STRATIGRAPHIC SIGNIFICANCE OF FOSSIL POLLEN AND SPORES OF THE CHUCKANUT FORMATION, NORTHWEST WASHINGTON

Thesis for the Degree of M. S.

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ABSTRACT

STRATIGRAPHIC SIGNIFICANCE OF FOSSIL POLLEN
AND SPORES OF THE CHUCKANUT FORMATION,
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The Chuckanut Formation, a series of strongly folded, terrestrial sandstones and shales, outcrops in northwestern Washington. The rocks have been previously assigned an age of Upper Cretaceous to lower Eocene based upon plant megafossils.

The microfossil flora of the standard section along the east shore of Samish Bay was examined in order to determine the relationship of the Chuckanut to the Burrard (middle Eocene) of British Columbia. A zonation and environmental interpretation of the standard section was desired for further refinement of the geological history of Tertiary rocks in the Pacific Northwest.

Twenty-two samples, representing 9,484 feet of section, were examined for palynomorphs. Data were collected for both relative frequency and stratigraphic analysis. Seventy-nine palynomorphs are described.

The Samish Bay section is divided into three zones. The zonation is based on changes in the relative frequency and the stratigraphic range of the palynomorphs. These

changes were brought about by changing environmental and climatic conditions during the deposition of the rocks.

An age of Paleocene to lower Eocene is assigned to the Samish Bay section.

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Peter H. Griggs

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INTRODUCTION

General Statement

This report is concerned with an investigation of the stratigraphic significance of fossil pollen and spores of the Chuckanut Formation in northwestern Washington. Little previous work has been done on the palynology of the Chuckanut and associated sedimentary rocks in this area. A complete taxonomy of the fossils is not presented at this time because the primary purpose of this report is a stratigraphic study. Illustrations and descriptions of the fossil forms present are given to clarify their use for the zonation and interpretation of the standard section.

Previous Work

Plant fossils from the Chuckanut were first studied by Newberry and listed in the "Report of the Wilkes Exploring Expedition" published in 1855. Newberry decided that the fossil plants were Upper Cretaceous in age. In later work by Lesquereux (1859) and Knowlton (1902) the strata containing these fossil plants were placed in the Eocene Puget Group. Chaney and La Motte (La Motte, 1938) collected and identified some fossil plants from the Chuckanut. Pabst (1962, doctoral dissertation) reported on the Equistales, Filicales, and Coniferales of the

Chuckanut Formation. This was the first attempt to systematically collect from different zones in the formation and place the floral assemblages in chronological order and compare them with other Pacific Coast Tertiary floras. Pabst, on the basis of these studies, concluded that the Chuckanut Formation is late Cretaceous and Paleocene in age. Berry (1926), after examination of the plant fossils from the Burrard Formation, which underlies the City of Vancouver, British Columbia, equated its megaflora with the Eocene Puget Group.

Previous to this report there has been no systematic or stratigraphic study of the microfossil flora of the Chuckanut Formation, but several studies have recently appeared in which the microfossil floras have given some basis for stratigraphic identification of comparable series in the general area. Rouse (1962) suggests that both Upper Cretaceous and middle Eocene age rocks are represented in the microfossil flora of the Burrard Formation. Crickmay and Pocock (1963) present evidence for an Upper Cretaceous microfossil flora in a sample collected from the Chuckanut Formation south of Deming, Washington, on the Nooksack River. Miller and Misch (1963) correlate the lower part of the Chuckanut Formation with the upper part of the Nanaimo Group, based on the fossil pollen and spore evidence from samples studied by John Fisher of Union Oil Co. of California. The Huntingdon Formation,

which overlies the Chuckanut, is interpreted as being middle Eocene by Miller and Misch (1963). Rouse (personal communication) believes that the microfossil flora of the Huntingdon may be as young as late Eocene-Oligocene (?).

GEOLOGY OF THE CHUCKANUT FORMATION

Regional Setting

In the area of northwest Washington and southwest British Columbia, rocks of two groups of formations are found; a basement complex of pre- Cretaceous metasedimentaries, metamorphics, and igneous intrusives and extrusives, and a series of unaltered sedimentary rocks of Upper Cretaceous to Eocene- Oligocene (?) age. The sedimentary rocks were deposited in a large structural basin the axis of which was northwest-southeast, essentially parallel to the Strait of Georgia. During the Cascade Range orogeny, which affected all these deposits except the late Eocene-Oligocene, the rocks were uplifted and folded. They now crop out along the mountain flanks on either side of the Strait of Georgia (Figure 1).

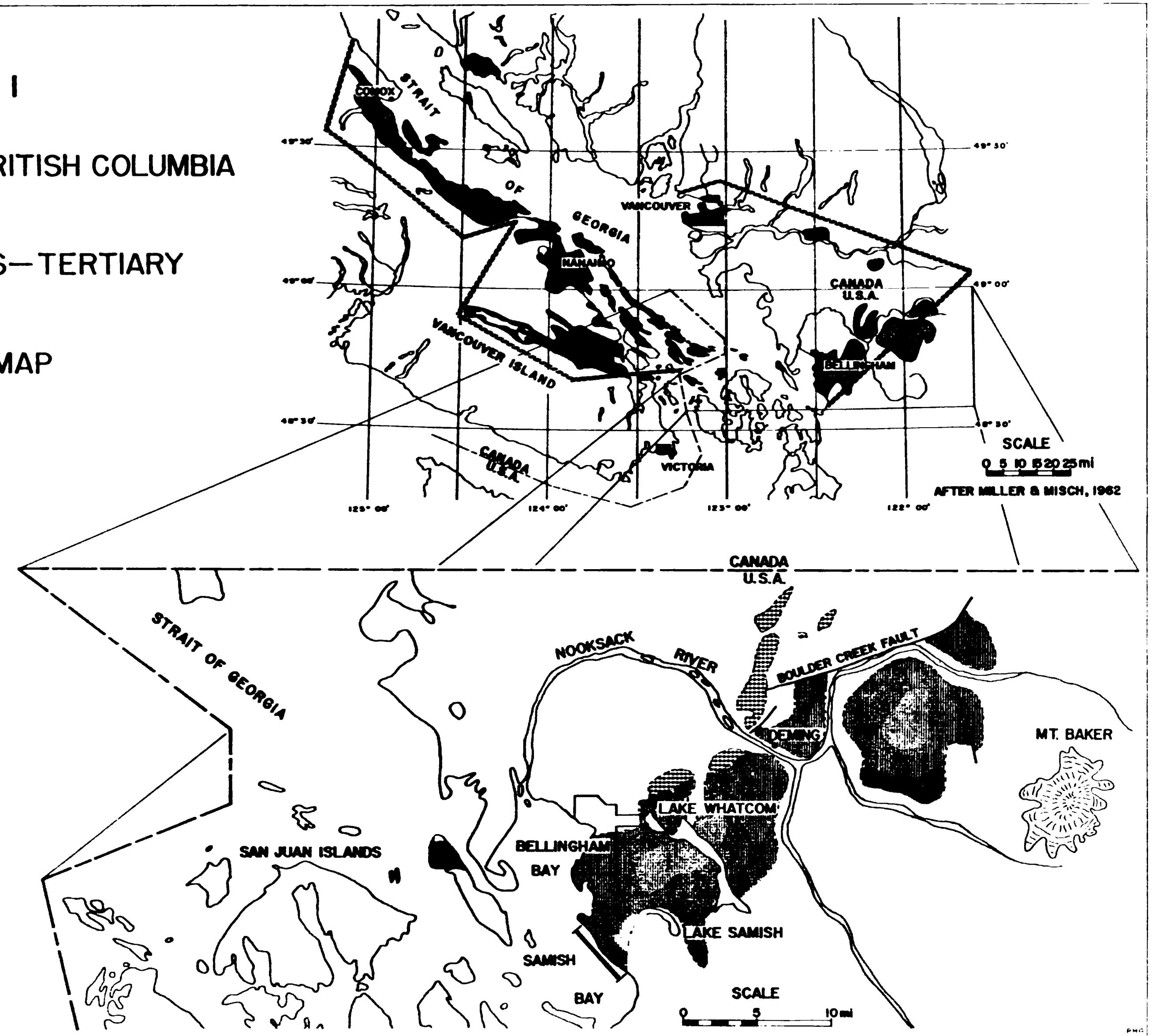
The Cretaceous-Cenozoic basin has become structurally divided to form the several basins and outliers identified in the area at the present time. Two of these "modern" basins are found on Vancouver Island, the Comox and Nanaimo Basins. The rock in these two basins consist of partly marine, coal-bearing beds which are dated as Campanian on the basis of molluscan faunas (Chrickmay and Pocock, 1963). On the mainland side of the Strait of

FIGURE I

N.W. WASHINGTON—S.W. BRITISH COLUMBIA

UPPER CRETACEOUS—TERTIARY

OUTCROP MAP



EXPLANATION

HUNTINGDON FM.

CHUCKANUT FM.

UPPER CRETACEOUS—TERTIARY FMS.

GENERAL OUTLINE OF BELLINGHAM, COMOX AND NANAIMO BASINS

STANDARD SECTION—AREA STUDIED

Georgia there is one large basin. Miller and Misch (1963) have named this the Bellingham Basin. The rocks of the Bellingham Basin are of continental origin. They crop out along the north side of the Fraser River and in the coastal mountains of northwestern Washington. Their age is in dispute. They have been assigned ages from Upper Cretaceous to upper Eocene-Oligocene (?) on the basis of both microfossil floras and larger plant fossils. Small outliers are also found on the mainland side of Malaspina Strait and on the American and Canadian San Juan Islands. The stratigraphic relationships of the rocks of the several basins is illustrated in Figure 2.

Chuckanut Formation

Pre- Cretaceous strata in northwest Washington are overlain by continental sandstones, shales, and conglomerates. White (1888) assigned these rocks to the Eocene Puget Group. Later, Willis (1898), Sheed (1903), and Jenkins (1923, 1924) mapped these rocks as part of the Puget Group, but referred to them as the Chuckanut Bay Sandstone. McLellan (1927) named the coal-bearing sandstones and conglomerates occurring in the northern part of Lummi Island and in the vicinity of Bellingham Bay the Chuckanut Formation. He believed these rocks formed the lower part of the Puget Group. Glover (1935) retained the name Chuckanut Formation in his investigation of the coal-bearing beds in Whatcom County.

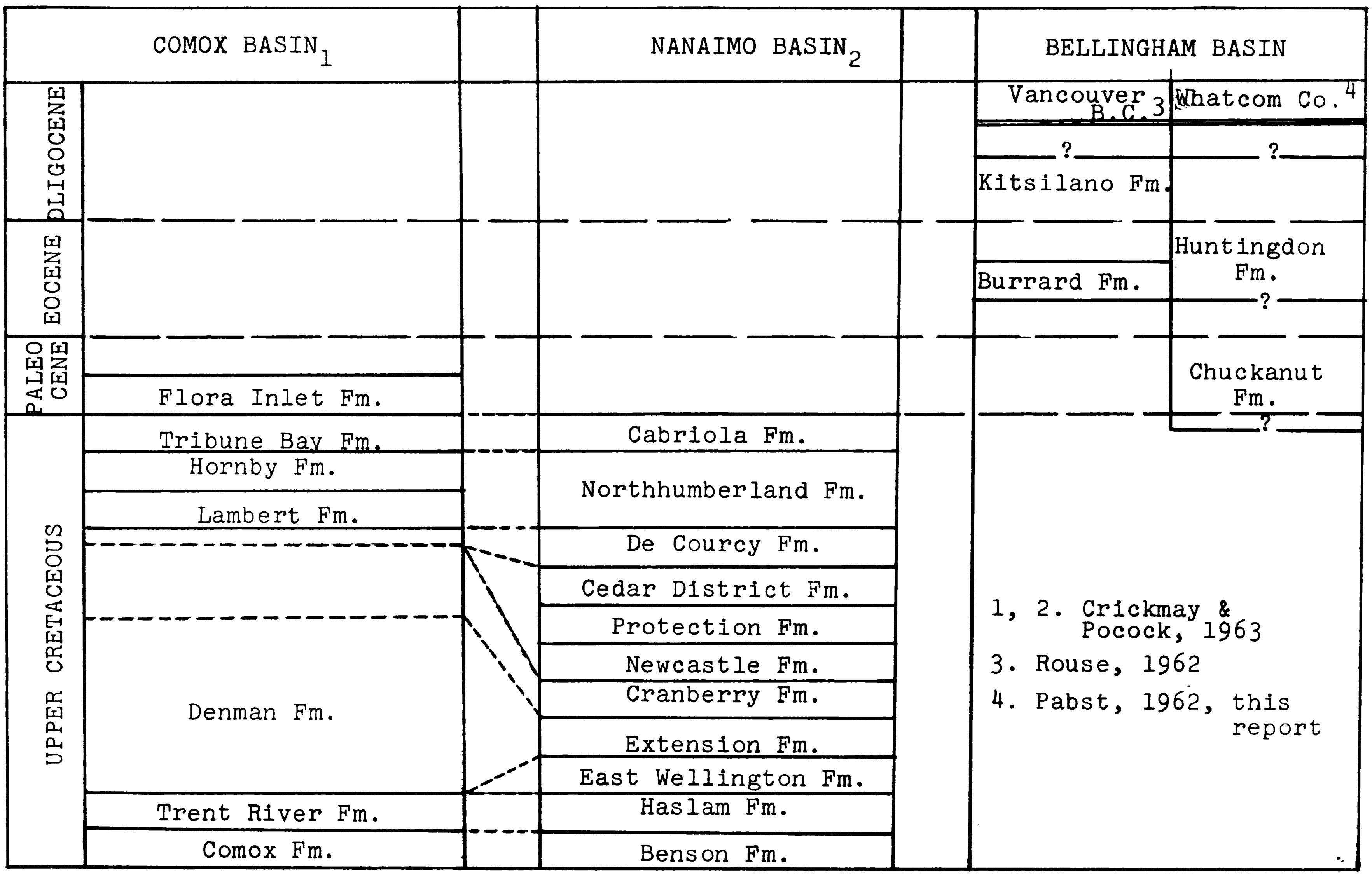


FIGURE 2.--Generalized stratigraphic relationship of Comox, Nanaimo, and Bellingham Basins.

Both Glover (1935) and Weaver (1937) gave detailed stratigraphic descriptions for standard Chuckanut sections. They reported 9,484 and 11,272 feet, respectively, for the section on the east shore of Samish Bay along Chuckanut Drive and 8,800 feet along the southwest shoreline of Lake Whatcom. Miller and Misch (1963) report that 15,000 feet and possibly as much as 20,000 feet of section may be present in the area east of American Sumas Mountain.

The Chuckanut Formation outcrops in an area that trends northeast-southwest from Samish Bay, on the west, to the town of Glacier, on the east. It rests unconformably on pre-Cretaceous rocks to the south; is overlain unconformably by the Huntingdon Formation on the northwest; and is in fault contact with pre-Cretaceous rocks in the north and northeast along the Boulder Creek Fault.

The rocks of the Chuckanut Formation are strongly folded into a series of anticlines and synclines, the axes of which trend northwest-southeast in the area south of Bellingham and Lake Whatcom. Northeast of Lake Whatcom the axes of the folds trend northeast-southwest. The structure of the rocks between the North Fork and the Middle Fork of the Nooksack River is not completely known. Dips within the Chuckanut range from a few degrees to vertical and locally the rocks are overturned. There is some evidence of minor reverse faulting and overthrusting.

The Chuckanut Formation consists, for the most part, of massive crossbedded to evenly stratified, medium- to coarse-grained sandstones and subordinate amounts of sandy shales. The shales vary from pure claystones to sandy and sometimes carbonaceous varieties. The shales are often quite fossiliferous with abundant fragments of plant leaves and stems. The coal seams range from a few inches up to 8 feet in thickness. The coal and shale sequences contain abundant pollen and spores, whereas, the sandstones and their associated shales were found to be practically barren. Intercalated within the sandstones and in some places at the base of the formation are thick lenses of conglomerate.

Good outcrops of the Chuckanut are hard to find in heavily forested regions. The standard section along the east shore of Samish Bay is exposed in roadcuts along Chuckanut Drive (Alternate U. S. 99). Good exposures are also found along the north shore of Lake Samish (Interstate 5) and in the roadcuts along the south shore of Lake Whatcom.

DESCRIPTION OF FIELD INVESTIGATION AND SAMPLING PROCEDURE

During the winter of 1963, a number of samples were collected from the Chuckanut Formation to evaluate its potential for a study of the microfossil flora. During the month of September, 1964, seventy-five samples were collected from the standard section, as described by Glover (1935), along the east shore of Samish Bay (Appendix A). The section measures 9,484 feet along the western limb of the Chuckanut syncline whose axes trends northwesterly and lies along the slope of Chuckanut Mountain. Much of the lower 5,100 feet of the section is in continuous outcrop but there are some concealed zones as much as 250 feet in thickness. Most of the upper part of the section is concealed, except for an outcrop of conglomerate at 7,700 feet above the base and a shale unit at the top of the section. A reversal in the dip across the axes of the syncline occurs at this point. The samples were collected from gray shales, carbonaceous shales, and coals. Care was taken to obtain unweathered samples, where possible, by collecting in deep road cuts and by digging deep enough to be beyond the effects of recent weathering. A maximum sample interval of 50 feet was maintained where outcrops permitted.

The base of the section is located along Chuckanut Drive in the SW, SW, Sec. 9, T36N-R3E and the top of the section, to the north along Chuckanut Drive, in the NE, SE, Sec. 25, T37N-R3E.

RESULTS OF PALYNOLOGICAL INVESTIGATION

Introduction

Palynology Applied to Stratigraphy

Plant microfossils are useful for providing detailed stratigraphic and ecologic information in many instances. Their use in stratigraphy and the zonation of sedimentary rocks, especially as applied to oil exploration, is clearly indicated in the recently published S.E.P.M. symposium; "Palynology in Oil Exploration," Aureal T. Cross, Editor (1964).

The application of palynological methods to certain correlation problems is most effective if the palynomorphs in the rocks through the complete type section or standard section of the formation are studied first. The relative stratigraphic position is usually well known in such sections. After examination of the residues the differences found in the floras may be sufficient to allow the formulation of stratigraphic-palynological zones. Kuyl, Muller, and Waterbolk (1955) list the criteria used to characterize these zones:

a. "types which occur only in one particular zone, or whose stratigraphic highest or lowest occurrence is to be found at the boundaries of that zone";

b. "types which occur most numerously in one particular zone, or whose main distribution ends or begins at the boundaries of that zone";

c. "a fairly constant association of types, the lowest and highest occurrence of which are usually to be found elsewhere in the stratigraphic column."

Two main factors control the differentiation of the pollen flora in the successive layers of a formation, i.e., evolution and migration.

Evolution.--The development of pollen and spores runs parallel to that of the major units in the plant kingdom. Evolution expresses itself in the appearance of new types, the modification of existing types, gradation between types, and the extinction of types.

Migration.--Climatic and edaphic changes in environment result in distinctive changes in the living flora. These changes are often sharply delineated from one stratigraphic layer to another and are often useful in the zonation and environmental interpretation of the deposition of successive layers of the formation. The factors that control the changes in environment are generally a reflection of geologic events which occur in or near the basin of deposition. Floristic changes due to migration usually provide a more detailed picture of geologic events than do those changes produced by evolution. Some events may produce temporary effects on the flora of an area, whereas, others may cause major and lasting changes.

System of Reference Used for Plant Microfossils Differentiated in This Study

The temporary classification system used in this study is modeled after the "formulae" proposed by Tschudy (1957). Each morphological type is assigned a code designation as illustrated in Table 1.

TABLE 1

POLLEN AND SPORE FORMULAE
(after Tschudy, 1957)

Inaperturate . . .	0	Porate	P_1
Sulcate.	S_1		P_2
	S_3		P_3
Colpate.	C_1		P_∞
	C_2	Trilete	Tl
	C_3	Monolete.	M
	C_∞	Vesiculate.	V
Colporate.	CP_2		
	CP_3		
	CP_∞		

Further subdivision is effected by an inspection of the sculpturing elements of the pollen grain or spore. Faegri and Iversen (1964, p. 26) present a key to the sculpturing elements as shown in Table 2.

Each of the twelve sculpturing descriptions have been grouped into seven shorthand designations as shown in Table 3.

Using these "formulae" a tricolpate pollen grain with reticulate sculpturing would be designated C_3r, plus a number indicating a tentative species designation as C_3r-5. The first species of smooth trilete spores would be assigned the "formula," Tlsm-1, the second Tlsm-2, etc.

Preparation Methods

Maceration

Several different procedures are used in maceration depending upon the lithology of the sample. Two procedures were used in this investigation; one for coal maceration and one for shale maceration. The coals were first crushed to 1/4-inch size. After thorough mixing, a 5 gram portion from each sample was placed in a beaker and covered with 52% hydrofluoric acid for 24 hours. After washing several times with distilled water to remove the acid, the residue was mixed with an equal amount (by volume) of dry potassium chlorate and covered with concentrated nitric acid. This

TABLE 2

KEY TO SCULPTURING ELEMENTS
Faegri and Iversen (1964)

A.	Sculpturing elements s.s. absent					
	B.	Surface even or diameter of pits $< 1\ \mu$				psilate
	BB.	Surface pitted, diameter of pits $\overline{\overline{>}}\ 1\ \mu$				foveolate
	BBB.	Surface with grooves				fossulate
AA.	Radial projections of sculpturing elements $\pm$ isodiametric					
	B.	No dimension $\overline{\overline{>}}\ 1\ \mu$				scabrate
	BB.	At least one dimension $\overline{\overline{>}}\ 1\ \mu$				
		C.	Sculpturing elements not pointed			
			D.	Greatest diameter of radial projections greater than height of elements		
				E.	Lower part of element not constricted	verrucate
				EE.	Lower part of element constricted	gemmate
			DD.	Height of element greater than greatest diameter of projection		
				E.	Upper end of element not thicker than base	baculate
				EE.	Upper end of element thicker than base	clavate
		CC.	Sculpturing elements pointed . . .			echinate
AAA.	Radial projections elongated (length at least twice breadth)					
	B.	Elements irregularly distributed . . .				rugulate
	BB.	Elements parallel.				striate
	BBB.	Elements forming a reticulum				reticulate

TABLE 3

SHORTHAND DESIGNATIONS
(after Tschudy, 1957)

Psilate (smooth)		sm
Foveolate		f
Scabrate Verrucate Gemmate Baculate Clavate	(projections)	p
Echinate (spiny)		sp
Fossulate Rugulate Striate	(striate)	st
Reticulate		r
Cicatricose		cic

mixture (Schulze Solution) was allowed to stand from 30 minutes to 12 hours. The residues were again washed in distilled water to remove the acid, then treated with a 5% solution of potassium hydroxide for 5 to 30 minutes. Washings were made with distilled water until the residue was neutral. The shales were macerated in more or less the same manner with usually more time in the hydrofluoric acid and less time in the Schulze Solution. All residues were stained with Safranin O. Preparations were stored in an aqueous solution containing a few drops of acetic acid as a preservative.

Slide Preparation

The residues were mounted in Clearcol on cover slips and allowed to dry. The cover slips were then inverted and mounted on the slide with HSR (Harleco Synthetic Resin). Five slides were made from each residue.

Analytical Procedure

Of the seventy-five samples collected only twenty-six had good preservation of the pollen and spores. Twenty-two of the twenty-six were selected for examination. The other four good samples were not used because of the close spacing of some of the samples in the coal units.

Slides from each sample were examined in two ways. First, each slide was examined to see what forms were present regardless of relative frequency. From results of this qualitative analysis, a stratigraphic range chart could be constructed for the section (Figure 3). Next, relative frequency counts were made from each sample. A minimum of five hundred spores and pollen grains were counted for each sample, approximately one hundred grains per slide and five slides per sample. These data were used to plot relative frequency diagrams for the section.

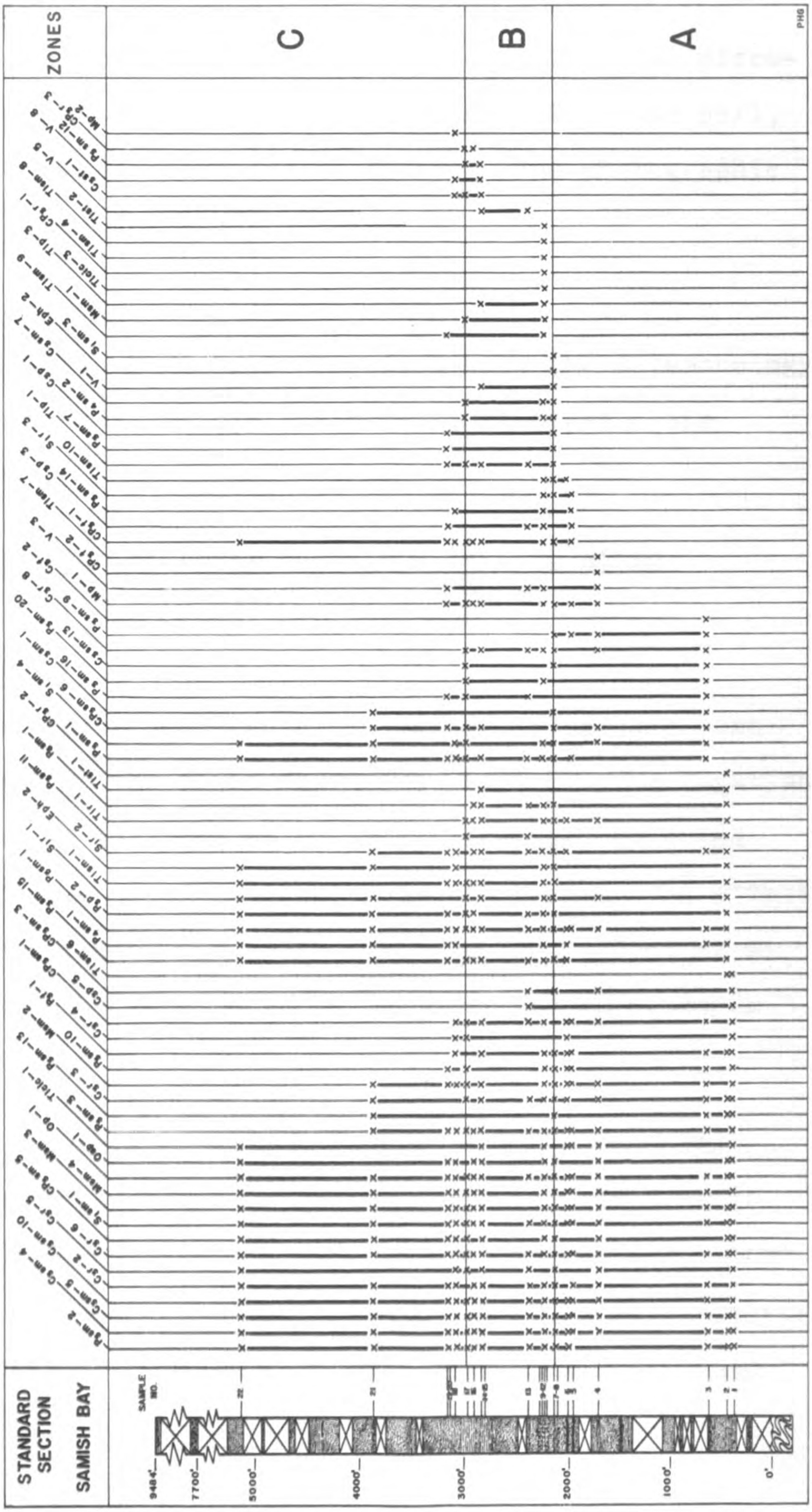


FIGURE 3 STRATIGRAPHIC RANGE OF CHUCKANUT PALYNOMORPHS

Photography

Photographs were taken with a Leitz Ortholux microscope and a Leitz Orthomat camera using a Fluorite 95/1, 54/1, or 40/1 objective and no filter. The photographic film used was Kodak Panatomic-X.

Slide Depository

All slides have been deposited with the paleontology collection of the Geology Department, Michigan State University.

Zonation of Lower Chuckanut Section Along the East Shore of Samish Bay

Zonal Divisions

Three zones based on plant microfossils have been established for the lower Chuckanut section. The zonation is based on an analysis of the stratigraphic range and relative frequency of nineteen selected forms. The stratigraphic location of the twenty-two samples used is shown in Table 4. The data on which the zonation is based is shown in Figure 4.

Zone A.--Triporate pollen are less abundant than form #7 in Zone A (compare graphs D and E). Form #7 is found in high abundance in most of the samples throughout the section, reaching a high of 62% in sample #6. Although three species of triporate pollen, #1, #2, and #3 range

TABLE 4

STRATIGRAPHIC LOCATION OF SAMPLES
USED IN ZONATION

Sample No.	Maceration No.	Collection No.	Strat. Location*
22	Pb 3791	PG 9/9/64-14	5170'
21	Pb 3799	PG 9/9/64-6	3870'
20	Pb 5204	PG 9/8/64-11	3160'
19	Pb 5203	PG 9/8/64-10	3135'
18	Pb 5212	PG 9/8/64-8	3095'
17	Pb 5207	PG 9/8/64-3	2955'
16	Pb 5205	PG 9/8/64-1	2925'
15	Pb 5224	PG 9/4/64-8	2820'
14	Pb 3771	PG 1/3/64-4	2795'
13	Pb 5221	PG 9/4/64-5	2380'
12	Pb 5218	PG 9/4/64-2	2285'
11	Pb 5217	PG 9/4/64-1	2265'
10	Pb 5234	PG 9/3/64-17	2245'
9	Pb 5233	PG 9/3/64-16	2228'
8	Pb 5230	PG 9/3/64-13	2145'
7	Pb 5229	PG 9/3/64-12	2112'
6	Pb 5241	PG 9/3/64-7	2000'
5	Pb 5240	PG 9/3/64-6	1925'
4	Pb 5237	PG 9/3/64-3	1690'
3	Pb 3786	PG 9/11/64-3	625'
2	Pb 3777	PG 1/2/64-2	443'
1	Pb 3781	PG 1/2/64-6	377'

*feet above base of section

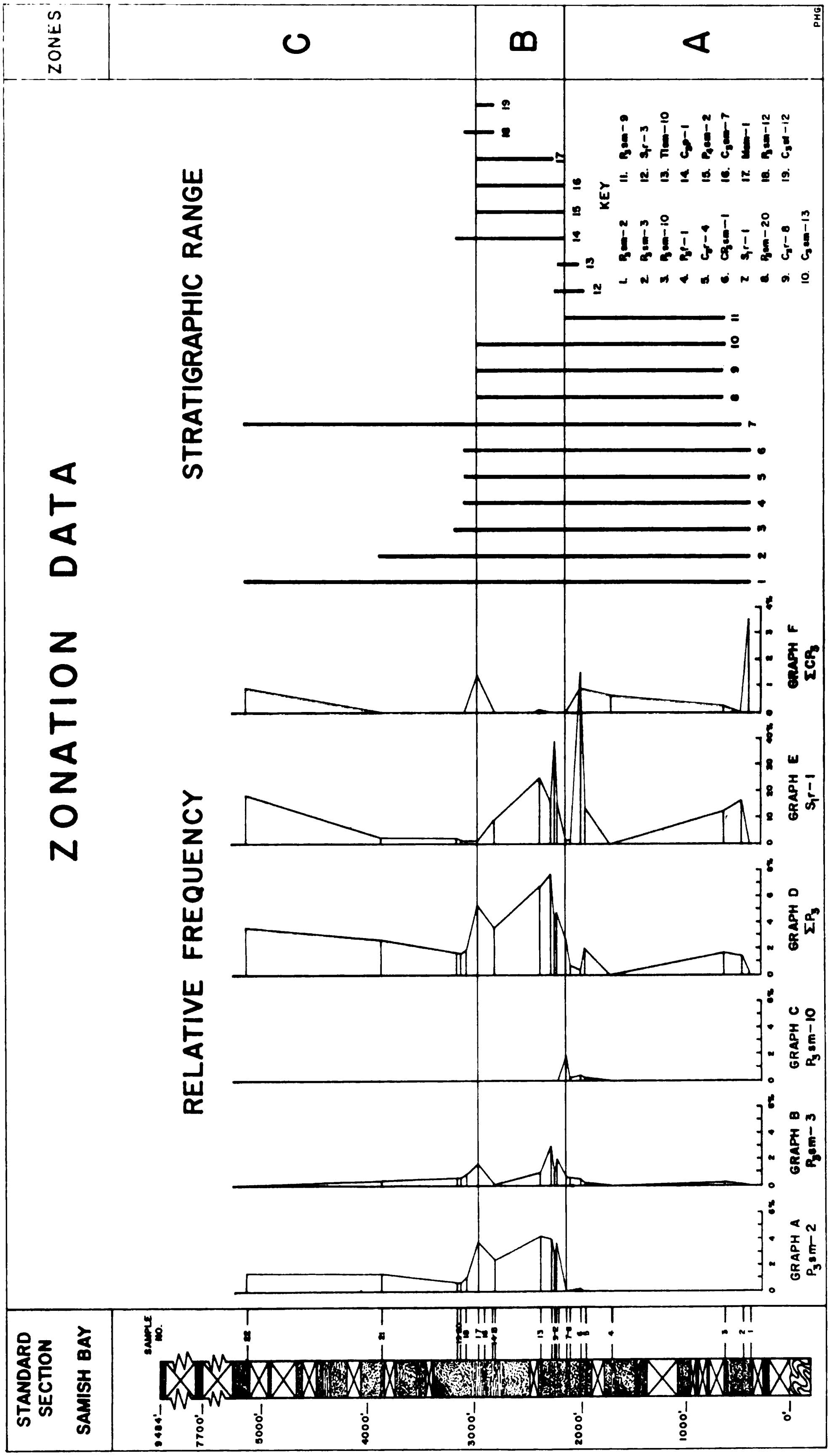


FIGURE 4 CHUCKANUT ZONATION — SAMISH BAY SECTION

throughout Zone A they are rarely abundant enough to be encountered when counting 500 grains (graph A, B, and C). Form #3 reaches a peak at the boundary between Zones A and B. Tricolporate pollen are abundant enough to account for up to 3.5% of the total microfossil flora in Zone A (graph F).

Only one significant form has a stratigraphic range that is restricted to Zone A. This is the triporate grain, #11. Two types first appear near the top of Zone A, #12 and #13. These two were found only at the boundary between Zones A and B.

Zone B.--The flora of Zone B is markedly different than that found in Zones A and C. Triporate pollen become more abundant in this zone (graph D), especially the two forms, #1 and #2 (graphs A and B). In the upper part of Zone A and throughout the lower third of Zone B, #7 (graph E) attains high percentages in several samples. The percentages of all tricolporate pollen (graph F) drop to very low levels in the lower part of Zone B. However, they show a peak at the upper boundary of Zone B.

The lower part of Zone B is marked by the first occurrence of a number of new forms. Besides the two previously mentioned, which occur first at the top of Zone A, four distinctive forms first occur in the lower part of Zone B. Two of these, #15 and #16, occur only in Zone B and appear to be good marker species for this zone. The other forms that first occur in the lower part of Zone B are, #14 and #17.

The boundary between Zones B and C is marked, in this section, by the disappearance of thirteen types. Form #3 and #14 have their top in sample #20. Forms #4, #5, #6 and #18 have their tops in sample #18. Forms #8, #9, #10, #15, #16, and #19 have their tops in sample #17.

Zone C.--The spores and pollen and their percentages of occurrence in Zone C is more nearly similar to Zone A than Zone B. The upper limit of the zone has not been established because sample material was not available from the upper part of the section. The triporate pollen drop off in abundance from that found in Zone B, although they are more abundant than in Zone A (graph D). The triporate and tricolporate pollen and form #7 all show increasing abundance in the top two samples (graphs D, E, and F). There are no good stratigraphic forms that are restricted to Zone C.

DISCUSSION

Depositional Environment

The major characteristic changes in the microfossil flora which differentiate Zone B from Zones A and C are interpreted as being due to environmental and climatic conditions controlling the flora rather than to evolutionary changes.

The sediments of the Chuckanut Formation were deposited subaerially on a wide alluvial plain close to sea level. The nearest highlands were to the north and northeast, beyond the present Cascades. Large streams flowing from the highlands to the sea deposited sediment in the Bellingham Basin from perhaps as early as Upper Cretaceous time, continuing on into the late Eocene or early Oligocene.

The sequence is characterized by thick sandstone and thinner shale units that show great lateral variation. Most of the gray shales, carbonaceous shales, and minor coal seams are richly fossiliferous. In some places the fossil leaves are so densely matted on the bedding surfaces that it is very difficult to distinguish the outlines of single leaves in the mass. Casts of large logs are often found embedded in many of the sandstones. Some of these stand vertically, in situ, with their roots still discernable in position in the thin coal seams or shales in which they grew. Nowhere in the Chuckanut Formation have there been found any marine fossils that would indicate marine deposition.

The sediments exhibit a great variety of sedimentary structures. Crossbedding, ripple marks and mud cracks are common. Armored mudballs and flute casts can also be found in many outcrops.

All physical evidence indicates that the sediments were deposited in forested coastal swamps and backwater areas near river mouths where rates of sedimentation were quite varied. Both brackish and fresh water swamps were often buried by irregular sheets and great lenses of sand which were deposited during high water inundations. Continuous subsidence in the depositional basins was balanced by deposition. The surface of the area was thus maintained at or near sea level.

Thick sandstone units are characteristic of Zones A and C. These sandstone units are usually associated with thinly-bedded shales and, in some instances, conglomerates. In Zone B the massive sandstones are not as prominent and are split by interbedded carbonaceous shales and thin coal seams. The shales and coals in Zone B contain abundant pollen and spores throughout this interval (Figure 3).

Zone B represents a time when the east shore of Samish Bay was occupied by fresh water swamps and brackish lagoons. The swamps and backwater areas were at some distance from the large streams that carried coarse sediment into the area during deposition of Zone A sediments and those that followed in Zone C.

Composition of the Flora

The microfossil flora of the Chuckanut Formation indicates that a warmer and more humid climate than that of today existed in this area of the Pacific coast during early Tertiary time. This is in line with the evidence presented by Pabst (1962) from the megaflora of the Chuckanut and by Rouse (1962) from the microfossil flora of the Burrard.

The seventy-nine palynomorphs described in this paper are listed by coded designations in Table 5, along with their corresponding generic names. Those genera and species that also occur in the Burrard are indicated as well as other pertinent occurences.

Although Pabst limited herself to the study of non-flowering plants in her thesis on the Chuckanut megaflora, she was able to present considerable evidence for reconstruction of the climatic and environmental conditions due to the large number of species present. Her paper includes twenty-two species. These are assigned to one genus of

TABLE 5

CHUCKANUT PALYNOMORPHS AND CORRESPONDING BURRARD SPECIES

	Chuckanut	Burrard	Other Pertinent Occurrences
Op-1	*Inaperturopollenites juniperoides*	*I. juniperoides*	
Osp-1	*Osmundacidites* sp.		
Msm-1	*Magnosporites staplinii*	*M. staplinii*	
Msm-2	*Laevigatosporites albertensis*	*L. albertensis*	
Msm-3	*Laevigatosporites discordatus*	*L. discordatus*	
Msm-4	*Laevigatosporites ovatus*	*L. ovatus*	Comox Fm. Rouse (1957)
Mp-1	*Verrucatosporites (Polypodiisporites) favus*	V. (*Polypodiisporites*) *favus*	
Mp-2	*Danaea* (?) sp.		
Tlsm-1	*Microlepia* (?) sp.	*Microlepia* (?) sp.	
Tlsm-4	Affiliation unknown		
Tlsm-6	*Sphagnum* sp.		
Tlsm-7	*Gleichenia concavisporites*	*G. concavisporites*	
Tlsm-8	*Sphagnum antiquasporites*	*S. antiquasporites*	Comox Fm. Rouse (1957)
Tlsm-9	*Cyathidites* (?) sp.		
Tlsm-10	*Cyathidites* (?) sp.		
Tlp-1	*Osmundacidites* sp.		

Tlp-3	Osmundacidites sp.		
Tlr-1	Lycopodium fastigioides		Upper Cret., N.Z., Couper (1953)
Tlst-1	Anemia (?) sp.		
Tlst-2	Anemia (?) sp.		
Tlcic-1	Cicatricosisporites sp.		
Ticic-3	Cicatricosisporites intersectus	C. intersectus	
S_1sm-1	Metasequoia (?) sp. Taxodium (?) sp. Glyptostrobus (?) sp.	Metasequoia sp. Taxodium sp.	
S_1sm-3	Affiliation unknown		
S_1sm-4	Ginkgo (?) sp.		
S_1r-1	Liliacidites sp.		Upper Cret.-Paleocene N.M., Anderson (1960)
S_1r-2	Sable granopollenites	S. granopollenites	
S_1r-3	Affiliation unknown		
C_3sm-1	Nyssa (?) sp.		
C_3sm-4	Quercus (?) sp.		
C_3sm-5	Tricolpopollenites granulosus	T. granulosus	
C_3sm-7	Quercus (?) sp.		
C_3sm-10	Nymphoides tripollenites	N. tripollenites	
C_3sm-13	Quercus (?) sp.		
C_3p-1	Tricolpites sp.		
C_3p-3	Affiliation unknown		
C_3p-5	Affiliation unknown		
C_3f-2	Quercus (?) sp.		

C_3r-2	Salix discolorites	S. discolorites	
C_3r-3	Tricolpites sp.		
C_3r-5	Quercus (?) sp.		
C_3r-6	Tricolpites interangulus		Upper Cret., Colo. Newman (1965)
C_3r-8	Tricolpites anguloluminosus		Paleocene N. Mexico Anderson (1960)
C_3st-1	Affiliation unknown		
Eph-1	Ephedra notensis		Eocene Australia, Cookson (1957)
Eph-2	Ephedra sp		
CP_3sm-1	Tricolporopollenites sp.		
CP_3sm-3	Ulmus sp.		
CP_3sm-5	Nyssa sp.		
CP_3sm-6	Affiliation unknown		
CP_3f-1	Tricolporopollenites confossus		Upper Cret., Colo. Newman (1965)
CP_3f-2	Affiliation unknown		
CP_3r-1	Cupanieidites reticularis		Eocene Australia, Cookson (1954)
CP_3r-2	Virburnum (?) sp.		
CP_3r-3	Affiliation unknown		
P_3sm-1	Affiliation unknown		
P_3sm-2	Betulaceae-Myricaceae		
P_3sm-3	Carya juxtaporites	C. juxtaporites	
P_3sm-7	Carya (?) sp.		

P_3sm-9	Betulaceae-Myricaceae		
P_3sm-10	*Corylus tripollenites*	*C. tripollenites*	
P_3sm-11	Affiliation unknown		
P_3sm-12	Affiliation unknown		
P_3sm-13	Affiliation unknown		
P_3sm-14	*Triorites minor*		Upper Cret. N.Z., Couper (1953)
P_3sm-15	Affiliation unknown		
P_3sm-16	Affiliation unknown		
P_3sm-20	*Triatriopollenites* (?) sp.		
P_3p-2	*Proteacidites marginus* (?)	*P. marginus*	
P_3f-1	*Protaecidites* sp.		
P_4sm-1	*Alnus quadrapollenites*	*A. quadrapollenites*	
P_4sm-2	*Carya* (?) sp.		
P_5sm-1	*Alnus quinquepollenites*	*A. quinquepollenites*	
P_6sm-1	Affiliation unknown		
V-1	*Tsuga* sp.		
V-3	*Podocarpus* sp.		
V-5	*Pinus* sp.		
V-8	*Picea-Abies* sps.		

scouring rush, fourteen genera of ferns in seven families and two orders, and five genera of conifers in two families. The megaflora and possible spore and pollen affiliations are listed in Table 6.

Of the twenty types of spores described in this paper, eight are assigned possible affiliations with the Chuckanut megaflora. The monolete spore, Mp-1, may possibly be assigned to the genus Danaea. Pabst describes a new species, Danaea borealis, and notes that it is the first time Danaea has been described from the Tertiary. The living genus Danaea is terrestial in habit and is restricted to the Neotropics.

Four spores are assigned to the family Schizaeaceae. Two of these, Tlcic-1 and Tlcic-3 are placed in the form-genus Cicatricosisporites. The other two, Tlst-1 and Tlst-2, are possibly affiliated with the genus Anemia. Pabst describes two genera from this family, Lygodium kaulfussii and Anemia elongata. Both of these genera are represented by modern species in tropical and subtropical regions in both hemispheres.

The three spores, Msm-2, Msm-3, Msm-4, are identical to Laevigatosporites albertensis, L. discordatus, and L. ovatus, respectively. These three spores also occur in the Burrard and Rouse states that they are probably related to Dryopteris and Asplenites. Three species of Dryopteris are described from the Chuckanut megaflora. Dryopteris is

TABLE 6

CHUCKANUT MEGAFLORA (PABST, 1962)
AND POSSIBLE SPORE AND POLLEN AFFILIATIONS

Tracheophyta	
Sphenopsida	
Equisetales	
Equisetaceae	
Equisetum newberryi Knowlton & Cockerell	
Pteropsida	
Filicineae	
Marattiaceae	
Danaea borealis Pabst	Mp-2 (?)
Filicales	
Schizaeaceae	Tlcic-1, -3
Lygodium kaulfussii Heer	
Anemia elongata (Newberry) Knowlton	Tlst-1, -2 (?)
Pteridaceae	
Pteris whatcomensis Pabst	
Dennstaedtia delicata Pabst	
Cyatheceae	
Cyathea pinnata (MacGinitie) La Motte	
Aspidiaceae	Msm-2, -3, -4
Rumohra bartona Pabst	
Dryopteris chuckanutensis Pabst	
Dryopteris gibbsi Pabst	
Dryopteris whatcomensis Pabst	
Athyrium gracillium Pabst	
Allantodiopsis erosa Knowlton & Maxon	
Blechnaceae	
Salpichlaena serrata Pabst	
Woodwardia clarus Pabst	
Lorinseria aurora Pabst	
Polypodiaceae	
Polypodium alternatum Pabst	
Gymnospermae	
Coniferales	
Taxodiaceae	
Matasequoia occidentalis (Newberry) Chaney	S_1sm-1 (?)
Taxodium dubium (Sternberg) Heer	S_1sm-1 (?)
Glyptostrobus dakotensis (Heer) Brown	S_1sm-1 (?)
Cupressaceae	
Libocedrus interrupta (Newberry) Pabst	
Juniperus washingtonensis Pabst	Op-1 (?)

probably the most frequently recognized genus of ferns in the North American Tertiary. The present distribution of the modern genus is temperate in both the New World and Old. Pabst states that "the Chuckanut species find their closest modern relatives in Mexican and Central American species."

Three spores, Osp-1, Tlp-1, and Tlp-3, appear to be related to the genus Osmunda and are placed in the fossil genus, Osmundacidites. Although Osmunda spores occur in the Burrard, Osp-1 is the only Chuckanut spore that resembles Rouse's Osmundacidites (Designate T_1), Tlp-1 and Tlp-3 appear to have no counterpart in the Burrard microfossil flora. Osmunda is a temperate and tropical fern found in moist woodlands and swamps in the northern hemisphere.

The large nondescript spore, Msm-1, appears to be identical to Magnosporites staplinii, a new genus and species described by Rouse from the Burrard. Although Rouse offers no suggestion in regards to botanical affinity he suggests that it is probably associated with fresh water plants, as these spores are found only in fresh water deposits.

Two spores, Tlsm-6 and Tlsm-8, are apparently of the genus Sphagnum. No affiliation below the generic level is offered for Tlsm-6. Tlsm-8 appears to be conspecific with Sphagnum antiquasporites Wilson and Webster which Rouse reports from the Burrard. _Sphagnum_ is usually indicative of acid peat bogs. Another spore that indicates moist woods or peat bog environments is _Lycopodium fastigioides_ Couper (Tlr-1). This genus has not yet been reported in the Burrard flora.

The monolete spore, Mp-1, appears as though it might be similiar to _Verrucatosporites_ (_Polypodiisporites_) _favus_ Pflug and Thompson. Rouse believes that this spore, which is present in the Burrard, represents the perispore from a specimen of _Laevigatosporites albertensis_ or _L. ovatus_.

The trilete spore, Tlsm-7, has been assigned to _Gleichenia concavisporites_ Rouse. This spore occures in the Burrard and is also reported from the Upper Cretaceous Oldman Formation (Rouse, 1957). In his discussion of _G. concavisporites_ from the Oldman, Rouse comments that the descriptions given by Selling (1946) for _G. emarginata_ and _G. linearis_ from the Hawaiian Islands are very similar to that of _G. concavisporites_.

Tentative generic names are assigned to three other Chuckanut spores. Specimens of Tlsm-1, appear to be similar to _Microlepia_. Rouse illustrates a spore from the Burrard which he has tentatively assigned to this genus. Two other spores, Tlsm-9 and Tlsm-10, are questionably assigned to the genus _Cyathidites_.

Of the five genera of conifers that Pabst describes from the Chuckanut four may possibly be represented in the microfossil flora. The form, S_1sm-1, has been broadly defined to include the pollen of Metasequoia, Taxodium, and Glyptostrobus. The pollen grains of these three genera are so similar that for practical purposes it is impossible to separate them in fossil form. Pabst states that Taxodium and Glyptostrobus are the most abundant conifers in the megafossil flora. Both grow in moist areas in warm temperate and subtropical regions. Rouse reports Taxodium hiatipites Wodehouse and describes a new species of Metasequoia, M. papillapollenites, from the Burrard. The Taxodium specimens from the Burrard are identical with those from the Green River Formation (Wodehouse, 1933). No macrofossils of Metasequoia have been reported from the Burrard and because of this Rouse indicates that the trees were probably some distance from the swamps. In the Chuckanut megaflora, Metasequoia, is the least abundant of the conifers.

The inaperturate grain, Op-1, appears to be identical to Inaperturopollenites juniperoides which Rouse describes from the Burrard. He states that there is little doubt that this is a species of Juniperus pollen. However, because of the difficulty in separating Juniperus pollen from other genera of the Cupressaceae he has placed it in the form-genus Inaperturopollenites. Two genera are reported from the Cupressaceae in the Chuckanut megaflora, Libocedrus and Juniperus. This type of fossil pollen, Op-1, may be representative of both these genera. *Juniperus* was probably closely associated with the cypress swamps, whereas, *Libocedrus* may have had a greater range, extending into the highlands to the north and northeast. Both of these conifers are found today in habitats where there is adequate soil moisture and rainfall.

In addition to the conifers mentioned above, the pollen flora includes at least five, and perhaps six, other conifers. Five of these are *Tsuga* (V-1), *Podocarpus* (V-3), *Pinus* (V-5), and *Picea-Abies* (V-8). All of these grains are rare and are usually badly corroded. This condition of preservation, along with their absence from the megafossil flora, might indicate that these trees grew in the highlands to the north and northeast and their pollen was carried to the site of deposition particularly by the streams flowing down from the highlands. Rouse reports two species of *Tsuga*, one of *Picea*, two of *Pinus*, and one of *Podocarpus* from the Burrard. No attempt is made to relate the Chuckanut forms at the species level to those of the Burrard. Another possible conifer is S_1sm-4 which is assigned to *Ginkgo*. Although this grain occurs throughout the section its botanical affinity to *Ginkgo* is in question.

The order Gnetales is represented by two palynomorphs. Both are believed to be pollen of the genus *Ephedra*. *Ephedripites*-1 is very similar to *Ephedra notensis* described by Cookson (1957) from the Eocene of Australia. No specific epithet is offered for _Ephedripites_-2. There are fifteen modern species of _Ephedra_ in North America. They are found most abundantly in California, Arizonia, and New Mexico. No _Ephedra_ pollen has yet been identified from the Burrard.

Of the seventy-nine palynomorphs described from the Chuckanut microfossil flora forty-nine are believed to be from angiosperms. Twenty-three of these have been assigned generic names based upon their morphologic affinities to pollen of extent genera. Ten have been placed in form-genera. Two are equated at the family level and fourteen are listed as "affiliation unknown."

The family Palmaceae is represented by two genera in the Chuckanut, _Liliacidites_ (S_1r-1) and _Sabal_ (S_1r-2). Although _Liliacidites_ is a form-genus created by Couper (1953) for pollen of apparent liliaceous affinity, the general morphology of the grain plus its high abundance in samples which are known to come from zones containing numerous palm fronds, warrants placing it in this family. _Sabal granopollenites_ (S_1r-2) is described by Rouse from the Burrard. He remarks that it is similar to modern pollen of _Sabal palmetto_. Today the palms have their northern limits between 30° and 40° N. in the northern hemisphere and are considered to be principally tropical. The present distribution of _Sabal_ is along the coast of North Carolina into Florida and west along the coastal plain on the Gulf states into southeastern Texas.

The pollen of Corylus, Quercus, and Carya suggest upland habitats. Corylus tripollenites Rouse (P_3sm-10) occurs in the Burrard. Rouse suggests that this species may be conspecific with Momipites coryloides described by Wodehouse (1933) from the Green River Formation. Corylus is found in woodland thickets in the temperate regions of the northern hemisphere. Five palynomorphs are tentatively assigned to the genus Quercus. They are C_3sm-4, C_3sm-7, C_3sm-13, C_3f-2, and C_3r-5. Although Rouse has described three new species of Quercus from the Burrard, no attempt is made to equate the Chuckanut forms with those in the Burrard, since in most cases the identification, even at the generic level, is in question. Quercus is found in a great variety of habitats in the northern hemisphere. Three palynomorphs are assigned to the genus Carya. Carya juxtaporites (Wodehouse) Rouse (P_3sm-3) is reported from the Burrard. The other two forms, P_3sm-7 and P_4sm-2, are tentatively assigned to Carya. P_3sm-7 differs from P_3sm-3 in the shape of the pores. P_4sm-2 is a rare four-pored Carya that was found only in Zone B. Today Carya is found in temperate climates in eastern Asia and eastern North America. Its habitats are varied.

The genus Nyssa may be represented by two forms, C_3sm-1 and CP_3sm-3. The latter is definitely Nyssa; the former is questionable. Rouse has one form from the

Burrard, *Tricolporopollenites* sp. (U_{27}), that resembles *Nyssa*. This was a single specimen and he only mentions that it resembles *Nyssa*. *Nyssa* is indigenous to eastern North America and Asia. Its habitats range from dry or moist woods to wet coastal swamps.

Nymphoides tripollenites Rouse (C_3sm-10) is present in both the Chuckanut and the Burrard. Rouse states that this species is almost identical with the modern *Nymphoides glabra*; the latter has a slightly more conspicuous granulation. There are twenty species of *Nymphoides* in the United States and their greatest distribution is in the temperate regions.

Two palynormorphs, C_3r-2 and C_3r-4, are referable to the genus *Salix*. Although they have been seperated on the difference in their reticulation; they should probably both be lumped together and referred to as *Salix discoloripites* Wodehouse. This species is present in the Burrard. *Salix* is almost world-wide in distribution, with present centers of distribution in the north temperate and subarctic regions.

The form, CP_3r-1, appears to be referable to the genus *Cupaniedites*. Cookson and Pike (1954) illustrate a species of *Cupaniedites*, *C. reticularis*, which appears to be very similiar to CP_3r-1. They refer this species to the pollen grains of the genus *Lepiderema* and of the genus *Sarcopteryx*. The family Sapindaceae, of which these are members, is primarly pantropical in distribution and abundant in Asia and America.

The family Proteaceae is represented by two palynomorphs, P_3p-2 and P_3f-1. The form designated as P_3p-2 appears to be the same as _Proteacidites marginus_, a new species described by Rouse from the Burrard. Although there appears to be no question that the other form, P_3f-1, is affiliated with the Proteaecae, no attempt is made to classify it beyond the generic level. This family is found only in the southern Hemisphere today. It is typically found in drier habitats suggesting that it may have been an upland plant during early Tertiary time in the Northwest.

Two species of _Alnus_ are represented in the Chuckanut, _Alnus quadrapollenites_ (P_4sm-1) and _A. quinquepollenites_ (P_5sm-1). These two species were first described by Rouse from the Burrard. He suggests that both might fall within _Alnus speciipites_ Wodehouse (1933). Wodehouse gave an all-encompassing diagnosis for his species and Rouse feels that he is justified in separating these two distinct types. _Alnus_ is found mostly in wet habitats in north-temperate regions of North America and in the Andes Mountains in South America.

Questionable assignment is given to CP_3sm-3 (_Ulmus_ ?), CP_3r-2 (_Viburnum_ ?), and P_3sm-2, P_3sm-9 (Betulaceae-Myricaceae).

The following palynomorphs are assigned to form-genera; _Tricolpopollenites granulosus_ Rouse (C_3sm-5), described from the Burrard, *Tricolpites* sp. Cookson ex Couper (C_3p-1 and C_3r-3), *Tricolpites interangulus* Newman (C_3r-6), *Tricolpites anguloluminosus* Anderson (C_3r-8), *Tricolporopollenites* Thompson and Pflug (CP_3sm-1), *Tricolporopollenites confossus* Newman (CP_3f-1), *Triorites minor* Couper (P_3sm-14), and *Triatriopollenites* Thompson and Pflug (P_3sm-20). The only botanical affiliation offered for this group is for *Triorites minor* which resembles pollen of the Betulaceae.

The presence of a rich fern flora with good development of angiosperms plus warm temperate and subtropical conifers indicates a flora which developed on a large coastal plain that was exposed to moist winds and received a large amount of precipitation. The development of such a flora as this would have been possible here only if the boundary between subtropical and temperate zones would have been much farther north than it is today. There is also evidence of more mixing of species from these two zones than is found today.

Age and Correlation

Although the microfossil flora of the Chuckanut Formation is very similar to that of the Burrard (Table 5), there are enough pertinent differences to conclude that the Chuckanut flora is somewhat older than that of the Burrard.

Pabst presents tentative age determinations for the Chuckanut megaflora based upon comparisons with described Tertiary ferns and conifers from other formations. She notes that plants collected from Oyster Creek (base of Samish Bay section) have their closest relationship with species from Upper Cretaceous and lower Paleocene formations such as the Denver, Vermejo, Mesa Verde, and Nanaimo, whereas, localities along the middle and upper part of the Samish Bay section (Chuckanut Drive and Pleasant Bay) contain floras that show their closest affinities with plants from the Fort Union, Paskapoo, Raton, and Wilcox group. These formations are middle and upper Paleocene and lower Eocene in age.

The age of the lower Chuckanut based upon the spore and pollen flora is younger than that given by Pabst. Two palynological reports by Rouse offer comparison for the Chuckanut microfossil flora. One is the Burrard paper, which has already been referred to extensively, and the other is the Comox microfossil flora (Rouse, 1957), Upper Cretaceous of Vancouver Island. Both the Burrard and the Comox lie within the framework of the Cretaceous-Cenozoic basin of which the Chuckanut is a part.

The Chuckanut microfossil flora has only two genera in common with the Comox, whereas, there are about thirty genera in the Burrard which are also found in the Chuckanut. Many of the species are also conspecific. The similarity of the Chuckanut with the Burrard microfossil heavily favors placing the lower part of the Samish Bay section at or near equivalence with the Burrard.

In comparing the Chuckanut microfossil flora with those floras reported by other authors, it is noted that both *Liliacidites* sp. (S_1r-1) and *Tricolporites anguloluminosus* (C_3r-8), described by Anderson (1960), occur in rocks of Upper Cretaceous to Paleocene age in New Mexico. Two other forms described by Newman (1965), *Tricolpites interangulus* and *Tricolporopollenites confossus*, are guide fossils to the Upper Cretaceous in Colorado.

Although the evidence indicates that the age of the lower Chuckanut is Paleocene to lower Eocene it should be noted that the section studied may represent only the lower one-half to one-third of the total thickness of the formation. If the Chuckanut is 15-20,000 feet thick as suggested by Miller and Misch (1963) then the upper part may extend into the middle Eocene and represent sediments that are equivalant to the Burrard.

CONCLUSION

The Chuckanut Formation was deposited subaerially on a wide alluvial plain close to sea level. The source of the sediments was to the north and northeast. Streams flowing into the Bellingham Basin deposited thick sands in shallow fresh water lakes and swamps. The resulting sequence is characterized by thick sandstone and thinner shale and coal units that show great lateral variation.

Both the mega- and microfossil floras indicate that the area was covered with a rich tropical to subtropical vegetation. The climate was warmer and more humid than that existing in the area today. The flora indicates that there was considerably more mixing of tropical and temperate elements in the early Tertiary. The Chuckanut species find their closest modern tropical relatives among species living in Mexico and Central America.

A comparison of the Chuckanut palynomorphs from the Samish Bay section with those described from the Burrard and Comox Formations of British Columbia indicates that the age of this section is Paleocene to lower Eocene. Pabst gives an age of Upper Cretaceous to Paleocene for this section based on the megafossil flora. The close similarity of the microfossil flora to the Burrard and its almost complete dissimilarity with the Comox is offered as evidence for assignment of a Paleocene to lower Eocene age for this section. It is possible, however, that Upper Cretaceous rocks exist between the lowest sample studied and the base of the section (377 ft.) or that they are present elsewhere in the formation but have been removed by erosion from this particular section.

SYSTEMATIC PALYNOLOGY

The taxonomic portion of this report contains the illustrations and descriptions of the coded species which were recovered and analyzed from the Chuckanut Formation. Seventy-nine palynomorphs are described and for most forms botanical affinities are included.

Reference specimen locations are given by coordinates of a Leitz Ortholux microscope equipped with standard mechanical stage.

Inaperature

Op-1

Plate 1, Figure 1

Class:	Inaperturate.
Shape:	Rounded; irregular.
Sculpture:	Scabrate to finely granulate, no dimension greater than 1 micron.
Construction:	Exine ca. 1 micron thick.
Dimensions:	25 microns.
Reference Specimen:	Pb 3799-B; 44.9 x 123.9.
Remarks:	This pollen is identical to *Inaperturopollenites juniperoides*, a species of *Juniperus* (?), which Rouse describes from the Burrard. Pabst describes two genera of the Cupressaceae from the Chuckanut; *Libocedrus interruptus* (Newberry) and *Juniperus washingtonensis*.

Osp-1

Plate 1, Figure 3

Class:	Inaperturate, (Trilete ?).
Shape:	Rounded; irregular.
Sculpture:	Echinate; spines 0.5-1.5 microns high.
Construction:	Exine equal to or less than 1 micron thick.
Dimensions:	46 microns.
Reference Specimen:	Pb 3777-A; 41.5 x 112.7.
Remarks:	This form is similar to the Osmundacidites that Rouse reports from the Burrard. This fossil genus was created by Couper (1953) for spores of osmundaceous affinities.

Monolete

Msm-1

Plate 1, Figure 2

Class:	Monolete, (inaperturate ?).
Shape:	Rounded to elliptical.
Sculpture:	Psilate.
Construction:	Exine 2-2.5 microns thick.
Aperture:	Laesurae extend more than 3/4 the length of spore; lips thickened and folded.
Dimensions:	100 microns.
Reference Specimen:	Pb 3771-B; 38.6 x 127.9.
Remarks:	This nondescript spore is identical to Magnosporites staplinii described by Rouse from the Burrard. Rouse offers no clues as to its botanical affiliation. However, he believes it to be associated with

fresh-water plants, as the spores are found only in fresh water deposits. This form is restricted to Zone B.

Msm-2

Plate 1, Figure 4

Class:	Monolete.
Shape:	Reniform.
Sculpture:	Psilate.
Construction:	Exine 0.5-1.0 micron thick.
Aperture:	Laesurae approximately 3/4 length of proximal side; lips simple to slightly thickened.
Dimensions:	25 microns.
Reference Specimen:	Pb 5237-A; 31.9 x 117.1.
Remarks:	Specimens of this form are identical with *Laevigatosporites albertensis* described by Rouse (1957) from the Oldman Formation of southern Alberta. This species, which is also found in the Burrard, is probably related to *Dryopteris*, three species of which are reported by Pabst from the Chuckanut.

Msm-3

Plate 1, Figure 5

Class:	Monolete.
Shape:	Reniform.
Sculpture:	Psilate.
Construction:	Exine 2.5-5.0 microns thick.
Aperture:	Laesurae approximately 3/4 length of proximal side; lips thickened and folded.
Dimensions:	Range: 51-68 microns, 6 specimens.

Reference Specimen: Pb 5230-A; 40.8 x 121.2.

Remarks: This form is similar to *Laevigatosporites discordatus* Thompson and Pflug. It is reported by Rouse in both the Burrard and Oldman Formations. Its closest affiliation appears to be to *Dryopteris*.

Msm-4

Plate 1, Figure 6

Class: Monolete.

Shape: Reniform.

Sculpture: Exine 2.5-5 microns thick.

Aperture: Laesurae approximately 3/4 length of proximal side; lips thickened and folded.

Dimensions: Echinate; spines 0.5-1.5 microns

Reference Specimen: Pb 5203-C; 41.0 x 115.3.

Remarks: This species is identical to *Laevigatosporites ovatus* Wilson and Webster. It is reported from the Burrard and Oldman Formations by Rouse.

Mp-1

Plate 1, Figure 7

Class: Monolete.

Shape: Reniform.

Sculpture: Verrucate; wart-like projections.

Construction: Exine ca. 2 microns thick.

Aperture: Laesurae approximately 2/3 length of proximal side; lips simple, no thickening.

Dimensions: 58 microns.

Reference Specimen: Pb 5207-D; 37.8 x 123.9.

Remarks: This spore may be the same as *Verrucatosporites* (*Polypodiisporites*) *favus* (R. Potonie) Pflug and Thompson that Rouse illustrates

Reference Specimen: Pb 5207-D; 37.8 x 123.9.

Remarks: This spore may be the same as Verrucatosporites (Polypodiisporites) favus (R. Potonie) Pflug and Thompson that Rouse illustrates from the Burrard. It occurred in every sample between # 4 and # 20.

Mp-2

Plate 1, Figure 8

Class: Monolete.

Shape: Reniform.

Sculpture: Clavate; club-shaped projections, 1-1.5 microns long.

Construction: Exine 1-1.5 microns thick.

Aperture: Laesurae approximately 3/4 length of proximal side; lips simple, no thickening.

Dimensions: 45 microns.

Reference Specimen: Pb 5212-D; 44.6 x 112.9.

Remarks: This spore closely resembles those of the fern genus Danaea. Pabst has described one species of Danaea from the Chuckanut megaflora. A single specimen of this spore was found in sample # 18.

Trilete

Tlsm-1

Plate 1, Figure 9

Class: Trilete.

Shape: Subtriangular.

Sculpture: Psilate.

Construction: Exine 1-2 microns thick.

Aperture: Laesurae narrow, approximately 3/4 radius of spore; lips thickened.

Dimensions: Range: 39-48 microns, 10 specimens.

Reference Specimen: Pb 5224-B; 39.5 x 114.1.

Remarks: This spore is very similar to those of the modern genus, Microlepia. Rouse illustrates a spore from the Burrard which he calls Microlepia (?) sp. They may very well be the same.

Tlsm-4

Plate 1, Figure 10

Class: Trilete.

Shape: Subtriangular; zonate.

Sculpture: Psilate.

Construction: Massive; thickness of exine not determined.

Aperture: Laesurae extend to equator; simple thickening of lips.

Dimensions: 84 microns.

Reference Specimen: Pb 5234-A; 34.0 x 114.3.

Remarks: A single specimen was found in sample # 10. Its botanical affiliation is unknown. This spore may be a contaminant.

Tlsm-6

Plate 1, Figure 12

Class: Trilete.

Shape: Subtriangular; strongly convex sides.

Sculpture: Psilate to slightly foveolate.

Construction: Exine 2-3 microns thick.

Aperture: Laesurae simple, from 1/2 to 2/3 radius of spore.

<u>Dimensions</u>: 30 microns.

<u>Reference Specimen</u>: Pb 3781-E; 38.2 x 121.8.

<u>Remarks</u>: The botanical affinity of this spore is not known, although it may be related to <u>Sphagnum</u>. It was found only in samples # 1 and # 2 in the lower part of the section.

Tlsm-7

Plate 1, Figure 11

<u>Class</u>: Trilete.

<u>Shape</u>: Subtriangular; sides straight to concave, kyrtome distinct.

<u>Sculpture</u>: Psilate.

<u>Construction</u>: Exine 1-1.5 microns thick.

<u>Aperture</u>: Laesurae simple, reaching the equator.

<u>Dimensions</u>: 25 microns.

<u>Reference Specimen</u>: Pb 5237-D; 42.6 x 118.6.

<u>Remarks</u>: This spore of the genus <u>Gleichenia</u> may be the same as <u>Gleichenia concavisporites</u> Rouse that was reported from the Oldman and the Burrard Formations by Rouse.

Tlsm-8

Plate 2, Figure 4

<u>Class</u>: Trilete.

<u>Shape</u>: Subtriangular; strongly convex sides.

<u>Sculpture</u>: Psilate.

<u>Construction</u>: Exine 1 micron thick.

<u>Aperture</u>: Laesurae simple 1/2 to 2/3 radius of spore.

<u>Dimensions</u>: 23 microns.

Reference Specimen: Pb 5218-C; 30.4 x 113.7.

Remarks: A single specimen of this spore was found in sample # 10. This spore is probably of the genus Sphagnum.

Tlsm-9

Plate 2, Figure 1

Class: Trilete.

Shape: Subtriangular to rounded.

Sculpture: Psilate to finely foveolate.

Construction: Exine 3 microns thick.

Aperture: Laesurae simple, from 2/3 to 3/4 radius of spore; lips simple, slightly thickened.

Dimensions: 116 microns.

Reference Specimen: Pb 5218-D; 44.5 x 123.7.

Remarks: This spore is placed in the genus Cyathidites Couper. It is possible that this form and Tlsm-10 are the same, although the wall is thicker in Tlsm-10. Pabst illustrates one species of Cyathea from the Chuckanut megaflora.

Tlsm-10

Plate 2, Figure 2

Class: Trilete.

Shape: Subtriangular to rounded.

Sculpture: Psilate.

Construction: Exine 3-4 microns thick.

Aperture: Laesurae simple, 3/4 radius of spore.

Dimensions: 104 microns.

Reference Specimen: Pb 5233-B; 32.0 x 119.8.

Remarks: This form is placed in the genus Cyathidites Couper.

Tlp-1

Plate 2, Figure 3

Class:	Trilete.
Shape:	Subtriangular to rounded.
Sculpture:	Baculate; rod shaped projections ca. 1 micron long.
Construction:	Exine 0.5-1 micron thick.
Aperture:	Laesurae simple, 2/3 radius of spore, no thickening of lips.
Dimensions:	31 microns.
Reference Specimen:	Pb 5233-C; 32.0 x 111.6.
Remarks:	This form is placed in the genus Osmundacidites Couper.

Tlp-3

Plate 2, Figure 7

Class:	Trilete.
Shape:	Subtriangular to rounded.
Sculpture:	Clavate; club shaped projections, 1.5-2 microns long.
Construction:	Exine 1-1.5 microns thick.
Aperture:	Laesurae simple, lips slightly thickened.
Dimensions:	35 microns.
Reference Specimen:	Pb 5218-D; 37.0 x 112.0.
Remarks:	This form is placed in the genus Osmundacidites Couper.

Tlr-1

Plate 2, Figure 5

Class:	Trilete.
Shape:	Subtriangular to rounded.
Sculpture:	Reticulate on distal face, muri 1.5-2 microns high, ca. 1 micron wide, lumen 8-10 microns wide.

Construction: Exine 1-2 microns thick.

Aperture: Laesurae reaching equator, lips simple.

Dimensions: 43 microns.

Reference Specimen: Pb 5237-A; 34.9 x 127.9.

Remarks: This spore appears to be identical to Lycopodium fastigioides described by Couper (1953) from the Upper Cretaceous on New Zealand.

Tlst-1

Plate 2, Figure 6

Class: Trilete.

Shape: Subtriangular.

Sculpture: Rugulate; rugae 4-5 microns wide, 2 microns high, laterally connected and spaced about 2 microns apart; rugae extend into proximal face only at tips of laesurae.

Construction: Exine ca. 2 microns thick.

Aperture: Laesurae approximately 3/4 radius of spore, lips thickened.

Dimensions: 44 microns.

Reference Specimen: Pb 5224-D; 34.8 x 114.8.

Remarks: This spore appears to be of the genus Anemia. Pabst reports one species of Anemia from the Chuckanut megaflora.

Tlst-2

Plate 2, Figure 8

Class: Trilete.

Shape: Subtriangular.

Sculpture: Rugulate; rugae 6-8 microns wide, 2 microns high, laterally connected and spaced ca. 1 micron apart; rugae only on distal surface.

Construction: Exine ca. 2 microns thick.

Aperture: Laesurae approximately 3/4 radius of spore, lips thickened.

Dimensions: 55 microns.

Reference Specimen: Pb 5218-D; 46.4 x 121.4.

Remarks: This spore appears to be of the genus Anemia.

Tlcic-1

Plate 2, Figure 9

Class: Trilete.

Shape: Subtriangular to circular.

Sculpture: Striate; ridges 1.5-2 microns wide, bifurcating, tops rounded to conical, 1 micron high at equator, more or less at right-angles to equator; grooves less than 1 micron wide.

Construction: Exine 1-1.5 microns thick.

Aperture: Laesurae extend approximately 3/4 radius of spore, lips thickened.

Dimensions: 40 microns.

Reference Specimen: Pb 5233-E; 33.1 x 114.7.

Remarks: This spore is placed in the form-genus Cicatricosisporites Potonie and Gelletich. This form-genus shows close similarity with the genus Mohria and the genus Anemia.

Tlcic-3

Plate 2, Figure 10

Class: Trilete.

Shape: Subtriangular to circular.

Sculpture: Striate; ridges crenulated, mostly continuous; 1-1.5 microns wide, in some cases bifurcating, top rounded to conical, 1 micron high at equator, crossing equator at various angles; groves less than 1 micron wide.

<u>Construction</u>: Exine 1 micron thick.

<u>Aperture</u>: Laesurae narrow, approximately 3/4 radius of spore, lips simple.

<u>Dimensions</u>: 46 microns.

<u>Reference Specimen</u>: Pb 5233-C; 46.6 x 111.4.

<u>Remarks</u>: This spore appears to be similar to <u>Cicatricosisporites intersectus</u> that Rouse describes from the Burrard.

<u>Monosulcate</u>

S_1sm-1

Plate 3, Figure 1

<u>Class</u>: Inaperaturate (code assigned as sulcate).

<u>Shape</u>: Circular.

<u>Sculpture</u>: Granulate; granules 0.5 micron or less, scattered.

<u>Construction</u>: Exine thin, less than 0.5 micron, usually folded or wrinkled.

<u>Aperture</u>: No apparent aperture.

<u>Dimensions</u>: 34 microns.

<u>Reference Specimen</u>: Pb 5203-A; 41.4 x 123.5.

<u>Remarks</u>: This form represents one or more of the three genera of Taxodiaceae that Pabst illustrates from the Chuckanut megaflora; <u>Metasequoia</u>, <u>Taxodium</u>, and <u>Glyptostrobus</u>. It is very difficult to separate the pollen of these three genera. The form illustrated is a typical split grain and exhibits no particular characteristics that would place it in any particular one of the three genera.

S_1sm-3

Plate 3, Figure 2

Class:	Monosulcate (inaperaturate ?).
Shape:	Circular.
Sculpture:	Granulate; granules 0.5 micron or less.
Construction:	Exine 1 micron thick.
Aperture:	Sulcus simple, may be just a split in the grain.
Dimensions:	17 microns.
Reference Specimen:	Pb 5230-D; 39.3 x 121.1.
Remarks:	The botanical affiliation of this grain is unknown.

S_1sm-4

Plate 3, Figure 3

Class:	Monosulcate.
Shape:	Oval to elliptical.
Sculpture:	Psilate.
Construction:	Exine 1 micron thick.
Aperture:	Sulcus simple, full length of grain.
Dimensions:	30 microns.
Reference Specimen:	Pb 5218-D; 43.0 x 124.0.
Remarks:	This grain is placed in the form-genus Monosulcites (Cookson) Couper 1953 as defined by Anderson (1960). Its botanical affiliation is unknown, however Couper suggests that it is morphologically comparable to the pollen of Ginkgo.

S_1r-1

Plate 3, Figure 4

Class:	Monosulcate.
Shape:	Oval to rounded.

Sculpture: Reticulate; lumina irregularly rounded, 1-3 microns wide; muri 0.5-1 micron wide, rounded.

Construction: Not determined.

Aperture: Sulcus simple, usually slightly open, extends nearly whole length of grain.

Dimensions: 35 microns.

Reference Specimen: Pb 5230-A; 32.2 x 127.0.

Remarks: This grain is placed in the genus Liliacidites Couper, 1953. The exact botanical affiliation of this grain is not known. The grain occurs in high abundance in those samples from layers with large numbers of palm fronds. It is probable that this pollen grain is from the same plant as that of the palm fronds.

S_1r-2

Plate 3, Figure 5

Class: Monosulcate.

Shape: Elliptical.

Sculpture: Reticulate; lumina angular, 1-2 microns wide; muri 0.5-1 micron wide.

Construction: Not determined.

Aperture: Sulcus simple, extends length of grain.

Dimensions: 28 microns.

Reference Specimen: Pb 3782-A; 45.1 x 120.0

Remarks: This grain is identical to the palm, Sabal granopollenites that Rouse describes from the Burrard.

S_1r-3

Plate 3, Figure 6

Class: Monosulcate (?).

Shape: Circular.

Sculpture: Reticulate; lumina angular, 1-3 wide; muri 0.5-1 micron wide, 1.5-2.5 microns high.

Construction: Not determined.

Aperture: Sulcus simple, extends length of grain, margins slightly thickened.

Dimensions: 20 microns.

Reference Specimen: Pb 5234-A; 39.5 x 126.4.

Remarks: The botanical affinity of this grain is unknown.

Tricolpate

C_3sm-1

Plate 3, Figure 8

Class: Tricolpate.

Shape: Oblate, circular in outline.

Sculpture: Psilate.

Construction: Exine ca. 1 micron thick.

Aperture: Colpi simple, extend over 3/4 distance to poles, margins thickened.

Dimensions: 50 microns.

Reference Specimen: Pb 3799-C; 33.3 x 115.7.

Remarks: This grain is believed to be that of *Nyssa*.

C_3sm-4

Plate 3, Figure 7

Class: Tricolpate.

Shape: Oblate, circular in outline.

Sculpture: Psilate.

Construction: Exine ca. 1 micron.

Aperture: Colpi simple, extend over 3/4 distance to poles, margins irregular.

Dimensions: 26 microns.

Reference Specimen: Pb 3782-A; 33.2 x 108.5.

Remarks: This grain is probably referable to the genus *Quercus*.

C_3sm-5

Plate 3, Figure 9

Class: Tricolpate.

Shape: Prolate; circular in polar view.

Sulpture: Psilate; microgranulate.

Construction: Not determined.

Aperture: Colpi simple, extend over 3/4 distance to poles.

Dimensions: Range 15-22 microns, 10 specimens.

Reference Specimen: Pb 3782-A; 33.5 x 121.0.

Remarks: This grain appears to be the same as *Tricolpopollenites granulosus* that Rouse describes from the Burrard. The botanical affiliation of this grain is not known.

C_3sm-7

Plate 3, Figure 10

Class: Tricolpate.

Shape: Oblate; circular in outline.

Sculpture: Foveolate; diameter of pits ca. 1 micron.

Construction: Exine 1 micron thick.

Aperture: Colpi simple, margins irregular, extend over 3/4 distance to poles.

Dimensions: 35 microns.

Reference Specimen: Pb 5230-D; 32.3 x 113.0.

Remarks: This grain is referable to the genus *Quercus*.

C_3sm-10

Plate 3, Figure 11

Class: Tricolpate (syncolpate ?).

Shape: Subtriangular.

Sculpture: Psilate to scabrate (micrugranulate).

Construction: Exine 1 micron thick.

Aperture: Colpi fuse at poles to form triangle (syncolpate), pole area depressed.

Dimensions: 30 microns.

Reference Specimen: Pb 5229-A; 45.5 x 118.3.

Remarks: This grain is identical to *Nymphoides tripollenites* that Rouse describes from the Burrard.

C_3sm-13

Plate 3, Figure 12

Class: Tricolpate.

Shape: Prolate; circular in polar view.

Sculpture: Scabrate to finely granulate.

Construction: Exine 1.5 microns thick.

Aperture: Colpi simple, extends over 3/4 distance to poles, margins simple.

Dimensions: 20 microns.

Reference Specimen: Pb 5221-B; 34.6 x 101.4.

Remarks: This grain is referable to the genus *Quercus*.

C_3p-1

Plate 4, Figure 2

Class: Tricolpate (tricolporate ?)

Shape: Rounded.

Sculpture: Clavate; club shape projections 5-6 microns high.

Construction: Not determined.

Aperture: Colpi simple, extend over 3/4 distance to poles, margins not thickened.

Dimensions: 50 microns.

Reference Specimen: Pb 5230-D; 32.2 x 121.5.

Remarks: The botanical affiliation of this grain is unknown. It is placed in the form-genus Tricolpites Cookson ex Couper.

C_3p-3

Plate 4, Figure 1

Class: Tricolpate (tricolporate ?).

Shape: Circular.

Sculpture: Verrucate; rounded projections 1 micron high, 1 micron wide.

Construction: Not determined.

Aperture: Colpi short (brevicolpate), thickening of colpi margins form interconnecting "arcs" between colpi.

Dimensions: Range 22-33 microns, 5 specimens.

Reference Specimen: Pb 5203-A; 37.6 x 123.5.

Remarks: The botanical affiliation of this grain is unknown.

C_3p-5

Plate 4, Figure 3

Class: Tricolpate.

Shape: Circular; prolate.

Sculpture: Scabrate/microreticulate; lumina uniform, less that 0.5 micron in diameter.

Construction: Exine 1 micron thick.

Aperture: Colpi simple, extend over 3/4 distance to poles, margins not thickened.

Dimensions: 18 microns.

Reference Specimen: Pb 5221-B; 45.1 x 110.2.

Remarks: The botanical affiliation of this grain is unknown.

C_3f-2

Plate 4, Figure 4

Class: Tricolpate.

Shape: Prolate; circular in polar view.

Sculpture: Scabrate to finely granulate; granules ca. 0.5 micron.

Construction: Not determined.

Aperture: Colpi simple, extend over 3/4 distance to poles.

Dimensions: 28 microns.

Reference Specimen: Pb 3786-D; 43.6 x 113.9.

Remarks: This grain may be related to the genus Quercus.

C_3r-2

Plate 4, Figure 5

Class: Tricolpate.

Shape: Circular; prolate.

Sculpture: Reticulate; reticulum coarse between colpi; lumina 1-2 microns with muri 0.5 micron wide and 0.5-1 micron high.

Construction: Exine 1-1.5 microns thick.

Aperture: Colpi simple, extend length of grain.

Dimensions: 13 microns.

Reference Specimen: Pb 3782-A; 43.4 x 125.8.

Remarks: This grain resembles C_3r-4 except for its coarser reticulum. It probably should be included with C_3r-4 under Salix discolorites Wodehouse.

C_3r-3

Plate 4, Figure 6

Class: Tricolpate.

Shape: Rounded; prolate.

Sculpture: Reticulate; evenly reticulate with wide lumina and narrow, delicate muri; lumina angular, diameter 2-3 microns, muri 0.5 micron wide, 2-3 microns high.

Construction: Not determined.

Aperture: Colpi simple, rims slightly thickened, extend 2/3 to 3/4 length of grain, colpi usually closed.

Dimensions: Range 22-42 microns, 4 specimens.

Reference Specimen: Pb 5230-A; 38.4 x 122.9.

Remarks: The botanical affiliation of this grain is unknown. It is placed in the form-genus Tricolpites Cookson ex Couper.

C_3r-4

Plate 4, Figure 7

Class: Tricolpate.

Shape: Circular; prolate.

Sculpture: Reticulate; finely reticulate, lumina 1 micron, muri 0.5 micron wide.

Construction: Not determined.

Aperture: Colpi simple, extend 3/4 length of grain, slight thickening of margin.

Dimensions: 15 microns.

Reference Specimen: Pb 5207-E; 43.2 x 120.4.

Remarks: This grain is identical to Salix discolorites Wodehouse. Rouse reports its presence in the Burrard.

C_3r-5

Plate 4, Figure 8

Class:	Tricolpate.
Shape:	Prolate; elliptical.
Sculpture:	Reticulate; lumina less than 1 micron wide, ornamention uniform.
Construction:	Exine 1 micron thick.
Aperture:	Colpi simple, more than 3/4 length of grain.
Dimension:	30 microns.
Reference Specimen:	Pb 5207-E; 42.0 x 115.4.
Remarks:	This grain is probably that of Quercus.

C_3r-6

Plate 4, Figure 9

Class:	Tricolpate.
Shape:	Circular; oblate.
Sculpture:	Reticulate; lumina 1 micron wide, muri 0.5 micron wide, 0.5 micron high.
Construction:	Not determined.
Aperture:	Colpi simple, 2/3 to 3/4 length of grain, colpi usually open.
Dimensions:	28 microns.
Reference Specimen:	Pb 5230-D; 35.0 x 122.5.
Remarks:	This grain resembles Tricolpites interangulus that Newman (1965) described from the Upper Cretaceous of Colorado. The lumina of this grain are slightly larger than that shown by Newman.

C_3r-8

Plate 4, Figure 10

Class:	Tricolpate.
Shape:	Circular; oblate.

Sculpture: Reticulate; lumina 2-3 microns wide; muri 0.5 micron wide, 0.5-1 micron high.

Construction: Not determined.

Aperture: Colpi simple 2/3 to 3/4 length of grain, colpi usually open.

Dimensions: 28 microns.

Reference Specimen: Pb 5230-D; 44.4 x 112.8

Remarks: This grain is identical to Tricolpites anguloluminosus described by Anderson (1960) from the Paleocene of New Mexico.

C_3st-1

Plate 4, Figure 11

Class: Tricolpate (tricolporate ?).

Shape: Circular.

Sculpture: Baculate; rod shaped projections, 1-2 microns long, closely spaced over entire surface of grain.

Construction: Not determined.

Aperture: Colpi simple, brevicolpate.

Dimensions: 30 microns.

Reference Specimen: Pb 3771-D; 41.9 x 113.8.

Remarks: The botanical affiliation of this grain is unknown.

Polycolpate

Ephedripites-1

Plate 4, Figure 12

Class: Polycolpate.

Shape: Elliptical.

Sculpture: Numerous alternating ridges and furrows (colpi ?) converging at polar ends of grain.

Construction: Exine ca. 1 micron thick.

Aperture: Numerous furrows lying between ridges, ca. 1.5-2 microns wide, extending length of grain. Aperture usually a split along one furrow.

Dimensions: 38 microns.

Reference Specimen: Pb 3799-C; 30.8 x 124.3.

Remarks: This *Ephedra* grain is very similar to *Ephedra notensis* described by Cookson (1957) from the Eocene of Australia.

Ephedripites-2

Plate 5, Figure 1

Class: Polycolpate (?).

Shape: Circular; oblate.

Sculpture: Numerous alternating ridges and furrows (colpi ?) converging at polar end of grain, with a slight spiral toward the poles of the major axis, ridges semi-circular in cross-section, 1-2 microns wide.

Construction: Exine 1 micron thick.

Aperture: Not determined.

Dimensions: 27 microns.

Reference Specimen: Pb 5229-B; 30.2 x 116.8.

Remarks: This grain is related to the genus *Ephedra*.

Tricolporate

CP_3sm-1

Plate 5, Figure 2

Class: Tricolporate.

Shape: Elliptical; prolate.

Sculpture: Psilate.

Construction: Not determined.

Aperture: Colpi long, 3/4 length of grain; margins thickened; ora distinct.

Dimensions: Range 17-24 microns, 5 specimens.

Reference Specimen: Pb 5218-A; 36.7 x 122.1.

Remarks: The botanical affinity of this grain is not known. It can be referred to the form-genus *Tricolporopollenites* Thompson and Pflug.

CP_3sm-3

Plate 5, Figure 3

Class: Tricolporate.

Shape: Circular.

Sculpture: Granulate.

Construction: Exine ca. 2 microns thick, thickening around ora.

Aperture: Colpi simple (brevicolporate); ora equatorial, circular.

Dimensions: 20 microns.

Reference Specimen: Pb 5221-B; 29.0 x 111.7.

Remarks: This grain appears to be related to the genus *Ulmus*.

CP_3sm-5

Plate 5, Figure 4

Class: Tricolporate.

Shape: Rounded to triaspidate.

Sculpture: Scabrate/microreticulate; lumina uniform, less than 0.5 micron in diameter.

Construction: Exine thickest (1-2 microns) at center of sides, thickening slightly in apertural area to form "lips."

Aperture: Colpi slit-like; tapering, 2/3 to 3/4 length of grain; ora circular, slightly protruding.

Dimensions: Range 31-48 microns, 5 specimens.

Reference Specimen: Pb 5230-A; 48.7 x 115.2.

Remarks: This type of grain is identical to those of the genus Nyssa.

CP_3sm-6

Plate 5, Figure 6

Class: Tricolporate.

Shape: Elliptical; prolate.

Sculpture: Psilate/scabrate.

Construction: Not determined.

Aperture: Colpi long, 3/4 length of grain; colpi margins thickened; ora indistinct.

Dimensions: 35 microns.

Reference Specimen: Pb 5229-A; 39.5 x 121.0.

Remarks: The botanical affinity of this grain is unknown.

CP_3f-1

Plate 5, Figure 5

Class: Tricolporate.

Shape: Prolate; oval in equatorial view.

Sculpture: Reticulate; lumina rounded, up to 1 micron in diameter; muri approximately as wide as lumina.

Construction: Not determined.

Aperture: Colpi broad, long, extending nearly length of grain, thickened along edges; ora distinct, large, rounded.

Dimensions: Range 42-52 microns, 4 specimens.

Reference Specimen: Pb 5229-B; 40.5 x 111.5.

Remarks: This pollen type appears to be identical to Tricolporopollenites confossus described by Newman (1965) from the Upper Cretaceous of Colorado.

CP_3f-2

Plate 5, Figure 7

Class: Tricolporate.

Shape: Circular.

Sculpture: Reticulate; lumina rounded, 1 micron wide; muri 1 micron wide, 0.5 micron high.

Construction: Not determined.

Aperture: Colpi simple, thickened along margins, extending 3/4 length of grain; ora distinct, large rounded.

Dimensions: 21 microns.

Reference Specimen: Pb 5237-B; 36.8 x 122.7

Remarks: The botanical affinity of this grain is unknown.

CP_3r-1

Plate 5, Figure 8

Class: Tricolporate (syncolporate).

Shape: Subtriangular.

Sculpture: Reticulate/scabrate; lumina less than 1 micron wide; scabrate along colpi margins.

Construction: Exine ca. 0.5-1 micron thick.

Aperture: Colpi simple, anastomosing at poles; ora equatoral, indistinct.

Dimensions: 18 microns.

Reference Specimen: Pb 5234-A; 33.7 x 122.1.

Remarks: This grain appears to be similar to *Cupanieidites reticularis* described by Cookson and Pike (1954) from the Eocene of Australia.

CP_3r-2

Plate 5, Figure 9

Class: Tricolporate.

Shape: Circular.

Sculpture: Reticulate/scabrate; reticulate in intercolpi areas, lumina angular, 1-2 microns wide, muri 1 micron high; scabrate along colpi margins.

Construction: Not determined.

Aperture: Colpi simple, extend nearly length of grain, margins slightly thickened ora distinct, large, circular.

Dimensions: 31 microns.

Reference Specimen: Pb 3782-A; 40.3 x 120.8.

Remarks: This grain may be related to the genus *Viburnum*.

CP_3r-3

Plate 5, Figure 10

Class: Tricolporate.

Shape: Prolate.

Sculpture: Reticulate; lumina angular, 1 micron wide; muri 0.5 micron wide, 0.5 micron high.

Construction: Not determined.

Aperture: Colpi simple, extend 3/4 length of grain, indistinct; ora small, indistinct.

Dimensions: 23 microns.

Reference Specimen: Pb 5207-D; 42.3 x 119.0.

Remarks: The botanical affinity of this grain is unknown.

Triporate

P_3sm-1

Plate 5, Figure 11

Class:	Triporate.
Shape:	Triangular to subtriangular.
Sculpture:	Psilate to slightly foveolate.
Construction:	Exine 1-2 microns thick; exine folded parallel to sides.
Aperture:	Pores simple, circular.
Dimensions:	35 microns.
Reference Specimen:	Pb 3799-A; 38.3 x 125.2.
Remarks:	The botanical affinity of this grain is unknown.

P_3sm-2

Plate 5, Figure 12

Class:	Triporate.
Shape:	Triaspidate to rounded.
Sculpture:	Psilate/scabrate.
Construction:	Exine relatively thin; sexine (?) thickened slightly at pores.
Aperture:	Pores equatorial, slightly protruding, round, slightly annulate, either atriate or bearing torsus pattern.
Dimensions:	34 microns.
Reference Specimen:	Pb 3799-C; 39.2 x 119.5.
Remarks:	This pollen type is similar to that found in the Betulaceae and Myricaceae.

P_3sm-3

Plate 6, Figure 1

Class: Triporate.

Shape: Triaspidate; corners broadly rounded.

Sculpture: Psilate; circular, wrinkle or thin spot in polar areas common.

Construction: Not determined.

Aperture: Pores sub-equatoral, all in one hemisphere, simple, circular, 2-4 microns in diameter.

Dimensions: 32 microns.

Reference Specimen: Pb 5207-E; 36.5 x 110.7.

Remarks: This grain is identical with Carya juxtaporites (Wodehouse) Rouse. This grain is also found in the Burrard.

P_3sm-7

Plate 6, Figure 2

Class: Triporate.

Shape: Triaspidate; corners broadly rounded.

Sculpture: Psilate.

Construction: Not determined.

Aperture: Pores subequatorial, all in one hemisphere, simple, elongate, 3-4 microns long, close to equator.

Dimensions: 34 microns.

Reference Specimen: Pb 5203-C; 47.9 x 118.5.

Remarks: This grain appears to be related to Carya.

P_3sm-9

Plate 6, Figure 3

Class:	Triporate.
Shape:	Triaspidate to trangular.
Sculpture:	Psilate.
Construction:	Sexine thickened at pores, forming annuli; nexine absent from pores, leaving atrium at each pore; arci formed in nexine (?), about 1.5-2 microns wide, usually extending straight from pore to pore.
Aperture:	Pores equatorial, rounded (?), annulate, atriate.
Dimensions:	27 microns.
Reference Specimen:	Pb 5230-C; 41.2 x 124.0.
Remarks:	This grain may be related to the Betulaceae or the Myricaceae.

P_3sm-10

Plate 6, Figure 4

Class:	Triporate.
Shape:	Triaspidate; corners broadly rounded; pores distinctly notched at corners.
Sculpture:	Psilate.
Construction:	Exine thin; slightly thickened at pores to form annulus; polar area occasionally thin or wrinkled.
Aperture:	Pores equatorial, simple, elongate, slightly annulate, distinctly cut into corners.
Dimensions:	27 microns.
Reference Specimen:	Pb 5207-E; 39.2 x 115.6.
Remarks:	This grain is identical to *Corylus tripollenites* described by Rouse from the Burrard.

P_3sm-11

Plate 6, Figure 5

Class:	Triporate (?).
Shape:	Subtriangular; sides concave, exine folded parallel to sides.
Sculpture:	Psilate/scabrate.
Construction:	Not determined.
Aperture:	Pores equatoral, simple, indistinct.
Dimensions:	26 microns.
Reference Specimen:	Pb 5207-D; 35.0 x 119.7.
Remarks:	The botanical affiliation of this grain is unknown.

P_3sm-12

Plate 6, Figure 6

Class:	Triporate.
Shape:	Subtriangular.
Sculpture:	Psilate; exine folded to form "Y" between pores and pole.
Construction:	Not determined.
Aperture:	Pores equatorial, simple, cut into sides of grain.
Dimensions:	20 microns.
Reference Specimen:	Pb 5207-D; 37.9 x 123.5.
Remarks:	The botanical affinity of this grain is unknown.

P_3sm-13

Plate 6, Figure 7

Class:	Triporate.
Shape:	Rounded.
Sculpture:	Scabrate; exine usually folded.
Construction:	Not determined.

Aperture: Pores equatorial, large, rounded, 3-4 microns wide, annulate (?).

Dimensions: 24 microns.

Reference Specimen: Pb 3782-A; 31.7 x 126.4.

Remarks: The botanical affinity of this grain is unknown.

P_3sm-14

Plate 6, Figure 8

Class: Triporate.

Shape: Subtriangular.

Sculpture: Psilate.

Construction: Sexine thickened at pores, forming annuli; arci formed in nexine (?), extending straight from pore to pore.

Aperture: Pores equatorial, rounded, 2-5 microns wide, annulate.

Dimensions: 21 microns.

Reference Specimen: Pb 5233-C; 42.7 x 111.9.

Remarks: This grain resembles Triorites minor described by Couper (1953) from the Upper Cretaceous of New Zealand. This type of pollen grain resembles those of the Betulaceae.

P_3sm-15

Plate 6, Figure 9

Class: Triporate.

Shape: Rounded.

Sculpture: Psilate to scabrate/very finely granulate; triradiate polar fold common.

Construction: Not determined.

Aperture: Pores equatorial, elongate, atriate, slightly protruding, interangular.

Dimensions: 18 microns.

Reference Specimen: Pb 5217-E; 31.8 x 122.8

Remarks: The botanical affinity of this grain is unknown.

P_3sm-16

Plate 6, Figure 10

Class: Triporate.

Shape: Triaspidate.

Sculpture: Psilate/scabrate.

Construction: Exine 1 micron thick.

Aperture: Pores equatorial, circular, 2-4 microns, proturding.

Dimensions: 21 microns.

Reference Specimen: Pb 5221-B; 44.0 x 126.1.

Remarks: The botanical affinity of this grain is unknown.

P_3sm-20

Plate 6, Figure 11

Class: Triporate.

Shape: Triangular/triaspidate; corners broadly rounded.

Sculpture: Scabrate; microgranulate, with granules 0.5 micron high.

Construction: Exine thin at each pole in triangular or circular area, nexine absent from poles, leaving broad atrium at each pore.

Aperture: Pores equatorial, simple, elongate, atriate, distinctly notched into equatorial margin.

Dimensions: 21 microns.

Reference Specimen: Pb 3786-D; 39.8 x 116.7.

Remarks: The botanical affinity of this grain is unknown. It is placed in the form-genus Triatriopollenites Thompson and Pflug.

P_3p-2

Plate 6, Figure 12

Class: Triporate.

Shape: Triangular; sides straight to slightly concave.

Sculpture: Reticulate; lumina circular to irregularly rounded, usually 1-2 microns wide; muri low and of variable width; reticulum often finer at poles than at equator.

Construction: Reticulum developed in sexine; nexine thickens at pores to form annuli.

Aperture: Pores equatorial, simple, circular, annulate, slightly protruding.

Dimensions: 30 microns.

Reference Specimen: Pb 3799-B; 43.5 x 119.9.

Remarks: This grain represents the genus Proteacidites. It closely resembles Proteacidites marginus described by Rouse from the Burrard.

P_3f-1

Plate 7, Figure 1

Class:	Triporate.
Shape:	Triangular; sides straight to slightly convex or slightly concave.
Sculpture:	Reticulate (microgranulate); granules 0.5-1 micron high.
Construction:	Reticulum developed in sexine, nexine forms narrow annulus at pores.
Aperture:	Pores equatorial, simple, annulate, 5-7 microns wide, cut into corners.
Dimensions:	32 microns.
Reference Specimen:	Pb 3782-A; 46.0 x 123.3.
Remarks:	This grain represents the genus *Proteacidites*.

Polyporate

P_4sm-1

Plate 7, Figure 2

Class:	Tetraporate.
Shape:	Tetragonal.
Sculpture:	Psilate to scabrate; arci distinct.
Construction:	Arci appear to be nexinous thickenings, concave between pores in polar view, sexine thickened at pores forming annulus, pores vestibulate.
Aperture:	Pores equatorial, circular to ovoid, 2-3 microns in diameter, protrude slightly, annulate, vestibulate.
Dimensions:	25 microns.
Reference Specimen:	Pb 5234-A; 34.6 x 113.6.
Remarks:	This grain is identical to *Alnus quadrapollenites* described by Rouse from the Burrard.

P_4sm-2

Plate 7, Figure 3

Class:	Tetraporate.
Shape:	Tetragonal.
Sculpture:	Psilate to scabrate.
Construction:	Not determined.
Aperture:	Pores equatorial to subequatorial, simple, circular, atriate (?).
Dimensions:	28 microns.
Reference Specimen:	Pb 5230-E; 32.1 x 118.7.
Remarks:	This grain appears to be a four-pored *Carya*. It is restricted to Zone B.

P_5sm-1

Plate 7, Figure 4

Class:	Pentaporate.
Shape:	Pentagonal.
Sculpture:	Psilate to scabrate; arci distinct.
Construction:	Arci appear to be nexinous thickenings concave between pores in polar view, sexine thickened at pores forming annulus, pores vestibulate.
Aperture:	Pores equatorial, circular to ovoid, 1-2 microns in diameter, protrude slightly, annulate, vestibulate.
Dimensions:	30 microns.
Reference Specimen:	Pb 5207-E; 34.9 x 114.3.
Remarks:	This grain appears to be identical to *Alnus quinquepollenites* Rouse although the Burrard species is smaller than that found in the Chuckanut.

P_6sm-1

Plate 6, Figure 5

Class:	Hexiporate.
Shape:	Hexagonal.
Sculpture:	Psilate to scabrate; arci distinct.
Construction:	Arci appear to be nexinous thickenings, concave between pores in polar view, sexine thickened at pores forming annulus, pores vestibulate.
Dimensions:	25 microns.
Reference Specimen:	Pb 5221-A; 33.2 x 119.8.
Remarks:	The botanical affinity of this grain is unknown, although it resembles Alnus.

Vesiculate

V-1

Plate 7, Figure 6

Class:	Vesiculate.
Shape:	Circular in polar view.
Sculpture:	Central body enclosed by a well developed marginal fringe of small bladders (?) or protrusions.
Construction:	Fringe of bladders made up of sexine. Bladders absent on distal surface.
Aperture:	None apparent.
Dimensions:	57 microns.
Reference Specimen:	Pb 3771-E; 39.5 x 115.0.
Remarks:	This grain represents the genus Tsuga. It is restricted to Zone B.

V-3

Plate 7, Figure 8

Class; Vesiculate.

Shape: Bilaterally symmetrical, two bladders; body circular in polar view.

Sculpture: Scabrate; bladders reticulate with thickened strip running across their base.

Construction: Not determined.

Aperture: None apparent.

Dimensions: 42 microns.

Reference Specimen: Pb 5234-A; 38.5 x 117.0.

Remarks: This grain represents the genus Podocarpus.

V-5

Plate 7, Figure 9

Class: Vesiculate.

Shape: Bilaterally symmetrical, two bladders. Body circular in polar view.

Sculpture: Sexine granulate to reticulate, reticulate bladders.

Construction: Not determined.

Aperture: None apparent.

Dimensions: Total 70-87 microns; body 40-55 microns.

Reference Specimen: Pb 5221-A; 31.8 x 126.8.

Remarks: This grain represents the genus Pinus.

V-8

Plate 7, Figure 7

Class:	Vesiculate.
Shape:	Bilaterally symmetrical, two bladders, bladders broadest at base.
Sculpture:	Granulate to reticulate.
Construction:	Not determined.
Aperture:	None apparent.
Dimensions:	Total 100 microns; body 68 microns.
Reference Specimen:	Pb 5224-B; 31.8 x 110.3.
Remarks:	This grain may be a representative of either the genus *Picea* or *Abies*.

PLATES

Plate 1

Figure 1.	Op-1:	x950; Pb 3799-B: 44.9 x 123.9.
Figure 2.	Msm-1:	x540; Pb 3771-B: 38.6 x 127.9.
Figure 3.	Osp-1:	x540; Pb 3777-A: 41.5 x 122.7.
Figure 4.	Msm-2:	x950; Pb 5237-A: 31.9 x 117.1.
Figure 5.	Msm-3:	x540; Pb 5230-A: 40.8 x 121.2.
Figure 6.	Msm-4:	x950; Pb 5203-C: 41.0 x 115.3.
Figure 7.	Mp-1:	x540; Pb 5207-D: 37.8 x 123.9.
Figure 8.	Mp-2:	x950; Pb 5212-D: 44.6 x 112.9.
Figure 9.	Tlsm-1:	x950; Pb 5224-B: 39.5 x 114.1.
Figure 10.	Tlsm-4:	x540; Pb 5234-A: 34.0 x 114.3.
Figure 11.	Tlsm-7:	x950; Pb 5237-D: 42.6 x 118.6.
Figure 12.	Tlsm-6:	x950; Pb 3781-E: 38.2 x 121.8.

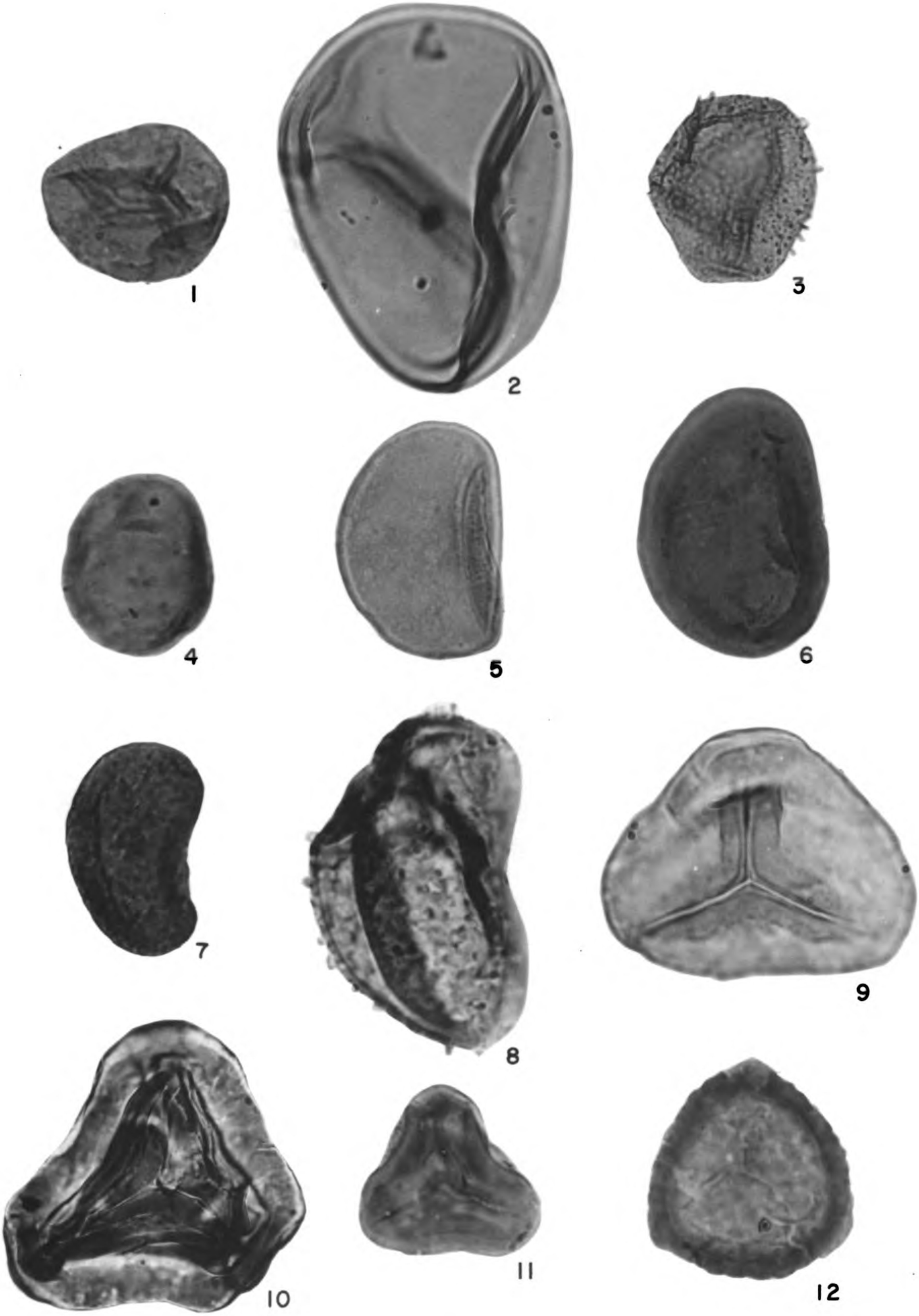


PLATE I

Plate 2

Figure 1.	Tlsm-9:	x400; Pb 5218-D: 44.5 x 123.7.
Figure 2.	Tlsm-10:	x540; Pb 5233-B: 32.0 x 119.8.
Figure 3.	Tlp-1:	x950; Pb 5233-C: 32.0 x 111.6.
Figure 4.	Tlsm-8:	x950; Pb 5218-C: 30.4 x 113.7.
Figure 5.	Tlr-1:	x950; Pb 5237-A: 34.9 x 127.9.
Figure 6.	Tlst-1:	x400; Pb 5224-D: 34.8 x 114.8.
Figure 7.	Tlp-3:	x950; Pb 5218-D: 37.0 x 112.0.
Figure 8.	Tlst-2:	x540; Pb 5218-D: 46.4 x 121.4.
Figure 9.	Tlcic-1:	x950; Pb 5233-E: 33.1 x 114.7.
Figure 10.	Tlcic-3:	x950; Pb 5233-C: 46.6 x 111.4.

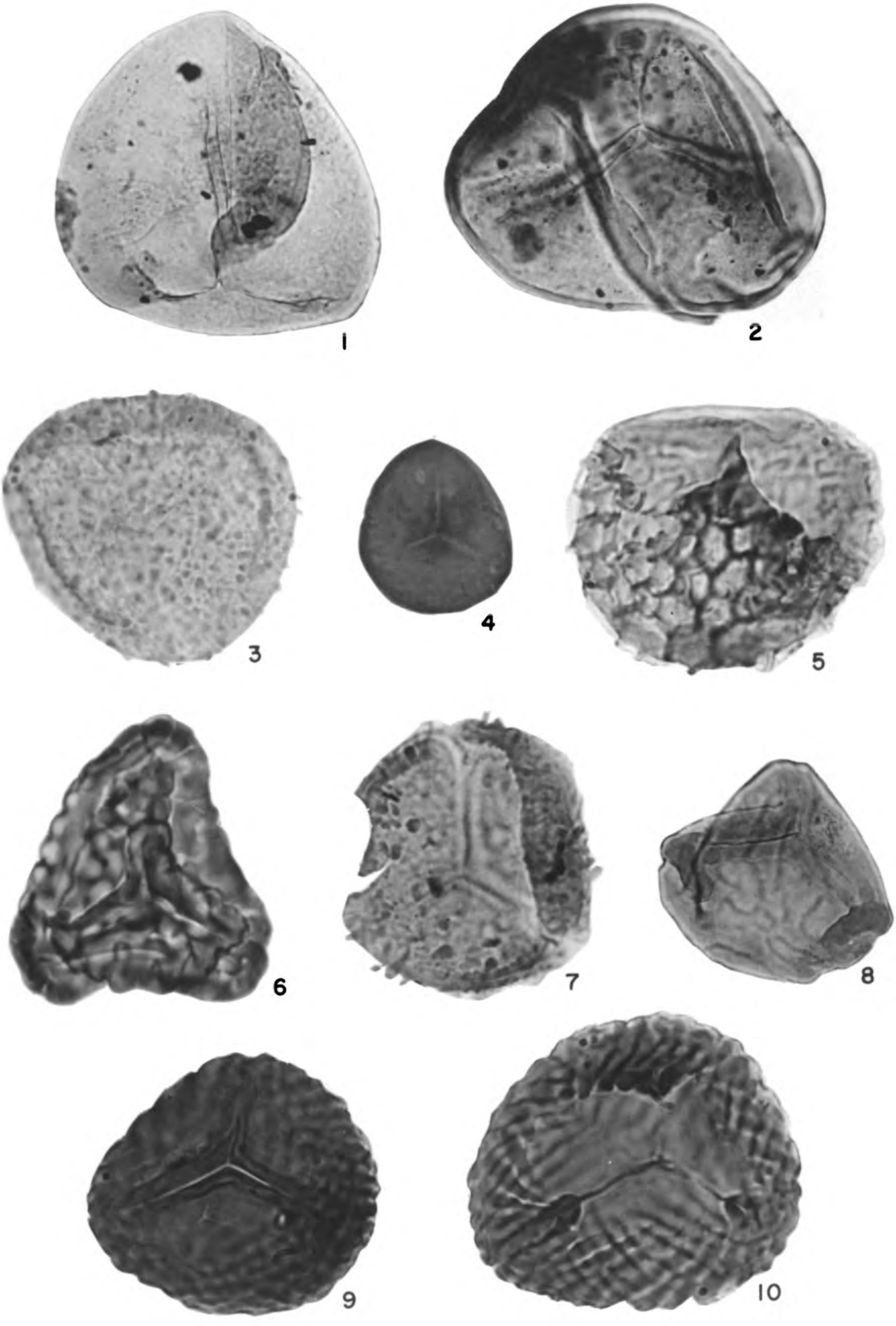


PLATE 2

Plate 3

Figure 1.	S_1sm-1:	x950; Pb 5203-A: 41.4 x 123.5.
Figure 2.	S_1sm-3:	x950; Pb 5230-D: 39.3 x 121.1.
Figure 3.	S_1sm-4:	x950; Pb 5218-D: 43.0 x 124.0.
Figure 4.	S_1r-1	x950; Pb 5230-A: 32.2 x 127.0.
Figure 5.	S_1r-2:	x950; Pb 3782-A: 45.1 x 120.0.
Figure 6.	S_1r-3:	x950; Pb 5234-A: 39.5 x 126.4.
Figure 7.	C_3sm-4:	x950; Pb 3782-A: 33.2 x 108.5.
Figure 8.	C_3sm-1:	x950; Pb 3799-C: 33.3 x 115.7.
Figure 9.	C_3sm-5:	x950; Pb 3782-A: 33.5 x 121.0.
Figure 10.	C_3sm-7:	x950; Pb 5230-D: 32.3 x 113.0.
Figure 11.	C_3sm-10:	x950; Pb 5229-A: 45.5 x 118.3.
Figure 12.	C_3sm-13:	x950; Pb 5221-B: 34.6 x 101.4.

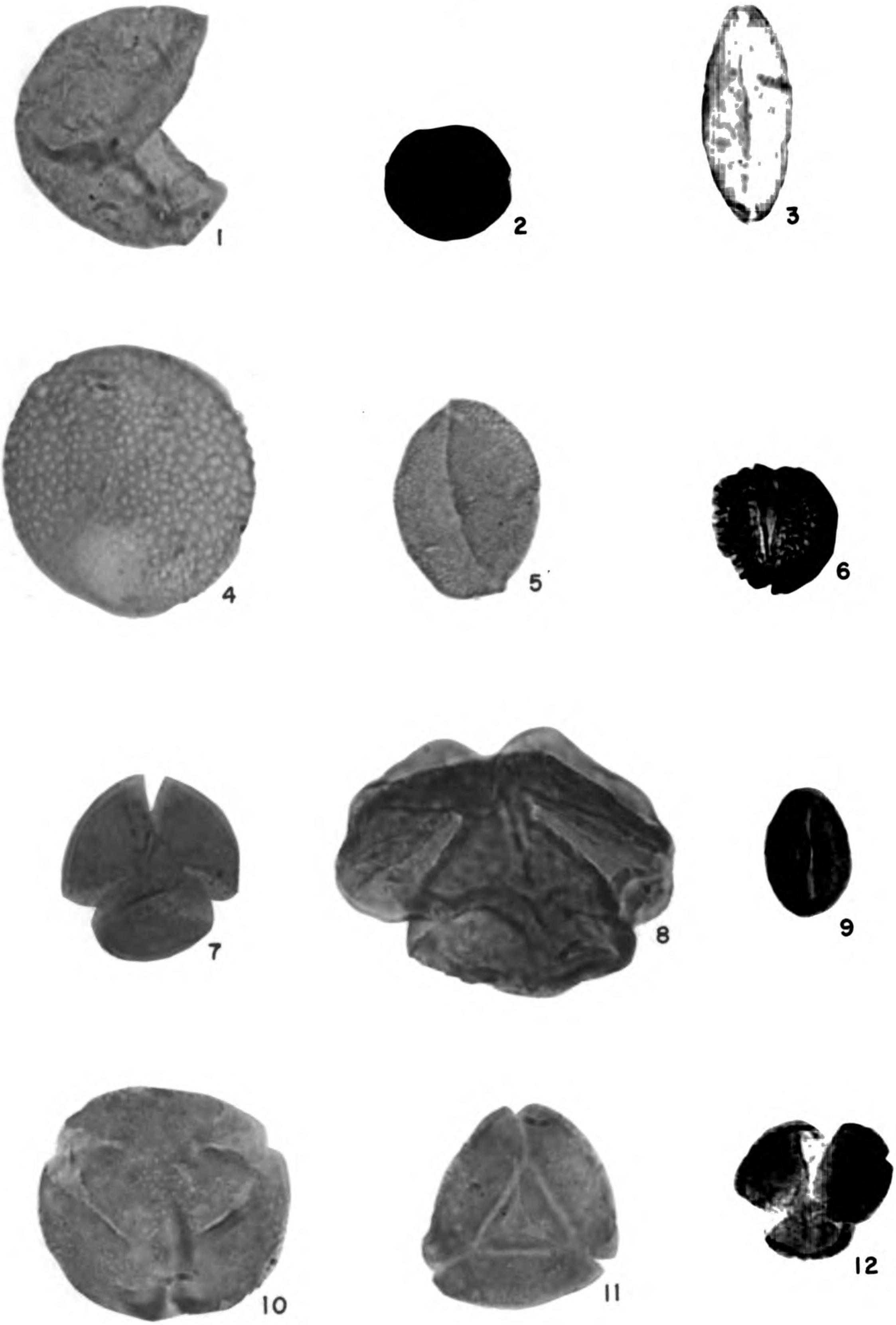


PLATE 3

Plate 4

Figure 1.	C_3p-3:	x950; Pb 5204-A: 37.6 x 123.5.
Figure 2.	C_3p-1:	x950; Pb 5230-D: 32.2 x 121.5.
Figure 3.	C_3p-5:	x950; Pb 5221-B: 45.1 x 110.2.
Figure 4.	C_3f-2:	x950; Pb 3786-D: 43.6 x 113.9.
Figure 5.	C_3r-2:	x950; Pb 3782-A: 43.4 x 125.8.
Figure 6.	C_3r-3:	x950; Pb 5230=A: 38.4 x 122.9.
Figure 7.	C_3r-4:	x950; Pb 5207-E: 43.2 x 120.4.
Figure 8.	C_3r-5:	x950; Pb 5207-E: 42.0 x 115.4.
Figure 9.	C_3r-6:	x950; Pb 5230-D: 35.0 x 122.5.
Figure 10.	C_3r-8:	x950; Pb 5230-D: 44.4 x 112.8.
Figure 11.	C_3st-1:	x950; Pb 3771-D: 41.9 x 113.8.
Figure 12.	_Ephedripites_-1:	x950; Pb 3799-C: 30.8 x 124.3.

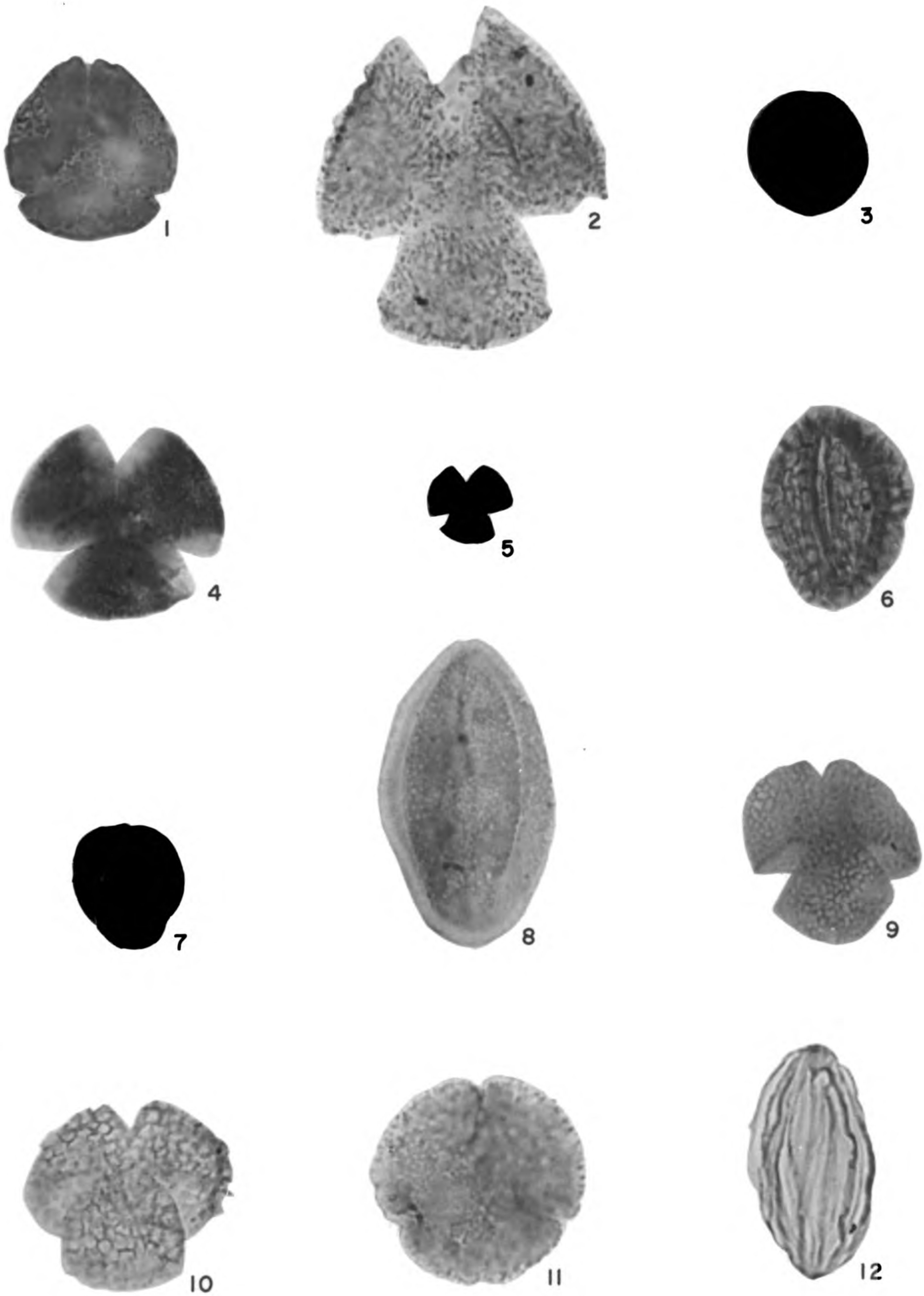


PLATE 4

Plate 5

Figure 1.	<u>Ephedripites</u>-2:	x950; Pb 5229-B: 30.2 x 116.8.
Figure 2.	CP_3sm-1:	x950; Pb 5218-A: 36.7 x 122.1.
Figure 3.	CP_3sm-3:	x950; Pb 5221-B: 29.0 x 111.7.
Figure 4.	CP_3sm-5:	x950; Pb 5230-A: 48.7 x 115.2.
Figure 5.	CP_3f-1:	x950; Pb 5229-B: 40.5 x 111.5.
Figure 6.	CP_3sm-6:	x950; Pb 5229-A: 39.5 x 121.0.
Figure 7.	CP_3f-2:	x950; Pb 5237-B: 36.8 x 122.7.
Figure 8.	CP_3r-1:	x950; Pb 5234-A: 33.7 x 122.1.
Figure 9.	CP_3r-2:	x950; Pb 3782-A: 40.3 x 120.8.
Figure 10.	CP_3r-3:	x950; Pb 5207-D: 42.3 x 119.0.
Figure 11.	P_3sm 1:	x950; Pb 3799-A: 38.3 x 125.2.
Figure 12.	P_3sm-2:	x950; Pb 3799-C: 39.2 x 119.5.

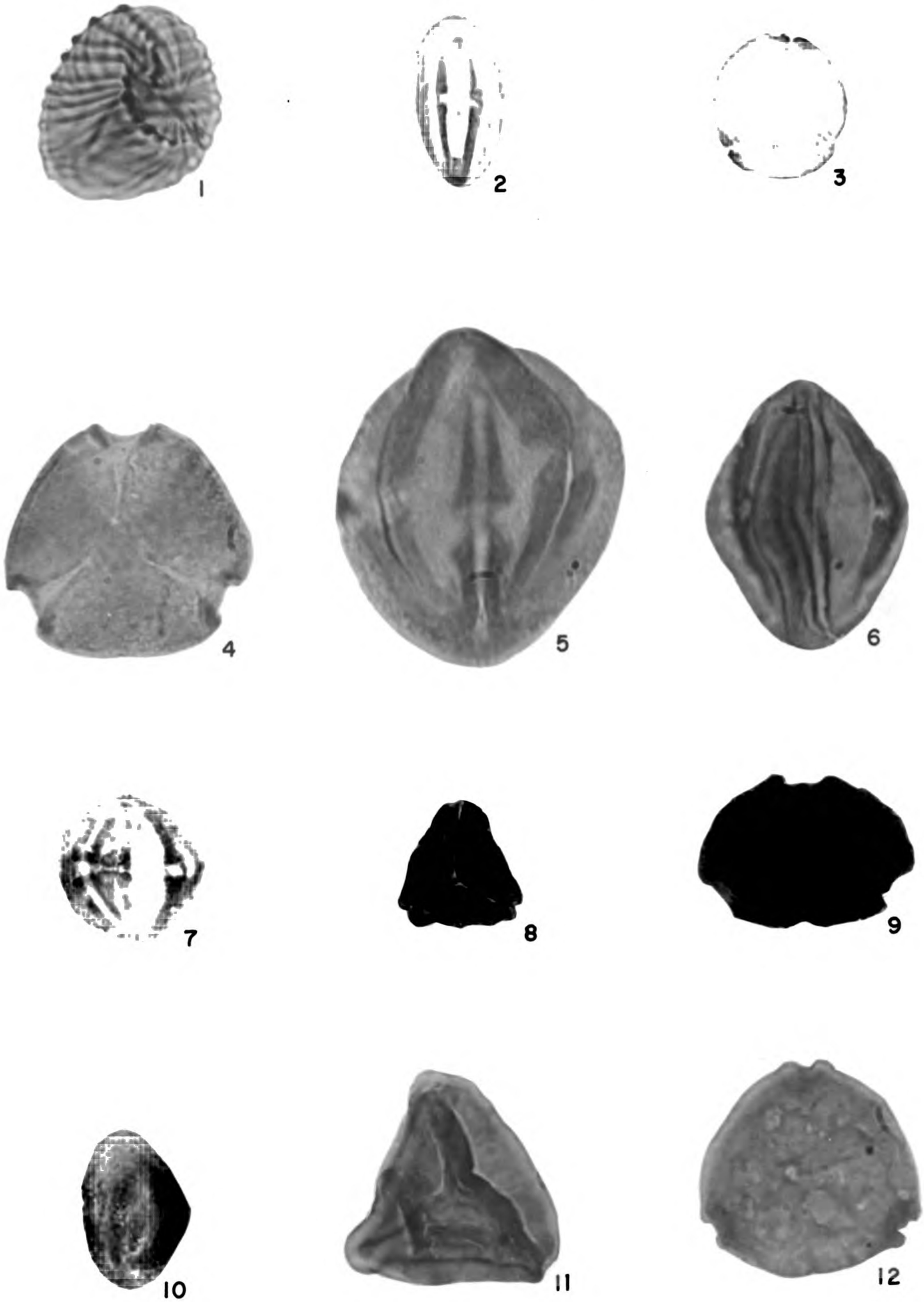


PLATE 5

Plate 6

Figure 1.	P_3sm-3:	x950; Pb 5207-E: 36.5 x 110.7.
Figure 2.	P_3sm-7:	x950; Pb 5203-C: 47.9 x 118.5.
Figure 3.	P_3sm-9:	x950; Pb 5230-C: 41.2 x 124.0.
Figure 4.	P_3sm-10:	x950; Pb 5207-E: 39.2 x 115.6.
Figure 5.	P_3sm-11:	x950; Pb 5207-D: 35.0 x 119.7.
Figure 6.	P_3sm-12:	x950; Pb 5207-D: 37.9 x 123.5.
Figure 7.	P_3sm-13:	x950; Pb 3782-A: 31.7 x 126.4.
Figure 8.	P_3sm-14:	x950; Pb 5233-C: 42.7 x 111.9.
Figure 9.	P_3sm-15:	x950; Pb 5217-E: 31.8 x 122.8.
Figure 10.	P_3sm-16:	x950; Pb 5221-B: 44.0 x 126.1.
Figure 11.	P_3sm-20:	x950; Pb 3786-D: 39.8 x 116.7.
Figure 12.	P_3p-2:	x950; Pb 3799-B: 43.5 x 119.9.

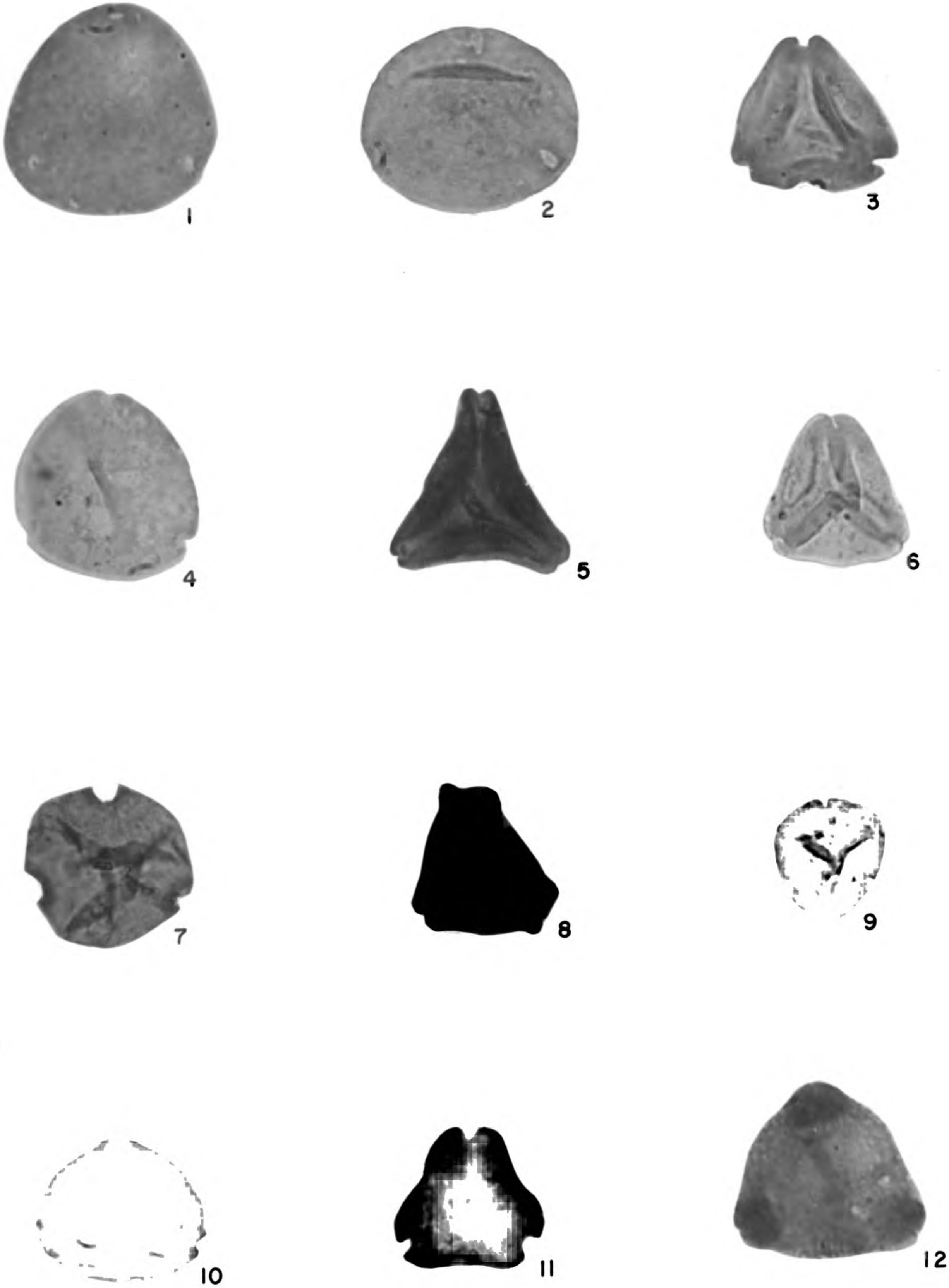


PLATE 6

Plate 7

Figure 1.	P_3f-1:	x950; Pb 3782-A: 46.2 x 123.3.
Figure 2.	P_4sm-1:	x950; Pb 5234-A: 34.6 x 113.6.
Figure 3.	P_4sm-2:	x950; Pb 5230-E: 32.1 x 118.7.
Figure 4.	P_5sm-1:	x950; Pb 5207-E: 34.9 x 114.3.
Figure 5.	P_6sm-1:	x950; Pb 5221-A: 33.2 x 119.8.
Figure 6.	V-1:	x540; Pb 3771-E: 39.5 x 115.0.
Figure 7.	V-8:	x540; Pb 5224-B: 31.8 x 110.3.
Figure 8.	V-3:	x540; Pb 5234-A: 38.5 x 117.0.
Figure 9.	V-5:	x540; Pb 5221-A: 31.8 x 126.8.

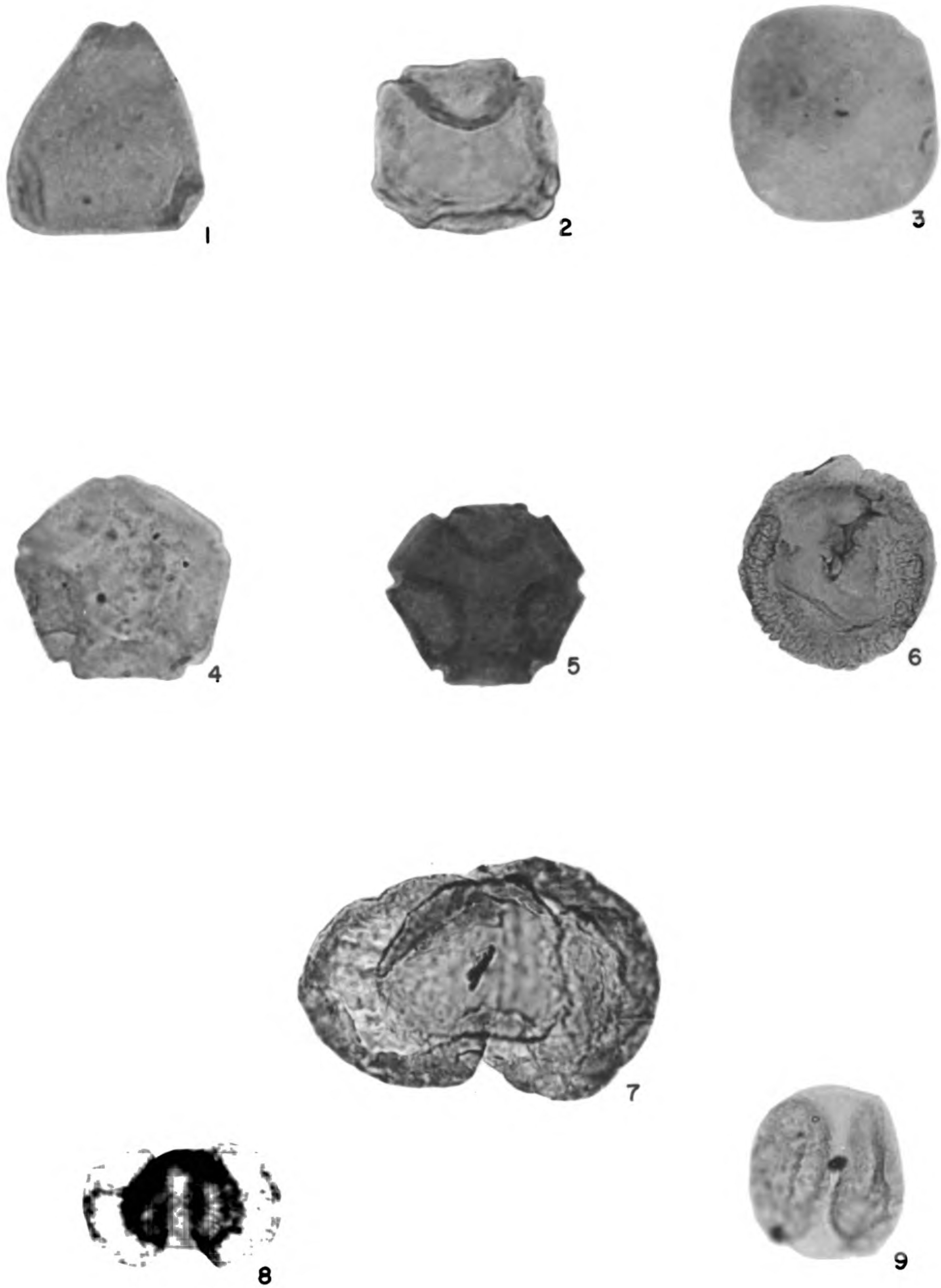


PLATE 7

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APPENDIX

APPENDIX A

STANDARD SECTION OF THE CHUCKANUT FORMATION

ALONG THE EAST SHORE OF SAMISH BAY

After Glover (1935)

Lithologic description	Thickness	Sample No.	Mac. No.
Sandstones, interbedded shaly sandstones, and sandy shales, mostly concealed.	1750'	PG-9/9/64-16 (top of unit)	Pb 3793
Conglomerate, coarse, rounded pebbles and cobbles, with grit and sandstone interbeds. Base and top concealed.	25'		
Sandstones with interbedded shaly sandstones and sandy shales, mostly concealed.	2550'	PG-9/9/64-15 PG-9/9/64-14 (bottom 100')	Pb 3792 Pb 3791
Concealed	180'		
Sandstone, coarse, cross-bedded.	25'	PG-9/9/64-13	Pb 3790
Concealed	240'		
Sandstone, massive	60'		
Concealed	130'		
Sandstone and shale	15'	PG-9/9/64-12	Pb 3789
Sandstone, crossbedded.	12'		
Shale, sandy	80'	PG-9/9/64-11 (middle)	Pb 3788

Sandstone, massive, jointed	125'		
Sandstone, interbedded shale	4'	PG-9/9/64-10	Pb 3787
Sandstone, coarse, leaf horizon at top.	40'		
Shale, sandy	4'	PG-9/9/64-9	Pb 5202
Sandstone, crossbedded	8'		
Concealed	135'		
Sandstone, coarse	60'		
Sandstone, shaly	85'	PG-9/9/64-8 (top)	Pb 5201
Shale, sandy	20'		
Sandstone, well bedded	20'		
Shale, carbonaceous	1'		
Sandstone	8'		
Shale, carbonaceous	1'	PG-9/9/64-6	Pb 3800
Sandstone, massive, thin layer carbonaceous shale	20'		
Shale	5'	PG-9/9/64-6	Pb 3799
Sandstone	6'		
Sandstone, shaly	3'		
Sandstone	5'		
Concealed	85'		
Sandstone, massive. Some shale interbeds.	105'		
Sandstone, massive, and shale containing leaves.	105'		
Shale, fossil leaves	6'	PG-9/9/64-5	Pb 3798
Sandstone, massive	25'		

Sandstone and interbedded shale	50'	PG-9/9/64-5 (top)	Pb 3797
Concealed	60'		
Sandstone, crossbedded	30'		
Sandstone. Small amount of shale, partly concealed.	75'	PG-9/9/64-3	Pb 3796
Sandstone, interbedded carbonaceous shale	60'	PG-1/3/64-8 (top)	Pb 3774
		PG-9/9/64-2 (35')	Pb 3795
		PG-9/9/64-1 (bottom)	Pb 3794
Sandstone, massive. Tree trunk imprints.	86'		
Shale, carbonaceous	6'	PG-9/8/64-11	Pb 5204
Sandstone, massive, cross-bedded.	25'		
Shale, carbonaceous	2'	PG-9/8/64-10	Pb 5203
Sandstone	2'		
Shale, carbonaceous	5'	PG-9/8/64-9	Pb 5213
Sandstone with some shale.	105'	PG-9/8/64-8 (75')	Pb 5212
		PG-9/8/64-7 (30')	Pb 5211
Shale, carbonaceous. Some interbedded massive sandstones.	65'	PG-9/8/64-6 (50')	Pb 5210
		PG-9/8/64-5 (35')	Pb 5209
		PG-9/8/64-4 (10')	Pb 5208
		PG-9/8/64-3 (bottom)	Pb 5207
Sandstone, crossbedded	15'		
Shale, carbonaceous, with sandstone lenses.	34'	PG-9/8/64-2 (top)	Pb 5206
		PG-9/8/64-1 (15')	Pb 5205

Sandstone, crossbedded, with interbedded shale. Palm horizon at top.	43'	PG-9/4/64-12 (top)	Pb 5216
		PG-9/4/64-11 (20')	Pb 5215
Sandstone, shaly partings. Contains tree imprints	50'	PG-9/4/64-10 (top)	Pb 5214
		PG-9/4/64-9 (45)	Pb 5225
Shale, coaly	1'	PG-9/4/64-8	Pb 5224
Sandstone	1'		
Shale, coaly	0.5'		
Sandstone	4'		
Shale, carbonaceous, with sandstone lenses containing carbonized stump. Palm horizon at top.	26'	PG-1/3/64-7 (top)	Pb 3774
		PG-1/3/64-6 (16')	Pb 3773
		PG-1/3/64-5 (11')	Pb 3772
		PG-1/3/64-4 (6')	Pb 3771
		PG-1/3/64-3 (4')	Pb 3770
		PG-1/3/64-2 (2')	Pb 3769
		PG-1/3/64-1 (bottom)	Pb 3768
Sandstone, massive, pebbly at base.	43'		
Sandstone, massive, thin shale layer at top.	10'	PG-9/4/64-7	Pb 5223
Sandstone, massive, with shale showing mud cracks	6'		
Sandstone, crossbedded, some sandy shale.	8'	PG-9/4/64-6	Pb 5222
Sandstone, massive	20'		
Concealed	175'		
Sandstone, poorly exposed	50'		
Concealed	50'		

Sandstone, massive	30'		
Sandstone, shaly, and carbonaceous shale	12'	PG-9/4/64-5	Pb 5221
Sandstone, massive	20'		
Sandstone, poorly bedded. Contains leaf imprints and probable ripple marks.	20'		
Sandstone, irregularly bedded. Shale partings.	50'	PG-9/4/64-4 (top) PG-9/4/64-3	Pb 5220 Pb 5219
Shale, palm horizon.	2'		
Sandstone, crossbedded.	8'		
Shale	2'		
Sandstone, massive.	6'		
Shale, partly carbonaceous.	6'	PG-9/4/64-1	Pb 5217
Sandstone, crossbedded, shale parting.	14'		
Shale and bony coal.	5'	PG-9/3/64-17	Pb 5234
Sandstone, crossbedded.	15'		
Shale and bony coal.	2'	PG-9/3/64-16	Pb 5233
Sandstone with pebbly layer, numerous tree trunk impressions.	55'		
Shale, massive	4'	PG-9/3/64-15	Pb 5232
Sandstone, shaly partings	6'		
Shale, leaf imprints	1'		
Sandstone, crossbedded	3'		
Sandstone, thin bedded, shaly. Palm horizon at base and leaf imprints at top.	10'	PG-9/3/64-14	Pb 5231

Sandstone, massive	2'		
Shale, carbonaceous, and thin bedded sandstone.	5'	PG-9/3/64-13	Pb 5230
Sandstone	5'		
Shale	1'		
Sandstone	5'		
Sandstone, shaly, thin bedded.	10'		
Sandstone, crossbedded, leaf imprints at top, coal at bottom.	10'	PG-9/3/64-12	Pb 5229
Sandstone, very irregular bedding	6'		
Shale, carbonaceous, with bony coal	7'	PG-9/3/64-11 (top)	Pb 5228
Sandstone, with shaly partings, coaly layer at top.	8'		
Shale, sandstone, and coaly shale, palm horizon at top.	12'	PG-9/3/64-10	Pb 5227
Sandstone, crossbedded	6'		
Shale, carbonaceous with bony coal.	7'	PG-9/3/64-9	Pb 5226
Sandstone, crossbedded, shaly parting	12'		
Shale, carbonaceous, palm horizon.	4'		
Sandstone, massive	6'		
Sandstone and interbedded massive shale.	15'		
Bony coal, palm horizon	2'	PG-9/3/64-8	Pb 5242
Sandstone, crossbedded, very lenticular.	6'		

Shale with carbonaceous layers.	4'		
Sandstone, crossbedded, shaly parting.	11'		
Shale, coaly, palm horizon.	0.3'	PG-9/3/64-7	Pb 5241
Sandstone	2'		
Coaly seam	0.2'		
Shale, massive	3'		
Coaly, seam	0.5'		
Sandstone, crossbedded, tree imprints.	47'		
Shale and bony coal	2'	PG-9/3/64-6	Pb 5240
Sandstone, crossbedded	5'		
Shale	1'		
Sandstone, crossbedded	5'		
Sandstone and shale, leaf horizon at top.	6'	PG-9/3/64-5	Pb 5239
Sandstone	8'		
Shale with coaly seam and sandstone lenses.	8'		
Shale and interbedded sandstone.	10'		
Concealed	115'		
Shale	5'	PG-9/3/64-4	Pb 5238
Sandstone, well defined crossbedding.	12'		
Concealed	10'		
Shale and shaly sandstone	7'	PG-9/3/64-3a	Pb 5273
Shale, sandy	10'		

Sandstone, shaly, concretionary.	8'		
Sandstone, shaly, compact. Conchoidal fracture.	12'		
Sandstone, massive, cross-bedded.	12'		
Coal, bony	2'		
Shale and interbedded sandstone.	10'		
Shale and coaly layer.	12'	PG-9/3/64-3	Pb 5237
Sandstone, fine grained, crossbedded.	8'		
Sandstone, shaly	6'		
Concealed	10'		
Sandstone, massive	5'		
Shale, palm horizon at top.	7'		
Sandstone, shaly partings	8'		
Shale, sandy	5'		
Sandstone, massive, slightly faulted.	60'		
Sandstone and interbedded coaly seam.	110'	PG-9/3/64-2	Pb 5236
Shale, very carbonaceous, interbedded with sandstone.	25'		
Shale and fine grained sandstone.	25'	PG-9/3/64-1	Pb 5235
Sandstone, massive, cross-bedded.	30'		
Conglomerate, pebbles up to 2 inches in diameter, composed of subangular quartz and schist.	15'		

Concealed	290'		
Sandstone, massive	110'		
Concealed	75'		
Sandstone, massive, poorly exposed.	20'		
Concealed	90'		
Sandstone	10'		
Concealed	140'		
Sandstone, massive	10'		
Shale, sandy, carbonaceous at top.	40'	PG-9/11/64-3 (top)	Pb3786
Sandstone, massive, medium grained, contains some intraformational conglomerate of clay pebbles. Numerous imprints of wood at several horizons.	115'		
Shale, carbonaceous, and shaly sandstone.	2'	PG-1/2/64-1	Pb 3776
Sandstone	4'		
Sandstone, shaly	6'		
Sandstone, massive, cross-bedded	12'		
Shale, carbonaceous. Good leaf imprints.	2'	PG-1/2/64-2	Pb 3777
Sandstone, contains imprints of wood.	3'		
Shale	0.5'	PG-1/2/64-3	Pb 3778
Sandstone, massive, medium grained.	30'		
Shale, carbonaceous. Contains well defined leaves and thin coaly layers.	3'	PG-1/2/64-4 (bottom)	Pb 3779

Shale, sandy with interbedded fine grained sandstone.	11'		
Shale, partings.	2.5'		
Sandstone, crossbedded	1.5'		
Shale	1'		
Sandstone, shaly, crossbedded	1.25'		
Shale	2'	PG-1/2/64-5	Pb 3780
Shale, carbonaceous	6'		
Sandstone, shaly	7'		
Shaly, peaty	1.5'	PG-1/2/64-6	Pb 3781
Sandstone, coarse, with pebble layers and lens of sandy shale.	10'		
Shale, bluish-gray, interbedded sandy shale.	4'		
Concealed. Probably mostly shale.	100'		
Sandstone, massive, buff colored.	8'		
Shale, sandy, with ferns and stem imprints.	6'		
Shale, carbonaceous	0.3'		
Sandstone, shaly, gray	4'		
Sandstone, massive, buff colored.	6'		
Shale, well bedded, fragments of carbonized wood.	2'	PG-9/11/64-2	Pb 3785
Shale, compact, sandy, conchoidal.	12'	PG-9/11/64-1	Pb 3784
Sandstone, shaly. Contains fossil leaves.	7'		

Shale, sandy	4'
Sandstone, massive	12'
Concealed	200'
	9,484'

Unconformity

Pre-Tertiary rocks