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STRATIGRAPHY OF EOCENE ROCKS IN A PART OF KING COUNTY, WASHINGTON

by

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STRATIGRAPHY OF EOCENE ROCKS IN A PART OF KING COUNTY, WASHINGTON[1]

By JAMES D. VINE[2]

ABSTRACT

Marine rocks of Eocene age in part of King County, Washington, are overlain by a sequence of nonmarine rocks of Eocene age including both volcanic and nonvolcanic types. The volcanic type is characterized by andesitic tuff-breccia and epiclastic sandstone, whereas the nonvolcanic type is characterized by arkosic micaceous sandstone, siltstone, and coal beds. The volcanic rocks are interstratified with the nonvolcanic rocks both stratigraphically and areally. The entire Eocene sequence is estimated to be 14,000 feet thick in the Tiger Mountain-Taylor Mountain upland area, about 20 miles east of Seattle. The Puget Group in the Green River area less than 11 miles to the south is a sequence of nearly equivalent age but only about 6,000 feet thick. Furthermore, the rocks in the Green River area are characterized only by arkosic micaceous sandstone, siltstone, and coal beds. An area near Seattle, recently mapped by Waldron (1962), contains a sequence of volcanic rocks overlain by coal-bearing arkosic micaceous sandstone that is probably equivalent to the upper parts of the sequence in both the Tiger Mountain-Taylor Mountain upland area and the Green River area. He named the volcanic rocks the Tukwila Formation and the overlying nonvolcanic rocks the Renton Formation, including both in the Puget Group because they are interstratified and partly equivalent.

Because the base and lower part of the Tukwila Formation is not exposed in the Seattle area but is exposed in the Tiger Mountain-Taylor Mountain upland area to the east, a reference area for the Tukwila Formation is established near Taylor Mountain. About 2,000 feet of arkosic micaceous sandstone, siltstone, and coal beds conformably below the Tukwila Formation are here defined as the Tiger Mountain Formation and also included in the Puget Group on the basis of lithologic similarity and correlation of fossils. The dominantly marine rocks, about 3,000 feet thick, conformably underlie the Tiger Mountain Formation and are here defined as the Raging River Formation to distinguish them from the Puget Group as well as from marine rocks in other areas that may be similar but not correlative or continuous. The age assignments as indicated by marine mollusks, foraminifera, and plant leaves are in moderate agreement that the boundary between the middle and late Eocene in the Tiger Mountain-Taylor Mountain upland area is close to the boundary between the marine rocks of the Raging River Formation and the nonmarine rocks of the Puget Group rather than within the Puget Group as is true in the Green River area.

[1]Publication authorized by the Director, U.S. Geological Survey.

[2]U.S. Geological Survey, Menlo Park, California. The writer wishes to express sincere thanks to Mr. E. H. Rogers, formerly Chief Engineer, Seattle Water Department, for granting permission to work within the Cedar River Watershed area and to Mr. D. H. Dowling, Branch Forester of the Weyerhaeuser Timber Company, for granting permission to work within the area of the Tiger Mountain timber reserve. This work was done cooperatively with the Washington State Division of Mines and Geology, Department of Conservation.

INTRODUCTION

The "Puget Group" is the term originally applied to the coal-bearing arkosic sandstone and shale in the Puget Sound lowland, west of the Cascade Range in western Washington (White, 1888; Willis, 1897) (fig. 1). In the Carbonado area of northern Pierce County, Willis (1898, p. 426-427) subdivided the Puget Group into three formations, but these formations were not recognizable else-

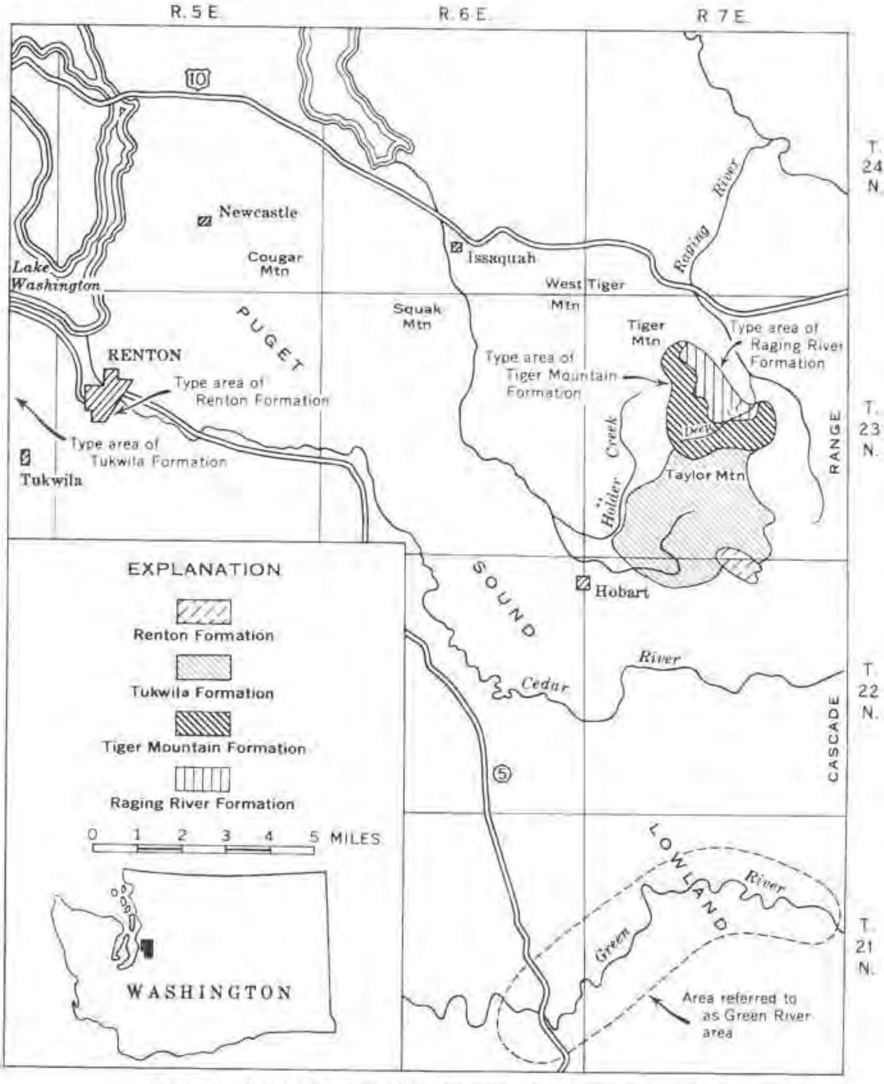

FIGURE 1.—Map of part of King County, Washington, showing location of areas described.

where (fig. 2). In a study of the coal fields of King County, Evans (1912, p. 46-49) also recognized three "series" in his Puget Formation in the canyon of the Green River but made little attempt to

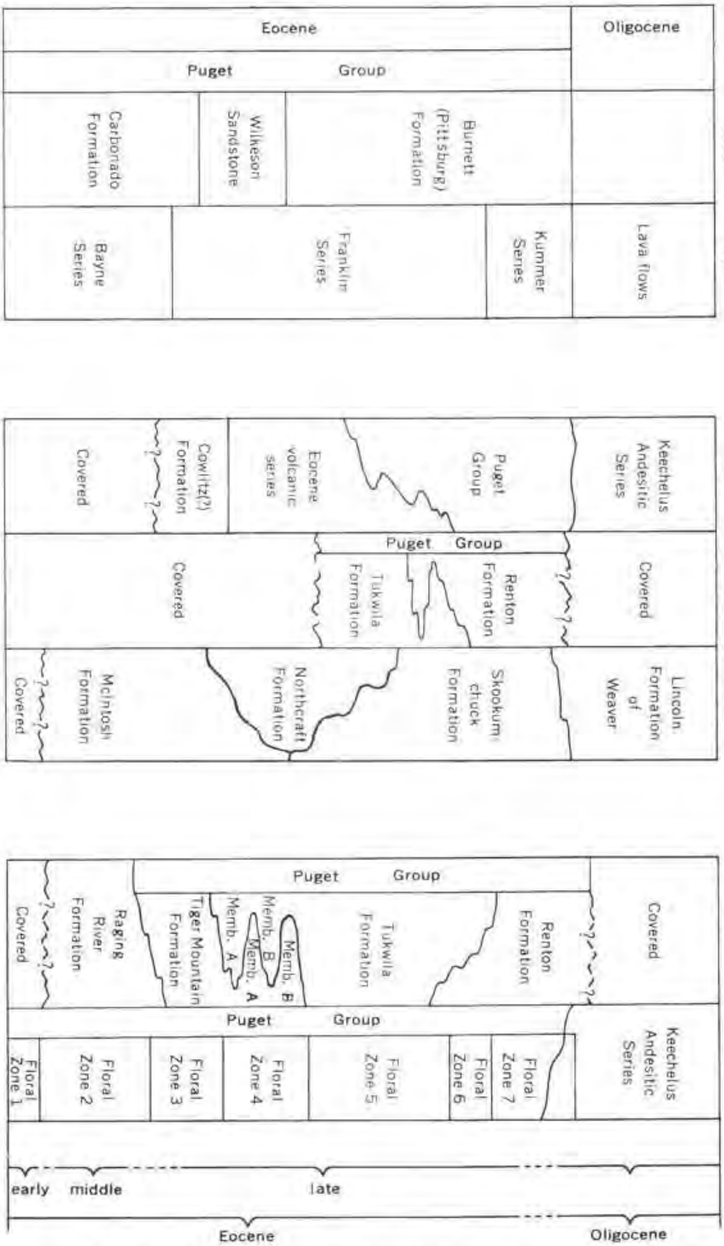

FIGURE 2.—Correlation chart showing Puget Group and equivalent formations.

map them. Evans (1912, p. 45) recognized igneous rocks below the Puget Group but did not distinguish between intrusive and extrusive rocks. Warren and others (1945) made a detailed geologic map of the King County coal field and recognized three major units within the Eocene: the Cowlitz(?) Formation, first named by Weaver (1912), overlain by the Eocene volcanic series, overlain in turn by the Puget Group. As mapped by Warren, the Cowlitz(?) Formation includes both marine rocks and coal-bearing rocks previously regarded by Evans as Puget Formation. The Eocene volcanic series of Warren includes andesitic tuffs and volcanic breccias that are distinguished from later intrusive dikes and sills; Warren also showed local intertonguing of the Eocene volcanic series with equivalent rocks in the Puget Group. Furthermore, he recognized the possibility of major facies changes within these units by suggesting that the Puget Group, where it is exposed in the Green River canyon, may be equivalent to the combined Cowlitz(?), Eocene volcanic series, and Puget Group where the three are mapped separately north of the Cedar River. This suggestion points the way for the present interpretation of the Eocene stratigraphy in this area.

FACIES RELATIONS WITHIN THE PUGET GROUP

Recently Waldron (1962) has given the name "Tukwila Formation" to the Eocene volcanic rocks in the Seattle area and the name "Renton Formation" to the overlying 3,000 feet of coal-bearing rocks, including them both in the Puget Group. This nomenclature extends the use of the term "Puget Group" to include volcanic rocks that heretofore were always distinguished from the Puget Group. In the Seattle area the Tukwila Formation as mapped by Waldron is essentially the same as the Eocene volcanic series mapped by Warren and others (1945). Warren also mapped the Eocene volcanic series in a southeast-trending range of mountains and hills that extends for a distance of over 15 miles from Newcastle, on the east side of Lake Washington, to the foot of the Cascade Range. This range includes (from northwest to southeast) Cougar Mountain, Squak Mountain, West Tiger Mountain, Tiger Mountain, and Taylor Mountain (fig. 1), all of which lie directly south of U.S. Highway 10.

Recent geologic mapping and stratigraphic studies by the U.S. Geological Survey in the Tiger Mountain and Taylor Mountain areas (in and adjacent to the Hobart quadrangle, King County, Wash.) indicate that the volcanic rocks of the Tukwila Formation are truly part of the Puget Group, being wholly contained within the sequence of coal-bearing rocks. The Tukwila Formation attains a maximum thickness of about 7,000 feet in the Tiger Mountain-Taylor Mountain area, where it is both overlain and underlain by nonmarine coal-bearing feldspathic and arkosic micaceous sandstone and shale of the Puget Group. Moreover, the Tukwila Formation forms a wedge within the Puget Group that thins abruptly southward. In the nearly 6,000 feet of Puget Group rocks that are present in the Green River area, about 11 miles south of Tiger Mountain, epiclastic volcanic material was found in only a few thin beds. In addition, clay pellets, clay matrix, and altered lithic grains in some sandstone beds probably represent material of volcanic origin.

A study of the clay minerals present in the matrix of sandstone beds of the Puget Group in the Green River area and in the volcanic and nonvolcanic rocks of the Tiger Mountain-Taylor Mountain area provides physical evidence for suggesting a lateral facies change between rocks in the two areas. Whereas the Tukwila Formation is characterized by chlorite and montmorillonite, many sandstone beds in the middle and lower parts of the Puget Group in the Green River area are characterized by two kinds of expandable mixed-layer clays. One is a randomly interlayered montmorillonite-illite mixture and the other is a regularly interlayered clay mineral, the composition of which is uncertain but may possibly be regularly interlayered montmorillonite-chlorite. In contrast to this, kaolinite is the most abundant clay mineral and locally the only clay mineral in the matrix of sandstone beds in the Renton Formation and also in the upper 1,000 to 2,000 feet of the Puget Group in the Green River area. There can be little doubt that the predominance of kaolinite in the upper part of the Puget Group in the Green River area is a reflection of the absence of volcanic activity in this vicinity during Renton time. The characteristic mixed-layer clays that include montmorillonite in the middle and lower parts of the Puget Group of the Green River area almost certainly result from the inclusion of contemporaneous volcanic material from the Tiger Mountain-Taylor Mountain area.

Paleontologic data tend to confirm the physical evidence that the Puget Group, as it is exposed in the Green River area, includes rocks that in the upper part are equivalent to the Renton Formation, in the middle part to the Tukwila Formation, and in the lower part to the continental and marine rocks that Warren and others (1945) mapped as the Cowlitz(?) Formation. From a study of more than 90 species of fossil leaves and many additional previously undescribed leaves, representing as many as seven floral zones, U.S. Geological Survey paleobotanist J. A. Wolfe (written communication, 1961) has shown that the Puget Group flora ranges from Capay through Keasey stages, or early Eocene through late Eocene and possibly to earliest Oligocene locally (fig. 2). The oldest of the floral zones, from a collection at the base of the section in the Green River area, was recognized by Wolfe (*in* Wolfe and others, 1961) as early Eocene. Six additional floral zones are of middle and late Eocene age, and the youngest may be in part of earliest Oligocene age. Included in the collection were some leaf fossils from the lower part of the andesitic volcanic rocks that lie above the Puget Group; these were found by Wolfe to belong to the youngest zone of late Eocene or earliest Oligocene age. The marine part of the rocks that Warren and others (1945) mapped as Cowlitz(?) has yielded a number of invertebrate fossils that have been studied by F. Stearns MacNeil, paleontologist with the U. S. Geological Survey. Regarding these collections MacNeil states (written communication, 1960) that there is little question that the fossils are of middle Eocene age. The marine rocks in the Tiger Mountain area are therefore older than the Cowlitz Formation in its type area in southwestern Washington, where it is regarded as of late Eocene age (Henriksen, 1956, p. 35, 64, 65).

The stratigraphic succession in the Tiger Mountain area is similar in many respects to that in the Centralia-Chehalis coal district (Snavely and others, 1958), about 65 miles to the southwest, where middle and, locally, late Eocene marine rocks of the McIntosh Formation (Snavely and others, 1951a) are overlain by the volcanic rocks of the Northcraft Formation and the coal-bearing sandstone of the Skookumchuck Formation, both of late Eocene age (Snavely and others, 1951b) (fig. 2). Though the volcanic rocks of the Northcraft Formation and the Tukwila Formation are lithologically similar and may be in part contemporaneous, they apparently represent two separate and distinct centers of volcanic activity during Puget time. Furthermore, the volcanic rocks in each area are underlain by middle Eocene marine rocks, the Northcraft Formation being directly underlain by the McIntosh Formation, and the Tukwila Formation being separated from underlying marine rocks by nonmarine coal-bearing sandstone. The lateral continuity of both the marine rocks and the volcanic rocks is interrupted in the area of outcrop by the continuous section of nonmarine coal-bearing sandstone in the Puget Group that is exposed in the Green River area. The marine rocks, however, are probably continuous in the subsurface west of the area of outcrop.

Because the Puget Group has long been regarded as the nonmarine coal-bearing sequence in the Puget Sound lowland, it is desirable to exclude the marine rocks from the Puget Group but to include all the nonmarine rocks that are of equivalent age. In the Tiger Mountain-Taylor Mountain upland it is proposed to define the sequence of Eocene rocks, giving a separate formation status to the marine rocks at the base, and to include the overlying nonmarine rocks in the Puget Group. The Puget Group is then subdivided into three formations based on the relative proportions of volcanic and nonvolcanic material. The two youngest subdivisions are thought to be identical with the Renton and Tukwila Formations recently defined by Waldron (1962). Because a group consists of divisions defined as formations, it is proposed to assign a new formal name to the oldest subdivision of the Puget Group.

RAGING RIVER FORMATION

The oldest rock unit exposed on the east side of Tiger Mountain comprises as much as 3,000 feet of marine rocks that are exposed at a number of localities in secs. 9, 10, 15, and 16, T. 23 N., R. 7 E., directly west of the valley of the Raging River. The base of the sequence is not exposed. Because these rocks are older than the Cowlitz Formation and widely separated from it, some revision of the nomenclature is indicated. It is proposed to name these rocks the Raging River Formation and to designate the area described above as the type area (fig. 1). The type area is on the west flank and south nose of a northwest-trending anticlinal structure whose axis and east flank are covered by glacial debris and alluvial deposits along the lower slopes of the Raging River valley.

The Raging River Formation consists chiefly of fine-grained sandstone, siltstone, and claystone beds that are characterized by an abundant marine fauna. These beds are generally dark-gray, thick-bedded, hard, and weather into massive ledges. Interbedded with the harder strata, however, are several units of more friable rock as much as 200 feet thick consisting of fine- to coarse-grained sandstone, siltstone, and chert pebble conglomerate. The sandstone beds throughout are poorly sorted and composed of grains that are largely of volcanic origin. In thin section, most of the grains appear angular, clouded in plain light, and mottled in polarized light; the matrix is commonly chloritic. Grain mount studies, using a staining technique to distinguish quartz, K-feldspar, and plagioclase indicate that from 50 to 90 percent of the plus-50-mesh fraction consists of plagioclase feldspar. Quartz and K-feldspar are almost entirely lacking in some samples. Nearly half of the grains in one very hard ledge of sandstone about 165 feet below the top have been altered to a globular green mineral related to glauconite or celadonite.

Ledges of sandstone in the Raging River Formation crop out intermittently below the glacial debris along three small streams that drain the east side of Tiger Mountain and flow into the Raging River. A number of discontinuous exposures are also present along the Washington State Forest Service road that provides access to the lookout tower on Tiger Mountain and along a connecting old logging road. The estimated thickness of about 3,000 feet for the formation is based on the attitude of the beds at a number of isolated outcrops and the interval between the highest and lowest exposures.

The lower part of the Raging River Formation is complicated by faulting, intrusion of igneous sills, and by baking and partial recrystallization of the rock constituents. The base is covered by extensive glacial deposits, and the nature of the underlying rocks is unknown. The upper contact of the formation is placed at the top of a unit of fossil-bearing dark-gray claystone about 160 feet thick that is overlain by gray nonfossiliferous micaceous sandstone. The contact is transitional where these rocks are exposed in a trench adjacent to the Tiger Mountain lookout road.

Warren and others (1945) mention finding marine fossils tentatively thought to correlate with the Cowlitz Formation of late Eocene age in the rocks here included in the Raging River Formation, but they did not publish the identifications. Kremer (1959) lists three Mollusca and nine Foraminifera from these same rocks, which he also regards as of late Eocene age, as follows:

Foraminifera

- *Bathysiphon* cf. *B. eocenica* Cushman and G. D. Hanna
- *Haplophragmoides* cf. *H. coldwaterensis* Mallory
- *Cyclammina pacifica* Beck
- *Cyclammina* sp.
- ?*Karreriella contorta* Beck
- ?*Trochammina* sp.
- *Robulus articulatus texanus* Cushman and Applin
- *Nonion planatum* Cushman and Thomas?
- *Eponides yeguaensis* Weinzierl and Applin

Mollusca

- Gastropoda
  - *Turritella uvasana* Conrad subsp. *stewarti* Merriam
  - *Potamides* cf. *P. carbonicola* Cooper
- Pelecypoda
  - *Corbicula willisi* White

The fossil identifications by F. Stearns MacNeil, which appear to him to indicate a middle Eocene age for the rocks, are listed in table 1, and the fossil localities are shown on figure 3. Foraminifera collected from the claystone directly above locality M649, about 125 feet below the top of the Raging River Formation, have been identified (table 2) by W. W. Rau (written communication, 1961), as being of late middle to early late Eocene age (late Ulatisian to early Narizian). He states that the fauna is locally a part of the *Bulimina* cf. *B. jacksonensis* zone of Rau (1958) and is similar to some assemblages known from the McIntosh Formation. The Raging River Formation is therefore to be regarded as middle and possibly early late Eocene in age.

TABLE 1.—*Fossil invertebrates from the Raging River Formation, King County, Wash.*

[Identifications by F. Stearns MacNeil, written communications 1959 and 1960]
[Localities arranged by probable stratigraphic position with youngest on right]

	Locality number①						
	M648	M643	M644	M645-6	M647	M1037	M649
Echinoderma							
Eupatagus n. sp. aff. *E. carolinensis* Clark and *E. ocalensis* Cooke	X						
Gastropoda							
Ficopsis cf. *F. redmondi crescentensis* Weaver and Palmer							X
Megistostoma gabbiana (Stoliczka)	X						
Pseudoliva lineata Gabb	X						
Scaphander cf. *S. costatus* (Gabb)	X						
Sinum aff. *S. occidentis* Weaver and Palmer				X			
Turritella cf. *T. andersoni* Dickerson var.?		X					
Turritella cf. *T. buwaldana* Dickerson	X						
Turritella sp. aff. *T. uvasana olequahensis* Weaver and Palmer and *T. uvasana sargeanti* Anderson and Hanna				X			
Turritella uvasana cf. subsp. *hendoni* Merriam						X	X
Turritella aff. *T. vaderensis* Weaver and Palmer				X			
Turritella cf. *T. vaderensis* Weaver and Palmer and *T. buwaldana* Dickerson			X				
Turritella n. sp. aff. *T. yabei* Kotaka	X						
Turritella sp. a small form comparing closely with both *T. buwaldana coosensis* Merriam and *T. uvasana hendoni* Merriam	X						
Pelecypoda							
Acila (*Truncacila*) *decisa* (Conrad)			X	X?			
Corbula sp.				X			
Crassatella uvasana cf. *C. uvasana mathewsoni* (Gabb)		X					
Gari aff. *G. hornii* (Gabb)				X			
Macoma sp.		X					
Mytilus dichotomus Cooper	X						X
Mytilus cf. *M. dichotomus* Cooper						X	
Nitidavenus sp. frag. resembles *N. conradi* (Dickerson)							X
Nuculana aff. *N. cowlitzensis* Weaver and Palmer				X			
Ostrea sp.					X		
Pitar (*Lamelliconcha*) *avenalensis* Vokes		X?					X
Pitar cf. *P.* (*Lamelliconcha*) *eocenica* (Weaver and Palmer)	X						
Pitar uvasana coquillensis Turner						X	
Pitar sp.	X			X?			
Pitaria cf. *P. soledadensis* Hanna							X
Plagiocardium (*Shedocardia*) *breweri* (Gabb)	X						
Pteria cf. *P. pellucida* (Gabb)	X						
Solen cf. *S. parallelus* (Gabb)					X		
Solena sp.	X						
?*Taras* sp.	X						
Tellina soledadensis Hanna				X?			X
Venericardia frag. probably *V. hornii* Gabb							X
Venericardia (*Pacificor*) cf. *V.* (*P.*) *weaveri* Verastegui and *V.* (*P.*) *lira* Verastegui				X			
Venericardia sp.				X			
Scaphopoda							
Dentalium cf. *D. stramineum* Gabb	X						

① Locality number description:

M648, Center NE¼SW¼ sec. 15, T. 23 N., R. 7 E.
M643, Center NE¼SE¼ sec. 9, T. 23 N., R. 7 E.
M644, SE¼NE¼SE¼ sec. 9, T. 23 N., R. 7 E.
M645-6, NE¼SE¼SE¼ sec. 9, T. 23 N., R. 7 E.
M647, NE¼NE¼NE¼ sec. 16, T. 23 N., R. 7 E.
M1037, NE¼NW¼ sec. 17, T. 23 N., R. 7 E.
M649, SW¼NE¼SW¼ sec. 9, T. 23 N., R. 7 E.
Hobart quadrangle, King County, Wash.

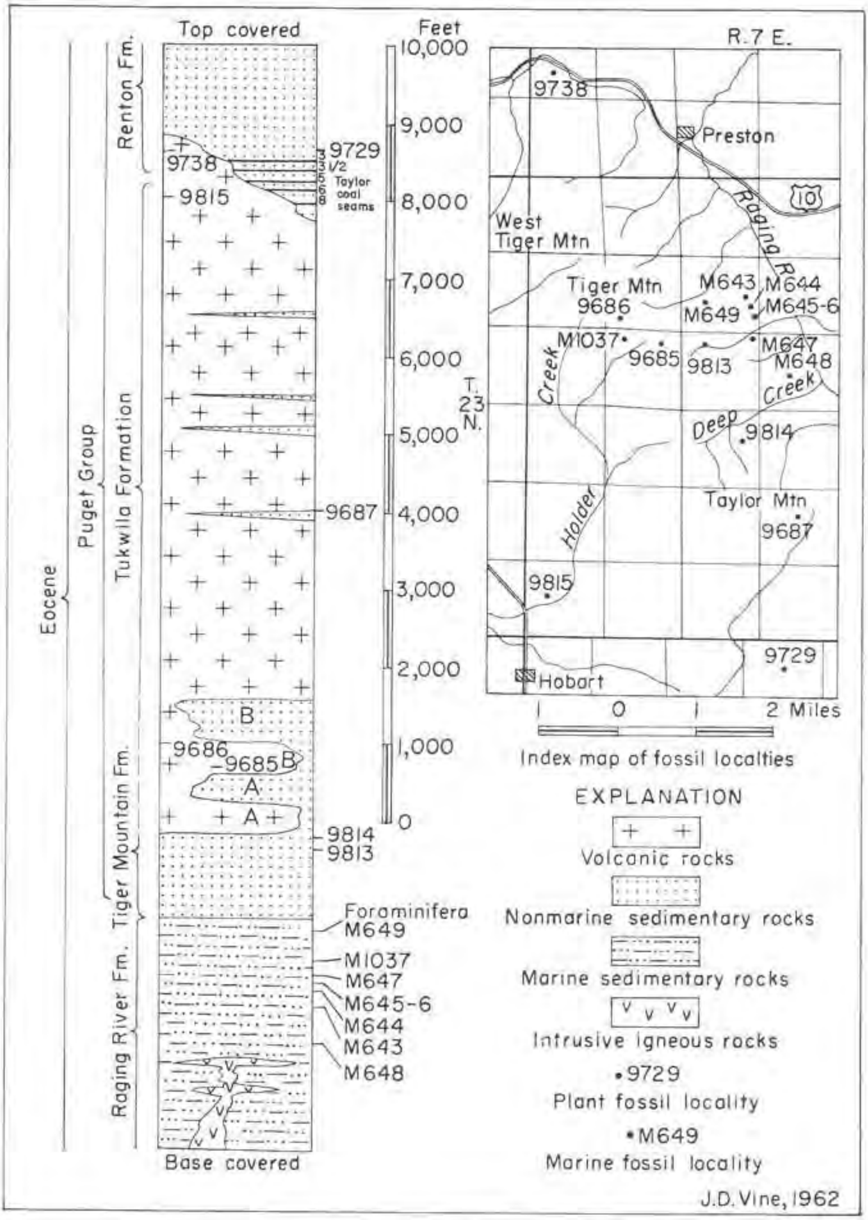

FIGURE 3.—Stratigraphic column and index map showing position of fossil localities, King County, Washington.

TABLE 2.—*Foraminiferal species from the Raging River Formation.*

[Identification by Weldon W. Rau, from a claystone sample at locality M649, about 35 feet stratigraphically above the megafossils from the same locality.]

Cyclammina sp.
Gaudryina jacksonensis coalingensis Cushman and G. D. Hanna
Quinqueloculina imperialis Hanna and Hanna
Quinqueloculina cf. *Q. minuta* Beck
Robulus cf. *R. texanus* (Cushman and Applin)
Robulus spp.
Marginulina subbullata Hantken
Dentalina cf. *D. consobrina* d'Orbigny
Dentalina spp.
Amphimorphina californica Cushman and McMasters
Bulimina cf. *B. jacksonensis* Cushman
Gyroidina orbicularis planata Cushman
Eponides yeguaensis Weinzierl and Applin
Cibicides cushmani Nuttall
Cibicidoides coalingensis (Cushman and G. D. Hanna)

PUGET GROUP

Use of the name "Puget Group" in the upland area near Tiger Mountain and Taylor Mountain in King County, Wash. is here extended from the usage of Evans (1912) and Warren and others (1945) to include three formations, the Tiger Mountain Formation at the base, the Tukwila Formation in the middle, and the Renton Formation at the top.

TIGER MOUNTAIN FORMATION

Conformably overlying and transitional with the lithology of the marine rocks of the Raging River Formation is a sequence of nonmarine arkosic sandstone, claystone, and coal that contains leaf impressions of land plants. To distinguish these nonmarine rocks from the marine rocks below and the volcanic rocks above, they are here designated the Tiger Mountain Formation, from exposures on the south and east slopes of Tiger Mountain. The stratigraphic sequence and relation to underlying rocks is exposed north of Deep Creek and directly west and south of the type area for the Raging River Formation. These exposures are in the SW¼ sec. 9, sec. 16, S½ sec. 17, N½ sec. 20, and N½ sec. 21, T. 23 N., R. 7 E. (fig. 1). The interstratification between the Tiger Mountain Formation and the partly equivalent and partly younger Tukwila Formation is best observed on the south side of Deep Creek (north flank of Taylor Mountain) in secs. 21 and 22, T. 23 N., R. 7 E. The localities on the south side of Tiger Mountain and the north side of Taylor Mountain may be regarded as the type area for the Tiger Mountain Formation.

Exposed rocks in the lower 1,100 feet of the Tiger Mountain Formation are mostly beds of medium-grained arkosic sandstone with a small but conspicuous percentage of unidentified black mineral grains and mica. The mica is white, black, or brown in color and is commonly crinkled. The clay matrix of the sandstone beds that were tested is a mixture of montmorillonite, chlorite, illite, and regular mixed-layer clays. However, the clay minerals in these rocks vary considerably. Kaolinite is abundant locally where the rocks have been hydrothermally altered. The upper part of the Tiger Mountain Formation, as much as 900 feet thick, is interstratified with the Tukwila Formation throughout an interval of as much as 1,725 feet. On the south side of Tiger Mountain at least two members of the Tukwila Formation are each overlain by members of the Tiger Mountain Formation. A similar situation exists on the south side of Deep Creek. Although the correlation of individual members across Deep Creek is uncertain, the upper sandstone member of the Tiger Mountain Formation in both areas includes granules and pebbles of chert that may be of local significance for correlation. The contact of the highest member of the Tiger Mountain Formation with the main body of the Tukwila Formation is arbitrarily defined as the contact above which volcanic rocks are predominant and below which nonvolcanic rocks are predominant. The contact probably transgresses time.

Fossil plant and leaf impressions have been found at a number of localities in the Tiger Mountain Formation. Material from two localities (fig. 3) at about the same stratigraphic position near the top of the lower main body of the Tiger Mountain Formation have been examined by Jack A. Wolfe (written communication, 1961) and identified as shown in table 3. His comments regarding the probable correlation with the floral zones of Wolfe and others (1961) are as follows: "Clearly these floras are no older than zone 2, and no younger than zone 4. The *Ulmus* and Sapindaceae appear to contradict each other; however, because the Sapindaceae has been previously known from one locality but the *Ulmus* from several, I attach much more significance to the range of the latter. This, combined with the *Leguminosites*, indicates a correlation with zone 3." Because floral zone 4 occurs in members of the Tukwila Formation that are equivalent to the upper part of the Tiger Mountain Formation, it is regarded as middle(?) and late Eocene age.

Thus, the base of the Puget Group in the Tiger Mountain area is notably younger than in the Green River area. This age difference is in part caused by the exclusion of the marine rocks of the Raging River Formation in the Tiger Mountain area from the Puget Group in order to maintain the customary usage of the Puget Group as a nonmarine sequence of rocks.

TABLE 3.—*Fossil leaves from the Tiger Mountain Formation, King County, Wash.*

[Identifications by Jack A. Wolfe]

	Locality number①	
	9813	9814
Coniferales		
Metasequoia glyptostroboides Hu and Cheng		X
Dicotyledones②		
Carya sp., n. sp.	X	X
Hyperbaena sp., n. sp.		X
Laurophyllum litseaefolia MacGinitie		X
Leguminosites sp., n. sp.		X
Litsea sp., n. sp.		X
Mallotus sp., n. sp.	X	
Rhus sp., n. sp.		X
Sapindaceae, gen. indet.		X
Triumfetta sp., n. sp.		X
Ulmus sp., n. sp. "B"		X

① Locality number descriptions:
9813, SW¼NE¼ sec. 21, T. 23 N., R. 7 E., Hobart quadrangle, Wash.
9814, NW¼NW¼ sec. 16, T. 23 N., R. 7 E., Hobart quadrangle, Wash.
② Several of the Puget dicotyledon species belong to new genera, and hence the generic names used in this paper should be considered provisional.

TUKWILA FORMATION

The volcanic rocks in the Puget Group were named the Tukwila Formation by Waldron (1962) for exposures near the town of Tukwila. Because the exposures of the Tukwila Formation are more complete in the Taylor Mountain area than in the type area near Tukwila, the following reference area in secs. 22, 27, and 34, T. 23 N., R. 7 E., is described. The Tukwila Formation represents a 7,000-foot-thick lens of volcanic material entirely enclosed within the coal-bearing sedimentary rocks of the Puget Group. Beds of sandstone, siltstone, and coal typical of the Puget Group overlie, underlie, and are interstratified with the andesitic volcanic rocks of the Tukwila Formation. Although distinguished by tuff-breccia and volcanic conglomerate, probably more than half the thickness of the Tukwila Formation consists of fine- to coarse-grained epiclastic rocks. The volcanic rocks contain little or no megascopically visible quartz and mica but are characterized by abundant plagioclase feldspar and a small amount of mafic materials.

The Tukwila Formation may be subdivided locally on the basis of gross lithology and texture. Tuff, fine-grained volcanic sandstone, and volcanic tuff-breccia characterize the lower members that are interstratified with the Tiger Mountain Formation. These rocks are overlain on Taylor Mountain by volcanic sandstone and spherulitic volcanic flows in the lower part; volcanic sandstone and 2- to 6-foot-thick vesicular basalt sills interstratified with 25- to 100-foot-thick beds of carbonaceous claystone, coal, and arkosic micaceous sandstone beds in the middle; and tuff-breccia and volcanic conglomerate in beds up to 100 feet thick, interbedded with medium- to coarse-grained volcanic sandstone and tuff, in the upper part. The tuff-breccia beds on Holder Creek, in sec. 31, T. 23 N., R. 7 E., and along the road cut of U.S. Highway 10 in the SE¼ sec. 25, T. 24 N., R. 6 E., are characteristic of the upper part. Similar coarse-textured rocks also make up most of West Tiger Mountain.

Alteration of the rocks in the Tukwila Formation is characteristic of all the outcrops in the Tiger Mountain-Taylor Mountain upland area. Chlorite is the most abundant alteration mineral and constitutes the bulk of many fine- to coarse-grained epiclastic rocks. The chloritic alteration extends into beds of quartz- and mica-bearing sandstone locally interstratified with the volcanic rock; both the matrix of the rock and the mica have been converted into chlorite. In some areas, moderate to intense hydrothermal alteration has converted the rock to kaolinite, quartz, and iron oxide minerals.

Plant fossils occur in the Tukwila Formation at many localities. The tuff-breccia and volcanic conglomerate locally contain abundant woody stems, trunks, and roots of trees. The finer textured rocks locally contain well-preserved leaf impressions; fossil leaf collections from these rocks include genera and species that have been identified by J. A. Wolfe (table 4) as belonging chiefly to floral zones 4 and 5 of Wolfe and others (1961). A flora from zone 6 was recognized locally from rocks exposed along U.S. Highway 10, about 3 miles east of Issaquah (J. A. Wolfe, written communication, 1961).

The upper contact of the Tukwila Formation with the overlying Renton Formation is locally sharp. On a regional scale, however, the contact probably transgresses time. When volcanic activity ceased, a range of volcanic hills presumably stood above the general level of the flood plains and coal swamps. The Renton Formation filled around and covered the volcanic hills so quickly that almost no volcanic debris from the hills was incorporated in the onlapping sediments.

TABLE 4.—*Fossil leaves from the Tukwila Formation, King County, Wash.*

[Identifications by Jack A. Wolfe]

	Locality number①				
	9685	9686	9687	9738	9815
Filicales					
Hemitelea pinnata MacGinitie			X		
Coniferales					
Metasequoia glyptostroboides Hu and Cheng			X		
Taxodium tinajorum Heer			X		
Equisetales					
Equisetum sp.		X			
Dicotyledones②					
Cercidiphyllum arcticum (Heer) Brown		X			
Cercidiphyllum elongatum Brown			X		
Cinnamomum dilleri Knowlton				X	
"*Convolvulites*" sp., n. sp.			X		
Cryptocarya presamarensis Sanborn				X	
Laurophyllum litseaefolia MacGinitie			X		
Litsea sp., n. sp.					X
Mallotus comstocki Sanborn				X	
Ocotea sp., n. sp.					X
Platanophyllum angustiloba (Lesquereux) MacGinitie	X	X	X		
"*Sapindus*" sp., n. sp.		X	X		
Tetracera sp., n. sp.				X	
Ulmus sp., n. sp.			X		

① Locality number descriptions:
9685, NE¼NE¼ sec. 17, T. 23 N., R. 7 E., Hobart quadrangle, Wash.
9686, SW¼SW¼ sec. 8, T. 23 N., R. 7 E., Hobart quadrangle, Wash.
9687, SE¼NW¼ sec. 27, T. 23 N., R. 7 E., Hobart quadrangle, Wash.
9738, NE¼SW¼ sec. 30, T. 24 N., R. 7 E., Fall City quadrangle, Wash.
9815, SW¼NW¼ sec. 31, T. 23 N., R. 7 E., Hobart quadrangle, Wash.

② Several of the Puget dicotyledon species belong to new genera, and hence the generic names used in this paper should be considered provisional.

The physiographic expression of the Tukwila Formation depends on the attitude of the beds, on the predominant texture of the rocks, and on the amount and depth of the alteration and weathering. The coarser tuff-breccia and volcanic conglomerate beds are, in general, more resistant than the finer grained rocks and form most of the ridges and ledges that crop out in the areas of exposure. Locally, however, as in the deep canyon on the north slope of Taylor Mountain, fresh exposures of the finer textured volcanic rocks form resistant ledges. The area underlain by the Tukwila Formation is characterized by hills or mountains that range from 500 to 2,500 feet above the general level of the surrounding country. This greater relief is due in part to the resistance of the volcanic rocks to erosion, in part to the resistance of later intrusive rocks that invaded the Tukwila Formation, and in part to the structural features that have, in general, elevated most of the area of volcanic rocks.

The late Eocene age of the Tukwila Formation in this area is estimated from a study of the flora within the formation, plus the flora and fauna from the overlying, underlying, and laterally equivalent rocks in the Green River area (Wolfe and others, 1961). The leaf flora from the overlying Renton Formation suggests a late Eocene and possibly an earliest Oligocene age, whereas the flora from the Tukwila suggests a late Eocene age. Nonvolcanic rocks of the Puget Group equivalent in age to the Tukwila Formation are present in the Green River area 6 to 8 miles south of the volcanic rock exposures in the Hobart quadrangle.

RENTON FORMATION

Rocks thought to be equivalent to those named the "Renton Formation" by Waldron (1962) overlie rocks in the Tukwila Formation south of Taylor Mountain. The Renton Formation in this area consists of feldspathic micaceous fine- to medium-grained sandstone interbedded in the upper part with beds of coal, carbonaceous siltstone, and claystone. Though the top of the Renton Formation is not exposed in this area, at least 2,250 feet of strata are estimated to be present.

Fossil leaves in the Renton Formation from locality 9729, south of Taylor Mountain, have been identified by Wolfe (in Wolfe and others, 1961) as belonging to floral zone 5 of late Eocene age, whereas a collection from locality 9688 from the canyon west of Squak Mountain is thought by Wolfe to represent floral zone 7, of late Eocene and possibly earliest Oligocene age. This indicates that the lower part of the Renton Formation in some areas is equivalent in age to the upper part of the Tukwila Formation in other areas. Although the Renton Formation overlaps the Tukwila Formation, only the Renton is known to extend into the earliest Oligocene.

SUMMARY

About 14,000 feet of middle and late Eocene rocks crop out in the Tiger Mountain-Taylor Mountain area, King County, Washington. Marine sedimentary rocks, here named the "Raging River Formation," including sandstone and siltstone about 3,000 feet thick, are the oldest rocks in the sequence. Transitional with and overlying the Raging River Formation is a sequence 2,000 feet thick of arkosic sandstone, siltstone, and coal, here named the "Tiger Mountain Formation." The boundary between middle and late Eocene probably lies close to the boundary between these two formations. Volcanic rocks of the Tukwila Formation are partly interstratified with and partly overlie the Tiger Mountain Formation. The Tukwila Formation, about 7,000 feet thick, may be subdivided locally on the basis of gross lithology. In general, the lower part is finer textured than the upper part and consists of volcanic sandstone, tuff, lapilli tuff, and lava flows. The upper, coarser textured part consists of tuff-breccia, volcanic conglomerate, and volcanic sandstone. The volcanic rocks of the Tukwila Formation are overlain, probably transgressively, by nonmarine sandstone, siltstone, and coal belonging to the Renton Formation of late Eocene and Oligocene(?) age, at least 2,250 feet thick south of Taylor Mountain.

A description of the Eocene stratigraphy in the Tiger Mountain-Taylor Mountain area is given in the following stratigraphic section, which was estimated from structure sections based on geologic mapping at a scale of 1:24,000.

Composite stratigraphic section of Eocene rocks in the Tiger Mountain-Taylor Mountain area, King County, Wash.

[The Raging River Formation and Tiger Mountain Formation were measured from about the center of sec. 15 to the southwest corner of sec. 16, T. 23 N., R. 7 E. The Tukwila Formation was measured along a series of lines in secs. 22, 27, and 34, T. 23 N., R. 7 E., and in the NE¼ sec. 4, T. 22 N., R. 7 E. The Renton Formation was measured in the NE¼ sec. 3, T. 22 N., R. 7 E.]

	Feet	*Feet*
Puget Group:		
Renton Formation:		
Sandstone, carbonaceous siltstone, claystone, and coal; sandstone is fine- to medium-grained, feldspathic, characteristically contains white mica flakes; the matrix is chiefly kaolinite. Nonmarine pelecypods, gastropods, and well-preserved leaf impressions are locally abundant. Contains locally commercial coal and clay beds; top not exposed	2,250+	
Total thickness Renton Formation (exposed)		2,250+

Composite stratigraphic section of Eocene rocks in the Tiger Mountain-Taylor Mountain area, King County, Wash.—Continued

	Feet	Feet
Tukwila Formation:		
Upper main body:		
Volcanic sandstone, medium- to coarse-grained, clastic texture; and thin beds of fine-grained tuffaceous rock containing locally abundant *Equisetum*. Tuff-breccia composed of volcanic boulders as much as 3 feet in diameter in a volcanic matrix is locally abundant. A 6-foot-thick vesicular basalt sill with plagioclase needles in a microcrystalline matrix occurs locally at the top	300	
Tuff-breccia and volcanic conglomerate; contains rounded volcanic boulders up to 3 feet in diameter in a porphyritic matrix of zoned plagioclase and microcrystalline material	100	
Volcanic sandstone, greenish-gray, medium- to coarse-grained, and lapilli tuff	775	
Sandstone, gray, fine- to medium-grained, cross-bedded; characteristically contains brown to black mica flakes; as much as 200 feet thick locally	50	
Volcanic sandstone, very fine grained, tuffaceous, and thin basalt sills similar to that at the top of the upper unit	1,000	
Sandstone, very fine grained; contains brown mica flakes	25	
Volcanic sandstone and siltstone, tuffaceous, and thin basalt sills similar to that at the top of the upper unit	375	
Sandstone, fine- to medium-grained; contains brown mica flakes; includes a 2-foot-thick basalt sill similar to that at the top of the upper unit	100	
Volcanic sandstone, tuff, and tuffaceous siltstone; locally includes tuff-breccia and basalt sills similar to that at the top of the upper unit. Contains well-preserved fossil leaf impressions on Taylor Mountain	1,000	
Sandstone, carbonaceous shale, and coal. The sandstone is fine- to medium-grained and is characterized by brown mica flakes and a chloritic matrix	100	
Volcanic sandstone, tuff, and volcanic flow rocks characterized by a glassy matrix with numerous spherulites	2,350	

Composite stratigraphic section of Eocene rocks in the Tiger Mountain-Taylor Mountain area, King County, Wash.—Continued

	Feet	Feet
Tiger Mountain Formation:		
Member B:		
Sandstone, medium- to coarse-grained, micaceous; locally granule and pebble conglomerate, crossbedded, friable; characteristically contains abundant dark-colored chert grains; thickness variable	525	
Tukwila Formation:		
Member B:		
Volcanic sandstone and tuff, greenish-gray to gray, very fine- to medium-grained, and thin lenses of lapilli tuff and tuff-breccia; contains locally abundant leaf impressions and *Equisetum*; thickness variable	475	
Tiger Mountain Formation:		
Member A:		
Sandstone, fine- to medium-grained, micaceous, feldspathic, crossbedded; impregnated south of Tiger Mountain with an iron-rich carbonaceous substance that is insoluble in common organic solvents; thickness variable........	375	
Tukwila Formation:		
Member A:		
Tuff, locally altered to a porcelanite, and volcanic siltstone and sandstone; on Tiger Mountain contains leaf impressions; thickness variable...	350	
Total thickness Tukwila Formation........		7,000
Tiger Mountain Formation:		
Lower main body:		
Sandstone, medium-grained, crossbedded; and siltstone; contains a variety of clay minerals, including a chlorite matrix in upper part, a montmorillonite matrix near the base. Transitional with marine rocks below; locally includes a bed of possibly commercial coal near the top.......	1,100	
Total thickness, Tiger Mountain Formation..		2,000
Raging River Formation:		
Sandstone, gray, volcanic, fine-grained, hard, thick-bedded, and dark-gray siltstone; contains abundant marine gastropods, pelecypods, and other fossils in upper 1,800 feet. Friable coarse-grained sandstone and chert pebble conglomerate is interbedded with the marine rocks. The sandstone beds are characteristically altered and contain chlorite and, locally, glauconite or celadonite........		3,000
Total thickness Eocene rocks exposed.........		14,250

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