

REMARKS: This pollen grain appears similar to the ones described by Frederiksen (1980). He gives a size range of 33 to 58 microns, mean 45 microns. The one specimen I observed is small, but probably the same species.

Gothanipollis A Rouse, 1977

figures 53 and 54

Gothanipollis A, Rouse, 1977, pl. 2, fig. 30.

DESCRIPTION: Syncolporate pollen, triangular with concave sides and blunt corners with flaring tips. Exine is punctate to weakly granulate. Size range 16 to 26 microns.

REMARKS: This form is identical to the one figured by Rouse (1977).

AGE: This form is an excellent Late Eocene indicator (Rouse, 1977). The presence of this palynomorph provides the basis for most of the Late Eocene age assignments.

cf. *Holkopollenites* A Rouse, 1977

figure 18

Holkopollenites A, Rouse, 1977, pl. 2, figs. 28, 29.

DESCRIPTION: Tricolporate pollen, 18 to 22 microns in diameter. Colpi are long and distinct, ora wider than colpi. Exine psilate to weakly granulate.

REMARKS: This pollen grain appears identical to the one figured by Rouse (1977) except that the exine is psilate to granulate instead of reticulate.

AGE: *Holkopollenites* A has a range of Early to Middle Eocene in the Canadian Arctic (Rouse, 1977). It appears that the range in northwestern Washington is Late Paleocene to Late Eocene on the basis of the present study.

Cupanieidites cf. *C. reticularis* Cookson and Pike, 1954

Not illustrated

Cupanieidites reticularis, Cookson and Pike, 1954, p. 214, pl. 2, figs. 87-89.

DESCRIPTION: Syncolpate pollen, isopolar, 26 to 31 microns in diameter. Exine structure and ornamentation not determined because of poor preservation.

REMARKS: This grain appears similar to the ones described by Cookson and Pike (1954).

Cupanieidites sp.

figure 34

DESCRIPTION: Pollen grain syncolpate, isopolar, sharply triangular with slightly convex sides. Exine granulate. Size 25 to 32 microns.

REMARKS: This is an uncommon microfossil found only in the sample from the west-central shore of Lake Whatcom.

Tricolporopollentites kruschii sensu Elsik, 1968

figure 33

Tricolporopollenites kruschii, Elsik, 1968, p. 628, pl. 30, figs. 7-10; pl. 31, figs. 1-4, 9, 11-16; pl. 34, figs. 1-5.

DESCRIPTION: Tricolporate pollen, 35 to 60 microns in diameter. Exine reticulate, becoming much finer near the colpi; colpi extending from pole to pole.

REMARKS: This pollen grain appears identical to the ones described by Elsik (1968).

AGE: Rouse (1977) gives an Eocene range for this species.

CLASS LILIOPSIDA (MONOCOTS)

ORDER ARECALES

FAMILY ARECACEAE

Sabal granopollenites Rouse, 1962

Not illustrated

Sabal granopollenites, Rouse, 1962, p. 202, pl. 1, figs. 3, 4.

DESCRIPTION: Monocolpate pollen, 30 to 33 microns, fusiform in outline. Colpus is long, narrow, and indistinct. Exine weakly reticulate.

REMARKS: The presence of this genus in the stratigraphically lower parts of the section indicate a tropical to subtropical climate was present during the Paleocene and Early to Middle Eocene time.

Arecipites sp.

Not illustrated

DESCRIPTION: Pollen grains monosulcate, reticulate with lumina less than 0.5 microns as stated by Anderson (1960) as the criteria used to separate this genus from *Liliacidites*.

REMARKS: This form is found only in the Samish Lake sample in very small quantity.

ORDER TYPHALES

FAMILY TYPHACEAE

Typha sp.

figures 8 and 9

Typha sp., Hopkins, 1966, p. 146, pl. 13, figs. 167, 168.

DESCRIPTION: Pollen grains irregularly spheroidal and small (18 to 25 microns). Single germ pore often indistinct. Exine is thin and covered with a foam-like reticulation.

REMARKS: These grains appear identical to those reported by Hopkins (1966). It was found only in the Kelly Road sample. Modern *Typha latifolia* grows in marshes of temperate North America. This suggests the climate was somewhat cooler in the Late Eocene as compared to Paleocene and Early Eocene.

ORDER LILIALES

FAMILY LILIACEAE (?)

Liliacidites sp.

figures 10 and 11

DESCRIPTION: Monocolpate pollen grains, prolate to perprolate 14 to 45 microns 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: Because the botanical affinity of this form is uncertain, it is placed in the form-genus *Liliacidites*. It may be affiliated with a family other than Liliaceae.

INCERTAE SEDIS

Ctenosporites wolfei Elsik and Jansonius, 1974

figure 26

Ctenosporites wolfei, Elsik and Jansonius, 1974, p. 957, pl. 1, figs. 2-4.
Ctenosporites wolfei, Rouse, 1977, pl. 2, fig. 48.

DESCRIPTION: For the genus Elsik and Jansonius (1974) give the following description: "Multicellular structures of fungal (?) origin; one main stem of a few to several (commonly seven to nine) cells and lateral or secondary septate branches (cf. filaments) along one side of the main stem. Main stem and lateral branches are straight to slightly curved; apex of the main stem may be curved toward the side of the lateral branches; lateral branches are curved concave to the apex of the main stem" (Elsik and Jansonius, 1974, p. 956).

They add for the specific description: "As for genus except main stem never has a complete apex; apex broken off at last branch or consisting of one or two open-ended (broken ?) cells. Main stem has four or five main cells from which arise the lateral branches; all branches are inclined or curved concave to the apex of the stem" Elsik and Jansonius 1974, p. 957).

REMARKS: Specimens from this study appear identical to Elsik and Jansonius' (1974) description.

AGE: Rouse (1977) gives a range of Eocene for this species.

Punctodiporites A Rouse, 1977

figures 24 and 25

Punctodiporites A, Rouse, 1977, pl. 2, figs. 44, 45.

DESCRIPTION: Fungal (?) spores, diporate, with a thickening around each pore like a collar. Size range 43 to 60 microns long by 20 to 40 microns wide.

REMARKS: These fungal (?) spores are identical to those figured by Rouse (1977).

AGE: This is an Eocene indicator (Rouse, 1977).

Dicellaesporites A Rouse, 1977

Not illustrated

Decellaesporites A, Rouse, 1977, pl. 2, fig. 39.

DESCRIPTION: Fungal (?) spores divided into two cells by a septum. Outside wall slightly constricted at septum, and psilate. Size range 30 to 40 microns long by 13 to 18 microns wide.

REMARKS: This fungal (?) spore appears identical to the one figured by Rouse (1977).

AGE: This palynomorph is an Eocene indicator (Rouse, 1977).

Fusiformisporites sp. 1

figure 20

DESCRIPTION: Oval spore, 22 to 26 microns in length. Spore divided into two cells by a septum in the middle. Several longitudinal ribs extend from poles to equatorial septum which is slightly constricted. The ribs terminate at the septum. The wall is thick and psilate.

REMARKS: This form was found only in the sample from the southwest shore of Lake Whatcom (sample locality 4).

Fusiformisporites sp. 2

figure 23

DESCRIPTION: Oval spore 28 to 30 microns in length, exine thickened in the middle and perhaps divided at the middle. Several longitudinal ribs extend from the pores to the equator. A ring-like thickening around each pole (pore ?).

REMARKS: This form is distinct from *Fusiformisporites* sp. 1 because it does not have as distinct a septum and the longitudinal ribs are coarser.

AGE: This form appears to be restricted to the Early Eocene portion of the Chuckanut Formation.

Acritarch cf. *Micrhystridium ?*

figure 55

DESCRIPTION: Inaperaturate palynomorph, 19 to 28 microns in diameter. Surface is covered with very fine hair-like spines.

REMARKS: These palynomorphs were seen in low quantity in the Toad Lake and Kelly Road samples.

Diporate A

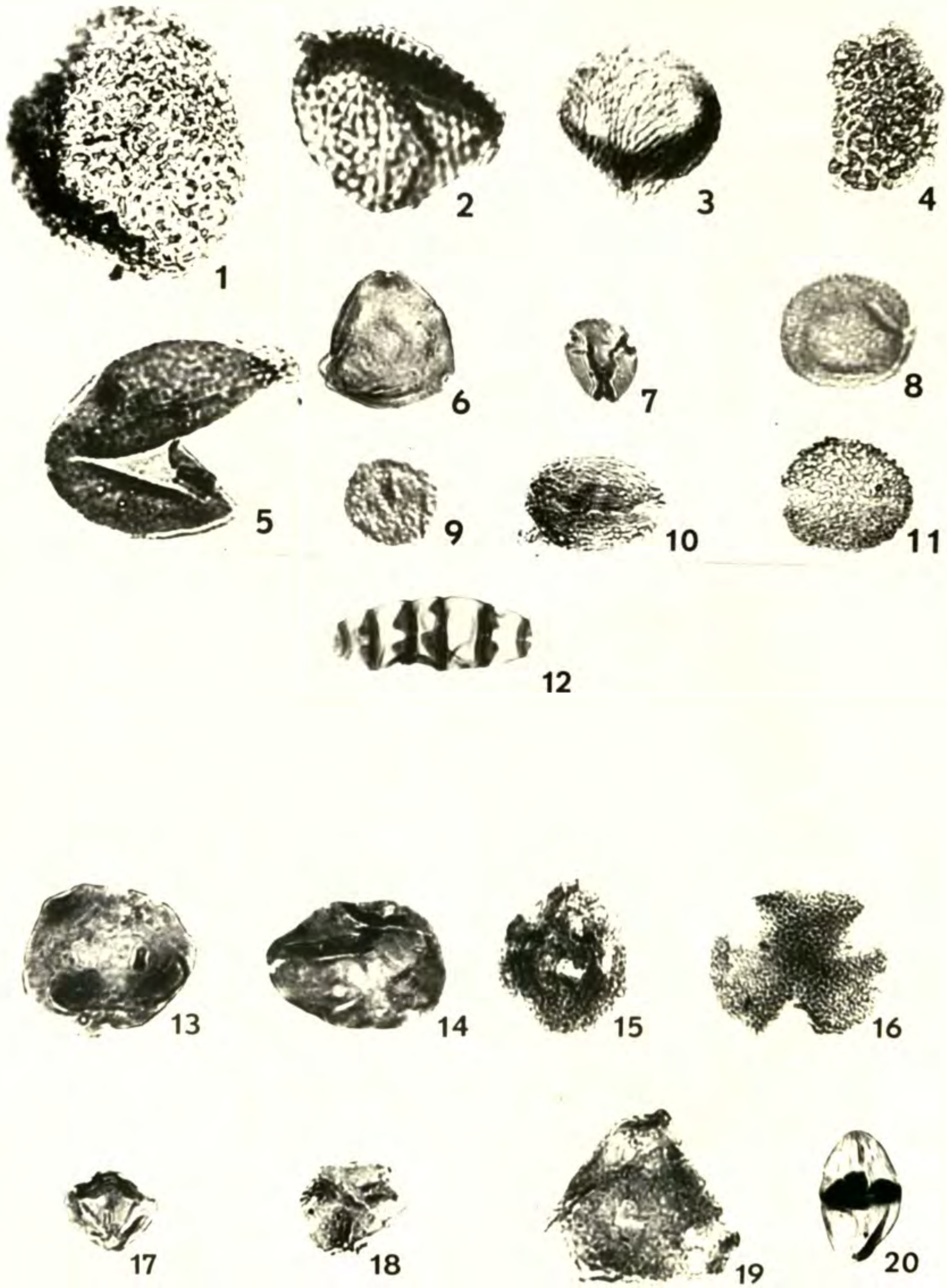
figure 56

DESCRIPTION: Pollen grain diporate 12 by 19 microns. Several warty projections on the surface.

REMARKS: Only one specimen was seen of this type. It was in the Kelly Road sample.

PLATES

All figures 1000X unless otherwise noted;
(i) indicates interference contrast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All figures 1000X unless otherwise noted;
(SEM) indicates Scanning Electron Micrograph;
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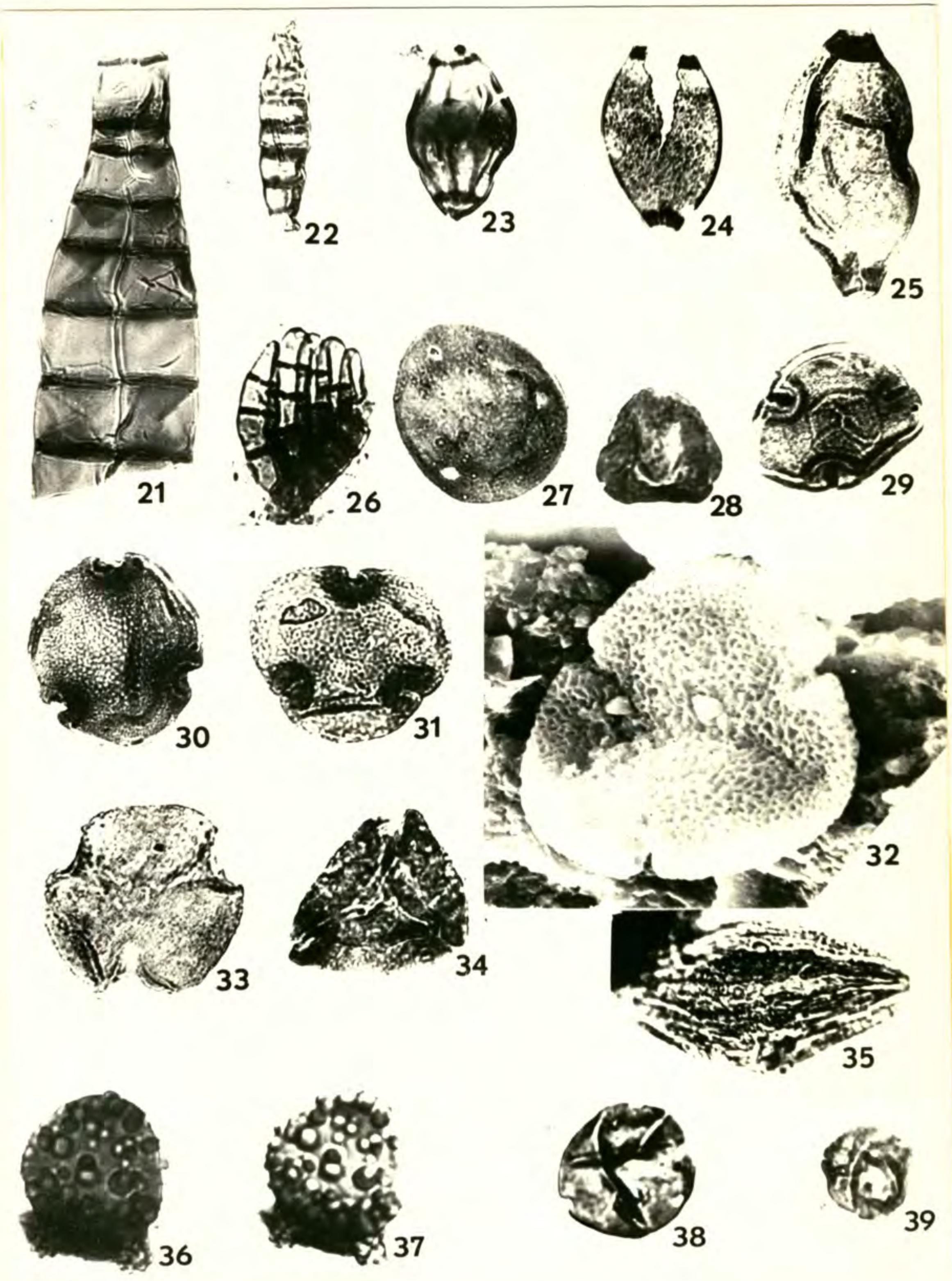
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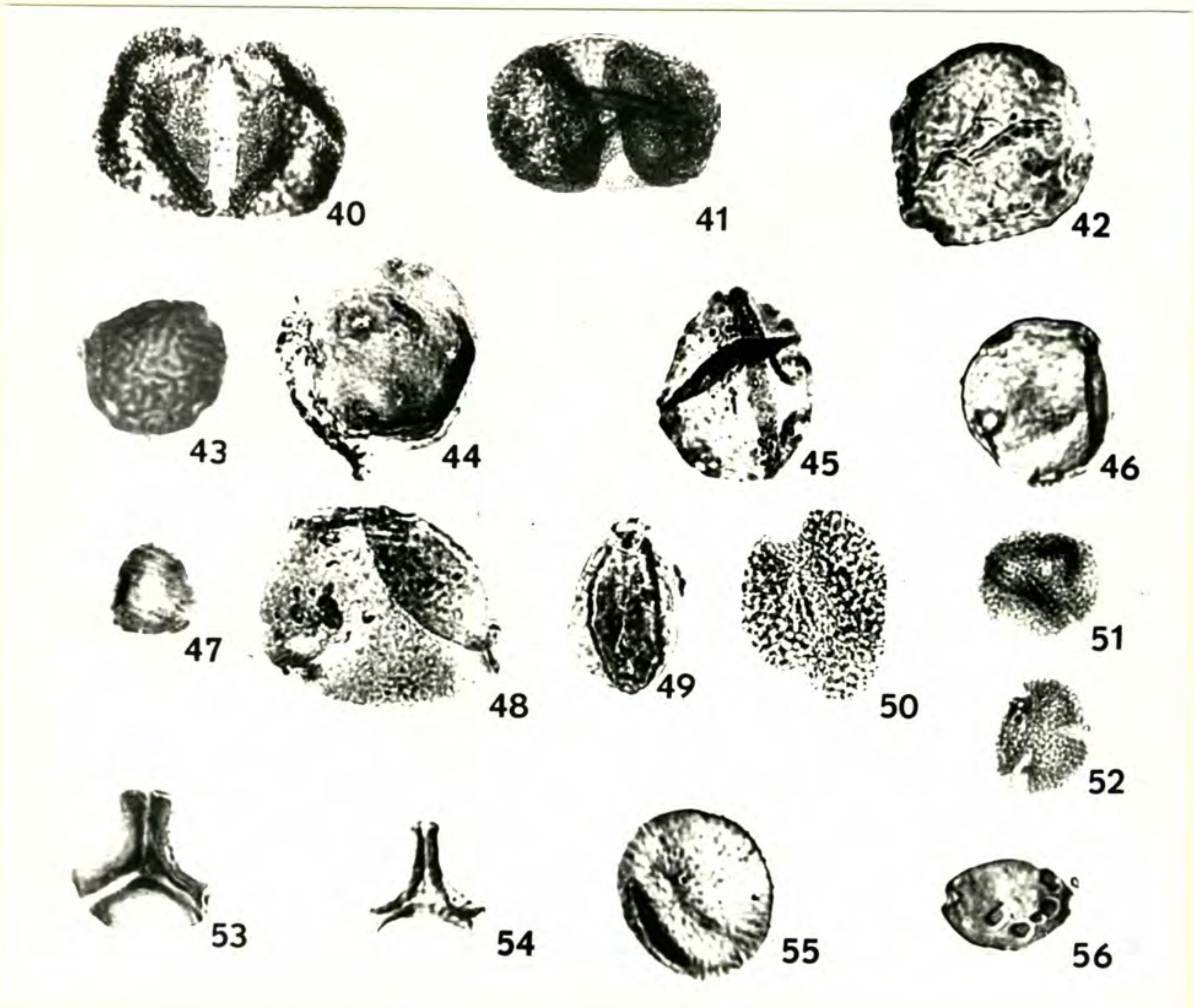
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