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GEOLOGY OF THE

WYNOOCHEE VALLEY QUADRANGLE

GRAYS HARBOR COUNTY, WASHINGTON

By

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GEOLOGY OF THE WYNOOCHEE VALLEY QUADRANGLE, GRAYS HARBOR COUNTY, WASHINGTON

By Weldon W. Rau

ABSTRACT

The Wynoochee Valley quadrangle includes over 200 square miles of the central part of Grays Harbor County, Washington. The area lies between the Chehalis River on the south and the Olympic Mountains on the north.

A sequence of Tertiary sedimentary and volcanic rocks are exposed within the mapped area. The oldest of these is the middle Eocene Crescent Formation, consisting largely of basalt flows interbedded and overlain by relatively thin beds of marine siltstone and sandstone. Many of the volcanic flows display pillow structure, and much zeolitic material is dispersed throughout vesicles and fractures of all the volcanic rocks.

Sedimentary rocks of late Eocene age overlie the Crescent Formation. They consist of siltstone and micaceous sandstone and contain foraminifers that are referred to the Narizian Stage of Mallory (1959). These strata correlate generally with the Skookumchuck-upper McIntosh sequence of other parts of southwest Washington.

The Lincoln Creek Formation overlies the sedimentary rocks of late Eocene age and unconformably onlaps older rocks. It consists of as much as 9,000 feet of marine, highly tuffaceous, concretionary, massive siltstone and poorly sorted fine sandstone. Foraminifers indicate that the Refugian Stage of Schenck and Kleinpell (1936) and the Zemorrian Stage of Kleinpell (1938) are both represented by the Lincoln Creek Formation, and therefore the formation is considered to be late Eocene and Oligocene in age.

The overlying Astoria(?) Formation probably does not exceed 3,500 feet in thickness in the mapped area. It is composed chiefly of marine carbonaceous siltstone, sandy siltstone, and some fine-grained micaceous feldspathic sandstone. At least one conglomerate bed is present in the formation. Foraminifers from the Astoria(?) Formation are placed in the Saucesian, Relizian, and possibly Luisian Stages of Kleinpell (1938) of early and middle Miocene age. Three foraminiferal zones are recognized and informally named the *Siphogenerina kleinpelli* zone, *Baggina washingtonensis* zone, and *Rotalia becki* zone.

A major unconformity separated the Astoria(?) Formation from the overlying Montesano Formation. The latter formation probably does not exceed 3,000 feet in thickness. In this unit three major rock types have been

mapped: siltstone and very fine-grained sandstone, medium- to coarse-grained sandstone, and conglomerate. Foraminifers from the Montesano Formation, although not entirely definitive, are best referred to the Mohnian and Delmontian Stages of Kleinpell (1938) of late Miocene age.

Quaternary rocks consist of large deposits of gravels of Pleistocene(?) age and are particularly common in the northern part of the area and on ridgetops to the south. Landslide debris is present, largely along major stream valleys, and Recent alluvium is being deposited in the major stream beds.

Folding and faulting have taken place in rocks of pre-Montesano age during several periods of time and are particularly apparent in the rocks exposed in the northwest part of the mapped area. In this area, lateral movement on at least one major northeast-trending fault has displaced several northwest-trending normal faults. Many structures seen in other parts of the mapped area have affected the Montesano Formation as well as the older rocks. The north-trending Wynoochee Valley anticline and an extension of the Melbourne anticline in the central part of the mapped area represent the major upwarp. Other, lesser anticlinal structures are the Caldwell and Still Creek anticlines. Several major synclinal structures are mapped, the larger of which are the Canyon River-Smith Creek syncline, the Black Creek basin, and the Wynoochee River syncline.

Oil and gas possibilities have been the principal matter of interest in connection with geologic studies of the Wynoochee Valley quadrangle. Available data indicate that within this area there are great thicknesses of potential source beds overlain by substantial thicknesses of reasonably well sorted sandstone at relatively shallow depths. These strata, together with the structural relations present, provide conditions in which commercial quantities of oil and gas could be contained.

INTRODUCTION

LOCATION AND GENERAL GEOGRAPHY

The Wynoochee Valley quadrangle lies between the Olympic Mountains to the north and the Chehalis River valley to the south, in Grays Harbor County, Washington. It constitutes an area of more than 200 square miles and is bounded by latitudes 47°00′ and 47°15′ and longitudes 123°30′ and 123°45′. The town of Montesano is immediately south of the south-central part of the quadrangle (Fig. 1).

The area is dissected by several major south-flowing streams and their tributaries. Both the Wynoochee River and the West Fork of the Satsop River flow southward through the entire length of the quadrangle, and the Wishkah River and its tributaries and the Middle Fork of the Satsop River flow across the northwest and northeast parts, respectively.

Areas between the main river valleys consist of low hills that are well dissected by tributary streams. The slopes are gentle to rather steep, depending on the underlying rocks. Generally, those

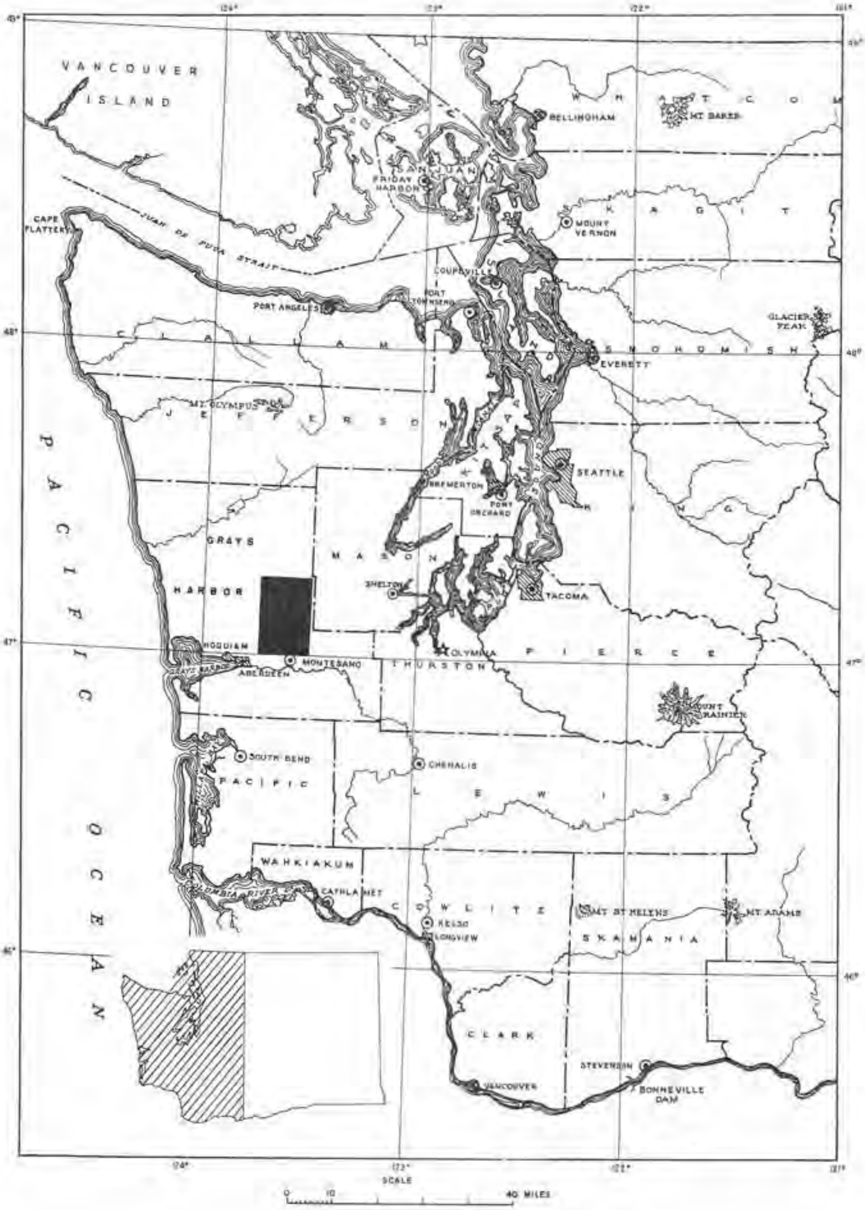


FIGURE 1.—Index map showing location of Wynoochee Valley quadrangle.

areas underlain by the Montesano Formation produce the steepest slopes. In only a few places does the total relief exceed 500 feet.

Most of the floor of the Wynoochee River valley and that of the south part of the Satsop River valley are dairy farm pasture land. Upland areas between the major drainages are largely timbered with second-growth Douglas fir, hemlock, and some spruce. Dense deciduous brush and small trees, mostly alder, occupy the nonforested areas, mainly in small stream valleys. Much of the upland country is maintained as tree farm land by several major timber companies.

The mean annual precipitation varies from 80 to 120 inches; some 85 percent of this occurs in a 7-month period, starting in October and extending through April.

County roads extend through most of the major valleys, and a widespread network of private logging roads provides access to most of the intervalley areas. The only railroad, which is operated by the Simpson Timber Company, extends across the northeast corner of the mapped area. In the earlier days of logging, however, numerous railroad lines were constructed throughout much of the area; their grades now provide useful trails that can be discerned on aerial photographs.

PURPOSE AND SCOPE

During the past 15 years or so, detailed geologic mapping of Tertiary rocks in various parts of southwest Washington has been conducted by both State and Federal geologic agencies, either jointly or separately. Studies on much of the area between the Columbia River and the Olympic Mountains are now completed, and the results are available in various reports, each of which presents a detailed geologic map of a segment of this region. The need for such studies has come about largely because of increased interest in exploration for petroleum and coal, as well as for other mineral commodities in southwest Washington.

This report is a detailed geologic contribution concerning a segment of southwest Washington that is regarded as one of the more favorable areas for oil and gas exploration. Eight test wells have been drilled in this area, and some petroleum has been encountered, but not in commercial quantity. In this study a special effort has been made to obtain all surface geologic information available within the Wynoochee Valley quadrangle. In addition, auger samples were examined for foraminiferal content; some of the samples were generously loaned for study by several oil companies. The resulting map and report present detailed geologic information that is believed will be useful in further exploration for petroleum and other mineral commodities of southwest Washington.

PREVIOUS WORK

The earliest published report that deals specifically with any part of the area of the Wynoochee Valley quadrangle was made by Weaver (1912), in which he described some of the megafauna and discussed the general stratigraphy of western Washington. The name "Montesano Formation" was first presented in that report for some of the beds exposed in the area of the Wynoochee Valley quadrangle. Arnold and Hannibal (1913), in their report on the Tertiary stratigraphy of western Oregon and Washington, mention that the area between the Chehalis River and the Olympic Mountains contains some 4,000 feet of strata they refer to as the Empire Formation. Pleistocene deposits of the area were first described by Bretz (1913) in his report on the Pleistocene geology of the Puget Sound region. He first mentioned the red gravels that were later referred to as the Satsop Formation. These beds are extensive in the Wynoochee Valley quadrangle and are included in this report under the heading "Deposits of Pleistocene(?) Age." Weaver's report of 1916 discusses the Tertiary Formations of western Washington and shows their general distribution. That study includes generalized structural and stratigraphic information from the Wishkah and Wynoochee River valleys. A study of the megafauna in rocks of Miocene age from a part of southern Washington was made by Etherington (1931). His area of study included the southeastern part of the Wynoochee Valley quadrangle. Besides a taxonomic discussion of the faunas, he also noted the distinct unconformity between the Montesano Formation and underlying rocks in the Wynoochee Valley area. Weaver (1937), in his report on Tertiary stratigraphy of western Washington and Oregon, made some changes and additions to his work of 1916. He considered beds beneath the Montesano Formation in the Wishkah River valley to be of middle Miocene age and referred them to the Astoria Formation. Although his maps show only the generalized distribution of the rock types, in most areas where he made observations the contacts between rock units were placed similarly to those on the map accompanying this report. His concept of the boundaries of formations is followed generally in this report. Recently, Fowler (1965) made a detailed study of the Montesano Formation for a Ph. D. dissertation, in which much of the area of the Wynoochee Valley quadrangle is discussed. His geologic map shows considerable refinement over those of previous workers, especially in connection with the distribution of the Montesano Formation. He was not particularly concerned, however, with the distribution of the underlying rocks and structures within them. Finally, many of the major oil companies have studied the Wynoochee Valley area and undoubtedly have made numerous geologic reports and maps, but most of these works are not available to the public.

FIELD WORK AND ACKNOWLEDGMENTS

Geologic field studies in the Wynoochee Valley quadrangle were begun in June 1963 and were continued through most of the following summer months until September 1966. Geologic data obtained in the field were compiled on aerial photographs at a scale of about 1:20,000 and subsequently were transferred to a 1:48,000 base map of the area prepared by the U.S. Geological Survey.

The author was ably assisted throughout the summer months in both the field and laboratory by John P. Braislin. In addition, many other staff members of the Washington Division of Mines and Geology have aided in various ways in the preparation of the report. Particular thanks are due to Marshall T. Huntting, Supervisor, for his editorial suggestions and for making it possible administratively to publish the report. Numerous oil companies have made available much information and have loaned fossil foraminiferal material for study. In this regard, special thanks are due the Continental Oil Co., Phillips Petroleum Co., Shell Oil Co., Standard Oil Company of California, and Union Oil Company of California. The granting of access by individual landowners, as well as timber companies, is greatly appreciated. Logging road maps and general location information made available by both the Simpson Timber Co. and the Weyerhaeuser Co. have been most useful.

STRATIGRAPHY

TERTIARY ROCKS

Crescent Formation

The oldest rocks exposed in the Wynoochee Valley quadrangle are confined in outcrop to the northwest corner, essentially north and west of the Middle Fork of the Wishkah River (Fig. 2, in pocket). These rocks are part of a thick sequence of predominantly volcanic rocks known to form a horseshoe-shaped outcrop pattern extending along the north, east, and south parts of the Olympic Peninsula. Arnold (1906) named these rocks the Crescent Formation, for exposures of volcanic and sedimentary rocks at Crescent Bay, on the north coast of the Olympic Peninsula. The usage of the term has been perpetuated recently by most workers (Durham, 1942; Brown and others, 1960; Gower, 1960; Rau, 1966; Wagner, in press; and Wolfe and McKee, in press). In addition, Pease and Hoover (1957) have tentatively correlated with the Crescent Formation a sequence of lava flows, pyroclastic rocks, and sedimentary beds exposed in a nearby area to the southeast.

The Crescent Formation within the Wynoochee Valley quadrangle is an upper part of the unit and consists largely of volcanic rocks but includes a lesser amount of sedimentary material. Many of the volcanic flows display pillow structures; others are massive but usually are highly fractured. Some flows are vesicular, but almost all vesicles and fractures in the massive flows are filled with zeolitic material. In places, particularly along the course of the Middle Fork of the Wishkah River, beds of pyroclastic material are common.

Marine sedimentary beds of dark-gray siltstone and sandstone are interbedded with some of the volcanic rocks, but, because these beds are relatively thin and discontinuous, they are not shown on the map. However, in the vicinity of the Middle Fork of the Wishkah River, sedimentary strata of substantial thickness consistently overlie the highest volcanic rocks. These beds are differentiated in Figure 2 and are recognized as a part of the Crescent Formation. They are believed to represent a continuation of sedimentation following the last stage of volcanism during Crescent time. Similar occurrences of sedimentary rocks of Crescent age overlying Crescent volcanics have been noted in a nearby area to the northeast, in the vicinity of the Satsop River and its tributaries (Rau, 1966). Those sedimentary rocks are distinctly older than the overlying sedimentary beds of late Eocene age. Although the lithologic break is between the uppermost volcanic rocks and the sedimentary beds immediately above, the stratigraphic break is an unconformity between the sedimentary beds of the Crescent Formation and the overlying sedimentary rocks of late Eocene age.

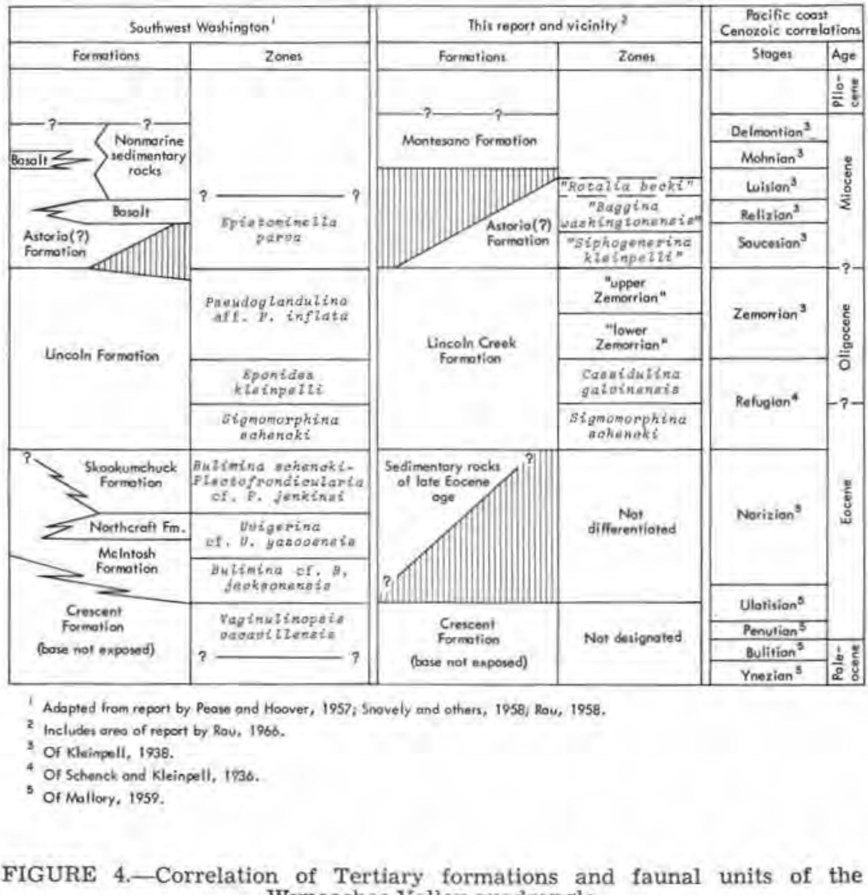
Age and Correlation

No fossils were found in the sedimentary interbeds of the Crescent Formation within the Wynoochee Valley quadrangle, but foraminifers were collected from four localities in the sedimentary rocks immediately above the highest flows of the Crescent Formation (Fig. 3). These assemblages indicate a general middle Eocene age, possibly representing the Ulatisian Stage of Mallory (1959). (Fig. 4). They may be compared with faunas of the sedimentary rocks that are both immediately above and interbedded in the volcanics of the Crescent Formation to the northeast of the Satsop River tributaries (Rau, 1966).

In addition to a direct correlation of these rocks with those assigned to the Crescent Formation in the northern part of the Olympic Peninsula, they may be compared in age and lithology with volcanic rocks in the Doty-Minot Peak area (Pease and Hoover, 1957), the Black Hills and the Willapa Hills of the Raymond quadrangle (Wagner, in press), and volcanics in the Grays River quadrangle (Wolfe and McKee, in press). In addition, the Crescent Formation may be correlated with the Metchosin Volcanics of Vancouver Island (Clapp, 1917, p. 255-292), the Siletz River Volcanics Series of Oregon (Snavely and Baldwin, 1948, p. 806-812), and volcanic rocks associated with the Umpqua Formation of Oregon (Hoover, 1963).

SPECIES	LOCALITIES			
	F-2	F-3	F-6	F-14
Alabamina wilcoxensis californica Mallory	...	...	...	R
Anomalina? sp.	...	...	R	...
Asterigerina crassaformis Cushman and Siegfus	...	F	...	...
Bulimina corrugata Cushman and Siegfus	...	...	R	...
cf. *B. ovula* d'Orbigny	F	C	...	...
Cassidulina globosa Hantken	...	R	...	...
Chilostomella cf. *C. hadleyi* Keijzer	...	...	F	...
Cibicides cf. *C. cocoaensis* (Cushman)	F	...	?	...
cf. *C. martinezensis* Cushman and Barksdale	...	...	...	F
cf. *C. pachecoensis* Smith	...	...	...	R
spiropunctatus Galloway and Morrey	R	F	F	...
cf. *C. venezuelanus* (Nuttall)	...	...	...	F
Dentalina consobrina d'Orbigny	R	...	...	...
spp.	...	...	R	...
Dorothia principiensis Cushman and Bermudez	...	R	...	...
sp.	R	...	...	...
Epistomina sp.	R	...	...	...
Eponides umbonatus (Reuss)	?	...	...	...
Gaudryina? sp.	...	...	R	...
Globigerina cf. *G. nitida* Martin	...	...	R	...
cf. *G. triloculinoides* Plummer	C	...	C	...
Glomospira charoides (Jones and Parker)	...	...	R	...
Gyroidina soldanii octocamerata Cushman and Hanna	R	R	R	F
Karreriella cf. *K. elongata* Mallory	...	...	...	R
Loxostomum cf. *L. applinae* (Plummer)	...	...	R	...
Nodosaria arundinea Schwager	...	F	...	...
cf. *N. deliciae* Martin	...	...	...	R
velascoensis Cushman	...	R	...	...
Nonion micrum Cole	...	R	...	R
Planularia cf. *P. truncana* (Gümbel)	...	R	...	...
Plectofrondicularia sp.	...	...	...	R
Pleurostomella acuta Hantken	R	...	?	...
Pseudoglandulina cf. *P. ovata* (Cushman and Applin)	R	R	...	...
Pullenia eocenica Cushman and Siegfus	...	...	R	R
Robulus spp.	C	R	...	C
Silicosigmoilina cf. *S. californica* Cushman and Church	F	F	...	...
Spiroloculina sp.	...	...	R	...
Spiroplectammina directa (Cushman and Siegfus)	F	...	R	...
cf. *S. tejonensis* Mallory	R	...	...	...
Tritaxilina colei Cushman and Siegfus	F	...	...	C
Uvigerina corrugata Cushman and Siegfus	...	?	...	...
garzaensis Cushman and Siegfus	...	...	...	F
Vaginulinopsis asperuliformis (Nuttall)	R	...	...	...
Vulvulina sp.	...	...	R	...

FIGURE 3.—Foraminifera from the Crescent Formation.
(C=common; F=few; R=rare; ?=questionably identified)



[1] Adapted from report by Pease and Hoover, 1957; Snavely and others, 1958; Rau, 1958.
[2] Includes area of report by Rau, 1966.
[3] Of Kleinpell, 1938.
[4] Of Schenck and Kleinpell, 1936.
[5] Of Mallory, 1959.

FIGURE 4.—Correlation of Tertiary formations and faunal units of the Wynoochee Valley quadrangle.

SEDIMENTARY ROCKS OF LATE EOCENE AGE

Outcrops of rocks of late Eocene age are confined to a small area in the northwest part of the Wynoochee Valley quadrangle—in the Middle Fork of the Wishkah River and a single exposure in the Wynoochee River valley. The latter occurrence is the northernmost outcrop of Tertiary rocks in the Wynoochee Valley of the mapped area. Although the areas of outcrop of sedimentary rocks of late Eocene age are limited, it may well be that additional areas of these rocks are now covered by a substantial thickness of Quaternary material in the north-central part of the Wynoochee Valley quadrangle.

In the Wishkah River area these rocks consist chiefly of siltstone bedded with thin micaceous sandstone and concretionary layers. In addition, at least one 30-foot basaltic sandstone bed is present. The rocks in the Wynoochee Valley outcrop consist mainly of massive, flinty, sandy siltstone containing occasional scattered concretions. In places these rocks are bedded with 1- to 2-inch sandstone layers.

Sedimentary rocks of late Eocene age in the Wishkah River valley lie unconformably on sedimentary rocks of the Crescent Formation and may be differentiated from them in that they are less indurated and deformed than those of the Crescent Formation. Also, they contain a foraminiferal assemblage distinctly different from that of the Crescent Formation (Fig. 5).

Age and Correlation

Although only one foraminiferal assemblage was collected from each outcrop of sedimentary rocks of late Eocene age in the Wynoochee Valley quadrangle (Fig. 5), others were collected in the Wishkah Valley immediately north of the quadrangle. All assemblages indicate a high position in the Eocene sequence of the Pacific coast and may be referred to the Narizian Stage of Mallory (1959). Locally, these beds are essentially a southwest extension of those late Eocene sedimentary rocks occurring a few miles to the north in the West Fork of the Satsop River and Little River (Rau, 1966). Because of the relatively small area of outcrop and the remoteness from any known unit of late Eocene age, these sedimentary rocks have not been referred to a named formation. However, on the basis of Foraminifera, lithology, and superposition, they may be considered a close correlative of a part of the Skookumchuck-upper McIntosh sequence of other areas of southwest Washington (Snavely and others, 1958). They are particularly similar to those beds exposed west of the type area of the Skookumchuck Formation, where sandstone beds grade laterally into the distinctly marine, fine-grained strata of the upper part of the McIntosh Formation. In addition, these late Eocene strata can be broadly correlated with some part of the Cowlitz Formation of southwest Washington (Weaver, 1912) and a lower part of the Twin River Formation of the northern part of the Olympic Peninsula (Brown and others, 1960; Gower, 1960; Rau, 1964). In Oregon, parts of both the Nestucca Formation (Snavely and Vokes, 1949) and the Coaledo Formation (Diller, 1899) probably represent a stratigraphic position similar to that of the late Eocene sequence of the mapped area. Furthermore, this late Eocene sequence is regarded as broadly correlating with those strata in California that are assigned to the upper part of the Narizian Stage of Mallory (1959).

SPECIES	LOCALITIES F-1	F-51
Alabamina kernensis Smith	...	F
Bulimina corrugata Cushman and Siegfus	C	...
pupoides d'Orbigny	F	...
sculptilis laciniata Cushman and Parker	...	C
Cassidulina globosa Hantken	...	F
Chilostomella cf. *C. oolina* Schwager	...	F
Cibicides haydoni (Cushman and Schenck)	...	F
hodgei Cushman and Schenck	...	F
sp.	...	R
Dentalina sp. A [of Rau, 1948]	C	...
Eponides umbonatus (Reuss)	F	...
Guttulina irregularis (d'Orbigny)	...	R
Gyroidina condoni (Cushman and Schenck)	...	F
Karreriella cf. *K. elongata* Mallory	F	?
Plectofrondicularia cf. *P. searsi* Cushman, R. E. and K. C. Stewart	C	F
Quinqueloculina cf. *Q. minuta* Beck	R	...
Robulus spp.	C	F
Sigmomorphina sp.	...	F
Spiroloculina sp.	R	...
Uvigerina garzaensis Cushman and Siegfus	R	...
Valvulineria cf. *V. jacksonensis welcomensis* Mallory	...	F

FIGURE 5.—Foraminifera from sedimentary rocks of late Eocene age.
(C=common; F=few; R=rare; ?=questionably identified)

Lincoln Creek Formation

A thick sequence of tuffaceous mudstone, siltstone, and sandstone lies with apparent conformity stratigraphically above sedimentary rocks of late Eocene age. They also are known to unconformably onlap older rocks in adjacent areas (Rau, 1966). On the basis of lithology and contained fossils, these tuffaceous strata are assigned to the Lincoln Creek Formation as defined by Beikman and others (1967). This formation attains its greatest known thickness in the area immediately to the north and east of the Wynoochee Valley quadrangle, where some 9,000 feet of strata were measured and details of the formation's stratigraphy were recorded (Rau, 1966). In addition, the unit includes most of the beds mapped as the Lincoln Formation of Weaver (1912) by Gower and Pease (1965), and by Snavely and others (1958) in the Centralia-Chehalis area, by Pease and Hoover (1957) in the Doty-Minot Peak area of southern Washington, by Wolfe and McKee (in press) in the Grays River quadrangle, and by Wagner (in press) in the Raymond quadrangle.

In the Wynoochee Valley quadrangle the major outcrop area of the formation is in the central part of the Wynoochee Valley anticline and extends northwestward to the vicinity of the Middle Fork of the Wishkah River (Fig. 2, in pocket). Less extensive outcrops occur in Helm Creek, the East Fork of the Wishkah River, Big Creek, and the West Fork of the Wishkah River. Nine local lithologic members were recognized in the Lincoln Creek Formation in the adjacent area to the north and east of the Wynoochee Valley quadrangle. Because the formation is generally massive and its outcrops are discontinuous, no attempt has been made to map subdivisions of the formation in the Wynoochee Valley quadrangle.

The most outstanding characteristic of the formation is that it is highly tuffaceous throughout. Sandstone beds usually contain a large percentage of glass shards. Some strata are composed almost entirely of light-colored ash or tuff particles and therefore are regarded as tuff beds. They vary from an inch to several feet in thickness and usually are more resistant than other strata. The Lincoln Creek Formation is characteristically massive. Almost all siltstone and silty sandstone beds are extremely thick and massive. In these units bedding is apparent only if a tuff or concretionary layer is present. Generally, fine-grained units are thick, and therefore in many small outcrops no bedding is apparent. Thin bedding and laminated bedding are not characteristic of the formation but are present in formations stratigraphically below as well as above. Concretions are common, either scattered throughout or, in some cases, arranged in layers. The formation is generally fossiliferous, containing both mollusks and foraminifers. Almost all massive siltstone beds display a blocky conchoidal fracture pattern, whereas massive, more sandy siltstone and fine sandstone beds show very little fracture pattern and are eroded largely by spalling. Rocks of the Lincoln Creek Formation are bluish gray when freshly exposed and are lighter gray when dry. Weathered outcrops of the formation are typically olive-greenish-gray colored, but are reddish brown in some areas.

Age and Correlation

Foraminifera from the Lincoln Creek Formation, in both the Wynoochee Valley quadrangle and other areas in the Grays Harbor basin, are referred to the Refugian Stage of Schenck and Kleinpell (1936) and the Zemorrian Stage of Kleinpell (1938) (Fig. 6). These stages are usually regarded as including the Oligocene of the Pacific coast. However, the ages of the lowermost and uppermost parts have been viewed variously by different workers. The lower part of the Refugian Stage has been considered to be late Eocene in age by some and early Oligocene by others (see Rau, 1966, p. 16, 28-31, for discussion). In this report it is considered to be late Eocene in age, therefore placing the lower part of the Lincoln Creek Formation in the upper Eocene sequence.

The Zemorrian Stage is considered Oligocene in age by some, Miocene by others, and both Oligocene and Miocene by still others. In the Wynoochee Valley quadrangle, as well as in other parts of the Grays Harbor basin, the writer regards the Zemorrian Stage as Oligocene in age for the following reasons. Zemorrian foraminiferal faunas, particularly in the Lincoln Creek Formation, have far more species in common with assemblages of Refugian strata below than they do with those of the Saucesian Stage above. There is a particularly noticeable difference between the character of foraminiferal assemblages of the Zemorrian Stage and that of the Saucesian Stage assemblages. Furthermore, in western Washington there usually is a marked lithologic difference between the rocks containing Zemorrian and those containing Saucesian assemblages. This apparent major break in both lithology and fauna between the Zemorrian and Saucesian affords a convenient boundary between the rocks of the major time-stratigraphic units of the Oligocene and Miocene. Therefore, the upper part of the Lincoln Creek Formation, here considered an upper part of the Zemorrian Stage, is referred to the upper Oligocene sequence of the Pacific coast.

Correlations of the Lincoln Creek Formation on the basis of superposition, foraminiferal faunas, and lithology can be made with other stratigraphic units in the Pacific Northwest and, to a certain extent, in California and southeastern Alaska. In the Puget Sound area of Washington the type Blakeley Formation on Bainbridge Island and vicinity contains a Zemorrian fauna. It also is generally

SPECIES	LOCALITIES																	
	F-4	F-5	F-8	F-9	F-10	F-11	F-12	F-13	F-15	F-17	F-18	F-19	F-39	F-40	F-57	F-59	F-61	F-71
Alabamina kernensis Smith	R							?										
Allomorphina macrostomata Karrer				F				F								F		
Anomalina californiensis Cushman and Hobson												C						
garzaensis Cushman and Siegfus							R	F		R						F	R	?
Anomalinoides cf. *A. trinitatensis* (Nuttall)										F								
Bolivina cf. *B. advena* Cushman												R						
marginata adelaidana Cushman and Kleinpell					R													
Buccella mansfieldi oregonensis (Cushman, R. E. and K. C. Stewart)																		?
Bulimina alligata Cushman and Laiming			R					F		F		F						R
ovata d'Orbigny								F						R				
pupoides d'Orbigny	R				R								C				R	F
cf. *B. pyrula* d'Orbigny						F												
sculptilis laciniata Cushman and Parker	R											?						
Buliminella subfusiformis Cushman								R										
Cancris joaquinensis Smith	R																	
Cassidulina crassipunctata Cushman and Hobson															F		F	
galvinensis Cushman and Frizzell	?																?	
cf. *C. globosa* Hantken	R	R										R						
Cassidulinoides sp.																	R	
Ceratobulimina washburnei Cushman and Schenck										R								
Chilostomella cf. *C. oolina* Schwager											R	R					R	F
Cibicides elmaensis Rau	F															?	C	
hodgei Cushman and Schenck	F	R																
cf. *C. perlucida* Nuttall										F								F
Dentalina cf. *D. adolphina* d'Orbigny												R						
communis (d'Orbigny)										R								
dusenburyi Beck		F																
quadrulata Cushman and Laiming														R		?		C
spinosa d'Orbigny	R																	
sp. A [of Rau, 1948]					R							?					R	
sp. D [of Rau, 1948]												R	?					
spp.					R		R					R						R
Eggerella bradyi (Cushman)					R							F						
Ellipsonodosaria cf. *E. cocoaensis* (Cushman)	C											F						
Entosolenia sp.					R		R					R						R
Epistomina eocenica Cushman and M. A. Hanna	F				?		F			F								F
Eponides dupréi ciervoensis Cushman and Simonson			R		R		R											C
kleinpelli Cushman and Frizzell	R																	
umbonatus (Reuss)		C	R				?	C		F		C						
Gaudryina alazanensis Cushman	R																	
Globigerina sp.			R		F	?	F	F		F		F			F			C
Globobulimina pacifica Cushman							?		R		R		F					C
Guttulina frankei Cushman and Ozawa			R													R	R	
irregularis d'Orbigny			F		F												R	
problema d'Orbigny							R											
sp. A [of Rau, 1958]	F	F			F													

FIGURE 6.—Foraminifera from the Lincoln Creek Formation.
(C=common; F=few; R=rare; ?=questionably identified)

SPECIES	LOCALITIES F-4	F-5	F-8	F-9	F-10	F-11	F-12	F-13	F-15	F-17	F-18	F-19	F-39	F-40	F-57	F-59	F-61	F-71
Gyroidina condoni (Cushman and Schenck)			?															
orbicularis planata Cushman	F	C	R		R		R	R		C		F			F	F	C	R
Karreriella chilostoma (Reuss)					R	?	?			F						R		R
washingtonensis Rau							?			R								
Lagena semistriata Williamson								R										
Marginulina sp.	R													R				
Martinottiella communis (d'Orbigny)			R	F	C	R	R	F	R		R	R			F	R		
Nodogenerina cf. *N. sanctaecrucis* Kleinpell			F				R								?			
wegemanni (Cole)		F																
Nodosaria arundinea Schwager			C				?	F			R		?	?	F	R		?
grandis Reuss	R		?					?						F				
pyrula d'Orbigny		F															?	F
cf. *N. raphanistrum* (Linné)								R					R				?	F
Nonion halkyardi Cushman	?		?															
Plectofrondicularia cf. *P. billmani* Rau					?		?											
packardi multilineata Cushman and Simonson	F											R						
cf. *P. packardi multilineata* Cushman and Simonson	F																	
packardi packardi Cushman and Schenck	F																	
vaughani Cushman								R		F		R			?	F		R
Pleurostomella cf. *P. rimosa* Cushman and Bermudez										F								
Pseudoglandulina inflata (Bornemann)	F								F	F		?					R	
aff. *P. inflata* (Bornemann)																		R
Pullenia eocenica Cushman and Siegfus			R		R		R			F		?						
Pyrgo lupheri Rau						R											R	
Quinqueloculina imperialis Hanna and Hanna	F				R				?						R	?	F	
weaveri Rau	F				?												R	
Robulus chehalisensis Rau										R		F					?	
cf. *R. limbosus hockleyensis* (Cushman and Applin)										R							?	
sp. [large with raised sutures]							R											
spp.	C	F	R					F				F	F	F				F
Sigmoilina tenuis (Czjzek)								?		R		R					R	
Sigmomorphina schencki Cushman and Ozawa																R		
Siphonodosaria frizzelli Rau	R		?				R	R				F					R	
Sphaeroidina sp.							R	?						F			F	
Spiroloculina texana Cushman and Ellisor							R			F							F	
cf. *S. wilcoxensis* Cushman and Garrett		R																
Spiroplectammina tejonensis Mallory							R			C								
Triloculina sp.	F							R		R								
Uvigerina atwilli Cushman and Simonson	C																	
cocoaensis Cushman	C															?		
gallowayi Cushman															?			C
garzaensis Cushman and Siegfus	F	C	C	R	R		R	F		R			R			R	R	C
Uvigerinella cf. *U. californica* Cushman												R		?				

FIGURE 6.—Foraminifera from the Lincoln Creek Formation—Continued.
(C=common; F=few; R=rare; ?=questionably identified)

a highly tuffaceous unit. Therefore, on the basis of both fauna and lithology, a correlation can be made of this unit with at least a part of the upper Lincoln Creek Formation. In the Port Angeles area to the north, the Twin River Formation, as redefined by Brown and Gower (1958), includes strata that contain faunas of both the Refugian and Zemorrian Stages, as well as a part of the subjacent Narizian Stage (Rau, 1964). It is overlain by rocks containing faunas of the Saucesian Stage. Therefore, on the basis of contained foraminifers and superposition, a major part of the Twin River Formation can be correlated with the Lincoln Creek Formation.

The following Oregon stratigraphic units may be correlated on various evidence with the Lincoln Creek Formation. The Keasey Formation of northwestern Oregon, at least in part, contains Refugian and possibly Zemorrian Foraminifera. Its lithology generally is comparable to that of the Lincoln Creek Formation in that many of its beds are tuffaceous, and its stratigraphic position is comparable to that of at least part of the Lincoln Creek Formation. In the Newport-Toledo area on the Oregon coast an upper part of the Toledo Formation, informally referred to as the "Alsea" formation (Snavely, written communication, 1966), contains foraminiferal faunas of both the Refugian and Zemorrian Stages. Beds of this formation are underlain by strata containing Narizian Foraminifera. Although much of the overlying Yaquina Formation has not yet yielded diagnostic foraminiferal evidence for its age, it is overlain by the Nye Mudstone of Saucesian age. Furthermore, the Alsea formation is somewhat tuffaceous, massive, concretionary, and otherwise lithologically similar to the Lincoln Creek Formation. In the Coos Bay area, on the Oregon coast to the south, the Bastendorff Shale rests on the late Eocene Coaledo Formation and contains Refugian and possibly Zemorrian Foraminifera, therefore suggesting a general correlation with at least the lower part of the Lincoln Creek Formation.

Among the units in California from which Refugian and (or) Zemorrian faunas are recorded, therefore suggesting a broad correlation with the Lincoln Creek Formation, are the San Lorenzo Formation (Sullivan, 1962; Cushman and Hobson, 1935), the Tumey Formation (Cushman and Simonson, 1944), the Wagonwheel Formation (Smith, 1956), and the Gaviota Formation (Wilson, 1954; Kleinpell and Weaver, 1963). In the Yakataga district of Alaska, the Poul Creek Formation (Miller, 1957) contains Foraminifera that are assigned to the Saucesian Stage as well as to the Refugian and Zemorrian Stages (Rau, 1963), and therefore at least a part of this formation may correlate in a general way with the Lincoln Creek Formation of southwest Washington.

Astoria (?) Formation

Marine siltstones and sandstones and some conglomerates of Miocene age overlie the Lincoln Creek Formation with apparent conformity throughout much of the quadrangle. These rocks are tentatively referred to the Astoria Formation. This name was first used in southwest Washington by Etherington (1931) and was applied to those strata older than the Montesano Formation and younger than the Lincoln-Blakeley sequence. In the Montesano quadrangle, immediately south of the area of this report, Gower and Pease (1965) have mapped similar rocks as the Astoria (?) Formation. As pointed out by these latter authors, some of the beds included in the Astoria(?) Formation in the southern part of the Montesano quadrangle may be equivalent to the overlying Montesano Formation of the northern part of that quadrangle and of the Wynoochee Valley quadrangle. Other places in southwest Washington where the formation has been mapped are the Doty-Minot Peak area (Pease and Hoover, 1957), the Centralia-Chehalis area (Snavely and others, 1958), the Raymond quadrangle (Wagner, in press), and the Grays River quadrangle (Wolfe and McKee, in press).

Areal distribution of the Astoria(?) Formation is extensive in and around the major structures of the Wynoochee Valley quadrangle (Fig. 2, in pocket). It constitutes the greater part of the Melbourne anticline extension in the south-central area of the quadrangle and also forms the central part of the south end of the Wynoochee Valley anticline, as well as occurring along its flanks. A broad area of outcrop extends westward from the western flank of this latter anticline into the vicinity of the West and Middle Forks of the Wishkah River. The formation crops out also in the central part of the Caldwell Creek anticline, where the axis crosses the Wynoochee River valley.

Although at no place within the Wynoochee Valley quadrangle could the thickness of the formation be measured accurately, it is estimated that the maximum thickness probably does not exceed 3,500 feet. Because of the unconformable relation between the formation and the overlying Montesano Formation, the thickness of the Astoria (?) Formation locally is extremely variable.

Within the Wynoochee Valley quadrangle the Astoria(?) Formation is chiefly a fine-grained unit of marine siltstone and sandy siltstone, but sandstone beds are present and are of considerable thickness in places. In addition, at least one conglomerate unit has been mapped in the area. Siltstone beds are usually dark gray when freshly broken but chocolate brown in weathered outcrops. They usually contain a large amount of macerated plant material. Mica is characteristically prevalent, and sand-size quartz grains commonly are dispersed through the siltstone. These fine-grained rocks typically display a pencil-like jointing or shear pattern.

Sandstone beds of the Astoria(?) Formation are bluish gray when freshly broken and light gray in weathered outcrops. Most are fine grained and usually silty, although a few relatively clean sandstone beds are exposed in the vicinities of Carter Creek and Anderson Creek on the east side of the Wynoochee Valley anticline, in the East Fork of the Wishkah River, and in Big Creek (Fig. 2). All the sandstones are highly feldspathic, are characteristically micaceous, and contain considerable amounts of carbonaceous material. Although most of the sandstone beds of the Astoria(?) Formation are massive, a few are well bedded and have mica flakes and carbonaceous material forming the lamellae.

At least one conglomerate unit, estimated to be some 100 feet thick in places, is known near or at the base of the Astoria(?) Formation. It is composed of very poorly sorted boulder- to sand-size, well-rounded clasts of dense basalt, argillite, limy concretions, and indurated fossiliferous sandstone or graywacke. A few beds of coarse, fairly well sorted sandstone and dark-colored siltstone are interbedded in, and in places overlie, the conglomerate unit. Conglomerate beds are known in the Middle Fork of the Wishkah River and extend southeastward across Big Creek (Fig. 2). Nearly vertical beds are very well exposed in the East Fork of the Wishkah River. There they grade upward into fairly well sorted medium- to coarse-grained sandstones of a lower part of the overlying sandstone unit. Conglomerate beds occur also in the Astoria(?) Formation in the Wynoochee River valley (sec. 22, T. 19 N., R. 8 W.) and typically are very poorly sorted, as are those to the northwest. Here their stratigraphic position within the Astoria(?) Formation is not as apparent as it is in the Wishkah River drainage at the base of the formation. However, the general linear northwest-southeast distribution of all conglomerate outcrops of the Astoria(?) Formation parallel to the regional strike suggests that they may be of the same unit within the Astoria(?) Formation.

Conglomerate beds of the Astoria(?) Formation are best characterized, and may be differentiated from the numerous conglomerates of the overlying Montesano Formation, in that they are very poorly sorted in both size and composition of the clasts. They vary in size from boulders to sand and are composed of dense basalt, argillite, limy concretions, and indurated sandstone.

The Astoria(?) Formation, in general, is most easily differentiated from the underlying Lincoln Creek Formation by its abundance of mica, considerable amounts of carbonaceous material, lack of tuffaceous material, and better bedding. It differs from the overlying Montesano Formation in that its sandstone beds are usually fine grained and silty and its conglomerate beds are poorly sorted. Also, its siltstone units contain considerable amounts of clay minerals and are, therefore, much less competent in outcrop than those of the Montesano Formation.

Age and Correlation

Foraminifera contained in beds of the Astoria(?) Formation of the Wynoochee Valley quadrangle can be placed in the Saucesian, Relizian, and possibly Luisian Stages of Kleinpell (1938) (Fig. 7). These stages are generally regarded as early to middle Miocene in age. Foraminifera of the Astoria(?) Formation represent what has been broadly referred to as the *Epistominella parva* zone (Rau, 1958) of southwest Washington. In recent years additional biostratigraphic studies have revealed that Foraminifera from strata of the Astoria(?) Formation in southwest Washington can be divided into three stratigraphic groups. These groups have become informally known as the *Siphogenerina kleinpelli*, *Baggina washingtonensis*, and *Rotalia becki* zones. In this report no attempt has been made to show the extent of these zones. However, they were found to be useful in mapping the area. Although details of the stratigraphic and geographic extent of these faunal concepts are not fully known, *Siphogenerina kleinpelli* Cushman, together with its associated assemblage, consistently occurs in the lower part of the Astoria(?) Formation throughout the Grays Harbor basin.

Selected species commonly found in this zone are as follows:

Bolivina advena Cushman
Buccella mansfieldi oregonensis (Cushman, R. E. and K. C. Stewart)
Cassidulina pulchella d'Orbigny
Epistominella parva (Cushman and Laiming)
Nonion costiferum Cushman
Planulina astoriensis Cushman, R. E. and K. C. Stewart
Plectofrondicularia californica Cushman and Stewart
Siphogenerina kleinpelli Cushman
Sphaeroidina variabilis Reuss
Uvigerinella obesa impolita Cushman and Laiming
Valvulineria araucana (d'Orbigny)

Characteristic assemblages of the zone have been collected in the Wynoochee Valley quadrangle from localities F-65 and F-66 (secs. 10 and 11, T. 19 N., R. 8 W.), along the Wynoochee River; F-20 (sec. 30, T. 20 N., R. 8 W.), in the river banks of the Middle Fork of the Wishkah River; F-75 (sec. 27, T. 19 N., R. 8 W.); and F-87 (sec. 1, T. 18 N., R. 8 W.)

Baggina washingtonensis Rau, together with its associated assemblage, sometimes locally referred to as the "Preacher's Slough fauna" (Rau, 1948), reliably occurs above beds containing the *Siphogenerina kleinpelli* assemblage, but is not found as widespread throughout the basin, probably because its containing rocks are less extensive due to their removal in places by erosion.

The following are species common to this zone:

Baggina washingtonensis Rau
Bolivina chehalisensis Rau
Buccella mansfieldi oregonensis (Cushman, R. E. and K. C. Stewart)
Cassidulina pulchella d'Orbigny
Cibicides aff. *C. perlucida* Nuttall
Epistominella parva (Cushman and Laiming)
Nonion costiferum Cushman
Uvigerinella californica Cushman

Typical assemblages of the *Baggina washingtonensis* zone have been collected in the Wynoochee Valley quadrangle from localities F-23, 24, 27, 28, 30, and 32 (sec. 31, T. 20 N., R. 8 W.; sec. 36, T. 20 N., R. 9 W.), all from along the Middle Fork of the Wishkah River. Others were found at F-91 and vicinity along the Wynoochee River road (sec. 35, T. 18 N., R. 8 W.).

The *Rotalia becki* assemblage usually occurs in rocks above the two previously mentioned assemblages; it constitutes the uppermost assemblage known in rocks of the Astoria(?) Formation. However, in some places this assemblage has been known to occur in beds stratigraphically below, or at least within, strata containing a predominance of one or the other of the two assemblages. Furthermore, the *Rotalia becki* assemblage is somewhat restricted in its geographic distribution within the basin, and therefore the value of this assemblage as a stratigraphic marker is considerably less than that of both the *Siphogenerina kleinpelli* and *Baggina washingtonensis* assemblages.

The following species typically occur together in the *Rotalia becki* zone:

Bolivina chehalisensis Rau
Buccella cf. *B. frigida* (Cushman)
Buliminella elegantissima (d'Orbigny)
Cassidulina pulchella d'Orbigny
Elphidium cf. *E. minutum* Cushman
Rotalia becki Bandy and Arnal
Uvigerina auberiana d'Orbigny
Valvulineria menloensis Rau

Characteristic assemblages of the *Rotalia becki* zone have been collected in the Wynoochee Valley quadrangle from locality F-90 (sec. 24, T. 18 N., R. 8 W.), in an artificial stream cut in Black Creek, and from a roadcut at locality F-92 (sec. 36, T. 18 N., R. 8 W.).

These three faunal zones indicate general differences in depositional environment. Greatest water depths are suggested by the *Siphogenerina kleinpelli* assemblage, possibly lower neritic conditions. Successively shallower conditions are indicated by the *Bag-*

gina washingtonensis and *Rotalia becki* faunas, the latter of which probably represents relatively shallow-water, near-shore conditions, possibly an upper neritic environment. This pattern of progressive shoaling from relatively deep water conditions in the lower part to shallow water depths in the upper part of the Astoria(?) Formation suggests that the basin of deposition became progressively more shallow. The deepest water assemblage therefore should be confined largely to the earlier stages of Astoria deposition, as is the case with the *Siphogenerina kleinpelli* fauna. Furthermore, only a shallow-water assemblage such as that of *Rotalia becki* should be found in the upper part of the Astoria(?) Formation. The apparent anomalous occurrence of the *Rotalia becki* assemblage in a few places lower in the formation may well be due to the existence locally of shallow-water conditions near the edge of the basin at all times during the deposition of the Astoria(?) Formation.

The exact position of these zones in Kleinpell's stage concept of the Pacific coast Miocene (Kleinpell, 1938) is not fully known. However, the following suggestions are presented on a tentative basis. Evidence for the position of the *Siphogenerina kleinpelli* zone is reasonably good, and firmly suggests that this zone should be placed in the Saucesian Stage. *Baggina washingtonensis* and its associated assemblages may well represent the Relizian Stage, and possibly an upper part of the Saucesian Stage and a lower part of the overlying Luisian Stage. Largely on the basis of superposition, the *Rotalia becki* zone could constitute at least a part of the Luisian Stage.

Based on Foraminifera, a correlation of the Astoria(?) Formation can be made, with varying degrees of certainty, with other rock units on the Pacific coast. In addition to a direct correlation with all beds previously referred to the Astoria(?) Formation in the Grays Harbor basin and adjacent areas of southwest Washington, a firm faunal correlation can be made also with the Clallam Formation of the northern Olympic Peninsula. Foraminifera from the lower part of the latter formation are regarded as Saucesian in age (Rau, 1964). Although the younger age limit of the Clallam Formation is uncertain, it may well extend into the Relizian and possibly the Luisian Stages, as does the Astoria(?) Formation.

On the west side of the Olympic Peninsula along the seacoast, a few small local outcrops of unnamed siltstone and sandstone are known to contain Foraminifera of Saucesian age, particularly in the vicinity of Trail 5, sec. 16, T. 25 N., R. 13 W., and at Browns Point, sec. 28, T. 25 N., R. 13 W. These beds also may be faunally correlated with at least a part of the Astoria(?) Formation of southwest Washington.

Strata of the Astoria(?) Formation, both at the type locality at Astoria, Oregon, and along the Oregon coast, contain foraminiferal assemblages that are variously placed in the Saucesian and Relizian

SPECIES	F-7	F-16	F-20	F-21	F-22	F-23	F-24	F-25	F-26	F-27	F-28	F-29	F-30	F-31
Baggina washingtonensis Rau						C	F			F	R		F	
Bolivina advena Cushman	R													
advena striatella Cushman		F			R						F			
chehalisensis Rau								F					C	
marginata adelaidana Cushman and Kleinpell			F		R						F			
cf. *B. marginata* Cushman														
Buccella cf. *B frigida* (Cushman)				?					?					F
mansfieldi oregonensis (Cushman, R. E. and K. C. Stewart)				R							?			
Bulimina alligata Cushman and Laiming														
ovata d'Orbigny	F			F	F	R								
pupoides d'Orbigny	F								C					
Buliminella elegantissima (d'Orbigny)														F
subfusiformis Cushman	F	R	F		C			F	R	F			F	?
Cassidulina cf. *C. californica* Cushman and Hughes			F											
crassipunctata Cushman and Hobson			F	?	F									
cf. *C. minuta* Cushman			?		R			R	?				R	R
pulchella d'Orbigny		C			C	F	F	F		F	F	R	F	
Cassidulinoides sp.														
Cibicides aff. *C. perlucida* Nuttall								F	R	R	F		R	R
Dentalina pauperata d'Orbigny														
quadrulata Cushman and Laiming														
spp.														
Elphidium cf. *E. minutum* Cushman														
Entosolenia sp.														
Epistominella parva (Cushman and Laiming)	R	F		R	F			C				F	F	F
Eponides umbonatus (Reuss)							?				R			
Globigerina cf. *G. bulloides* d'Orbigny			R		R			F	F	C				
Globobulimina pacifica Cushman					R									
Guttulina hughesi Cushman and Laiming														
Gyroidina relizana Kleinpell			R											
soldanii d'Orbigny									?					
Lagena costata (Williamson)					R									
hexagona (Williamson)														
semistriata Williamson														
Marginulina subbullata Hantken														
Nodogenerina advena Cushman and Laiming													R	
Nodosaria estorffi Kleinpell														
cf. *N. hammilli* Kleinpell														
parexilis Cushman and K. C. Stewart														
Nonion costiferum Cushman	?					C								
incisum kernensis Kleinpell				F										
pompilioides (Fichtel and Moll)														
sp.		R			?				R			R		
Nonionella miocenica Cushman				R										
Planulina astoriensis Cushman, R. E. and K. C. Stewart								F	?					
Plectofrondicularia billmani Rau													?	
californica Cushman and Stewart														
cf. *P. miocenica* Cushman			R											
vaughani Cushman														
Pseudoglandulina inflata (Bornemann)	R													
aff. *P. inflata* (Bornemann)														
Pullenia salisburyi R. E. and K. C. Stewart								F						
Pyrgo sp.														
Quinqueloculina spp.	R						R							
Robulus cf. *R. laimingi* Bandy and Arnal														
cf. *R. nikobarensis* (Schwager)													F	
spp.						R				R				
Rotalia becki Bandy and Arnal		F							F					
Sigmomorphina cf. *S. reedi* Cushman and Laiming														
Siphogenerina kleinpelli Cushman			C											
Siphonodosaria frizzelli Rau														
Sphaeroidina variabilis Reuss			F		F		R				F			
Uvigerina auberiana d'Orbigny														
cf. *U. hootsi* Rankin		C		F	?	C						C		
cf. *U. joaquinensis* Kleinpell		?					F		F				F	
Uvigerinella californica Cushman						R				C				C
obesa impolita Cushman and Laiming		F	C	R			C	F	F	R	C		C	R
Valvulineria araucana (d'Orbigny)		F	R		C	F	?	F	R					
menloensis Rau														?
Virgulina bramlettei Galloway and Morrey														
californiensis Cushman									F					

FIGURE 7.—Foraminifera from the Astoria(?) For

F-44	F-45	F-46	F-47	F-48	F-60	F-62	F-63	F-64	F-65	F-66	F-67	F-68	F-69	F-70	F-72	F-73	F-74	F-75	F-76	F-77	F-78	F-87	F-90	F-91	F-92
...	...	...	...	...	...	...	...	...	...	...	F	...	...	...	...	...	...	...	...	...	...	...	...	C	...
...	?	...	...	...	...	...	...	R	...	...	...	F	...	...	...	R	R	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
F	...	...	...	...	...	...	...	?	...	...	F	...	...	F	...	...	R	C	...	...	...	F	F	F	?
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	F	...	F	F	...	...	...	...	...
...	...	...	...	...	...	...	...	?	...	...	...	...	...	...	F	...	...	...	...	...	F	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	F	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	C	C	C	...	...	C	...	...	C	C	C	...	F	F	...	C	F	...	?	F	R
R	F	...	...	...	...	...	...	F	...	...	...	...	R	...	...	R	C	...	...	...	...	...	...	...	...
R	...	...	R	C	...	?	...	F	R	...	...	R	...	...	...	F	F	...	R	...	...	...	R	R	R
...	...	...	...	...	...	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R	...	R
...	...	...	F	...	...	...	...	...	...	F	R	R	R	...	...	...	C	F	...	C	F	F	...	R	R
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(C=common; F=few; R=rare; ?=questionably identified)

Stages of Kleinpell (Cushman and others, 1947; Snavely and others, 1964). In addition, the Nye Mudstone of the Newport area of west-central Oregon contains a Saucesian assemblage, and therefore a faunal correlation is suggested with at least the lower part of the Astoria(?) Formation of the Wynoochee Valley quadrangle.

In California a number of rock units are placed in either the Saucesian or the Relizian stage and therefore are here regarded as general correlatives of the Astoria(?) Formation of southwest Washington (Kleinpell, 1938; Kleinpell and Weaver, 1963; Weaver and others, 1944).

MONTESANO FORMATION

Siltstones and fine silty sandstones, medium to coarse well-sorted sandstones, and conglomerate overlie the Astoria(?) Formation and older rocks with distinct unconformity. Outcrop areas of these beds are far more extensive in the Wynoochee Valley quadrangle than all other Tertiary rocks combined. These beds are referred to the Montesano Formation, a name Weaver (1912, p. 20) first applied to rocks that he regarded as late Miocene in age and that are exposed near the town of Montesano. Some of these rocks are in the area of the present report. Subsequent reports (Weaver, 1916, 1937; Etherington, 1931) extend the geographic distribution of the Montesano Formation into much of the area of the Wynoochee Valley quadrangle and present more accurate details on the thickness of the formation. Gower and Pease (1965) mapped the distribution of this formation in the northwest part of the adjacent Montesano quadrangle but did not attempt to differentiate this unit from the Astoria(?) Formation in other parts of that quadrangle. Wagner (in press) also has mapped beds in the Raymond quadrangle as part of the Montesano Formation. Recent detailed studies of the stratigraphy, Foraminifera, and paleoecology of the Montesano Formation have been recorded in a doctoral thesis by Fowler (1965) in which eight sections were measured in the formation and the Foraminifera contained therein were discussed. Most of these measured sections are within the Wynoochee Valley quadrangle, and therefore they have been most useful in the mapping of this quadrangle.

The Montesano Formation flanks the major anticlinal structures of the Melbourne anticline extension and the Wynoochee Valley anticline. Its outcrop area covers most of the southwest third and much of the east half of the quadrangle (Fig. 2, in pocket). The formation probably does not exceed 3,000 feet in thickness within the Wynoochee Valley quadrangle. An estimated 2,500-foot thickness of strata are exposed in the Wynoochee River valley and immediate vicinity south of the Wynoochee Valley anticline. Nearly this much thickness of strata are estimated to be exposed in the various forks of the Wishkah River to the northwest. However, in the southwest part of the mapped area only about 1,700 feet of the Montesano Formation was penetrated by the Continental Oil Company Wishkah No. 1 well (Fig. 2, well no. 2). In addition, to the northeast some 1,700 to 1,800 feet of section is exposed in the West Fork and Middle Fork of the Satsop River and in the Canyon River.

The lithology of the Montesano Formation is extremely varied, ranging from mudstone and siltstone to cobble-size conglomerate. In view of this fact and in order to present some basic knowledge about the distribution of rock types in this widespread formation, the various lithologies have been grouped into three major rock types and their general distribution shown on the map (Fig. 2). These major rock types are: (1) Tmsl—fine-grained clastic rocks, largely mudstone, siltstone, and very fine-grained silty sandstone; (2) Tmss—coarse-grained clastic rocks, chiefly medium- to coarse-grained sandstone but also some fine-grained silty sandstone; and (3) Tmc—very coarse clastic rocks, chiefly conglomerates, but including beds of grit and very coarse sandstone. Generally, variations in lithologies encountered in outcrops throughout the mapped area vary well within the description of one of the three major rock types. However, in some cases fairly large areas are underlain with rocks, the lithologies of which range between those of two rock types; that is, mainly from sandy siltstone to fine silty sandstone, and therefore range from the fine clastic category to that of the coarse clastics. In most such cases the attempt was to keep the coarse clastic unit (Tmss) distinctly a sandstone, and therefore, in questionable situations the rocks were mapped in the fine-grained clastic group (Tmsl).

The accuracy of the mapped position of lithologic boundaries within the formation varies considerably. Although outcrops may be abundant and well exposed in limited areas, such as in the main streambeds, large areas between streams or in areas not dissected by large streams may have very few, if any, outcrops available for study. Therefore, in many places boundary lines between rock types have to be projected considerable distances and the position of many of these contacts can only be regarded as tentative.

The stratigraphic distribution of the three major rock types varies throughout the mapped area. From one area to another, fine clastic rocks grade laterally to coarse clastic rocks. In other places a lithologic unit gradually changes stratigraphic position laterally within the formation; for example, a conglomerate that is near the base of the formation on the southwest side of the Wynoochee Valley anticline gradually changes to a higher position in the formation to the east. This type of distribution, although somewhat unpredictable, nevertheless is what normally can be expected on or near the edge of a major basin. In general, the greatest thickness of fine-grained clastic rock; that is, mudstone and siltstone, occurs in the southwest part of the area, whereas the greatest thickness of coarser grained clastic rock, such as well-sorted medium-grained sandstone, is in the eastern part of the mapped area.

Lithologic variations and stratigraphic distribution of various rock types can be studied best in the major stream valleys, where upturned beds of the formation are usually well exposed. In the western part of the Wynoochee Valley quadrangle, probably the most complete and nearly continuous section is exposed in the valley of the Middle Fork of the Wishkah River. A similar section is exposed also in the valleys of the East Fork of the Wishkah River and its tributaries and in the Wynoochee River valley. Two distinct members are present in this area southwest of the Wynoochee Valley anticline. Some 1,500 feet of thickness in the lower part of the formation is composed of sandstone (Tmss). The lower part of the unit usually consists of some 500 to 700 feet of massive well-sorted clean medium-grained well-rounded friable sandstone; also, scattered throughout are some carbonized wood and plant material, large calcareous concretions, and fossils. Conglomerate and grit beds, ranging in thickness from a few inches to 10 feet and containing abundant fossils, are scattered through this part of the section also. The upper part of the lower member differs in that it consists largely of finer grained, more silty, poorly sorted micaceous sandstone that usually displays vague, rather thin bedding. Although its bedding is apparent on outcrops, particularly weathered outcrops, nevertheless it does not break evenly along bedding planes. Fossils and concretions also are scattered throughout this upper part of the lower member. All sandstones of the lower member are feldspathic, composed generally of feldspar, quartz, lithic fragments, and, in places, mica. They are bluish gray when freshly broken, and orange-brown when weathered. The conglomerates are composed largely of basalt pebbles and include some indurated graywackes and other "Olympic-type" rocks.

The upper member in the southwest part of the Wynoochee quadrangle is distinctly a fine-grained unit composed largely of mudstone, siltstone, and, in places, very fine-grained silty sandstone. Its complete thickness is not known, as its upper beds are truncated and overlain by gravels of Pleistocene(?) age. However, an estimated thickness of at least 1,000 feet is exposed in the major drainages in the immediate area. These rocks are generally very massive, but in places, particularly near the top, bedding is poorly developed. They are bluish gray when freshly broken, and light brownish-buff when weathered. Much of the upper member is tuffaceous and has a high percentage of volcanic glass shards in the coarser grained beds, particularly in the uppermost beds exposed. Macerated carbonaceous material is common in places. The rocks are fossiliferous; Foraminifera are much more abundant here than in the lower part of the formation.

In the northeast part of the Wynoochee Valley quadrangle and immediately to the north, the Montesano Formation dips south and southeastward, forming the northern part of the Canyon River-Smith Creek syncline. These beds rest unconformably on the Lincoln Creek Formation in the West and Middle Forks of the Satsop River and unconformably on the lower part of the Astoria(?) Formation in the Canyon River (Rau, 1966, Fig. 2). In the streambeds the Montesano Formation is well exposed and is some 1,700 to 1,800 feet in thickness. The stratigraphic distribution of rock types is somewhat different from that in the southwest part of the quadrangle. Coarse clastic rocks, mainly sandstones, are distinctly the most predominant rock type. Generally, there are four recognizable lithologic units. The lowest of these is a sandstone ranging in thickness from approximately 500 to 700 feet. Much of the unit is massive, but bedding is made apparent in places by conglomerate lenses, layers of carbonized wood, and concretionary beds. Crossbedding is also present in places. Much of the sandstone is feldspathic, friable, and well sorted. The sand grains are fairly well rounded and range in size from fine to medium grained and, in places, up to grit size where in association with pebble conglomerate lenses. Conglomerate beds ranging in thickness from a few inches to as much as 25 feet are scattered through the lower sandstone unit. The clasts are well rounded, composed largely of basalt, and range in size from grit to large pebbles. Invertebrate fossils are abundant in the conglomerate layers and are also scattered throughout the sandstone. Carbonaceous material, common in much of the unit, consists of small particles of macerated plant material, wood fragments, and even small logs. Mica commonly is concentrated in thin layers, making bedding apparent. This sandstone unit is bluish gray when freshly broken, and weathers to tones of yellow, orange, and brown.

Overlying the lower sandstone unit in the northern part of the Canyon River-Smith Creek syncline in the area of the Canyon River and the West Fork of the Satsop River is a fine-grained unit approximately 200 feet thick. This unit apparently becomes coarser grained to the east and no longer recognizable in the Middle Fork of the Satsop River. However, it appears to be thicker in the south and west parts of the Canyon River-Smith Creek syncline, where the upturned beds are dissected by the West Fork of the Satsop River in the vicinity of Wyn Mountain. The apparent unusual thickness of this fine-grained unit in this area may be the result of faulting or perhaps minor undulation of relatively flat-lying beds. Nevertheless, indications are that, aside from these possibilities, there is a greater thickness of fine-grained rocks exposed here than to the north or south. In the Canyon River-West Fork of the Satsop River area, this unit consists largely of sandy siltstone and silty, very fine sandstone that contain mica and carbonaceous material in places; some concretionary layers are also present. It is coarser grained here than to the south, and apparently continues to become even coarser grained along strike to the east as it loses its identity in the Middle Fork of the Satsop River, where it is represented by fine-grained sandstone. In the northern area this unit is generally massive, but has bedding somewhat developed near the top. Southward, along the West Fork of the Satsop River in the vicinity of Wyn Mountain, these rocks are essentially siltstone and mudstone. Almost all of them are bedded, in some places rather poorly, but for the most part the unit is well bedded in the Wyn Mountain area. In places it is thinly bedded with paper-thin layers of fine-grained sandstone, some of which are highly micaceous.

The overlying unit is a sandstone of some 1,000 feet in thickness, well exposed in the area of the Canyon River-Smith Creek syncline in the valleys of the Canyon River and the West and Middle Forks of the Satsop River. Most of these rocks are massive medium-grained well-sorted friable sandstone containing considerable amounts of carbonaceous material in the form of macerated plant fragments, carbonized limbs, and logs. Sand grains are generally well rounded, ranging in grain size from fine to coarse, but a large part of the unit is composed of medium- to coarse-grained sand. Numerous grit and pebble conglomerate lenses are scattered throughout the unit. Some crude bedding separates thick units of very massive beds. In a few places good bedding is formed by relatively thin siltstone layers. Some crossbedding is made apparent by local grit or pebble layers within sandstone beds. A few large calcareous concretions are present in the lower part of the unit.

The uppermost part of the Montesano Formation in the northern part of the Canyon River-Smith Creek syncline consists chiefly of very coarse clastic material and is, therefore, shown in Figure 2 (in pocket) as a conglomerate (Tmc). Outcrops of the rocks are best seen in the Canyon River valley and particularly in the valley of the Middle Fork of the Satsop River. Although sandstone is present here, abundant grit and small pebbles are scattered throughout these sandstone beds. Several thick beds and numerous discontinuous lenses of conglomerate are present in the uppermost part of the formation. Carbonaceous material ranging in size from macerated plant fragments to small carbonized logs is common.

In the central part of the Wynoochee Valley quadrangle, in the vicinity of the Still Creek anticline, relatively fine-grained rocks represent a lower part of the Montesano Formation. Much of this area is poorly exposed, and no continuous sections are available for study; therefore lithologic, as well as structural, details are not well known. However, the available information suggests that most of the rocks exposed in the area of the central part of the Still Creek anticline are relatively fine grained. Some are sandstones, but they are silty and very fine grained. Therefore the entire area is shown on the map (Fig. 2) as a fine-grained rock unit (Tmsl).

The overlying rocks are primarily sandstones and are distinctly coarser grained than those of the lower unit in this area. These sandstones are well exposed in the West and Middle Forks of the Satsop River. Their outcrop area flanks the Still Creek anticline, covers much of the area in the southeastern part of the Wynoochee Valley quadrangle, and forms the peripheral area of much of the Black Creek basin. No sections were measured through these rocks, but it is conservatively estimated that there is at least 1,000 feet of thickness and, in places, possibly as much as 2,000 feet. These rocks are chiefly massive to crudely bedded, medium- to coarse-grained, well-sorted feldspathic, micaceous, carbonaceous sandstones. Thin discontinuous beds of pebble conglomerate are common, and many of them contain a high concentration of invertebrate fossil remains. Mica is commonly concentrated in the layers, forming crossbedding and in some cases normal bedding. Much carbonaceous material is present; it commonly occurs as large pieces of carbonized wood. Most of the sandstone is clean, well sorted, and composed of well-rounded sand grains. Large calcareous concretions are scattered throughout the unit. A few strata are crudely bedded silty sandstone. Feldspar, quartz, and lithic fragments are the most abundant constitutents of the rocks. The unit is bluish gray when freshly broken and weathers to tones of yellow, orange, and brown.

Although thin conglomerate beds and other very coarse-grained rocks are scattered through much of the sandstone in the eastern and especially the southeastern part of the mapped area, a concentration of very coarse sedimentary rocks, essentially conglomerates, occur at the top of this sandstone and are mapped (Fig. 2) as Tmc. These conglomerates are particularly well developed in many of the peripheral areas of the Black Creek basin. They are composed of grit to small pebble-sized, well-rounded clasts that consist largely of fragments of basalt, indurated graywacke, and argillite. These very coarse-grained rocks can be seen most easily in the area southeast of the head of the East Fork of Sylvia Creek, in the vicinity of Prices Peak, and in the middle fork of Bitter Creek. Small, poorly exposed, and weathered outcrops of these conglomerates commonly are difficult to differentiate from deposits of Pleistocene(?) gravels. Generally they may be distinguished by their greater induration, steeper dip of their beds, the presence of marine fossils, and their position subjacent to other rocks of the Montesano Formation.

The uppermost rocks exposed in the southeastern part of the Wynoochee Valley quadrangle are principally fine grained (Tmsl), as are those exposed in the southwestern part of the area. The outcrop area occupies the central part of the Black Creek basin. Many of the rocks are massive sandy siltstone or very fine silty sandstone. In a few places they are crudely bedded, and macerated plant material is present. Although these rocks are considered fine grained, many of them are generally coarser grained than the mudstones and siltstones of the upper unit in the southwest part of the quadrangle. Continuous sections are not available for study in the Black Creek basin area, and therefore the thickness of these rocks is not accurately known. However, it is conservatively estimated that a thickness of at least 1,000 feet of fine-grained material may be present in the central part of the Black Creek basin.

Age and Correlation

Weaver (1912) originally referred the Montesano Formation to the upper Miocene, based on megafossil collections, chiefly from the Sylvia Creek drainage within the southeast part of the Wynoochee Valley quadrangle. In the following years, after having studied many additional megafossil collections from numerous localities in the formation, Weaver (1937, 1943, 1944) extended the age of the formation to include a part of the Pliocene and concluded that most of the formation probably was Pliocene in age. Recent studies of Foraminifera, although not entirely conclusive, favor a late Miocene age for the formation because foraminiferal assemblages are best compared with those known from the Mohnian and Delmontian Stages of Kleinpell (1938) of California. These stages are regarded as representing the upper Miocene of the Pacific coast.

Throughout the course of field investigations in the Wynoochee Valley quadrangle, foraminiferal samples were collected only from key areas. No attempt was made to make extensive collections of materials for the purpose of detailed biostratigraphic or paleoecologic studies. Foraminifera have been used primarily as an aid in the identification of a formation in places where its lithologic characteristics are similar to those of other formations in the area. A list of those species from the Montesano Formation encountered throughout the course of this study are presented in Figure 8. Of these, the following species are believed to have some significance in connection with the relative age of the containing beds:

Bolivina brevior Cushman
Bolivina rankini Kleinpell
Buccella frigida (Cushman)
Buliminella curta Cushman
Nonionella cf. *N. basispinata* (Cushman and Moyer)
Rotalia cf. *R. garveyensis* Natland
Uvigerina modeloensis Cushman and Kleinpell
Uvigerina hootsi Rankin
Virgulina cf. *V. californiensis ticensis* Cushman and Kleinpell
Virgulina subplana Barbat and Johnson

SPECIES	LOCALITIES																															
	F-33	F-34	F-35	F-36	F-37	F-38	F-49	F-50	F-52	F-53	F-54	F-55	F-56	F-58	F-74	F-80	F-81	F-82	F-83	F-84	F-85	F-86	F-88	F-89	F-93	F-94	F-95	F-96	F-97	F-98	F-99	F-100
Bolivina brevior Cushman					R			C																								
marginata Cushman				R				F																								
rankini Kleinpell					R			F																		?		?		?		
Buccella frigida (Cushman)	R		F			F					?		R	R						?	?			R		F	F				R	F
Bulimina ovula d'Orbigny	?	C		F	?		F	?	C		F			?	R	?	R	F		R		F		C		C		R				C
Buliminella curta Cushman	C		F	F	C	F	F	C	C	R	R				?		R	F	R			R	F			F	C	R		F		
elegantissima (d'Orbigny)											R	C	R	F												F	R	F	R	R	R	
subfusiformis Cushman		R			R			R	R	C						R						R		R				F		F		
Cassidulina laevigata carinata Silvestri			?	C	C	C	F	C									F	F	F	C	C			R	R							
cf. *C. minuta* Cushman											R		R			R									?					R		
Cibicides mckannai Galloway and Wissler			?		?	C							R		?			C	C	C	C											
Dentalina cf. *D. baggi* Galloway and Wissler																		F	F													
cf. *D. monicana* Pierce									R																							
spp.				R	F	R		R							R					R	R											
Entosolenia sp.					R	R									?																	
Epistominella pacifica (Cushman)		R		C	F	R	F		F			R	F		?	F	R			R		C				C	F	C		F	?	
smithi (R. E. and K. C. Stewart)			R	R			F									F												?		?		
Frondicularia cf. *F. advena* Cushman																					R											
Glandulina? sp.						R												R	R													
Globigerina cf. *G. bulloides* d'Orbigny		R		R	R	R	R		F	F	R	F										R		C		R		F	F	R		
Globobulimina pacifica Cushman				F													R															
pyrula (d'Orbigny)				F														R								F			R			
Lagena cf. *L. acuticosta* Reuss						R	R														R											
spp.						R		R										R														
Nonion belridgensis Barbat and Johnson			R	?																		?		F								
Nonionella cf. *N. basispinata* (Cushman and Moyer)		F	R		R							R		F						F				R		C	F	R	?	?	F	?
miocenica Cushman			R	R			R	F			R											F		F	F			?				F
Polymorphina cf. *P. charlottensis* Cushman																		R														
Pullenia salisburyi R. E. and K. C. Stewart			R	F	R	C	F									F	R				R											
Pyrgo sp.						R																										
Quinqueloculina sp.					R	R	R	R			R									R		R										
Robulus sp.								R												R												
Rotalia cf. *R. garveyensis* Natland					F	F																R										
Uvigerina hootsi Rankin																F																
modeloensis Cushman and Kleinpell																C							?									
subperegrina Cushman and Kleinpell				C	C	F	C				R				?		R	R	R													
Virgulina californiensis ticensis Cushman and Kleinpell											C	R	F	R									C	C	R	C		R	?			?
subplana Barbat and Johnson			R	F		R	F	R							R	?				F												
Virgulinella miocenica Cushman and Ponton																													R			

FIGURE 8.—Foraminifera from the Montesano Formation.
(C=common; F=few; R=rare; ?=questionably identified)

Both *Bolivina brevior* and *B. rankini*, together with similar forms, are characteristic of the upper part of the Pacific coast Miocene sequence. Normally they are not found above the Delmontian Stage, although some do occur below in the middle part of the Miocene strata. *Buccella frigida* has a known occurrence that extends from middle Miocene to the Recent. Its importance is largely as a means of differentiating faunas of the Montesano Formation from those of the underlying Astoria Formation. *Buliminella curta* typically occurs in the Luisian, Mohnian, and Delmontian Stages, and is most common in the upper two stages. *Nonionella basispinata* and similar forms are common in beds of the upper Miocene and lower Pliocene of the Pacific coast. Their occurrence also extends up into Recent deposits. This form is particularly useful as an aid in differentiating assemblages of the Montesano Formation from those of the Astoria Formation. *Rotalia garveyensis*, although only tentatively identified in this report from limited occurrences in the Montesano Formation, has been noted in the formation by several other workers in the area (Billman, written communication, 1966; Fowler, 1965). This species has proven very useful, particularly in the Los Angeles basin, where its upper limit of occurrence has been found to mark the top of the Delmontian Stage. Although its occurrence in the Montesano Formation may not have the same stratigraphic significance as that in the Los Angeles basin, it is interesting to note that all occurrences of the form in the Montesano Formation are from the upper part of the unit. Therefore, based on past usage of the species, essentially all of the Montesano Formation would be considered no younger than the Delmontian Stage and thus no younger than late Miocene. *Uvigerina modeloensis* and *U. hootsi* are both characteristic of the Mohnian and Delmontian Stages, but are known also in the uppermost part of the Luisian Stage. They do occur above the Delmontian Stage, but only in limited numbers. *Virgulina californiensis* is well represented in the formation, and most specimens are best referred to the subspecies *V. californiensis ticensis*. The species is known throughout much of the Miocene sequence of the Pacific coast. However, the known occurrence of the subspecies *V. californiensis ticensis* is somewhat restricted geographically as well as stratigraphically, as its only recorded occurrence has been from the Mohnian Stage of California. *Virgulina subplana* is recorded only from a high position in the California Miocene sequence, being essentially confined to the Delmontian Stage. All other species listed in Figure 8 either are known to have a wide stratigraphic range, their identification is uncertain, or records of their stratigraphic occurrence are few, and therefore they have little, if any, stratigraphic significance. Nevertheless, it is apparent that those species discussed from the Montesano Formation and known to have stratigraphic significance in other areas of the Pacific coast, are characteristic and, in some cases, are confined to beds of the Mohnian or Delmontian Stages of the upper part of the Pacific coast Miocene sequence.

Locally, in the State of Washington, there are no other marine units known that can be correlated with the Montesano Formation on the basis of foraminifers or mollusks. Nonmarine beds in the Toledo-Castle Rock area (Roberts, 1958), where they are referred to as the Wilkes Formation, and to the north in the Centralia-Chehalis area (Snavely and others, 1958) are regarded as possibly late Miocene in age on the basis of contained plant fragments and superposition in relation to rocks of middle(?) Miocene age. These strata may have been deposited, at least in part, during marine deposition of the Montesano Formation to the west, but a direct correlation is not possible on the basis of either foraminifers or mollusks.

Weaver (1937, 1943) and Weaver and others (1944), using megafossils, correlate a part of the Montesano Formation with a part of the Empire Formation of the Coos Bay area of Oregon. However, they consider the fauna of the Empire Formation to be Pliocene in age. Insofar as is known to this writer, Foraminifera from the Empire Formation have not been studied.

In the vicinity of Depoe Bay, sandstone and some interbedded sandy siltstone beds that overlie the youngest volcanic rocks exposed along the coast have produced a few very meager foraminiferal assemblages (Snavely, written communication 1967). They suggest a noticeably younger age than is assigned to the beds of the Astoria Formation directly beneath the flows. It may have been that the youngest beds in this sequence were deposited at a time similar to that of the Montesano Formation.

In California a number of units are referred to either or both the Mohnian and Delmontian Stages of the upper Miocene sequence of the Pacific coast (Weaver and others, 1944), and all may well correlate with the Montesano Formation. A few of these formations warrant mentioning here, as their known foraminiferal assemblages compare favorably with those of the Montesano Formation. Originally Weaver (1912) considered the megafauna of the Montesano Formation to correlate with those of the San Pablo Formation of California. Although the writer is not familiar with the Foraminifera from the San Pablo unit, it is generally referred to the Delmontian Stage.

The Monterey Formation of California, although widespread both stratigraphically and geographically, does, in part, constitute the type Delmontian Stage in an area near the type area of the formation. The Foraminifera from an upper part of the Monterey Formation locally, at least in the vicinity of the type area, are similar to those of the Montesano Formation (Kleinpell, 1938). Barbat and Johnson (1934) record a well-known assemblage, sometimes referred to as the "Nonion-Nonionella" fauna, from the Reef Ridge Shale exposed on the west side of the San Joaquin Valley of

California. This assemblage is generally similar to that of the Montesano Formation. Several species are common to both formations, and a number of other forms from the Montesano Formation are similar to those of the Reef Ridge Shale of California. In addition, Foraminifera recorded from that part of the Modelo Formation of the Santa Monica Mountains in California that is regarded as the Mohnian Stage (Kleinpell, 1938; Pierce, 1956) are similar to many of those of the Montesano Formation.

QUATERNARY DEPOSITS

Deposits of Pleistocene(?) Age

Much of the northern part of the Wynoochee Valley quadrangle is thickly mantled with gravel and, in places, clay, silt, and sand. These sediments are thought to be Pleistocene in age. Thinner deposits are found capping many of the ridges throughout much of the remaining area to the south. Because this report is primarily concerned with the stratigraphy and structure of rocks of Tertiary age, no attempt is made to determine in detail the composition, source, or age of the overlying sediments. Nevertheless, observations on the areal extent of those deposits with a substantial thickness have been recorded and their distribution, although generalized, is shown on the map (Fig. 2, in pocket) by means of a black stippled pattern. Although not differentiated on the map, two major types of deposits are included: (1) thinly bedded, essentially varved clay and silt; and (2) sand and gravel.

Outcrops of clay and silt are confined largely to the valley floor of the Wishkah River and its tributaries in the northwest part of the mapped area. A few small deposits are present also in the northern part of the Wynoochee River valley and the various tributaries of the Satsop River. All these fine-grained thinly bedded deposits rest horizontally, or nearly so, on tilted beds of Tertiary age. They are typical lacustrine sediments that apparently were deposited as the result of temporary damming of the drainage, possibly by ice, some time early in the Pleistocene Epoch.

Thick deposits of crudely stratified, deeply weathered sand and gravel overlie the lacustrine sediments in the northern part of the mapped area and extend southward along many of the ridges. In places along the southern extent of the Wynoochee River valley, similar sand and gravel deposits occur at a lower level, forming terraces adjacent to the present river valley. These deposits are, at least in part, what Bretz (1913, p. 40) referred to as red gravel and later included in his Satsop Formation. They are composed largely of basalt pebbles and some red and gray argillite pebbles and other types also suggesting a local origin from the Olympic Mountains. The surface of these deposits is deeply weathered, and some basalt pebbles have been almost completely altered to clay minerals. The crude stratification of these deposits indicates that they had a fluvial origin and may well have been deposited as outwash gravels by runoff from melting ice in the local area of the Olympic Mountains during an early part of the Pleistocene Epoch.

Landslide Debris

Although landslides or small areas of mass wasting are distributed over much of the mapped area, the principal areas of landsliding are confined largely to places underlain by fine-grained rocks, mainly where major stream valley walls have been oversteepened during Recent or perhaps even late Pleistocene time. Siltstone and mudstone beds of the Astoria(?) Formation are particularly susceptible to landsliding. Typical examples can be viewed along the east side of the Wynoochee Valley road in sec. 27, T. 19 N., R. 8 W., where hummocky topography is well developed. Landslides are also common in areas underlain by certain mudstone and siltstone beds of the Lincoln Creek Formation, as can be seen where the Wynoochee River has cut through these rocks in the northern part of the Wynoochee Valley anticline. Although much of the Montesano Formation characteristically is not susceptible to landsliding, some of the fine-grained beds are less competent, and landslides have developed in them. Such slides have occurred in the valley of the West Fork of the Satsop River in the vicinity of Wyn Mountain, where the valley walls have been oversteepened, mainly along the major bends of the river.

Alluvium

Recent stream deposits of silt, sand, and gravel occur along all rivers and larger streams. Many are limited in areal extent and are subject to seasonal shifting. Therefore, only the most widespread and stable deposits are shown on the map (Fig. 2). They are confined mostly to the Wynoochee River valley and to the lower part of the Satsop River valley. These deposits generally range in thickness from a few feet to as much as 30 feet.

STRUCTURE

Most of the prominent structural features in the Wynoochee Valley quadrangle trend generally northward and northwestward. Of these, the most pronounced is the Wynoochee Valley anticline, which extends over much of the central part of the mapped area. It is a continuation of the Melbourne anticline, which is a major north-trending fold in the Montesano quadrangle to the south and which extends into the southern part of the Wynoochee Valley quadrangle. These two folds are separated by a west-trending downwarp that forms the west part of the Black Creek basin and the eastern end of the Wynoochee River syncline.

Folding and faulting of rocks of Tertiary age within the mapped area have taken place both before and after the deposition of the Montesano Formation. Pre-Montesano deformation is noticeably more severe and has resulted in the formation of numerous faults and large areas of steeply dipping beds. The northwest part of the mapped area is probably disturbed the most because it is closest to the Olympic Mountains, where major deformation has taken place. It is postulated here that the north- and northwest-trending faults and folds of the Wynoochee Valley area as well as surrounding areas are primarily en échelon structures and are the result of major lateral northeast-trending forces. Lateral displacement has taken place during, and in places after, the development of northwest-trending structures. One such northeast-trending fault that formed after the development of northwest faults and folds is mapped (Fig. 2) in the area of a part of the East Fork of the Wishkah River. To the northwest of the Wynoochee quadrangle, other northeast-trending faults have been mapped in the valley of the upper part of the Wynoochee River, the Humptulips Valley, and the Quinault Valley (Harvey, 1959; Huntting and others, 1961). Lateral movement on such major faults near the southern periphery of the Olympic Mountains may well have been the mechanism that has caused en échelon northwest-trending faults and folds common to the Wynoochee Valley quadrangle, as well as surrounding areas to the south and east.

Not only did the pre-Montesano deformation result in folding and faulting of the rocks but, as indicated by the erosion surfaces formed on these rocks, general uplift and emergence of the area must have followed.

FOLDS

In the northwest part of the Wynoochee Valley quadrangle, in the area drained by the various forks of the Wishkah River and its tributaries, rocks of the Astoria(?) Formation and the Lincoln Creek Formation are strongly deformed. Many of the folds are too small to show on the map, and because exposures between streams are limited, it is not possible to trace these folds any appreciable distance. Therefore, only gross structures of this area are shown. The Wynoochee Valley anticline lies east of this area and is the largest of the known folds in rocks of pre-Montesano age. It is asymmetrical with the west flank noticeably steeper than the east; it plunges to the south and is faulted, at least in the northern part. Its extent is, for the most part, well delineated, particularly in the area of Carter Creek and the Wynoochee River valley.

The north-plunging Melbourne anticline to the south is separated from the Wynoochee Valley anticline by an east-west downwarp in the southern part of the mapped area. Rocks of the Astoria(?) Formation are exposed in the central part of this structure. These beds plunge northward; their area of outcrop bifurcates, and a western part extends across the Wynoochee Valley. This western part is here designated the Caldwell Creek anticline. West of the Wynoochee River, rocks of the Astoria(?) Formation plunge northwestward beneath the Montesano Formation. According to the attitudes within these younger beds of the Montesano Formation, they have been folded upward to some extent also in the area north and east of Wedekind Creek.

The downwarp formed between this anticline and the Wynoochee Valley anticline is here referred to as the Wynoochee River syncline. This structure is easily discerned along the Wynoochee Valley road and in the high cliffs along the Wynoochee River.

To the south of the Caldwell Creek anticline lies a downwarp whose axis extends westward approximately along a part of Wedekind Creek, and therefore it is referred to here as the Wedekind Creek syncline. All rocks exposed within the area of this structure are referred to the Montesano Formation.

The Black Creek basin lies east of the southern part of the Wynoochee Valley anticline and the north end of the Melbourne anticline. Several synclinal structures plunge toward Black Creek in this area and form a shallow basin-like structure. Minor flexures are present within this area, but the preponderance of structural data substantiates a major basin-like structure.

The north flank of the Black Creek basin constitutes the south limb of the Still Creek anticline. Within the central part of this area, structural, as well as lithologic, details are not readily discernible due to poor exposures. However, based on the available structural information from surrounding areas, an upwarp is indicated. Those rocks from which structural information is available are referred to the Montesano Formation, and therefore the Still Creek anticline was formed after the deposition of the Montesano Formation.

In the vicinity of an east tributary to Carter Creek (sec. 6, T. 19 N., R. 7 W.) a small area of outcrop is mapped as the Lincoln Creek Formation. Several west dips suggesting a reversal are recorded in this area. These rocks are surrounded by younger beds of either the Astoria(?) Formation or the Montesano Formation. Although the dips in beds of the Montesano Formation are somewhat less than those in the older rocks, broad folding has taken place also in these surrounding younger rocks. Therefore, it is suggested that an upwarp may well have formed in this area prior to the deposition of the Montesano Formation, but that some additional uplift may have taken place during post-Montesano time as well (Fig. 2, Cross Section A-A′).

In the northeast part of the Wynoochee Valley quadrangle, beds of the Montesano Formation are gently folded into a broad shallow syncline that plunges southeastward in the Canyon River area. On the basis of flat-lying beds, it is considered that the axis of this structure probably continues southward into the Smith Creek area, where structural evidence indicates an additional downwarp that plunges northward. The entire feature is referred to here as the Canyon River-Smith Creek syncline. Although the preponderance of structural data from this relatively large area of lower dips indicates a major downwarp, there is also evidence for a number of small flexures or folds within this area of major downwarp.

FAULTS

Although a number of faults have been mapped, particularly in rocks older than the Montesano Formation, others may not have been recognized because of the lack of continuous exposures and the great thickness of massive beds in much of the area. Faults are shown only where steeply dipping beds and shearing are apparent, and where faulting is necessary to explain otherwise anomalous stratigraphic relations. In some cases the observed distribution of rock units could be explained by other means, such as folding or lithofacies changes, but because greatly disturbed strata do occur in these areas, faulting appears the most likely manner in which the distribution of beds may have taken place. Many of the faults proposed in the older rocks in the northwest part of the mapped area are based on incomplete evidence, and therefore their exact position and complete extent are not known.

Three ages of faulting are shown, two of which are confined to rocks older than the Montesano Formation; the third group cuts that formation as well as the older rocks. In the former two groups, those faults trending northwestwardly are far more common. They are thought to be, for the most part, normal faults. As previously mentioned, it is believed they are the result of drag on more profound ruptures on which lateral displacement has taken place in northeast and southwest directions. One such fault is mapped (Fig. 2) in the vicinity of the East Fork of the Wishkah River, but because the northwest-trending faults of this area are cut and displaced by this strike-slip fault, much of the movement on it took place after the northwest-trending faults were formed. However, it is thought that lateral movement on other northeast-trending faults (not shown on the map) is responsible for most of the forces that caused the northwest-trending faults as well as folds. These northwest-trending structures may be regarded mostly as en èchelon faults and folds resulting from drag caused by strike-slip movement on major northeast-trending faults. The magnitude of horizontal displacement on these strike-slip faults is shown in the vicinity of the East Fork of the Wishkah River, where northwest-trending faults have been displaced approximately 1 mile to the northeast on the southeast side of this strike-slip fault. Lateral movement may have taken place on some of the northwest-trending faults also, but probably at a later time following their initial rupture. Most of these faults, as well as folds parallel to them, display a broad arcuate pattern suggesting a major bowing of the rocks in a northeasterly direction. The bending of these structures may have resulted in additional movement on many of the northwest-trending faults, but in a strike-slip manner. This movement may have taken place in the period of faulting and folding during which the Montesano Formation as well as older rocks were displaced.

Although only a few faults are mapped as cutting the Montesano Formation, others undoubtedly exist. Only those that are obvious or necessary to explain certain stratigraphic relations are shown. Of these, perhaps the most extensive is shown in the north-central part of the map (Fig. 2) trending northwestwardly across the Wynoochee Valley and the upper part of Carter Creek. Evidence for this fault is particularly apparent in the Wynoochee River valley where greatly disturbed rocks of the Montesano Formation can be seen in contact with the Lincoln Creek Formation. This is one of the few places in the area where beds of the Montesano Formation are steeply dipping. Several other faults are known to cut the Montesano Formation, but local evidence of deformation is less, and because they cannot be traced for any appreciable distance, their extent is unknown.

UNCONFORMITIES

Unconformities record at least three periods of major emergence: (1) after the deposition of the Crescent Formation and prior to that of sedimentary rocks of late Eocene age, (2) following the deposition of the Astoria(?) Formation and before the deposition of the Montesano Formation, and (3) the period of final emergence some time after deposition of the Montesano Formation and prior to the deposition of Pleistocene deposits. Surface evidence for the first of these unconformities, which was formed during Eocene time, is limited to the northwest part of the mapped area. However, in other parts of western Washington this unconformity is manifested by greater induration of sedimentary rocks below than above the contact, by angular differences in the bedding of the units involved, and by a profound difference in the foraminiferal assemblages occurring in the rocks below and above the contact (Rau, 1966). This unconformity, although not recognized everywhere, has been noted in a number of places throughout both western Washington and Oregon. Therefore, it probably constitutes one of the principal hiatuses in the geologic record of that region.

The second major unconformity occurs between the Montesano Formation and underlying rocks and is extremely well marked in the geologic record of the Wynoochee Valley quadrangle. The following evidence makes this break obvious. In many places a decided angular difference can be seen between the bedding of the Montesano Formation and the rocks below. This is particularly apparent in the East Fork of the Wishkah River, Helm Creek, and the Wynoochee River valley, where very steeply dipping beds of the Astoria(?) Formation are overlain by moderately dipping beds of the Montesano Formation. In this same area and additional areas to the east, probably the most obvious evidence for unconformability is that structural trends in the older rocks are interrupted at the contact of the overlying Montesano Formation. In most places where the contact can be seen in the Wynoochee Valley quadrangle, the Montesano Formation rests on the Astoria(?) Formation. However, immediately to the northeast, in the West and Middle Forks of the Satsop River, the Astoria(?) Formation is cut out and the Montesano Formation lies on the Lincoln Creek Formation. The actual pre-Montesano irregular erosional surface can be seen in a number of places throughout the area, as in the Middle Fork of the Wishkah River valley and in the Wynoochee River valley, where filled remains of borings have been discerned in the underlying Astoria(?) Formation. Foraminiferal evidence also strongly supports an angular unconformity at the base of the Montesano Formation. Assemblages collected from immediately below the Montesano Formation at various places in the mapped area and nearby vicinity are assigned variously from late Oligocene to middle Miocene in age (Zemorrian, Saucesian, Relizian, and possibly Luisian Stages). All foraminiferal assemblages collected from the Montesano Formation suggest a late Miocene age (Mohnian and Delmontian Stages). Therefore, within this area beds believed to be no older than late Miocene in age rest unconformably on rocks ranging in age from as old as late Oligocene (Lincoln Creek Formation, Zemorrian Stage) to as young as middle Miocene (Astoria(?) Formation, Relizian, and possibly Luisian Stages).

The third major unconformity records the last emergence and a period of erosion that took place some time following the deposition of the Montesano Formation and prior to the deposition of Pleistocene(?) clays, silts, and gravels. Bedding in the latter deposits is almost always horizontal, or very nearly so. In many places the horizontal or low-dipping beds of overlying material are in noticeable contrast with the moderately dipping beds of the underlying Montesano Formation and older rocks, thus marking a decided angular unconformity.

Local unconformities may exist in other parts of the Tertiary section, but are not thought to constitute major breaks in the geologic column. In several places angular relationships have been noted between beds of the Montesano Formation. Although these may be penecontemporaneous features, it is possible also that they do represent short periods of local uplifts during "Montesano time."

ECONOMIC GEOLOGY

OIL AND GAS POSSIBILITIES

The possibility of finding substantial quantities of petroleum in western Washington has intrigued oil operators for many years, and although considerable amounts of oil and gas have been found, none have been in commercial quantity. Eight test wells have been drilled within the Wynoochee Valley quadrangle, and some shows of petroleum have been found but not in a quantity great enough to be of commercial value. Six of these wells were drilled, presumably on the Caldwell Creek anticline, in the southwestern part of the mapped area; one was drilled in the northwestern part of the map area; and the other in the vicinity of the Still Creek anticline, in the southeast (Fig. 2, in pocket). Records indicate that four of the six wells drilled in the vicinity of the Caldwell Creek anticline resulted in shows of oil or gas ranging from good to slight (Livingston, 1958). These eight wells have tested only three areas within the more than 200 square miles of the Wynoochee Valley quadrangle, and there remain a number of favorable areas yet to be tested. Nearly the entire area is underlain by strata thousands of feet thick that can be regarded as a favorable source for oil and gas. Although there are no known oil or gas seeps within the area, essentially all mudstone and siltstone beds of the Lincoln Creek and Astoria(?) Formations emit a strong petroliferous odor when freshly broken. For the most part, these formations are reasonably rich with the skeletal remains of invertebrate organisms, particularly foraminifers, radiolarians, and mollusks, and therefore confirm the existence of organisms during deposition of these rocks. The overlying Montesano Formation also contains appreciable numbers of fossils, particularly mollusks, but they are concentrated in lenses or other small parts of the formation and therefore suggest the presence of less organic material throughout the formation than do those strata below.

The rocks that appear most favorable as reservoirs are in the Montesano and Astoria(?) Formations. Most of those beds mapped (Fig. 2) as Tmss and Tmc in the Montesano Formation are reasonably clean and well-sorted medium-grained sandstones, grits, and conglomerates. No laboratory tests were made, but field observations suggest that many of these beds probably could serve as excellent reservoirs for petroleum.

Because the Montesano Formation is the youngest Tertiary unit in the area, its sandstone and conglomerate beds are nowhere at great depths, and in many places are at the surface. However, in numerous other areas these potential reservoir rocks are capped by relatively impervious siltstone and mudstone beds, mapped largely as Tmsl. Where these cap rocks are present, stratigraphic conditions for potential reservoirs do exist at shallow depths. The underlying Astoria(?) Formation also contains sandstone beds, although generally they are finer grained and less well sorted than those of the Montesano Formation. Because in most places the Astoria(?) Formation has undergone more disturbance than the Montesano Formation, it is difficult to accurately trace the extent of many of the sandstone units, particularly in areas of few continuous outcrops. However, several were noticed and mapped for short distances in the Wishkah River area and also along the east flank of the Wynoochee Valley anticline. Sandstone beds of the Astoria(?) Formation are present also in the area of the Melbourne anticline extension, but were not mapped because of the limited extent of their outcrop area.

The underlying Lincoln Creek Formation and sedimentary rocks of late Eocene age constitute a thickness of as much as 10,000 feet, but probably few of these beds serve as reservoirs for petroleum. Most of them are highly tuffaceous siltstones and poorly sorted fine-grained sandstones. A few coarser grained, relatively thin sandstone beds are known in these rock units, but, because of their high volcanic ash content and poorly sorted nature, it is not likely that their permeability and porosity would be particularly favorable for reservoir conditions. A basaltic sandstone unit, possibly at least 100 feet in thickness, is known to be present in adjacent areas at the base of the Lincoln Creek Formation; however, where seen on the surface this unit is also poorly sorted and therefore there would be some question about its quality as a reservoir rock.

Structures or possible conditions in which petroleum could be trapped are common within the Wynoochee Valley quadrangle. All the anticlinal structures mapped can be considered potential traps for petroleum. Most of them have not been drilled. Although six wells were drilled in the vicinity of the Caldwell anticline, the most favorable part of this structure was not tested. The Continental Oil Co.-Griffin-Wagner well was the only attempt to test the Still Creek anticline. All other major anticlines have not been drilled, and some of them may be particularly attractive to future operators. Of especial interest may be the Melbourne anticline extension, parts of the Wynoochee Valley anticline, and additional parts of the Caldwell Creek anticline.

Besides the major anticlinal structures, many small shallow folds are present in the Montesano Formation and can also be considered potential traps for petroleum. Conditions besides anticlinal structures, such as the thinning or pinching out of sandstone beds, particularly in the Montesano Formation, can also be considered favorable for trapping of oil and gas. The onlap of beds of the Montesano Formation on upturned beds of the Astoria(?) and Lincoln Creek Formations also may form conditions favorable for trapping of petroleum. Faults may play a part in forming reservoir situations, particularly in the northwestern part of the area. However, details necessary to evaluate any potential trap in that area would be difficult to obtain because continuous outcrops are limited in extent.

In summary, great thicknesses of potential source beds overlain by substantial thicknesses of reasonably good reservoir rock are present at shallow depths in the Wynoochee Valley quadrangle. Numerous structural and stratigraphic conditions exist in which commercial quantities of oil and gas could be contained.

OTHER COMMODITIES

The only basalt available for quarrying crops out north and west of the Middle Fork of the Wishkah River. It is mapped as Tc and constitutes the volcanic flows of the Crescent Formation. Basalt from this formation generally does not produce high-quality road metal or aggregate because it contains much devitrified glass, chlorite, and other minerals that cause the rock to break down under heavy loads. Because no other source of basalt is known in place for a considerable distance to the south, this rock is used locally on logging and forest roads.

Other sources of road rock are the various gravels of Pleistocene(?) age and the alluvium in the major river valleys. The older gravels of Pleistocene(?) age form a thick cover over much of the northern part of the area and over many of the ridges to the south, particularly along the western part of the mapped area. These gravels are deeply weathered and therefore do not make high-quality road material. However, because of their availability, they are used locally on many of the forest roads. The best materials from these deposits are at depth, and by removing the greatly weathered gravel at the surface, in most places less weathered and higher quality material can be found. Within the mapped area, probably the best materials available for road metal and other aggregate are the sand and gravel bars along the lower part of the Wynoochee River and possibly the Satsop River. They are composed largely of basalt, some intrusive rocks, and gray and red argillites that have withstood transportation downstream from Pleistocene(?) gravel deposits, as well as directly from the Olympic Mountains. Because some rather large areas of the Wynoochee Valley quadrangle are not covered by gravel and are otherwise some distance from a source of road material, some consideration should be given to the conglomerates of the Montesano Formation (mapped as Tmc) (Fig. 2) if exposed where such material may be needed. Although these conglomerates are somewhat indurated, nevertheless they could be quarried and crushed to produce a reasonably good road material for local use.

Although no tests were run in connection with this study, material for lightweight expandable aggregate may well be present within the mapped area. The highly tuffaceous siltstone beds of the Lincoln Creek Formation and also the siltstone beds of the Astoria(?) Formation warrant testing, provided a local market for such material exists.

Some of the lacustrine clay or silt deposits of Pleistocene(?) age that are present immediately above the Tertiary rocks in the Wishkah River and its tributaries are particularly well sorted and may have some commercial value, perhaps as abrasives or for other uses.

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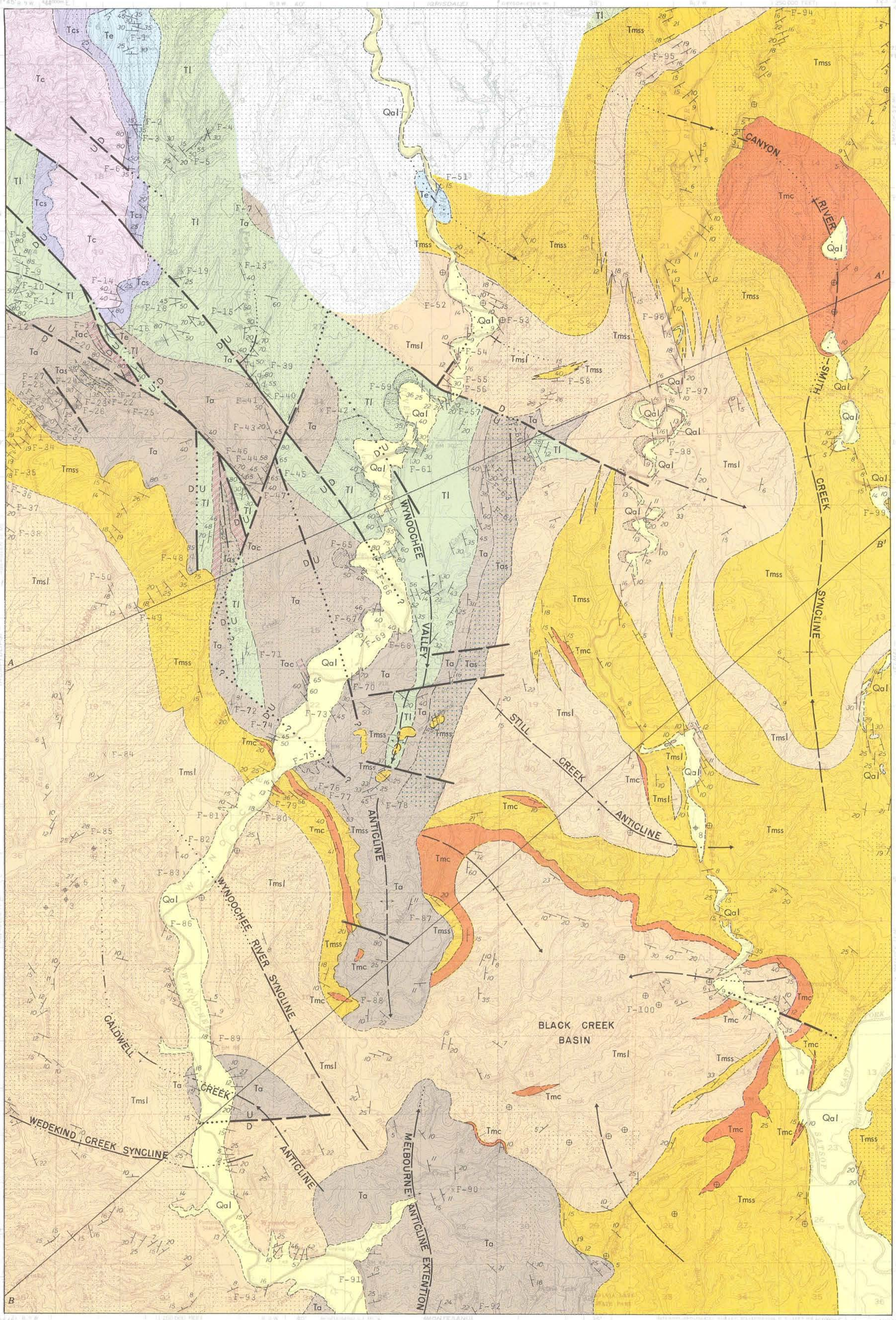
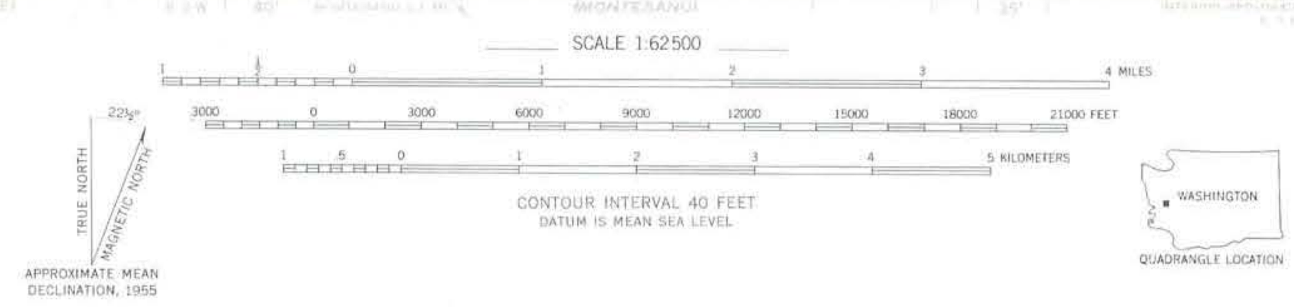
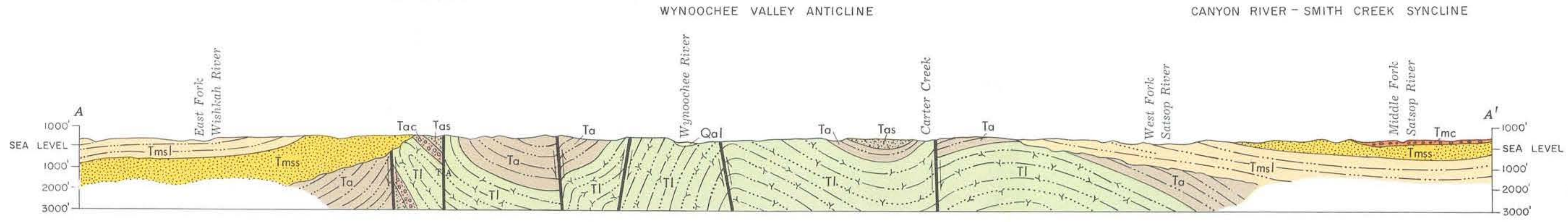
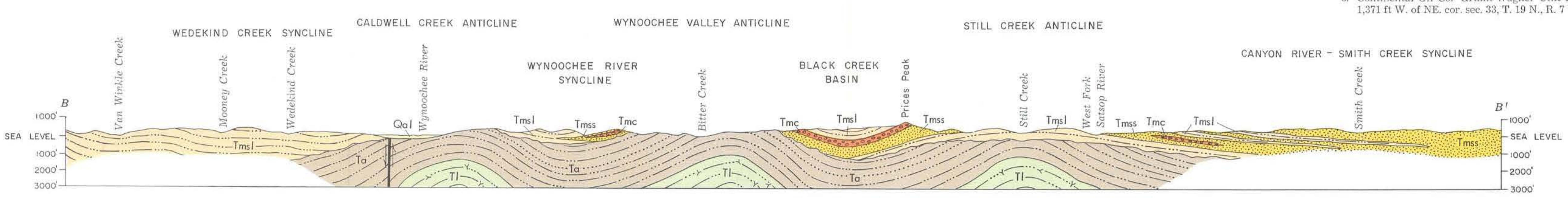


Base map by U.S. Geological Survey, 1955

Geology mapped in 1963-66







EXPLANATION

QUATERNARY

Recent

Qal

Alluvium
Unconsolidated silt, sand, and gravel

Pleistocene and Recent

Landslide debris
Areas of slumped masses of bedrock

Pleistocene(?)

Approximate area covered by deposits of Pleistocene(?) age
Gravel, sand, silt, and clay, largely of fluvial origin. Gravel is commonly iron stained and deeply weathered. Blue silt and clay lacustrine deposits, commonly laminated, occur in places beneath gravel and are exposed mostly in the valley floor of the Wishkah River and its tributaries

UNCONFORMITY

TERTIARY

Upper Miocene

Tmc, Tmss, Tmsl

Montesano Formation
Tmsl, *massive to well-bedded light olive-gray mudstone, siltstone, and very fine-grained silty sandstone*
Tmss, *friable massive light-gray well-sorted medium- to coarse-grained sandstone*
Tmc, *grit, pebble, and small cobble conglomerate composed chiefly of basalt, red limy argillite, and other "Olympic" type rocks*

UNCONFORMITY

Lower and middle Miocene

Ta, Tas, Tac

Astoria(?) Formation
Ta, *mostly massive to well-bedded chocolate-brown micaceous carbonaceous siltstone and sandy siltstone. Includes undifferentiated sedimentary rocks, mostly siltstone and fine-grained sandstone*
Tas, *massive to well-bedded light-gray fine- to medium-grained silty feldspathic micaceous carbonaceous sandstone*
Tac, *very poorly sorted conglomerate consisting of well-rounded clasts ranging in size from fine sand to large boulders of dense basalt, argillite, and indurated sandstone. Some clasts are limy concretions.*

Eocene and Oligocene

Tl

Lincoln Creek Formation
Very massive tuffaceous concretionary fossiliferous olive-greenish-gray mudstone, siltstone, and silty fine-grained sandstone

Upper Eocene

Te

Sedimentary rocks of late Eocene age
Bedded siltstone and fine-grained micaceous sandstone and some scattered concretions

UNCONFORMITY

Middle Eocene

Tcs, Tc

Crescent Formation
Tcs, *indurated well-bedded dark-gray siltstone and lesser amounts of sandstone*
Tc, *pillow and massive flows and volcanic breccia. Some flows are vesicular; much zeolitic material in fractures and vesicles*

Contact
Long dash where approximately located; short dash where indefinite or concealed

D
U
?

Fault
Dashed where approximately located; dotted where concealed; queried where doubtful. U, upthrown side; D, downthrown side. Arrows indicate direction of apparent movement

Anticline Syncline
Folds, approximately located
Showing trace of axial plane and direction of plunge. Dotted where concealed

35
Strike and dip of beds

75
Strike and dip of overturned beds

Strike of vertical beds

⊕
Horizontal beds

F-47
Foraminifera collecting locality

2
Dry holes

1. Continental Oil Co. State No. 1. 707 ft N., 1,640 ft W. of SW. cor. sec. 36, T. 20 N., R. 9 W.
2. Continental Oil Co., Wishkah No. 1. 909 ft S., 1,000 ft W. of NE. cor. sec. 1, T. 18 N., R. 9 W.
3. Wishkah Oil Corp. and E. A. Sims et al. Grays Harbor-Sims No. 1. NW¼NW¼ sec. 6, T. 18 N., R. 8 W.
4. The Sharples Corp. Fee-Sims No. 2. 217 ft N., 250 ft E. of SW. cor. sec. 31, T. 19 N., R. 8 W.
5. Continental Oil Co. Sims Oil Royalty Co. No. 1. 547 ft N., 1,125 ft E. of SW. cor. sec. 31, T. 19 N., R. 8 W.
6. The Sharples Corp. Weyerhaeuser No. 2. 3,354 ft N., 2,315 ft W. of SE. cor. sec. 31, T. 19 N., R. 8 W.
7. The Sharples Corp. Fee-Sims No. 1. 940 ft N., 990 ft W. of SE. cor. sec. 31, T. 19 N., R. 8 W.
8. Continental Oil Co. Griffin-Wagner Unit No. 1. 1,576 ft S., 1,371 ft W. of NE. cor. sec. 33, T. 19 N., R. 7 W.

GEOLOGIC MAP AND SECTIONS OF THE WYNOOCHEE VALLEY QUADRANGLE, WASHINGTON

By

Weldon W. Rau

1967