PALYNOLOGY AND PALEOECOLOGY OF THE MIOCENE SUCKER CREEK FLORA FROM THE OREGON - IDAHO BOUNDARY

> Thesis for the Degree of Ph.D. Michigan State University RALPH E. TAGGART 1971

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# ABSTRACT

# PALYNOLOGY AND PALEOECOLOGY OF THE MIOCENE SUCKER CREEK FLORA FROM THE OREGON - IDAHO BOUNDARY

Ву

Ralph E. Taggart

Three geological sections in the Sucker Creek area of Malheur County, Oregon and Owyhee County, Idaho were measured and sampled for palynological analysis. The study sections comprise approximately 400 feet of composite section representing a sedimentary interval during which most or all of the macrofossil-bearing beds of the Sucker Creek flora were deposited. Although the sites of the study sections are included in the mapped extent of the Sucker Creek Formation, the sediments are not correlatable with those of the type section for the formation. The plant-bearing sediments appear to be somewhat older than the Sucker Creek type section and it is suggested that the Sucker Creek Formation, as mapped, is in need of revision. The floristic and faunal evidence suggests a late Miocene age for the Formation as a whole and, at present, late Barstovian is the most precise age determination which can be made.

The pollen profiles from the study sections suggest two distinct episodes of vegetation development. The beginning of the composite sequence is characterized by an equilibrium between two major forest types, a mesic deciduous forest, probably cool temperate in aspect, occupying the lowlands of an inter-montane valley system and a montane conifer forest on the adjacent uplands. The lowlands were apparently well drained at the beginning of the depositional interval but this situation was followed by extensive impoundment of water, probably in the form of ox-bow lakes. Infilling of the lake systems with both organic and detrital sediments resulted in a successional series involving marsh and swamp communities. Distinct flood-plain communities were also in evidence at this time.

Following this phase, a major shift in the pollen record indicates a significant change in the nature of the source vegetation. Many of the mesic deciduous genera and all of the montane conifer genera disappear from the record. The remaining pollen types suggest a comparatively depauperate riparian forest in a region of predominantly xeric aspect. It is postulated that this shift in vegetation types was due to an interaction of local and regional factors, including destruction of the existing forest Vegetation due to local volcanic activity, a regional warming trend, possibly coupled with a decrease in thermal equibility, and the decreasing rainfall brought about by the gradual uplift of the Cascades to the west. It is not possible to determine, on the basis of data presently available, whether this shift in vegetation dominance was a pivotal one for the region or if it represents a shorter term successional sequence or small-scale oscillation.

Several new microfossil records for the flora are described including the alga <u>Botryococcus</u>, several new spores, and pollen including a new <u>Abies</u> type, several new <u>Pinus</u>, <u>Podocarpus</u>, <u>Castanea</u>, <u>Mahonia</u>, several Compositae, <u>Elaeagnus</u>, <u>Ilex</u>, two Onagraceae, <u>Nymphaea</u>, <u>Nyssa</u>, Caprifoliaceae, <u>Pachysandra</u>, and several unusual although unidentified pollen and spore types.



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Ву

Ralph E. Taggart

# A THESIS

Submitted to Michigan State University in partial fulfillment of the requirements for the degree of

# DOCTOR OF PHILOSOPHY

Department of Botany and Plant Pathology



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ii

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During the Spring of 1971 I received two awards whose proceeds were applied to defray the cost of preparing this manuscript. The first was a Distinguished Graduate Student Award provided by the Society of the Sigma Xi and the second was the Ernst A. Bessey Graduate Student Award tendered annually by the Department of Botany and Plant Pathology. I feel honored to have received both of these prizes.

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iii

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provided the essential background that can make graduate study a continuing adventure.

TABLE OF CONTENTS

																	Page
ACKNO	OWLI	EDGEM	ENTS	•	•	•	•	•	•	•	•	•	•	•	•	•	ii
LIST	OF	FIGU	RES	•	•	•	•	•	•	•	•	•	•	•	•	•	vii
LIST	OF	PLAT	ES	•	•	•	•	•	•	•	•	•	•	•	•	•	viii
Chapt	ter																
I.		INTR	ODUCT	ION		•	•	•	•	•	•	•	•	•	•	•	1
II.		METH	ODS	•	•	•	•	•	•	•	•	•	•	•	•	•	6
			Field Labor	Pr ato	oce ry	dur Pro	tes oced	lure	•	•	•	•	•	•	•	•	6 8
III.		GEOL	OGY	•	•	•	•	•	•	•	•	•	•	•	•	•	17
		]	Physi Struc Strat	ogr tur igr	aph e aph	чу • • У	• •		• •	• •	• •	• •	• •	• •	•	• •	17 18 19
IV.		STRA	TIGRA	PHI	СР	ALY	NOL	OGY		•	•	•	•	•	•	•	35
			Valle Short Rockv Compa	y S cut ill ris	ect Se e S on	ion cti ect of	i .on :ion Stu		Sec	tio	ns	• • •	• • •	• • •	•	•	35 42 46 49
v.		PALE	OECOL	OGY		•	•	•	•	•	•	•	•	•	•	•	53
		]	Patte Dur	rns ing	of Su	Ve Icke	eget er C	ati ree	on k T	Cha ime	nge	•	•	•	•	•	65
VI.		SYST	EMATI	CS	•	•	•	•	•	•	•	•	•	•	•	•	84
		1	Nomen Syste	cla mat	tur ic	e Des	cri	pti	ons	•	•	•	•	•	•	•	84 92

																	Page
LITERATU	RE	CIT	ED	•	•	•	•	•	•	•	•	•	•	•	•	•	159
APPENDIX	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	165
PLATES	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	174

# 

.

Fig 

# LIST OF FIGURES

Figure		Ρ	age
1.	Outline map of the study area showing the location of sites discussed in the text .	•	3
2.	Correlation chart of the Cenozoic formations of eastern Oregon	•	21
3.	Stratigigraphic terminology	•	22
4.	Generalized diagram of the rock units of each of the study sections and the proposed correlations	•	24
5.	Relative frequency pollen and spore profiles from the Valley section	•	36
6.	Relative frequency pollen and spore profiles from the Upper Swamp Series in the Valley section	•	40
7.	Relative frequency pollen and spore profiles from the Shortcut section	•	43
8.	Relative frequency pollen and spore profiles from the Rockville section	•	47
9.	A generalized ecological classification of selected pollen types found in the Sucker Creek sediments	•	59
10.	A list of selected Sucker Creek macrofossil genera and their occurrence in the upper and lower portions of the composite regional section	•	69
11.	Oligocene-Miocene temperature trends postu- lated on the basis of (A) ecological analysis (Axelrod and Bailey, 1969) and (B) leaf morphology (Wolfe and Hopkins		
		•	78

# LIST OF PLATES

.

Plate		Page
1.	A view of the valley system formed by the rocks of the Rockville section	175
2.	A view of the Shortcut section	177
3.	Figures 1 through 19	179
4.	Figures 1 through 10	181
5.	Figures 1 and 2	183
6.	Figures 1 and 2	185
7.	Figures 1 through 8	187
8.	Figures 1 through 21	189
9.	Figures 1 through 13	191
10.	Figures 1 through 15	193
<b>1</b> 1.	Figures 1 through 16	195

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#### CHAPTER I

# INTRODUCTION

The Sucker Creek flora of southeastern Oregon and southwestern Idaho is only one of a complex of floras and florules from the Columbia Plateau and adjacent regions in Washington, Oregon, and Idaho. An extensive record of the Tertiary flora of the general region is preserved in a variety of sediments derived from widespread regional volcanism in middle and late Tertiary time. As pointed out by Chaney (Chaney and Axelrod, 1959), the large volume of sediments and extensive impoundment of local basins produced ideal conditions for fossilization of plant material at many locations in the Pacific northwest during Miocene and Pliocene time.

The Sucker Creek flora is actually a composite entity built up from data acquired from approximately a dozen florules from localities in the general vicinity of Sucker Creek in southeastern Oregon. The center of the fossil-bearing area is located approximately 35 miles southwest of the town of Nampa, Idaho and most of the localities are accessible by means of Sucker Creek Road, a graded dirt road which branches northward from U.S.

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Route 95 approximately 0.1 mile southwest of the highway bridge across Sucker Creek and about 2.3 miles southwest of the point where Route 95 crosses the Oregon - Idaho state line. Figure 1 shows the general location of the region in relation to an outline map of the states of Oregon and Idaho and also indicates the geographic relationships of the various localities which will be discussed in this paper.

The first known collections in the Sucker Creek area were made by Lindgren and the material appeared in a report by Knowlton on the Payette flora (1898). According to Graham (1965), Chaney and Berry both made small collections in subsequent years. The largest of the early collections, reportedly consisting of several hundred specimens, was made by Hinshaw in 1923. This material was deposited in the Carnegie Museum and was studied by Brooks in 1935. Smith collected in the area during several field seasons in the early 1930's and reported on the material in 1938 and 1939. About 1935 Percy Train collected approximately 750 specimens in the area on consignment to the University of Michigan. Some interesting specimens from this suite were described by Arnold in a series of papers (1936a, 1936b, and 1937). The flora was briefly considered by Chaney and Axelrod (1959) in their monographic treatment of the Miocene floras of the Columbia Plateau. The most definitive treatment to date was presented by Graham (1965). Graham undertook a revision of all of the macrofossil material from the various



ROCKVILLE SECTION
SHORTCUT SECTION
VALLEY SECTION
QUARRY LOCALITY
MAPLE RIDGE LOCALITY
PINE LOCALITY

ROAD OR TRAIL PERMANENT STREAM INTERMITTENT STREAM

FIGURE 1. Outline map of the study area showing the location of sites discussed in the text.

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collection sites and made numerous new collections in the In addition to this conventional paleobotanical area. treatment, Graham also described the pollen grains and spores preserved in the rocks at some of the macrofossil collecting localities. This initial study of Sucker Creek palynomorphs added a number of new taxa to the flora in addition to confirming the presence of taxa previously established on the basis of fossil leaves or seeds. Graham considered the flora to represent a warm temperate lowland deciduous forest complex which graded into communities of cooler aspect at higher elevations. Axelrod (1969) includes the Sucker Creek flora in his analysis of the topographic history of the Snake River Basin. On the basis of the macrofossil assemblage, Axelrod classified the flora as a mixed deciduous hardwood slope forest.

One of the principal limitations to our present understanding of the nature of the Sucker Creek flora is the complete lack of any stratigraphic control between the various collecting localities. The various florules are assumed to represent the same floristic entity and are considered together in any discussion of the fossil flora of the area. Such a practice is often resorted to in studying Tertiary floras of the Western interior where the isolated nature of the depositional basins makes correlation between localities difficult or impossible.

In light of this problem, the present study has two main objectives. The first of these is to describe

the stratigraphic interval during which most or all of the plant fossil-bearing beds were deposited with a goal of properly intercalating the various collecting localities into this local sequence. Once the stratigraphic sequence was established, the second major objective involved sampling the entire study interval and evaluating the quantitative and qualitative distribution of the various palynomorphs. The bulk of this paper is devoted to describing the methods, results, and conclusions arising from this study.

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## CHAPTER II

#### METHODS

#### Field Procedures

The author made an initial field reconnaisance of the Sucker Creek area in 1969 during a collection trip in the company of Dr. Aureal T. Cross. Dr. Cross had made additional collections in the area during the 1962 and 1965 field seasons and his familiarity with the area, both on the basis of his own experience and various published reports, was of great assistance.

The bulk of the field work was undertaken during the summer of 1970. The initial stages involved a careful reconnaisance of the area with the aid of aerial photographs, a preliminary version of the U.S. Geological Survey 15 minute Rockville Quadrangle sheet, and previous reports and field notes. The purpose of this phase was to locate as many of the plant-bearing localities as possible and to choose geological sections which would be suitable for detailed study. The assistance of Dr. Cross, who joined the author in the field for a week during this phase of the study, was invaluable in helping to define the stratigraphic relationships of certain of the productive megafossil localities.

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The final phase of the field study involved the measurement and sampling of three geological sections. The first of the measured sections is located in the NW4NW4 of T28S R46E, approximately 1.5 miles NW of the Rockville Schoolhouse which is located at the junction of Sucker Creek and Shortcut roads in Malheur County, Oregon. This section will be referred to as the "Rockville section" throughout this paper. The location of this and the other study sections is indicated on the map in Figure The second section, to be referred to as the "Short-1. cut section," is located in the NW\sW\sTlS R5W, approximately 1 mile north of the junction of Shortcut Road and Route 95 in Owyhee County, Idaho. The third section, called the "Valley section" outcrops along the course of a small intermittent stream in the NE<sup>1</sup>/<sub>2</sub> T27S R46E. This stream crosses Sucker Creek Road from the southwest approximately 0.25 miles from that road's intersection with Route 95 in Malheur County, Oregon.

The Rockville and Shortcut sections were measured with a Brunton Pocket Transit and tape, while the Valley section was measured by means of paced traverse with the Brunton compass. In an attempt to document most strata within the study sections, samples were collected from each lithological unit. Some particularly thick or variable units were sampled more than once. Two tenfoot intervals in the Valley section, each consisting of a complex of organic siltstones, mudstones, and lignite,

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were sampled at close stratigraphic intervals in order to document any changes in the pollen flora within that particular facies. Samples for maceration were also collected at several of the macrofossil localities.

Fossil plants, petrified wood, and fossil animals of interest were assigned field collection numbers and returned to the laboratory for detailed study.

## Laboratory Procedures

The field descriptions of rock units were recorded in the laboratory and the field measurements reduced to absolute stratigraphic thickness. The composite stratigraphic sections were plotted and the location of each field sample was intercalated into its proper section. All samples for maceration were assigned to Michigan State University Palynology Laboratory maceration number consisting of the prefix <u>Pb</u>, (paleobotanical), followed by a four digit number. These maceration numbers were crossindexed to the original field collection numbers in the master maceration index on file in the Palynology Laboratory at Michigan State University.

Sample Processing.--The prime objective of processing the rock samples from the field is to free the enclosed palynomorphs in such a form that they are amenable to qualitative and quantitative study. An ideal processing regime would not only free all types of pollen and spores, regardless of their relative degree of

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preservation, but would also introduce no bias in the quantitative representation of each of the entities as originally contained in the parent rock matrix. There are no techniques which will completely satisfy these rigid requirements and those which come closest are not applicable to a wide variety of sediments. Thin-sectioning where the palynomorphs are observed <u>in situ</u> within the parent matrix probably introduces a minimal bias and such techniques were used by Wodehouse (1933) in his study of the Eocene pollen of the Green River oil shales. Unfortunately, the limited occurrence of rocks with the requisite high pollen concentrations and suitable optical qualities in thin section greatly limits the scope of such techniques.

A more commonly used approach involves the chemical or physical disaggregation of the rock matrix to free the enclosed material for study. Brown (1960) and Gray (in Kummel and Raup, 1965) present useful summaries of the techniques now in use. Most laboratories employ relatively standardized techniques for treatment of various types of samples, but such procedures are, at best, guidelines from which optimized techniques for specific samples must be developed as the need arises. Samples from the Sucker Creek area vary considerably in their lithology and pollen and spore content and considerable time was devoted to the problem of developing a processing regime which would be satisfactory for a majority of the samples. Lignites,
lignitic shales, and highly organic silt and mudstones were usually characterized by high concentrations of well preserved palynomorphs and presented no particular sensitivity to details of the extraction procedure. The various volcanic shales, bentonites, and sands, which comprised the bulk of the measured sections, usually had low pollen and spore concentrations coupled with marginal preservation. Any procedure involving treatment with strong bases, boiling in acid with subsequent oxidation at the air-liquid interface, or attempts to refine the organic fraction by treatment with oxidants such as nitric acid (HNO<sub>2</sub>) or Schultze's reagent, a mixture of nitric acid and saturated potassium chiorate (KCl03), tended to result in either barren preparations or slides of poor quality with skewed palynomorph distributions. Although there is no empirical way to judge the effectiveness of any processing schedule, other than by comparison with the results of other techniques, the procedure to be described was successful in producing useful pollen and spore preparations from the greatest number of samples.

A typical sample consisted of either 10 or 20 grams of sediment. The decision as to the weight of samples to be processed was based on an intuitive evaluation of the probable productivity. The sample was crushed in a mortar with a pestle until the largest fragments were approximately pea-sized. A sample of the parent rock was tested with a 10 percent solution of hydrochloric acid (HCl) and





if any effervescence was observed, the sample was soaked in 5 percent HCl for 12 hours and then washed with water several times to remove any trace of acid. Samples which were not reactive to HCl were immediately introduced into the next stage in processing.

A 200 ml polyethylene beaker was filled to 1/3 capacity with crushed ice and 70 percent reagent grade hydrofluoric acid (HF) was added until the beaker was filled to the 100 ml mark. The beaker was placed under a fume hood and the entire sample was immediately poured into the acid-ice slurry and stirred with a plastic stirring rod. The purpose of this procedures was to completely eliminate the possibility of the solution boiling when the sample was added. Most of the Sucker Creek samples were highly reactive when placed in HF and the elimination of boiling appeared to significantly increase the yield of pollen and spores in marginal samples. The samples were allowed to stand in HF overnight under the fume hood. The next morning the excess acid was decanted and the samples were washed several times in water to remove all traces of the acid. Polyethylene beakers and centrifuge tubes were used until the final water wash, after which the samples could be transferred to glassware.

The samples were washed once in 5 per cent HCl and the excess acid was decanted off. Approximately 25 ml of saturated zinc chloride (ZnCl<sub>2</sub>) solution (specific gravity 1.95) was added to the centrifuge tube. The sample was

suspended in the heavy-liquid and given several seconds treatment in a Branson Instruments model PZ-150 "Sonogen" ultrasonic generator to homogenize the suspension. Treatment in excess of 30 seconds was avoided as more lengthy treatment tended to fragment vesiculate pollen types. The sample was then centrifuged for 15 minutes at 1550 r.p.m. and the floating and suspended organic fraction was decanted into a clean centrifuge tube. The tube was filled with water and the contents were carefully mixed so that the organic material could be spun down on a subsequent run on the centrifuge. The organic fraction was washed several times in water to remove all traces of zinc chloride. The zinc chloride solution is corrosive to pollen grains and spores and care was taken to limit the time during which the samples were exposed to this reagent.

Samples of sufficiently high quality at this stage in the processing were stained and stored in vials of glycerin jelly for later mounting. Most samples however had sufficiently high concentrations of clay particles and fine organic detritus to justify further processing. These samples were sieved through a Buckbee Mears Company BMC Micro Mesh screen with a nominal mesh size of 20 micrometers. Any material remaining on the surface of the screen was transferred to small glass sample vials. A microscopic examination of the <20µm fraction was made and if any pollen grains were noted, the fraction was re-sieved

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with a BMC 10 micrometer sieve and the >10 fraction was added to the >20 material in the sample vials. The use of the micro-sieves was resorted to only when debris made observation of the palynomorphs difficult due to mechanical interference or dilution effects. The residue was stained and stored in glycerin jelly for later mounting.

A drop of the glycerin jelly residue was mounted on a standard microscope slide and cover slip. The cover glass was ringed with clear nail enamel to prevent drying. Four slides were prepared from each vial of residue where volume permitted. Excess residue from each sample was stored in tightly capped glass vials. All slides used in this study are on file in the Palynology Laboratory at Michigan State University.

Analytical Techniques.--A Leitz Ortholux microscope (serial number 599742) was used for all observation and photography during the study. All of the slides available were examined for the occurrence of new palynomorphs or specimens of particular interest. The location of such specimens was recorded using the coordinates on the calibrated mechanical stage. In addition, each slide was given a small cross to the right of the cover slip using a diamond marking stylus. At the conclusion of the study, the location of all described specimens was computed on the basis of the distance above or below and to the left

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of the reference mark. A given taxonomic description might include the following information under the location heading:

The specimen in question would be found on the third slide prepared from residue PB-9301. The specimen could be located on this slide by centering the reference mark in the low powered field and moving the stage 5.6 mm above the reference mark and 9.1 mm to the left. The horizontal coordinate always represents the distance to the left of the reference mark, while a + or - sign next to the vertical coordinate indicates a distance above or below the reference mark. In all cases, the slide is placed in the stage holder with the label to the left of the observer.

Specimens were photographed using a Leitz Orthomat microscope camera system. Both Kodak Plus-X and Panatomic X films were used. Processing and printing followed standard techniques. Enlargements were adjusted so that the effective magnification on the final plates was 1000X.

Identification of the various palynomorphs was accomplished by comparison of the unknown specimen with information from three sources; standard reference texts such as Wodehouse (1935) and Erdtman (1943, 1966, 1969); published papers; and modern pollen reference slides. The latter source is the most definitive and was used preferentially whenever adequate material was available.

A quantitative evaluation of the palynomorph assemblage of each productive sample was made by making systematic traverses of the slides, tallying the pollen grains and spores encountered until a total of 200 palynomorphs had been counted from each sample. Occasionally a smaller sum had to be used due to low pollen and spore concentration, but every attempt was made to tally 200 grains if adequate material was available. Τn order to eliminate size bias from the counts, only those grains whose geometric centers were included in the field of view were counted. Detached bladders of vesiculate grains were not tallied, while the bodies of such grains were counted as a single grain, regardless of the number of attached bladders. Algae, fungal entities and bryophyte spores, while included in the qualitative evaluation of the samples, were not included in the sample counts, which included only those forms which could safely be considered either pteridophyte spores or gymnosperm or angiosperm pollen grains. Those palynomorphs of vascular origin which were poorly displayed or too poorly preserved to permit either identification or consistent recognition were tailied as "Undifferentiated Unknowns." Entities which could not immediately be identified but which were sufficiently distinct to allow consistent recognition were given numerical designations and tallied separately. In this manner, data were not lost in the event the entity could ultimately be identified. The relative percentage

for each entity in any given sample was calculated from the following formula:

$$\$ = \frac{Np}{FS} \times 100$$

where Np is the number of grains of the type in question and FS is the fixed sum or total number of entities counted for the sample in question. The total array of all relative percentages for any given sample constitutes the <u>pollen spectrum</u> of the sample. For an entire section, the data from the various pollen spectra are arrayed vertically in the form of a saw-tooth graph to show the shifts in relative per cent contribution of each entity throughout the entire section. Pollen profiles constructed from the study data appear in Figures 5 through 8 and are discussed in the chapter on stratigraphic palynology.

## CHAPTER III

## GEOLOGY

# Physiography

The Sucker Creek area is considered part of the Owyhee Upland region of the Columbia Plateau physiographic province and is located just north of the Great Basin province (Dicken, 1955). The region's complex surface features are developed on basaltic and rhyolitic sheets which range from Miccone to Recent in age. Permanent and ephemeral streams have formed numerous gorges in the region with a variety of land forms produced as a result of the differential rates of erosion of intrusive, extrusive, and sedimentary rocks. Virtually all of the sedimentary rocks in the area consist of reworked clastic material of volcanic origin. Relief varies from 2,230 feet at the level of the Snake River (Kittleman, 1962) to 8,065 feet in the Owyhee ranges near Silver City, Idaho. Elevation in the fossil leaf area is in the order of 3,500 feet with the adjacent Mahogany Mountains reaching 6,500 feet. The Owyhee Upland is drained by the Snake River which has two main tributaries in the study area,

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the Owyhee River, now dammed as an irrigation reservoir, and Sucker Creek. Sucker Creek drains the east slope of the Mahogeny Mountains and carries water throughout the year. McBride Creek and Carter Creek are the two main tributaries of Sucker Creek in the study area. In both of these there is very little water flow during the warmest months. According to Kittleman (1962), the profile of the valley of Sucker Creek suggests at least one cycle of erosion since the inception of the present drainage system.

### Structure

Folding in the area is comparatively gentle. The only feature of any note in the study area is a small anticlinal ridge near the point where Sucker Creek crosses Route 95 (Kittleman, 1962). Assessment of regional dip is difficult due to the lenticular nature of most strata, but appears to average 1-3 degrees westward. Locally dips may be as great as  $50^{\circ}$  when beds are disturbed by tilting of fault blocks or localized warping. No dips in excess of  $10^{\circ}$  were noted in measuring any of the study sections and in almost all cases these dips tended west. The numerous faults in the area tend north-south and are, according to Kittleman (1962), indicative of at least four periods of deformation.

Stratigraphy

The stratigraphic relationships of the rocks of the Owyhee Upland area in general and the Sucker Creek area in particular have undergone varying degrees of study throughout the years, but even the most recent work in the area has failed to completely unravel the complex relationships of the many isolated basins in which sediments were accumulating during late Tertiary time. Cope defined the Pliocene Idaho Formation in the area on the basis of fossil fish in 1883. Lindgren defined the Payette Formation in 1898 and considered it to be Upper Miocene in age on the basis of the fossil plants studied by Knowlton (1898). Both the Payette and Idaho Formations were recognized in the mapping of the Nampa and Silver City areas by Lindgren and Drake (1904, 1904a), but no clear distinction between them was made at that time. Both formational names were used by Kirkham (1931) working in the western part of the Snake River Plain east of the Owynee Upland, but again, the formations were poorly defined. Kirkham did note that the Miocene Payette is often separated from the Pliocene Idaho by a rhyolite which he called the Owyhee Rhyolite. Locally, a basalt, which he called the Owyhee Basalt, is often present above the Owyhee Rhyolite. Additional mapping and work in the area by Bryan (1929), Renick (1930), Corcoran (1953), and Doak (1953) clarified the relationships of some of the interbedded rhyolites and basalts but retained the Payette - Idaho nomenclature for the major

sedimentary units. Chaney (Chaney and Axelrod, 1959) considered the plant-bearing beds of the Sucker Creek area to be of essentially the same age as the Payette of Kirkham (1931) but felt that they represented a distinct facies which, when more fully understood, might justify the application of a new formational name. Kittleman's thesis (1962) on the geology of the Owyhee Reservoir area redefined the nomenclature of many of the units in the area. Kittleman felt that, since it was not possible to directly correlate the rocks in the Owyhee Reservoir area with those definitely known to belong to the Payette and Idaho sequence, the use of new names for these units was justified. The history of the stratigraphic terminology for the rock units in the area is summarized in Figure 3, while Figure 2 summarizes the regional correlations of these units with sections in other parts of Oregon. Kittleman proposed the name Sucker Creek Formation for beds presumably equivalent to the Payette and renamed the overlying rhyolite the Jump Creek Rhyolite since the name Owyhee had already been preempted for the basalt. The old Idaho equivalents were elevated to group status and he proposed the names Deer Butte and Grassy Mountain Formations for the two component units of the new group.

All of the fossil plant localities occur in the area which Kittleman maps as the Sucker Creek Formation (1962). Kittleman defines the formation as consisting of approximately 1,600 feet of interbedded volcanic and

	JOHN DAY	DESCHUTES-		HARNEY	STEENS MTN	ОѠҮНЕЕ
	VALLEY	UMATILLA AREA	N. E. OREGON	BASIN	JUNTURA Area	RIVER
			A     a a i a m		A 1 1 4 4 1 4 4	Alluvium
	En-AnY	ALLEVIE				
RECENT &	flows & cinders	flows & cones		flows & cones		flows & cones
PLEISTOCENE		intracanyon bas.				intracanyon bas.
				Harney Fm.		
		Veschutes Fm.			Drinkwater Basalt	a. ChalkButte Fm.
		McKay Res. & Arlington		fanglom.	Drewsey Fm	G GrassyMtn.Fm.
PLIOCENE	Rattlesnake Fm.	peds				
		Dalles Fm.	Ironsides beds	Danforth Fm.	Juntura Fm.	
						Obeer Butte Fm.
	Mascall Fm.		beds at Austin	Steens Basalt	Steens Mtn. Volcan	Owyhee Baselt
	Columbia R. Basalt	C. R. B.	C.R.B.	rhyolite	Alvord Crk	Sucker Site
MIOCENE			A		E L	Creek Fm. Hull.
	John Day Fm.	John Day Fm.	flows			Ē
OLIG OCENE						
	Clarno Fm.	Clarno Fm.	Clarno fm.			



Bryan, 1929 [

ttleman, 1962	alluvium basalts at Cow Lks.		or. Henn Grassy Mtn.	U - Deer Butte	E.		Owynee		P140		Sucker Creek Fm.
Υ.	Pliocene Pl.&R				Aiocene						
aldwin, 1959	alluvium Cow Ik, volcanics inner canvon flows	Crace Mto Bacol +	beds at Kern	E beds at	DPinnacle Point			Owyhee Basalt		Ahyolite And member	Payette Fm.
8	Pleis.	ə	Pliocen				ə	u ə	201	Ň	-
rcoran, 1953 oa k, 1953	alluvium	grave ls	(upper)		Grassy Mtn Basalt	Idaho Fm. (lower)		Owyhee Basalt		Owyhee Rhyolite	Payette Fm.
ပိဝိ	В.	.†slq	əu	eneceil		d	Nio. or Plio.		W IO.		
Bryan, 1929 Renick, 1930	alluvium Idaho Fm.				Grassy Mtn.Basalt	Pay ette Fm. (upper)	Blackjack Basalt	Payette Fm.(lower)	Owyhee Basalt	rhyolite porphyry	older Tertiary sedimentaries
1.0.1	В.	Pleistor Plio.			Miocene					S.oiM	



Development of stratigraphic terminology in the Owyhee Reservoir area. Redrawn from Kittleman (1962).

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Ĵţ 5đ â ar, arkosic sandstones, arkosic conglomerates, and carbonaceous volcanic shales. There is a tuff member, the Leslie Gulch tuff member, to the east and a poorly known basalt near the base of the formation. The base of the formation is not exposed in the area. Unfortunately, the type section consists of approximately 400 feet of sediment at the top of the sequence. The type section is located considerably to the north of the plant fossil area in S½ SW½ Sec. 28, T.24S., R.46E. in Malheur County, Oregon. The relationship of the study sequence to the Sucker Creek formation (<u>sensu latu</u>) of Kittleman will be discussed later in this chapter.

Graham (1965) does not discuss the stratigraphic relationship of any of the plant localities in his treatment of the flora.

Detailed data on each of the measured sections is contained in Appendix A. The following discussion will involve somewhat more generalized comments on the nature of the section at each locality with reference to the generalized correlation diagram in Figure 4.

Rockville Section.--The Rockville exposure is easily accessible from Sucker Creek Road just north of its Junction with Carter Creek Road (Figure 1). The upper part of the sequence is exposed along the east flank of a ridge directly west of Sucker Creek road at this point and the entire section is exposed in the valley system



FIGURE 4. Generalized diagram of the rock units of each of the study sections and the proposed correlations. Line A—A´marks the base of the prominant white ash bed that is present at each section.

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behind this ridge. A photograph of this latter exposure appears in Plate 1 and was taken facing northwest from the top of the ridge paralleling Sucker Creek Road. A small dirt road branching off of Sucker Creek Road just beyond the ridge offers convenient access to the entire valley system. The oldest sediments in the section outcrop at the base of the knoll to the far right in Plate 1 and consist of approximately 5 feet of greenish bentonitic shale overlain by approximately 1 foot of sandy shale, also somewhat green in color. Several feet of organic shale overlie the sandy shale. The lower part of the sequence is highly fossiliferous and numerous very fine fossil leaves have been collected. The matrix is a fine shale with a very light maroon color. The leaves are predominantly of the Quercus consimilis type and the stem tips of Equisetum octangulatum. The top of the unit consists of a light brown highly fissile shale containing numerous plant fragments and insect parts. This very characteristic bed will be referred to as the "Insect Bed." The Insect Bed is overlain by a thin green bentonitic shale which in turn is overlain by a prominent white ash bed approximately 22 feet in thickness. This ash weathers to a pure white color but on close examination can be seen to contain tiny black mineral inclusions and carbonized plant fragments. This bed is a very prominent marker in the section and is easily visible in Plate 1 wherever it outcrops. The white ash is overlain by approximately 35

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feet of cross bedded, poorly consolidated sand. The sand is overlain by another sequence of organic shales. This shale sequence contains entire petrified tree stumps rooted in place. Numerous pockets of fossil wood, representing weathered tree stumps can be seen along the top of the ridge paralleling Sucker Creek Road and a number of intact stumps may be seen in situ on the northwest slope of the hill located behind the prominent ridge in the center of Plate 1. There are several feet of sand overlying the shale sequence followed by a thick shale with little organic material. This shale grades from gray or brown at its contact with the sand to a highly indurated form at the top of the section which weathers to tan or rust brown along exposed edges and contains seeds of Cedrela trainii. These beds may be traced laterally to several outcrops along the upper part of the cut-off trail from Sucker Creek Road. The lithology and fossil content of these beds is identical to that of the Specimen Ridge (Quarry), and Pine localities while the Maple Ridge beds (Figure 1) would appear to represent an even more indurated form of the same shale sequence. The uppermost Rockville shale bed would appear to be the stratigraphic equivalent of all three macrofossil localities. The Rockville section consists of approximately 95 feet of sediments which were deposited under conditions ranging from stagnant swamps through quiet water and main river channel environments.

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Shortcut Section. -- The Shortcut section is clearly exposed and easily accessible from Shortcut Road across McBride Creek approximately 0.5 miles from the junction of Shortcut Road and Route 95. The section consists of approximately 115 feet of sediment and is illustrated in Plate 2. The base of the section consists of approximately 20 feet of poorly consolidated green sand with thin bands of organic material toward the top of the unit. Overlying the sand is a series of organic shales, mud and siltstones, and lignite. Fossil wood fragments are found weathering out of this zone. At the top of this unit is a bed of thin fissile brown shale with insect parts. This bed is identical in all respects to the Insect Bed of the Rockville section. Immediately above the insect layer is a thin green bentonitic shale overlain by a prominent white ash bed, apparently identical to that of the Rockville sequence. A poorly cemented cross-bedded sand overlies the white ash. This sand has water-worn pebbles up to 3 inches in diameter in the upper two feet. The sand is overlain by a thin shale and approximately 2 feet of additional sand. An organic shale layer overlies this sand and contains pockets of fossil wood which are apparently derived from the weathering of logs or stumps. Depositional environments represented in the section appear to include stagnant water, relatively guiet water, and major distributary channels. The presence of the larger pebbles at the top of

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the sand unit would appear to indicate an environment of fairly high energy.

<u>Correlation of the Rockville and Shortcut Sec-</u> <u>tions</u>.--The Rockville and Shortcut sections correlate quite closely on both lithological and fossil criteria. The vertical sequence indicated below is common to both sections. The numbers assigned to these units correspond to those of Figure 4.

- 1. gray shale
- 2. organic interval
  (wood)
- 3. sand
- 4. white ash
- 5. green shale
- 6. insect bed
- 7. organic interval

The lithological character of each unit as well as their relative positions match perfectly between the two sections. The general patterns of the correlations are indicated in Figure 4. The only uncertainty regards the precise point where the oldest sediments at Rockville fit S t 1 R W D. 0. fì Sà. org thi into the Shortcut complex and where the youngest Shortcut beds fit into the upper Rockville sequence. There is little doubt that the two sections represent virtually the same sedimentary interval, overlapping in such a way that the very oldest sediments are found at the base of the Shortcut section and the very youngest rocks are found at the top of the Rockville section.

Valley Section. -- The Valley section is exposed along the course of a small intermittent stream near the junction of Sucker Creek Road and Route 95. The base of the sequence consists of approximately 5 feet of gray clay-shale which is overlain by a thick sand varying in color from rust-brown to olive green, depending on the degree of weathering. The cement exhibits weak effervescence with HCl. Approximately a third of the way up this unit there is a thin limey layer of very hard rock. This layer is gray in color and is rich in organic material. The sand continues up to the 165 foot layer where it is overlain by a brown shale containing numerous plant fragments and a few fossil leaves. This shale is overlain by a 10 foot sequence of lignite and organic mudstone and siltstone. Small varves of sand and mica flakes are common in this unit. Above this unit is a sandy brown shale which is overlain in turn by another organic unit much like the first. Above this unit is a thick series of fine-grained shales of a very light maroon S

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color. Fossil leaves of extremely high quality are very abundant in the lower part of the shale sequence. Of all of the leaf-bearing beds in the Sucker Creek area, these beds are unsurpassed in the number and quality of the leaves, fruits, and seeds which can be collected here. Particularly fine specimens of Glyptostrobus, including branches with attached male and female strobili, Quercus, Acer, Salix, and a variety of other deciduous leaves have been collected. Another organic series overlies the shale sequence. A thin green bentonitic ash overlies the organic sequence and is overlain in turn by a white ash typical of the Rockville-Shortcut complex. Above the white ash there appears to be an unconformity which may represent the contact between the Sucker Creek formation and later Miocene sedimentary rocks and flows as mapped by Kittleman (1962). The correlation between the Rockville and Shortcut sections and the Valley section is difficult on lithological grounds alone. The white ash and underlying green shale appear identical to similar units in the other study sections and the correlation of those beds is indicated in Figure 4. The top of the white ash at the Valley section is probably truncated by erosion and may not represent the total thickness originally deposited. The complex organic beds characteristic of both Rockville and Shortcut are difficult to relate to the Valley sequence and the correlation indicated in Figure 4 is largely based on palynological data and is

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fully discussed in the following chapter on stratigraphic palynology.

Relationship of the Study Sections to the Sucker Creek Formation. -- There is little doubt that the composite stratigraphic sequence described in the present study represents a well defined and mappable unit. The difficulty is in relating this unit to the Sucker Creek Formation as defined by Kittleman (1962). As stated previously, only approximately 400 feet of section are expressly defined in the type section, with the majority of the mapping of the full extent of the formation carried out using topographic criteria. The sediments of the study sections appear to contain most or all of the fossil plant beds but do not have any lithological similarity to the type section to the north. The fact that all of the study sections are truncated and overlain by flows younger than the Jump Creek Rhyolite might tend to indicate that the study sequence represents an older unit than the type section. Within the study sections, progressively younger sediments are exposed when traced northward, a trend which, if continued, would also indicate a younger age for the sequence to the north at the type locality. The presence of a tilted fault block in which progressively older sediments are exposed southward is a distinct possibility. Kittleman (personal written communication) feels that this is a viable hypothesis. Hills to the ESE of the junction

of Route 95 and Sucker Creek Road have exposed sediments which seem to be similar to the beds of the type section, even to the presence of well-defined opaline layers, which are lacking in any of the study sections. If the study sections are part of a fault block, a fault associated with the anticlinal ridge near the junction of the two roads is required to explain the close juxtaposition of otherwise unrelated sediments. A provisional assessment, in the absence of further work in the area, would at least tend to indicate that the sedimentary interval represented by the study sections is older than that of the type section.

The problem of the proper nomenclature of this and other units in the area is not as easily solved. Repeated traverses from the plant-bearing beds to the south and the type section to the north failed to indicate any lithological connection between these important units. On the basis of such a lack of direct correlation, there appears to be no valid reason for including the plant-bearing units to the south within the Sucker Creek Formation. There is little doubt that the complex of sediments mapped by Kittleman as the Sucker Creek Formation is in need of redefinition and possible modification of nomenclature. The type beds to the north contain a fauna which has been referred to in the literature as the Sucker Creek fauna and any nomenclatural change should, if possible, retain some reference to the term Sucker
Creek for both the flora and fauna. One alternative might be to raise the present Sucker Creek Formation (<u>sensu latu</u>) to group status and redefine the type section and the sedimentary interval of the present study as separate formations, provided the relative stratigraphic relationships could be determined with somewhat more certainty than they are known at present.

Giving both units member status within the Sucker Creek Formation as presently mapped is untenable for two reasons. First, as discussed previously, there are at present no grounds to consider the present formation, as mapped, to have any stratigraphic continuity, and secondly, both of the units to be included are composed of diverse lithological constituents while members, in the commonly used sense, are usually of relatively homogeneous composition.

In any case, the plant-bearing beds in the Sucker Creek area would appear to belong to a definable stratigraphic interval. A task remaining for future investigation is the relationship of this unit with other sedimentary intervals on a broader scale to more clearly define the late Miocene sequence in the area.

Age of the Flora.--Based on the evidence of the fossil plants of the macroflora, Chaney and Axelrod (1959) considered the flora to be late Miocene in age. Graham (1965) concurred in this view. According to Kittleman (1962) the sediments in the type section are late Barstovian

in age based on the fossil mammals recovered from those rocks. Evernden et al. (1964) gives a date of 16.7 million years for a plagioclase sample from the Sucker Creek region. Although precise collection data was not available, James, one of the authors of the dating paper, recalls that the sample was collected approximately 9 miles north of Sheaville along U.S. Route 95 just east of the point where the road curves sharply to the northeast (personal written communication to Dr. A. T. Cross). This sample was interbedded with ash beds and evidently represents an isolated flow structure too small to be marked on Kittleman's map (1962). Although the collection site is located not far from the Valley section (Figure 1) it is in an area where fault activity is suspected and its relationship to the study sections is not clear. Barring a closer correlation of dated material with the composite study sequence, a late Barstovian age for the leaf-bearing sediments is the best approximation that can be made at present.

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### CHAPTER IV

# STRATIGRAPHIC PALYNOLOGY

The material in this chapter will consist of a description of the patterns exhibited by the relative frequency pollen profiles from the study sections. The ecological implications of the profiles will be discussed in the following chapter.

# Valley Section

The sediments of the Valley section are characterized by relatively productive samples with the general exception of the poorly cemented sand which comprises the lower 180 feet of section. The only productive samples in this interval were derived from a clay-shale at the base of the section and a thin limey layer at the 275 foot layer. The quantitative data for the entire section are summarized in Figure 5. The pattern on palynomorph distribution appears to be relatively consistent from the base of the section up to the 150 foot level where the first of the extensive swamp deposits appear. The most prominent component of the microflora throughout this interval is the pollen of the genus Picea, which varies in

Figure 5.--Relative frequency pollen and spore profiles from the Valley section. Relative frequency, in per cent, is indicated in a horizontal direction while the level within the section is indicated on the vertical axis.



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relative percentage from 25 to 35 per cent. <u>Pinus</u> pollen, ranging from approximately 30 percent at the base of the section and maintaining a level of approximately 10 percent throughout most of the interval, is second in importance closely followed by <u>Alnus</u>, <u>Abies</u>, and <u>Ulmus</u>. Pollen of <u>Tsuga</u>, the Taxodiaceae (TCT), <u>Quercus</u>, <u>Fagus</u>, <u>Pterocarya</u>, and the Gramineae are consistantly present in the range of 1-2 per cent, while monolete and trilete spores, and pollen of <u>Carya</u>, <u>Juglans</u>, <u>Tilia</u>, and <u>Acer</u> are consistantly present, but never exceeding approximately 1 per cent. Other taxa are sporadic in distribution and of little quantitative importance.

A major feature of the profile at the 150 to 145 foot level is a pronounced peak in Alnus pollen in excess of 40 per cent. This peak is roughly coincident with a drop in Picea to somewhat less than 10 per cent. Abies and Tsuga also exhibit decreases at this point, but the other components of the profile are comparatively unaffected. Above this point in the section additional taxa appear, but do not attain any great quantitative importance. These include Betula, Carpinus, Castanea, Liquidambar, Populus, Salix, and a number of irregularly distributed forms. In addition to the appearance of these new taxa, the upper half of the section is also characterized by an overall increase in the relative importance of Ulmus and Quercus pollen grains. A small peak in Abies preceeds a pronounced Picea peak of approximately 50 percent at the 125 foot level.

A very pronounced peak in taxodiaceous pollen (TCT) culminates at the 70 foot level and is accompanied by a decrease in <u>Picea</u> and <u>Abies</u> and the disappearance of <u>Tsuga</u>. The TCT peak appears to coincide with a slight drop in the relative importance of <u>Quercus</u> and <u>Alnus</u> pollen. From the 70 foot level to the top of the section there are two small TCT peaks and two peaks in <u>Picea</u> and <u>Abies</u>, with a similar pair of peaks in the <u>Ulmus</u> curve. The uppermost productive sample in the section is characterized by slight declines in the importance of <u>Picea</u>, <u>Abies</u>, <u>Pinus</u>, and <u>Ulmus</u>, and a slight increase in <u>Alnus</u>, the Compositae, and the Gramineae.

In addition to examining the profile for the entire Valley section, it was decided to study a single facies in some detail to determine if small-scale successional events were resolvable and to see to what extent the patterns revealed by detailed sampling were discernable in the large-scale profile. In order to gather data on this point, a 10 foot sequence of lignites and organic silt and mudstones was sampled in detail and a pollen profile prepared. The sequence is located in the 142 to 132 foot interval and the profile appears in Figure 6. In spite of the slightly jagged profile, the overall impression is one of uniformity in the representation of the various pollen types throughout the interval. There are only three points in the curves which depart from this overall uniform aspect. The first of these is Figure 6.--Relative frequency pollen and spore profiles from the Upper Swamp Series in the Valley section. Relative frequency, in per cent, is indicated on the horizontal axis while position in the section is indicated on the vertical axis.





a pronounced <u>Ulmus</u> peak at 3.5 feet and the second is a smaller peak in <u>Quercus</u> at 0.5 feet. The third point is a rather pronounced and uniform increase in the relative percentage of taxodiaceous pollen (TCT) toward the top of the sequence. This increase corresponds to the beginning of the major TCT peak in the curve for the entire section and it would appear that the trends within this small lithological unit are in accord with the largescale but more poorly defined patterns throughout the entire section.

# Shortcut Section

The pollen profile for the Shortcut section is diagrammed in Figure 7. The profile is characterized in its lowest levels by a high percentage of Picea pollen, ranging from slightly more than 50 per cent at the 108 foot level to about 1 per cent at 75 feet. There is a secondary peak at 72 feet and the pollen disappears from the record by the 62 foot level. Abies and Tsuga occur in moderate numbers in the lower portion of the section but disappear by the 72 foot level. Alnus pollen occurs at levels of 1-5 per cent in the lower part of the section with a peak of 59 per cent at the 75 foot level. There is a rapid reduction to approximately 2 per cent at the 72 foot level, with this low percentage being maintained throughout the remainder of the section. Of the remaining angiospermous pollen types, Ulmus is probably the most important, ranging from 2 to 12 per cent in the lower portion

Figure 7.--Relative frequency pollen and spore profiles from the Shortcut section. Relative frequency, in percent, is indicated on the horizontal axis while position in the section is indicated on the vertical axis.

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SHORTCUT SECTION

of the sequence, becoming reduced to 1 per cent at the 72 foot level and disappearing from the record by 62 feet. A number of other pollen types, including Betula, Carya, Castanea, Fagus, and Juglans exhibit similar patterns in that they commonly occur in the lower part of the sequence but disappear from the record by the 72 foot level. The Acer curve is quite similar except for a limited occurrence at the 8-9 foot level. Quercus and Pterocarya are well represented in the lower third of the section and persist at reduced numbers above 72 feet. Pollen assigned to the Gramineae shows a similar pattern except for a secondary peak near the top of the measured section. The pollen of Salix and the Taxodiaceae (TCT) is found with little change throughout the section. The pollen of Pinus, despite a reduction at the 75 and 72 foot levels shows a general increase in relative importance from the base to the top of the sedimentary interval. Pollen of the Compositae is the most significant group in the upper part of the section. The grains are virtually absent from the lower section, gradually rising to a value of 5 per cent at the 75 foot level. At this point the curve begins a rapid increase reaching approximately 30 percent at 62 feet and generally this percentage is maintained to the top of the section. A number of differentiated unknown pollen types exhibit a similar pattern. Other, less numerous pollen, taxa whose distribution is wholly or partially

confined to the levels above 72 feet inclue Populus, Malvaceae, Cheno-Am, Unknown 63 and Unknown 72.

The general pattern of distribution of the various palynomorphs throughout the section is characterized by a significant shift in dominance of the various pollen types. This shift occurs at approximately the 72 foot level near the top of a series of highly organic sediments.

#### Rockville Section

The pollen profile for the Rockville section is illustrated in Figure 8. In the lowermost part of the section the pollen dominant is Picea, approaching 40 per cent in two peaks near the base of the section and dropping to a very low value by 82 feet. Picea pollen persists at this relatively low percentage throughout the remainder of the section. Abies and Tsuga generally show a similar pattern but with peaks in the order of 5-6 per cent. Both types disappear from the record by the 82 foot level. Pinus pollen is well represented although somewhat variable in the lower part of the section and gradually increases in importance upward, reaching a peak of almost 70 per cent at a level 2-3 feet above the top of the measured section. Ulmus pollen is quite important in the lower section but disappears from the record at the Betula, Carpinus, Carya, Fagus, Liquid-82 foot level. ambar, Juglans, and Pterocarya show similar distribution

Figure 8.--Relative frequency pollen and spore profiles from the Rockville section. Relative frequency, in per cent, is indicated on the horizontal axis while position in the section is indicated on the vertical axis.



ROCKVILLE SECTION

patterns. Acer, Alnus, Castanea, and Tilia are best represented in the lower part of the section and are sporadic in occurrence above 82 feet. Taxodiaceous pollen (TCT) is variable in the lowermost part of the section and persists at somewhat reduced numbers from 82 feet through to the top of the section. Quercus pollen occurs throughout the entire section but reaches its greatest relative importance above 82 feet. Populus and Salix are both irregularly distributed throughout the interval. Poorly represented in the lower part of the section, but dominant above the 82 foot level are pollen types such as the Compositae, Cheno-Am, Malvaceae, Unknown 72, and Unknown 63. There are significant peaks in both Cheno-Am and Malvaceae at the 15 foot level. The major feature of the section profile is the abrupt shift in pollen dominance at the 82 foot level.

### Comparison of Study Sections

In the most general terms, the entire Valley section and the lower Shortcut and Rockville sections are characterized by pollen spectra of basically similar composition. The spectra are dominated by <u>Picea</u>, <u>Ulmus</u>, and <u>Pinus</u>, with other types such as <u>Abies</u>, <u>Tsuga</u>, TCT, <u>Alnus</u>, <u>Betula</u>, <u>Carya</u>, <u>Castanea</u>, <u>Fagus</u>, <u>Juglans</u>, <u>Pterocarya</u>, and <u>Quercus</u> comprising the remainder of the total count. This type of pollen spectrum is characteristic of all of the samples from which Graham was able to isolate pollen and spores (1965). Immediately below a prominent white ash

layer in both the Rockville and Shortcut sections, a change in the nature of the pollen spectrum occurs. Picea pollen, a dominant in beds below this level disappears entirely or becomes very much reduced. Abies and Tsuga, never as abundant as Picea, disappear entirely above this critical level, as does the pollen of Betula, Carya, Fagus, Liquidambar, and Juglans. Other types, such as TCT, Acer, Castanea, and Pterocarya either disappear above the critical level or persist at reduced numbers, while others, of which Quercus, Populus, and Salix are examples, may increase in numbers above the transition interval. Pinus pollen typically shows a gradual increase in importance from older to younger sediments. Pollen types such as the Compositae, Malvaceae, Cheno-Am, Unknown 63, and Unknown 72, which are either absent or rare below the transition zone assume a dominant role in the upper part of both sections. Similar lithologies and a close correspondence in the two pollen profiles would tend to support the correlation of these two sections described in Chapter III. The Valley section does not show such a sudden change at beds assumed to be of comparable age and the only point of similarity between the upper Valley section and the upper portions of the Rockville - Shortcut complex is the slight increase in the Compositae and Unknown 63 at the very top of the Valley Section. Correlation of the beds immediately below the prominent ash layer in the Valley section with the beds of the lower

Shortcut and Rockville sections must be approached with some care. It is possible that the two Picea peaks at the base of both the Shortcut (107 and 72 feet) and Rockville (95 and 82 feet) sections may be equivalent to the two peaks at 65 and 35 feet in the Valley section. The pronounced peak in Alnus that occurs immediately prior to the final Picea peak at both Shortcut and Rockville may be represented by the series of perturbations in the Alnus curve at the 40 foot level in the Valley section, but this is far from a secure interpretation. Another alternative in relating the Valley sediments to those of the Rockville - Shortcut sequence is to consider the plant-bearing shales between 130 and 50 feet in the Valley as a thicker expression of the complex and often highly organic shale series at the base of the Rockville and above the basal sand in the Shortcut section. Following this interpretation, the earliest of the two Picea peaks at Rockville and Shortcut would be equivalent to the broad peak at approximately 160 feet in the Valley, while the final Picea peak at Rockville and Shortcut would correlate with the sharp peak at 125 feet in the Valley section. The significant Alnus peak just above 150 feet in the Valley section would then be in the proper position to correspond to the Alnus peak at the base of the Rockville - Shortcut complex.

The shape of the various pollen profiles lends weight to the hypothesis that the Valley section, from the

lignitic series at approximately 150 feet to the thin green shale below the prominent white ash at approximately 35 feet, probably represents the same interval as the 82 to 62 foot sequence at the Shortcut section. The base of the Rockville, from 97 to approximately 80 feet may include only the upper portion of this interval. There are shale zones at the base of both the Rockville and Shortcut sections which have much the same lithology and macrofossil content as the thick fossiliferous shale sequence in the Valley section, and the fact that this problematical sequence of beds is located immediately above a thick sand at both the Shortcut and Valley sections tends to support this latter hypothesis for correlating the Shortcut-Rockville and Valley sections.

#### CHAPTER V

#### PALEOECOLOGY

The quality of the inferences which can be made regarding the paleoecology of a fossil flora can generally be considered to be dependent on four factors:

- 1. The reliability of taxonomic assignments and the level to which they are made.
- 2. The extent to which the ecological requirements of the extant equivalents of the fossil taxa are known.
- 3. The size and diversity of the flora.
- 4. The relationship between the relative abundance of the plant parts studied, i.e., leaves, stems, fruits, pollen grains, or spores, and the relative abundance and spatial distribution of the parent plants.

The first factor, the reliability and level of taxonomic assignments within the flora, is extremely critical and the importance of this phase of a study cannot be over-estimated. Identification of Tertiary fossil material is always more difficult and the conclusions more tentative than would be the case for equivalent modern material. This is due to several factors, including the quantity and quality of the fossil material and

our inadequate knowledge of the equivalent organs or structures in modern taxa. The pollen of modern forest trees from temperate areas can usually be assigned to a genus, but rarely to a species. The same is true of equivalent Tertiary material. Herbaceous pollen may be assignable to the generic level, but more commonly a family designation is the best that can be achieved and often this can be doubtful. The primary limitation to the study of most pollen types is the limited number of characters available for assessment when the light microscope is used. The size and variability of a taxonomic group is often directly related to the degree of precision which can be expected in the identification of pollen grains within the group. If corresponding fossil material is degraded in quality due to poor preservation, identification with a modern group becomes even more difficult. The problems involved in the nomenclature of Tertiary pollen grains and spores are discussed in the chapter on the systematics of the flora.

The second factor, the extent to which the ecological requirements of the presumed equivalents of the fossil taxon are known, intergrades somewhat with the first factor considered. Obviously, the ecological requirements of a species are likely to be more easily categorized and somewhat less generalized than those of a genus, especially if the higher rank is quite large and variable in its composition. Similarly, the ecological

requirements of a genus are more useful in ecological reconstruction than those of a whole family. For most large families, only the most general statements regarding ecological trends can be made.

When ecological data are available for a given taxonomic group, they are more likely to consist of patterns of distribution within a generalized climatological-geographical context rather than a detailed analysis of ultimate limiting factors operating to produce the present distribution of the group.

A uniformatarian approach to the problem of paleo-ecological synthesis may also create unique pitfalls in any analysis. The modern distribution of any particular taxon is the end product of a continuous interaction of plant and environment in both time and space. Since the modern distribution pattern is a result of the complex interplay of environment and the various tolerance levels, dispersal capabilities and opportunities, and the continuous modification of the genome through the action of natural selection on various mutations, the question can and must be raised as to what extent the distributional patterns of modern taxa adequately reflect the equilibria likely to have been established at some time in the past. The fact that much of the temperate vegetation of the northern hemisphere is either recently recovered or still recovering from the geologically recent glacial-fluvialpluvial episodes of the Pleistocene, suggests the need for

caution in applying recent distributional phenomena as an infallible Rosetta Stone to the problems of Tertiary paleoecology. The equilibria represented by the distribution on some modern taxa may not be entirely typical. Axelrod (1941) suggests that ecotypic variation in many Tertiary taxa may have been somewhat greater than at present and that this may serve to explain some otherwise anomalous combinations of taxa that comprise some Tertiary plant communities.

The size of the flora is also very important. A large aggregation of taxa with a degree of ecological compatibility is more useful than a small florule. Α large flora is also more likely to reveal some of the nuances of community structure than a comparatively depauperate assemblage. A large flora with a degree of ecological compatibility also makes it easier to assess the position of certain taxa which might have a wide ecological amplitude or requirements of an unusual nature which might otherwise alter the interpretation of the entire assemblage. The presence of a nominally warmtemperate form in a flora of otherwise cool-temperate aspect suggests two alternatives. Either we can shift the whole flora to a warm-temperate setting to satisfy the presumed requirements of just one or two taxa, or we can postulate the existence of more sheltered microhabitats or the existence of an ecotype that is somewhat more cold tolerant. The latter approach certainly appears

to be the sounder of the two when only a small number of anomalous forms are present.

Drawing inferences based on the shift in relative abundance of the various taxa in a flora is a complex task and one in which the interpretive values are different for different types of material, such as leaves, seeds, fruits, pollen grains, or spores. The problem, in a narrower sense, of how the number of pollen grains of various taxa in a sediment reflect the source vegetation is highly complex and, as yet, not amenable to rigorous evaluation. In practice, interpretations of pollen profiles and spectra are often subjective in that the representation of the various palynomorph taxa is a complex function of all of the following factors:

- 1. Pollen and spore production in the source areas.
- 2. Transportation of the material by means of various vectors to the basin of deposition.
- 3. Sedimentation and initial preservation of the palynomorphs.
- 4. Post-depositional modification of the pollen suite.
- 5. Methodological bias introduced by the recovery techniques.
- 6. Bias and systematic errors introduced by the means chosen to display the data.

The complex nature of the interrelationship of these factors means that there is no unique interpretation regarding the nature of the source vegetation as judged from the pollen data alone. Large shifts in the quantitative

and qualitative composition of the flora can indicate general trends which appear probably on the basis of our knowledge of present vegetation, but a large element of uncertainty exists in every case. If subsidiary evidence in the form of fossil leaves, fruits, or wood is available for the same deposit, the overall reliability of any judgements is increased, due in part to the fact that the distributional controls for other plant parts may not be the same as those operating on pollen grains and spores. Uncertainty regarding identifications within the flora may also be reduced if the presence of a given taxon is supported by data from several different plant parts. The extensive data which are available on the composition of the Sucker Creek macroflora provides a valuable crosscheck on the data derived from the pollen and spore flora and will be injected into the discussion whenever appropriate.

The first step in any ecological analysis of a fossil assemblage is to categorize the elements of the flora in terms of the general type of plant communities in which their modern counterparts would be likely to occur. This problem is complicated somewhat, as mentioned earlier, by the fact that most of the palynomorphs could only be identified to the level of genus, while others were only assignable to families or groups of families. Any characterization of the community types must therefore be somewhat broad in scope. Figure 9 is an attempt to

	Lake or Pond	Marsh	Swamp	Flood- Plain	Mesic Bottomland Forest	Mesic Slope Forest	Dry Slope Fores <b>t</b>	Savanna/ Prairie/ Scrub	Boreal or Montane Forest
Abies	1	1	I	I	I	1	1	B	×
Picea	I	I	I	ł	I	ı	ı	ı	×
Tsuga	1	I	I	I	I	<b>۰</b> ۰	I	1	×
Pinus	I	I	I	I	I	ł	×	I	I
<u>Taxod</u> iaceae	I	ı	×	×	I	ł	ł	1	1
Acer	I	I	×	×	×	×	I	I	I
Alnus	I	I	۰۰	×	×	I	I	I	<b>۰</b> ۰
Betula	I	ı	I	۰.	Х	<u>ر.</u>	I	I	r•
Carya	1	I	I	I	<b>~•</b>	<b>۰</b> ۰	×	I	I
Castanea	1	I	I	ı	×	X	I	I	I
Fagus	I	1	I	I	X	X	I	ł	I
Juglans	I	I	I	I	X	X	ł	I	ł
Liquidambar	I	1	I	I	×	X	ł	I	1
Quercus	I	I	۰.	۰.	×	×	×	X	I
Pterocarya	I	1	I	I	<b>۰</b> ۰	X	۰.	1	1
Tilia	I	ł	I	1	X	×	1	ı	I
Ulmus	I	ı	۰.	<b>ر،</b>	Х	×	i	I	I
Populus	ı	I	I	×	۰.	I	I	ł	<b>۰</b> ۰
Salix	I	ı	<u>ر</u> .	×	I	I	1	I	I
Potamogeton	×	I	I	I	I	I	I	1	I
lymphaea	×	I	I	I	ı	I	1	I	ł
Typha	<b>۰</b> ۰	×	۰.	1	1	I	1	ı	I
Compositae	ł	ı	I	<b>۰</b> ۰	<b>۰</b> ۰	۰.	<b>۰</b> ۰	×	۰.
Gramineae	I	ł	I	۰.	<b>۰</b> ۰	۰.	٢.	×	ł
Chenopodiaceae-									
Amaranthaceae	I	1	I	ł	1	1	1	X	ı
Leguminosae	I	ı	I	I	1	1	ł	X	I

Figure 9.--A generalized ecological classification of selected pollen types found in the Sucker Creek sediments. A dash (-) indicates the taxon in guestion was probably not present in a given community type, a guestion mark (?) indicates the taxon was probably present, but not in large numbers, while an (X) indicates the the taxon was probably present in significant numbers.

classify the more common components of the Sucker Creek microflora in terms of the presumed ecological affinities of the source plants.

Taking the flora as a whole, there are several distinct community types whose presence is indicated. Each of these will be considered in detail.

Lakes or Ponds. -- Potamogeton and Nymphaea are both genera which are indicative of ponds or lakes. In addition to these plants, algal material referable to the genus Botryococcus, as well as a number of unassignable algal cells and cysts, would strongly suggest the presence of impounded water in some configuration. Botryococcus is restricted to such environments and it is present in virtually all productive samples from all three study sections. The nature of the biotic evidence supports the hypothesis that most of the plant-bearing sediments accumulated in lacustrine basins, despite the fact that Kittleman (1962) considers most of the Sucker Creek sediments to have been fluviatile in origin. The individual basins may have been limited in extent but they must have been widespread in their occurrence to account for the lithological correlations which it is possible to make. Detailed study of the organic-rich sediments of the Valley section indicates that there were periodic incursions of coarser clastic material in the form of sand and mica flakes. Although it is possible that such material could accumulate in the marginal swamps associated with a single

large lake, periodic breeching of natural levees in a series of oxbow lakes closely associated with a large river system would appear to provide a more satisfactory model which would account for both the lacustrine and fluviatile nature of some of the Sucker Creek sediments.

Marshes.--Small numbers of Typha pollen grains are the only unequivocal evidence available for the existence of this community type. The poor representation of these pollen grains would indicate that large stands of the plant were not common and it seems reasonable to envision small marshy pockets, almost certainly associated with the oxbow ponds or lakes, as the likely habitat for the source plants.

<u>Swamps</u>.--Pollen grains of the Taxodiaceae are the only common type which are at all characteristic of this plant community. The presence of lignites, organic silt and mudstones, and highly organic shales at various levels in the study sections provides subsidiary evidence for the existence of localized swamps in which organic material was accumulating. It seems possible that both swamps and marshes were a natural consequence of the hydrologic succession developing from the ponds or lakes discussed previously. <u>Equisetum</u>, commonly found in many of the Sucker Creek sediments, may have played a role in the filling in of lake margins just as it does in parts of North America today.

Floodplain.--The existance of a major river system in the Sucker Creek area strongly suggests the existence of floodplain habitats. <u>Populus</u> and <u>Salix</u> would almost certainly be important members of such communities. Abundant leaves of <u>Platanus</u> from several localities, most notably the Maple Ridge site, provide subsidiary evidence. Leaves of <u>Salix</u> are extremely common at all localities. <u>Alnus</u> was probably associated with either a floodplain or lake-side community, for at times extremely large clumps of several hundred pollen grains can be noted in the organic facies. Such large aggregations suggest that alder clumps grew close enough to the water for entire catkins to drop directly into the basin.

Mesic Bottomland and Slope Forest.--The division between these two forest types is not clear and a gradational situation probably existed. These two forest types appear to have served as a source for the majority of the plants indicated from both the macrofossil and microfossil record. A diverse assemblage of maple, chestnut, beech, sweetgum, oaks, basswood, walnut and elm probably covered much of the lowlands, extending upward onto adjacent slopes. Soil and moisture patterns and varying slope exposures probably served to partition off the complex into a mosaic of community types. <u>Podocarpus</u> and <u>Cephalotaxus</u>, two genera native to the mountains of central and western China, are new records for the flora

and probably occurred as very rare plants in the lowland or slope forest.

Dry Slope Forest.--Drier sites, particularly those which might result from complex topographic relief, might be expected to support a somewhat less mesic oak-hickory forest complex which might tend toward pine dominance on sites where moisture was more limited. The Pine locality (Figure 1) is characterized by large numbers of pine needles, indicating that this genus may have formed extensive stands, but the sites were probably removed from the depositional basins at most locations since the plant is otherwise quite rare in the macro-fossil record. It is also possible that pine, in company with oaks and hickories may have played a successional role in the development of a more mesic forest community.

Xeric Communities.--The existence of certain xeric community types, either local or regional in extent, is suggested by the presence of pollen types such as the Compositae, Gramineae, Malvaceae (cf. Sphaeralcea) Chenopodiaceae-Amaranthaceae (cf. Sarcobatus), and pollen, thorns, and pods referable to the Leguminosae. The presumed distribution patterns and significance of this community type will be discussed in detail when the overall patterns suggested by the stratigraphic pollen sequence are considered in detail.

Montane Conifer Forest, -- The presence of large numbers of spruce pollen grains in company with those of fir and hemlock suggest a community type of boreal aspect. Since the bulk of the flora is decidedly temperate, although probably cool temperate, in aspect, the only reasonable model that would permit the close spatial association of a temperate deciduous forest and a forest of boreal affinities is the existence of diverse topography in the immediate area of the depositional basin. Although hemlock often occurs in relict enclaves in the Appalachians today (Braun, 1950), its most logical habitat in the Sucker Creek landscape was as a part of a slope transition forest tending into a spruce-fir forest at higher elevations. Alnus and Betula may have been part of this complex. It is also possible that aspens may have grown in this upland forest, but the fragile nature of Populus pollen makes it likely that most of the Sucker Creek Populus pollen was derived from cottonwoods along a floodplain near the depositional basin.

This classification of the macro-community types indicated by the Sucker Creek pollen record is completely compatible with the broad regional picture outlined by Axelrod (1968) who recognizes the following major forest types from the Miocene of the Snake River basin:

- I. Sub-alpine Conifer Forest
- II. Conifer-Hardwood Forest
- III. Mixed Deciduous Hardwood Forest

In his treatment of the Miocene Trapper Creek flora from southern Idaho, Axelrod (1964) recognized virtually the same array of major community types outlined in this chapter. Since the Trapper Creek flora consists primarily of fossil leaves, which presumably have limited dispersal capabilities, the consistent representation of the upland conifer forest suggests that the Trapper Creek sediments were deposited at a somewhat higher altitude than those of Sucker Creek, but that the regional flora may have been somewhat similar.

# Patterns of Vegetation Change During Sucker Creek Time

During the earliest part of the depositional interval, represented by the sediments at the base of the Valley and Shortcut sections, the pollen profiles suggest an extensive development of the mesic slope and bottomland forest types. A rich forest of oak and elm with maples, hickory, chestnut, beech, sweetgum, walnut, basswood, and wingnut (Pterocarya) probably covered much of the valley floor and extended upward onto adjacent slopes. The record of aquatic vegetation is meager and this, coupled with the coarse nature of the sediments suggests that deposition was probably confined to well-defined stream channels with relatively well-drained conditions throughout much of the valley bottom. The scarcity of Salix and possibly Populus pollen suggests that true floodplains may have been somewhat rare. The scarcity of taxodiaceous pollen suggests that swamps were not common. Somewhat
drier conditions probably existed on some slope exposures with oak-hickory forests grading into pine stands. These drier areas were close enough to permit relatively large quantities of pine pollen to enter the record, but not sufficiently close for deposition of other pollen types indicative of similar conditions. A montane conifer forest of spruce, fir, and hemlock undoubtedly covered extensive upland areas, extending down quite far toward the depositional basin. The fact that these pollen types are large and heavy, particularly the grains of fir, suggests that the high percentages contributed by these genera are a result of wind and water transport from extensive stands not far removed from the sites of sediment accumulation.

The abrupt change in the nature of the Valley and Shortcut sediments from coarse sand to shales and highly organic mudstones and siltstones suggests that extensive impoundment of water into ponds or lakes occurred at the time the sediments approximately half-way up the Valley section were deposited. The introduction into the pollen record of <u>Potamogeton</u> and <u>Typha</u> support the hypothesis that extensive quiet water conditions existed at this level in the section. At this point there begins a gradual rise in the percentage of taxodiaceous pollen suggesting that normal hydrologic succession was beginning to fill in the impoundments, producing swamps. An increase in the percentage of willow pollen, followed by a later increase in <u>Populus</u>, along

with a series of pulse-like increases in oak, might well represent a more extensive flood-plain component in the vegetation of the valley floor. The entire deciduous forest mosaic was probably developed on a more poorly drained landscape than had been the case previously and many small lakes may have been present.

These lakes began to fill with both organic and detrital sediments, producing swamps and wet areas of increasing extent as the area of open water was reduced. The relatively short persistence of Potamogeton in the central part of the sequence, coupled with a slight increase in cattail and a continued rise in the taxodiaceous pollen percentage all serve to indicate that such a successional sequence was occurring on the valley floor. Alder was probably part of this sequence and the major Alnus peak in all sections was probably a result of extensive development of shrubs on the wet margins of the lake basins. The rather sharp drop in spruce pollen which appears to be coincident with the alder peak in both the Valley and Shortcut sections requires careful analysis. In general, the deciduous pollen types drop only slightly or remain unchanged, suggesting that the rather precipitous drop in spruce pollen may reflect an upward withdrawal of the montane conifer forest, rather than a mere depression of the spruce curve due to the interactive nature of relative pollen diagrams. It is possible that there was a slight warming trend during this interval,

but this is hard to determine. The relative extent of both the montane conifer forest of the adjacent uplands and the deciduous forest of the valley floor undoubtedly underwent oscillations of varying magnitude depending on the local climatic pulsations during the interval in question. During the time represented by the upper third of the Valley section strata taxodiaceous swamps were quite extensive locally, probably as a result of filling of the local ponds or lakes. These extensive areas of shallowing water with a steady accumulation of mud and organic material resulted in ideal conditions for the preservation of fossil leaves and it is from these beds and their presumed equivalents in other isolated localities that the finest macrofossil record of the lowland deciduous forest complex is preserved. Figure 10 is a list of the various macrofossil taxa which are characteristic of this level in the section. It is also interesting to note that the finest specimens of Glyptostrobus, complete with attached male and female strobili, occur in these shale beds in the Valley section at the same stratigraphic level as the main peak in taxodiaceous pollen.

Aside from the presumed oscillations in the relative extent of the lowland deciduous and montane conifer forests and the apparent hydrologic successional sequence occurring in and around the depositional basins, the overall vegetation mosaic suggested by the pollen

Genus	Lower Section	Upper Section
Cephalotaxus	x	••
Picea	X*	
Pinus	X*	X*
Glyptostrobus	X*	2*
Thuja	Х	-
Cyperacites	X*	×*
Typha	X*	?
Acer	X*	X*
Ailanthus	Х	
Alnus	X*	*
Arbutus	Х	
Betula	X*	Х
Castanea	X*	X*
Cedrela	Х	Х
Cornus	Х	
Crataegus	Х	
Diospyros	Х	
Fagus	Х*	
Fraxinus	X	
Ilex	?*	X*
Mahonia	Х*	х
Nyssa	Х*	
Oreopanax		х
Ostrya	Х	
Platanus	Х	х
Populus	Х*	X*
Ptelea	Х	
Quercus	Х*	X*
Symphoricarpos		Х
Salix	Х*	X*
Tilia	Х*	
Ulmus	X*	?

Figure 10.--A list of selected Sucker Creek macrofossil
genera and their occurrence in the upper and
lower portions of the composite regional sec tion. An (X) denotes the presence of the
genus while a (?) indicates uncertainty due
to poor preservation and a limited amount of
material. An asterisk (\*) indicates that
pollen of the taxon also occurs at the indi cated level. The list was compiled from
Graham (1965) and material in the Michigan
State collections.

preserved in the Valley and lower Shortcut and Rockville sections appears to have been relatively consistent in composition.

The profound change which occurs in the nature of the pollen curves in the lower Shortcut and Rockville sections implies a significant change in the nature of the source vegetation. As previously stated, the pollen flora prior to the dominance shift is perfectly in accord with that of the entire Valley section, but in the green shale overlying the last of these beds the nature of the pollen flora is abruptly changed. Spruce pollen, previously so abundant, is reduced to insignificance or disappears entirely. Fir and hemlock pollen disappear as well. The pollen record of the montane conifer forest ceases to have any significance for the remainder of the sedimentary interval studied and it seems reasonable to assume that the entire forest type disappeared from the general area in which deposition was taking place. The deciduous forest growing at lower elevations appears to have undergone many changes as well. Elm, which had previously dominated the deciduous tree pollen complex disappears entirely, as do other mesic forest types such as birch, hornbeam, chestnut, beech, sweetgum, and walnut. Wingnut (Pterocarya) disappears from the Rockville area but persists in much reduced numbers at the Shortcut site. Alder and taxodiaceous pollen are both present, but at reduced numbers. Oak pollen may

be somewhat reduced in importance or may even increase, while willow, poplar, and maple also persist. The overall picture is one of reduced diversity in the deciduous forest component with the remaining types guite possibly associated closely with the drainage system. The local lowland flora may well have consisted of a riparian community with willows, poplars, maples, oaks, and sycamores as the major components. The latter is not present in the pollen record but its leaves are a common fossil of beds assigned to the upper portions of the Rockville-Shortcut complex and their equivalents. Figure 10 contrasts the somewhat limited macroflora of the beds of the upper part of the composite section with those of the lower section. The preponderance of willows, sycamores and oaks, particularly of the scrub-oak type, support the hypothesis that the upper Rockville and Shortcut beds record the presence of a comparatively depauperate flora of riparian aspect. Swamps were still present and a number of exotics, such as Cedrela and Glyptostrobus, continued to grow in the area, but in general, the diversity of the woody forest vegetation was much reduced.

An entirely new complex dominates the pollen above the transition level, indicating that a new series of community types was becoming important in the region. A variety of composite pollen grains, including a high percentage of grains of sagebrush (<u>Artemisia</u>), pollen

of the Malvaceae, including one type resembling Sphaeralcea, and the pollen of the Chenopodiaceae-Amaranthaceae strongly suggest a herbaceous component of decidedly xeric aspect. Pollen and thorns assignable to the Leguminosae and the pollen of grasses reinforce the concept of distinctly xeric communities that were probably somewhat removed from the stream valleys but still close enough to dominate the record at two of the three localities. The overall aspect of the region at this time may have been very much like that of the same area today. The dominant vegetation of the drier lowlands is sagebrush (Artemisia tridentata) and cheatgrass (Bromus tectorum), but if one travels from 3500 feet, typical of the fossil localities, to 6-7000 feet in the Owyhee mountains in the Silver City, Idaho area, the vegetation shifts from sagebrush dominance up through a juniper transition zone into a spruce forest zone on the higher In the case of streams however, the local vegepeaks. tation consists of a riparian flora of willow, poplar, and oak, as well as numerous herbs, in very close association with the drier sagebrush community and within site of the spruce forest of the upland. A similar situation, with a somewhat more diverse riparian community, may well have existed in the area in late Miocene time.

Pine pollen is very important in the upper part of the Rockville - Shortcut complex. The type characteristic of the lower part of the section is replaced by several

new types above the transition interval where the overall importance of pine pollen appears to gradually increase, barring small fluctuations, as one approaches the top of both the Rockville and Shortcut sections. The very high percentages, occurring in a sample collected several feet above the top of the measured Rockville section, correspond in their stratigraphic position to the beds of the Pine Locality (Figure 1) where numerous fascicles of pine needles have been found. A number of pine species were probably present in the area at this time occupying sites of varying elevation and exposure depending upon the tolerance levels of the various species.

The abrupt change in the nature of the pollen record in both the Rockville and Shortcut section undoubtedly represents a significant change in the nature of the source vegetation as outlined previously. Before the regional significance of this change can be assessed however, three factors must be considered:

- How much time was required for the shift in vegetation types?
- 2. What was the lateral extent of the modified community mosaic?
- 3. How long did the modified community structures persist in the area?

These questions are all critical to any discussion of the mechanism and significance of the observed shift in pollen dominance.

The amount of time required to bring about the shift is extremely important. The change may have been a

gradual one with the vegetation responding to long-term changes in climatic patterns, or it may have been rather abrupt. As previously stated, the observed shift in the pollen curves occurs abruptly in the sedimentary record but this in itself is not conclusive. A gradual shift may appear to be abrupt if there is a depositional hiatus or diastem in the sedimentary record. Unfortunately, there is little stratigraphic data which can be brought to bear on the problem. No evidence for such a depositional break was observed in the course of measuring and sampling the study sections. In the absence of evidence to the contrary, it must be assumed that there is no prominent break in the record at the critical level. Sedimentation may have been slow, but in geological terms the time interval during which the shift occurred cannot have been very great. Such a comparatively rapid shift would appear to favor a mechanism involving the action of local factors rather than the slower, long-term phenomena associated with widespread cliseral changes.

The question as to the lateral extent of the vegetation change can be answered with more precision. Both the Rockville and Shortcut sections clearly show the shift, while the Valley section, located to the south (Figure 1), shows little change at levels assumed to be of comparable age. There is a slight increase in some xeric forms, but the major displacement of the more mesic forest elements is not observed. If the beds at the top

of the Valley are contemporaneous with the critical strata at Rockville and Shortcut, then the changes occurring in the vegetation to the north are only slightly reflected in the sediments in the Valley area. It was not possible to locate conformable beds above the white ash layer in the Valley so that it cannot be said whether the shift in pollen dominance was a progressive one which worked its way south at a later time or if the situation recorded in the upper Valley beds and the middle of the Rockville-Shortcut complex represents a fairly stable readjustment of the aerial extent of the various community types.

There is no pollen evidence available to attempt an assessment of the length of time the new pattern of vegetation distribution may have persisted in the area. There is some indirect evidence available from fossil mammal remains from the type section of the Sucker Creek Formation, presumably of a somewhat younger age than the composite study sequence. According to Kittleman (1962) the mammals represent both streamside browsing and various grazing types. Such a fauna would be perfectly consistant with the environment postulated on the basis of the upper Rockville - Shortcut pollen profiles, but would be somewhat anomalous in the mesic deciduousmontane conifer forests of the early part of the sequence. The mammalian evidence would seem to provide a tentative basis for assuming that the modified riparian - xeric

complex of the upper part of the study sequence probably persisted at least until the end of Sucker Creek time (sensu latu).

In summary then, the change in dominance in the local flora occurred during a relatively short interval. The change was synchronous in an east-west direction but is only slightly reflected in the record an equal distance to the south. There is evidence that the change in the nature of the flora may have persisted at least through the remainder of Sucker Creek time. The principal question at this point is whether or not the observed changes in the nature of the vegetation in the Sucker Creek area are consistent with any of the hypothesis which have been advanced to describe the patterns of climatic change in the Pacific northwest during middle and late Tertiary Since most of the studies of fossil plants in time. western North America have been oriented toward reconstructing the environments under which the ancient floras grew, there is a great deal of data which can be brought to bear on the problem. Two principal theories regarding late Tertiary climatic trends have emerged. The first of these, summarized by Axelrod and Bailey (1969), theorizes that there has been a steady decline in effective temperature throughout the western United States since Eocene time and that the regularity of this decrease is interrupted at intervals by very sudden drops in effective temperature which are attributed to uplift activity.

Graphs which they have prepared for both eastern Oregon and western Nevada are reproduced in Figure 11A. These graphs were prepared on the basis of an exhaustive ecological analysis of a large number of Tertiary floras from the areas concerned. In Axelrod and Bailey's view, the major cause of variation in composition between floras of similar stratigraphic position is a result of altitudinal differentiation and the thrust of their paper is that a careful analysis of the composition of a flora may be used to determine the elevation at which the source plants were growing. Axelrod applies this technique in his treatment of the topographic history of the Snake River basin (1969).

The second theory, perhaps best exemplified by the work of Wolfe and Hopkins (1967), hypothesizes that the pattern of temperature change from Eocene to the end of the Pliocene was a somewhat aperiodic oscillation from periods of relative warmth to significantly cooler intervals. The latter part of their paleotemperature curve for northwestern North America covering the Oligocene and Miocene is reproduced in Figure 11B. The curve is constructed on the basis of a morphological analysis of the various leaf types using as evaluative criteria many of the observations originally made by Bailey and Sinnott (1915, 1916). Such a morphological approach to paleoenvironmental analysis was initially used by Chaney and



(8) summer wet summer OLIGOCENE MIOCENE ary ٤ ۰. ш WARI EMPERAT ٤ ш WARM ⊢ -EMPERATE TEMPERATE 000 C 0 0 L ⊢

FIGURE 11. Oligocene – Miocene temperature trends postulated on the basis of (A) ecological analysis (Axelrod and Bailey, 1969) and (B) leaf morphology (Wolfe and Hopkins, 1967).

Sanborne (1933) and the method is discussed in some detail by Dorf (1969).

In addition to temperature, another factor which must be considered for floras of late Tertiary age from both the Columbia Plateau and Great Basin provinces is the ever-decreasing rainfall resulting from the developing rainshadow which was a consequence of the gradual uplift of the Cascades to the west during the middle and late Tertiary time. Whatever the pattern of temperature change during this interval, a pattern of decreasing moisture availability must be superimposed upon it in order to arrive at some approximation of the general climatic regime under which a flora such as the Sucker Creek must have grown.

In comparing the nature of the change observed in the Rockville and Shortcut sections with the relatively uniform temperature and moisture declines which are a consequence of Axelrod and Bailey's model, it is apparent that major local factors would have to come into play to cause the shift in pollen dominance observed in the Sucker Creek sediments. In contrast, the temperature fluctuations inherent in Wolfe and Hopkin's model could, in company with declining moisture availability, provide sufficient climatic variability to be an important factor in causing the type of vegetation changes observed in the Sucker Creek area. The low temperature interval in late Miocene time (Figure 11B) is consistent with the presence

of a montane conifer forest in close proximity to a lowland deciduous forest of possible cool temperate aspect, characteristic of the lower part of the composite study section. Under such cool conditions, provided there was sufficient thermal equibility throughout the year, the ever increasing-moisture stress brought about by the uplift of the Cascades would have only a limited effect on the flora. An abrupt rise in temperature, such as that indicated on the graph following the late Miocene minimum, particularly if accompanied by a decrease in equibility, would certainly cause moisture availability to become a factor of increasing importance. As long as the various plant communities were able to maintain their integrity, microclimatic amelioration may have been sufficient to overcome the gradual increase in moisture stress, but any local events which would disrupt community integrity might well serve as a triggering factor resulting in a comparatively sudden shift to communities of decidedly more xeric aspect. It seems quite possible that the factors which could cause such local disturbances might be linked to the volcanic events which produced the sediments in which the flora was preserved. One such effect might be the damming and diversion of subsidiary drainage channels, resulting in pronounced moisture deprivation in areas downstream from the diversion.

A second and probably more significant factor might have been the localized destruction of vegetation due to gas

venting and ash falls. Such an effect was noted by Dorf (1945) in a study of the ash falls in the Paricutin area of Mexico. He noted that most of the forest vegetation within three miles of the cone was killed and that the resulting ash blanket ruined cultivated fields within the same radius. The extent to which the Sucker Creek forest may have been affected would depend on many factors but it is quite likely that re-establishment of the original vegetation on denuded sites might be much delayed and, in fact, might never occur if water availability were sufficiently critical. The Valley section might represent a more protected site further from the source of the ash where the original vegetation may have persisted with little change. To what extent the vegetation was altered over the entire region and whether we are observing just a small portion of a progressive decrease in the extent of the mesic forest vegetation can only be determined from additional studies in the same area.

The pattern shown by the Sucker Creek pollen profiles would appear to be consistent with the somewhat irregular temperature regime postulated by Wolfe and Hopkins (1967) rather than the uniform deterioration theorized by Axelrod and Bailey (1969). Both of these models are, by necessity, highly generalized and the extent to which short-termed variability played an important part cannot be determined due to the limited "resolving power" provided by paleobotanical studies within the region.

Situations such as that exemplified by the Sucker Creek pollen sequence almost certainly represent the product of the interaction of both local and long-term regional climatic factors.

Viewing the patterns of distribution of the various taxa from the leaf localities and comparing them to the picture provided by the pollen record provides a useful insight into the kinds of problems likely to be encountered in studying middle and late Tertiary floras. The relatively smaller number of taxa recorded from localities such as Specimen Ridge (Quarry), Maple Ridge, and the Pine Locality (see Figure 1) is not a matter of chance representation or poorer preservation characteristic of these highly indurated beds, but is, in fact, a faithful representation of the plants which were growing around the local basins. They do not reflect the more diverse flora of the lower part of the composite section but rather the comparatively depauperate riparian assemblage characteristic of the upper Rockville and Shortcut Although this is clearly evident when the sections. complete pollen profile is examined, it was not possible for Graham to recognize this because the rocks of the plant-bearing beds themselves are barren of pollen and these were the only strata examined in his study (1965).

It is highly undesirable to consider the plants from a number of florules to be representative of a single flora unless a number of conditions are satisfied. First, the

relative stratigraphic position of all of the important localities should be known. Secondly, the extent of variation in the composition of the various florules must be analyzed to determine, if possible, to what extent the variation reflects normal variability in representation and preservation or a significant difference in the nature of the source communities. Examination of the pollen of the leaf-bearing beds is not conclusive unless all localities are represented by pollen spectra. Macrofloral analysis provides a high degree of taxonomic resolution as well as providing representation for those taxa that would not otherwise appear in the pollen and spore record. Microfloral analysis can however resolve changes in the regional flora which might otherwise be masked in the comparatively localized representation provided by macrofossil deposits. Both approaches to floral analysis are complementary and both are preferred whenever possible. It is encouraging that such synthetic approaches are being increasingly applied to a number of the "wellstudied" Tertiary floras. The end result can only be a more complete understanding of the patterns of distribution and dynamics of the vegetation of a particularly critical period of earth history.

#### CHAPTER VI

#### SYSTEMATICS

### Nomenclature

The problem as to what constitutes a suitable system of nomenclature for Tertiary pollen and spores is a complex one for which a number of alternative suggestions have been proposed. An excellent account of the current status of the problem is summarized by Traverse Tertiary material is particularly difficult in (1955). a nomenclatural sense because it is amenable to treatment by either or both of two diametrically opposed approaches to the problem. The first approach is most commonly applied to Paleozoic and Mesozoic pollen grains and spores where the source plants can either be assumed to be extinct or at best, only distantly related to extant In such cases a system of form nomenclature, based taxa. primarily on the morphological attributes of the pollen grains or spores, can be used to good effect. Such nomenclature has been developed to a high degree of precision and is specifically provided for in the International Code

of Botanical Nomenclature (Lanjouw, 1966). Such systems are particularly useful for the stratigraphic palynologist and permit ready identification within the framework of the system. A fossil spore "species" in such a system is not equated with a biological species concept but is simply a convenient level of classification which could include one or more taxa of one to several ranks if it were possible to examine the source plants with the same degree of precision used for extant material. The vast literature on Mesozoic and Paleozoic palynology uses form taxa almost exclusively.

The second basic approach to the problem is encountered in pollen analysis of Pleistocene and modern materials where all of the pollen grains and spores encountered can be assumed to have been produced by plant species still recognized in the world's flora. The level of taxonomic precision which can be obtained in such studies is to some extent governed by the type of pollen and spore material being dealt with and the goals of the particular study. Studies dealing with the broad patterns of Pleistocene forest development for example might deal primarily with forest tree and shrub pollen identified to the generic level, while herbaceous plants might be identified only to family unless particularly distinctive forms were present. Other studies, such as unraveling the patterns of Pleistocene tundra development might require careful evaluation of herbaceous pollen at the generic and

even the specific level where possible. In all cases however, the prevailing nomenclatural practice is to assign the material to the lowest rank to which it can be identified with certainty. Alder pollen which could not be assigned to a modern species would be called <u>Alnus</u> or <u>Alnus</u> sp(p). Under no circumstances would an organ species be created to cover the pollen grains, for it is obvious that they are derived from a modern taxon already described under one or more binomials. The creation of a separate binomial to cover the pollen alone would be superfluous and such a practice would certainly be rejected by any competent pollen analyst.

It is in the treatment of Tertiary material that these two rational approaches often are ignored or are altered in a most confusing fashion. Part of the problem may be traced to the transitional nature of the Tertiary flora. Although most families and many genera of modern dicots are well established by Paleocene and Eocene time, it is highly unlikely that many "modern" species have persisted since the early Tertiary. Extensive analysis of late Miocene floras by Chaney and Axelrod (1959) indicates that many of the temperate plants are either morphologically indistinguishable or extremely similar to extant species. By Pliocene time most gymnosperms and woody dicots probably belonged to extant species. While the case with herbaceous dicots is less well understood, due to their poor representation in the fossil record, the

increasing weight of pollen evidence indicates that at least many modern genera and virtually all the typical herbaceous families were present by late Tertiary time (Leopold, 1969). In view of this pattern of development, a very persuasive case can be made for assigning most early Tertiary palynomorphs to form taxa in view of the uncertainty regarding the antecedents of the source plants. Since the rates of evolution of different taxa are likely to be different, numerous exceptions to this general practice can probably be justified, but in general assignment of angiosperm pollen from early Tertiary deposits to form taxa would appear to be a sound practice. An equally persuasive argument can also be made for assigning late Tertiary palynomorphs to modern taxa whenever possible (see Traverse, 1955).

Unfortunately, the situation is made somewhat complex by the existence of systems which attempt to combine the virtues of the two basic approaches outlined above. Systems such as that of Potonie', Thompson, and Thiergart (1950) involve the extensive use of organ genera which are linked etymologically with various modern taxa. Genera such as <u>Alnipollenites</u> are created to which any number of "species" may be assigned. Such a name represents a legitimate organ genus in the sense discussed by Schopf (1969) and is intended to indicate that the pollen included within the genus has the characteristics of Alnus. The practice of applying such names

to pollen from a late Tertiary flora such as the Sucker Creek is questionable at best. The genus Alnus is unequivocally present in the world's Miocene flora and the problem is reduced to the rather simple question of whether the pollen grains in question do belong to that genus. If, in the opinion of a competent researcher the material can be so assigned it is best referred to as Alnus and not to an artificial construct. Most modern plant taxa are rigorously described on the basis of their floral morphology, yet few taxonomists would consider modern binomials to represent "flower species" for the names have a much wider connotation. A modern plant taxonomist would have little hesitation about identifying a leaf of Alnus for example and few Tertiary paleobotanists would call a Miocene alder leaf Alniphyllites. Such a leaf would be referred to as Alnus with the same confidence that a pollen analyst would recognize dispersed Alnus pollen. The only realistic reason for assigning material to an organ genus is if the identification is suspect, and here we return to the nub of the problem. If, in the case of our hypothetical fossil pollen, the material cannot confidently be assigned to the genus Alnus, only two alternatives are possible. Either the material may be described as a member of the Corylaceae with uncertain generic affinities, or it must be assigned a form name. In either case, the use of the name Alnipollenites is patently misleading and should be avoided. Such use of

organ genera and the distortions of form systems such as the <u>halbnäturlische</u> system of Potonié imply a degree of taxonomic precision which is not present. Placing the pollen grains in question within the Corylaceae and indicating the extent to which they resemble and differ from <u>Alnus</u> pollen is a far better alternative and clearly states the degree of taxonomic uncertainty. If the grains cannot be assigned to a family then the application of a form name is certainly the only approach that does not imply more than is warranted based on the nature of the material.

Once the decision is made to assign the material to the lowest taxon of the lowest taxonomic rank, the problem of the application of binomials to fossil pollen material arises. Traverse (1955) assigns most of his Oligocene pollen to extant genera and erects new specific epithets for each type. The use of such a procedure in a flora such as the Sucker Creek where a well-studied macroflora is present provides a number of unique problems. Using the pollen of Quercus as an example, two or three distinct types of oak pollen may be recognized in the microflora but the status of these types is difficult to evaluate since most modern oak pollen cannot reliably be assigned to specific rank. If, after a review of the literature one were to decide that all three types of pollen were distinct from oak pollen previously described, then one approach might be to erect

three new species within the genus Quercus to describe the pollen in question. The subsequent problem is two-fold. First, there are between four and six well authenticated species of oak present in the macroflora. Due to the nature of the material and its close resemblance to modern species, assignments on the basis of the leaves are likely to be fairly reliable. Since all of these six species are likely to have produced pollen which would enter the record, it becomes obvious that one or more of our pollen "species" is composed of pollen produced by more than one "biological" species. Extensive study of leaf material over the years has resulted in the creation of fossil species which probably parallel a modern population concept quite closely. In the case cited above, there is no clear way to separate the "leaf" species from the "pollen" species although the two represent entirely different concepts. Rather than take a step backward and assign each type of material in the flora a different organ designation, the developing rationale has been to reserve binomials for material which is subject to rigorous analysis and to use less precise assignments to material that cannot be analyzed with the same precision. As mentioned previously, it is possible to assign the leaves to taxonomic categories closely paralleling a modern species concept and the use of binomials is entirely appropriate. Twigs and acorns of oaks cannot usually be separated with such precision

and is usually the practice to refer to them simply as <u>Quercus</u> sp. or spp. thus avoiding an unnecessary proliferation of names. The pollen presents the same problem as these less easily identified plant parts and rationally can be treated the same way. Oak pollen can be assigned to the genus <u>Quercus</u> and the various morphological types discussed in terms of their probable or possible affinities within the genus without creating "species" which have little biological integrity.

Similar problems arise if the material is assigned to pollen "species," within an extant genus, previously described in the literature. The use of the same binomial for material from two different floras implies a biological equivalency despite the fact that the "species" is based purely on morphological grounds. The morphological species concept is the core of paleontological practice in the widest sense, but is valid primarily in the framework of a form or organ nomenclature. If a morphospecies is erected within an extant genus, there is no way, based on the form of the name, to differentiate this "species" from those erected on a firmer systematic basis. If a flora consists of several species, some of which parallel and probably correspond to a modern population concept and others erected on morphological grounds, the status of the genus within the flora becomes more confused rather than clearer.

In order to eliminate such ambiguities as much as possible, the following system will be adhered to in treating the Sucker Creek palynomorphs. First, material will be assigned to the lowest taxonomic rank where identification is reasonably certain, usually a genus. If the pollen grains or spores resemble those of a still lower rank but problems exist in that placement, they will be discussed under the designation of the higher rank. Pollen grains or spores which were not identified to an extant family or genus are treated at the end of the systematics chapter under their survey designations. In the event that the material assigned to a given family or genus is widely known under a binomial or form designation, this will be mentioned in the discussion of the taxon in question.

## Systematic Descriptions

#### ALGAE

Division CHRYSOPHYTA Genus BOTRYOCOCCUS Kützing

### (Plate 3-18)

The interconnected cup-like waxey bodies constituting the remains of this alga are identical in every respect to those of the extant species <u>B</u>. <u>braunii</u>. This genus has not previously been described from the flora although it has been found in Tertiary deposits from most continents. Traverse (1955) gives an excellent summary of the Tertiary distribution of the genus as well as discussing its pre-Cenozoic record. The genus has an extensive fossil history and appears to have been one of the prime constituents of boghead coals (Bertrand, 1927, 1928). Colonial masses of <u>Botryococcus</u> are the most common fossils of non-vascular origin in the Sucker Creek sediments and are often preserved when fossil pollen grains and spores are either absent or highly corroded. They appear to occur in small numbers in the fine-grained organic beds of the Valley and lower Shortcut and Rockville complex.

Location: Pb-9245-1 V+4.7xH14.8

Algal Remains of Uncertain Affinity

### Type 1

### (Plate 3-16)

This cellular filament is morphologically similar to those of various filamentous Chlorophyta but it cannot be stated with certainty that it is not a septate mycelium. Filaments of this type have not previously been described from the flora.

Location: Pb-9211-1 V+4.6xH10.0

# <u>Type 2</u>

## (Plate 3-17)

These filaments of spherical cells resemble those of certain of the Nostocaceae in the Cyanophyta but such a placement is tentative. Filaments of this type are a new addition to the flora. They are comparatively rare. Location: Pb-9191-3 V+6.2xH11.5

## Type 3

## (Plate 3-14)

These entities consist of short uniseriate filaments with rounded cells at their ends. They compare quite closely with hormogonia produced by members of the Oscillatoriaceae in the Cyanophyta. They are found throughout the study sections but are usually somewhat rare. Remains of this type are a new addition to the flora.

Location: Pb-9196-1 V-2.9xH9.5

### Type 4

#### (Plate 3-9)

Only a single specimen of this type was noted during the study. It may represent an algal hormogonium but the assignment is highly tentative.

Location: Pb-9196-1 V+8.4xH25.9

#### FUNGI

The role and utility of fungal spores in palynology is discussed by Graham (1962) but in actual practice little use is made of fungal material. The principal problem lies in the identification of dispersed spores. The morphology of most fungal spores is so generalized that identification to any meaningful level is usually not possible. Somewhat more complex structures such as sporangia, fruiting bodies, or differentiated hyphae may be somewhat more diagnostic. Fungal bodies are found throughout the study sections and are among the more common palynomorphs.

# Genus ALTERNARIA Nees emend Wiltshire

### (Plate 3-11)

The characteristic conidiophores of this member of the Monoliniales are the only fungal entities which can confidently be identified to the level of genus. According to Alexopoulos (1952) the genus causes leaf spot diseases in several crops. Various leaf spots, probably of fungal origin, may be noted on many of the fossil leaves in the macroflora and it is possible that the genus may have played a role as a leaf parasite in the Sucker Creek forest. According to Johnson and Sparrow (1961), members of the genus are commonly found growing on submerged wood in fresh and mildly brackish water. Pady and Kapica (1954) reported Alternaria conidiophores in over 2 per cent of the air samples obtained over the open ocean. In view of these observations, the genus is likely to be well represented in a variety of deposits and its presence is not likely to have any environmental significance.

Location: Pb-9191-3 V-5.4xH27.0

Fungal Remains of Uncertain Affinity

## Type 1

### (Plate 3-1)

Spores of this type are not common and appear to be confined to organic sediments. The general aspect of these spores is similar to that of <u>Cladisporium</u> in the Monoliniales. <u>Cladisporium</u> is a genus of stem parasites. Spores of this type have been previously described from the flora by Graham (1965).

Location: Pb-9157-1 V+7.4xH15.8

# Type 3

## (Plate 3-2)

This body resembles the terminal chamber of an elongate conidium similar to Type 19 illustrated in Plate 3-12. This form is found in small numbers throughout the section.

Location: Pb-9157-2 V+5.6xH14.8

## Type 4

## (Plate 3-3)

This spore superficially resembles those of Type 7 except that it lacks the fine wall markings. The biological affinities are unknown. Spores of this type are found in the organic beds of all sections studied.

Location: Pb-9157-1 V-0.8xH17.3

## Type 5

## (Plate 3-15)

The botanical affinities of this body are obscure. It occurs in the organic beds of all three study sections and is easily recognized.

Location: Pb-9157-2 V+3.7xH25.6

## Туре б

### (Plate 3-7)

This body probably represents a two-chambered ascus. Remains of this type are found throughout the study sections.

Location: Pb-9158-1 V+4.1xH16.1

### Type 7

### (Plate 3-5)

The botanical affinities of this spore are unknown. It is easily recognized by its somewhat tear-drop shape and the fine radial striations on the wall. It is found in the organic facies of all the study sections.

Location: Pb-9158-6 V+4.0xH17.8

# Type 9

### (Plate 3-6)

This spore is a larger variant of Type 1 and may also represent <u>Cladisporium</u>. Its distribution in the study sections is essentially the same as that of Type 1. Location: Pb-9157-6 V-1.9xH8.7

## Type 12

## (Plate 3-4)

This type is comparatively rare and confined to the organic facies of the study sections. It may represent a two-chambered ascus but this is a tentative assignment.

Location: Pb-9158-7 V+9.6xH13.5

## Type 14

#### (Plate 3-13)

The botanical affinities of this interesting twochambered structure are unknown. The complex pore-like perforations in the end walls may represent a dispersal mechanism or they may have been produced as a result of differential decay. Only a single specimen was noted.

Location: Pb-9165-6 V+7.3xH11.8

# <u>Type 15</u>

## (Plate 3-8)

Only a single specimen of this type was found and its botanical affinities are unknown.

Location: Pb-9182-1 V+8.3xH5.0

# <u>Type 16</u>

## (Plate 3-10)

These small spherical spores have a minutely spinulate spore coat which is quite characteristic. They undoubtedly represent the dispersed spores of some basidiomycete. Spores of this type are rare but may be found throughout the study sections.

Location: Pb-9186-1 V0.0xH14.2

## Type 19

# (Plate 3-12)

A single specimen of this type was noted. It appears to be a septate conidium and its affinities are probably with the Monoliniales.

Location: Pb-9211-1 V+6.6xH23.4

# Type 21

# (Plate 3-19)

Only a single specimen of this highly characteristic form was noted in the course of the study. The specimen was recovered from the lower Valley section and its botanical affinities are unknown.

Location: Pb-9260-1 V+5.4xH13.7
# Division TRACHEOPHYTA Sub-division LYCOPSIDA

# Genus LYCOPODIUM L.

There are two distinct types of <u>Lycopodium</u> spores present in the flora. The types are morphologically distinct and would appear to indicate the presence of at least two species.

# Type 1

# (Plate 4-3)

The spores of this type measure from 35 to 45 micrometers from an apex to the center of the opposite side. They are sub-triangular in shape and have a rugulate surface texture similar to the living <u>L</u>. <u>inundatum</u>. This type of spore is a new record for the flora and it is found in the Valley and lower Shortcut and Rockville sections.

Location: Pb-9223-1 V+1.1xH21.3

# Type 2

# (Plate 4-9)

These spores appear identical with the Lycopodium spores previously described from the flora by Graham (1965). They are sub-triangular in shape and measure 30 to 40 micrometers from apex to the center of an opposite side. The surface is strongly reticulate and the spores appear similar in all respects to those of the extant <u>L</u>. alpinum and <u>L</u>. complanatum. Spores of this type are not common and occur in the Valley and lower Shortcut and Rockville sections.

Location: Pb-9263-1 V+10.4xH9.4

Sub-division PTEROPSIDA Class FILICINEAE Family OSMUNDACEAE Genus OSMUNDA L. (Plate 4-8)

Only a single spore referable to this genus was found in the course of the study. The specimen was recovered from the Valley section and it seems probable that the source plants were present in only small numbers and in particularly moist and favorable habitats. The specimen is similar to a specimen figured by Graham (1963) which he calls <u>O</u>. <u>claytonites</u>. It is sub-spherical measuring approximately 40 micrometers in diameter. The rays of the trilete scar measure approximately 16 micrometers in length. Spores of similar size and morphology have been isolated from a variety of western Tertiary sediments and are commonly referred to as <u>Osmundacites wellmanii</u> in the palynological literature.

Location: Pb-9322-1 V+7.2xH12.7

# Family POLYPODIACEAE

Genus POLYPODIUM L.

(Plate 4-2)

These spores are quite similar to those produced by the living <u>P</u>. <u>vulgare</u> and are the only ones within the family that can be assigned to a genus with some degree of certainty. The spores are monolete and reniform, ranging in size from 35 by 45 to 50 by 70 micrometers. The single scar is 30 to 40 micrometers in length and the surface of the spore is characteristically rugulate. Spores of this type were previously described from the flora by Graham (1965). They are very common in some beds at the middle of the Valley section and comparatively rare elsewhere.

Location: Pb-9268-3 V-3.7xH10.6

Polypodiaceae Spores of Uncertain Generic Affinity

# <u>Type 1</u>

# (Plate 4-7)

These small reniform monolete spores average 17 by 26 micrometers in size. They represent the smooth endospore which remains after the sculptured exospore has been shed. Because of their generalized features they cannot be assigned to any particular genus. Spores of this type occur in small numbers throughout the study sections.

Location: Pb-9157-1 V-8.1xH12.5

# Type 2

# (Plate 4-1)

These spores are uniformly larger than those of Type 1, averaging 30 by 45 micrometers in size. They are monolete with the smooth reniform shape characteristic of endospores within the Polypodiaceae, but cannot reliably be assigned to any particular genus because of their generalized morphological features. Graham (1965) identified spores of this type as Woodwardia on the basis of the occurrence of Woodwardia fronds in the macroflora. Although such occurrences are useful in indicating possible affinities of the spores, the use of such a procedure in identifying the dispersed spores is completely inadmissable. There is at present no unequivocable evidence for the presence of Woodwardia in the microflora although it is likely that some of the spores of this type may have been produced by the genus. Spores of this type are found in small numbers throughout the study sections, particularly in the organic facies.

Location: Pb-9157-1 V-8.7xH12.6

# VASCULAR PLANT SPORES OF UNCERTAIN

#### SYSTEMATIC POSITION

#### Monolete

# Type 1

# (Plate 4-4)

The spores of this type are reniform, ranging in size from 25 by 42 to 30 by 50 micrometers. The surface

is densely fimbriate but it has not been possible to determine if this is the original condition of the spores or whether it is the result of differential decay or the accumulation of organic debris. The spores occur in small numbers in the Valley and lower Shortcut and Rockville sections.

Location: Pb-9308-3 V+7.4xHl4.6

# Type 2

#### (Plate 4-5)

Only a single specimen of this type was noted in the study. It is ovate, 34 by 44 micrometers in size and has a single scar which is visible on the upper surface in the illustration. The surface is verrucate. The spore was recovered from the organic beds near the center of the Valley section.

Location: Pb-9324-3 V+9.7xH11.1

# Trilete

# Type 1

# (Plate 4-10)

The spores of this type are sub-triangular, measuring approximately 36 micrometers from an apex to the center of the opposite side. The surface is coarsely granulate and the trilete scar is bordered by a thickened ridge with a rugulate texture. It was not possible to relate this type to any particular modern group. A small number of specimens were observed in preparation from the organic beds at the middle of the Valley section. Location: Pb-9158-7 V+13.5xH16.1

# Type 2

#### (Plate 4-6)

Only a single specimen, recovered from the base of the Rockville section, was noted in the course of the study. It measures approximately 26 micrometers in diameter and has a smooth surface somewhat pitted by differential corrosion.

Location: Pb-9182-1 V+7.9xHll.6

Class GYMNOSPERMAE

Family PINACEAE

Genus ABIES L.

(Plate 5)

Two types of <u>Abies</u> pollen were observed during the study. Pollen of the genus is characterized by large size, a pronounced re-entrant angle between the bladders and cap, and a sharp transition in sculpturing between the cap and bladders. Graham (1965) considered <u>Abies</u> pollen to be relatively rare in the Sucker Creek microflora but this is definitely not the case. <u>Abies</u> pollen is confined to the Valley and lower Shortcut and Rockville sections but where it is present it often reaches levels of 10 percent of the total number of pollen grains and spores. The pollen grains of <u>Abies</u> are quite large and heavy and representation at a level of up to 10 percent would indicate that fir stands were often present near the depositional basin.

#### Type 1

#### (Plate 5-1)

This is the most common type accounting for over 95 percent of the fir pollen counted during the quantitative phase of the study. The cap is thick and measures between 120 and 140 micrometers across. The bladders are attached with a pronounced re-entrant angle and measure between 85 and 100 micrometers in diameter. The cap is rugulate while the bladders have a reticulate pattern superimposed on a rugulate surface texture. This type appears identical to the form described by Graham (1965). The various modern equivalents of the various fir species described from the Miocene of the Columbia Plateau intergrade to such a degree in their pollen morphology that it is not possible to make a specific determination on the basis of the fossil pollen.

Location: Pb-9157-1 V+9.4xH17.5

# Type 2

#### (Plate 5-2)

This pollen type is comparatively rare and appears to be confined to the Valley section. The cap is quite thick and measures approximately 90 micrometers across with a finely rugulate surface texture. The bladders are coarsely reticulate and measure 58 to 65 micrometers in diameter. Grains of this type have not previously been described from the flora and it has not been possible to relate the pollen to any modern species.

Location: Pb-9158-1 V-5.2xH16.0

Genus PICEA L.

# (Plate 6)

Pollen of spruce is one of the most significant components of the microflora and is dominant at many levels in the Valley and lower Shortcut and Rockville sections. The pollen occurs in two forms which can usually be readily differentiated unless the orientation of the grain is extremely poor.

#### Type 1

#### (Plate 6-1)

This grain is the larger of the two types and is generally the most common. The grains commonly measure between 100 and 130 micrometers across the cap with the entire grain measuring 130 to 150 micrometers in length. Both the cap and bladders are rugulate. Although not figured, this is undoubtedly the larger of the two types discussed by Graham (1965) in his treatment of the spruce pollen of the microflora. Grains of this type are quite similar morphologically to those of the living <u>P</u>. likiangensis.

Location: Pb-9157-1 V+10.2xH19.1

#### Type 2

#### (Plate 6-2)

This pollen type is typical of that illustrated by Graham (1965) and is quite similar to that of the living <u>P. engelmanni</u>. The bladders are commonly folded quite close to the body of the grain, the latter measuring from 96 to 120 micrometers in length. The cap and bladders range from verrucate to rugulate in surface texture.

Location: Pb-9158-7 V+18.0xH5.3

# Genus PINUS L.

Pine pollen is a major constituent of the pollen spectra at all levels in all sections. Five morphological types (1, 2, 4, 5, 6) are recognized in the present study.

# Type 1

#### (Plate 7-2)

The bodies of the grains measure 45 to 55 micrometers across and have a finely rugulate surface texture. The bladders are finely reticulate and usually somewhat flattened. This appears to be the same type as illustrated by Graham (1965). It strongly resembles the pollen of <u>P</u>. <u>strobus</u> and <u>P</u>. <u>monticola</u>, both of which are similar in their vegetative morphology to <u>P</u>. <u>wheeleri</u>, a widely distributed species in the Miocene of western North America. This type reaches its greatest numbers in the Valley and lower Shortcut and Rockville sections, but may be found in the upper part of the latter two sections in somewhat reduced numbers. <u>P. baileyana</u>, a pollen type described by Traverse (1955) from the Brandon lignite of Vermont (Oligocene?), is almost identical to this pollen type.

Location: Pb-9169-3 V+20.1xH11.4

# Type 2

#### (Plate 7-6)

Pollen of this type appears confined to the lower part of the Valley section. The cap averages approximately 35 micrometers long and is quite thick for its size. The bladders vary from 25 to 34 micrometers in diameter and are often somewhat flattened with an auriculate margin where they are folded against the body of the grain. Pollen of this type has not previously been described from the flora and it has not been possible to relate it to a species within the genus although the grains resemble those of <u>P</u>. <u>remorata</u> of the western United States.

Location: Pb-9157-1 V+6.2xH14.6

# Type 4

# (Plate 7-4)

Grains of this type range in size from 30 to 40 micrometers across the cap with the bladders averaging approximately 25 micrometers in diameter. The bladders are coarsely reticulate and the body ranges from granular to finely vertucate. This pollen type has not previously been described from the flora and its affinities within the genus are not known. It is a comparatively rare pollen type which is distributed throughout the study sections.

Location: Pb-9157-6 V+1.1xH7.9

#### Type 5

#### (Plate 7-5)

This pollen type closely resembles the pollen of the living <u>P</u>. <u>muricata</u> and is characterized by a shallow re-entrant angle at the point of attachment of the bladders and cap. The body measures 50 to 60 micrometers in length with its texture ranging from verrucate to rugulate. The bladders are coarsely reticulate and average approximately 30 micrometers in diameter. This pollen type has not previously been described from the flora. Morphologically it is identical to <u>P</u>. <u>pristipollinia</u>, a pollen type described by Traverse (1955) from the Brandon lignite of Vermont. It is found in the upper half of the Rockville and Shortcut sections.

Location: Pb-9191-3 V-5.2xH13.0

# Type 6

#### (Plate 7-3)

This pollen type has a body ranging from 45 to 55 micrometers in length with bladders averaging 33 micrometers in diameter. There is a sharp re-entrant angle at the point of attachment of the bladders and cap. The body is granular to finely rugulate and the bladders are coarsely reticulate. This pollen type is a new addition to the flora and strongly resembles the pollen of the extant <u>P</u>. <u>contorta</u>. It is found in the upper half of the Rockville and Shortcut sections.

Location: Pb-9191-3 V+6.3xH11.5

Genus TSUGA L.

#### (Plate 7-1)

The hemlock pollen observed during the study is spherical, ranging from 70 to slightly over 100 micrometers in diameter. The surface is convoluted and one side of the grain tends to be collapsed due to a thinning of the exine in that area. The exine often becomes somewhat separated from the body of the grain giving it the appearance of being surrounded by a sac-like bladder. This pollen type was first described from the flora by Graham (1965) who considered it to resemble the pollen of <u>T. heterophylla</u>, an extant species growing in western North America. Pollen of this type is confined to the Valley and lower Shortcut and Rockville sections. It may reach relative percentages as high as 5 percent but values of 1-2 percent are more common.

Location: Pb-9158-1 V-6.1xHl6.8

# Family PODOCARPACEAE

Genus PODOCARPUS L'Herit. ex Pers.

# (Plate 7-8)

Pollen of this genus is a new record for the flora and may represent the youngest known record of the genus in the Tertiary of North America. The cap ranges from 30 to 40 micrometers across and is deeply convoluted, characteristically staining very deeply. The bladders are large in relation to the body of the grain and are coarsely reticulate. The length of intact grains varies from 68 to 82 micrometers. The grains are apparently confined to the Valley section where they occur at levels of 1-2 per 1000 in the organic sediments in the middle of the section. Podocarpus has long been considered to have had only a Mesozoic distribution in North America but recent studies indicate that it may have had a distinct if somewhat limited role in various Tertiary floras. The first authenticated occurrence of Tertiary leaf material was reported by Dilcher (1969), who was able to recover Podocarpus cuticular material from the Eocene deposits of Puryear, Tennessee. This find, coupled with occurrences of pollen of the genus in Tertiary deposits (Sparks, 1967 and Leopold, 1969) would appear to indicate that the genus was present and somewhat widespread in early Tertiary time in North America. The presence of pollen of the genus in the Miocene Sucker Creek flora probably represents the latest record of the genus in North America. Although

it cannot be demonstrated with certainty, the overall patterns of derivation of plants from temperate Tertiary floras in western North America would favor the hypothesis that the source plants for the pollen were probably derived from temperate Asian forms rather than sub-tropical or southern hemisphere species. P. macrophylla of Japan and P. neriifolia of mainland China are two species which appear likely as possible analogues of the Sucker Creek source plants. P. neriifolia is widely distributed from the Himalyas to southwestern China (Lee, 1935), while P. macrophylla is to be found in warm to moderate temperate areas in Japan. It is possible that Podocarpus occupied habitats of a somewhat sheltered nature and was probably to be found in small numbers in the more mesic lowlands rather than the more rigorous sites on the higher slopes. The trees may have persisted in the areas as relicts, only to be eliminated during the drying interval indicated during the latter part of the Rockville -Shortcut sequence.

Location: Pb-9157-3 V-4.6xH7.1

#### Family TAXODIACEAE

#### (Plate 7-7)

Identification of pollen assigned to the Taxodiaceae (TCT) cannot be accomplished at the generic level with any degree of reliability using the light microscope. Criteria for distinguishing individual genera (see Traverse, 1955) will partition out the various morphological types present

in the flora but these various types have no consistent relationship to the identity of the source plants. Taggart (1967) applied the criteria outlined by Traverse (1955) to the range of variability presented by Taxodium pollen preserved in modern sediments in southern Illinois cypress swamps. Based on their morphology, it was possible to recognize the presence morphological analogues of Taxodium, Glyptostrobus, Metasequoia, and Sequoia. Since Taxodium was in actuality the only source plant, it was felt that the morphological criteria resulting in such incorrect determinations should be rejected. On the basis of plants known to have been growing in the Columbia Plateau region during Miocene time, two genera, Taxodium and Glyptostrobus emerge as the two likely possibilities for the Sucker Creek source plants. Glyptostrobus is found in the macroflora while Taxodium, although widely distributed in floras of similar age, is not. On this basis alone, it is highly likely that a great deal of the taxodiaceous pollen is derived from Glyptostrobus. In addition, the peak in TCT pollen in the Valley section corresponds to a peak in the occurrence of Glyptostrobus macrofossils. At least some of the fossil wood in the upper Rockville organic beds is assignable to the Taxodiaceae and provisionally has been placed in the genus Glyptostrobus. Although it must be admitted that Taxodium or even other genera in the family may have grown in the area without being represented in the macroflora, it appears probable that much of the TCT

pollen in the Sucker Creek sediments was derived from <u>Glyptostrobus</u>. It must be emphasized however that this conclusion is inferential and is in no way based on the morphology of the fossil pollen grains.

The grains themselves are typically 25 to 32 micrometers in diameter and may assume a variety of forms, all of which are ultimately derived from an original spherical form. The specimen illustrated shows a gaping ruptured sphere with a small germinal papilla, typically assigned to the form species Taxodiaceaepollenites hiatus (Pot.) Kremp. Another form, often referred to the genus Sequoia or its "form" equivalents, consists of unruptured grains with a somewhat longer papilla. Another common configuration consists of collapsed and folded grains, often referred to as Glyptostrobus. The form illustrated is the most common, but a complete series of gradational forms may be found reinforcing the authors opinion that no valid distinctions within the family may be made on the basis of pollen morphology observed with the light microscope.

Location: Pb-9158-1 V+4.1xH17.3

#### Class ANGIOSPERMAE

# Sub-class MONOCOTYLEDONAE

#### Family GRAMINEAE

Grass-like pollen is a common constituent of the microflora but the generalized morphological features of

the pollen grains do not permit them to be identified with any precision below the level of family. Pollen of the family typically has a thin hyaline exine with a single pore. The latter is often surrounded by thickened annulus. In the fossil material the pore is rarely observed due to the ease with which the grains are collapsed and torn. Tearing commonly involves the pore structure and it is not possible to demonstrate its presence in all cases.

# <u>Type 1</u>

# (Plate 9-2)

This is the most common type encountered, comprising over 90 percent of the grains assigned to the family. The hyaline exine is typically folded and torn. The grains range in size from 30 to 50 micrometers. Due to the distorted nature of most of the material it is possible that some grains belonging to the Cyperaceae may have been tallied in this group.

Location: Pb-9157-1 V+8.6xH14.0

# Type 2

#### (Plate 9-3)

In this form the pore is commonly preserved, probably due to the thicker and somewhat more resistant exine. In the specimen figured the pore is visible in optical section at the top of the pollen grain. The grains are somewhat ovate measuring 25 to 35 by 35 to 45 micrometers. The pore is approximately 4 micrometers in diameter. This form is not common and is confined to the upper Shortcut and Rockville sections.

Location: Pb-9230-1 V-5.8xH9.3

# Type 3

# (Plate 9-4)

This form is somewhat smaller than the previous types ranging from 22 to 28 micrometers in diameter. The pore is usually visible and the grains are rarely collapsed, probably due in part to their smaller size. This type is rare and only a small number of grains were observed in the upper Rockville section.

Location: Pb-9191-3 V-5.9xH27.4

Family POTAMOGETONACEAE

Genus POTAMOGETON L.

#### (Plate 10-5)

Pollen of this genus was first described from the flora by Graham (1965). The grains are spherical, inaperturate, and have a well-developed reticulum. They range in size from 30 to 35 micrometers. It is not possible to relate the fossil material to any extant species due to the generalized nature of the pollen within the genus. It is found in the upper Valley and lower Shortcut and Rockville sections and is one of the types used as an indicator of open water habitats.

Location: Pb-9158-1 V-2.7xH17.0

Family TYPHACEAE

Genus TYPHA L.

(Plate 10-10)

These grains are typically spherical with a single aperture. The borders of the pore are somewhat diffuse and the grain has a reticulate exine structure. The grains range from 25 to 30 micrometers in diameter. Pollen of this type was previously described by Graham (1965). It appears to be most closely allied to <u>T</u>. <u>angustifolia</u>, based on the fact that the grains are shed singly rather than in rhombohedral tetrads. Grains of the latter type are characteristic of <u>T</u>. <u>latifolia</u>. The pollen is found at intervals throughout all of the study sections but the grains are never very common.

Location: Pb-9158-1 V-2.0xHll.8

Sub-class DICOTYLEDONAE

Family ACERACEAE

Genus ACER L.

Maple pollen is relatively common in the macroflora and two general types are recognized. There are undoubtedly more than two taxa represented, but separation of even modern material at the species level is extremely difficult. There are six species of maple recognized from the Miocene of the Columbia Plateau and all of them occur in the macroflora (Graham, 1965). Future study may serve to partition the maple pollen complex into groups

that more closely approximate individual species or groups of species.

#### Type 1

# (Plate 8-1)

These grains are tricolpate with the colpi reaching almost to the poles. The grains are prolate and measure approximately 25 by 35 micrometers. The exine has a clear striate pattern which makes this type easy to recognize. Graham (1965) illustrates pollen of this type and cites its similarity to that of <u>A</u>. <u>negundo</u>. Grains of this type are found throughout the study sections but are most numerous in the Valley and lower Shortcut and Rockville sections prior to the floristic transition. Box elders were probably members of the floodplain community and persisted in this role after the majority of the mesic forest trees had disappeared from the area.

Location: Pb-9158-7 V+17.1xH10.7

# Type 2

# (Plate 8-2)

Except for its larger size and somewhat more gaping colpi when viewed in polar view, the overall characteristics of this type are similar to Type 1. The grains range in size from 37 to 42 by 49 to 61 micrometers. The character of the striae suggest that this type may be allied to the <u>A. saccharum</u> - <u>A. grandidentatum</u> group. This type is confined to the lower part of the composite section and was first described by Graham (1965). It is interesting to note that the overall peak in <u>Acer</u> pollen, composed primarily of Type 2, occurs in the fossiliferous shale of the upper Valley section where very fine maple leaves have been collected.

Location: Pb-9268-3 V+0.1xH7.7

# Family AQUIFOLIACEAE

# Genus ILEX L.

The fossil record of <u>Ilex</u> in the Miocene of the Columbia Plateau is very limited. Only one species, <u>Ilex fulva</u>, occurs in the macroflora and it is quite rare. Holly pollen has not previously been recognized in the flora but two types were noted in the present study. Both types are limited in occurrence being confined to the organic sediments near the middle of the Valley section. It is possible that the source plants for both types were associated with the development of the swamps which appear to have been present at that time.

# <u>Type 1</u>

#### (Plate 9-5)

The grains range in size from 19 to 22 by 31 to 37 micrometers. The surface is densely covered by clavae up to 2.5 micrometers in length. The grains are tricolpate with the furrows constricted at their midpoint. This constriction is often obscured by the dense sculpturing of the exine.

Location: Pb-9157-1 V-7.8xH32.9

# Type 2

# (Plate 9-6)

The grains of this type are of the same general size as those of Type 1 but the clavae are uniformly smaller, averaging approximately 1 micrometer in length. The furrows also have very little constriction at their centers.

Location: Pb-9264-1 V+7.6xH16.5

The two pollen types described are quite distinct and no gradational forms were noted in any of the grains examined. Traverse (1955) describes several <u>Ilex</u> "species" in the Brandon lignite pollen flora but the Sucker Creek material does not resemble any of them. On the basis of the pollen data it would appear that at least two species of holly grew in the Valley area during Sucker Creek time but they were probably not common. The lack of a complete suite of reference material made it impossible to relate the fossil material to any modern species.

Family BERBERIDACEAE

Genus MAHONIA Nutt.

(Plate 10-1)

Three species of <u>Mahonia</u> are presently recognized in the macroflora (Graham, 1965), two of which are allied

to species now growing in eastern Asia and one of which is presently found in western North America. The Mahonia pollen found during the present study is a new record for the flora. The grains are tricolpate and spheroidal, ranging from 35 to 43 micrometers in diameter. The surface ranges from coarsely granular to finely verrucate. The furrows usually gape giving the grains the appearance of an incised sphere. The fossil material closely matches pollen of M. aquifolium in the Michigan State reference collection, but there was not enough material available from other species to fully evaluate the status of the fossil material. Although Mahonia leaves are well represented in fossil deposits of late Tertiary age from western North America, this is the first record, to the author's knowledge, of pollen of the genus. Pollen of this type occurs in most samples from the Valley and lower Rockville and Shortcut sections but is rare or absent in the upper parts of the latter two sections.

Location: Pb-9158-1 V+4.2xH5.9

#### Family BUXACEAE

#### Genus PACHYSANDRA Michx.

#### (Plate 10-8)

The first clear report of the occurrence of <u>Pachysandra</u> pollen in the Tertiary of western North America was made by Gray and Sohma (1964). Pollen of the same

general type has been referred to as Erdtmanopollis spp. or Multiporopollenites ludlowensis in the stratigraphic palynological literature but the affinities of these pollen types with Pachysandra is clearly indicated in Gray and Sohma's paper. This is the first record of pollen of this type in the Sucker Creek flora although it has been reported from a wide variety of late Miocene floras in the Columbia Plateau and adjacent regions (Gray and Sohma, 1964). The pollen from the Sucker Creek sediments is spherical, measuring approximately 50 micrometers in diameter, and multiporate. Each of the pores is surrounded by a "circlet" of wedge-shaped and rectangular sculpture elements. Of the various types illustrated by Gray and Sohma (1964) those from Moose Creek, Idaho appear closest to the Sucker Creek material. The grains are found in small numbers in the lower and middle Valley section in highly organic sediments. Due to the large size and heavy nature of the pollen and the low sprawling habit of the source plants that would not facilitate ready dispersal of the pollen grains, it is unlikely that the plants grew at any distance from the basin.

Location: Pb-9324-1 V+0.4xH22.3

#### Family CAPRIFOLIACEAE

# (Plate 10-6)

Two specimens referable to the family were noted during the present study. They average 15 by 20 micrometers in size and have a well developed reticulate surface pattern. The grains are tricolporate and appear to have small inward projections on the pore rims. The specimens appear identical to <u>Caprifoliipites viridifluminis</u> described by Wodehouse from the Eocene Green River formation (1933). As noted by Wodehouse, except for its small size, pollen of this type is identical to <u>Viburnum</u>. Pollen of this type has not previously been described from the flora although the family is represented by a single specimen of <u>Symphoricarpos salmonensis</u> from the macroflora. The pollen grains were recovered from the organic sequence in the middle of the Valley section.

Location: Pb-9324-2 V-3.3xH10.9

Family CHENOPODIACEAE

Genus SARCOBATUS Nees.

(Plate 8-9)

Pollen grains of the Chenopodiaceae and Amaranthaceae are usually difficult to separate from one another due to the similarity of their morphological features and are usually lumped into a single category labeled "Cheno-Am." Certain members of the family are distinctive enough to permit recognition and pollen of <u>Sarcobatus</u> is one of these. The pollen grains are multiporate and spherical, ranging

from approximately 20 to 28 micrometers in diameter. The exine is granular and each pore is set in a somewhat depressed field giving the grains the appearance of polyhedra rather than spheres. <u>Sarcobatus</u> has not previously been recognized in the microflora but it has been described from a number of other late Tertiary floras including the Creede flora (late Oligocene) of Colorado and the Troublesome Formation (Middle Miocene) of northcentral Colorado (Leopold, 1969). The pollen grains may be noted from samples at all levels in the study sections but reach their greatest abundance in the upper Rockville and Shortcut sections.

Location: Pb-9158-7 V+8.5xH19.7

Chenopodiaceae of Uncertain Generic Affinity

# Type 1

#### (Plate 8-8)

As stated previously, pollen of the Chenopodiaceae is often difficult to distinguish from that of the Amaranthaceae. Grains of this type might well belong to either family. The grains are spherical, averaging 30 micrometers in diameter, and multiporate with a distinctive granular appearance. Graham (1965) illustrated pollen of this type and noted its resemblance to pollen of <u>Atriplex</u>, <u>Chenopodium</u>, and <u>Amaranthus</u>. The form can be found in the lower part of the composite section but reaches its greatest variability in the upper Shortcut and Rockville sections.

Location: Pb-9324-1 V+0.4xHll.8

Family COMPOSITAE

Genus ARTEMISIA L.

Pollen of this genus occurs in two distinct sizes which, coupled with morphological differences, would tend to indicate that at least two taxa are involved. The grains are tricolporate but the pores are difficult to observe due to the tendency of the grains to orient preferentially in polar view. The grains lack visible spines, the furrows are deep and prominant, and a columellate tectum is well-developed in the interporate regions.

# <u>Type 1</u>

# (Plate 8-10)

These grains average 23 micrometers in diameter with an interporate wall thickness of approximately 4 micrometers of which the columellae and other ectexine elements comprise approximately half this thickness.

Location: Pb-9191-3 V+2.9xH22.6

# Type 2

# (Plate 8-11)

This form is approximately 20 micrometers in diameter and the wall in the interporate region is approximately 4.5 micrometers thick with the ectexine comprising approximately two-thirds of this thickness.

Location: Pb-9182-1 V+121.0xH33.0

Although the two types are similar in some features, the size variation and the differences in wall structure in the interporate region justifies the recognition of two distinct types. The larger of the two, Type 1, is indistinguishable from <u>A</u>. <u>tridentata</u>, the dominant species in the Sucker Creek area today.

Compositae Pollen of Uncertain Generic Affinity

# Type 1

# (Plate 8-14)

This type appears identical to the grains described by Graham (1965) as "Unknown Composite Pollen." This is the only Compositae type which is consistantly present in the mesic forest zone of the composite section. The grains are comparatively rare in the lower part of the section and unlike other members of the family their frequency does not increase toward the top of the section. The grains are tricolporate and approximately 20 micrometers in diameter. The spines are broad at their bases and comparatively short, rarely exceeding 1 micrometer in length.

Location: Pb-9158-6 V0.0xH10.7

# Type 2

#### (Plate 8-15)

Grains of this type are tricolporate and spinose. The grains average approximately 25 micrometers in diameter and the spines are short, averaging approximately 1 micrometer in length. The exine is granular and appears to break into a polygonal pattern in L-O analysis. Pollen of this type has not previously been described from the flora. Only two grains were encountered in the study, both of which were found in the upper Rockville section.

Location: Pb-9197-1 V+3.2xH20.0

# Туре 3

# (Plate 8-16)

These tricolporate pollen grains average 25 to 30 micrometers in diameter with spines approximately 2 micrometers in height. The base of the spines have a diameter approximately equal to their height. This pollen type is a new addition to the flora and it is relatively common in the upper Rockville and Shortcut sections.

Location: Pb-9196-1 V+1.7xH8.4

# Type 4

#### (Plate 8-17)

These tricolporate pollen grains average 18 to 22 micrometers in diameter with spines which are approximately 3 micrometer in length. The base of the spines range from 2-2.5 micrometers in diameter. These grains have not previously been described from the flora and are found in the upper Shortcut and Rockville sections.

Location: Pb-9195-1 V+3.3xH25.1

# Type 5

# (Plate 8-12)

Grains of this type are tricolporate, ranging from 22 to 27 micrometers in diameter. The spines are comparatively long averaging approximately 6 micrometers in length and 2.5 to 3 micrometers in diameter at their bases. This type has not previously been described from the flora and appears limited to the Upper Rockville and Shortcut sections.

Location: Pb-9246-1 V-0.9xH26.3

# Type 6

#### (Plate 8-13)

These are the largest composite grains encountered in the study, ranging from 30 to 35 micrometers in diameter. The grains are tricolporate with spines measuring 3 micrometers in length and 2.5-3 micrometers in diameter at the base. Pollen of this type is a new addition to the flora.

Location: Pb-9197-1 V+2.6xH22.2

The greatest number and variety of Compositae pollen are found in the upper Rockville and Shortcut sections. Due to the generally poor preservation characteristic of these beds, coupled with the large number of species in the family, identification of the pollen types to genus must await further study.

Family CORYLACEAE

Genus ALNUS Mill.

(Plate 8-3)

Alder pollen from the Sucker Creek study sections ranges in form from tetraporate through hexaporate with the pentaporate condition being the most common. The pores are equatorially arranged with each pore surrounded by annular thickening giving the pores a protruberant appearance. Sub-exinous thickenings, arranged in arcs between the pores give the grains a characteristic appearance in transmitted light. The exine is smooth and the grains range from 22 to 30 micrometers in diameter. Graham (1965) describes pollen of this type and his figures on the distribution of pore numbers appears to correspond with the observations made during the present study. Graham concluded that pore number was not a useful character in delimiting taxa within the genus and the author concurs. Alder is widely distributed in middle and late Tertiary floras both in the form of leaves and pollen, but only a few leaves have been collected from the Sucker Creek sediments. Alder pollen dominates the record at some levels and then drops to moderate or low numbers at other points on the study sections. It is possible that alders were associated with a restricted community type and that

they were not widespread in the deciduous forest complex. A likely hypothesis is that the shrubs or small trees grew in swampy situations closely associated with the sites of organic sedimentation. The latter may be inferred on the basis of the fact that clumps of large numbers of the grains may be observed in some of the lignitic sediments suggesting that whole catkins dropped into the swamp. These organic sediments do not contain well-preserved fossil leaves and this probably accounts for its poor representation in the macrofossil record. Alder pollen is reasonably common in all productive samples from the lower part of the composite section but persists into the upper xeric zone in much reduced numbers.

Location: Pb-9158-6 V+5.0xH10.0

Genus BETULA L.

#### (Plate 8-4)

These pollen grains are triporate with a sub-rounded outline and average 25 micrometers. The pores are aspidate due to the presence of annular thickenings. The exine is smooth and the fact that the grains have few outstanding features makes it impossible to relate it to any particular modern species or species group. Graham (1965) was the first to describe the occurrence of birch pollen in the Sucker Creek flora. There is no way to determine how many species might be represented in the fossil material. Graham's total for birch pollen grains (560) is larger than that which he found for alder (485) giving the impression that birch is somewhat more common, but this is not the case. Birch and alder usually occur in the same samples but the latter exceeds birch in almost all cases. The relative numbers of the two genera as determined by Graham would appear to indicate that none of his samples represent levels comparable to the alder maxima observable in the three study sections. Birch pollen is confined to the lower part of the composite sequence occurring only in the Valley and the lower Shortcut and Rockville sections.

Location: Pb-9165-20 V+14.4xH16.6

Genus CARPINUS L.

#### (Plate 8-6)

Grains of this type range in diameter from 20 to 25 micrometers with a somewhat rounded triangular outline. The grains are triporate with the pores arranged around the equator. The pores are annulate but protrude to far less a degree than those of <u>Alnus</u> or <u>Betula</u>. The exine ranges from psilate to faintly granular. Graham (1965) describes pollen of this type and remarks that it is difficult to distinguish pollen of <u>Carpinus</u> and <u>Ostrya</u>. Since <u>Ostrya</u> is the only genus of the two represented in the macroflora, Graham was of the opinion that the Sucker Creek pollen material represented that genus. Although the two genera are somewhat similar, Wodehouse (1935) noted that <u>Ostrya</u> pollen differed from that of <u>Carpinus</u> in two characters: Ostrya has up to 25 percent of the grains with four pores while <u>Carpinus</u> grains have only three pores, and the pores of <u>Ostrya</u> are elliptical, often twice as long as broad, while those of <u>Carpinus</u> are circular. All of the Sucker Creek pollen grains had three pores and the pores were uniformly circular, both in the material observed in the present study and the material described by Graham. All of these characters correspond to <u>Carpinus</u> and it is on this basis that the material is so assigned. The pollen is restricted to the mesic forest zone in the lower part of the composite section.

Location: Pb-9207-1 V+6.1xH25.2

Family ELAEAGNACEAE

Genus ELAEAGNUS L.

(Plate 8-20)

The pollen grains are sub-circular to sub-triangular with three short colpi. The grains range in size from 23 to 28 micrometers in diameter. The exine is granular and pores are present in the equatorial region of the furrows but are quite inconspicuous. The exine is thickened in the area of the colpi giving the grains their angular appearance. The grains are very similar to those of <u>E</u>. <u>pungens</u> in the Michigan State reference collection but insufficient material was available for detailed comparison with other species. The genus includes shrubs which are widely distributed in the temperate areas of Europe, Asia, and North America. Lee (1935) lists 24 species, most of which grow at altitudes ranging from 500 to 6000 feet in Szechuan and Hupeh provinces in China. Pollen of the genus has not previously been described from the flora but it has been noted in deposits of Oligo-Miocene age from Alaska (Leopold, 1969). Pollen grains of this type have been noted in the Valley and lower Rockville sections.

Location: Pb-9219-1 V+7.7xH17.4

Genus SHEPHERDIA Nutt.

#### (Plate 8-19)

The presence of this genus in the flora was first documented from the flora by Graham (1965), who described the material as Shepherdia argenteaites based on its resemblance to the pollen of the extant S. argentea, presently found in the northern United States and Canada. According to Graham (1965), the species is found in sagebrush and pinyon-juniper woodlands in western North America ranging in altitude from 3500 to 6500 feet, Jepson (1960) indicates that the species is often closely associated with watercourses where it occurs in California. The grains are tricolporate, ranging from 20 to 30 micrometers in diameter, and have a pronounced triangular outline. The exine is granular. The colpi are quite long, extending almost to the poles, a feature which distinguishes Shepherdia pollen from Elaeagnus where the colpi are quite short. This type is confined to the mesic forest zone.

Location: Pb-9218-1 V-4.1xH22.2

# Family ERICACEAE

(Plate 8-18, 21)

Pollen grains in this family are commonly shed as tetrahedral tetrads. The individual grains are tricolporate but the colpi are shared by adjacent grains making the structure of the furrows and pores somewhat obscure in the fossil material. The individual grains have a psilate surface texture and the tetrads vary in size from 30 to 40 micrometers in diameter, somewhat smaller than the tetrads described by Graham (1965). The size of the tetrads in the present study is similar to those described by Traverse (1955) and there may be several taxa involved. Arbutus has previously been described from the macroflora and leaves of Vaccinium were collected in the course of the present study so that at least two ericaceous genera are known to be represented. Tetrads in the order of 30 to 40 micrometers are consistant in size with those of Vaccinium but it is possible that other genera may have been the source plants. It would appear that at least two taxa are represented in the microflora, those illustrated here and the somewhat larger tetrads described by Graham (1965). All of the ericaceous pollen observed in the present study was confined to the mesic forest zone of the Valley and lower Shortcut and Rockville sections.

Location: #18 Pb-9308-3 V+5.3xH14.2

#21 Pb-9246-1 V+1.9xH23.0
# Family FAGACEAE

# Genus CASTANEA Mill.

### (Plate 8-5)

Pollen of this genus has not previously been described from the flora although its leaves have been found (Graham, 1965). The grains are tricolporate and quite small, averaging 9 by 16 micrometers in size. The furrows extend almost from pole to pole and a transverse furrow is evident in the equatorial region of each longitudinal furrow. The exine is psilate. The grains correspond in all respects to pollen described by Traverse (1955) from the Brandon lignite and which he described as C. insleyana. Except for a single occurrence in a lignitic bed in the upper Rockville section, the pollen of this genus is confined to the Valley and lower Shortcut and Rockville sections. Castanea was probably a member of the mesic bottomland forest but the small number of leaves and the paucity of the pollen record indicates that the trees were probably not common.

Location: Pb-9157-2 V+8.4xH26.1

# Genus FAGUS L.

# (Plate 9-1)

The grains range from ovate to sub-spheroidal and are tricolporate with the furrows extending almost to the poles. The grains range from 30 by 40 to 40 micrometers in diameter depending upon their shape. The surface is

136

coarsely granular. Graham (1965), who first described the occurrence of pollen of this type in the flora, noted that the material closely resembles the pollen of <u>F</u>. grandifolia. The single species known from the macroflora (<u>F</u>. <u>washoensis</u>) is morphologically similar to <u>F</u>. grandifolia and it is therefore likely that the pollen was derived from trees of the F. washoensis type.

Location: Pb-9158-1 V-6.8xH7.0

Genus QUERCUS L.

(Plate 10-11, 13)

The oaks of the Sucker Creek macroflora are a heterogenous assemblage of approximately six species of varying taxonomic and ecological affinities (Graham, 1965). Graham noted the presence of two forms of oak pollen, a small form approximately 18 by 30 micrometers and a larger form up to 32 by 42 micrometers. The grains are tricolpate with the smaller forms tending to tricolporate. Exine surface structure ranges from psilate to granular. The results of the present study indicate that the size distinction breaks down when a large number of grains are examined and that the oak pollen complex is an intergrading series in which it is not possible to relate individual members to distinct modern taxa. It is probable that all of the macrofossil species contributed to the pollen record and it is possible that additional species, growing farther from the basins, may be represented as well.

Location: #11 Pb-9157-1 V+9.3xH14.6

#13 Pb-9157-1 V+9.9xH10.0

Family HAMAMELIDACEAE Genus LIQUIDAMBAR L.

(Plate 9-8)

The grains of this type are spherical and multiporate. The pores are evenly distributed over the surface of the grains and each pore has a conspicuously flecked membrane. The exine is granular and the diameter of the grains ranges from 32 to 40 micrometers. Pollen of this genus was originally described by Graham (1965) from the Sucker Creek sediments. It is fairly common in the mesic forest zone at the bottom of the composite section. Location: Pb-9158-7 V+18.7xH22.0

Family JUGLANDACEAE

Genus CARYA Nutt.

(Plate 8-7)

The grains are triporate and sub-triangular or rounded in polar view with a diameter of approximately 45 micrometers. The pores tend to be somewhat elliptical in shape, averaging 3 by 5 micrometers in size. The pores tend to be displaced slightly into one hemisphere with their long axis pointing toward the poles in a majority of cases. The surface texture is psilate to minutely granular. Hickory pollen was first described from the Sucker Creek by Graham (1965). Observation suggests that there may be two size classes, the first measuring 40 to 45 micrometers, typical of the figured specimen, and a second larger form averaging approximately 65 micrometers, typical of the form described by Graham. Only one species of Carya is known from the macroflora but the habitats of extant species would suggest that it is likely that other species may have grown at a greater distance from the depositional basin. Pollen evidence suggests that more than one species is probably present. The pollen is confined to the mesic forest zone and does not persist following the floristic transition.

Location: Pb-9205-1 V+8.9xH22.8

Genus JUGLANS L.

(Plate 9-7)

Grains of this genus are highly variable in size ranging from 25 to 50 micrometers. The grains are spherical and multiporate with the pores tending to be concentrated in one hemisphere. The grains may appear somewhat angular in polar view but there is little tendency for them to orient preferentially in that configuration. The pores are annulate but the extent of the development of the annuli is variable. The exine is psilate with no conspicuous features. Pollen of this type was first described from the microflora by Graham (1965). There is no macrofossil record of the genus in the flora although one species of <u>Juglans</u> is recognized in the Blue Mountains and Trout Creek floras of late Miocene age (Chaney and Axelrod, 1959). Pollen similar to that found in this study has been described from the Oligocene (?) Brandon lignite of Vermont (Traverse, 1955), the Miocene Kilgore flora of Nebraska (MacGinitie, 1962), and the Miocene of Alaska (Leopold, 1969). The variability of the Sucker Creek material would suggest that more than one species may be represented in the pollen record. The pollen is restricted to the mesic forest zone and is not found above the floristic transition.

Location: Pb-9157-2 V+2.5H19.5

Genus PTEROCARYA Kunth.

#### (Plate 10-4)

The grains are multiporate and somewhat angular in outline. The pores are confined to the equatorial region and are rarely displaced by any significant distance. The number of pores varies but most grains range between 5 and 9. The grains average 35 micrometers in diameter and have a psilate or finely granular surface texture. Graham (1965) in his initial description of this pollen type in the Sucker Creek microflora, stated that the grains have a finely reticulate surface texture under oil immersion. The extent to which this reticulum is developed appears to be highly variable and the majority of the grains observed in this study were not reticulate. Pterocarya is a widespread

member of the microflora of the middle and late Tertiary of the northwest and one species (<u>P. mixta</u>) is known from the Sucker Creek macroflora. Pollen of the genus is found throughout the Valley and Shortcut section but appears to be limited to the mesic forest zone on the Rockville section. The genus is endemic to eastern Asia and according to Lee (1935) the nine species native to China are primarily upland species growing at elevations from 4,000 to 6,000 feet.

Location: Pb-9272-4 V+7.8xH7.4

#### Family LEGUMINOSAE

### (Plate 9-11)

Graham (1965) described a polyad which he considered to represent the Leguminosae and also described both leaves and seed pods which appeared to be referable to the family. During the counting of palynomorphs in the upper part of the Shortcut and Rockville sections a number of pollen masses resembling polyads of the Leguminosae were noted. Unfortunately, most of these specimens were poorly preserved and are not very distinctive. The form illustrated is similar in many respects to polyads produced by the genus <u>Acacia</u>, but the assignment is tentative. The specimen consists of a closely packed polyad of grains with a total diameter of 28 micrometers. Little can be observed of the structure of the individual grains. Despite their generally poor preservation, the presence of a number of different polyad forms in the upper Shortcut and Rockville time would suggest that several species belonging to the family were present during the interval in question.

Location: Pb-9182-1 V+0.3xH18.5

Family MALVACEAE Genus SPHAERALCEA A. St.-Hil.

(Plate 9-10)

The grains are 30 to 40 micrometers in diameter, spherical, and obscurely tricolpate with short furrows. The exine, exclusive of the prominent spines, is coarsely granular to finely reticulate. The spines range in length from 2.5 to 3 micrometers and are as broad at their bases as they are long. The spines are hyaline and somewhat blunt at the tips but expand rapidly toward the base flaring into a widened buttress with a striate appearance. The grains are found throughout the study sections and appear identical to those of the modern Sphaeralcea, a genus of shrubs widely distributed in arid western North America. According to Leopold (1969), pollen of this type is widely distributed in the middle and late Tertiary of the western United States. Graham described a single grain of this type under the Malvaceae in his treatment of the flora.

Location: Pb-9311-3 V-1.7xH20.4

Malvaceae Pollen of Uncertain Generic Affinity

# <u>Type 1</u>

### (Plate 9-9)

These pollen grains are spherical with a fairly uniform diameter ranging from 22 to 25 micrometers. The grains are tricolpate with inconspicuous furrows. The spines range from 3 to 3.5 micrometers in length with hyaline blunt tips and somewhat flared bases with a striated appearance. The base of the spines average approximately 2.5 micrometers in diameter. The exine varies from faintly granular to finely punctate. This pollen type, previously undescribed from the flora, can be placed with some confidence in the family, but its generic affinities are not clear. It has a close resemblance to pollen of the Malvastrum type from the Middle Miocene Suntrana formation of the Alaska Range (Leopold, 1969). These grains occur in small numbers above the floristic transition in the upper Shortcut and Rockville sections.

Location: Pb-9182-1 V+9.1xH27.2

Family NYMPHAEACEAE

Genus NYMPHAEA L.

#### (Plate 10-2)

Rhizomes and leaves of plants apparently similar to the living <u>N</u>. <u>odorata</u> have been described from various Miocene floras in the Columbia Plateau region (Chaney and Axelrod, 1959) but this is the first record of the genus .

ι

from the Sucker Creek flora. The grains range from 50 to 60 micrometers in length and have a single longitudinal operculum or furrow. The exine is thin and the grains are usually found in a collapsed or torn condition. The exine is hyaline and is covered with thin spines, the latter averaging 3 micrometers in length and approximately 0.5 micrometers in diameter at their bases. The grains are confined to the central part of the Valley section where they presumably indicate a period of ponding.

Location: Pb-9272-4 V+9.3xH17.6

Family NYSSACEAE

Genus NYSSA Gronov. ex L.

#### (Plate 10-3)

Grains of this type are ovate ranging in size from 30 to 35 by 40 to 46 micrometers. They are tricolporate with the furrows extending well into the polar areas. The pores have a thickened rim which gives the grains a characteristic appearance in polar view. The exine is granular in texture. Only two specimens of <u>Nyssa</u> are known from the macroflora. The first of these is a leaf, referred to <u>N</u>. <u>copeana</u>, which is similar to the modern <u>N</u>. <u>sylvatica</u>, and the second is a fruit, <u>N</u>. <u>hesperia</u>, similar to the extant <u>N</u>. <u>aquatica</u>. The equivalents of both modern species almost certainly would have been growing not far from the basins so that the paucity of leaves would indicate that the trees were not common. The pollen alone cannot be related to

either form exclusively, although certain inferences may be drawn based on the relatively small numbers occurring in the samples studies. The grains occur only in the mesic forest zone and are usually present only in highly organic beds indicative of swamp-like depositional conditions. Taggart (1967) in examining sediments taken from Taxodium dubium - Nyssa aquatica swamps in southern Illinois noted that Nyssa pollen, presumably that of N. aquatica, was always very abundant when Taxodium and N. aquatica were growing in close association and that when N. aquatica was not present locally, the quantity of Nyssa pollen was quite low. In the latter case, much of the pollen record was probably derived from black gum (N. sylvatica) trees which were scattered in small numbers in the adjacent bottomland forest. In the Sucker Creek flora, despite the fact that swamps were present, the genus is not well represented in the pollen record, strongly suggesting that the source plants were likely to be scattered black gum trees growing in the bottomland forest rather than water tupelo in characteristically dense marginal stands around the swamp basins. Nyssa is a common member of late Tertiary pollen floras from the far west (Gray, 1964; Leopold, 1969), but this is the first pollen record of the genus in the Sucker Creek flora.

Location: Pb-9157-2 V-4.2x8.1

#### Family ONAGRACEAE

Pollen of this family represents a new record for the Sucker Creek flora. Two distinct pollen types were recognized in the course of the present study.

### Type 1

#### (Plate 9-13)

The grains are triangular in polar view with short furrows or long pores at the apices of the triangles. The ends of the apices are inflated into pronounced vestibula with a heavy granular structure. The main body of the grain has a somewhat finer granular structure. The base of each vestibulum is thickened forming a prominent ring. In poorly preserved material the furrow area is destroyed leaving the ends of the arms terminated in a thick collar-like ring or flange. The grains are fairly uniform in size ranging from 42 to 50 micrometers measured from any one apex to the center of the opposite side. Pollen of this type has been reported from a number of Tertiary floras from various localities in North America and it is known under a variety of names. Grains of this type are commonly referred to Epilobium, a modern genus which has pollen of similar morphology and size. Traverse (1955) referred to similar material from the Brandon flora as Jussiaea. The Sucker Creek material is similar morphologically to the pollen of this genus but it is approximately 33 percent smaller than equivalent modern material.

146

The form equivalent of this type is called <u>Pollenites</u> <u>oculis-noctis</u>. The general morphology of the material is quite common in the family as a whole and although the material closely resembles <u>Epilobium</u>, a careful study of the pollen of additional genera would be required to confirm this assignment. This pollen type is a relatively rare occurrence and is limited to organic beds in the Valley and lower Shortcut and Rockville sections.

Location: Pb-9246-1 V+9.8xH9.0

### Type 2

#### (Plate 9-12)

The grains of this type are morphologically similar to those of Type 1 but they are much larger. The grains measure approximately 90 micrometers from an apex to the center of an opposite side. Pronounced vestibula with a granular to verrucate surface texture and slit-like furrows are a prominant feature of this type. The body of the grains is hyaline and the base of the vestibulum has a thickened annular collar which persists when the pore area has decayed. Although this type can be assigned to the family with some certainty, there was no modern genus or fossil form to which the specimens could be matched in terms of both their size and morphology. <u>Jussiaea</u> pollen is quite similar in overall size as is the pollen of <u>Oenothera</u>, but none of the material examined from these genera had the pronounced vestibular development, related to the overall size of the grain, which is characteristic of the fossil material. Pollen of this type was only found in the organic interval at the middle of the Valley section and it is possible that the source plant may have been an aquatic herb.

Location: Pb-9158-1 V-3.6xH15.2

Family SALICACEAE

Genus POPULUS L.

(Plate 10-7)

The grains are spherical and aporate with a psilate to finely granular exine. They range in diameter from 22 to 30 micrometers. The exine is thin and fragile and the grains are often found in a torn and corroded condition. This pollen type may be under-represented in many samples due to the fact that the grains are easily destroyed. The limited number of morphological features makes it impossible to assign the material to any one modern species. Three Populus species are known from the macroflora and were apparently associated with the floodplain and lakeside communities. The ephemeral nature of the pollen grains makes it likely that most of the pollen in the record was derived from these local communities rather than from aspens which may have been associated with the successional sequence in the montane conifer forest in the uplands.

Location: Pb-9158-1 V-6.1xH18.9

Genus SALIX L.

(Plate 10-14)

Pollen of this type is ovate ranging in size from 17 by 25 to 50 by 70 micrometers. The grains are characteristically tricolpate with a reticulate exine. There are several <u>Salix</u> species which are very common in the macroflora and the various pollen types undoubtedly represent several tree and shrub species within the genus. Pollen of this type was first described from the flora by Graham (1965) and it occurs throughout the study sections. Location: Pb-9157-6 V+5.2xH11.0

Family TILIACEAE

Genus TILIA L.

(Plate 10-9)

Grains are tricolpate and sub-triangular in polar view. The colpi are short and the margo is conspicuous. The exine ranges from granular to finely reticulate. The grains range in size from 32 to 40 micrometers. The first description of pollen of this type in the Sucker Creek flora was made by Graham (1965). The pollen is never common and is confined to the mesic forest zone of the Valley and lower Shortcut and Rockville sections.

Location: Pb-9308 V+9.0xH19.5

149

Family ULMACEAE

Genus ULMUS L.

(Plate 10-12)

The grains are porate and sub-circular to slightly angular in polar view. The grains range in size from 25 to 32 micrometers. The pores are equatorially arranged and usually number four. The grains are rugulate giving them a characteristic appearance. Graham (1965) was the first to describe Ulmus pollen from the Sucker Creek microflora and noted that it comprised approximately 20 per cent of all the pollen counted despite the relatively poor representation of elms in the macroflora. Elm pollen is restricted to the mesic forest zone of the Valley and lower Shortcut and Rockville sections where it usually dominates the deciduous tree pollen component unless exceeded in numbers by peaks in alder. The poor macrofossil record indicates that elms were not common along the streamside or lake border communities but the large number of pollen grains suggest that it was one of the more important genera in the adjacent mesic bottomland and slope communities. Morphologically, elm pollen may be confused with that of Zelkova, a genus now endemic to the temperate deciduous forests of eastern Asia. Zelkova is represented in the macroflora by a single leaf and it is possible that some pollen of this genus was tallied as Ulmus, although it is doubtful that Zelkova pollen constitutes an appreciable percentage of the total.

Location: Pb-9158-7 V+17.2xH10.7



Spores and Pollen Grains of Uncertain

### Taxonomic Position

A significant number of palynomorphs were encountered in the course of the study which could not reliably be assigned to a family or, occasionally, even to a higher category. Many of these grains were poorly preserved or oriented or they had no outstanding features. Some of these types are being illustrated and briefly described in order to confirm their presence in the flora and in the hope that later work may serve to indicate their taxonomic affinities. All of these entities belong to the Differentiated Unknowns category discussed in Chapter II and are described under their survey designation consisting of the letter U (unknown) followed by a number.

#### U13

### (Plate 11-6)

These grains are circular in polar view, tricolpate, and have a rugulate surface texture. The colpi are long and extend almost to the poles. The grains average approximately 50 micrometers in diameter and, aside from their coarser surface texture, they strongly resemble grains of the genus <u>Mahonia</u>. None of the <u>Mahonia</u> pollen observed by the author had such a coarse surface and pending the examination of additional material, the grains were placed in the unknown category. Pollen of this type

151

is confined to the mesic forest zone of the composite section.

Location: Pb-9157-1 V-8.8xH12.3

### U49

#### (Plate 11-3)

The grains of this type measure approximately 20 by 25 micrometers and are tricolporate with a reticulate surface. The grains are found only in the Valley section and resemble the grains of <u>Sambucus</u>, although the small amount of material available and the occurrence of similar morphological types in the Rosaceae makes detailed placement impossible.

Location: Pb-9158-1 V-3.2xH9.0

# U61

### (Plate 11-1)

A single grain of this type, measuring 30 by approximately 45 micrometers, was recovered from the upper part of the Rockville section. The grain is tricolpate and has a well developed tectate exine. The grains resemble those of <u>Rhus</u> although similar morphological types are produced in the Euphorbiaceae.

Location: Pb-9177-1 V-4.2xH4.9

### U63

#### (Plate 11-10)

Pollen of this type is very common in the upper Rockville and Shortcut sections. The grains are spherical, tricolporate, and average 22 micrometers in diameter. The exine consists of a well-developed columellate tectum. Pollen of this type may be related to <u>Artemisia</u> since the grains always occur together and their morphological features are quite similar. However <u>Artemisia</u> grains identical to the fossil material could be found. Pollen of this type is either rare or completely absent from beds below the floristic transition but they may be found in fair numbers in almost all productive samples above it.

Location: Pb-9191-3 V5.8xH17.1

# U66a

# (Plate 11-7)

Pollen of this type probably belongs in the Compositae but the grains are usually poorly displayed and it is not possible to be certain about some of the details of their morphology. The pollen appears to be tricolporate and is approximately 22 by 30 micrometers in size. The exine is hyaline with faint longitudinal lines. The grains are spiny with the spines are up to 2 micrometers in length. The grains are commonly tightly folded and appear to be monosulcate in that orientation. The grains are limited to the upper Shortcut and Rockville sections.

Location: Pb-9191-3 V+5.8xH17.1

# <u>U67</u>

### (Plate 11-12)

The pollen of this type is tricolpate and averages 17 micrometers in polar view. The surface is faintly granular. This pollen type is confined to the upper Shortcut and Rockville sections and its affinities are completely unknown.

Location: Pb-9196-1 V+3.6xH15.9

# <u>U71</u>

# (Plate 11-11)

This entity appears to be aporate and lacks any observable scars. It is spherical and has a pronounced reticulum formed by surface ridges. Several specimens were recovered from the upper Rockville section.

Location: Pb-9197-1 V+3.9xH22.0

# U72

# (Plate 11-4)

These grains are tricolporate and measure approximately 20 by 27 micrometers. The grains have a small polar index and the exine consists of a columellate tectum. They are found in the upper Rockville and Shortcut sections where they are often quite common.

Location: Pb-9197-1 V+11.0xH16.5

# U78

### (Plate 11-15)

A single specimen of this type was noted in a sample from the upper Rockville section. It appears to be spherical with a reticulate surface. No pores, furrows, or scars were noted and the affinities of this specimen are unknown.

Location: Pb-9197-1 V+9.6xH17.5

# U79

### (Plate 11-8)

The grains of this type average 20 by 25 micrometers in size. They are tricolpate and have a granular surface. Except for their larger size, specimens of this type are basically similar to those of U67. The grains are found in the upper Shortcut and Rockville sections.

Location: Pb-9229-1 V+8.0xH14.5

# U92

#### (Plate 11-9)

A single grain of this type, measuring 42 by 50 micrometers, was recovered from the base of the Rockville section. The grain is tricolpate with a pronounced beaded reticulum. The character is the reticulum is much like that of the Liliaceae but the presence of three furrows eliminates that as a possibility. It is possible that the fossil represents a large-grained form of Salix, similar to a large grain described by Graham (1965) but further assessment must await the isolation of additional material.

Location: Pb-9224-1 V+9.1xH12.2

### <u>U93</u>

# (Plate 11-5)

The grain is tricolpate, measuring 55 micrometers in diameter in polar view, with a well developed columellate exine structure that appears granular in surface view. A single specimen of this type was recovered from the lower Rockville section.

Location: Pb-9220-1 V9.1xH15.4

# U103

#### (Plate 11-13)

These plicate structures average 20 by 80 micrometers in length and are found in the upper Shortcut and Rockville sections. Despite their distinctive appearance, their biological affinities are unknown.

Location: Pb-9230-1 V-2.7xH26.3

## U106

#### (Plate 11-2)

These pollen grains appear to be tricolporate and measure approximately 30 micrometers in diameter in polar view. The exine is thick and has a faintly striate appearance. Pollen of this type has only been noted from the lower Valley section and its affinities are unknown.

Location: Pb-9260-1 V+1.6xH5.4

### U108

# (Plate 11-16)

The grains of this type are tricolporate, average 35 to 40 micrometers in diameter in polar view, and have a granular surface texture. This type occurs in the lowermost Valley section and they may represent somewhat corroded grains of Fagus.

Location: Pb-9263-1 V+3.9xH24.7

# U120

### (Plate 10-15)

The grains of this type are tricolpate with a diameter of approximately 60 to 70 micrometers in polar view. The surface is somewhat granular and is covered with scattered rod-like sculpturing elements with slightly swollen tips. The overall aspect of the grains is similar to some of the Cactaceae but no close counterparts of the fossil material were observed that would support its inclusion in that family. Grains of this type have only been found in the middle of the Valley section.

Location: Pb-9311-3 V-3.5xH23.9

# U121

#### (Plate 11-14)

A single specimen of this type was isolated from the middle Valley section. The grain is tricolpate and the columellate exine appears granular in surface view. The grain has a slight resemblance to those of Lonicera. The grain is 55 micrometers in diameter which is consistent with <u>Lonicera</u> but the details of the furrow margin do not correspond precisely with the grains of that genus.

Location: Pb-9157-1 V+2.2xH25.3

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# APPENDIX

#### APPENDIX

Detailed data on each of the three measured study sections is included below. Data includes the position of each unit, measured from the top of the measured section and a description of the lithology of the unit in question. If samples were collected in any particular unit, the sample number and its position, measured from the top of the section, will appear in parentheses following the description of the overall rock units. If no data is included for the position of a sample it represents a channel sample of the entire rock unit.

## ROCKVILLE SECTION

### NW4NW4 T28S R46E

Malheur County, Oregon

Feet from Top of Section	Lithology and Sample Data
0.0 - 6.0	Gray-brown to yellow-brown shale, somewhat indurated, weathering yellow-brown on exposed edges. <u>Cedrela</u> seeds. (Pb-9176 - 1.6', Pb-9177 - 5.2')
6.0 - 7.6	Fine light gray shale with no clear bedding planes. (Pb-9178 - 6.4-6.8')

Feet from Top of Section	Lithology and Sample Data
7.6 - 9.3	Gray shale weathering brown. Black organic material on some bedding planes. (Pb-9179 - 8.1-8.6')
9.3 - 10.2	Alternating laminations of coarse and fine buff-green shale. (Pb-9180 - 9.4')
10.2 - 10.3	Fine gray shale with a faint maroon caste. (Pb-9181)
10.3 - 11.5	Sandy yellow-orange to green shale with gray interbedding, the latter with maroon shading. (Pb-9182 - 10.3-10.5')
11.5 - 12.1	Fine gray shale with black organic frag- ments on some bedding planes. (Pb-9183 - 11.5-11.6)
12.1 - 12.7	Sandy buff to green shale.
12.7 13.1	Fine gray shale.
13.1 - 13.8	Sandy yellow-brown shale.
13.8 - 16.9	Maroon to reddish-brown organic shale with some interbedded yellow-green sand. Stem fragments present. (Pb-9184 - 13.8- 13.9', Pb-9185 - 15.0', Pb-9186 - 16.2').
16.9 - 17.0	Sandy yellow-brown shale with maroon organic interbedding. (Pb-9187)
17.0 - 18.2	Maroon organic shale; fossil wood zone.
18.2 - 18.3	Maroon organic shale with iron staining on partings.
18.3 - 20.3	Maroon lignite to organic shale, iron on some partings. Some dark gray interbed- ding, leaf and stem fragments. (Pb-9188 - 18.5', Pb-9189 - 19.6')
20.3 - 22.5	Dark gray shale with somewhat coarser interbedding. Weathers to a green-gray clay. (Pb-9190 - 20.6')
22.5 - 22.6	Maroon organic shale with interbedded layers of yellow-gray sandy shale. (Pb-9192)
Foot from Ton	
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of Section	Lithology and Sample Data
22.6 - 27.2	Sandy yellow to green-gray shale with maroon-gray organic varves; organic debris. (Pb-9193 - 23.4', Pb-9194 - 25.7')
27.2 - 29.0	Sandy greenish shale with little organic material.
29.0 - 34.6	Interbedded sandy yellow-green shale and yellow sand. Iron staining and plant fragments. (Pb-9195 - 29.4', Pb-9199 - 33.7')
34.6 - 39.7	Angular, poorly sorted yellow-green sand. (Pb-9196 - 35.7')
39.7 - 52.7	Yellow-green cross-bedded sand, weathers reddish brown. (Pb-9197 - 44.5')
52.7 - 58.0	Sandy gray-green shale with irregularly bedded organic layers.
58.0 - 79.5	Very light gray ash, weathers white. Organic material on irregular bedding planes. Cinder-like particles scattered irregularly through the mass. (Pb-9200 - 69.5')
79.5 - 80.0	A continuation of the bed above but somewhat more resistant with reddish inclusions. (Pb-9201 - 70.8')
80.0 - 80.7	Less resistant white ash, reddish caste.
80.7 - 82.1	Fine yellow-green shale weathering to a yellow clay. (Pb-9202 - 81.0')
82.1 - 82.5	Maroon to reddish brown shale, fissile, many leaves, seeds, and insect parts. (Pb-9203 - 82.4')
82.5 - 82.6	Maroon-gray organic shale, conchoidal breakage pattern. (Pb-9204)
82.6 - 83.6	Vari-colored fissile shale; reddish- maroon to vellow-gray, (Pb-9205 - 83.3')

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Feet from Top of Section	Lithology and Sample Data
83.6 - 86.4	Dark gray organic shale with varves of coarses yellow-green sand. (Pb-9206 - 84.9', Pb-9207 - 85.7', Pb-9208 - 86.2')
86.4 - 87.5	Brown to maroon-gray organic shale inter- bedded with coarse xel shale or fine sand. (Pb-9209 - 86.6', Pb-9210 - 87.3')
87.5 - 87.6	Maroon-gray organic shale with iron stains on some bedding planes. (Pb-9211)
87.6 - 87.8	Brown organic shale.
87.8 - 88.0	Sandy green shale with organic partings.
88.0 - 90.8	Very dark gray organic shale with numerous plant fragments on bedding planes. (Pb-9212 - 89.0')
90.8 - 91.1	Brown and gray organic shale. (Pb-9213 - 90.9-91.0', Pb-9114 - 91.0-91.1')
91.1 - 91.6	Poorly sorted angular orange to yellow- green sand. (Pb-9215 - 91.2-91.3')
91.6 - 91.7	Brown organic shale with plant fragments. (Pb-9216)
91.7 - 92.6	Sandy yellow to buff-green shale. (Pb-9217 - 92.1')
92.6 - 92.9	Fine gray shale weathering white-gray or light brown on some planes. Slightly indurated. (Pb-9218 - 92.7-92.8')
92.9 - 93.7	Dark gray shale, somewhat organic.
93.7 - 95.6	Light buff-gray shale with a slight maroon caste. Upper 6 inches constitutes the level of leaf locality 7/21/70. Layer coarsens toward bottom. (Pb-9224 - 94.0', Pb-9220 - 95.0')
95.6 - 95.7	Fine green shale with white crystalline inclusions. (Pb-9221)
95.7 - 95.9	Buff to reddish brown shale, organic partings.

Feet from Top

of Section Lithology and Sample Data

95.9 - 96.9+ Fine green shale. (Pb-9222 - 96.3')

Bottom of Measured Section

SHORTCUT SECTION

NW1 SW1 TIS R5W

Owyhee County, Idaho

Feet from Top of Section	Lithology and Sample Data
0.0 - 2.1	Alternating coarse to fine green-gray shale. (Pb-9226 - 0.8')
2.1 - 4.5	Dark and maroon-gray organic shale; chert- like nodules, sand, and mica flakes inter- bedded. (Pb-9227 - 2.7', Pb-9228 - 3.3')
4.5 - 6.2	Yellow to yellow-green sand with some iron staining.
6.2 - 7.5	Poorly consolidated greenish sand with orange iron staining. (Pb-9229 - 6.4')
7.5 - 7.7	Angular yellow, poorly cemented sand that is heavily iron stained. (Pb-9230 - 7.5- 7.6')
7.7 - 8.8	Weathered coarse yellow-green shale with organic interbedding. (Pb-9231 - 8.3')
8.8 - 11.4	Angular, poorly consolidated yellow- green-gray sand. (Pb-9232 - 9.5')
11.4 - 30.2	Poorly consolidated yellow-gray sand. Upper two feet includes water-worn pebbles up to 3" in diameter. Black carbonized plant fragments, mostly stem segments, scattered throughout. (Pb-9233 - 11.8', Pb-9234 - 27.6', Pb-9235 - 29.6')
30.2 - 61.2	Light gray ash weathering white. Cinder fragments and organic detritus on some bedding planes. Some layers of maroon organic material with chert-like nodules at their centers. (Pb-9236 - 31.0', Pb-9237 - 38.0', Pb-9238 - 29.0')

Feet from Top of Section	Lithology and Sample Data
61.2 - 62.7	Orange to yellow-green shale weathering to soft clay. (Pb-9239 - 61.7')
62.7 - 64.7	Fissile maroon-gray shale weathering brown. Leaves, seeds, and insect parts. Pb-9240 - 63.6')
64.7 - 68.0	Dark to maroon gray organic shale, Conchoidal breakage, some slightly coarser interbedding. (Pb-9241 - 67.0')
68.0 - 69.0	Yellow-brown to yellow-green shale with maroon organic laminae. (Pb-9242 - 68.3', Pb-9243 - 68.6-69.0')
69.0 - 70.3	Maroon organic shale drying gray. Unevenly spaced varves of varying organic content. (Pb-9244 - 69.5')
70.3 - 71.1	Buff-gray shale weathering into thin sheets which turn brown at their edges. Plant fragments. (Pb-9245 - 70.7')
71.1 - 71.6	Yellow-green to green shale with organic partings. (Pb-9246 - 71.3')
71.6 - 72.3	Maroon-gray shale, thin lignite partings. (Pb-9247 - 72.0')
72.3 - 72.4	Maroon organic shale with organic frag- ments on bedding planes.
72.4 - 72.8	Green shale.
72.8 - 73.0	Maroon organic shale with organic frag- ments on bedding planes. Fine gray laminae. (Pb-9248 - 72.9-73.0')
73.0 - 75.9	Light to dark gray shale with organic material on some partings. (Pb-9249 - 75.0')
75.9 - 82.1	Reddish brown lignitic to organic shale. Shaley at the base becoming more lignitic toward the top of the unit. (Pb-9250 - 76.3', Pb-9251 - 78.7', Pb-9252 - 81.5')
82.1 - 89.3	Yellow and gray sand, iron stained at base. (Pb-9253 - 83.1')

Feet from Top	Lithology and Sample Data
89.3 - 92.7	Coarse dark red-brown organic shale inter- bedded by thin yellow sand layers. (Pb-9254 - 89.7')
92.7 - 93.7	Green-gray-yellow sand.
93.7 - 94.4	Light to dark gray-brown shale with organic debris on bedding planes. (Pb-9255 - 94.0')
94.4 - 101.4	Green-gray-yellow sand.
101.4 - 102.0	Dark brown organic shale.
102.0 - 115.4+	Angular, poorly consolidated yellow sand with mica flakes. Irregularly spaced thick organic partings. (Pb-9256 - 106.5' - no organic material; Pb-9257 - 106.7' - organic parting)
Base of Measure	ed Section
	VALLEY SECTION
	NE¼ T27S R46E
	Malheur County, Oregon
Feet from Top of Section	Lithology and Sample Data
0.0 - 30.0	Light gray ash bed, weathers white. Cinder particles and carbonized plant fragments on some bedding planes. (Pb-9302 - 5.0', Pb-9303 - 17.5', Pb-9305 - 29.0')

- 30.0 34.0 Light yellow-green shale with poorly preserved plant fragments. (Pb-9274 32.0')
- 34.0 36.5 Very dark gray organic shale. (Pb-9275-35.5')
- 36.6 36.7 Fine green-yellow-gray ashy shale.
- 36.7 38.5 Greenish gray to dark gray shale, high organic content. Stump in place. (Pb-9276 37.5')

Feet from Top of Section	Lithology and Sample Data
38.5 - 41.5	Weathered greenish gray shale. (Pb-9277 - 40.0')
41.5 - 46.5	Gray shale with maroon caste, highly organic. (Pb-9273 - 45.5')
46.5 - 50.5	Dark organic shale, dries to a laminated gray-maroon. (Pb-9272 - 49.4')
50.5 - 52.5	Light yellow-brown shale with black organic material on some bedding planes. (Pb-9271 - 51.7')
52.5 - 130.0	Light gray to maroon-brown shale. The lower 10 - 20 feet represents the highly fossiliferous Valley Plant Beds. (Pb- 9270 - 62.5', Pb-9269 - 77.5', Pb-9268 - 114.8', Pb-9267 - 115.6-115.9', Pb-9266 - 127.9')
130.0 - 142.0	Interbedded organic shales, mudstones, sand. "Upper Swamp Series." (Pb-9308 - 9324)
142.0 - 147.8	Sandy red-brown shale, organic material on some bedding planes. (Pb-9265 - 146.8')
147.8 - 157.1	Interbedded organic shales, mudstones, and sands. "Lower Swamp Series." (Pb-9280 - 9301)
157.1 - 157.6	Fine yellow sand with mica flakes and organic debris. (Pb-9264)
157.6 - 162.5	Coarse brown shale with a high organic content. (Pb-9263 - 161.3)
162.5 <b>-</b> 275.5	Olive to brown sand. Moderately consolid- ated with some calcareous cement. Well- developed joint pattern. (Pb-9262 - 195.0')
275.5 - 276.0	Dark gray impure limestone with high organic content. (Pb-9261)
276.0 - 336.0	Continuation of the massive sand above.
336.0 - 341.5	Gray clay-shale. (Pb-9260 - 338.2')

Base of Measured Section.

A view of the valley system formed by the rocks of the Rockville section. The photograph was taken facing NW from the top of the knoll paralleling Sucker Creek Road approximately 0.5 N of the junction of Sucker Creek and Carter Creek Roads (Figure 1).



A view of the Shortcut section. The thick basal sand and the white ash bed are particularly prominent in this view. The Insect Bed is marked by the small terraces in the beds which appear to lie directly below the white cap of the knoll in the foreground.





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# Figure

1	Fungal Type l
2	Fungal Type 3
3	Fungal Type 4
4	Fungal Type 12
5	Fungal Type 7
6	Fungal Type 9
7	Fungal Type 6
8	Fungal Type 15
9	Algal Type 4
10	Fungal Type 16
11	<u>Alternaria</u> sp.
12	Fungal Type 19
13	Fungal Type 14
14	Algal Type 3
15	Fungal Type 5
16	Algal Type 1
17	Algal Type 2
18	Botryococcus sp.
19	Fungal Type 21



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PLATE ·4

# Figure

1	Polypodiaceae, Type 2
2	Polypodium sp.
3	Lycopodium, Type l
4	Monolete Type 4
5	Monolete Type 2
6	Trilete Type 2
7	Polypodiaceae, Type l
8	Osmunda sp.
9	Lycopodium, Type 2
10	Trilete Type l



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Figure

1Abies, Type 12Abies, Type 2

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Figure

1 <u>Picea</u>, Type 1 2 <u>Picea</u>, Type 2 (740X)

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All illustrations 1000X unless otherwise indicated.

#### PLATE 6.



Figure

1	Tsuga sp.
2	<u>Pinus</u> , Type l
3	<u>Pinus</u> , Type 6
4	<u>Pinus</u> , Type 4
5	<u>Pinus</u> , Type 5
6	<u>Pinus</u> , Type 2
7	Taxodiaceae
8	Podocarpus sp.



Figure

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1	Acer, Type 1
2	Acer, Type 2
3	Alnus sp.
4	Betula sp.
5	<u>Castanea</u> sp.
6	Carpinus sp.
7	Carya sp.
8	Chenopodiaceae, Type 1
9	Sarcobatus sp.
10	Artemisia, Type 1
11	Artemisia, Type 2
12	Compositae, Type 5
13	Compositae, Type 6
14	Compositae, Type l
15	Compositae, Type 2
16	Compositae, Type 3
17	Compositae, Type 4
18	Ericaceae
19	Shepherdia sp.
20	<u>Elaeagnus</u> sp.
21	Ericaceae

190 PLATE 8.



PLATE	9
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Figure

1	Fagus sp.
2	Gramineae, Type l
3	Gramineae, Type 2
4	Gramineae, Type 3
5	<u>Ilex</u> , Type l
6	<u>Ilex</u> , Type 2
7	Juglans sp.
8	Liquidambar sp.
9	Malvaceae, Type l
10	Sphaeralcea sp.
11	Leguminosae
12	Onagraceae, Type 2
L3	Onagraceae, Type 1



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Figure

1	Mahonia sp.
2	Nymphaea sp.
3	Nyssa sp.
4	Pterocarya sp.
5	Potamogeton sp.
6	Caprifoliaceae, Type l
7	Populus sp.
8	Pachysandra sp.
9	<u>Tilia</u> sp.
10	Typha sp.
11	Quercus sp.
12	<u>Ulmus</u> sp.
13	Quercus sp.
14	<u>Salix</u> sp.
15	Unknown 120



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# Figure

1	Unknown	61
2	Unknown	106
3	Unknown	49
4	Unknown	72
5	Unknown	93
6	Unknown	13
7	Unknown	66a
8	Unknown	79
9	Unknown	92
10	Unknown	63
11	Unknown	71
12	Unknown	67
13	Unknown	103
14	Unknown	121
15	Unknown	78
16	Unknown	108



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