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Paleogene Biostratigraphy of Nonmarine Rocks in King County, Washington

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By JACK A. WOLFE

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CONTENTS

	Page	Systematic descriptions—Continued	Page
Abstract.....	1	Fagaceae.....	18
Introduction.....	1	Ulmaceae.....	18
Previous work.....	2	Moraceae.....	19
Occurrence of the fossils.....	2	Cercidiphyllaceae.....	19
Time-stratigraphic units.....	5	Menispermaceae.....	20
Franklinian Stage.....	6	Hamamelidaceae.....	22
Fultonian Stage.....	7	Leguminosae.....	22
Ravenian Stage.....	7	Euphorbiaceae.....	23
Kummerian Stage.....	8	Anacardiaceae.....	23
Time-stratigraphic units in the Hobart, Issaquah, Maple Valley, and Renton quadrangles.....	11	Rhamnaceae.....	23
Relationships of the marine megafossil, mammalian, and paleobotanical geochronologies.....	12	Tiliaceae.....	24
Systematic descriptions.....	13	Theaceae.....	25
Aspidiaceae.....	14	Caprifoliaceae.....	25
Juglandaceae.....	14	Dicotyledonae incertae sedis.....	26
Betulaceae.....	17	Fossil plant localities.....	26
		References.....	28
		Index.....	31

ILLUSTRATIONS

[Plates follow index]

		Page
PLATES	1-7. Fossil leaves of Puget Group and related rocks.	
FIGURE	1. Map of part of King County.....	3
	2, 3. Stratigraphic section:	
	2. Green River canyon.....	4
	3. Tiger Mountain area.....	11
	4-20. Drawings showing:	
	4-6. Marginal venation:	
	4. <i>Vinea pugetensis</i>	14
	5. <i>Carya cashmanensis</i>	15
	6. <i>Carya pugetensis</i>	15
	7. Ultimate and marginal venation of <i>Pugetia longifolia</i>	16
	8-10. Marginal venation:	
	8. <i>Pterocarya pugetensis</i>	17
	9. <i>Alnus kluckingi</i>	17
	10. <i>Alnus operia</i>	17
	11. Ultimate and marginal venation of <i>Ulmus oregoniana</i>	18
	12. Ultimate, marginal, and intercostal venation of <i>Artocarpoides kummerensis</i>	19
	13, 14. Ultimate venation:	
	13. <i>Goweria dilleri</i>	21
	14. <i>Goweria linearis</i>	21
	15. Marginal venation of <i>Hyperbaena</i> and <i>Cinnamomum</i>	21
	16, 17. Ultimate venation:	
	16. <i>Hypserpa cashmanensis</i>	22
	17. <i>Hypserpa franklinensis</i>	22
	18. Ultimate, marginal, and intercostal venation of <i>Rhamnites cashmanensis</i>	24
	19. Ultimate venation of <i>Willisia</i> and <i>Microcos</i>	25
	20. Marginal venation of <i>Ternstroemites ravenensis</i>	25

TABLES

		Page
TABLE	1. Partial checklist of fossil plants from Paleogene rocks in the Green River canyon section.....	5
	2. Stratigraphic ranges of important species in Paleogene rocks.....	8
	3. Suggested relationships of plant stages and marine megafossil stages.....	13

PALEOGENE BIOSTRATIGRAPHY OF NONMARINE ROCKS IN KING COUNTY, WASHINGTON

By JACK A. WOLFE

ABSTRACT

In the canyon of the Green River and in adjacent areas, rocks of the Puget Group and overlying unnamed volcanic rocks contain a rich and abundant flora. These rocks are divided into four newly named formal time-stratigraphic units based on the ranges of plant species from 35 localities. These units are, in ascending order: the Franklinian, Fultonian, Ravenian, and Kummerian Stages. Informal subdivisions (lower and upper) are also made for the three upper stages.

The Green River canyon floras are correlated with floras from beds whose stratigraphic relationships to marine faunas are probably or certainly known. These correlations indicate that the Franklinian, Fultonian, and Ravenian Stages are probably of Eocene age and apparently represent most, if not all, of the Eocene Series. The Kummerian seems to be of early Oligocene age. Analysis of upper Kummerian floras indicates that they can be separated from floras that occur in rocks that paleontologists of marine megafossils consider to be of middle Oligocene age. The Ohanapecosh Formation (south of Mount Rainier) is on the basis of fossil plants, considered to be entirely of Oligocene age.

Fossil plants from 10 localities in the Tiger Mountain area indicate that the three formations of the Puget Group cropping out are equivalent to the middle and upper part of the Puget Group and the lower part of the unnamed volcanic rocks in Green River canyon. The Tiger Mountain Formation is assigned a late Fultonian (middle Eocene) age, and the Tukwila Formation is thought to be of early Ravenian through early Kummerian (late Eocene through earliest Oligocene) age; the Renton Formation contains fossil plants indicative of a late Ravenian through late Kummerian (latest Eocene through early Oligocene) age, and is thus equivalent to and probably interfingers with the upper part of the Tukwila.

Only about 80 of 140 distinct specific entities in the Puget flora have been determined to genus. The systematics of 31 species, 25 of which are new, are discussed in detail. The 31 species are assigned to 25 genera, 5 of which are new. Of the 25 genera, 8 are considered to be extinct, 4 are form genera, and 13 are thought to be extant.

INTRODUCTION

The Paleogene floras of the conterminous United States west of the Cordillera are virtually unknown: only middle and late Oligocene floras have been extensively studied. The only significant contributions have been those of MacGinitie (1941) on the early Eocene Chalk Bluffs flora, Sanborn (1935) on the late Eocene Comstock flora, and Potbury (1935) on the early Oligocene LaPorte flora, although a few species have been

described by Knowlton (1900, 1902) and Brown (1940, 1956). The relative ages of these floras have been determined chiefly on the stratigraphic relationships of the enclosing beds to fossiliferous marine beds, although the age of the LaPorte flora was until recently based solely on paleobotanical correlations. The lack of several described floras in beds of known superposition, however, has made the value of paleobotanical correlations dubious.

On the west flank of the Cascade Range in west-central Washington and in the adjacent Puget lowland is exposed an unusually complete section of Paleogene nonmarine rocks containing abundant plant fossils. Several Oligocene species have been reported (Wolfe, 1961) from the older andesitic volcanic rocks, formerly called the Keechelus Andesitic Series.

In the Puget lowland and adjacent foothills of the Cascades, andesitic rocks of early Oligocene age inter-tongue with the upper part of the coal-bearing Puget Group (Wolfe and others, 1961). In the canyon of Green River (fig. 1), the Puget Group is about 6,300 feet thick and consists of coal, shale, and sandstone containing abundant and well-preserved fossil plants. The beds exposed in and near the canyon have been mined extensively for coal; earlier information from the mine workings in conjunction with the recent detailed geologic mapping by J. D. Vine and H. D. Gower (unpub. data) has allowed a precise determination of the relative stratigraphic positions of most of the various plant localities. The lowest rocks exposed in the canyon contain floras indicative of an early Eocene age, that is, an age about the same as that of the early Eocene Chalk Bluffs flora of California (MacGinitie, 1941), and the unbroken sequence of the Puget Group in Green River canyon spans most, if not all, of the Eocene. Largely on the basis of the fossil plants, four time-stratigraphic units are erected: the Franklinian, Fultonian, Ravenian, and Kummerian Stages.

To the north of Green River canyon, in the Tiger Mountain area, the Puget Group rests gradationally on marine beds of the Raging River Formation of middle Eocene age. The fossil plants from just above the marine beds are, however, the same age as those in

about the middle of the Green River canyon section, and hence the Raging River Formation is correlative with at least part of the lower half of the Puget Group as exposed in Green River canyon.

Coal-bearing rocks of lithology similar to that of the Puget Group exposed in Green River canyon are known throughout western Washington as far south as southern Pierce County and as far north as the Canadian border. These rocks apparently underlie large areas of the Cascade Range because they are exposed on the east side of the Cascades near Roslyn. The only method currently available for working out the stratigraphic relationships of these various patches of Paleogene rocks is through the contained fossil plants.

This paper is based on a study of part of the flora of the Puget Group and associated volcanic rocks to emphasize the stratigraphic aspects of the fossil plants rather than the floristic aspects. Species that are known from but one locality have generally been excluded from study although these species may have considerable ecologic or floristic significance. Emphasis has been placed on those species that occur in two or more localities and particularly on species that are restricted stratigraphically and that appear to be phylogenetically related to other species higher or lower in the section.

On the basis of the change in the specific composition in the flora, the Puget Group can be subdivided in the Green River section. These subdivisions are considered to be provincial stages, that is, time-stratigraphic units applicable to nonmarine plant-bearing rocks throughout the same ancient floristic province. In the area covered by the mapping of J. D. Vine and H. D. Gower (unpub. data), the Puget Group can be more finely subdivided; it is uncertain, however, whether these substages can be recognized throughout the floristic province, although at least some of the substages can be recognized throughout western Washington and Oregon. For this reason, these substages are not given formal status here.

I particularly wish to thank H. D. Gower and J. D. Vine for their assistance in furnishing detailed stratigraphic information and for collecting fossils at new localities. Dr. H. D. MacGinitie has assisted considerably in numerous discussions of Paleogene paleobotany.

Most of the fossil plants were collected during 1960 and 1961. Stratigraphic information on several older collections made by F. H. Knowlton and G. O. Smith is sufficiently detailed to be used in the current work. Unfortunately, detailed information is lacking on most of the old collections from the Carbonado area; in addition, some of these collections apparently are mixed.

PREVIOUS WORK

The Paleogene floras of western Washington have received little attention. Newberry (1863) described a few species from the Paleocene Chuckanut Formation and also listed (1898) a few species from the Puget Group in Pierce County. In 1894, Newberry (in Hollick, 1894) described a species of *Salvinia* from the Pierce County outcrops. Knowlton (in Willis and Smith, 1899) discussed the stratigraphic significance of floras from the Puget Group. He visited King and Pierce Counties and made collections himself. Although he left a large manuscript on the flora of the Puget Group when he died, this manuscript is useless because of the numerous invalid generic assignments, brief specific descriptions, and poor locality data.

Brown (1939, 1940) figured a few specimens from the so-called Steel's Crossing locality. The flora from this locality has been discussed by several authors in connection with other Paleogene floras.

OCCURRENCE OF THE FOSSILS

Most of the fossil plants are from the Cumberland quadrangle. The Green River has cut a deep winding canyon through the middle of this region in a generally west direction, exposing a nearly continuous sequence, 6,300 feet thick, of coal-bearing rocks assigned to the Puget Group. This section has been discussed in detail by J. D. Vine and H. D. Gower (unpub. data). Because of detailed information from mine workings, the rocks in the southern part of the Ravensdale mining district (fig. 1) and near Black Diamond can be related with confidence to the section in the canyon. The rocks exposed near Durham, at Ravensdale, and in the southeastern part of the quadrangle have a less certain relationship to the canyon section; the lithologic and paleobotanical correlations agree so well, however, that these localities are considered part of the Green River section (fig. 2). In this section, 31 localities occur in the Puget Group and 4 occur in the overlying andesitic volcanic rocks.

Green River canyon area.—Mine workings and the numerous exposures in the canyon of Green River have provided data for the construction of a detailed stratigraphic section. The lower part of the section contains much sandstone with minor amounts of carbonaceous shale and impure bituminous coal. The most conspicuous coal bed in the lower part of the section is the Franklin bed 12 (Fulton), which is a zone 40 feet thick and contains much coal, impure coal, and lenses of shale. Above the Franklin bed 12 is the Big Dirty bed, which is also about 40 feet thick but contains more

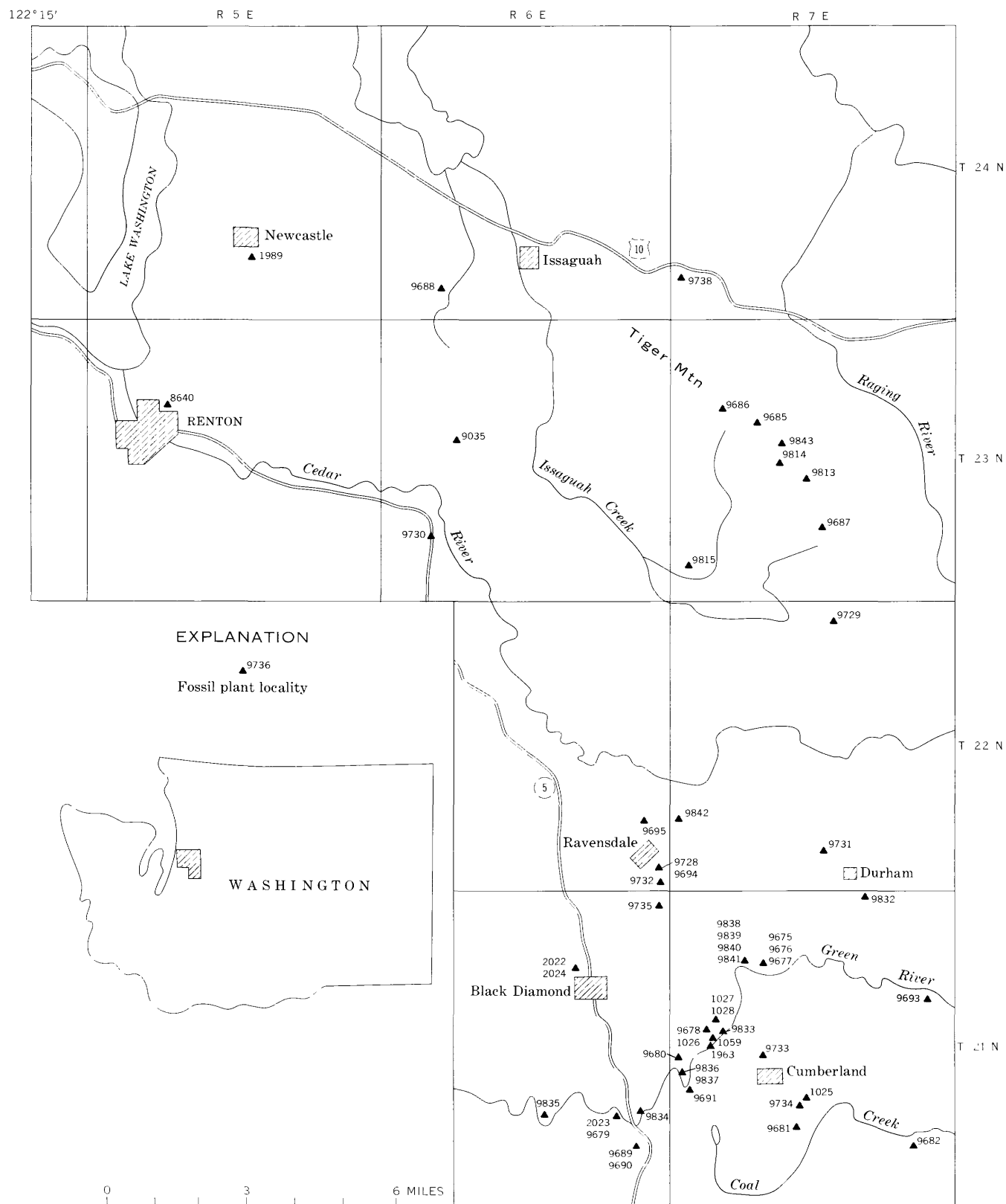


FIGURE 1.—Part of King County, Wash., showing fossil plant localities.

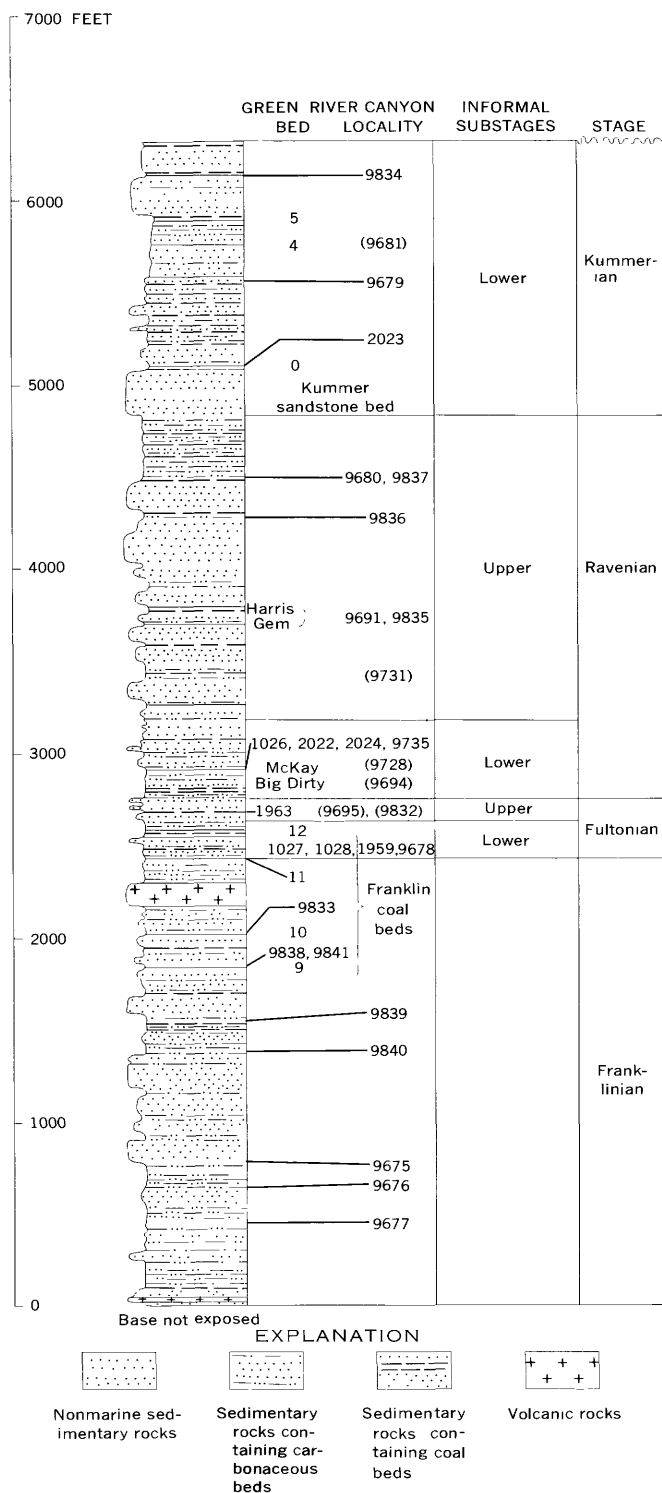


FIGURE 2.—Stratigraphic section of the Puget Group undifferentiated in Green River canyon. Localities in parentheses are placed approximately because relationships are uncertain.

impure coals. The McKay bed, which is above the Big Dirty, is relatively thin (about 7 ft) but is a low-ash bituminous coal. The Gem-Harris beds occur in a coal zone underlying the Kummer sandstone bed, and the Kummer beds overlie the sandstone. It is probable that the coal zones containing all these beds, if not the individual beds themselves, are persistent throughout the Cumberland quadrangle.

Above the Puget Group are andesitic volcanic rocks previously assigned to the Keechelus Andesitic Series. The volcanic rocks are thought to be conformable on the Puget Group, and studies of the fossil plants from these rocks are included in the present report.

Ravensdale area.—A thick coal zone consisting of the Ryan and Ravensdale coal beds is separated from the Green River section by a fault. The upper part of this coal zone probably corresponds with the McKay and the thick Big Dirty beds in Green River canyon. Localities 9694 and 9728 occur below the Ravensdale 4 and 5 beds, respectively; these localities apparently represent an interval for which no plants are known in the Green River section.

Georgetown area.—The thickness and high rank of the Landsburg bed 1 indicate that it is probably equivalent to the Franklin bed 12. The high-rank and low-ash content of the overlying Rogers bed, as well as the stratigraphic distance above the Landsburg bed 1, indicate that the Rogers and the McKay are probably the same bed. Locality 9695 occurs about midway between the Rogers bed and Landsburg bed 1, and thus is stratigraphically at about the same position as locality 1963.

Durham area.—This area is separated from the main part of the Green River section by the Green River fault. The lower part of the section contains a thick impure coal (Durham bed 1) intercalated with carbonaceous siltstone. Lithologically, this coal zone is most similar to the Big Dirty bed in the Green River section. Overlying the Durham bed 1 are two other coal beds, which probably represent the coal zone in the Green River section that contains the McKay bed. Higher in the Durham section is the Cashman coal bed; this could be the correlative of the Gem-Harris beds or it may be the equivalent of an impure coaly zone in the Green River section between the McKay and the Gem-Harris beds. Locality 9832 is immediately below the Durham bed 1, and locality 9731 is below the Cashman bed.

TIME-STRATIGRAPHIC UNITS

The methods used here to erect time-stratigraphic units are classical: the collection of plants in standard sections and the interpretation of the fossils in terms of restriction and overlap of teilzones of various species or genera. For some range zones, it is also possible to define at least one parameter of the zone because of the presence of two or more member species of a phylad. The ranges of these species (for example, the ranges of certain species of *Goveria*, *Artocarpoides*, and *Rhamnites*) are more reliable stratigraphically than even widespread and characteristic forms such as *Anacardites franklinensis*, of whose ancestral and descendant species nothing is known.

Formal zones have not been erected for two reasons. First, zonal names (for example, the zone of *Castanopsis longipetiolata*) are cumbersome terms. Second, if some other worker revises the species on which a zonal name is based, then either the generic name or the epithet, or both, may be different. A constancy of names for biostratigraphic and time-stratigraphic units is desirable, and such constancy cannot always be obtained if the name is based on nomenclature which is generally unstable. Therefore, only stages have been named formally, and what might be termed as assemblage zones by some workers are here termed substages.

The fact that all stages but the Franklinian have boundaries that coincide with boundaries of informal zones in no way makes the stages invalid. The code of stratigraphic nomenclature (Cohee, 1962) in fact notes that such a practice gives stages objective reference points. Measured sections for the type sections are given by J. D. Vine and H. D. Gower (unpub. data).

The boundaries for the substages depicted in figure 2 are not as precise as the figure indicates. Most boundaries have been placed at some prominent lithologic change. Without palynologic data, it is impossible to place the boundaries with any degree of certainty, except to indicate that the boundary of a particular substage or stage falls between two particular localities.

In table 1 are included all the species previously or herein described and other undescribed species determined to genus. About 140 species have been recognized in the Puget Group and overlying andesitic rocks in King County. The other forms are either rare or unstudied at this time, but some will probably prove to be of stratigraphic value. Members of Lauraceae, in particular, have been largely excluded from this study; without extensive cuticular studies, I hesitate to determine members of this family generically, and only a few apparently well-defined species have been included. Table 2 is a summary of the ranges of the more stratigraphically significant species.

TABLE 1.—Partial checklist of fossil plants from Paleogene rocks in the Green River canyon section

Species	USGS Paleobotany locality																																			
	9677	9676	9675	9842	9839	9841	9838	9833	9678	1027	1028	1059	1963	9832	9695	9732	9694	9728	9735	2024	2022	1026	9731	9691	9835	9836	9837	9690	2023	9679	9834	9681	9693	9690	9689	
<i>Anemia eocenica</i> Berry					X										X		X																			
<i>Allantodiopsis pugetensis</i> Wolfe									X						X		X																			
<i>Hemitelia pinnata</i> MacG		X			X								X				X																			
<i>Lastrea fischeri</i> Heer																	X																			
<i>Salvinia elliptica</i> Newb																																				
<i>Glyptostrobus</i> sp.	X	X				X	X	X						X			X		X						X											
<i>Metasequoia glyptostroboides</i> Hu and Cheng		X														X	X							X					X							
<i>Sequoia affinis</i> Lesq																	X							X												
<i>Sabalites</i> sp.					X												X																			
<i>Smilax</i> n. sp.																																				
<i>Carya cashmanensis</i> Wolfe																							X													
<i>Carya pugetensis</i> Wolfe									X														X													
<i>Engelhardtia</i> sp.																							X													
<i>Pugetia longifolia</i> Wolfe	X				X	X			X	X	X	X	X	X		X							X													
<i>Pterocarya pugetensis</i> Wolfe																X		X																		
<i>Vinea pugetensis</i> Wolfe																	X																			
<i>Alnus kluckingi</i> Wolfe																																				
<i>Alnus operia</i> MacG		X														X																				
<i>Alnus</i> n. sp.																X																				
<i>Castanopsis franklinensis</i>																																				
<i>Castanopsis longipetiolata</i> (Knowl.) MacG	X	X	X				X																													
<i>Dryophyllum pugetensis</i> Wolfe																																				
<i>Quercus nevadensis</i> of Potb.																																				
<i>Ulmus oregoniana</i> Knowl.	X	X		X				X	X		X		X	X	X																					
<i>Artocarpoides kummerensis</i> Wolfe															X																					
<i>Artocarpoides litseaefolia</i> (MacG.) Wolfe	X				X	X		X	X				X	X	X	X							X													
<i>Cercidiphyllum piperoides</i> (Lesq.) LaM	X	X	X					X	X		X		X	X			X																			
<i>Cryptocarya presamarensis</i> Sanb.																																				
<i>Cryptocarya presamarensis</i> of MacG			X																																	
<i>Laurophyllum raminerum</i> Potb.																																				
<i>Neolitsea lata</i> MacG		X				X																														
<i>Ocotea eocenica</i> Chan. and Sanb.																																				
<i>Ocotea</i> n. sp.																																				
<i>Persea pseudocarolinensis</i> Lesq	X	X			X																															
<i>Arcangelisia?</i> n. sp.																																				
<i>Calkinsia franklinensis</i> Wolfe								X	X														X													
<i>Fibraurea</i> n. sp.								X	X																											</

TABLE 1.—Partial checklist of fossil plants from Paleogene rocks in the Green River canyon section—Continued

Species	USGS Paleobotany locality																			
	9677	9676	9675	9642	9639	9641	9638	9633	9678	1027	1028	1059	1963	9632	9695	9732	9694	9728	9735	2024
<i>Hyperba cashmanensis</i> Wolfe.....									X				X		X		X			
<i>Hyperba franklinensis</i> Wolfe.....									X				X	X						
<i>Fothergilla durhamensis</i> Wolfe.....													X							
<i>Hamamelites voyana</i> (Lesq.) MacG.....						X														
<i>Liquidambar californica</i> Lesq.....																				
<i>Platanus</i> n. sp.....																				
<i>Cesalpinies</i> sp.....		X																		
<i>Cladastis pugetensis</i> Wolfe.....																				
<i>Leguminosites falcatum</i> Potb.....																				
<i>Tetrapteris simpsoni</i> R. W. Br.....									X											
<i>Macaranga pugetensis</i> Wolfe.....									X											
<i>Mallotus riparius</i> MacG.....		X																		
<i>Anacardites franklinensis</i> Wolfe.....									X	X										
<i>Cupania oregonia</i> Chan. and Sanb.....																				
<i>Rhamnus cashmanensis</i> Wolfe.....									X											
<i>Rhamnus franklinensis</i> Wolfe.....									X											
<i>Rhamnus plena</i> MacG.....	X								X						X					
<i>Microcos</i> n. sp.....									X											
<i>Willisia rentonensis</i> Wolfe.....									X	X				X						
<i>Dillenia</i> n. sp.....									X											
<i>Tetracera oregonia</i> Chan. and Sanb.....																				
<i>Camellia multiflora</i> (Potb.) Wolfe.....																				
<i>Ternstroemia ravenensis</i> Wolfe.....																				
<i>Gordonia egregia</i> (Lesq.) MacG.....	X				X	X			X				X							
<i>Eugenia?</i> n. sp.....																				
<i>Cornus kelloggii</i> of Potb.....																				
<i>Nerium hinoidea</i> MacG.....	X					X														
<i>Cordia rotunda</i> Chan. and Sanb.....																				
<i>Viburnum pugetensis</i> Wolfe.....	X					X			X				X							
<i>Viburnum variabilis</i> MacG.....																				
<i>Macclintockia pugetensis</i> Wolfe.....																				
<i>Phyllites alchorneopsis</i> Potb.....																				

FRANKLINIAN STAGE

Definition

The Franklinian Stage is proposed as a time-stratigraphic term for plant-bearing rocks in the ancient floristic province equivalent in age to the lowest part of the Puget Group exposed in Green River canyon. The upper boundary of the type section of the Franklinian Stage is arbitrarily placed at the bottom of the Franklin bed 11.

Flora

The flora of the Franklinian Stage is characterized by the following species:

Castanopsis longipetiolata
Cryptocarya presamarensis of MacG.
Neolitsea lata
Persea pseudocarolinensis
Hamamelites voyana
Mallotus riparius
Nerium hinoidea

Several other species also make their first appearance in the exposed Green River canyon section:

Anemia eocenica
Hemitelea pinnata
Alnus operia
Ulmus oregoniana
Calkinsia franklinensis
Pugetia longifolia
Artocarpoides litseafolia
Goweria linearis
Rhamnus plena

*Gordonia egregia**Viburnum pugetensis*

Some members of both groups may be found in rocks older than Franklinian; *Hemitelea pinnata*, for example, is known at several localities that are definitely of Paleocene age.

Age

The age of the Franklinian in relation to traditional epochs is somewhat uncertain. None of the dicotyledons listed above have been reported from rocks of known Paleocene age. Paleocene floras to the east (Brown, 1962) and north (Wolfe, 1966), although greatly similar to one another, are different on the specific level from the Franklinian. Characteristic Paleocene forms such as *Carya antiquora*, *Cocculus flabella*, *Dicotylphyllum flexuosa*, and *D. richardsoni* are absent from the Franklinian.

The Chalk Bluffs flora (MacGinitie, 1941) of the northern Sierra Nevada has many species in common with the Franklinian flora; included are some of the species listed above as characteristic of this stage. It seems certain that the beds containing the Chalk Bluffs flora are assignable to the Franklinian. The age previously assigned to the Chalk Bluff flora is that equivalent to the Capay Stage (lower Eocene) of Weaver and others (1944). This assignment is somewhat problematic but is based on the regional structural and lithologic relationships of the gravels containing the flora to the marine sequence in the Sacramento Valley. The Franklinian Stage is thus tentatively considered to be of early

Eocene age; no certain relationship to the marine sequence can be demonstrated at this time.

FULTONIAN STAGE

Definition

The Fultonian Stage is proposed as a time-stratigraphic term for plant-bearing rocks in the same ancient floristic province equivalent in age to the middle part of the Puget Group exposed in Green River canyon. The lower boundary of the type section is placed at the base of the Franklin bed 11, and the upper boundary is placed at the base of the Big Dirty bed. The beds exposed below the Durham bed 1 in the Durham bed 1 strip pit are designated as a reference section for the Fultonian Stage.

Flora

The flora of the Fultonian Stage is characterized by the joint occurrence of the following species:

- Vinea pugetensis* (restricted)
- Castanopsis franklinensis* (restricted)
- Gordonia egregia* (highest occurrence)
- Pugetia longifolia* (highest occurrence)
- Ulmus oregoniana* (highest occurrence)
- Allantodiopsis pugetensis* (lowest occurrence)
- Carya pugetensis* (lowest occurrence)
- Hyperbaena dilleri* (lowest occurrence)
- Rhamnites franklinensis* (lowest occurrence)
- Willisia rentonensis* (lowest occurrence)

The flora from the lower part of the Fultonian—the interval immediately overlying the Franklin bed 12—appears distinctive from the flora from the upper part of the Fultonian, which was collected from the lower part of the Big Dirty bed. Three species are restricted to the lower part of the Fultonian: *Hypserpa franklinensis*, *Macaranga pugetensis*, and *Anacardites franklinensis*. The first species is related and is probably ancestral to *Hypserpa cashmanensis*, which has its lowest occurrence in the upper part of the Fultonian. Similarly, *Goveria linearis* from the Franklinian and lower part of the Fultonian apparently gave rise to the species *G. dilleri* of the upper part of the Fultonian and Ravenian. *Pterocarya pugetensis* and *Dryophyllum pugetensis* also make their first appearance in the late Fultonian, and *Fothergilla durhamensis* is restricted to the late Fultonian.

Age

No previously described flora or flora of known relationship to marine rocks from western North America contains the species considered diagnostic of Fultonian age. Floras from beds intercalated with marine rocks of late Eocene age (Tejon), for example, the flora from locality 9106 in the McIntosh Formation, are referable to the overlying Ravenian Stage. In the Tiger Mountain

area, beds with floras of late Fultonian age immediately overlie the marine beds of the middle Eocene Raging River Formation. It is thus probable that the Fultonian Stage is partly of middle Eocene age although at present this cannot be confirmed by direct correlations. The Fultonian could also include beds of early Eocene age (Capay of Weaver and others, 1944).

RAVENIAN STAGE

Definition

The type section of the Ravenian Stage is designated as the beds from the base of the Big Dirty coal bed to the base of the Kummer sandstone bed from Green River canyon to the vicinity of Black Diamond. The beds exposed in the Cashman strip pit northwest of Durham and the beds from the base of the Ravensdale 3 to the top of the Ravensdale 9 are designated as reference sections. The Big Dirty bed is assigned to the Ravenian because of the Ravensdale section. Locality 9728 contains *Artocarpoides litseafolia* and can therefore be no younger than early Ravenian. Inasmuch as locality 9694, which lies below 9728 and is between Ravensdale beds 3 and 4 (the probable Big Dirty equivalent), is lower Ravenian, the Big Dirty bed is thought to be mostly within the Ravenian. In addition, the Ravensdale bed 9, which overlies bed 5, contains similar to the McKay bed, low ash coal and thus is probably an extension of the McKay bed; this indicates that the Ravensdale beds 3 and 4 are well down in the Big Dirty coal zone.

Flora

The Ravenian flora is characterized by the following species:

- Ternstroemites ravenensis* (restricted)
- Allantodiopsis pugetensis* (highest occurrence)
- Carya pugetensis* (highest occurrence)
- Pterocarya pugetensis* (highest occurrence)
- Dryophyllum pugetensis* (highest occurrence)
- Hypserpa cashmanensis* (highest occurrence)
- Hyperbaena dilleri* (highest occurrence)
- Willisia rentonensis* (highest occurrence)
- Viburnum pugetensis* (highest occurrence)
- Cladrastis pugetensis* (lowest occurrence)

Floras from localities in the lower part of the type Ravenian and in the referred section near Ravensdale appear distinct from the floras above the horizon of the McKay bed in the type section. These lower floras contain the highest occurrence of *Hemitelea pinnata*, *Anemia eocenica*, *Alnus operia*, *Rhamnites franklinensis*, *Goveria dilleri*, and *Artocarpoides litseafolia*. *Artocarpoides* and *Rhamnites* are represented in the upper part of the Ravenian by the related and probably descendant species *R. cashmanensis* and *A. kummeren-*

TABLE 2.—Stratigraphic ranges of important

Series	Stage	Informal substage	Localities	<i>Cryptocarya presamarensis</i> of MacG.	<i>Viburnum variabilis</i>	<i>Persea pseudocarolinensis</i>	<i>Mallotus riparius</i>	<i>Castanopsis longipetiolata</i>	<i>Neollsea lata</i>	<i>Nerium hinoidea</i>	<i>Hamamelites rojana</i>	<i>Rhamnus plena</i>	<i>Cakinsia franklinensis</i>	<i>Goueria linearis</i>	<i>Gordonia egregia</i>	<i>Pugelia longifolia</i>	<i>Ulmus oregoniana</i>	<i>Hemideia pinnata</i>	<i>Anemita eocenica</i>	<i>Alnus operia</i>	<i>Artocarpoides tisseiifolia</i>	<i>Viburnum pugdensis</i>	<i>Hyperpa franklinensis</i>	<i>Macaranga pugdensis</i>	<i>Anacardites franklinensis</i>
Oligocene	Lower	Kummerian	Upper	9758, 9759, 9760, 9761																					
			Lower	9682, 9689, 9690, 9693																					
		Ravenian	Upper	2023, 9679, 9681, 9834																					
			Lower	9680, 9691, 9835, 9836, 9837, 9731																		X			
	Middle	Fultonian	Upper	1026, 2022, 2024, 9735, 9694, 9728														X	X	X	X	X			
			Lower	9695, 9732, 9832, 1963											X	X	X	X	X	X	X	X			
		Franklinian	Upper	1027, 1028, 1059, 9678								X	X	X	X	X	X	X	X	X	X	X	X	X	X
			Lower	9833, 9838, 9841				X	X	X	X		X	X	X	X	X	X	X	X	X	X			
Eocene	Lower	Franklinian		9675, 9676, 9677, 9839, 9840	X	X	X	X	X	X		X			X	X	X	X	X	X	X				

sis. In addition, *Carya cashmanensis* and *Alnus kluckingi* occur in the upper but not in the lower parts of the Ravenian.

Age

Tie-ins between floral beds of the Ravenian Stage and marine beds are better than for either the Franklinian or Fultonian Stages. Lower Ravenian floras occur in the Tukwila Formation which interfingers with the Tiger Mountain Formation which conformably overlies the marine middle Eocene Raging River Formation. The predominantly marine McIntosh Formation was assigned a late Eocene (Tejon) age by Snively, Brown, Roberts, and Rau (1958). The flora from locality 9106 in the McIntosh contains *Allantodiopsis pugetensis*, *Pterocarya pugetensis*, *Hyperpa cashmanensis*, *Rhammites cashmanensis*, and *Artocarpoides kummerensis*, species diagnostic of a late Ravenian age. The Comstock flora (Sanborn, 1935) of western Oregon occurs in the uppermost part of the Comstock Formation of Turner (1938) and lowermost part of the predominantly non-marine Fisher Formation (Snively and others, 1958); in terms of marine invertebrate workers, the Comstock flora is of latest Tejon and earliest Keasey age. The occurrence in the Comstock flora of *Allantodiopsis pugetensis*, *Hyperbaena dilleri*, and *Artocarpoides kummerensis* indicates a late Ravenian age for this flora. These data indicate that the Ravenian Stage is probably equivalent to all the Tejon and to the lower part of the Keasey stages; that is, the Ravenian includes most or all of the late Eocene as recognized in the northeastern Pacific by workers in marine megafossils.

KUMMERIAN STAGE

Definition

The type section of the Kummerian Stage is designated as the beds from the base of the Kummer sandstone bed to and including the andesitic rocks overlying the Puget Group in Green River canyon. The beds of the upper 300 feet of the Puget Group and the lower 300 feet of the overlying andesitic rocks on Coal Creek are designated as a reference section.

Flora

The flora of the Kummerian Stage is characterized by the joint occurrence of the following species:

- Phyllites alchorneopsis* (restricted)
- Leguminosites falcatum* (restricted)
- Camellia multiflora* (restricted)
- Cornus kelloggi* of Potbury (restricted)
- Cryptocarya presamarensis* (highest occurrence)
- Laurophyllum raminervum* (highest occurrence)
- Artocarpoides kummerensis* (highest occurrence)

The floras from localities between the Kummer sandstone bed and the local top of the Puget Group are recognizably different from those of the overlying andesitic volcanic rocks. These lower Kummerian floras contain species lacking in the upper part of the Kummerian—that is, *Cladrastis pugetensis*, *Liquidambar californica*, and *Cercidiphyllum piperoides*. More noteworthy is the absence in the lower part of the Kummerian of species, such as *Ocotea eocernua*, *Cupania oregona* and *Tetracera oregona* (this species is, however, rare in the late Ravenian and early Kummerian floras in the Tiger Mountain area), that are com-

	×	×						<i>Castanopsis franklinensis</i>
	×	×	×	×				<i>Vinea pugdensis</i>
		×	×					<i>Fothergilla durhamensis</i>
	×	×	×					<i>Rhamnites franklinensis</i>
		×	×	×				<i>Goneria dilleri</i>
	×	×	×	×				<i>Allantodiopsis pugdensis</i>
	×	×	×	×				<i>Willisia rentonensis</i>
	×	×	×	×				<i>Hyperba cashmanensis</i>
	×	×	×	×				<i>Carya pugdensis</i>
	×		×	×	×			<i>Hyperbaena dilleri</i>
		×		×				<i>Pterocarya pugdensis</i>
	×	×	×	×				<i>Dryophyllum pugdensis</i>
		×	×	×				<i>Ternstroemites rupestris</i>
	×	×	×	×				<i>Cladrasia pugdensis</i>
		×						<i>Rhamnites cashmanensis</i>
	×	×						<i>Carya cashmanensis</i>
		×						<i>Alnus blucingi</i>
		×	×	×				<i>Arctostaphylos kumataensis</i>
		×	×	×				<i>Laurophyllum ramirezi</i>
		×	×	×				<i>Cryptocarya presamensis</i>
		×		×				<i>Candelia multiflora</i>
		×						<i>Leguminosites salicatum</i>
		×						<i>Cornus kelloggii</i> of Potb.
		×	×					<i>Phyllites alchorneopsis</i>
		×						<i>Macintockia pugdensis</i>
		×	×	×				<i>Platanus</i> n. sp.
		×						<i>Ocotea coernea</i>
		×						<i>Cupania oregonia</i>
		×						<i>Tetracera oregonia</i>
		×						<i>Cordia rotunda</i>
		×						<i>Cercidiphyllum crenatum</i>
		×						<i>Ficus quimbini</i>
		×						<i>Ficus plinaria</i>
		×						<i>Prunus franklinensis</i>
		×						<i>Prunus pristina</i>
		×						<i>Meliosoma desculifolia</i>
		×						<i>Alnus thornei</i>

The age of the Ohanapecosh Formation in the Mount Rainier area and of some rocks purported to be part of the Ohanapecosh on Summit Creek, has been thought to be Eocene. Fiske, Hopson, and Waters (1963 p. 20) stated that the Ohanapecosh is "mostly of late Eocene age." This age assignment is based on (1) two fossil plant collections made by R. V. Fisher and reported on by R. W. Brown, (2) a collection from purported Ohanapecosh rocks on Summit Creek never seen

The specimen of a conifer is probably *Glyptostrobus*, although specifically indeterminate. *Carya magnifica* is

known from two other Tertiary units: the late Oligocene and Miocene part of the Kootznahoo Formation and an unnamed late Oligocene or early Miocene unit on Kukak Bay. Both occurrences are in Alaska. Hollick (1936) misidentified specimens of the Paleocene *Carya antiquora* Newberry as *C. magnifica*. The specimen determined by Brown lacks any venation below the level of the secondaries, and any familial, much less a generic or specific, assignment is questionable. The *Ulmus* is also fragmentary and poorly preserved, but in all characters preserved it is identical with the "*Carya magnifica*." *Cercidiphyllum arcticum* as used by Brown has been shown to contain species and genera none of which are considered to be *Cercidiphyllum* (Wolfe, 1966); the types of *Cercidiphyllum arcticum*, from the Paleocene of Greenland, have been referred to the Paleocene species *Cocculus flabella* (Newberry) Wolfe. The leaves from locality 9316 are not as well preserved as is desirable for specific determination and are here referred to *Cercidiphyllum* sp. cf. *C. crenatum* (Unger) Brown; this species is known only from Oligocene and younger rocks.

Regarding the age of Fisher's collections, Brown stated: "So far as I can determine from these collections the age of all of them is Eocene. However, from the limited material no separation into parts of the Eocene can be made." It is also of some significance that Brown reported *Alnus corylina* Knowlton and Cockerell from another of Fisher's "Eocene" localities. Although the specimen was misidentified by Brown, this species is restricted to the Homerian Stage (Miocene to early Pliocene(?)) of Alaska and also occurs in the late Miocene of Oregon (Wolfe, 1966); its presence would not indicate an Eocene age.

The second basis for an Eocene age for the Ohanapecosh Formation is the flora collection from Summit Creek (Univ. Calif. Mus. Paleontology). This collection was made by me in company with J. A. Ellingson and H. D. Gower, from a small patch of sandstone and coal-bearing rocks that Fiske, Hopson, and Waters (1963) interpreted as a tongue in the Ohanapecosh. The field evidence, however, is not straightforward; according to Fiske, Hopson, and Waters (p. 18) the patch is about 1,500 feet stratigraphically below the oldest Ohanapecosh rocks exposed in the southeast corner of the park. It is equally possible to say, on the basis of the field evidence, that these rocks on Summit Creek are unrelated to the Ohanapecosh Formation. From a floral list I supplied originally to Ellingson, Brown (in Fiske and others, 1963, p. 18) considered the flora to be of middle Eocene or slightly younger age. This flora contains, according to the nomenclature used

here: *Hemitelia pinnata*, *Ulmus oregoniana*, *Rhamnus plena*, and *Vinea pugetensis*, species indicative of a Ful-tonian (middle Eocene) age. These rocks are considerably older than any others assigned to the Ohanapecosh Formation, and on the basis of their lithologic difference from the Ohanapecosh, probably represent another unit.

The third basis for an Eocene age of the Ohanapecosh Formation is a collection that Brown determined only to the generic level:

<i>Sabal</i> sp.	<i>Platanus</i> sp.
<i>Carya</i> sp.	<i>Cinnamomum</i> sp.
<i>Castanea</i> sp.	<i>Laurus</i> sp.
<i>Chaetoptelea</i> sp.	<i>Sassafras</i> sp.
<i>Hydrangea</i> sp.	<i>Liquidambar</i> sp.

Although Fiske, Hopson, and Waters (1963, p. 18) cited Brown as declaring that this floral assemblage indicates a late Eocene age, the reasoning by which Brown arrived at this conclusion is not given. All these genera are living today; all are known in the Oligocene of the Northwest, and all but two (*Sabal* and *Chaetoptelea*) are known in the Miocene of this area. It is impossible, on the basis of the list given, to restrict the assemblage to the late Eocene.

Thus, the evidence on which the Ohanapecosh Formation is assigned to the late Eocene by Fiske, Hopson, and Waters, is not sufficient for substantiating the age assignment; they did not discuss the floras of large collections from the Ohanapecosh south of Mount Rainier (Wolfe, 1961). Seven species, all restricted to the Oligocene, were listed by me as occurring in these localities. Moreover, Brown made a small collection, now in the National Museum from the same locality as 9759, and this collection bears the notation "Oligocene?" in Brown's handwriting. It is therefore clear that in the area south of Mount Rainier, the only diagnostic fossils from certain Ohanapecosh indicate an Oligocene age.

Age

Because the upper part of the Ravenian Stage can be correlated with the upper part of the Tejon and lowermost Keasey stages, the Kummerian is probably equivalent to at least part of the Keasey stage. Fossil plants have been collected (loc. 9134) at about the same stratigraphic interval as the Gries Ranch fauna (early Lincoln age of Weaver and others, 1944) in the Toutle Formation. Included in this small collection is an assemblage diagnostic of the upper part of the Kummerian: *Tetracera oregonia*, *Artocarpoides kummerensis*, and *Macclintockia pugetensis*. *M. pugetensis* is common in rocks in the marine sequence at the head of the Gulf of Alaska; where this species has been found, it occurs only in the marine units Keasey or early Lincoln age.

Paleontologists working with the marine megafossil invertebrates on the Pacific coast are apparently uncertain as to whether the Keasey Stage is of late Eocene or early Oligocene age, as evidenced by the placing of this stage on the Eocene-Oligocene boundary by Weaver and others (1944). The fossil plants certainly have no bearing on this particular problem, inasmuch as paleobotanists cannot make direct correlations to the type sections of the Eocene and Oligocene. Hence, I have arbitrarily placed the Kummerian Stage entirely within the Oligocene.

TIME-STRATIGRAPHIC UNITS IN THE HOBART, ISSAQUAH, MAPLE VALLEY, AND RENTON QUADRANGLES

Fossil plants have been collected from several localities in the Tiger Mountain area (figs. 1, 3). Comparison of these plants (table 1) with those in the Green River section indicate that in the Green River section the substages occur in the same stratigraphic sequence as in the Tiger Mountain area. Neither the Franklinian nor the lower part of the Fultonian Stages, however, are represented in the collections from the Tiger Mountain area. In this area, rocks below the upper part of the Fultonian are marine and are assigned to the Raging River Formation (Vine, 1962), which is of Domengine (middle Eocene) age.

The lowest nonmarine rock unit in the Tiger Mountain area is the Tiger Mountain Formation. Two fossil plant localities (9813, 9814) in the formation contain *Goweria dilleri*, *Ulmus oregoniana*, *Willisia rentonensis*, and *Pugetia longifolia*, and thus indicate a late Fultonian (middle Eocene) age.

Fossil plants from the overlying Tukwila Formation represent several different substages. The four species in the lowest collections (9685, 9686) are not useful in determining the substage for the containing rocks. The flora from the next higher locality (9687), however, is assigned to the lower Ravenian on the basis of the joint occurrence of *Hemitelea pinnata*, *Goweria dilleri*, *Ternstroemites ravenensis*, and *Artocarpoides litseafolia*. A lower Ravenian flora is also represented by locality 8640 (Steel's Crossing flora of various authors), which contains *Artocarpoides litseafolia*, *Allantodiopsis pugetensis*, and *Willisia rentonensis*. Locality 9738, which is high in the Tukwila, contains *Hyperbaena dilleri*, *Cryptocarya presamarensis*, *Malotus comstocki*, and *Tetracera oregona* and thus is of late Ravenian age. The highest locality (9035) in the

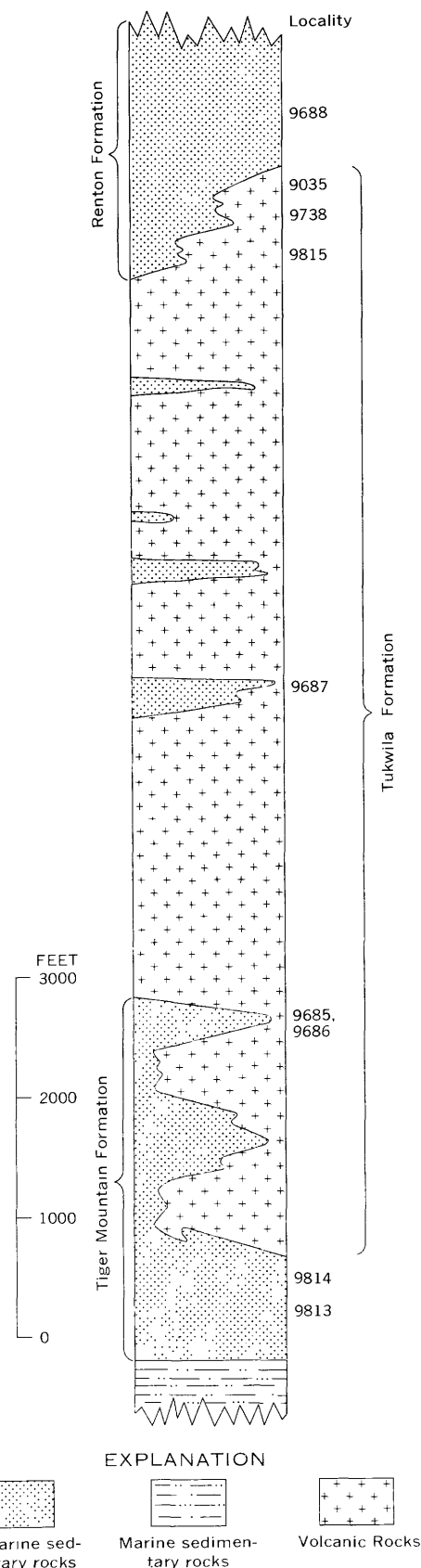


FIGURE 3.—Stratigraphic section of Puget group in Tiger Mountain area.

Tukwila Formation is of early Kummerian age and contains *Ilex oregona* of Potbury, *Tetracera oregona*, and *Persea pseudocarolinensis* of Potbury. The Tukwila Formation thus includes rocks ranging in age from early through late Ravenian and may contain some rocks of early Kummerian age.

Rocks assigned to the Renton Formation apparently are, in part, time equivalents of the Tukwila Formation; the Renton is composed predominantly of sandstone, shale, and coal, but the Tukwila is a volcanic unit. In the southeastern part of the Hobart quadrangle, the Taylor coal field contains a flora (loc. 9729) in which *Ternstroemites ravenensis* and *Rhamnites cashmanensis* are represented; these species indicate a late Ravenian age. Because the Taylor area is separated from the Tiger Mountain area by heavily forested country with few outcrops, the stratigraphic relationship of the Renton Formation in the two areas cannot be determined in the field. In the Tiger Mountain (loc. 9730), the Newcastle (loc. 1989), and the Issaquah (loc. 9688) areas, the Renton Formation contains *Macclintockia pugetensis*, which is characteristic of the upper part of the Kummerian Stage. This stage assignment is consistent with the fact that in the Tiger Mountain area the Renton Formation is known to overlies conformably the Tukwila Formation conformably, which here is as young as early Kummerian. Thus, the Renton Formation ranges in age from late Ravenian through late Kummerian (late Eocene through early Oligocene).

RELATIONSHIPS OF THE MARINE MEGAFOSSIL, MAMMALIAN AND PALEOBOTANICAL GEOCHRONOLOGIES

The geochronologies employed by the various paleontological disciplines for the Tertiary differ. The Neogene epoch boundaries, for example, the Miocene-Pliocene boundary, of the mammalian and marine megafossil paleontologists are not coincidental (Durham and others, 1954). On the Pacific coast, little is known of the time relationship between mammalian faunas and the Paleogene "stages" used by marine paleontologists (Weaver and others, 1944).

At this time, our knowledge of the floras of the non-marine mammal-rich Rocky Mountain Tertiary is so poor that no precise correlations can be made between the Pacific coast and Rocky Mountain Paleogene floras. Only one Paleogene mammalian fauna on the Pacific coast occurs in stratigraphic and topographic proximity to a flora. The Upper Clarno flora occurs at about the same stratigraphic level (perhaps 200 ft lower) as the Clarno fauna. This fauna has been assigned a Duchesnian-Chadronian age (latest Eocene and early Oligocene in the mammalian geochronology) by McKenna

(in Evernden and others, 1964, p. 182), but a potassium-argon age determination indicates a probable early Chadronian age (Evernden and James, 1964, p. 957). The Upper Clarno flora is mostly known on the basis of fructifications and wood, but some leaves do occur in the nut bed. Among the species determined are *Cercidiphyllum piperoides*, *Hyperbaena dilleri*, *Platanophyllum angustiloba*, and *Tetracera oregona*. The stratigraphic distribution of these species in the Puget Group indicates that the Upper Clarno flora should be assigned a late Ravenian age.

The Comstock flora (Sanborn, 1935) occurs in beds that interfinger with marine beds of "Tejon and Keasey" age (late Eocene) (Vokes and others, 1951). The Comstock flora, as discussed above (p. 8), is of late Ravenian age and thus is an approximate age equivalent of the Upper Clarno flora. Apparently, the early Oligocene Chadronian age of the mammalian paleontologists represents part of the same time interval as the beds of the upper part of the Tejon and lower part of the Keasey stages (latest Eocene). The Eocene-Oligocene boundary of the mammalian paleontologists is thus probably older than the boundary used by marine megafossil paleontologists.

The Eocene-Oligocene boundary (the Ravenian-Kummerian boundary) utilized in this report is placed at an apparent floral break between the Ravenian and Kummerian Stages. This placement of the boundary is based on convenience and on an approximate correspondence to both the marine megafossil and the mammalian Eocene-Oligocene boundaries; the plant boundary is apparently slightly younger than the mammalian boundary and slightly older than the marine megafossil boundary.

In the discussions of the ages of the various stages erected in this report, I have pointed out the probable age relationships of the plant stages to the marine megafossil stages. These relationships are summarized in table 3. It should be noted that where a considerable amount of information is available, the plant and marine stages, as for example the Kummerian and Ravenian Stages, and the Lincoln, Keasey, and Tejon Stages of Weaver and others (1944), have boundaries that are not thought to coincide. This is to be expected because changes in the marine environment and the evolution of marine organisms should not necessarily be mirrored by changes in the nonmarine environment and the evolution of tracheophytes. Although the Franklinian and Fultonian are shown in table 3 as the precise equivalents of the Capay and Domengine Stages of Weaver and others (1944), this equivalency will probably be invalidated as more information becomes available.

TABLE 3.—Suggested relationships of plant stages (Wolfe, this report) and marine megafossil stages (Weaver and others, 1944)

Series	Plant stages		Marine megafossil stages	Series
Oligocene	Kummerian	Upper	“Lincoln” (lower part)	Oligocene
		Lower	“Keasey”	
Eocene	Ravenian	Upper	“Tejon”	Eocene
		Lower	“Transition”	
	Fultonian	Upper	“Domengine”	
		Lower		
	Franklinian		“Capay”	

SYSTEMATIC DESCRIPTIONS

If the floral lists previously published for Eocene leaf floras are examined, the Eocene flora has a modern aspect on the generic level. Well-documented and detailed systematic work on fruits and seeds, however, indicates that most Eocene plant genera are probably extinct. These disparate results, based on studies of two different organs, might be reconciled if it is assumed that foliage has followed more conservative evolutionary patterns than fructifications. This assumption has some factual support—there are a large number of leaves in two or more orders or families that superficially look alike, for example: *Cinnamomum* (Lauraceae, Ranales), *Hyperbaena* (Menispermaceae, Ranales), and *Microcos* (Tiliaceae, Malvales); *Liquidambar* (Hamamelidaceae, Rosales), *Acer* (Aceraceae, Sapindales), and *Kalopanax* (Araliaceae, Umbelliflorae). If foliage is investigated in detail, however, particularly if cleared material is used, resemblances of this nature are seen to be convergence of a superficial character.

Investigations of cleared material of Recent foliage indicates that foliage can generally form a satisfactory basis for the differentiation of genera and species. A noteworthy exception to this generalization is Lauraceae, but it should be noted that the fructifications of this family are also not satisfactory for generic characterizations. At suprageneric levels, foliage is a less satisfactory organ for taxonomic purposes although in

several families studied, for example, Juglandaceae, Betulaceae, Fagaceae, Menispermaceae, Sapindaceae, and Tiliaceae basic venation and margin patterns appear in most or all members of the individual families or subfamilies. At the ordinal level, however, foliage patterns appear to be too numerous to allow satisfactory characterizations. Given the fundamental morphologic simplicity of foliage, it is difficult to consider the morphologic divergence of foliage at the higher taxonomic levels as an indication of evolutionary conservatism.

In the fossil record we are, unfortunately, usually dealing with fragments of the foliage system. In general, we have only the lamina and petiole preserved, and if leaves are compound, we may have only a piece of the lamina (the leaflet); other characters of the foliar system, for example, arrangement of the leaves and stipular appendages, are generally unknown. Moreover, some characters, such as the absence or presence and character of pubescence, are lacking on most fossil leaves. Despite these limitations, however, isolated leaves and leaflets have a large number of characters that can be used in classification. These characters include shape; shape and spacing of teeth; spacing and number of secondary veins; number of primary veins and relationship to lobes (if present); relationship of secondary, tertiary, or quaternary veins to margin and teeth (if present); presence of glands; length of petiole; pattern of nervilles; size of areoles; pattern of freely ending veinlets. It should be clear that no matter how variable a particular character, such as shape, may be, the limits of the variation are themselves useful criteria. In some species that have both a nonentire and an entire margin, the fact that this variation is present is fully as significant as the fact that a species always has a finely serrate margin. The three groups of characters that typically have the greatest significance on the generic level are the relationship of the veins to the margin, the pattern of the nervilles, and the character of the areoles and contained veinlets.

These groups of characters can be used, for example, to delineate the Menispermaceae, which is a moderate-sized predominately tropical family. Cleared leaves of extant members of this family indicate that the family can be characterized by leaves that typically have entire margins, a strong marginal vein, secondary or marginal tertiary veins that join directly with the marginal vein, small quadrangular areoles, typically linear, simple, freely ending veinlets in the areoles, and palmate venation. If a fossil leaf with these characters is found, it generally can be confidently placed in Menispermaceae. The fossil may have a combination of other characters

that are the same as those in a particular extant genus of Menispermaceae, or the fossil may have a combination of characters that cannot be found in any extant genus and thus may represent an extinct genus. For example, in the leaves assigned to a new genus *Goweria*, all characters except two (shape of base and pattern of apical secondary veins) can be found in the extant genus *Linacea*; all other extant genera of Menispermaceae observed differ to an even greater degree.

In leaflets of *Pugetia* (see this report), all characters of the leaflets can be found in different genera of Juglandaceae. The distribution of the teeth, shape of the leaflets, and the relationship of the veins to the teeth indicate that *Pugetia* is related to *Alfaroa*. The shape of the teeth and the pattern of the freely ending veinlets in *Alfaroa* are uniform and distinct from the same character groups in *Pugetia*, which resembles *Carya* in these features.

Because of the above approach to classification of fossil leaves, five new genera have been erected in this report. If all material collected from the Puget Group thus far were classified, the number of genera considered to be extinct would probably increase considerably. Some of the Puget species have also been assigned to form genera such as *Rhamnites* because at this time the foliage of extant Rhamnaceae has not been investigated in sufficient detail to allow an accurate classification of the fossils. Of the 25 genera discussed, 13 are considered to be extant, although there is some doubt as to whether *Ulmus oregoniana* is validly assigned to this extant genus. At least eight of the genera are considered to be extinct.

Family ASPIDIACEAE

Genus ALLANTODIOPSIS Knowlton and Maxon

Allantodiopsis pugetensis Wolfe, new species

Plate 1, figure 6

Diagnosis.—Pinnules linear, obovate; venation pinnate; base cuneate, apex acuminate; length 8.0–18.5 cm, width 1.5–3.0 cm; veins numerous, closely spaced (about 1 mm apart), parallel, unforked or once-forking near midrib; margin entire to serrate with one tooth per vein.

Discussion.—*Allantodiopsis pugetensis* differs from the one previously known species of the genus, *A. erosa*, Knowlton and Maxon in being much narrower. In addition, in *A. erosa* the veins typically fork two or three times, whereas in *A. pugetensis* some specimens display only unforked secondaries and other specimens have only a few once-branching secondaries.

Holotype.—USNM 42080.

Paratypes.—USNM 42081, 42082.

Occurrence.—8640, 9678, 9695, 9731, 9735.

Family JUGLANDACEAE

Genus VINEA Wolfe, new genus

Diagnosis.—Leaves apparently pinnately compound; lateral leaflets pinnate, sessile; shape asymmetric, quadrate in basal half of lamina, tapering to an acuminate apex; secondaries irregularly spaced; one to three conspicuous abmedial tertiaries per secondary, arising as bifurcations of secondaries; secondaries camptodrome or craspedodrome, typically the latter; teeth broadly triangular, dentate, many with a subsidiary tooth on the primary tooth; nervilles percurrent, branching; terminal leaflets cordate, petiolulate.

Type species.—*V. pugetensis* Wolfe.

Discussion.—No complete leaves illustrating the compoundness of *Vinea* have been found. This feature is deduced from the fact that large numbers of sessile, asymmetric laminae are found with a few stalked, symmetric laminae; this also indicates that a single leaf had a large number (at least 11) leaflets.

The forking secondaries of *Vinea* are most similar to those in certain species of *Carya*, for example, *C. tonkinensis* LeC. The broadly triangular, dentate teeth of the fossils, however, indicate a closer relationship with *Pterocarya* (*Cycloptera*) or *Juglans* (*Cardiocaryon*). Except for the conspicuous craspedodromy and probable cordate terminal leaflet, *Vinea* might be considered as congeneric with *Juglans*.

Vinea is named in honor of James D. Vine, U.S. Geological Survey.

Vinea pugetensis Wolfe, new species

Plate 2, figure 3; text figure 4

Diagnosis.—Leaflets oval to ovate, base asymmetric, rounded; length 4.2–13 cm, width 2.5–6.0 cm; 15 or 16 pairs of secondaries, departing from midrib at angles of 30°–50°, straight to convex; intersecondaries common, parallel to secondaries; two to four teeth per secondary vein.

Discussion.—*Vinea pugetensis* is common in the lower

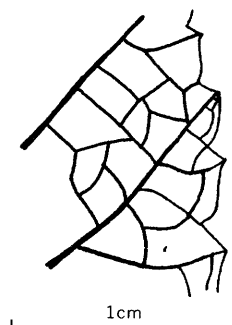


FIGURE 4.—Marginal venation of *Vinea pugetensis*. Holotype, USNM 42083, loc. 9832.

and upper Fultonian. This species is also abundant in the leaf-bearing shales of the Roslyn Formation.

Holotype.—USNM 42083.

Paratype.—USNM 42084.

Occurrence.—1963, 9678, 9732, 9832.

Genus *CARYA* Nuttall

Carya cashmanensis Wolfe, new species

Plate 1, figure 2; text figure 5

Diagnosis.—Lateral leaflets oval to obovate; venation pinnate; base asymmetric, acute, apex attenuated; length 4.5–9.0 cm, width 2.0–3.3 cm; 10–18 pairs of irregularly spaced secondaries, departing from midrib at angles of 50° – 80° , straight to broadly convex, working conspicuously; intersecondaries numerous, parallel to secondaries; secondaries camptodrome or craspedodrome; abmedial tertiaries craspedodrome; margin serrate, with numerous teeth (three to seven per secondary vein); sessile. Terminal leaflets obovate; base cuneate; petiolule apparently 1.5 cm long.

Discussion.—The holotype of *Carya cashmanensis* is a compression and its counterpart of a compound leaf with at least five leaflets. The large size of the most basal leaflet on the specimen indicates that there was at least one (probably two or three) more pair of lateral leaflets.

The conspicuously forking secondaries and numerous, closely spaced teeth of *Carya cashmanensis* allies this species to the extent *C. tonkinensis* LeC. and its fossil relatives in western North America, such as *C. bendirei* (Lesq.) Chan. and Axel. and *C. simulata* (Knowl.) R. W. Br. The last-named species is particularly close to *C. cashmanensis* but differs in having broader leaflets and a sessile terminal.

The phylad of *C. cashmanensis* is one of the longest ranging in the Pacific coast Tertiary. An undescribed species of this phylad is known in the Oligocene, and the two Miocene species mentioned above are common throughout the Northwest. The last known species of the group in North America was originally described as a species of *Aesculus* (Condit, 1944, p. 50) from the early Pliocene of California. Certainly the Puget, and probably also the Oligocene, species existed under tropical and (or) subtropical climates, but by the early Pliocene, representatives of the phylad lived in a temperate climate. The extant *C. tonkinensis* lives in the tropics of Indochina, although a closely related species, *C. cathayensis*, occurs in the warm-temperate regions of east Asia.

Holotype.—USNM 42085.

Paratype.—USNM 42086.

Occurrence.—9680, 9731.

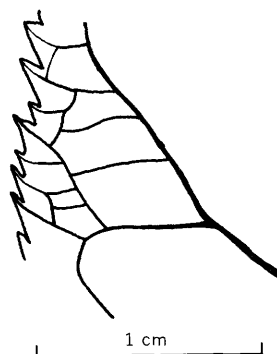


FIGURE 5.—Marginal venation of *Carya cashmanensis*. Paratype, USNM 42086, loc. 9731.

Carya pugetensis Wolfe, new species

Plate 1, figure 1; text figure 6

Diagnosis.—Lateral leaflets oval, asymmetric; venation pinnate; base narrowly rounded, asymmetric, apex tapering, length 3.0–7.2 cm, width 1.4–2.8 cm; 18 or 19 pairs of regularly spaced secondaries, departing from midrib at an angle of 60° – 80° , straight to broadly convex, craspedodrome; intersecondaries rare, parallel to secondaries; abmedial tertiaries craspedodrome, one per secondary; nervilles percurrent; margin serrate, with two teeth per secondary vein; sessile. Terminal leaflets oval, symmetric; base narrowly rounded; sessile.

Discussion.—*Carya pugetensis* represents a phylad distinct from that of *C. cashmanensis*. The craspedodrome and closely spaced secondaries with a single abmedial tertiary branch are features that ally *C. pugetensis* to the extant *C. myristicaeformis* Nutt. The teeth of the fossil, however, are elongated basally and are sharper than those in the living species.

The record of the *Carya pugetensis* phylad is more erratic than that of the *C. cashmanensis*, although it is sufficient to indicate a gradual adaptation to warm-

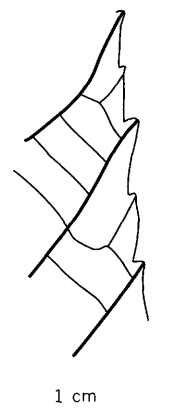


FIGURE 6.—Marginal venation of *Carya pugetensis*. Holotype, USNM 42087, loc. 9680.

temperate climate. A new species in the early Miocene highly warm-temperate to subtropical floras of Oregon probably gave rise to the late Miocene and early Pliocene *C. typhinoides* (Lesq.) Cond., which lived under warm-temperate conditions. *C. myristicaeformis* lives in the warm-temperate regions of northern Mexico.

Holotype.—USNM 42087.

Occurrence.—9678, 9680, 9694.

Genus PUGETIA Wolfe, new genus

Diagnosis.—Leaflets linear-ovate; venation pinnate; numerous secondary veins, extending nearly to margin, with angular secondary loops; nervilles percurrent, branching; areoles small, with dendroid compound freely ending veinlets; margin with small irregularly spaced rounded teeth that are elongated basally; secondaries near teeth fork, with apical fork looping to secondary above and basal fork ending in angular sinus or extending along apical margin of tooth; sessile or with a short petiolule.

Type species.—*Pugetia longifolia* Wolfe.

Discussion.—The dendroid compound freely ending veinlets and irregularly shaped small areoles of *Pugetia* are similar to those of certain genera of Sapindaceae, particularly *Euphoria*. The general shape of the leaflets, pattern of the secondary venation, and feeding of the teeth are common in Sapindaceae; however, no genus of extant Sapindaceae has leaflets that combine the typically linear shape, multitudinous secondaries, and the irregularly spaced small teeth. Leaflets of *Euphoria* resemble the broader leaflets of *Pugetia*, but teeth are absent in the former genus. Typically, teeth in Sapindaceae are either small and uniformly distributed or large and irregularly distributed.

Another sapindalean family, Juglandaceae, also contains foliage similar to that of *Pugetia*. In the elongate and acuminate shape, numerous and parallel secondary veins, marginal venation, and irregular spacing of the teeth, the leaflets of *Pugetia* and *Alfaroa* are similar. There are two primary differences, however: (1) the teeth in *Alfaroa* are sharp, not rounded, and (2) the ultimate venation of *Alfaroa* is tight with only linear, simple freely ending veinlets. Similar teeth and venation occur in the closely related *Carya*, whose leaflets are on the basis of megascopic characters very dissimilar to those of *Pugetia*. Because all characters of *Pugetia* can be found in Juglandaceae and most in *Alfaroa*, *Pugetia* is provisionally assigned to Juglandaceae.

***Pugetia longifolia* Wolfe, new species**

Plate 2, figures 1, 2, 4-6; text figure 7

Diagnosis.—Leaflets falcate; base narrowly to broadly rounded, often shallowly cordate, apex nar-

rowly acuminate; length 13.0–20.0 cm, width 4.2–5.6 cm; 26–32 pairs of irregularly spaced secondaries, departing from midrib at an angle of 70°–90°, typically straight to convex but in many leaves broadly concave near base; intersecondaries common, parallel to secondaries; margin typically revolute in basal part of lamina, but with small irregularly spaced teeth in apical part; sessile or with petiolule up to 0.2 cm long.

Discussion.—*Pugetia longifolia* occurs from the base of the Puget through the upper Fultonian, although it is most abundant in the lower Fultonian.

Holotype.—USNM 42122.

Paratypes.—USNM 42123–42126.

Occurrence.—1027, 1028, 1059, 1963, 9677, 9678, 9732, 9832, 9838, 9841.

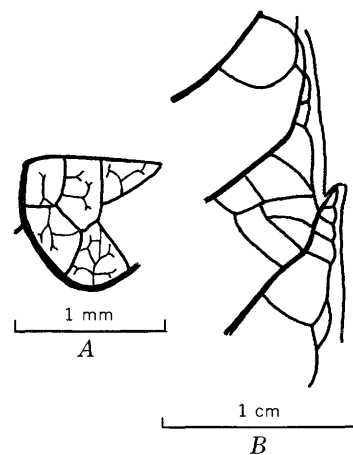


FIGURE 7.—Ultimate and marginal venation of *Pugetia longifolia*. A, Paratype, USNM 42125, loc. 9678. B, Paratype, USNM 42124, loc. 9678.

Genus PTEROCARYA Kunth

***Pterocarya pugetensis* Wolfe, new species**

Plate 1, figures 3–5; text figure 8

Diagnosis.—Lateral leaflets oval to ovate, asymmetric; venation pinnate; base acute to narrowly rounded, apex acuminate; length 8.0–11.0 cm, width 3.9–6.0 cm; 12 or 13 pairs of irregularly spaced secondaries, departing from midrib at an angle of 55°–80°, broadly convex, camptodrome with sharp looping; intersecondaries rare, parallel to secondaries; abmedial tertiaries craspedodrome, three to five per secondary; nervilles percurrent; margin serrate, with three to five rounded teeth per secondary; sessile. Terminal leaflets oval, symmetric; base cuneate; petiolule 0.5 cm long.

Discussion.—The lack of looping by the abmedial tertiary veins indicates that *Pterocarya pugetensis* belongs

to the subgenus *Platyptera*. Several other species of this subgenus are known from the Pacific coast tertiary, particularly in the Oligocene, Miocene, and Pliocene. The species most similar to *P. pugetensis* is "*Juglans*" *orientalis* MacG. from the Oligocene of Oregon and California. "*J.*" *orientalis*, however, has lateral leaflets that are more linear and that have a much more rounded base.

Holotype.—USNM 42088.

Paratypes.—USNM 42089, 42090.

Occurrence.—9680, 9832, 9837.

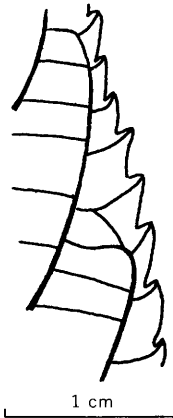


FIGURE 8.—Marginal venation of *Pterocarya pugetensis*. Holotype, USNM 42088, loc. 9837.

Family BETULACEAE

Genus *ALNUS* Linnaeus

Alnus kluckingi Wolfe, new species

Plate 3, figures 1, 2; text figure 9

Diagnosis.—Leaves ovate; venation pinnate; base broadly to narrowly rounded, apex acuminate; length 4.7–8.5 cm, width 2.3–4.0 cm; 9–10 pairs of irregularly spaced secondaries, departing from midrib at angles of 50°–70°, broadly convex, craspedodrome, giving off one to three craspedodrome tertiary branches; intersecondaries common, parallel to secondaries; nervilles branching, percurrent; margin serrate to dentate, with narrowly triangular teeth; petiole at least 1.5 cm long.

Discussion.—The leaves of *Alnus kluckingi* are similar to those of *A. operia*, and probably the two species are closely related. There are some significant differences between leaves of the two species. In *A. kluckingi* the teeth are narrowly triangular and are of a constant shape on one leaf; in *A. operia* the teeth are typically broadly triangular and occur on the same leaf with narrowly triangular teeth.

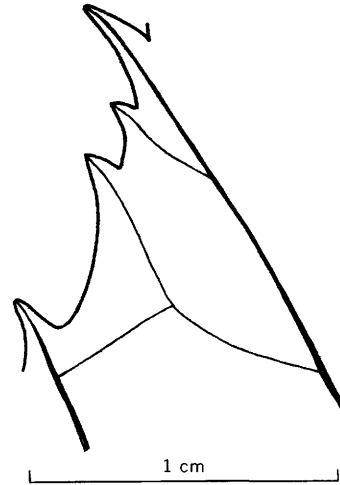


FIGURE 9.—Marginal venation of *Alnus kluckingi*. Holotype, USNM 42094, loc. 9837.

Alnus kluckingi is named for Edward P. Klucking, in recognition of his work on Betulaceae.

Holotype.—USNM 42094.

Paratypes.—USNM 42095–42097.

Occurrence.—9731, 9837.

Alnus operia MacGinitie

Plate 3, figures 3, 5; text figure 10

Alnus operia MacGinitie, 1941, Carnegie Inst. Washington Pub. 534, p. 104, pl. 12, fig. 7.

Discussion.—Leaves of *Alnus operia* are abundant at the localities in the middle part of the Puget section. A few fragmentary specimens have been found in the lower part of the section.

Hypotypes.—USNM 42091–42093.

Occurrence.—1963, 9676, 9678, 9694, 9732, 9735.

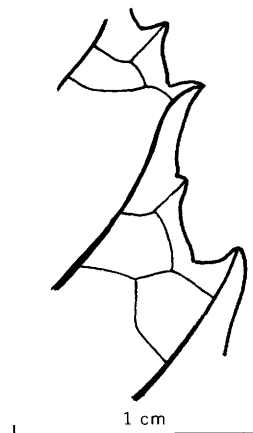


FIGURE 10.—Marginal venation of *Alnus operia*. Hypotype, USNM 42093, loc. 9678.

Family FAGACEAE

Genus *CASTANOPSIS* Spach*Castanopsis franklinensis* Wolfe, new species

Plate 3, figures 6, 7

Diagnosis.—Leaves broadly oval to obovate; venation pinnate; base narrowly rounded to cuneate, apex narrowly rounded; length 6.0–10.0 cm, width 3.4–5.6 cm; 9–13 pairs of irregularly spaced secondaries, departing from midrib at angles of 50°–90°, straight to broadly convex, craspedodrome; intersecondaries absent; secondaries departing from middle part of lamina often working to give off one abmedial tertiary; nervilles percurrent; margin dentate to serrate, with large teeth, one or two per secondary; teeth typically only on upper two-thirds of lamina; petiole 2.0 cm long.

Discussion.—*Castanopsis franklinensis* has leaves similar to those of the extant *C. formosana* Hay. The leaves of the latter species, however, have a broadly rounded base, a somewhat broader lamina, and teeth that are consistently serrate.

Holotype.—USNM 42098.

Paratype.—USNM 42099.

Occurrence.—1963, 9678.

Genus *DRYOPHYLLUM* Debey*Dryophyllum pugetensis* Wolfe, new species

Plate 3, figures 4, 8

Diagnosis.—Leaves linear oval to obovate, falcate; venation pinnate; base cuneate, apex acuminate; length 5.5–16.5 cm, width 2.0–8.0 cm; 12–16 pairs of regularly spaced, parallel secondaries, departing from midrib at an angle of 30°–40°, straight to broadly convex, craspedodrome; intersecondaries absent; nervilles percurrent; margin serrate, with large teeth, one per secondary; in basal part of lamina margin often revolute rather than with teeth; petiole 3.0–3.2 cm long.

Discussion.—In lower Tertiary beds, leaves with a general resemblance to extant Fagaceae are collected in many localities. Some of these leaves can be assigned with some confidence to extant genera of Fagaceae, but others differ sufficiently from extant species and genera to be considered members of extinct genera. The genus *Dryophyllum* was originally constituted to contain the species of but extinct genera, but as used by some authors, this genus also contains species more correctly assignable to extant genera.

Dryophyllum pugetensis is assigned to *Dryophyllum* on the basis of the large simple and numerous teeth and the numerous parallel secondaries. In my opinion, *Castanopsis longipetiolata* should also be assigned to *Dryophyllum*, for leaves of *Castanopsis* are typically

entire or, if teeth are present, the teeth are few. In addition, *Castanopsis* typically does not have as many secondaries as are found in species of *Dryophyllum*. *C. longipetiolata* and *D. pugetensis* appear to be closely related; leaves of the two species differ primarily in that the teeth in *D. pugetensis* are sharper and the secondaries are straighter.

Holotype.—USNM 42100.

Paratype.—USNM 42101, 42163.

Occurrence.—2022, 2024, 9680, 9694, 9832.

Family ULMACEAE

Genus *ULMUS* Linnaeus*Ulmus oregoniana* Knowlton

Text figure 11

Ulmus oregoniana Knowlton, 1900, U.S. Geol. Survey 20th Ann. Rept., pt. 3, p. 44, pl. 2, figs. 1, 2.

Supplementary description.—Leaves ovate; venation pinnate; base narrowly rounded, asymmetric, in many specimens shallowly cordate, apex acute; length 2.6–10 cm, width 1.4–4.0 cm; 11–16 pairs of irregularly spaced secondaries, departing from midrib at an angle of 30°–60°, straight to broadly convex, undulatory, craspedodrome; intersecondaries common, parallel to secondaries; abmedial tertiaries craspedodrome, none to as many as four per secondary (typically two); margin dentate, with broadly triangular and apiculate teeth, one to four per secondary; petiole 0.4–0.6 cm long.

Discussion.—The asymmetry, combined with the apiculate and compoundly dentate margin, indicate that the generic assignment of *Ulmus oregoniana* may be correct; however, some of the leaves of this species are small and have simple teeth and thus resemble such species of *Zelkova* as *Z. hesperia* (Knowl.) R. W. Br. Neither the small size of the areoles nor the prominent secondary forkings in *U. oregoniana* is typical of extant

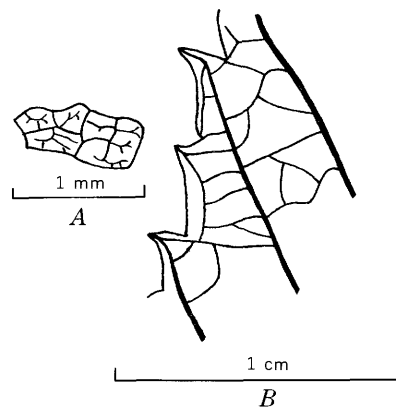


FIGURE 11.—Ultimate and marginal venation of *Ulmus oregoniana*. A, B. Hypotype, USNM 42102, loc. 9678.

species of *Ulmus*, and hence the possibility should be considered that *U. oregoniana* may represent an extinct genus of Ulmaceae.

Hypotypes.—USNM 42102, 42103.

Occurrence.—1028, 1963, 9676, 9677, 9678, 9732, 9832, 9833, 9842.

Family MORACEAE

Genus ARTOCARPOIDES Saporta

Artocarpoides litseafolia (MacGinitie) Wolfe, new combination

Laurophyllum litseafolia MacGinitie, 1941, Carnegie Inst. Washington Pub. 534, p. 116, pl. 18, figs. 2, 3; pl. 19, figs. 1, 2; pl. 22, fig. 2.

Discussion.—*Artocarpoides litseafolia* and *A. kummerensis* include a series of gradational specimens in the Puget flora. The former, *A. litseafolia*, contains groups of specimens that are consistently cordate, that have conspicuously forked secondaries, and that have a length:width ratio of less than 2:1. Forms with a cordate base do occur in the upper part of the Puget section, but they are rare; the broadly to narrowly rounded forms predominate. Typically, leaves of *A. kummerensis* have a length:width ratio of more than 2:1.

Berry (1922, p. 8) assigned leaves from the Wilcox Group to *Artocarpoides*, and these appear to be related to the Puget leaves. The percurrent, forking nervilles, forking secondaries and once-forking freely ending veinlets of the Puget and Wilcox specimens are found in leaves of Moraceae. Lacking adequate representation of cleared leaves of this family, the fossils have been referred to the form genus *Artocarpoides*.

Hypotypes.—USNM 42106, 42107.

Occurrence.—1963, 8640, 9677, 9678, 9695, 9728, 9732, 9735, 9832, 9833, 9839, 9841.

Artocarpoides kummerensis Wolfe, new species

Plate 4, figures 1, 7; text figure 12

Diagnosis.—Leaves obovate; venation pinnate; base broadly rounded, occasionally shallowly cordate, apex acuminate; length 7.5–11.0 cm, width 3.0–5.3 cm; 9 or 10 pairs of irregularly spaced secondaries, departing from midrib at an angle of 40°–60°, broadly convex, forking and looping conspicuously to form a series of submarginal secondary and tertiary loops; intersecondaries common, perpendicular to midrib; nervilles percurrent and branching; margin revolute; petiole 3.0–3.3 cm long.

Discussion.—See under *Artocarpoides litseafolia*.

Holotype.—USNM 42104.

Paratypes.—USNM 42105, 42158, 42159.

Occurrence.—9681, 9688, 9690, 9731, 9834.

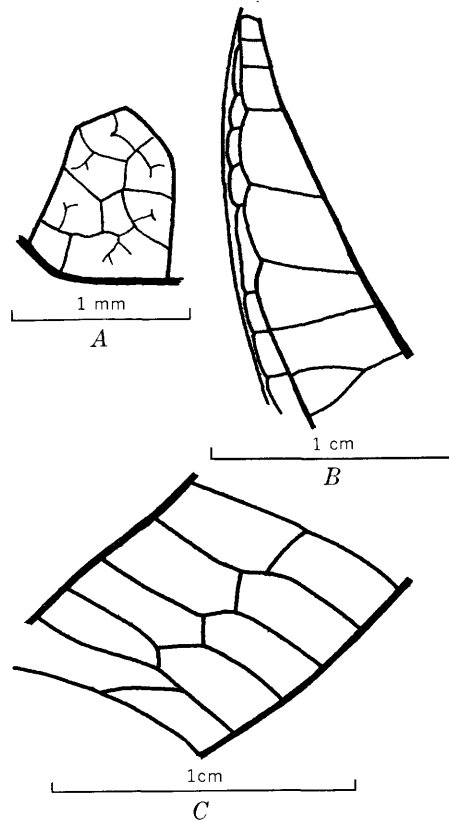


FIGURE 12.—Ultimate, marginal, and intercostal venation of *Artocarpoides kummerensis*. A. Paratype, USNM 42159, loc. 9731. B, C. Holotype, USNM 42104, loc. 9731.

Family CERCIDIPHYLLACEAE

Genus CERCIDIPHYLLUM Siebold and Zuccarini

Cercidiphyllum piperoides (Lesquereux) LaMotte

Cercidiphyllum piperoides (Lesquereux) LaMotte, 1952, Geol. Soc. Am. Mem. 51, p. 120. (See synonymy.)

Discussion.—LaMotte has demonstrated clearly that the name *Cercidiphyllum elongatum* Brown is a junior synonym of several other names.

The known range of *Cercidiphyllum piperoides* is from the Franklinian through the upper Kummerian; the upper extent of the range is indicated by the occurrence of this species at locality 9143 in the Toutle Formation. Specimens from Ravenian and older rocks appear to differ from the younger material in being typically less cordate and more elongated; further work may indicate the desirability of placing the Kummerian specimens in a distinct species.

Cercidiphyllum piperoides can be distinguished readily from leaves of the post-Kummerian *C. crenatum* (Ung.) R. W. Br. In the latter species, the basal sides of the teeth are more elongate than the apical sides, in contrast to the approximately equal-sided teeth of *C.*

piperoides. The areoles in *C. piperoides* are about one-half the size of those in *C. crenatum*; most of the areoles in the latter species contain veinlets that branch two or three times, but in *C. piperoides* the veinlets, if present, branch once or not at all. Moreover, the leaves of *C. crenatum* are consistently deeply cordate.

The occurrence of *C. piperoides* in the Salmon, Princeton, and Republic floras indicates that these floras are probably no younger than the Kummerian; on general composition, a Kummerian age is more likely than pre-Kummerian.

The leaves called *Cercidiphyllum arcticum* by Wolfe (in Vine, 1962, p. 15) are now considered to represent *C. piperoides*. The former species is not certainly known in post-paleocene rocks and has been reassigned to *Cocculus* as *C. flabella* (Newb.) Wolfe. Some specimens from locality 8640 near Renton may also represent *Cocculus* although they are not conspecific with *C. flabella*.

Occurrence.—1028, 1963, 9675, 9676, 9677, 9678, 9679, 9686, 9687, 9694, 9729, 9731, 9732, 9832, 9833.

Family MENISPERMACEAE

Genus CALKINSIA Wolfe, new genus

Diagnosis.—Leaves obovate; venation palmate, with three primaries; lateral primaries extending two-thirds to three-quarters the distance to the apex; two to four pairs of central secondaries, looping just within the margin; lateral abmedial secondaries numerous, camptodrome or (typically) craspedodrome; nervilles widely spaced, straight or branching, percurrent; abmedial tertiaries always craspedodrome; margin entire, with marginal vein.

Type species: *C. franklinensis* Wolfe.

Discussion.—The type species of *Calkinsia* also occurs at Chalk Bluffs, and MacGinitie (1941, p. 115) was the first to suggest that leaves of this type might be referable to Menispermaceae. The craspedodrome secondaries and tertiaries, palmate venation, and marginal vein support this suggestion. I have not been able to find any genus of extant Menispermaceae, however that combines the characters of these Puget and Chalk Bluffs fossils. As MacGinitie noted, the resemblance to *Hyperbaena* is considerable, but there are several significant differences (MacGinitie, 1941, p. 115). Perhaps a closer resemblance is present between the leaves of *Calkinsia* and *Hypserpa*. In the latter genus, however, the lateral primaries do not extend more than half the distance to the apex, and the areoles are intruded by once or twice-branching veinlets.

Calkinsia is named in honor of Frank C. Calkins, in recognition of his numerous contributions to the geology of Washington.

Calkinsia franklinensis Wolfe, new species

Plate 4, figures 4, 8

Cinnamomum dilleri auct. non Kowilton. MacGinitie, 1941. Carnegie Inst. Washington Pub. 534, p. 115, pl. 21, fig. 6: pl. 23, fig. 1.

Diagnosis.—Leaves broadly obovate; base, cuneate, apex abruptly acute; length 4.4–12.7 cm, width 3.6–8.2 cm; three or four pairs of broadly convex central secondaries, departing from midrib at an angle of 40°–50°; lateral abmedial secondaries departing at angles of 60°–90°; petiole more than 1.4 cm long, thick.

Discussion.—The leaves in the LaPorte flora called *Cinnamomum dilleri* (Potbury, 1935, p. 66) are also referable to *Calkinsia*. The LaPorte leaves differ from *C. franklinensis* in having one less pair of central secondaries and fewer lateral abmedial secondaries.

Holotype.—USNM 42149.

Paratypes.—USNM 42150; Univ. Calif. Mus. Paleontology 2196, 2197.

Occurrence.—9833, 9678.

Genus GOWERIA Wolfe, new genus

Diagnosis.—Leaves ovate to oval, lanceolate; venation palmate; five primaries, extending no more than half the distance to the apex; secondaries straight or nearly so, looping angularly near margin; abmedial tertiaries forming a series of submarginal loops; nervilles percurrent, widely spaced, branching; areoles very small, most lacking veinlets or with linear, simple freely ending veinlets; margin revolute and with marginal vein; petiole thick, more than 1.0 cm long.

Type species.—*G. dilleri* (Knowlton) Wolfe [*Benzoin*].

Discussion.—The palmate venation, conspicuous secondary loops, entering the marginal vein, and minute areoles with few or no freely ending veinlets indicate that these Puget leaves are members of Menispermaceae. Although in general aspects of venation leaves of *Goweria* are very similar to those of genera such as *Linacea*, the latter genus and its extant relatives have a symmetric base and the apical secondary veins join the marginal vein.

Goweria is named for Howard D. Gower, U.S. Geological Survey.

Goweria dilleri (Knowlton) Wolfe, new combination

Plate 7, figures 1, 2; text figure 13

Benzoin dilleri Knowlton, 1900. U.S. Geol. Survey 20th Ann. Rept., Pt. 3, p. 46, pl. 4, fig. 3.

Diagnosis.—Leaves ovate, falcate; base asymmetric, broadly rounded, apex acuminate; length 9.0–12.0 cm, width 4.5–5.0 cm; seven pairs of secondaries, departing from midrib at an angle of 40°–70°; intersecondaries numerous, parallel to secondaries.



FIGURE 13.—Ultimate venation of *Goweria dilleri*. A, Hypotype, USNM 42135, loc. 9735. B, Hypotype, USNM 32132, loc. 9695.

Discussion.—Knowlton (1900, p. 47) suggested that *Benzoin dilleri* also occurred in some of the Washington Eocene localities. Some of the Puget specimens are conspecific with *Goweria dilleri*, but others represent a new species, *G. linearis*.

Hypotypes.—USNM 42132–42135.

Occurrence.—1963, 9695, 9733, 9735.

***Goweria linearis* Wolfe, new species**

Plate 7, figures 6, 7; text figure 14

Diagnosis.—Leaves ovate, falcate; base asymmetric, broadly rounded, apex acuminate; length 10.0–10.5 cm, width 2.5–3.0 cm; 8–10 pairs of secondaries, departing from midrib at angles of 50°–80°; intersecondaries common, parallel to secondaries; petiole at least 1.0 cm long.

Discussion.—Leaves of *Goweria linearis* are similar to those of *G. dilleri*, and it is probable that the former species is ancestral to the latter. The primary difference between the two species is in shape, which is more linear in *G. linearis* and in *G. dilleri* is more deltoid. In addition, *G. linearis* has more numerous secondaries than in *G. dilleri*.

Holotype.—USNM 42136.

Paratype.—USNM 42137.

Occurrence.—1027, 1028, 9678, 9833, 9838.

Genus HYPERBAENA Miers

***Hyperbaena dilleri* (Knowlton) Wolfe, new combination**

Text figure 15

Cinnamomum dilleri Knowlton, 1900, U.S. Geol. Survey 18th Ann. Rept., pt. 3, p. 47, pl. 4, fig. 1.

Knowlton, 1902, U.S. Geol. Survey Bull. 204, p. 59.

Sanborn, 1935, Carnegie Inst. Washington Pub. 465, p. 18, pl. 4, figs. 1, 3, 4, 6–8.

Discussion.—Although some leaves within a single species of *Cinnamomum* may superficially appear to be palmate, examination shows the conspicuous “primar-

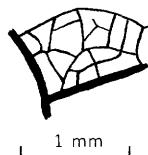


FIGURE 14.—Ultimate venation of *Goweria linearis*. Holotype, USNM 42136, loc. 9678.

ies” to be secondaries that typically depart from the midrib a short distance above the base of the lamina; the true reduced primaries or basal secondaries typical of leaves of Lauraceae are present even in leaves in which the “primaries” appear to depart from the base. On this basis, the leaves of *Cinnamomum dilleri* are not Lauraceae, for the prominent veins are primaries, and the basal secondaries of Lauraceae are lacking. In addition, the many secondaries and all abmedial tertiaries are craspedodrome, extending directly into the marginal vein. This last feature, as well as the general aspect of the venation, indicates that *C. dilleri* is a member of Menispermaceae. The ultimate venation and percurrent, conspicuously branched nervilles of the fossils places them in *Hyperbaena*.

The LaPorte record of *Cinnamomum dilleri* (Potbury, 1935, p. 66) is based on specimens with a broadly obovate shape and an abruptly acute apex and hence cannot represent *C. dilleri*; the LaPorte specimens are, however, members of Menispermaceae. The same can be said of the Chalk Bluffs specimens assigned to this species (MacGinitie, 1941, p. 115).

Hypotypes.—USNM 42160, 42161.

Occurrence.—1027, 8640, 9678, 9680, 9731, 9738.

Genus HYPSEPERPA Miers

***Hypserpa cashmanensis* Wolfe, new species**

Plate 4, figures 2, 3, 5; text figure 16

Diagnosis.—Leaves oval; venation palmate; base narrowly rounded, apex rounded; length 6.2–7.5 cm,

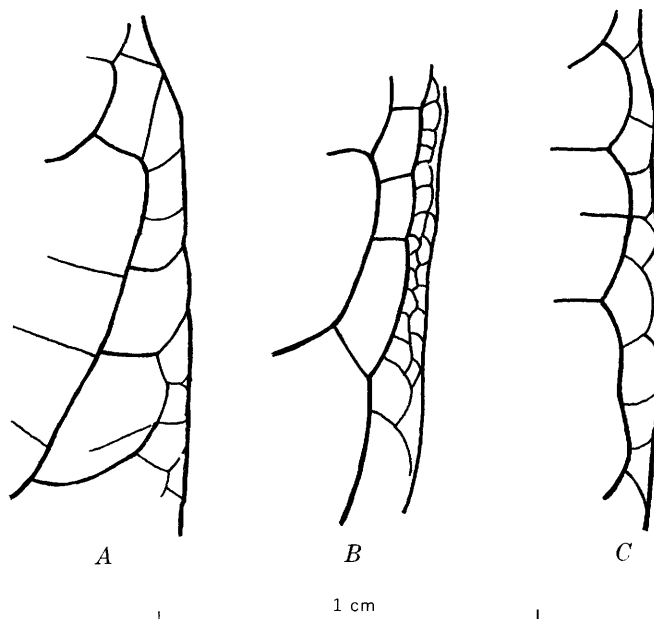


FIGURE 15.—Marginal venation of *Hyperbaena* and *Cinnamomum*. A, *H. dilleri*, lectotype, USNM 7581, Comstock, Oregon. B, *H. mexicana*, Recent. C, *C. tricophylla*, Recent.

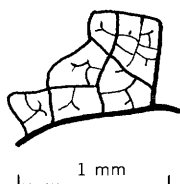


FIGURE 16.—Ultimate venation of *Hypserpa cashmanensis*. Paratype, USNM 42110, loc. 1963.

width 2.0–3.8 cm; five primaries; the pair of primaries adjacent to midrib extending about one-third the distance to the apex, the basal pair of primaries inconspicuous; six or seven pairs of irregularly spaced secondaries, departing from midrib at an angle of 50° – 80° , broadly to narrowly convex, looping conspicuously with secondaries above; intersecondaries numerous, many extending abmedially to secondary loops; a series of marginal secondary loops; nervilles widely spaced, percurrent, branching conspicuously midway between the secondaries; marginal vein present; margin entire; petiole thick, 2.2 cm long.

Discussion.—The ultimate venation and general type of primary and secondary venation with conspicuous loops of these Puget leaves is also found in some extant species of *Hypserpa*. In leaves of this genus the secondary loops may form a continuous, prominent marginal vein and the nervilles may be widely spaced and branch conspicuously.

Holotype.—USNM 42108.

Paratypes.—USNM 42109, 42110.

Occurrence.—1963, 9694, 9695, 9731.

***Hypserpa franklinensis* Wolfe, new species**

Plate 4, figure 6; text figure 17

Diagnosis.—Leaves narrowly oval; venation palmate; base asymmetric, narrowly rounded, apex acute; length 7.0–15.1 cm, width 2.9–4.0 cm; five primary veins, the apical pair extending one-fourth the distance to the apex, the basal pair inconspicuous; 9–13 pairs of irregularly spaced secondaries, straight to broadly convex, departing from midrib at an angle of 60° – 70° , looping submarginally to form a conspicuous submarginal loop; intersecondaries numerous, parallel to secondaries, a few extending abmedially to join secondary loops; a series of marginal secondary loops; nervilles widely spaced, percurrent, branches conspicuously midway between the secondaries; marginal vein present; margin entire; petiole 1.8–2.1 cm long.

Discussion.—*Hypserpa franklinensis* is similar and probably ancestral to *H. cashmanensis*. Although there is a considerable overlap of characters between the two species, *H. franklinensis* is more linear, has more numer-



FIGURE 17.—Ultimate venation of *Hypserpa franklinensis*. Holotype USNM 42111, loc. 9678.

ous secondaries, and the secondaries depart at a lower angle.

Holotype.—USNM 42111.

Paratypes.—USNM 42112, 42113.

Occurrence.—1028, 9678.

Family HAMAMELIDACEAE

Genus FOTHERGILLA Murray

***Fothergilla durhamensis* Wolfe, new species**

Plate 5, figure 5

Diagnosis.—Leaves simple; venation pinnate; shape ovate, slightly asymmetric; base rounded, asymmetric, apex acuminate; length 7.7–8.5 cm, width 4.0–4.2 cm; 9–10 pairs of straight craspedodrome secondaries, departing from midrib at a 30° – 40° angle; five or six abmedial tertiaries on basal secondaries, two or three on next pair of secondaries, none to two on next pair, and none on successive pairs; intersecondaries lacking; nervilles percurrent; margin serrate with apiculate teeth and arcuate sinuses.

Discussion.—*Fothergilla durhamensis* differs from the extant *F. major* Lodd. mainly in having numerous secondary teeth in the basal half of the margin.

Holotype.—USNM 42114.

Paratype.—USNM 42115.

Occurrence.—1963, 9732, 9832.

Family LEGUMINOSAE

Genus CLADRASTIS Michaux

***Cladrastis pugetensis* Wolfe, new species**

Plate 5, figures 2–4

Diagnosis.—Leaflets broadly oval; venation pinnate; apex narrowly mucronate, base acute; length 5.0–10.0 cm, width 4.0–8.6 cm; 8–12 pairs of irregularly spaced secondaries, departing from midrib at an angle of 50° – 70° , straight to broadly convex, forking two or three times to form conspicuous submarginal loops; intersecondaries numerous, parallel to secondaries; nervilles obcurrent, branching; margin entire; petiolule 0.2 cm long, ridged perpendicular to long axis of lamina.

Discussion.—These Puget fossils are very similar to the extant *Cladrastis lutea* Michx., particularly in the

characteristic forking and looping of the secondaries. The major difference between the Recent and fossil leaflets is in the broadly oval to obovate shape of the fossils; in *C. lutea* the leaflets are typically much narrower although terminal leaflets are rarely as broad as the fossils. The symmetry of the holotype of *C. pugetensis* indicates that it is probably a terminal leaflet, but the equally broad figured paratype is probably a lateral leaflet.

Holotype.—USNM 42116.

Paratype.—USNM 42117, 42162.

Occurrence.—2023, 2024, 9679, 9680, 9681, 9694, 9729, 9731, 9837.

Family EUPHORBIACEAE

Genus MACARANGA Thouars

***Macaranga pugetensis* Wolfe, new species**

Plate 5, figure 1

Diagnosis.—Leaves round; base deeply cordate, apex abruptly acute; length 9.5–10.0 cm, width 10.0–11.5 cm; venation palmate; nine primary veins; pair adjacent to midrib (most apical) extending two-thirds to three-fourths the distance to the apex, and with four abmedial secondary veins; the next pair of primaries with five abmedial secondaries; the next pair of primaries with two abmedial secondaries; the fourth pair of primaries are relatively inconspicuous, with one abmedial secondary on one side of lamina and two on the other; three central primaries, parallel to first (apical) pair of primaries; all primaries, secondaries and abmedial tertiaries craspedodrome; nervilles percurrent, with prominent quaternary ties; margin with fine teeth for each craspedodrome vein; petiole not preserved.

Discussion.—The prominent quaternary ties between the nervilles, the very small and regular spaced teeth indicate that the fossils are representatives of *Macaranga* and most closely related to *M. tanarius* Muell.-Arg. The fossils differ from this extant species in having a cordate rather than peltate base, fewer secondary veins, and an abruptly acute rather than an acuminate apex. Extant species of *Macaranga* that have a cordate base do not closely resemble *M. pugetensis* in marginal venation.

Holotype.—USNM 42118.

Occurrence.—9678, 9734.

Family ANACARDIACEAE

Genus ANACARDITES Saporta

***Anacardites franklinensis* Wolfe, new species**

Plate 6, figures 1, 5

Diagnosis.—Leaves ovate, widest at or near base; venation pinnate; base very broad, shallowly cordate,

apex narrowly rounded; length 7.0–12.0 cm, width 7.2–9.0 cm; 9–12 pairs of undulatory and irregularly spaced secondaries, departing from midrib at an angle of 70°–90°, straight to broadly convex, forking prominently with conspicuous angular submarginal loops; intersecondaries numerous, parallel to secondaries; nervilles percurrent, branching; margin entire; petiole 1.0 cm long.

Discussion.—Leaves of extant species of *Anacardium* also show a conspicuous forking and looping of the secondary and abmedial tertiary veins as in the fossils. However *Anacardites franklinensis* can be distinguished from species of *Anacardium* by the position of the forks in the secondary vein; in the fossils the first forks typically occur but one-fourth to one-half the distance from the midrib to the margin, but in *Anacardium* the first forks typically occur in the outer fourth of the lamina. In addition, none of the extant species of *Anacardium* examined have leaves with an ovate shape and a deeply cordate base. There is thus considerable question as to whether the fossils should be assigned to *Anacardium* and I think it is better to assign them to *Anacardites*.

Anacardites franklinensis is known from specimens from the Franklin bed 12, and collections from the Roslyn mines contain abundant and well-preserved specimens.

Holotype.—USNM 42119.

Paratypes.—USNM 42120, 42121.

Occurrence.—1027, 9076 (Roslyn), 9678.

Family RHAMNACEAE

Genus RHAMNITES Forbes

***Rhamnites cashmanensis* Wolfe, new species**

Plate 6, figure 2; text figure 18

Diagnosis.—Leaves oval; venation pinnate; base asymmetric, decurrent along petiole, apex narrowly rounded; length 9.0–13.0 cm, width 4.3–7.7 cm; 9–13 pairs of irregularly spaced secondaries, departing from midrib at an angle of 50°–70°, broadly convex, looping just within the margin and forming a series of smooth marginal loops; intersecondaries rare, parallel to secondaries; nervilles slightly obcurrent, most unbranching, concave towards midrib; margin entire; petiole more than 2.0 cm long.

Discussion.—These leaves have a rhamnaceous aspect in their thin, obcurrent, closely spaced nervilles and the smoothly looping secondaries. Certain other genera, for example *Camptotheca*, have similar leaves. I am not absolutely convinced that *Rhamnites cashmanensis* is a member of Rhamnaceae, but this familial reference is the best one that I can make at this time. Although some

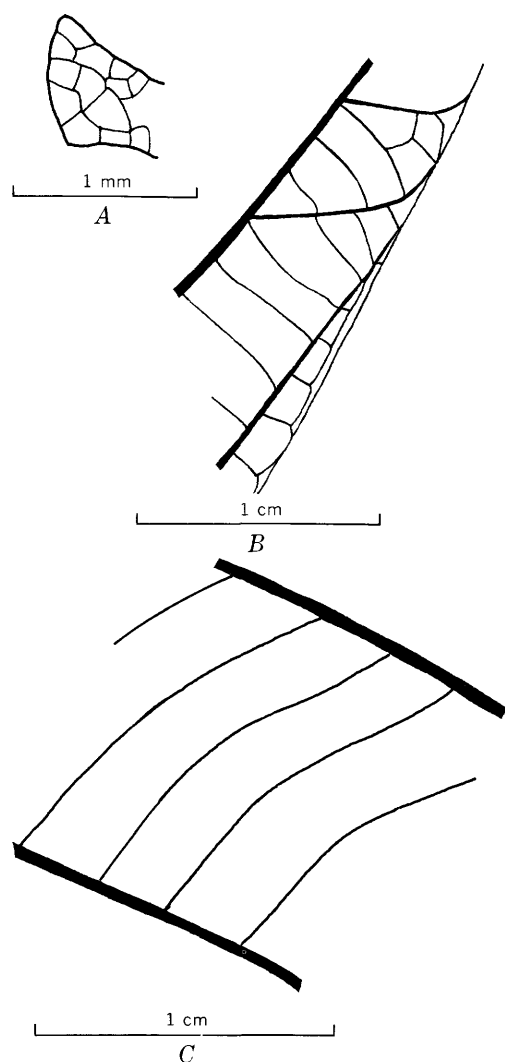


FIGURE 18.—Ultimate, marginal, and intercostal venation of *Rhamnites cashmanensis*. A, B, C. Holotype, USNM 42127, loc. 9731.

species of *Rhamnites* are probably not related to *R. cashmanensis*, other early Tertiary species of the genus appear to be congeneric with the Puget form, particularly *R. knowltoni* Berry from the Wilcox Group. The most conspicuous difference between the two species is that the latter, as described by Berry (1922, p. 16), has 7–9 pairs of secondaries, but *R. cashmanensis* has 9–13 pairs.

Holotype.—USNM 42127.

Paratype.—USNM 42128.

Occurrence.—9729, 9731.

***Rhamnites franklinensis* Wolfe, new species**

Plate 6, figure 4

Diagnosis.—Leaves oval to obovate; venation pinnate; base asymmetric, acute, apex acute; length 12.0–

14.5 cm, width 6.0–7.0 cm; 12–14 pairs of convex secondaries, departing from midrib at an angle of 40°–70°, looping just within the margin and forming a series of smooth marginal loops; intersecondaries lacking; nervilles slightly obcurrent, most unbranching, concave towards midrib; margin entire.

Discussion.—*Rhamnites franklinensis* is similar to and probably ancestral to *R. cashmanensis*. The primary differences between leaves of the two species are that *R. cashmanensis* has (1) wider spacing of the nervilles (2–3 mm as compared to 1–2) (2) more prominent abmedial tertiary loops, and (3) a consistently acute base and apex.

Holotype.—USNM 42129.

Paratypes.—USNM 42130, 42131.

Occurrence.—1028, 9678, 9694, 9695.

Family TILIACEAE

Genus WILLISIA Wolfe, new genus

Diagnosis.—Leaves oval, asymmetric; venation palmate; six to nine primary veins, normally with one more on large side of lamina; apical pair of lateral primaries extending about half the distance to the apex; lateral abmedial secondaries on second pair of primaries on large size only; secondaries forking conspicuously to loop just within the margin; nervilles percurrent, widely spaced, typically unbranching; conspicuous quaternary mesh between nervilles; areoles of moderate size, intruded by linear simple veinlets; margin entire or revolute.

Type species.—*W. rentonensis* Wolfe

Discussion.—Palmately veined, highly asymmetric, leaves are of frequent occurrence in extant Tiliaceae. The characteristic flat-sided shape of *Willisia* is also found in leaves of *Grewia* and *Luehea*, and the primary and secondary venation of the fossils is also similar to that of these two extant genera. However, *Grewia* and *Luehea* consistently have nonentire margins. The asymmetric, entire-margined leaves of *Microcos* have some similarities to *Willisia*, particularly in ultimate venation, but the asymmetry is less prominent and there are fewer primaries in *Microcos*. Hence, the Puget leaves are assigned to a new genus now considered to be extinct.

Willisia is named in honor of Bailey Willis.

***Willisia rentonensis* Wolfe, new species**

Plate 7, figures 3, 5; text figure 19

Diagnosis.—Leaves decidedly asymmetric; base cuneate on one side of lamina and cordate on the other; apex acuminate; length 4.3–9.2 cm, width 2.1–4.0 cm;

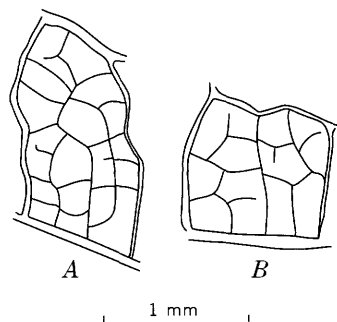


FIGURE 19.—Ultimate venation of *Willisia* and *Microcos*. A, *Willisia rentonensis*, paratype, USNM 42141, loc. 9731. B, *Microcos stylocarpa*, Recent.

four to six first lateral abmedial secondaries, two to four second lateral abmedial secondaries; five or six pairs of central secondaries, departing at an angle of 30° – 90° (greatest near apex); intersecondaries common, perpendicular to midrib.

Holotype.—USNM 42138.

Paratypes.—USNM 42139–42141.

Occurrence.—1027, 1028, 8640, 9694, 9731, 9732, 9733, 9832.

Family THEACEAE

Genus CAMELLIA Linnaeus

Camellia multiflora (Potbury) Wolfe, new combination

Euphorbiophyllum multiflorum Potbury, Carnegie Inst. Wash. Pub. 465, p. 73, pl. 9, figs. 1–4.

Discussion.—Potbury noted that the finely serrate margin of the type specimens was a character unusual in Euphorbiaceae. In addition, the fossils have fewer and more widely spaced nervilles than is typical for that family. The various features of the margin and venation, including the abmedial branching of the veinlets noted by Potbury, are found in leaves of *Camellia*, and the LaPorte species is thus transferred to that genus.

Occurrence.—9681.

Genus TERNSTROEMITES Berry

Ternstroemites ravenensis Wolfe, new species

Plate 7, figure 4; text figure 20

Diagnosis.—Leaves oval to obovate; venation pinnate; base cuneate, apex acute; length 11.4–25.0 cm, width 3.1–6.3 cm; 16–22 pairs of irregularly spaced secondaries, departing from midrib at an angle of 40° – 60° , straight to broadly convex, looping angularly; intersecondaries numerous, parallel to secondaries, many extending half the distance to the margin; a series of abmedial tertiary loops; abmedial quaternar-

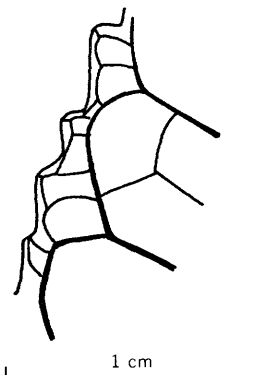


FIGURE 20.—Marginal venation of *Ternstroemites ravenensis*. Paratype, USNM 42153, loc. 9729.

ies craspedodrome; nervilles widely spaced, percurrent, irregularly branching; margin evenly and coarsely crenate; two or three teeth per secondary; petiole 1.7–3.0 cm long.

Discussion.—The crenate margin, extensive submarginal tertiary looping, and the general aspect of secondary and intercostal venation of these Puget leaves is also found in extant species of Theaceae. Most leaves of this family are difficult to distinguish generically, and the general type of leaf represented by *Ternstroemites ravenensis* is found in several genera such as *Franklinia*, *Gordonia*, and *Schima*. *T. ravenensis* is particularly abundant at loc. 9694, where its specimens make up more than half of the dicot leaves preserved.

Holotype.—USNM 42151.

Paratypes.—USNM 42152, 42153.

Occurrence.—2024, 9694, 9729, 9731.

Family CAPRIFOLIACEAE

Genus VIBURNUM Linnaeus

Viburnum pugetensis Wolfe, new species

Plate 6, figure 3; plate 7, figure 10

Diagnosis.—Leaves ovate to oval; asymmetric; venation pinnate; base broadly rounded, typically shallowly cordate, apex acuminate; length 3.2–10.5 cm, width 6.0–10.0 cm; six to nine pairs of irregularly spaced secondaries, departing from midrib at an angle of 30° – 90° (greater near base), broadly convex, forking and craspedodrome; in basal half of lamina each secondary gives off three or four abmedial tertiaries, in apical half secondaries give off two or three tertiaries; tertiaries craspedodrome; margin serrate, with numerous sharp, narrow teeth; sinuses arcuate.

Discussion.—The Puget leaves of *Viburnum* appear to be referable to a single species, which is closest to the extant *V. japonicum*. The fossils, however, have more numerous and narrower teeth than the Recent

leaves and have a cordate base instead of a broadly rounded and decurrent base as in *V. japonicum*.

Holotype.—USNM 42142.

Paratypes.—USNM 42143, 42144.

Occurrence.—1963, 2024, 9076 (Roslyn), 9678, 9680, 9691, 9731, 9732, 9837, 9841.

DICOTYLEDONAE Incertae Sedis

Genus *MACCLINTOCKIA* Heer

Macclintockia pugetensis Wolfe, new species

Plate 7, figures 8, 9

Daphnogene kanii auct. non Heer. Hollick, 1936, U.S. Geol. Survey Prof. Paper 182, p. 121, pl. 67, fig. 11.

Diagnosis.—Leaves pinnate, venation palmate; shape linear, oval to obovate; length 7 to more than 12 cm, width 4–6 cm; apex narrowly rounded, base cuneate and decurrent along petiole; two strong pairs of acrodrome primary veins flanking midrib and typically departing only apical to where second pair of lateral 2 additional pairs of primaries, one pair weakly developed, the second pair forming a distinct marginal vein; central secondary veins departing in apical half of lamina at an angle of about 40°, joining first pair of lateral primaries and near apex forming submarginal angular loops with primaries; lateral secondary veins departing only apical to where second pair of lateral primaries end and departing at an angle of about 40°, camptodrome; lateral tertiary veins craspedodrome; areoles typically quadrangular, about 0.4 mm in diameter, intruded by linear simple veinlets; petiole swollen at top, 2.0–2.5 cm in length; margin entire or with up to four large and irregularly spaced teeth near apex.

Discussion.—The affinities of *Macclintockia* are unknown. The occurrence of these leaves in marine rocks or in rocks that were deposited in lowland areas adjacent to the sea (see Koch, 1963, p. 82–83 for localities) indicates that *Macclintockia* may have been a swampy or strand plant. In addition to the occurrences cited by Koch, *Macclintockia* is known from marine rocks of late Eocene or early Oligocene age at the head of the Gulf of Alaska, from the Eocene near Vancouver, British Columbia, from Oligocene marine rocks in the northern part of the Olympic peninsula, Washington, from the Toutle Formation in southwestern Washington, and from the early Oligocene part of the Puget Group and the overlying andesitic rocks.

Macclintockia pugetensis is most similar to *M. kanii* (Heer) Sew. and Conw. from the Paleocene of Greenland. The Puget specimens, however, have a thicker and shorter petiole, a cuneate rather than rounded base,

and the first pair of lateral primaries depart farther from the base of the lamina.

Holotype.—USNM 42146.

Paratypes.—USNM 42145, 42147.

Occurrence.—1989, 9688, 9689, 9690, 9730.

FOSSIL PLANT LOCALITIES

USGS Paleobotany locality	Stage and lithologic unit	Locality data, collector, and year
1025---	Upper Ravenian, Puget Group.	"Eureka mine, near Cumberland." Willis, 1895.
1026---	Lower Ravenian, Puget Group.	"Franklin Colliery on Green River. Above McKay vein." Willis, 1895.
1027---	Lower Fultonian, Puget Group.	"Franklin Colliery on Green River. Vein 12." Willis, 1897.
1028---	Lower Fultonian, Puget Group.	"Franklin Colliery on Green River. Vein 12." Willis, 1895.
1059---	Lower Fultonian, Puget Group.	"Canyon of Green River. Vein 12." Knowlton, 1898.
1963---	Upper Fultonian, Puget Group.	"Canyon of Green River, just below pump house. 100–150 ft above vein 12." Knowlton, 1898.
1989---	Upper Kummerian, Renton Formation.	"Newcastle mine dump." Knowlton, 1898.
2022---	Lower Ravenian, Puget Group.	"Lawson mine near Black Diamond." Knowlton, 1898.
2023---	Lower Kummerian, Puget Group.	"Clay mine on Green River." Knowlton, 1898.
2024---	Lower Ravenian, Puget Group.	"Black Diamond, new slope below the coal." Knowlton 1898.
8640---	Lower Ravenian, Tukwila Formation.	East abutment of covered bridge, Steel's Crossing, 3 miles west of Renton. Brown and Simson, 1938.
9035---	Lower Kummerian, Tukwila(?) Formation.	NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 2, T. 23 N., R. 5 E. Norbistrath, 1944.
9076---	Lower Fultonian, Roslyn Formation.	Roslyn Formation. Northwestern Improvement Co., 1946.
9106---	Lower Ravenian, McIntosh Formation.	NE $\frac{1}{4}$ sec. 2, T. 14 N., R. 2 E. Snively, 1948; Snively, Roberts, and Brown, 1949.
9675---	Franklinian, Puget Group.	NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 8, T. 21 N., R. 7 E. About 450 ft above lowest exposed rocks of Puget Group. Vine, Gower, and Wolfe, 1960.
9676---	Franklinian, Puget Group.	NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 8, T. 21 N., R. 7 E. About 350 ft above lowest exposed rocks of Puget Group. Vine, Gower, and Wolfe, 1960.
9677---	Franklinian, Puget Group.	NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 8, T. 21 N., R. 7 E. About 200 ft above lowest exposed rocks of Puget Group. Vine, Gower, and Wolfe, 1960.

<i>USGS Paleobotany locality</i>	<i>Stage and lithologic unit</i>	<i>Locality data, collector, and year</i>	<i>USGS Paleobotany locality</i>	<i>Stage and lithologic unit</i>	<i>Locality data, collector, and year</i>
9678---	Lower Fultonian, Puget Group.	NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 18, T. 21 N., R. 7 E. Immediately above Franklin bed 12 (Fulton). Vine, Gower, and Wolfe, 1960; Wolfe, 1961.	9693---	Upper Kummerian, unnamed volcanic rocks.	NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 13, T. 21 N., R. 7 E. Gower and Wolfe, 1960.
9679---	Lower Kummerian, Puget Group.	SE $\frac{1}{4}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 26, T. 21 N., R. 6 E. About 150 ft below Kummer No. 3 bed. Vine, Gower, and Wolfe, 1960.	9694---	Lower Ravenian, Puget Group.	NE $\frac{1}{4}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 36, T. 22 N., R. 6 E. Between Ravensdale beds 3 and 4. Wolfe; 1960, 1961.
9680---	Upper Ravenian, Puget Group.	NE $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 19, T. 21 N., R. 7 E. Just below Kummer sandstone bed. Vine, Gower, and Wolfe, 1960.	9695---	Upper Fultonian, Puget Group.	NE $\frac{1}{4}$ NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 25, T. 22 N., R. 6 E. About 250 ft below McKay bed. Vine and Wolfe; Gower and Wolfe, 1961.
9681---	Lower Kummerian, Puget Group.	S $\frac{1}{2}$ NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 33, T. 21 N., R. 7 E. About 200 ft below contact with un- named volcanic rocks. Vine, Gower, and Wolfe, 1960.	9728---	Lower Ravenian(?), Puget Group.	SE $\frac{1}{4}$ NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 36, T. 22 N., R. 6 E. Just below Ravensdale bed 5. Gower, 1960.
9682---	Upper Kummerian, unnamed volcanic rocks.	NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 36, T. 21 N., R. 7 E. About 250 ft above contact with Puget Group. Vine, Gower, and Wolfe, 1960.	9729---	Upper Ravenian, Renton Forma- tion.	NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 3, T. 22 N., R. 7 E. About halfway between coal beds 1 and 0, Taylor coal field. Vine, 1960.
9685---	Lower Ravenian(?), Tukwila Forma- tion.	NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 17, T. 23 N., R. 7 E. Lower part of for- mation. Vine, Gower, and Wolfe, 1960.	9730---	Upper Kummerian, Renton Forma- tion.	NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 29, T. 23 N., R. 6 E. About 50 ft below coal bed A, Cedar Moun- tain area. Vine, 1960.
9686---	Lower Ravenian(?), Tukwila Forma- tion.	SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 8, T. 23 N., R. 7 E. Lower part of for- mation. Vine, Gower, and Wolfe, 1960.	9731---	Upper Ravenian, Puget Group.	NE $\frac{1}{4}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 33, T. 22 N., R. 7 E. Just below Cashman bed. Gower, 1960; Wolfe, 1961.
9687---	Lower Ravenian, Tukwila Forma- tion.	SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 27, T. 23 N., R. 7 E. Sandstone bed C. Vine and Wolfe, 1960.	9732---	Upper Fultonian, Puget Group.	NW $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 36, T. 22 N., R. 6 E. Above Raven bed 4. Gower, 1960; Wolfe, 1961.
9688---	Upper Kummerian, Renton Forma- tion.	SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 32, T. 24 N., R. 6 E. Probably about 200 ft above Bagley coal bed. Vine and Wolfe, 1960.	9733---	Lower Fultonian, Puget Group.	N $\frac{1}{2}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 16, T. 21 N., R. 7 E. Occidental bed 6. Gower, 1960.
9689---	Upper Kummerian, unnamed volcanic rocks.	SW $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 36, T. 21 N., R. 6 E. About 450 ft above contact with Puget Group. Gower and Wolfe, 1960.	9734---	Lower Fultonian, Puget Group.	NW $\frac{1}{4}$ SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 28, T. 21 N., R. 7 E. Just above Navy bed 6. Gower, 1960.
9690---	Upper Kummerian, unnamed volcanic rocks.	NW $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 36, T. 21 N., R. 6 E. About 220 ft above contact with Puget Group. Gower and Wolfe, 1960.	9735---	Lower Ravenian, Puget Group.	NW $\frac{1}{4}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 1, T. 21 N., R. 6 E. McKay bed. Gower, 1960.
9691---	Upper Ravenian, Puget Group.	NW $\frac{1}{4}$ SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 19, T. 21 N., R. 7 E. Above or below Gem bed. Gower and Wolfe, 1960.	9738---	Upper Ravenian, Tukwila Forma- tion.	NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 30, T. 24 N., R. 7 E. Upper part of formation. Vine, 1960.
9692---	Upper Ravenian, Puget Group.	Center SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 23, T. 21 N., R. 7 E. About 1,000 ft (?) below contact with andesitic volcanic rocks. Gower and Wolfe, 1960.	9813---	Upper Fultonian(?), Tiger Mountain Formation.	SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 21, T. 23 N., R. 7 E., Vine, 1961. Coaly zone near top of lower main body of formation.
			9814---	Upper Fultonian, Tiger Mountain Formation.	NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 16, T. 23 N., R. 7 E., Vine, 1961. Coaly zone near top of lower main body of formation.
			9815---	Upper Ravenian(?), Tukwila Formation.	SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 31, T. 23 N., R. 7 E., Vine, 1961. Base of prominent volcanic breccia bed on Holder Creek.
			9832---	Upper Fultonian, Puget Group.	NE $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 2, T. 21 N., R. 7 E. Just below Durham bed 1. Wolfe, 1961.

USGS Paleobotany locality	Stage and lithologic unit	Locality data, collector, and year
9833---	Franklinian, Puget Group.	NE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 19, T. 21 N., R. 7 E. Just above Franklin bed 10. Wolfe, 1961.
9834---	Lower Kummerian, Puget Group.	NW $\frac{1}{4}$ NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 25, T. 21 N., R. 6 E. Just below Kummer bed 5. Gower and Wolfe, 1961.
9835---	Upper Ravenian, Puget Group.	SE $\frac{1}{4}$ NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 27, T. 21 N., R. 6 E. Just above Gem bed. Wolfe, 1961.
9836---	Upper Ravenian, Puget Group.	SW $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 19, T. 21 N., R. 7 E. About 350 ft above Gem bed. Gower and Wolfe, 1961.
9837---	Upper Ravenian, Puget Group.	NW $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 19, T. 21 N., R. 7 E. About 450 ft above Gem bed and probably same horizon as 9680. Gower and Wolfe, 1961.
9838---	Franklinian, Puget Group.	SW $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 8, T. 21 N., R. 7 E. 70-120 ft below Franklin No. 10 bed. Gower and Wolfe, 1961.
9839---	Franklinian, Puget Group.	NW $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 8, T. 21 N., R. 7 E. 340 ft below Franklin No. 10 bed. Gower and Wolfe, 1961.
9840---	Franklinian, Puget Group.	NW $\frac{1}{4}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 8, T. 21 N., R. 7 E. 560 ft below Franklin bed 10. Gower and Wolfe, 1961.
9841---	Franklinian, Puget Group.	SW $\frac{1}{4}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 8, T. 21 N., R. 7 E. About 70 ft below Franklin bed 10. Gower and Wolfe, 1961.
9842---	Franklinian(?), Puget Group.	NW $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 30, T. 22 N., R. 7 E. About 2,000 (?) ft below McKay bed. Gower and Wolfe, 1961.
9843---	Upper Fultonian, Tiger Mountain Formation.	SE $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 16, T. 23 N., R. 7 E. Near top of formation. Vine, Gower, and Wolfe, 1961.

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Page

	Page
Cascade Range.....	1, 2
Cashman coal bed.....	4
<i>cashmanensis</i> , <i>Carya</i>	5, 8, 9, 15
<i>Hypserpa</i>	6, 7, 8, 9, 21, 22
<i>Rhamnites</i>	6, 7, 8, 9, 12, 23, 24
<i>Castanea castaneaefolia</i>	9
sp.....	10
<i>castaneaefolia</i> , <i>Castanea</i>	9
<i>Castanopsis</i>	18
<i>formosana</i>	18
<i>franklinensis</i>	5, 7, 9, 18, pl. 3
<i>longipetiolata</i>	5, 6, 8, 18
<i>cathayensis</i> , <i>Carya</i>	15
Cercidiphyllaceae.....	19
<i>Cercidiphyllum</i>	10, 19
<i>arcticum</i>	9, 10, 20
<i>crenatum</i>	9, 10, 19, 20
<i>elongatum</i>	19
<i>piperoides</i>	5, 8, 12, 19, 20
Chadronian age.....	12
<i>Chaetoptelea</i>	10
sp.....	10
Chalk Bluffs flora.....	1, 6
Chuckanut Formation.....	2
<i>Cinnamomum</i>	13, 21
<i>dilleri</i>	20, 21
<i>tricophylla</i>	21
sp.....	10, 13
<i>Cladrastis</i>	22
<i>lutea</i>	22, 23
<i>pugetensis</i>	6, 7, 8, 9, 22, 23, pl. 5
Clarno flora.....	12
Coal Creek.....	8
<i>Cocculus</i>	20
<i>flabella</i>	6, 10, 20
Comstock flora.....	1, 8, 12
Comstock Formation.....	8
<i>comstocki</i> , <i>Mallotus</i>	11
<i>Cordia rotunda</i>	6, 9
<i>Cornus kelloggii</i>	6, 8, 9
Correlation, marine beds.....	6, 7, 8, 10, 11
terrestrial beds.....	9, 11, 12
<i>corylina</i> , <i>Alnus</i>	10
<i>crenatum</i> , <i>Cercidiphyllum</i>	9, 10, 19, 20
<i>Cryptocarya presamarensis</i>	5, 6, 8, 9, 11
Cumberland quadrangle.....	2, 4
<i>Cupania oregona</i>	6, 8, 9
(<i>Cycloptera</i> , <i>Pterocarya</i>	14
D	
<i>dakotensis</i> , <i>Glyptostrobus</i>	9
<i>Daphnogene kanii</i>	26
Definition of stages, Franklinian.....	6
Fultonian.....	7
Kummerian.....	8
Ravenian.....	7
Dicotyledonae Incertae Sedis.....	26
<i>Dicotylphyllum flexuosa</i>	6
<i>richardsoni</i>	6
<i>Dillenia</i> sp.....	6
<i>dilleri</i> , <i>Benzoin</i>	20, 21
<i>Cinnamomum</i>	20, 21
<i>Goweria</i>	5, 7, 9, 11, 20, 21
<i>Hyperbaena</i>	5, 7, 8, 9, 11, 12, 21
Domengina Stage.....	11, 12

31

	Page
<i>glyptostroboidea</i> , <i>Metasequoia</i>	5
<i>Glyptostrobus</i>	9
<i>dakotensis</i>	9
sp.....	5
<i>Gordonia</i>	25
<i>egregia</i>	6, 7, 8
Gower, H. D.....	2, 5, 10, 20
<i>Goweria</i>	5, 14, 20
<i>dilleri</i>	5, 7, 9, 11, 20, 21, pl. 7
<i>linearis</i>	5, 6, 7, 8, 21, pl. 7
Green River canyon.....	1, 2, 4, 7
Paleogene fossil plants.....	5
Puget Group.....	2, 4
Green River canyon area.....	2, 11
Greenland.....	10
<i>Grewia</i>	24
Gries Ranch fauna.....	10
Gulf of Alaska.....	9, 10
H.....	
Hamamelidaceae.....	13, 22
<i>Hamamelites voyana</i>	6, 8
<i>Hemitelea pinnata</i>	5, 6, 7, 8, 10, 11
<i>hesperia</i> , <i>Zelkova</i>	18
<i>hinodea</i> , <i>Nerium</i>	6, 8
Hobart quadrangle.....	12
Homerian Stage.....	10
<i>Hydrangea</i> sp.....	10
<i>Hyperbaena</i>	13, 20, 21
<i>dilleri</i>	5, 7, 8, 9, 11, 12, 21, fig. 15
<i>mexicana</i>	21
<i>Hypserpa</i>	20, 21, 22
<i>cashmanensis</i>	6, 7, 8, 9, 21, 22, pl. 4
<i>franklinensis</i>	6, 7, 8, 22, pl. 4
I.....	
<i>Ilex oregona</i>	11
Issaquah area.....	12
J.....	
<i>japonicum</i> , <i>Viburnum</i>	25, 26
Juglandaceae.....	13, 14, 16
<i>Juglans</i>	14
<i>orientalis</i>	17
(<i>Cardiocaryon</i>).....	14
K.....	
<i>Kalopanax</i>	13
<i>kanei</i> , <i>Macclintockia</i>	26
<i>kani</i> , <i>Daphnogene</i>	26
Keasey stage.....	8, 10, 11, 12, 13
Keechelus Andesitic Series.....	1, 4, 9
<i>kelloggi</i> , <i>Cornus</i>	6, 8, 9
<i>kluckingi</i> , <i>Alnus</i>	5, 8, 9, 17
Knowlton, F. H.....	2
<i>knowltoni</i> , <i>Rhamnites</i>	24
Kootznahoo Formation.....	10
Kukak Bay.....	10
Kummer sandstone bed.....	4, 7, 8
<i>kummerensis</i> , <i>Artocarpoides</i>	5, 7, 8, 9, 10, 19
Kumnerian Stage.....	1, 8, 9, 10, 11, 12
L.....	
Landsburg bed 1.....	4
LaPorte flora.....	1, 20
<i>Lastrea fischeri</i>	5
<i>lata</i> , <i>Neolitsea</i>	5, 6, 8
Lauraceae.....	5, 13, 21
<i>Laurophyllum litseaefolia</i>	19
<i>raminerum</i>	5, 8, 9
<i>Laurus</i>	9
sp.....	9, 10
Leguminosae.....	22
<i>Leguminosites falcatum</i>	6, 8, 9
Linaceae.....	14, 20
Lincoln Stage.....	10, 12, 13
<i>linearis</i> , <i>Goweria</i>	5, 6, 7, 8, 21

	Page
<i>Liquidambar</i>	13
<i>californica</i>	6, 8
sp.....	10
<i>litseaefolia</i> , <i>Artocarpoides</i>	5, 6, 7, 8, 11, 19
<i>Laurophyllum</i>	19
<i>longifolia</i> , <i>Pugetia</i>	5, 6, 7, 8, 11, 16
<i>longipetiolata</i> , <i>Castanopsis</i>	5, 6, 8, 18
<i>Luehea</i>	24
<i>lutea</i> , <i>Cladrastis</i>	22, 23
M.....	
<i>Macaranga</i>	23
<i>pugetensis</i>	6, 7, 8, 23, pl. 5
<i>tanarius</i>	23
<i>Macclintockia</i>	26
<i>kanei</i>	26
<i>pugetensis</i>	6, 9, 10, 12, 26, pl. 7
MacGinitie, H. D.....	2
<i>magnifica</i> , <i>Carya</i>	9, 10
<i>major</i> , <i>Fothergilla</i>	22
<i>Mallotus comstocki</i>	11
<i>riparius</i>	6, 8
Malvales.....	13
McIntosh Formation.....	7, 8
McKay bed.....	4, 7
<i>Meliosoma aesculifolia</i>	9
Menispermaceae.....	13, 14, 20, 21
<i>Metasequoia</i>	9
<i>glyptostroboidea</i>	5
<i>occidentalis</i>	9
<i>mexicana</i> , <i>Hyperbaena</i>	21
<i>Microcos</i>	13, 24, 25
<i>stylocarpa</i>	25
sp.....	6
Moraceae.....	19
Mount Rainier.....	9, 10
<i>multiforma</i> , <i>Camellia</i>	6, 8, 9, 25
<i>multiformum</i> , <i>Euphorbiophyllum</i>	25
<i>myristicaeformis</i> , <i>Carya</i>	15, 16
N.....	
<i>Neolitsea lata</i>	5, 6, 8
<i>Nerium hinodea</i>	6, 8
<i>nevadensis</i> , <i>Quercus</i>	5
Newcastle area.....	12
O.....	
<i>occidentalis</i> , <i>Metasequoia</i>	9
<i>Ocotea ecernua</i>	5, 8, 9
sp.....	5
Ohanapeecosh Formation.....	9, 10
Oligocene floras.....	1, 8, 9
<i>opera</i> , <i>Alnus</i>	5, 6, 7, 8, 17
<i>oregona</i> , <i>Cupania</i>	6, 8, 9
<i>Ilex</i>	11
<i>Tetracera</i>	6, 8, 9, 10, 11, 12
<i>oregoniana</i> , <i>Ulmus</i>	5, 6, 7, 8, 10, 11, 14, 18, 19
<i>orientalis</i> , <i>Juglans</i>	17
P.....	
Paleogene floras.....	1, 2
<i>Persea pseudocarolinensis</i>	5, 6, 8, 11
<i>Phyllites alchorneopsis</i>	6, 8, 9
Pierce County.....	2
<i>pinnata</i> , <i>Hemitelea</i>	5, 6, 7, 8, 10, 11
<i>piperoides</i> , <i>Cercidiphyllum</i>	5, 8, 12, 19, 20
<i>Platanophyllum angustiloba</i>	12
<i>Platanus</i> sp.....	6, 9, 10
<i>Platyptera</i>	17
<i>plena</i> , <i>Rhamnus</i>	6, 8, 10
<i>plinerva</i> , <i>Ficus</i>	9
<i>presamarensis</i> , <i>Cryptocarya</i>	5, 6, 8, 9, 11
<i>pristina</i> , <i>Prunus</i>	9
Provincial stages.....	2
<i>Prunus franklinensis</i>	9
<i>pristina</i>	9
<i>pseudocarolinensis</i> , <i>Persea</i>	5, 7, 8, 11

	Page
<i>Pterocarya</i>	16
<i>pugetensis</i>	5, 7, 8, 9, 16, 17, pl. 1
(<i>Cycloptera</i>).....	14
Puget Group.....	1, 2, 4, 5, 8, 11, 12, 14
coal-bearing rocks.....	1, 2, 4
<i>pugetensis</i> , <i>Allantodiopsis</i>	5, 7, 8, 9, 11, 14
<i>Carya</i>	5, 7, 9, 15
<i>Cladrastis</i>	6, 7, 8, 9, 22, 23
<i>Dryophyllum</i>	5, 7, 9, 18
<i>Macaranga</i>	6, 7, 8, 23
<i>Macclintockia</i>	6, 9, 10, 12, 26
<i>Pterocarya</i>	5, 7, 8, 9, 16, 17
<i>Viburnum</i>	6, 7, 8, 25
<i>Vinea</i>	5, 7, 9, 10, 14
<i>Pugetia</i>	14, 16
<i>longifolia</i>	5, 6, 7, 8, 11, 16, pl. 2
Q.....	
<i>Quercus nevadensis</i>	5
<i>quisumbingi</i> , <i>Ficus</i>	9
R.....	
Raging River Formation.....	1, 2, 7, 8, 11
<i>raminerum</i> , <i>Laurophyllum</i>	5, 8, 9
Ranales.....	13
<i>ravenensis</i> , <i>Ternstroemites</i>	6, 7, 9, 11, 12, 25
Ravenian Stage.....	1, 7, 8, 10, 11, 12
Ravensdale.....	2
Ravensdale area.....	4
Ravensdale bed 3.....	7
Ravensdale bed 4.....	4, 7
Ravensdale bed 9.....	7
Ravensdale coal beds.....	4, 7
Ravensdale mining district.....	2
Renton Formation.....	12
<i>rentonensis</i> , <i>Willisia</i>	6, 7, 9, 11, 24, 25
Rhamnaceae.....	14, 23
<i>Rhamnites</i>	5, 7, 14, 23, 24
<i>cashmanensis</i>	6, 7, 8, 9, 12, 23, 24, pl. 6
<i>franklinensis</i>	6, 7, 9, 24, pl. 6
<i>knowltoni</i>	24
<i>Rhamnus plena</i>	6, 8, 10
<i>richardsoni</i> , <i>Dicotylophyllum</i>	6
<i>riparius</i> , <i>Mallotus</i>	6, 8
Rogers bed.....	4
Rosales.....	13
Roslyn.....	2
<i>rotunda</i> , <i>Cordia</i>	6, 9
Ryan coal beds.....	4
S.....	
<i>Sabal</i>	10
sp.....	10
<i>Sabalites</i> sp.....	5
Sacramento Valley.....	6
<i>Salvinia</i>	2
<i>elliptica</i>	5
Sapindaceae.....	9, 13, 16
Sapindales.....	13
<i>Sassafras</i> sp.....	10
Schima.....	25
<i>Sequoia</i>	9
<i>affinis</i>	5
Sierra Nevada.....	6
<i>simpsoni</i> , <i>Tetrapteris</i>	6
<i>simulata</i> , <i>Carya</i>	15
<i>Smilax</i> sp.....	5
Smith, G. O.....	2
Stage, definition of use.....	5
Steel's Crossing 'ora.....	11
Steel's Crossing locality.....	2
Stratigraphic relationships, plant stages to	
mammalian stages.....	12
plant stages to marine megafossil stages.....	13
<i>stylocarpa</i> , <i>Microcos</i>	25

	Page		Page		Page
Substage, definition.....	5	Time-stratigraphic units.....	6	Upper Clarno flora.....	12
Summit Creek.....	9, 10	Cumberland quadrangle.....	2, 4	V.....	
Systematic description of flora.....	13	Hobart quadrangle.....	11, 12	<i>variabilis</i> , <i>Viburnum</i>	6, 8
T.....		Issaquah quadrangle.....	11	<i>Viburnum</i>	25
<i>tanarius</i> , <i>Macaranga</i>	23	Maple Valley quadrangle.....	11	<i>japonicum</i>	25, 26
Taylor coal field.....	12	Renton quadrangle.....	11, 12	<i>pugetensis</i>	6, 7, 8, 25, pls. 6, 7
Tejon Stage.....	7, 8, 10, 12	<i>tonkinensis</i> , <i>Carya</i>	14, 15	<i>variabilis</i>	6, 8
<i>Ternstroemites</i>	25	Toutle Formation.....	10, 19	Vine, J. D.....	2, 5, 14
<i>ravenensis</i>	6, 7, 9, 11, 12, 25, pl. 7	<i>tricophylla</i> , <i>Cinnamomum</i>	21	<i>Vinea</i>	14
<i>Tetracera oregona</i>	6, 8, 9, 10, 11, 12	Tukwila Formation.....	8, 11, 12	<i>pugetensis</i>	5, 7, 9, 10, 14, pl. 2
<i>Tetrapteris simpsoni</i>	6	<i>typhinoides</i> , <i>Carya</i>	16	<i>voyana</i> , <i>Hamamelites</i>	6, 8
Theaceae.....	25	U.....		W.....	
<i>thomae</i> , <i>Alangium</i>	9	Ulmaceae.....	18, 19	<i>Willisia</i>	24, 25
Tiger Mountain area.....	1, 7, 8, 11, 12	<i>Ulmus</i>	10, 18, 19	<i>rentonensis</i>	6, 7, 9, 11, 24, 25, pl. 7
Tiger Mountain Formation.....	8, 11	<i>oregoniana</i>	5, 6, 7, 8, 10, 11, 14, 18, 19, fig. 11	Z.....	
Tiliaceae.....	13, 24	sp.....	9	<i>Zelkova</i>	18
		Umbelliflorae.....	13	<i>hesperia</i>	18

PLATES 1–7

PLATE 1

[All figures natural size]

- FIGURE 1. *Carya pugetensis* Wolfe. (p. 15)
Holotype, USNM 42087, loc. 9680.
2. *Carya cashmanensis* Wolfe. (p. 15)
Holotype, USNM 42085, loc. 9731.
- 3-5. *Pterocarya pugetensis* Wolfe. (p. 16)
Holotype, USNM 42088, loc. 9837 (fig. 3). Paratypes, USNM 42089,
42090, locs. 9837, 9680 (figs. 4, 5).
6. *Allantodiopsis pugetensis* Wolfe. (p. 14)
Holotype, USNM 42080, loc. 9678.



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6

FOSSIL LEAVES OF PUGET GROUP AND RELATED ROCKS

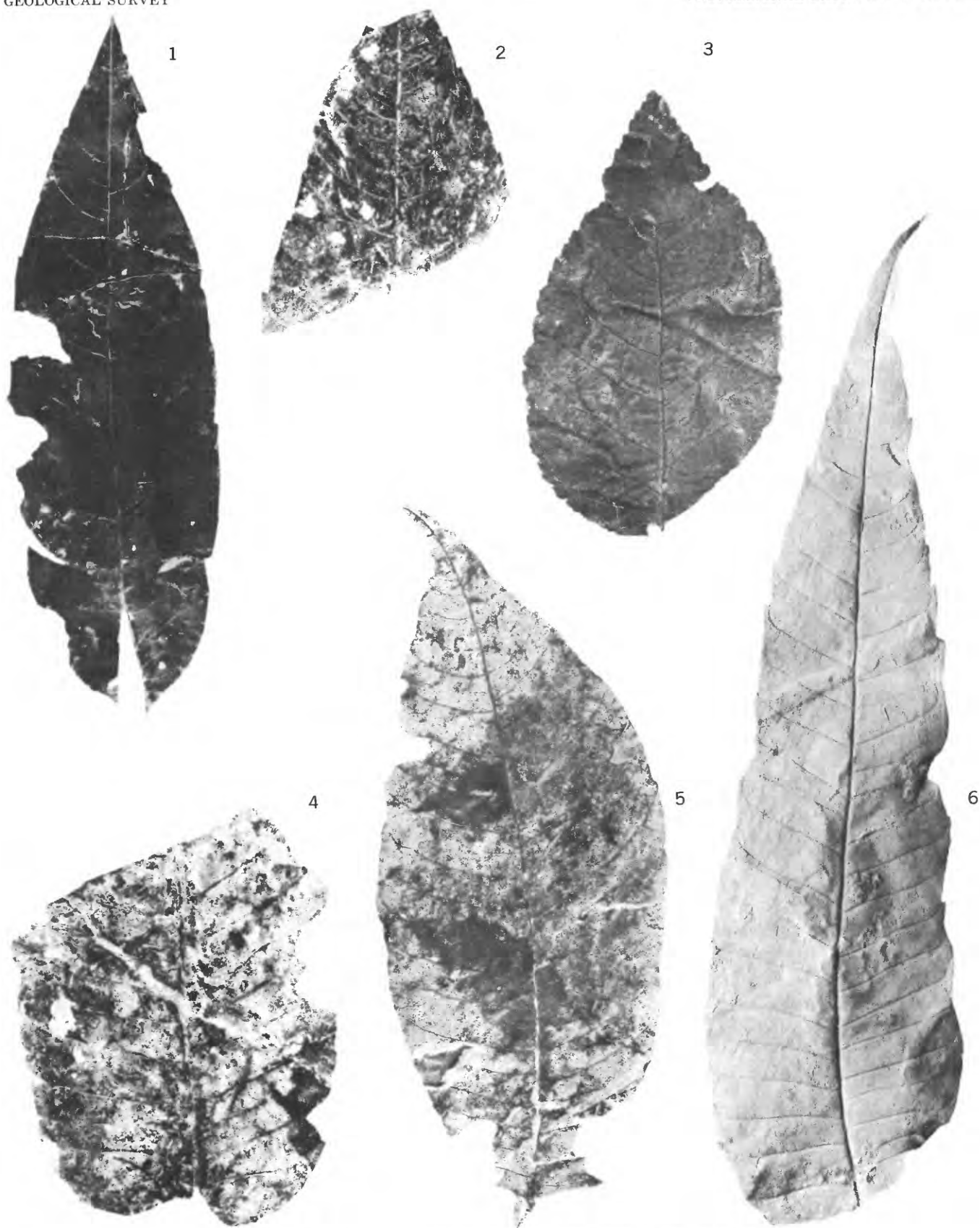
PLATE 2

[All figures natural size]

FIGURES 1, 2, 4–6. *Pugetia longifolia* Wolfe. (p. 16)

Paratypes, USNM 42123–42126, loc. 9678 (figs. 1, 2, 4, 5). Holotype,
USNM 42122, loc. 1963 (fig. 6).

3. *Vinea pugetensis* Wolfe. (p. 14)
Holotype, USNM 42083, loc. 9832.

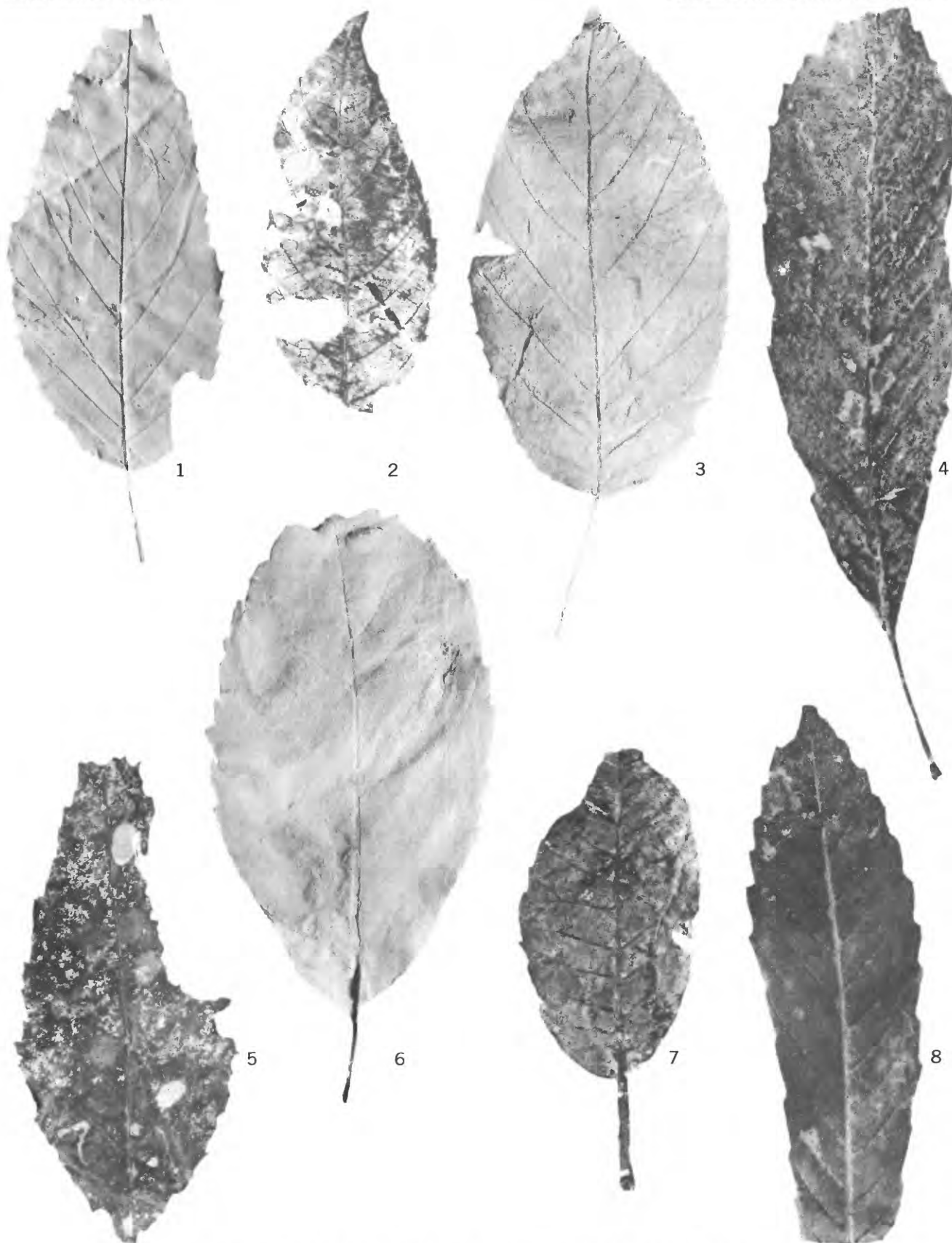


FOSSIL LEAVES OF PUGET GROUP AND RELATED ROCKS

PLATE 3

[All figures natural size]

- FIGURES 1, 2. *Alnus kluckingi* Wolfe. (p. 17)
Holotype, USNM 42094, loc. 9837 (fig. 2). Paratype, USNM 42095, loc. 9731 (fig. 2).
- 3, 5. *Alnus operia* MacGinitie.
Hypotypes, USNM 42093, 42091, locs. 1963, 9678.
- 4, 8. *Dryophyllum pugetensis* Wolfe. (p. 18)
Holotype, USNM 42100, loc. 9694 (fig. 4). Paratype, USNM 42101, loc. 9694 (fig. 8).
- 6, 7. *Castanopsis franklinensis* Wolfe. (p. 18)
Paratype, USNM 42099, loc. 1963 (fig. 6). Holotype, USNM 42098, loc. 9678 (fig. 7).

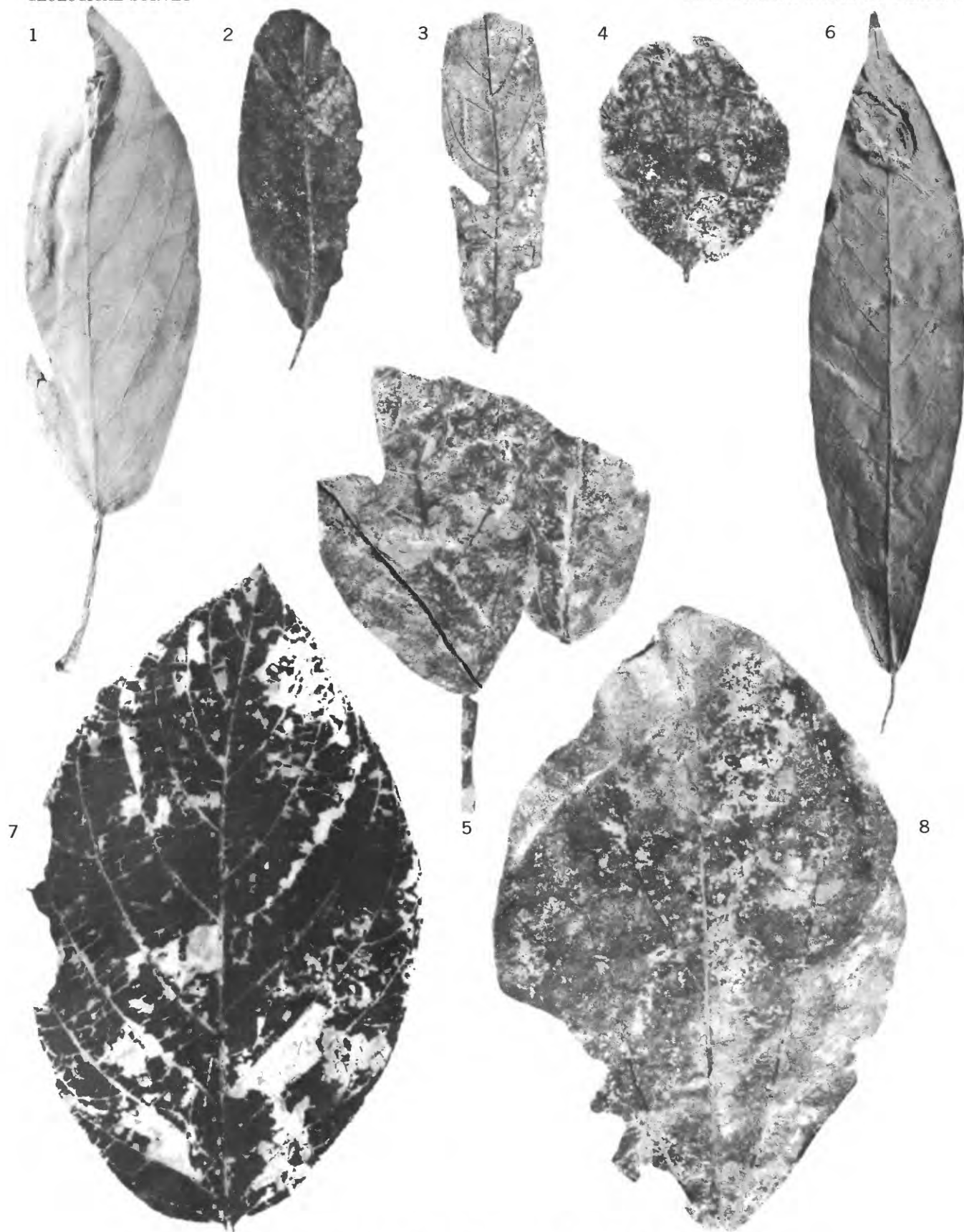


FOSSIL LEAVES OF PUGET GROUP AND RELATED ROCKS

PLATE 4

[All figures natural size]

- FIGURES 1, 7. *Artocarpoides kummerensis* Wolfe. (p. 19)
Holotype, USNM 42104, loc. 9731 (fig. 1). Paratype, USNM 42105, loc. 9731 (fig. 7).
- 2, 3, 5. *Hypserpa cashmanensis* Wolfe. (p. 21)
Paratypes, USNM 42110, 42109, locs. 1963, 9731 (figs. 2, 5) Holotype, USNM 42108, loc. 9731 (fig. 4).
- 4, 8. *Calkinsia franklinensis* Wolfe. (p. 20)
Paratype, USNM 42150, loc. 9678 (fig. 4). Holotype, USNM 42149, loc. 9678 (fig. 8).
6. *Hypserpa franklinensis* Wolfe. (p. 22)
Holotype, USNM 42111, loc. 9678.

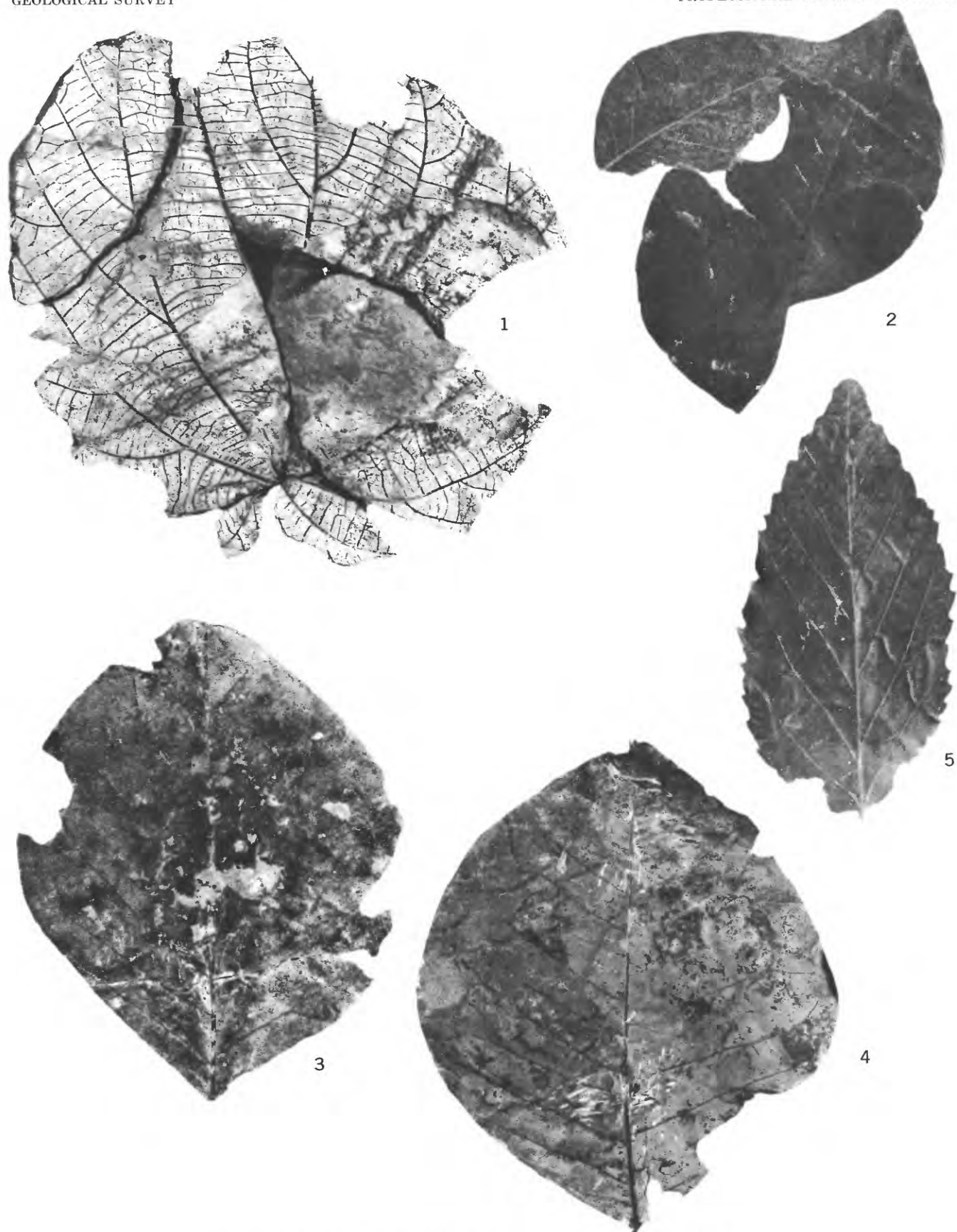


FOSSIL LEAVES OF PUGET GROUP AND RELATED ROCKS

PLATE 5

[All figures natural size]

- FIGURE 1. *Macaranga pugetensis* Wolfe. (p. 23)
 Holotype, USNM 42118, loc. 9678.
- 2-4. *Cladrastis pugetensis* Wolfe. (p. 22)
 Paratypes, USNM 42117, 42162, locs. 9694, 9680 (figs. 2, 3). Holotype,
 USNM 42116, loc. 9731 (fig. 4).
5. *Fothergilla durhamensis* Wolfe. (p. 22)
 Holotype, USNM 42114, loc. 9832.

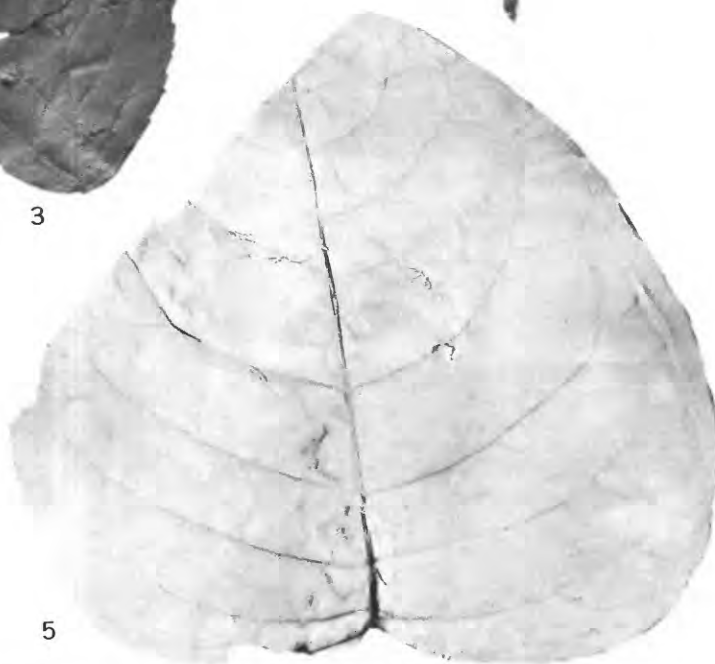
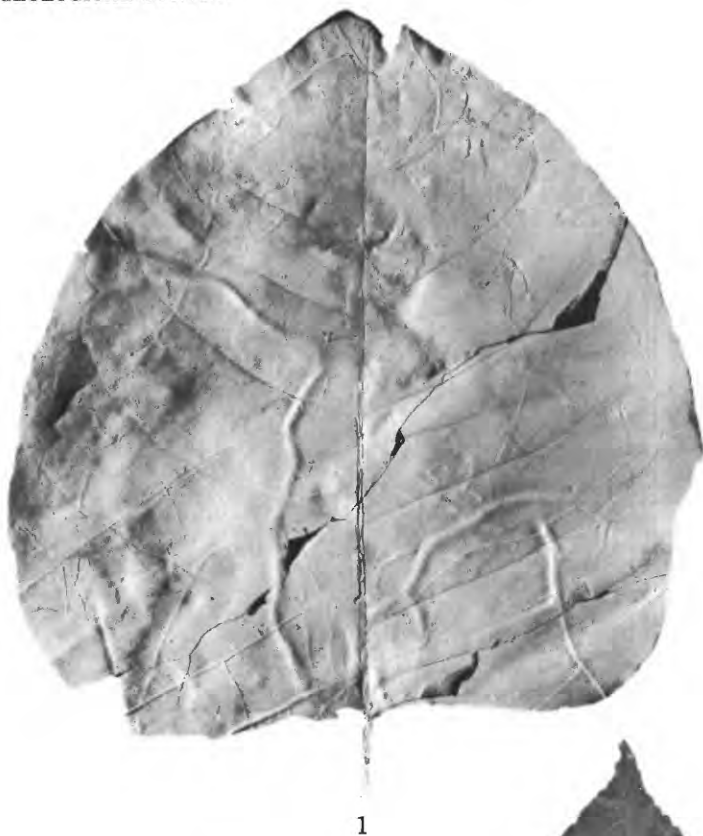


FOSSIL LEAVES OF PUGET GROUP AND RELATED ROCKS

PLATE 6

[All figures natural size]

- FIGURES 1, 5. *Anacardites franklinensis* Wolfe. (p. 23)
Paratype, USNM 42120, loc. 9076 (fig. 1). Holotype, USNM 42119, loc. 9076 (fig. 5).
2. *Rhamnites cashmanensis* Wolfe. (p. 23)
Holotype, USNM 42127, loc. 9731.
3. *Viburnum pugetensis* Wolfe. (p. 25)
Holotype, USNM 42142, loc. 9678.
4. *Rhamnites franklinensis* Wolfe. (p. 24)
Holotype, USNM 42129, loc. 9678.



FOSSIL LEAVES OF PUGET GROUP AND RELATED ROCKS

PLATE 7

[All figures natural size]

- FIGURES 1, 2. *Goveria dilleri* (Knowlton) Wolfe. (p. 20)
Hypotypes, USNM 42132, 42134, locs. 9695, 9735.
- 3, 5. *Willisia rentonensis* Wolfe. (p. 24)
Holotype, USNM 42138, loc. 8640 (fig. 3). Paratype, USNM 42139, loc. 8640 (fig. 5).
4. *Ternstroemites ravenensis* Wolfe. (p. 25)
Holotype, USNM 42151, loc. 9694.
- 6, 7. *Goveria linearis* Wolfe. (p. 21)
Holotype, USNM 42136, loc. 9678 (fig. 6). Paratypes, USNM 42137, loc. 1027 (fig. 7).
- 8, 9. *Macclintockia pugetensis* Wolfe. (p. 26)
Holotype, USNM 42146, loc. 9688 (fig. 8). Paratype, USNM 42147, loc. 9688 (fig. 9).
10. *Viburnum pugetensis* Wolfe. (p. 25)
Paratype, USNM 42143, loc. 9678.



FOSSIL LEAVES OF PUGET GROUP AND RELATED ROCKS