COLUMBIA RIVER BASALT IN RELATION TO STRATIGRAPHY OF NORTHWEST OREGON

by

HERBERT G SCHLICKER

A THESIS

submitted to

OREGON STATE COLLEGE

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1954

APPROVED:

Redacted for privacy

Professor of Geology

In Charge of Major

Redacted for privacy

Head of Geology Department

Redacted for privacy

Chairman of School Graduate Committee

Redacted for privacy

Dean of Graduate School

Date thesis is presented 6/6/53

Typed by Mary Willits

ACKNOWLEDGEMENTS

For his direction and consideration during the preparation of this thesis, I wish to extend my appreciation to Dr. L. F. Hintze.

Mr. H. A. Boyd was of immeasurable assistance in the writing of the thesis and to him I am gratefully indebted.

The writer wishes to extend his appreciation to Dr. I. S. Allison for his helpful criticisms and suggestions as well as for the final reading of this thesis.

For assistance on several field trips and for the discussions on flora in this thesis, the writer takes pleasure in expressing thanks to Mr. Herbert L. Hergert.

Appreciation is expressed to the fellow graduates and students for their assistance and cooperation. To my wife, Bethene, for her help in typing and to my family for their patience and understanding throughout the year I express my deepest appreciation.

TABLE OF CONTENTS

Page

LIST OF PLATES

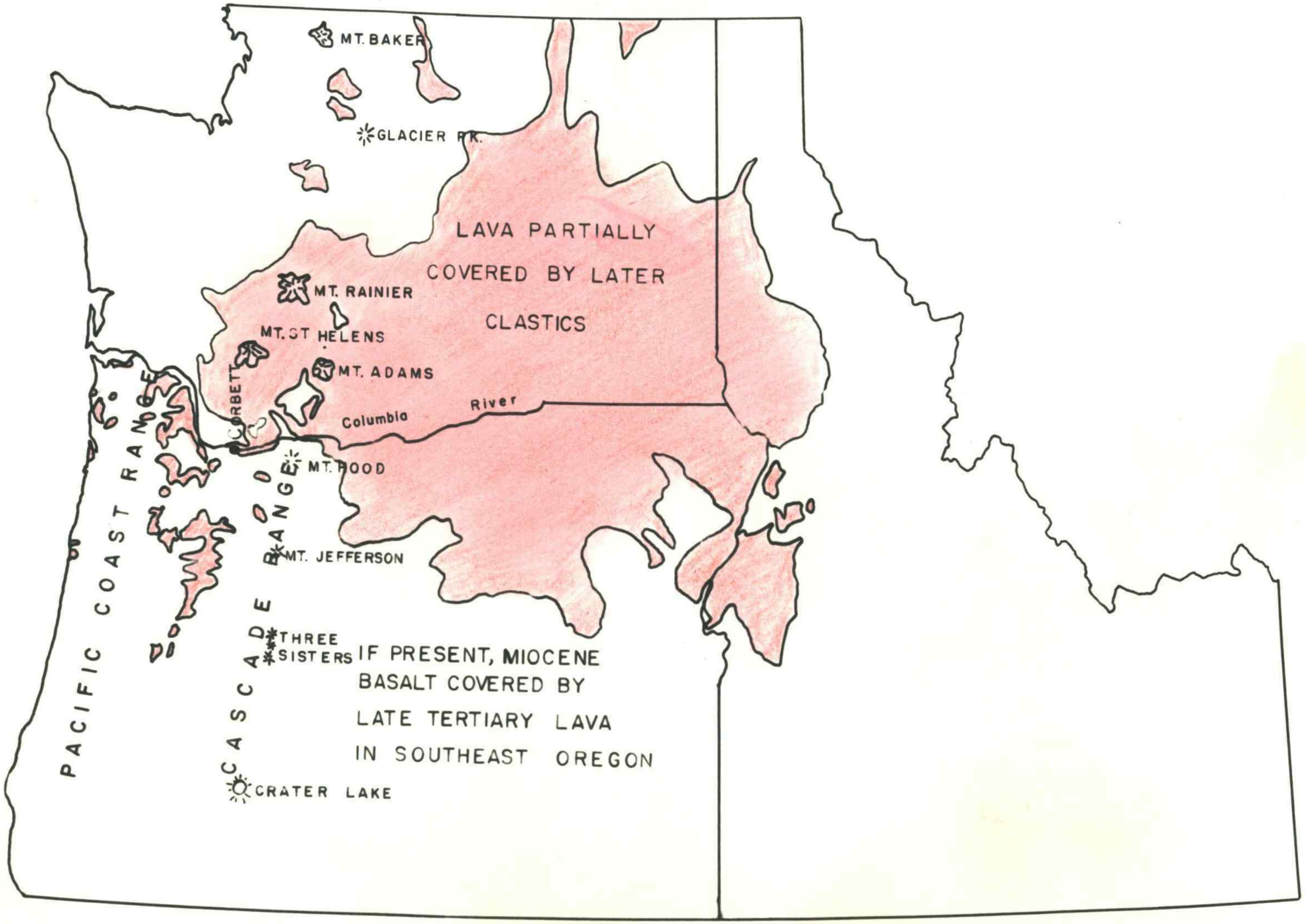
COLUMBIA RIVER BASALT IN RELATION
TO STRATIGRAPHY OF NORTHWEST OREGON

INTRODUCTION

Miocene basalts are exposed over some 200,000 square miles in the Columbia Plateau of northeastern Oregon, eastern Washington, and central Idaho (see Plate I), extending westward to the Cascade Range where they disappear beneath the later volcanics. The Miocene basalt can be traced westward beneath the Cascades in the Columbia River Gorge as far west as Corbett, Oregon, where it dips westward below younger formations. In the Willamette Valley basalts resembling the Columbia River basalt are observed to emerge from beneath younger lavas.

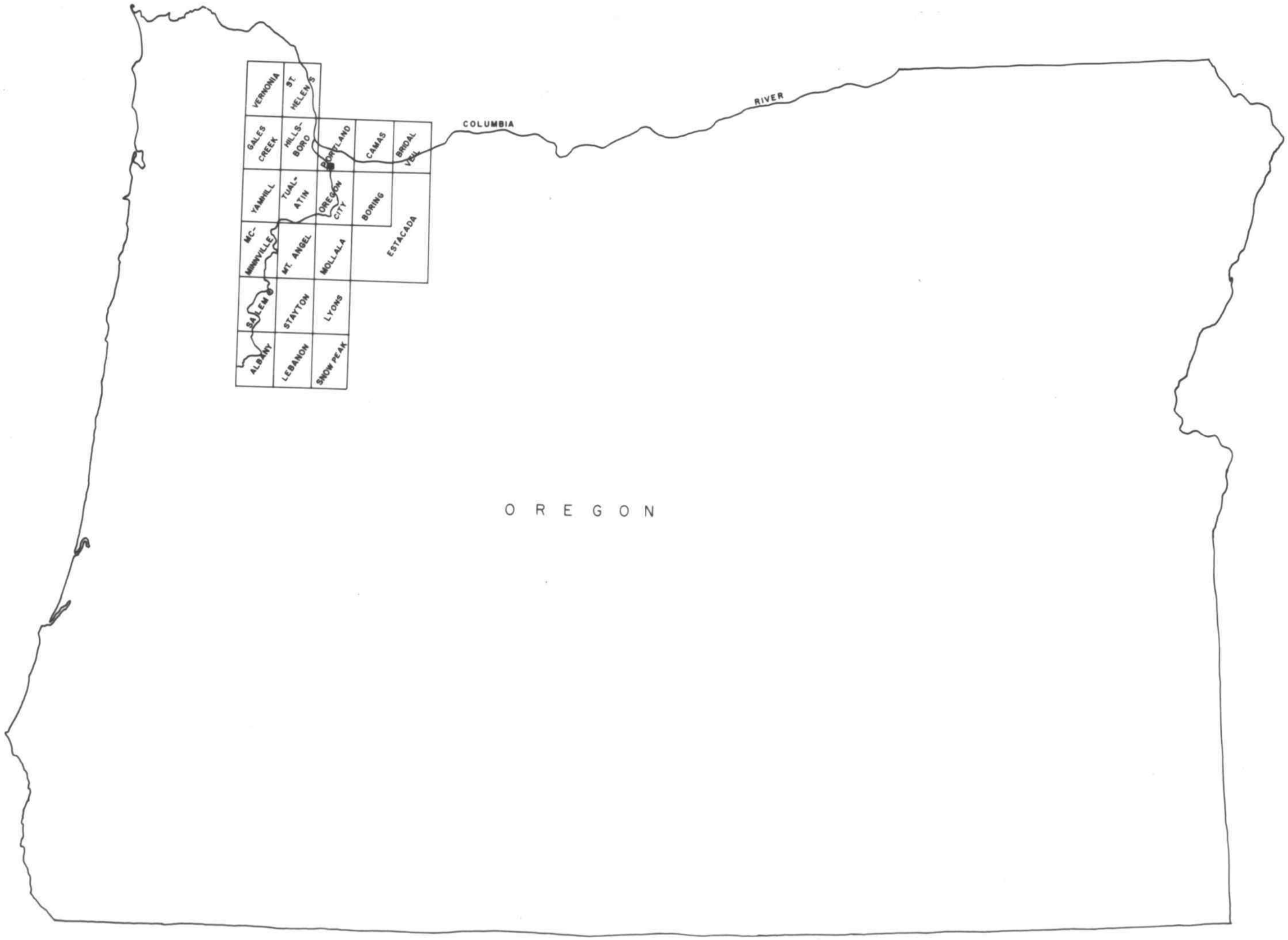
It was intended that this thesis deal with the correlation of Miocene basalts in the northern Willamette Valley; however, after reviewing the available literature of the superjacent and subjacent formations in this area, the writer found it essential to correlate additional strata. The problem has evolved into a study of the relationship of the Columbia River basalt in relation to the stratigraphy of northwest Oregon.

In order to evaluate the problem properly, it was necessary to compile a geological map of northern Willamette Valley area (Plate X), as no such compilation was known to exist. The location in Oregon of the area studied is shown on Plate II together with quadrangle names. The map was



DISTRIBUTION OF MIOCENE BASALT PLATE I

INDEX MAP SHOWING LOCATION OF QUADRANGLES **PLATE II**



compiled from all available published and unpublished sources as credited in the Index to Geologic Mapping on Plate X. In addition the writer spent more than a month in the field tracing formations across previously unmapped areas. Since in previously mapped areas various names were used for equivalent formations, it was necessary to review the stratigraphic nomenclature of the northern Willamette Valley formations as defined and used by various authors. In order to show the structural and stratigraphic relationship of the Columbia River basalts to other rock units in the Valley a correlation table (Plate IX) was prepared showing the usage of various authors and the usage adopted in this paper. A review of the formations directly or indirectly involved in this problem is presented on following pages.

Identification of the various lavas occurring in the Tertiary stratigraphy of northwest Oregon was attempted by petrographic means. The author cut 25 thin sections, mostly from rock identified in the field, in order to examine the Eocene (Tillamook), Miocene (Columbia River), and Pliocene (Boring or Cascade) lavas for individual characteristics useful in determining the age of unknown specimens by thin section. No apparent criteria for thin section recognition of these various lavas were observed because the lava in one formation varies in mineralogy and texture from flow to flow, and vertical and horizontal gradations occur within a single flow. Mineral alteration appeared to be the most reliable criterion; however, it was best observed in the field.

The Willamette River extends north and south through the approximate center of the area. The area can be divided into three topographic units, the Willamette Valley and river terraces, the Cascade foothills to the east, and the older rocks of the Coast Range uplift to the west. The structure and physiography west of the Cascades are the dominant factors which obscure direct evidence for correlating the Miocene basalts in the Willamette Valley with the lavas of the Columbia Plateau.

South of Salem the Willamette Valley is typified by the river floodplain, a broad valley floor, lateral gravel terraces, and scattered buttes. Approximately twelve miles south of Salem the north-dipping Miocene basalt at the interpreted axis of the Willamette syncline (Plate VII) projects above the valley floor to form the southern escarpment of the Salem Hills. Farther south along the axis of the syncline the basalt remains only at higher elevations as cappings on certain buttes.

The rocks become progressively older towards the axis of the Coast Range uplift to the west. The Columbia River lava of the eastern limb of the Willamette syncline is buried beneath the later Tertiary volcanics of the Cascade mountains, but the lava in the west limb has been undercut by erosion of the less resistant Oligocene sediments and crops out as a westward facing escarpment. Farther to the west Eocene lavas which form the core of the Coast Range dip beneath the Oligocene and upper Eocene strata. Occasionally these older lavas greatly resemble the Miocene lavas and they are identified, when possible, by their geographic and stratigraphic position.

PREVIOUS GEOLOGIC WORK IN NORTHWEST OREGON

Geologists spent the first sixty years in northwest Oregon concentrating on the geology along the Columbia River. As later work was done some distance away from the Gorge, direct correlations were not made and local formational names were used. The following brief chronological history of geologic studies in northwest Oregon is here presented to show why certain correlations were not made earlier.

Hodge (20) reports that Thomas Condon in 1871 collected leaves from the Warrendale formation (at that time unnamed), which crops out beneath the Columbia River basalt in the Gorge. This formation was described by LeConte (21) in 1873, and leaves which he collected were identified as Miocene by Lesquereux (22).

In 1896 Diller (15) discussed the Cascade Range and pointed out that minor volcanic activity occurred before extrusion of the Columbia River basalts. He named the pyroclastic material which occurs beneath the Columbia River basalt, the Eagle Creek formation. This name was preoccupied, however, so Packard and Smith (29) later proposed the name Warrendale formation in its stead.

The Satsop gravels overlying the Columbia River basalts were described by Bretz (7) and were traced across the Cascade anticline by Williams (44). Later, Bretz (8) examined the Satsop gravels in the Gorge and correlated them with the type Satsop section near Kelso, Washington.

Barnes and Butler (5) mapped the formations along the Columbia River Gorge and southward along the border of the Estacada and the Mt. Hood quadrangles. They discussed the regional structure and stratigraphy of the Cascade Range.

In 1932 Sheets (32) and Allen (1) discussed the geology of the Columbia River and Mt. Hood vicinity. Bogue (6) made a detailed study of the petrography of the Mt. Hood and Columbia River lavas. These writers criticized and amplified the work of Barnes and Butler.

Felts (17) mapped the Lebanon quadrangle in 1936, wherein he applied the names Scio beds and Berlin volcanics respectively to the tuffs and breccias occurring below the Miocene basalts.

A detailed discussion of the geology of the Columbia River Gorge and the Cascade Range was presented by Hodge (20) in 1938. Hodge gave the name Troutdale to certain gravels previously included by Bretz in the Satsop, thus restricting the term. He also described and named the Rhododendron formation.

Thayer in 1939 (34) published a geologic report on the Salem Hills and Santiam Basin in which were discussed some new aspects of the structure of the Cascades. He named and described the Illahe formation, a fossiliferous marine tuffaceous sandstone occurring below the Columbia River basalt. He called the terrestrial equivalent of the Illahe formation the Mehama volcanics. He studied formations near the crest of the Cascades and suggested that the Olallie lavas are a possible equivalent of the Rhododendron formation. He applied the name Fern Ridge tuff to the thick post-Miocene tuff beds.

The Salem quadrangle was mapped in 1939 by Mundorff (26). He named (unpublished) the Helmick beds which contain a marine fauna older than that of the Illahe. They were thought to be Eocene on the basis of macrofossils.

O'Neill (28) mapped the Stayton quadrangle in 1939. He reported that the terrestrial Mehama volcanics lay to the east of the Stayton quadrangle. A geologic investigation of Portland and vicinity by Treasher (35 and 36) was published in 1942. The mapped area included the Oregon portions of Portland, Camas, Oregon City, and Boring quadrangles. He gave the names Boring "agglomerate" and Boring lavas respectively to the breccia and overlying expanded basalt of Plio-Pleistocene age. The latter is typically exposed in the Boring quadrangle. These were presumed to be related to the Rhododendron and "Cascan" formations of Hodge but were extruded from local sources.

In 1944 Nichols (27) investigated the Molalla area for high-alumina clay. He believed the clastic Molalla formation to be lower Miocene and stratigraphically beneath the

Stayton lavas. He also suggests the possibility of intra-Molalla basalt flows.

Wilkinson et al (43) mapped and described the geology in the St. Helens quadrangle. They applied the name Goble volcanics to upper Eocene basalt and related sediments.

Libby et al (23) in 1945 discussed the laterization of the Columbia River basalt in northwest Oregon. They stated the possibility of dating the folding by use of the present position of laterite.

Warren et al (39) mapped the northwest corner of Oregon. They named the volcanic core of the Coast Range the Tillamook volcanics which are in excess of 5,000 feet thick. They also describe sedimentary rocks and contained faunas ranging in age from Eocene to Pleistocene.

The geology of the Molalla quadrangle was completed by Harper (18) in 1946. He named (unpublished) the Molalla formation which he tentatively assigned to the Pliocene. Oligocene marine strata were called Butte Creek beds and older lavas were named Pre-Butte Creek lavas.

Brown (9) mapped the McMinnville quadrangle in 1950 and stated that the basalts in the Eola Hills are Columbia River lavas.

At Bradley Park on U. S. Highway 30, Lowry and Baldwin (24) observed that the Columbia River basalts actually are interbedded with the marine Astoria formation of Miocene age.

The Albany quadrangle was mapped by Allison (3) and was published during completion of this thesis.

STRATIGRAPHY

Introduction

The Cenozoic rocks of northwest Oregon are partly of direct volcanic origin (see Plate III), and partly marine and terrestrial sediments derived mostly from volcanic source rocks.

The lowermost, the Tillamook volcanics, comprise between six and ten thousand feet of basalt flows and local volcanic breccias. The next younger formation, the marine Rocky Point formation of Cowlitz age, a thousand feet thick, consists of clastics and is the only formation in the area which does not contain generous amounts of volcanic ash.

Oligocene marine sediments contain large amounts of tuff and occasional local occurrences of interbedded basalt flows.

The Mehama volcanics of Oligocene and possibly lower Miocene age represent typical northwest Oregon terrestrial beds of volcanic ash and breccia with interbedded basalt flows. This volcanism, which was active throughout the Oligocene period, supplied the dominant volcanic element to the estimated 5,000 feet of marine sediments. The base of the Mehama is not exposed; therefore the maximum thickness is not known. Gentle folding followed by erosion preceded the next younger formation.

CHART OF TERTIARY LITHOLOGY IN NORTHWEST OREGON

PLEISTOCENE LAVA	3000 ft.
PLIO-PLEISTOCENE VOLCANICS	1000 ft.
MIOCENE BASALT	2500 ft.
TERRESTRIAL TUFF AND BRECCIA	1500 ft.
OLIGOCENE TUFFACEOUS MARINE SEDIMENTS	5000 ft.
EOCENE MARINE SEDIMENTS	7500 ft.
EOCENE LAVA AND SEDIMENTS	7000 ft.

PLATE III

One of the greatest known outpourings of basaltic lava occurred during middle and late Miocene time, and is known as the Columbia River basalt. These basalt flows number up to 28 or more as seen in the Gorge and range from 300 feet thick at the most westerly occurrence to over 3,000 feet in aggregate thickness in the Gorge. Slight folding and weathering preceded the deposition to follow.

During mid-Pliocene time thick sequences of gravels and volcanic sediments were deposited from the crest of the Cascade anticline westward into the Willamette and Washougal valleys. These gravels, called Troutdale gravels, contain considerable amounts of quartzite pebbles. The upper Troutdale gravels interfinger with the next younger formation and are therefore in part equivalent.

Pliocene volcanoes are responsible for the lavas and agglomerate and volcanic breccia which give youthful relief to the Cascade Range. These lavas thin rapidly westward and occur farthest west where they erupted from local vents near Portland. The pyroclastics are referred to as the Boring "agglomerate" and the Rhododendron formations. The lavas are called Boring lavas and Cascade andesites. Southwest of the Mt. Hood area thick beds of pure tuff containing glass shards up to one inch long are common. These beds are at least 1500 feet thick in places.

It is estimated that in northwest Oregon about 14,000 feet of Tertiary strata are directly volcanic while only about 12,500 feet are marine strata which, however, are dominated by volcanic material. Only minor amounts of marine strata do not contain appreciable amounts of volcanic material (see Plate III). Their relative volumes have not been estimated.

Eocene Lavas

Metchosin Volcanics

The Metchosin volcanics, named in 1912 by Clapp (12), have been referred to in this and previous discussions of Eocene lavas of northwest Oregon; therefore, brief mention of these lavas is given here. These volcanics occur in a belt five to seven miles wide which runs parallel to the southwest coast of Vancouver Island, British Columbia, Canada. Clapp states that the rocks are dominantly basic basalts with a minor amount of augite andesine. Many diabase intrusions are seen to cut the older rocks.

The description of the rock by Clapp is identical to that of the rock described herein as Tillamook volcanics and will not be discussed here.

The thickness of these lavas on Vancouver Island is estimated to be 5,000 feet, or about one-half as thick as Eocene lavas in the Coast Range of Oregon.

Clapp, in dating these lavas, could only definitely place the upper age limit as pre-Tertiary on the basis that the overlying sediments were Eocene and therefore the lavas are pre-Eocene. Since they were metamorphosed prior to the deposition of later sediments, Clapp thought that they were either late-Triassic or lower Jurassic.

Weaver (40, p.27) correlates thick sequences of volcanics in the Coast Ranges of Oregon and Washington with the Metchosin of Clapp. The Crescent formation, which has been dated mid-Eocene on the basis of a megafauna (40, p.41), overlies the Metchosin along the Strait of Juan de Fuca. The Metchosin in Washington is therefore older than mid-Eocene.

The name Metchosin for rocks described on Vancouver Island is not used in northwest Oregon because the type Metchosin area is so distant and because better exposures capable of more accurate dating have been described from the Tillamook area by Warren et al (39) in 1945.

Tillamook Volcanic Series

The Tillamook volcanic series was named by Warren, Norbisrath, and Grivetti (39) in 1942, when they made a geologic reconnaissance for oil and gas in northwest Oregon.

The Tillamook volcanics are typically exposed in eastern Tillamook County where six to ten thousand feet of massive basaltic lavas interbedded with breccia and minor amounts of sediment occur along the Trask River. The lower-most portion of the type section, near the forks of the

Trask River, is sedimentary in nature and contains a fragmentary marine Eocene fauna. If this stratum represents only an interbed in the Tillamook volcanics, the thickness figure represents only the minimum (39).

Clapp (12, p.94) suggests that the Metchosin basalts on Vancouver Island, which are tentatively correlated by Baldwin (4, p.13) with the Tillamook volcanics, were extruded into deep water because of the complete lack of accompanying sediments. The lack of sediments could easily have resulted from a low surrounding topography and thus little inflow of sediments. He also attributes the hydrothermal alteration of femic minerals to the reaction of the water with the hot lava (12, p.90). The joint pattern is massive and the crude columnar jointing ordinarily characteristic of thin flows is absent. There is little indication of individual flows throughout a great thickness. The submarine nature of these rocks is recognized by most geologists.

The rock crumbles on exposure to air because of numerous closely spaced fractures, and weathers to a brownish buff color. Yellow clay results from weathering of palagonite (4, p.6).

The breccia fragments vary in size from fine grained basaltic particles in a tuffaceous matrix to huge coarse grained blocks typical to those occurring close to a volcanic neck. The occasional occurrence of volcanic cones in the Metchosin volcanics suggests that the lavas sometimes reached above the surface of the water, at least in the rocks called Metchosin on Vancouver Island (12, pp.91,94). If this were so for the Tillamook volcanics in Oregon, an occasional flow with terrestrial characteristics may have resulted.

In the hand specimen the basalts are greenish gray except along the fractures where the rock has a purplish tint. Many of the fractures show small slickensides. The porphyritic varieties usually contain phenocrysts of plagioclase; however, near Jordan Creek along the Wolf Creek Highway the rock is an augite porphyry containing numerous large phenocrysts of clino-pyroxene. Some rocks contain considerable amounts of disseminated pyrite crystals. The groundmass is quite often glassy but an ophitic groundmass is not uncommon. Specimens have been described having as much as fifteen percent magnetite (4, p.7). Along the banks of the Marys River near Wren, Oregon, selective deposition by river currents has concentrated magnetite sand in layers several inches deep, previously weathered out of the Eocene Siletz River basalts in that vicinity. According to Baldwin (4, p.13) the Siletz River volcanics may be in part equivalent to the Tillamook volcanics.

The amygdaloidal basalts contain fillings of zeolite, epidote and quartz, the first being the most common. In highly fractured zones the zeolitic rocks have a mottled appearance.

The greenish color of the rock has resulted from alteration of the ferro-magnesian minerals presumably during or shortly after the extrusion (12, p.90). This metamorphism occurred under low temperature conditions since the feldspars were unaltered. Sausseritization has occurred only locally as a result of contact phenomena (12, p.90).

The Tillamook volcanic series is unconformably overlain by the marine Rocky Point formation which contains an upper Eocene (Cowlitz age) fauna (38, p.221). If the fragmentary fossils, either at the base or in interbeds within the Tillamook volcanics, are actually mid-Eocene, then the upper part of the series is upper middle Eocene (39). Since the basal contact has not been definitely identified, the formation can be dated only as older than late Eocene.

Rocks mapped as Tillamook volcanics occur only along the western edge of the map area of this report (Plate X) in the McMinnville, Yamhill and Gales Creek quadrangles.

Siletz River Volcanics

The Siletz River volcanics were named by Baldwin (4, p.6) in 1947 for the basalts and breccias interbedded with minor amounts of tuffaceous sediments along the Siletz River in the Coast Range of Oregon. Although the rocks do not occur within the mapped area (Plate X), they are mentioned here because of their relationship to the Tillamook volcanics to the north and the Coffin Butte volcanics to the east.

Three to five thousand feet of volcanics are exposed in the valley of the south fork of the Siletz River. No basal contact was observed but sedimentary interbeds are present in many sections (4, p.6).

The Siletz volcanic series has been thought by Baldwin (4, p.9) to be largely submarine in origin. He states that steam explosions underwater could cause brecciation and mudflows, and the interbeds could be totally volcanic as no terrigenous material is detected.

Overlying the Siletz River volcanics are marine sediments equivalent to the Tyee formation of the central portion of the Oregon Coast Range (4, p.10). The Tyee formation is correlated with the Domengine (mid-Eocene) of California on the basis of megafossils. Therefore the upper limit of the Siletz River volcanics is pre-middle Eocene and compares in age with the Metchosin in Washington.

Goble Volcanic Series

Thick basaltic flows alternating with pyroclastic and sedimentary beds occurring typically near Goble, Oregon, were named the Goble volcanic series by Wilkinson *et al* (43, p.4) in 1942. They state that at least 5,000 feet of basalts and interbedded breccias are exposed between Kelso and Woodland, Washington. According to the writer's observation these rocks are similar in outcrop and hand specimen to the Tillamook volcanics.

According to Wilkinson et al (43, p.9), interbedded marine strata are said to contain an upper Eocene Cowlitz fauna. The overlying formation contains an Oligocene fauna equivalent to that from the Gries Ranch locality, thereby dating the volcanic series as upper Eocene and possibly extending into lower Oligocene. The alleged presence of an upper Eocene fauna in interbeds within the lavas disfavors correlation of the upper part of the Goble formation with other mid-Eocene volcanics of the Coast Range of Oregon; however, it seems reasonable to suspect that lower portions of the Goble may be their equivalents.

Coffin Butte Volcanics

The Coffin Butte volcanics were named in 1953 by Allison (3, p.3) for Eocene basalt occurrences in the western part of the Albany quadrangle. The basalt is typically exposed at Coffin Butte quarries near Camp Adair where several hundred feet of basalt containing zeolites and pillow structure are exposed. Several sedimentary interbeds are visible in the quarries. The age of the Coffin Butte volcanics is presumed to be middle Eocene because structurally they appear to dip below sediments containing upper Eocene fossils (3, p.4).

The lithologic similarity, and the Eocene age, together with its geographic position in the eastern foothills of the Coast Range, suggests that these rocks are equivalent to part of the Siletz River volcanics. The basalt exposures at Coffin Butte have been previously referred to as Siletz River volcanics by Baldwin (4, p.6), but no direct tracing of these rocks from Coffin Butte to exposures of Siletz volcanics can be made.

Pre-Butte Creek Lavas

The name "Pre-Butte Creek lavas" was proposed in an unpublished thesis by Harper (18, p.4) in 1946, to include all of the lavas occurring in the Molalla quadrangle which were presumed to be earlier than the marine Butte Creek formation.

According to Harper (18, p.6) these rocks are exposed southeast of Molalla along the Molalla River and can be traced southward to "within a few miles" of lavas called the Sardine series by Thayer (34, p.6).

Northwest of Wilhoit these lavas occupy a strip four miles wide which can be traced westward to the Silverton-Mulino Highway where the lavas appear to dip below the valley alluvium.

In Butte Creek Canyon, four miles east of Scotts Mills, lavas are exposed below the marine Butte Creek beds. These lavas are thin individual flows interbedded with sandstones and conglomerates and might be interpreted as interbeds within the Butte Creek beds.

Harper (18, p.5) states that approximately 1,500 feet of Pre-Butte Creek lavas are exposed in the Molalla quadrangle, but thicker sequences occur to the southeast. Thayer (34, p.8) indicates a thickness of 6,000 feet for the Sardine series which is probably partly equivalent to the Pre-Butte Creek lavas.

The Pre-Butte Creek lavas as mapped by Harper (18), but undifferentiated by him, are composed of two main types. The lower lavas are massive and irregular basalt flows interbedded with tuff and breccia, and found in the area northwest of Wilhoit and westward as far as the Silverton-Mulino Highway. The upper lavas are porphyritic basalts exposed in cliffs and ridges above the Molalla River and near the southeast corner of the quadrangle.

Lower Basalts

The massive irregular basalts are deeply weathered along their joint planes and pillow structure was noted by Harper (18, p.4). Thin soil strata between the flows have been baked red or yellow so as to stain the surface of the rock exposure and give it a mottled appearance.

In certain areas the basalts are amygdaloidal and contain vesicle fillings of calcite, zeolites, and epidote

(18, p.4). Veins and amygdules of quartz were found in a rock quarry one mile south of Glad Tidings.

West of Scotts Mills the basalts are interbedded with conglomerates and sandstones which probably represent interbeds in the lower part of the Butte Creek formation. The basalts may represent the upper portion of the older lavas. The age of the fossil assemblage occurring in the marine strata lying directly on the lava is Eocene according to H. E. Vokes as quoted by Harper (18, p.5).

Upper Basalts

The upper lava was not found anywhere to lie directly upon the lower massive basalts. Harper (18, p.4) has indicated that this lava is older than the Molalla formation and that it occurs as resistant ridges with the Molalla formation supposedly butting against it. This may be true of part of the lava as the relationship of the upper and lower lavas is not completely known, but the writer is convinced that much of the upper lava overlies the Molalla formation and is younger than Miocene for the following reasons:

1. Where it outcrops above the Molalla River it has a moderate dip and is conformable with the Molalla formation.

2. The basalt is weathered only slightly in contrast to extensive weathering and alteration of the older lavas.
3. Areas of slump containing large blocks of porphyritic basalt indicate that it is underlain by weaker material, which may well be the Molalla formation.
4. A coal mine near Wilhoit follows a coal seam to a point beneath the lavas, proving that basalts overlie the sediments in this area. Carbonaceous seams in the Molalla formation four miles to the northeast further suggest that the strata may be continuous beneath the lava.
5. The porphyritic basalt is comparable in all respects to the Boring lavas to the north and east, and to the uppermost Sardine Series of Thayer to the south.
6. These lavas have been traced to within several miles of the upper part of the Sardine Series (34, p.6) with which they agree lithologically.
7. The lavas are found on both sides of the Molalla River and the bedding of the Molalla formation is such that it could not have been

plastered along the sides of the canyon against ridges of older rocks.

8. The Molalla formation is found to lie stratigraphically above a series of basalts similar to the older massive basalts; therefore, it occupies the terrestrial stratigraphic position equivalent to the marine Butte Creek beds and separates the lower basalts from the later porphyritic lavas.

The last statement indicates a bracketing of the Oligocene shoreline which must lie between the Butte Creek outcrop and the Molalla River (see x-sect. C-C', Plate VIII).

<u>New Era Exposure of Eocene Basalts</u>

In the Willamette River north of New Era, as shown on Plate X, and cross section D-D', Plate VIII, a thick sequence of basalt flows was observed, which is probably related to the Tillamook volcanic series. This basalt is best observed in a railroad cut at Coalco, one mile north of New Era, where it dips about 35 degrees N. 70 degrees E. The Columbia River basalt in that vicinity dips a maximum of nine degrees.

Numerous steeply dipping flows striking parallel to the river stand out as islands while the erosion of the weaker tuff and breccia interbeds resulted in deep channels.

The older basalt is found to occupy the entire width of the Willamette River and is observed several hundred feet above the river on either side. By using the minimum angle of dip the basalts were calculated to be at least 1,500 feet thick.

Megascopically the rocks are mottled black and white. The light spots are made by numerous zeolites which occur as amygdules ranging in size up to three inches. The main zeolite is pectolite, but stilbite is abundant along joints, as also is calcite. The rock in places is exceptionally porphyritic and contains phenocrysts of plagioclase as much as a half inch long. The groundmass is largely glassy. The rock crumbles easily and is weathered to varying degrees. Some of the less porphyritic and amygdaloidal rock occurring in the channel proper appeared to be less decomposed.

Since the occurrence of these rocks is limited to such a narrow strip and the contact with the later Columbia River basalts is obscured, the conclusion that these rocks are Eocene is based on the following:

1. Lithologically they are not comparable to the Columbia River basalts because of the numerous zeolites, the extremely large phenocrysts in the porphyritic varieties, the large amount of glass in the groundmass, and the type of weathering which is similar to that of the Tillamook volcanics and Siletz River volcanics

on the Wolf Creek Highway, and the volcanics at Coffin Butte, Oregon.

2. The writer has calculated the thickness of these basalts to be a minimum of 1,500 feet. This is based on the visible exposure which is limited by the width of the river. The Columbia River basalts have a maximum estimated thickness of 600 feet in this area.
3. The 45 degree dip is excessive for Columbia River lavas since they seldom dip more than 10 degrees in this region. The Columbia River lavas observed within 200 yards of this outcrop dip only five degrees and such an abrupt change of dip would not be reasonable.

The occurrence of this rock is highly suggestive of a buried ridge of Eocene rocks which may never have been covered completely until the Boring lavas were extruded. This area is geographically near the Oligocene shoreline proposed by Lowry (24).

Conclusions

The oldest rocks in northwest Oregon are a thick series of mid-Eocene and older basalts and interbedded tuffs and breccias. The anticlinal Coast Range uplift has a core of Eocene basalt flows which has been exposed by erosion; and Eocene basalts also are found in the western foothills of the northern Cascade Mountains of Oregon where later flows of basalt and andesite failed to cover them or where they have been re-exposed by erosion.

Test wells drilled in the valley area between the Coast Range and the Cascade Mountains have indicated that a synclinal structure formed after the extrusion of the Eocene basalts, but before the outpouring of the Columbia River basalt. Weaver states that this downwarp may amount to 15,000 feet (41, p.1407).

The Metchosin volcanics of Clapp (12, p.86) and Weaver (41, p.1407) are considered to include both the Tillamook volcanics of Warren *et al* (39) and the Siletz River volcanics of Baldwin (4, p.6). The name "Metchosin" has generally been used in too broad a sense to be of value in northwest Oregon where good exposures of mid-Eocene volcanics can be dated more accurately than can the Metchosin. For the present, at any rate, writers such as Warren *et al* (39), Baldwin (4), Wilkinson, *et al* (43) and Allison (3), do not use "Metchosin" for Eocene volcanics in Oregon.

The writer concludes generally that in northwest Oregon the previously mentioned Eocene lavas conform to a definite structural and geographical pattern which in a broad sense sets these lavas apart from later lavas. Occasionally, however, limited exposures with obscure stratigraphic relationships hinder recognition of these lavas.

Eocene Sedimentary Formations

Rocky Point Formation

Following accumulation of the thick sequence of the Tillamook volcanic series, crustal deformation provided highland sources for clastics on the one hand and down-warped basins which received these sediments on the other. The oldest rocks lying upon the Tillamook volcanics along eastern foothills of the Coast Range of northwest Oregon are called the Rocky Point formation. The Rocky Point formation has been named by Deacon (14, p.9) who decided that the lithology of the upper Eocene strata in northwest Oregon was sufficiently different from the type section of Cowlitz in southwest Washington to warrant a local formational name. The type section for the Rocky Point formation is on Rock Creek near Keasey Station, some 40 miles northwest of Portland and about 10 miles west of the west edge of the Vernonia quadrangle as shown in Plate X.

Deacon (14, p.9) recognizes three lithic divisions within the Rocky Point formation. The lower member is composed of more than three hundred feet of basaltic conglomerate and sandstone. The middle member consists of a minimum thickness of 100 feet of micaceous siltstone with resistant coarse interbeds near the middle. The upper member, 550 feet thick, is essentially a well stratified micaceous graywacke sandstone containing large calcareous concretions. The total thickness of the Rocky Point formation is nearly 1,000 feet.

Helmick Beds

The name Helmick beds was proposed in an unpublished thesis by Mundorff (26, p.20) for upper Eocene strata typically exposed in the southwest corner of the Salem quadrangle at Helmick Hill and along the Willamette River at Buena Vista.

The rocks are thin bedded, friable micaceous sandstones, shales and occasional lenses of calcareous concretions. According to Mundorff (26, p.21) the mineral grains are mostly quartz and feldspar with minor quantities of hornblende, augite and "white mica".

Actual stratigraphic position of the Helmick beds is not apparent since the lower contact is unexposed and the younger Oligocene beds nowhere are seen in contact with the Helmick beds.

An upper Eocene age for the Helmick beds has been determined on the basis of a megafauna identified by Mundorff (26), and a microfauna studied by Cushman, Stewart, and Stewart (13). The Rocky Point formation as compared to the Helmick beds is much thicker on the outcrop, but has the same general lithology, similar stratigraphic position as determined by fauna, and a similar relationship to the volcanics of the Coast Range. That these formations are time equivalents of one another is likely. Baldwin (4, pp.18 and 25) states that there is a minimum thickness of 7500 feet of upper Eocene rocks in the Dallas and Valsetz quadrangles.

<u>Nehalem Formation</u>

Between the Rocky Point and the Keasey formation at the type Rocky Point section near Keasey Station is a series of heterogeneous beds which Deacon (14, p.18) has named (unpublished) the Nehalem formation. The lithology of the Nehalem formation is extremely variable from place to place, but the dominant lithologies are tuffs and mudstones. The tuffs are non-stratified but the mudstones are stratified and shaly. The thickness ranges from 300 to 400 feet. The lower strata are either upper Eocene or lower Oligocene and the formation probably extends into the Oligocene (14, p.55).

Oligocene Marine Sedimentary Formations

<u>Keasey Formation</u>

The deposition of the Keasey shales in the upper Nehalem Basin in northwest Oregon succeeded the accumulation of the previous beds with little or no stratigraphic break. The lithology of the Keasey formation differs from that of the Nehalem formation in that the sediments are finer and decidedly more uniform areally. There is an increase in the content of tuffaceous material upwards.

In the type section 0.7 miles downstream from Keasey Station the Rocky Point formation is overlain by 500 feet of generally well stratified, fossiliferous, dark gray shale. This is considered to be the lower member of the Keasey formation which is also represented along the Nehalem River between Timber and Vernonia. It appears to thin southward. The middle Keasey is mainly silty, tuffaceous shale containing cemented beds, while the upper member is stratified, tuffaceous, sandy shales. The middle and upper Keasey is best seen east of Sunset Camp along the Wolf Creek Highway (14, p.30).

The total thickness of the Keasey formation is at least 1,700 feet as measured by Deacon (14, p.53). Warren *et al* (39) gave 1,800 feet as the thickness.

Effinger (16) correlated the Keasey fauna with the Gries Ranch fauna of Washington which is Oligocene in age.

Pittsburg Bluff Formation

The Pittsburg Bluff formation exposed in the upper Nehalem basin was studied by Warren and Norbisrath (38) in 1946. The following description of the Pittsburg Bluff formation is based on that of Warren and Norbisrath.

The exposures on the Nehalem River Highway near Pittsburg represent the marine fossiliferous beds near the base of the formation. They are fine grained sandstones which grade upward into coarser massive sandstone which interfingers with cross-bedded, near-shore, brackish water deposited sandstone. Abundant calcareous concretions occur along the bedding. As the abundance of animal fossils decreases upwards, the amount of plant remains increases. The beds grade from one type to another in rather short distances horizontally.

Upper beds typical of the Pittsburg Bluff formation are exposed between Pittsburg and Wilark on the highway along the east fork of the Nehalem River. These beds are massive, loosely consolidated brown weathering sandstones containing pillow-like limestone concretions and fairly well stratified tuffaceous sandstone and shale containing some fossils. The uppermost beds of the Pittsburg Bluff are sandy with thick beds of white, fine-grained tuff. An interbedded mudflow containing fragments of volcanic rocks is noted near the top of the formation.

The relationship of Pittsburg Bluff to the underlying Keasey formation is not seen but structural differences suggest that they are unconformable (38, p.230). The total thickness was calculated to be 826 feet but the possibility of faults and questionable structure in poorly exposed strata make this figure unreliable.

Scappoose Formation

The strata overlying the Pittsburg Bluff formation, best exposed east of the upper Nehalem basin in the hills west of the Columbia River, have been named the Scappoose formation by Warren and Norbisrath (38, p.221) in 1946. This formation is found in contact with the Pittsburg Bluff formation in the south fork of Scappoose Creek and along Rocky Point road a few miles east and southeast of Scappoose. The Scappoose formation is overlain by the Columbia River basalts.

According to Warren and Norbisrath (38) the Scappoose formation is lithologically similar to the underlying Pittsburgh Bluff and is identified only by a difference in fauna. Separation of the two formations would be impossible where fossils have weathered beyond identification.

Extensive erosion prior to extrusion of the Columbia River basalts has caused the Scappoose to be completely absent in some areas. The total thickness elsewhere is not certain since no definite amount of erosion can be determined. The thickness appears to range from 0 to 1,800 feet.

Since formations are cartographic lithogenetic units, they cannot be defined solely on the basis of faunal content, according to current stratigraphic usage. It appears to the present author that the Scappoose formation does not exist as a lithic entity separate from the Pittsburg Bluff formation. A solution presented here is to consider these strata as belonging to the Pittsburg Bluff formation until further field work definitely proves the mappability of the Scappoose formation without continuous reference to fossils.

Eugene Formation

Exposures of marine sandstone, sandy shale, conglomerate and tuff in quarries and roadcuts within the city limits of Eugene, Oregon, were considered by Schenck (33, p.453) in 1927 to be the type section for the Eugene formation. Fossils from these exposures were believed by Schenck to be limited to the Oligocene of the West Coast.

Along the eastern margin of the Willamette Valley north of Eugene the Oligocene strata dip eastward beneath later lavas.

Felts (17) in 1936 and Allison (3) in 1953, in the Lebanon and Albany quadrangles respectively, recognized the Oligocene marine strata as the Eugene formation of Schenck. These areas are shown by the orange pattern (Plate X) in the forementioned quadrangles. Until now the Eugene formation has not been recognized north of these quadrangles, at least not on available maps.

Illahe Formation

The Illahe beds were first described by Thayer (34) from the type section at Illahe Hill five miles southwest of Salem near the east bank of the Willamette River. They are sandstones and siltstones containing abundant fossils which are representative of the Pittsburg Bluff age as are those in the Eugene formation. The amount and size of volcanic particles increase to the east where, according to Thayer (34, p.7), the Illahe marine sediments probably interfinger with the terrestrial Mehama volcanics. They are overlain by the Miocene Columbia River basalts to be discussed later.

Because the Illahe beds correspond in lithology, stratigraphic position and structure to the Eugene formation, and because they contain a similar fauna, the writer here proposes that the local name Illahe be dropped in favor of the prior designation, the Eugene formation.

Butte Creek Beds

The Butte Creek beds were named by Harper (18) in an unpublished thesis for marine Oligocene strata occurring geographically in the southern part of the Molalla quadrangle and lying stratigraphically between the Eocene and the Miocene lavas. The fossils from these beds are similar to those of the Illahe, Eugene, and Pittsburg Bluff formations and therefore are considered to be mid-Oligocene in age. For a lithologic description of these beds the reader is referred to the descriptions of the Eugene and Illahe formations.

Because of the similarities previously mentioned along with the corresponding geographic trends of the outcrops of the Butte Creek beds and the Illahe formation (herein considered Eugene), it is herewith suggested that the Butte Creek beds also be known as the Eugene formation.

The Oligocene beds in the Willamette Valley are observed to dip an average of four degrees to the east. North of Salem they are exposed west of the Eola Hills and also in the Butte Creek area 20 miles to the east. The calculated thickness between these two points is approximately 8,000 feet, but hidden structural complications probably considerably lessen this thickness.

Oligocene Terrestrial Volcanics

Mehama Volcanics

Terrestrial tuffs, lavas, and breccias typically displayed north and east of Mehama were named the Mehama volcanics by Thayer (34) in 1939. He describes one locality where 600 feet of fine-grained tuffs contain fossil wood and another exposure composed entirely of flow breccia which contains huge flow fragments (25 x 10 x 50 feet). The total thickness of the formation is not known.

The grain size of the Mehama volcanics decreases westward and according to Thayer (34) the formation probably interfingers with the Illahe (Eugene) formation. The Mehama formation is unconformably overlain by the Columbia River basalt.

According to Mr. Herbert Hergert[1] (personal communication) the flora of the Mehama volcanics is similar to that of the Scio beds and of the Berlin volcanics discussed on following pages and listed on a table (Plate IV).

Since the terrestrial Mehama volcanics and the marine Eugene formation appear to be contemporaneous, and they are both unconformably overlain by mid-Miocene Columbia River basalt, they are considered to be at least partly equivalent; therefore Mehama volcanics are considered Oligocene in age.

Berlin Volcanics

From the description of the Berlin volcanics by Felts (17, p.36) the writer considers the formation to be a continuation of the Mehama volcanics because of their similarity of lithology, stratigraphic position, and relationship to the marine Eugene formation. Where it is seen to overlie the Eugene formation, the relationships may be strictly local and probably represent merely an interfingering of the marine strata from the west with the terrestrial beds to the east.

---

[1] Hergert, Herbert L., unpublished work. Part of a study of the Tertiary paleobotany of the western Cascades under a faculty research grant to Herbert L. Hergert, research chemist, Oregon Forest Products Laboratory, and Harry K. Phinney, Assistant Professor of Botany and Geology, Oregon State College.

Scio Beds

The Scio beds of Felts (17, p.31) consist of a series of sandstones and water-laid tuffs and breccias. The unit varies from a fine-grained decomposed vitric tuff to conglomeratic sediments containing pyroclastic fragments as much as three centimeters across. Felts (17, p.32) believed that the quartz grains found in the tuff originated from a crystal tuff rather than from an older sandstone.

According to Felts (17, p.33), the Scio beds appear to overlie the marine Oligocene, but no contact was observed. They are overlain by Miocene basalt herein correlated with the Columbia River basalt. According to Sanborn (30), the leaves in the Scio beds are Oligo-Miocene.

The Scio beds are here considered to be upper Oligocene in age through a rather involved type of reasoning:

1. The Scio beds are correlated with the Mehama formation by means of flora and stratigraphic position.
2. The terrestrial Mehama formation, according to Thayer (34), appears to interfinger with the marine Illahe formation of Oligocene age.
3. The writer has already demonstrated the equivalence of the Illahe and Eugene formations.
4. Therefore, the Eugene formation and the Scio beds are, in part at least, temporal equivalents of one another.

As the Oligocene sea retreated, it was followed by the continued deposition of terrestrial sediments, which naturally overlie the preceding marine beds. Therefore, the uppermost Scio beds came to overlie the Eugene formation as was suggested by Felts (17).

A comparison of the floras occurring in the Scio beds, the Mehama formation and the Berlin volcanics shows that these formations contain identical species and are indistinguishable on a floral basis (see Plate IV).

The data on Plate IV are based on information from Hergert (personal communication). Mr. Herbert Hergert collected and identified fossil leaves from the following localities in the Lebanon and Snow Peak quadrangles. The localities refer to those listed on Plate IV.

FORMATION	LOCATION
Scio	Franklin Butte, one mile south of Scio.
Mehama	Bilyeu Creek, five miles southeast of Scio.
"	Thomas Creek, five miles east of Scio.
Berlin	Sweethome, in a cut along Oregon Electric R.R. a half mile south of Sweethome and one mile north of Sweethome on the North Side Road between Sweethome and Foster.
"	Roaring River[2], junction of Roaring River and Crabtree Creek southeast of Scio.
"	McDowell Creek, one mile south of Berlin.

[2]The Roaring River locality is considered by Hergert to represent the Berlin formation although this has not yet been demonstrated by mapping.

PLATE IV

CHECKLIST OF FLORA OCCURRING IN THE SCIO, MEHAMA, AND BERLIN FORMATIONS

	SCIO F'M	MEHAMA F'M		BERLIN F'M		
LIST OF SPECIES	FRANKLIN BUTTE	BILYEU CREEK	THOMAS CREEK	SWEETHOME	ROARING RIVER	McDOWELL CREEK
Prunus franklinensis	X	X	X	X		
Amelanchier similis	X				X	
Equisetum oregonense	X	X		X	X	
Vaccinium scioensis	X					
Platanus aceroides	X	X	X	X	X	X
Metasequoia occidentalis	X	X	X		X	
Grewia oregana	X					
Tilia williamsi	X	X	X	X		
Engelhardtia oregana	X			X	X	
Phoebe oregonensis	X	X	X	X	X	
Salix sp.	X					
Vitis florissantella	X	X				
Castanopsis (Tetracera)	X		X	X	X	X
Populus lindgreni	X	X				
Vaccinium prearboreum	X			X		
Franxinus scioensis	X					
Pteris silvacola	X					
Magnolia sp.		X				
Diospyros sp.				X		
Taxodium distichim			X	X	X	X
Hydrangea bendirei				X		
Cercidiphyllum crenatum		X			X	

Note: Above localities are all Oligo-Miocene. Most of the species are unique and do not occur elsewhere. For fuller discussion of "Franklin Butte Flora" and other localities, cf. Sanborn (30 and 31).

Herbert L. Hergert (personal communication), May 1953.

Oligo-Miocene Terrestrial Formations

Warrendale Formation

The Warrendale formation was first described as the Eagle Creek formation and named by Williams (44) from exposures in the Columbia River Gorge. Since the name Eagle Creek had previously been used elsewhere, Packard and Smith (29) suggested the name Warrendale, which will be used in this paper.

The Warrendale formation according to Hodge (20) is composed of terrestrial tuffs, breccias, agglomerates, and interbedded basalt flows.

The Warrendale formation crops out farthest west near McCord Creek where it dips beneath the Columbia River basalt. The base of the Warrendale formation is not exposed in the Gorge, but at Red Bluffs on the Washington side of the River the thickness was estimated by Barnes and Butler (5, p.20) to be 2,100 feet. The southerly dip of the formation here accounts for its lower elevation on the south side of the Gorge in Oregon.

The Warrendale formation is considered to be Oligo-Miocene in age and correlated with the John Day formation exposed in the Dayville quadrangle of central Oregon. The John Day formation contains a vertebrate fauna indicative of a lower Miocene age and a flora similar to that of the

Warrendale. That the Warrendale and upper John Day formations are contemporaneous is indicated by the similarity of their lithologies and floral content (Plate V). Thus the Warrendale is at least in part lower Miocene. A stratigraphically lower portion is possibly upper Oligocene. The Warrendale formation is, therefore, considered to be Oligo-Miocene[3] in age.

Molalla Formation

The Molalla formation was named by Harper (18, p.11) in 1946, for stratified tuffaceous sandstones, gravels and a coarse tuff breccia best exposed along the Molalla River three miles southeast of Molalla.

At the junction of Trout Creek with the Molalla River the Molalla formation unconformably overlies a basalt flow which the writer believes to be equivalent to the lower Pre-Butte Creek lavas to the west, since these lavas are lithologically similar and they appear to project structurally (see x-sect. C-C', Plate VIII) through the ridge between Butte Creek and the Molalla River. The Molalla formation is capped near Trout Creek by gray porphyritic

---

[3]The writer considers that some areas of deposition received sediments of Oligocene and lower Miocene age without a stratigraphic break. Erosion has since removed the Miocene and even upper Oligocene strata in some localities, leaving Miocene in others. These strata of indefinite Oligocene to Miocene age are termed Oligo-Miocene in this paper.

basalt and along the west bank of the Molalla River farther north by later conglomerates. Harper (18, p.13) included the later conglomerate in the Molalla formation. He tentatively placed the Molalla formation in the Pliocene because of the similarity of the upper Molalla to the Troutdale gravels to the north, and the likeness of part of the Fern Ridge tuff exposed to the south with that part of the Molalla formation containing devitrified glass shards.

Correlations are difficult in this area because the Miocene Columbia River lavas are absent and the Plio-Pleistocene sediments are in direct contact with Oligo-Miocene rocks. Large amounts of tuff were deposited during both epochs.

The writer favors an Oligo-Miocene age for the lower and main part of the Molalla formation, and considers the upper gravels to be Pliocene or later, and equivalent to the Troutdale or later terrace and glacial gravels.

The lower Molalla is believed to be Oligo-Miocene for the following reasons:

1. The large blocks of porphyritic lava in the breccia overlying the stratified tuffaceous sandstone of the Molalla are similar to those found in Warrendale formation, which underlies the Columbia River basalt in the Gorge.
2. The lithology and stratification is similar to parts of the Warrendale formation and it appears

likely that the Molalla formation was formed under similar conditions during approximately the same period.

3. Extensive study of fossil leaves in the Molalla formation by Hergert (personal communication) indicates that they are similar to those of the Warrendale and John Day formations of Oligo-Miocene age (see Plate V).
4. The writer has suggested by cross section (x-sect B-A', Plate VIII) that the Warrendale is equivalent to the Molalla formation to the southwest. This correlation is based on the similarity of lithology (with minor differences interpreted to result from geographic position) and on the similarity of their floras (Plate V).

The upper cross-bedded gravels are much less altered and contain little tuff; therefore, they are not lithologically a part of the Molalla formation, but probably are equivalent in age to the Troutdale formation.

If the lower Molalla is Oligo-Miocene, then it must be a partial (if not complete) terrestrial equivalent of the Oligocene Butte Creek formation as exposed to the west. The Molalla is generally younger than the Butte Creek formation because of the lithologic similarity of its upper part to the Warrendale formation dated Oligo-Miocene, whereas the Butte Creek beds are considered Oligocene in age.

The upper gravels which were mapped by Harper (18) as part of the Molalla formation are correlated herein with the Troutdale gravels, but because of a difference in source areas the quartzite pebbles characteristic of the Troutdale gravels are absent. Where they occur the gravels usually form a thin veneer on the older Molalla formation.

Erosion by the ancestral Columbia River of Hodge (20) is possibly responsible for the absence of the Columbia River basalt between the Molalla River and the Clackamas River.

<u>Molalla Flora</u>

Harper (18, p.12) makes reference to the 1941 work of Beverly Wilder of the University of California. He states that Wilder's study indicates that the sediments are Miocene in age (18, p.14).

The stratigraphic succession of floras in the Cascade Range are being studied by Hergert. That correlation of the Molalla formation with other Miocene strata can be substantiated by leaves is apparent. The following is quoted from Hergert (personal communication), May 1953:

> "<u>Age relationships</u>
>
> "Comparison of the 22 listed species present in the Molalla flora with the 16 present in the Troutdale flora indicates that the two floras are dissimilar. There are only two species in common, both of which have a rather broad range in time during the middle Tertiary. There are present in the Molalla flora, however, a fairly large proportion of

species which are present in Miocene floras in Oregon, Washington and Idaho. Examination of Plate V indicates that there are eleven species in common with the lower Miocene Eagle Creek flora (Warrendale formation, Oregon), nine species with the middle Miocene Latah flora (Latah formation, western Washington and Idaho), and ten species with the upper Miocene Mascall flora (Mascall formation, eastern Oregon).

"The possibility that the Molalla flora may be Pliocene in age is apparently ruled out, since only three Molalla species are found in Pliocene flora in Oregon and an additional two (Salix hesperia and Populus eotremuloides) in California Pliocene flora localities.

"The existence of many Molalla species in other Miocene localities and the presence of only a few Molalla species in either Oligocene or Pliocene localities indicates that the Molalla flora is Miocene in age. Two species, Quercus pseudo-lyrata and Ginkgo adantoides, are especially noteworthy since they have only been found in the Miocene in Oregon.

"To establish whether the locality is upper or lower Miocene in age is somewhat more difficult. It is believed that the Molalla flora is lower Miocene in age on the basis of the following considerations:

1. Over 50% of the species are in common with the nearby lower Miocene Eagle Creek flora, including Hicoria pecanoides and Sorbas alvordensis which have not been found in any other Oregon localities.

2. The occurrence of certain species, such as Alnus Carpinoides and Engelhardtia, which have not been found in Oregon localities younger than lower Miocene.

3. The occurrence of certain semi-tropical species indicative of early rather than late Tertiary paleo-climatology as yet unidentified.

"Further work on the flora may reveal additional species which are in common with the lower Miocene Eagle Creek flora and the newly discovered Callowash River flora."

PLATE V
CHECKLIST OF OCCURRENCE OF MOLALLA
SPECIES IN OTHER FLORAS

LIST OF SPECIES	OLIGO-MIOCENE		MIOCENE LOWER		MIOCENE MID		LOWER PLIOCENE		
	BRIDGE CREEK	FRANKLIN BUTTE	WARRENDALE	MOLALLA	LATAH	MASCALL	ELLENSBURG	TROUTDALE	THE DALLES
Abies axelrodi								X	
Amorpha condoni								X	X
Chamaecyparis gracilis						X		X	
Cornus ovalis	X				X			X	
Diospyros andersonai					X	X		X	
Fraxinus caudata							X	X	
Liquidambar pachyphyllum			X	X	X	X	X	X	
Prunus treasheri								X	
Pterocarya oregoniana								X	X
Quercus winstanleyi							X	X	X
Rhamnus troutdalensis								X	
Salix wildcatensis								X	
Sequoia affinis								X	
Ulmus californica							X	X	X
Umbellularia salicifolia					X	X		X	
Zelkova oregoniana	X		X	X	X	X		X	
Alnus carpinoides	X		X	X					
Berchemia multinervis				X					
Cedrela oregoniana				X		X			
Cercidiphyllum crenatum	X		X	X		X			
Engelhardtia oregana		X		X					
Fagus washoensis				X	X	X			
Fokienia sp.			X	X	X				
Ginkgo adantoides			X	X	X	X			
Hicoria pecanoides			X	X					
Metasequoia occidentalis	X	X		X	X	X			
Platanus aceroides	X	X		X					
Populus eotremuloides				X					
Quercus pseudo-lyrata			X	X		X	X		
Quercus simulata			X	X	X		X		
Salix hesperia				X	X	X	X		X
Sassafras pseudopopulus				X					
Sorbus alvordensis			X	X					
Taxodium dubium				X	X	X	X		
Acer sp.			X	X					
Liriodendron sp.				X					

Note: Above data from Chaney (11, p.354) except for Molalla flora by Herbert L. Hergert (personal communication). For specific localities see Chaney (11).

Miocene Basalt

Columbia River Basalt

The Columbia River basalts comprise a thick series of flows resulting from intermittent volcanic activity during the middle Miocene epoch. Usage which includes lavas other than mid-Miocene is obsolete and has not been used by recent authors (43, p.19), (20, p.847), and (25, p.3).

The Columbia River basalt is exposed over large parts of Oregon, Washington, and Idaho (see Plate I). It formerly covered additional areas where it has been either buried by subsequent formations or removed by erosion.

The Columbia River Gorge is the only place where continuous exposures of Columbia River basalts can be traced westward beneath the Cascade Range. Unfortunately the beds dip below the Pliocene gravels at Corbett, Oregon. South of the Gorge the basalts are covered by later lavas except in small isolated patches in the deeper stream valleys.

In the typical exposures of north central Oregon and south central Washington individual basalt flows range in thickness from 50 feet to 200 feet, and in some places the aggregate thickness is over 3,000 feet (20, p.857).

The Columbia River basalt is seen to thin westward from its exposures in eastern Oregon. In the Columbia River Gorge where both top and bottom contacts of the basalt are visible, the lavas are only 2,000 feet thick. Continuing westward the basalt is only 1,000 feet thick in the Portland Hills. Farther west Wilkinson (43, p.19) reports 700 feet in the St. Helens quadrangle, and Warren and Norbisrath (38) report 500 feet in the upper Nehalem Basin. Farther to the west along the Columbia River near Bradley Park the basalt is only 300 feet thick. Since the interbeds of mid-Miocene sands are moderately thick here, it is thought that many of the flows failed to reach this area. Thayer reports an average thickness of 400 feet for basalts in the Salem Hills, which indicates that the basalt thins to the south as well as westward.

A typical specimen of Columbia River lava is black to gray in color, and usually very dense. The tops and bottoms of the flows are vesicular and occasionally scoriaceous. Porphyritic varieties are usually not apparent in fresh fragments but in weathered specimens the occasional olivine crystal is colored red-brown while the plagioclase crystals are lighter in color.

Glassy flow breccia in the Columbia River Gorge at Crown Point is considered to be part of the Columbia River basalt formation by Lowry and Baldwin (25, p.3). In the Wickiup Mountain area southeast of Astoria, Warren et al (39) report a thick angular flow breccia which they correlate with the Columbia River basalts.

Columnar jointing is commonly well developed with columns ranging from a few inches to several feet in diameter. Loosening along the horizontal jointing in these columns produced the "brickbat" talus slopes which prevail at nearly every steep exposure of Columbia River basalt. This talus is only slightly weathered and is sufficiently fresh to be used in road building. Where columnar jointing did not develop the rock crops out in massive blocks which greatly resemble the fresher exposures of Eocene lavas.

A characteristic red-baked soil zone is present between some of the flows. This zone probably represents the rapid weathering and soil production from the highly scoriaceous top surface of the flow. The heat from the succeeding flow then baked this soil to a red clay, in places to a degree highly suggestive of a common manufactured brick.

The initial dip on the Columbia River basalt was very small and the basalt must have flowed as far as do the modern Hawaiian lavas. Even if a maximum distance were assumed, the total area covered by lava from a single vent would be small when compared to the total area covered by the Columbia River lavas. The sources for these lavas were probably dikes or fissures and also circular vents. Warren et al (39) mentions numerous dikes in areas where remnants of the Columbia River basalt occur in northwest Oregon. Wilkinson et al (43, p.19) gives the source of part of the Columbia River basalts in the St. Helens area as possibly being from dikes on Scappoose Creek, Alder Creek, and Merrill Creek. Hodge (20, p.849) favors central vents for lava sources in the Columbia River Gorge because of the lack of dikes intersecting the Gorge. He states that the possibility of numerous dikes intersecting the Gorge would be very great whereas a few central vents would have much less chance of being intersected by the river (20, p.849). Both plugs or volcanic necks and dikes are observable in Columbia River basalt areas where erosion has progressed sufficiently to expose the base of the basalts. The fact that great volcanic peaks did not result from these extrusions indicates that the extrusions were continually of the basic and fluid type. A strato-volcano composed of varied lava types would have left better visible evidence.

The development of a vast, nearly level, lava plain, of the size which is exhibited by the Columbia River lava plain, could have been accomplished only by many separate extrusions, interrupted perhaps by short periods of quiescence locally. As flow upon flow poured out from central vents and fissures, the plain remained nearly level because the lava flows continually filled in the low places.

Thinner sequences of basalt occur in fringe areas where there are fewer flows and where the higher areas remained above the basaltic flood. It is probable that moderately high areas which were never covered, or only thinly covered by the Columbia River basalt, were the first to be eroded, so some may be represented now by valleys cut into the former hills of softer sediments.

West of the Cascade Range extensive laterization of the Miocene basalts has resulted in numerous deposits of ferruginous bauxite (23, p.1). These deposits are located principally in Marion, Washington and Columbia counties (23, p.1).

Conditions necessary for the formation of bauxite are known to have occurred prior to the deposition of the Fern Ridge tuff because a nodule of high-grade gibbsite was found several feet above the contact of the Columbia River basalt and the Fern Ridge tuff (23, p.69). Libby states further that considerable erosion must have been taking place in the laterite at the time the Fern Ridge tuff was being deposited. Laterization which produced the deposits was confined to Miocene basalts, and any area made up of these lavas in western Oregon may possibly contain bauxitic deposits (23, p.3).

The Columbia River basalt is considered to be middle Miocene in age because, wherever observed, the lower contact is unconformable either upon dated lower Miocene or upper Oligocene strata with an angular and erosional discordance. In central Oregon the basalt lies unconformably upon the upper John Day formation which has been dated lower Miocene by means of vertebrate fossils; and in the Columbia River

Gorge it lies upon the Warrendale formation, herein considered to be equivalent to the John Day formation. The upper limit of the basalt is known to be pre-upper Miocene in the John Day Valley near Dayville, Oregon, because the basalt there is overlain by the Mascall formation which contains upper Miocene vertebrates.

West of the Cascade Range the Columbia River lavas lie upon upper Oligocene or lower Miocene marine sediments which are dated by invertebrate faunas. Weaver (40) describes a sandstone which contains fossils characteristic of the Astoria formation at Astoria which interfingers with the lower Columbia River basalt north of the Columbia River. Between Bradley Park and Astoria along the Columbia River Highway, Lowry and Baldwin (25, p.5) point out Astoria sandstone interbedded with the Miocene basalt flows. Here the writer has viewed yellow nearly pure quartz sand beds nearly fifty feet thick between flows of Columbia River basalt. In the upper Nehalem basin the Columbia River basalt overlies the upper Oligocene Scappoose formation with an angular unconformity (38, p.234). In the Willamette Valley the Columbia River basalts lie on a mature topography developed on upper Oligocene or lower Miocene sediments. In the Stayton, Salem, Molalla, and McMinnville quadrangles the basalt lies on the Eugene formation or its equivalents. The basalt is overlain by Fern Ridge tuff in the Stayton quadrangle according to

Thayer (34, p.8). In the Portland Hills and in the Tualatin Valley areas the basalts are overlain by silts of Pliocene age which were correlated with the Troutdale formation by Lowry and Baldwin (25, p.12). Wilkinson et al (43, p.24) reports Troutdale gravels lying upon the Miocene lavas in the St. Helens quadrangle.

The upper limit of the Columbia River basalt has not been dated faunally in western Oregon. In the Columbia River Gorge the basalt is overlain unconformably by the Troutdale gravels which are considered to be mid-Pliocene. Wilkinson et al (43) reports the same relationship in the St. Helens quadrangle.

It is therefore apparent that certain lavas occurring in the Willamette Valley are post-lower Miocene and pre-early Pliocene, and therefore were formed during approximately if not exactly the same time as were the basalts of Columbia Plateau.

South of the Gorge the pre-Columbia River basalt Cascades stood high and remained above the basalt flood (32, p.138). In the Santiam valley east of the mapped area rocks are exposed which may be lower Oligocene (34). West of this area in the foothills of the Cascades are the younger Mehama volcanics of upper Oligocene age. The Warrendale formation of Oligo-Miocene age is exposed in the present Columbia River Gorge. This outcrop pattern suggests a north-south pile of volcanics prior to the extrusion of the Columbia River basalts.

Stayton Lava

The Stayton lavas were named by Thayer for basalts which he traced continuously from the Salem Hills to a structure he named the Mehama anticline (34, p.7). Lithologically these basalts are similar to the basalts of the Columbia Plateau and a description here would be repetitous.

The Stayton lava lies unconformably upon the Eugene and the Mehama formations and therefore is post-early Miocene. The Fern Ridge tuffs of Pliocene age lie unconformably on the Stayton lava, so the upper limit of the basalt is fixed at least as pre-upper Pliocene. The age of the Fern Ridge tuff will be demonstrated in a later section.

Thayer (34, p.8) suggests that the Stayton lavas are marginal flows of Columbia River basalt since the formations thicken to the northeast.

The name Stayton lavas has been used in the mapping of adjoining Molalla, Lebanon and Stayton quadrangles by later geologists (see map inset Plate X for authors' names).

Salem Basalts

The Salem basalts were named by Mundorff (26, p.46) for lavas the same age as the Stayton lavas, and considered

Stayton lavas by Thayer (34, p.7). Mundorff agreed that they were probably partly equivalent, but he felt that since part of the Salem lavas were basic andesite (26, p.54) instead of basalt, they were not entirely equivalent, lithologically at least.

Since a small variation in chemistry of the lava from a single vent is common, it is not unlikely that occasional andesite flows could occur within the basic Stayton lavas. The fact that the basalts in the Salem Hills and Waldo Hills are a single map unit forming the east limb and part of the west limb of the Willamette syncline in the Stayton and Salem quadrangles, and that the basalts in the Eola Hills of the McMinnville quadrangle make part of the west limb of the same syncline, is further evidence of the correspondence of Stayton and Salem lavas.

Conclusions

After evaluation of all evidence submitted in this paper the writer is convinced that the Stayton and Salem basalt formations are actually the fringe area of the Miocene Columbia plateau lavas. Evidence in support of this conclusion is summarized here.

1. The Columbia River basalt is seen to be continuous beneath the Cascade Range in the Gorge; therefore this relationship may be expected

to exist at least for a reasonable distance south of the Gorge.

2. The similar stratigraphic ages of the Columbia River basalt of the Gorge and the Miocene basalt of the Willamette Valley suggest that they are part of the same formation.
3. The mineralogy and lithology of the several lavas being compared are similar.
    a. The interbedded soil zones in the Miocene basalt both east and west of the Cascades suggest that they were formed under similar conditions with corresponding periods of weathering between flows.
    b. Laterization is known to have affected only Miocene basalt. The Columbia River basalts west and south of Portland have been laterized as have the Stayton and the Salem basalts. Neither the Eocene nor the Plio-Pleistocene lavas are known to be so laterized.
4. The Columbia River basalts are interpreted to project beneath the northern part of the Willamette Valley (see x-sect A-A' and C-C', Plate VIII). These cross sections as shown represent the most reasonable structural interpretations of the Miocene basalts.

The absence of Miocene lava immediately south of the Chehalem Hills may be attributed to topographic high areas which the basalt surrounded but failed to cover. This factor, no doubt, plays an important part in the discontinuity of these basalts with those in the Eola Hills.

The Stayton basin is surrounded on three sides by Miocene lavas which dip outward. The basin is best explained by considering that this area was the site of a former hill of older sediments surrounded by Miocene lava. Erosion removed the sediments below the level of the resistant lavas, thereby producing the present topographic basin. This may be the reason for the lava-free area in the Willamette Valley south of the Salem Hills.

Pliocene Sediments

Troutdale Formation

The name Troutdale formation was proposed by Hodge (20, p.873) for gravels which he described as having been deposited as a great piedmont fan deposit lying on the west side of the Cascades. These gravels lie on the Columbia River basalt where the latter is present and they are widely capped by later andesitic lavas. The Boring lavas overlie the gravels to the southwest. According to Hodge (20, p.876), the Troutdale formation pinches out eastward but thickens westward and reaches maximum thickness in the northern Willamette Valley. Troutdale gravels are well exposed along the Clackamas River near Estacada from where they were traced by Treasher (36) to the south edge of the Boring quadrangle. A short distance farther south the gravels are hidden by a cover of Boring lavas. South of this Boring lava ridge similar gravels can be traced to the Molalla quadrangle, but they lack the quartzite pebbles characteristic of the Troutdale formation. It is these gravels which are called upper Molalla gravels in preceding pages. (See x-sect B-A', Plate VIII).

Hodge (20, p.875) describes the gravels as being partly contemporaneous with the lower Rhododendron pyroclastics with which they interfinger.

The Troutdale formation was deposited upon the eroded surface of the Columbia River basalt and therefore is post-late Miocene and probably mid-Pliocene. Since the upper Troutdale interfingers with the lower Rhododendron formation the former is not much later than mid-Pliocene.

Pliocene Volcanics

<u>Fern Ridge Tuffs</u>

The Fern Ridge tuffs were described by Thayer (34, p.8) from their type section five miles northeast of Stayton. He states that they are as much as 1,500 feet thick north-east of Mehama. The lower beds are tuffaceous or fine grained water-laid clastics, while the upper part is a coarse boulder conglomerate with a tuffaceous matrix (34, p.8).

Thayer expressed the belief that the Fern Ridge tuffs were deposited on the fresh uneroded surface of the Columbia River lavas and are therefore upper Miocene or lower Pliocene. O'Neill (27, p.44) disagrees with this correlation in that he points out that a mature erosional surface on the Columbia River lavas indicates that the Fern Ridge tuff could not have been deposited much before mid-Pliocene.

According to Libby et al (23, p.69), the presence of a nodule of high-grade gibbsite in contact with the Columbia River lavas and lying beneath the Fern Ridge tuff is sufficient evidence that laterization took place before deposition of the tuff. Erosion was necessarily taking place in the basalt in order to have such a weathering product included in a later formation (23, p.69). The writer therefore agrees with O'Neill that the contact between the Columbia River basalt and the Fern Ridge tuff is unconformable.

Rhododendron Formation

The Rhododendron formation was first described by Hodge (19, p.157) for the exposures of pyroclastic rocks at Rhododendron, Oregon. Although Hodge recognizes the main centers of vulcanism to be in the Cascade area, he notes occurrences of Rhododendron volcanoes in the northern Willamette Valley. These westward occurrences were re-named Boring "agglomerate" by Treasher (35, p.10) in 1942.

The Rhododendron formation is composed of volcanic breccia, interbedded lava flows and gravels derived from volcanic sources. According to Sheets (32, p.54), samples of tuff contained crystals common to those in the included lavas and in the "Cascan" (20, p.879) lavas of slightly later date. The tuff contains rock fragments ranging from pea size up to twelve feet across which are dominantly andesite porphyry (32, p.54). Glassy basalt and scoria fragments are also common (32, p.54). According to Barnes and Butler (5, p.81), this tuffaceous conglomerate phase of the Rhododendron formation is water deposited.

The Rhododendron formation occurs around vents and as intracanyon deposits. Barnes and Butler (5, p.81) state that the Rhododendron formation is composed of groups of isolated beds and is not a continuous formation. They state further that it is difficult to reconstruct the sources for these pyroclastics from field evidence. From the nature of the formation it is obvious that the thickness is extremely variable. Sheets (32, p.53) has observed thicknesses ranging from 100 feet to 2,000 feet.

According to Hodge (20, p.875) the Rhododendron formation is in part contemporaneous with the upper Troutdale formation, and in part post-Troutdale (20, p.879). The Rhododendron formation (pyroclastic) is only a beginning phase of extrusive activity which has continued up to the present (20, p.877).

The Rhododendron formation is overlain by the Plio-Pleistocene Cascade andesites; therefore, the Rhododendron pyroclastics are probably late Pliocene in age.

Boring "Agglomerate"

The Boring "agglomerate" sic [4] of Treasher (35, p.10) is lithologically and stratigraphically similar to the

[4] According to the usage of Williams and Wentworth (44, p.45) Treasher's use of the word "agglomerate" in describing this formation is incorrect. The lithology of this unit is volcanic breccia and tuff, therefore the writer places Treasher's term agglomerate in quotes.

Rhododendron formation and is unique only in its sources and distribution. The Boring "agglomerate" erupted from vents including Mt. Sylvania in the Portland Hills, Mt. Tabor, and the several volcanic cones in the Boring Hills.

The writer considers the Boring "agglomerate" of Treasher to be a westward occurrence, from different vents, of the type of volcanic activity which produced the pyroclastics of the Rhododendron formation previously described.

Plio-Pleistocene Lavas

Cascade Andesites

The activity of the Rhododendron vulcanism gradually subsided until the once explosive volcanoes began to produce lavas of the "Cascan" formation of Hodge (20, p.879), as stated by Treasher (35, p.9) in describing the Boring lava extrusions.

The Plio-Pleistocene lavas of the Cascade Range were called the Cascade formation by Williams (43) in 1916. Barnes and Butler (5, p.84) considered the name to be the Cascade formation, but referred to the rocks as the Cascade andesites. Sheets (32, p.66) and Allen (1, p.68) in 1932 utilized the contraction of Cascade andesites, the "Cascan" formation, for convenience. This has been the usage of Hodge (20, p.879).

The writer considers the name Cascade andesite as a formational name to be consistent with common practice of binomial nomenclature, the first name geographic and the second name lithologic; thus Cascade andesite is consistent with the terms Columbia River basalts, Troutdale gravels, etc.

The Cascade andesite lies upon the Rhododendron formation, but because of the patchy distribution of the latter it is not everywhere underlain by pyroclastics. The Cascade andesites occur as the capping formation across the entire width of the Cascade Range in the Columbia River Gorge vicinity except where they are overlain by the more recent andesites extruded from Mt. Hood.

Lavas of this period occurring in the Portland vicinity were called Boring lavas by Treasher (35, p.10). The Boring lavas cap the Columbia River basalts along the western slope of the Portland Hills, in the West Lynn district, and east and south from Oregon City as far as the northeast corner of the Molalla quadrangle.

The Cascade andesites are in part made up of basalt and trachyte flows of many types (20, p.882). The basaltic lavas are relatively light colored in contrast to the Columbia River basalts. A thin section examination shows numerous phenocrysts of light colored plagioclase crystals set in a matrix containing enough minute feldspar crystals to give the rock a gray color. The feldspars are very close to ab 50 and so minor fluctuations in the chemistry of the magma resulted in changes in the composition of the lava in andesite-basalt range. It seems reasonable that the lavas occurring the greatest distances from their sources be of the more basic type in the Cascan formation. It is well known that basaltic lavas are more fluid and so might well have travelled a greater distance westward from the vents at the site of the present day Cascade Range.

The thickness of the formation ranges from 100 feet up to 1,000 feet except in the canyons where the thickness is "much greater" (20, p.885).

The Cascade andesites have not been accurately dated. They lie upon the Rhododendron with little or no break in time; therefore they must be post-late Pliocene or early Pleistocene.

Boring Lavas

The Boring lavas of Treasher (35, p.11) are similar lithologically to the more basic flows of the Cascade andesites. They erupted from the same vents as the previously described Boring "agglomerate"; thus they have generally the same distribution in the Portland and Boring hills. The lavas were slightly less viscous than the Cascade andesites and therefore they were able to flow greater distances over lower gradients. It is possible that part of the more basic Cascade andesite lavas flowed far enough west to be known now as part of the Boring lavas.

The writer considers the Boring lavas which originated mostly from local vents to be a westward equivalent of the Cascade andesites.

SUMMARY OF CHARACTERISTICS OF TERTIARY LAVAS

Three distinct Tertiary basaltic lava units which are recognized in northwest Oregon have been discussed on previous pages under the headings of Eocene volcanics, Miocene lavas, and Plio-Pleistocene volcanics. As might be expected, numerous variations within the lithologies of these basalts result occasionally in questionable identification in exposures where the stratigraphic position is not clearly known.

Eocene Lavas

The Tillamook volcanics occur usually in massive red and yellow stained outcrops and often are amygdaloidal. These lavas are commonly epidotized or chloritized so as to give the rock a slightly green color. They are usually associated with marine sediments. Occasionally Eocene basalt resembles the dense, fine-grained Columbia River basalt. This probably is due to an occasional sub-aerial extrusion caused by build-up of volcanic materials above the surface of the water.

Miocene Lavas

The Columbia River basalts have the most uniform characteristics for recognition. They are observed to be entirely terrestrial and usually are displayed in flows of uniform thickness with well developed columnar jointing. Basalt interbedded in the Astoria formation at Bradley Park on the Columbia River near Astoria does not appear to have characteristics of submarine lavas. A distinctive soil zone is usually present between the flows. The rock is usually dark and dense and phenocrysts are not usually apparent. Weathering is usually slight except where laterization has taken place, and then the rock is entirely decomposed. This laterization is found so far only in the Miocene lavas and is therefore a useful criterion. The Columbia River basalts are occasionally confused with either the Eocene or the Plio-Pleistocene lavas. When the blocky-jointed interior of a thick flow of Miocene Columbia River basalt is highly weathered, it closely resembles the denser Eocene lava. Occasionally Miocene basalt contains a considerable number of light colored feldspar crystals and more closely resembles the darker colored Plio-Pleistocene lava.

Plio-Pleistocene Lavas

The Cascade andesites and their equivalents are either late Pliocene or early Pleistocene in age. The Cascade andesite (and equivalent local Boring basalts) occurs as thin flows and the total thickness is rarely more than 100 feet in the Portland and Oregon City areas except as intra-canyon flows where the thickness is greater. The aggregate thickness of this lava increases eastward towards the crest of the Cascades. The rock is light colored and is usually highly porphyritic with light-colored feldspar phenocrysts. The Cascade andesite contains numerous small vesicles or voids which indicate that the lava contained considerable amounts of volatiles.

When identification of the lava unit is not apparent, a combination of criteria is sometimes helpful. For this reason the table Summary of Characteristics of Tertiary Lavas (Plate VI) was prepared.

PLATE VI

CHARACTERISTICS OF TERTIARY LAVAS

AGE	EOCENE	MIOCENE	PLIO-PLEISTOCENE
COLOR	Green to black	Gray to black	Gray
TEXTURE	Coarsely vesicular or amygdaloidal Often porphyritic	Usually dense but sometimes scoriaceous near contact	"Expanded", many small vesicles Highly porphyritic
MINERALOGY	Phenocrysts: basic plagioclase, ferromagnesian minerals Secondary minerals: epidote, calcite, zeolites, chlorite, magnetite, pyrite	Phenocrysts: basic plagioclase, hypersthene Secondary minerals: limonite or hematite stain	Phenocrysts: andesine, clinopyroxene, olivine Secondary minerals: limonite stain
STRUCTURE	Massive jointing, thick domed flows, pillow structure, sedimentary interbeds Often highly fractured with serpentine coated fracture seams	Columnar jointing, flows uniform thickness, low angle dip, red baked contact	Crude columnar to platy jointing, flows often intracanyon, often high initial dip
WEATHERING	Red and brown along seams, often rotten and crumbly	Usually fresh except where laterized	Weathering slight
THICKNESS	5,000 - 10,000 ft.	400 - 3,000 ft.	100 ft. plus
STRATIGRAPHIC RELATIONS	Lower contact unexposed, overlain by Eocene and later sediments	Overlies Oligocene marine beds, overlain by Troutdale gravels and Fern Ridge tuff	Lies on Troutdale or Rhododendron formation

STRUCTURE

Coast Range

The Coast Range is folded into an anticlinorium which plunges to the north. Although the sediments generally dip away from the axis of the fold, numerous smaller folds and faults affect the dips locally. The northward plunge of the upfold is easily detected by the southward divergence of the Eocene rock outcrops northwest of Forest Grove.

In the St. Helens quadrangle Wilkinson *et al* (42, p.33) describes a syncline with the axis striking southeast and plunging in that direction.

Willamette Valley

In the Willamette Valley the Eocene and Oligocene rocks have a general east dip. Post-Miocene folding is detected largely by the attitude of the Columbia River basalt flows. Since the initial dip of the basalt was small, dips of more than a few degrees are considered to be deformational.

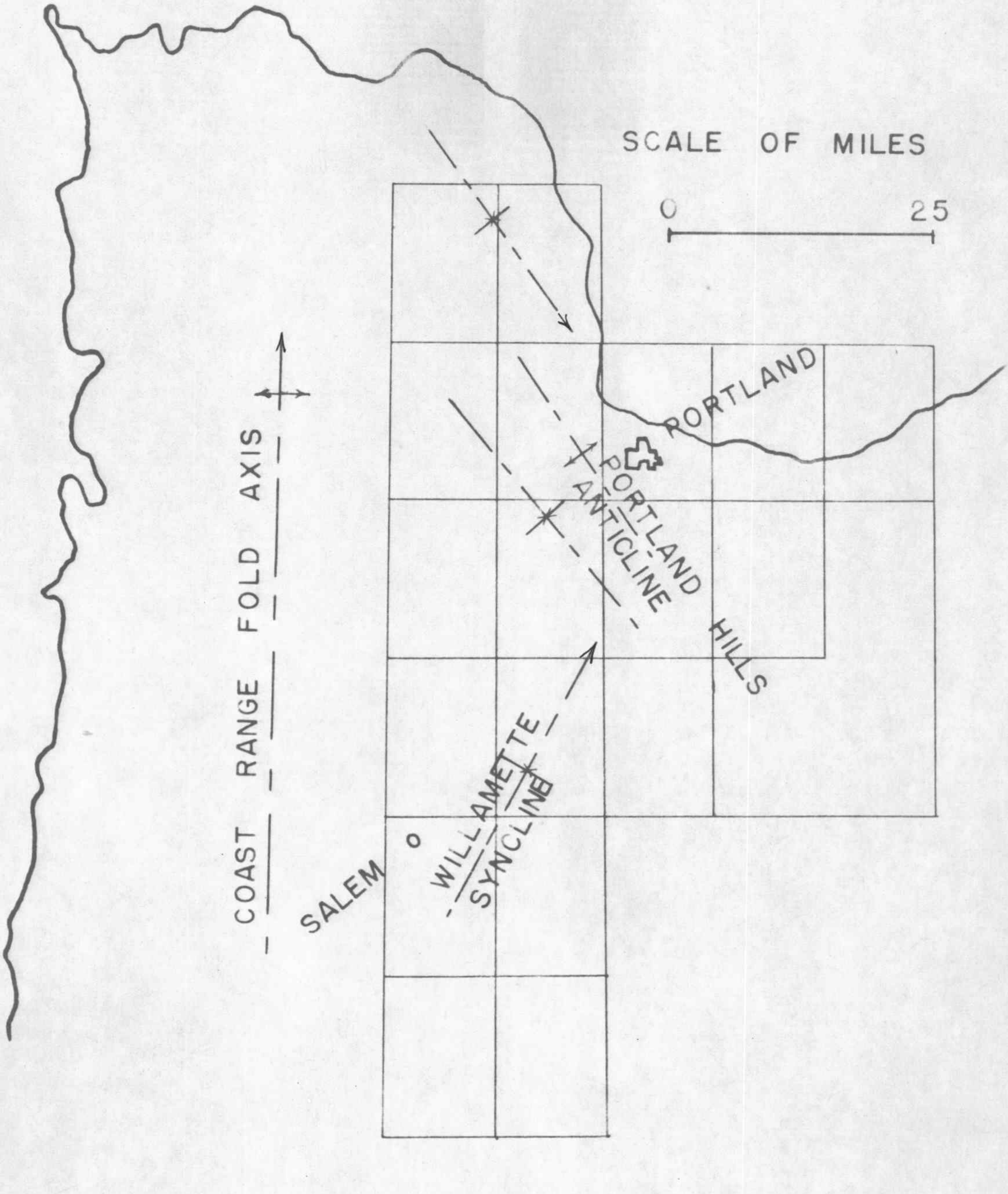
The Willamette Valley northeast of Salem is situated along the axis of a north plunging structure named the Willamette syncline by Thayer (34, p.13). The syncline is formed by the eastward dipping basalt flows in the Eola Hills and the northwest dipping Stayton lavas in the Waldo Hills. The downwarped lavas (if present) along the axis of the syncline are interpreted to be buried by valley fill several hundred feet thick.

In the Tualatin Valley west of Portland the Miocene basalt is folded into a syncline with its axis trending northwest through the city of Hillsboro. The Tualatin syncline is bounded on the southwest by the Chehalem Hills and on the northeast by the Portland Hills anticline.

The Portland Hills anticline which trends northwest through Portland along the west bank of the Willamette River has been described by Treasher (35, p.8), who states that folding is sufficient in itself to produce such a structure. In the opinion of the writer a fault along the northeast edge of the anticline is suggested by the scarp of the Portland Hills northwest of that city.

Western Cascades

The Cascade Range is considered to be a north-south pile of volcanic materials of moderate relief prior to the extrusions of the Columbia River basalts. The Columbia River basalts which occur at lower elevations have since been gently folded. Later Cascade lavas have flowed out all along the Cascade Range with moderate to steep initial dips which mask later folding if such occurred.



STRUCTURE MAP

PLATE VII

ECONOMIC GEOLOGY

The relatively unaltered and geologically younger formations of northwest Oregon have but little to offer in the way of economic minerals. Gold, copper, sphalerite and galena have been mined in the upper reaches of the North Santiam River, but high labor costs and inaccessibility have thwarted most mining ventures.

The economic worth of resources in this area is coupled to the development of industry which in turn is dependent upon cheap hydroelectric power. The abundant water resources in northwest Oregon are therefore a factor in determining the economic importance of brick and tile clay, road metal, cement and, to a small extent, building stone.

There are numerous deposits of clay suitable for brick within the Willamette Valley. The yearly value of clay products in Oregon approaches 1,000,000 dollars (2, p.5) and the majority of brick plants are in northwest Oregon.

Numerous rock quarries and gravel pits are in continual operation to provide the aggregates required in concrete used in all types of construction, and to provide materials for highway construction and repair. The Columbia River basalt is preferred for highway construction where it is available.

Limestone occurring in the Eocene marine deposits southwest of Dallas, Oregon, is crushed and used in soil locally for enrichment.

A process for "popping" calcareous shale by heat treatment has been recently developed and "lightweight aggregate" is being produced commercially. One plant is located just east of the Sunset Tunnel on the Sunset Highway about fifty miles west of Portland, Oregon, and another in Portland. The shales utilized are marine Oligocene Keasey shales.

"Ferruginous bauxite" occurs in many areas west of the Cascade Range as a result of the laterization of the Columbia River basalts (23). During World War II critical shortages of aluminum activated a study of these deposits as well as the construction of a pilot plant at Salem, Oregon, to process other clays. No bauxite was processed, however, since the war's end preceded completion of the plant. With the end of the war the cost of processing low grade ores did not warrant further expenditures.

As better methods are developed for the processing of "ferruginous bauxite" many of the bauxitic ores in Oregon may become of commercial importance.

GEOLOGIC HISTORY

Pre-Columbia River Basalt Time

The oldest exposed rocks in northwest Oregon are the rocks of the mid-Eocene Tillamook volcanic series which are best seen in the eroded core of the Coast Range. Other exposures of Eocene volcanic rocks have been recognized as Pre-Butte Creek lavas in the Molalla quadrangle, a small unnamed outcrop of steeply dipping lavas occurring in the channel of the Willamette River one mile north of New Era, the Siletz volcanic series, and the Coffin Butte volcanics north of Corvallis. In the Coast Range, Eocene volcanics are unconformably overlain by late Eocene clastic rocks which are recognized in the mapped area only along the flanks of the Coast Range (undifferentiated Ts and Tes, Plate X) and the Helmick beds exposed in the southwest corner of the Salem quadrangle.

A mid-Eocene sea with its east coastline lying near the present day foothills of the Cascade Range must have literally boiled at times from sub-aqueous vulcanism which took place at that time. During intervals of quiescence, sea life migrated back to where it had been obliterated by a previous eruption only to have the process repeated. At times the sea must have been dotted with fiery volcanic islands which probably greatly resembled the active volcanoes in the Aleutian Islands. When the volcanic phase of the Eocene epoch had ceased, folding occurred which exposed the submarine lavas to vigorous erosion by waves and weather. As the sea eroded its way landward, deposition of the coarser clastics resulted in the formation of a basal conglomerate seen in the Rocky Point formation in northwest Oregon. That erosion had reduced the high areas by the end of the Eocene epoch is evidenced by the increasingly finer texture of the sediments upward in the Rocky Point formation. That a variety of conditions prevailed during the transitional period from the deposition of Eocene clastics to the more tuffaceous Oligocene phase is evidenced by the heterogeneous lithology of the Nehalem formation in the upper Nehalem basin.

In early Oligocene time subsidence occurred which caused a general deepening of the sea and probably a submergence of most if not all of the land areas to the west of the present day Cascade foothills. Volcanoes, which supplied the vast quantities of ash to the Oligocene sea, became increasingly active later in the epoch. By the end of the Oligocene epoch vast quantities of terrestrial tuff and tuffaceous marine sediments had accumulated. After folding and uplift, an extensive period of erosion by mid-Miocene reduced the area to a mature topography characterized by gently rounded hills.

Immediately prior to the extrusion of Columbia River lavas, the area west of the present Cascade Range was one of low mature topography with a relief of about 500 feet. The Cascade area probably had slightly greater elevation since it had remained above the level of the seas and had been the main source area throughout Oligocene time.

Columbia River Basalt Time

Beginning with the mid-Miocene, lavas quietly erupted from vents and fissures. As the lava poured out, it spread out as thick syrup filling the depressions, but having a nearly level upper surface. The flow from one outburst was seldom thicker than 100 feet and probably flowed a maximum distance of fifty miles from its source. A neighboring flow may or may not have been able to reach the first one, but other "well spaced" fissures probably supplied lavas to the intervening gaps. Continual sporadic eruptions of basalt, with geologically short quiescent periods locally, resulted in one of the largest aggregations of basaltic lava known in geologic history. When the eruptions had ceased, a vast lava plain with an average thickness of more than 3,000 feet covered more than half of Oregon and Washington, and part of Idaho. The lavas in the Willamette Valley were joined to the main body of the Columbia Plateau in eastern Oregon by a connecting strip of lava which crossed the Cascades near the present Gorge. The basalts spread out west of the Cascades but were much thinner near the extremities of the formation.

Post Columbia River Basalt Time

Following the extrusion of the basalts, but prior to folding, in some areas, the top thirty or more feet was completely altered by laterization. That this laterization was quite extensive west of the Cascades is apparent from the fact that almost any area containing Miocene basalt flows contains patches of laterite. This period of laterization represents tropical to sub-tropical humid climatic conditions with the land at or near sea level.

Gentle folding and erosion followed the period of laterization. Fast running streams loaded with gravels and ash derived from eastern highlands deposited thick sequences of gravels and tuffs in the area adjacent to the present day Columbia River Gorge. During the final stages of the deposition of this gravel, active vulcanism in the Cascade area produced quantities of tuff and breccia which were deposited with and upon the cross-bedded gravels. In late Pliocene or early Pleistocene the area was folded further as is evidenced by the attitude of the Pliocene gravels. Extrusions of andesite, which continued up to almost recent times, have given the youthful relief to the Cascade Range. Sub-recent epirogenic uplift or eustatic changes in sea level in response to Pleistocene climate changes is evidenced by the several terraces formed by the Willamette River and its tributaries. It is possible a lowering of sea level might have been responsible for the lowering of the base level of erosion in this area.

SUMMARY

Conclusions which are presented in more detail in the body of the thesis are here summarized. Stratigraphic correlations have involved strata of Eocene to Pleistocene age.

Eocene lavas and related sediments of the Coast Range of northwest Oregon described as Tillamook, Goble, Siletz River and Coffin Butte volcanics are similar in lithology, structure and stratigraphic age. It is suggested that the earlier used name Tillamook volcanics be used for Eocene volcanics in the Coast Range of northwest Oregon.

Since the Scappoose formation in the northwest Oregon has not been proved a mappable unit, it is herein suggested that the name Scappoose be dropped and the strata previously considered to be Scappoose be included in the Pittsburg Bluff formation.

The Eugene formation of Schenck (33) should be extended northward to include the Illahe of Thayer (34) and the Butte Creek beds of Harper (18).

The Mehama and Berlin volcanic formations are similar in all respects. Since the name Mehama has priority, its use should be extended to include the Berlin volcanics.

The Salem and Stayton basalts are concluded to have been continuous with the Columbia Lava Plateau east of the

Cascades; therefore, the names Salem lava and Stayton basalts should be dropped in favor of the name Columbia River basalt.

The Boring "agglomerate" formation as well as the Boring lavas are westward extensions of formations in the Cascade Range. Their occurrence from local vents near Portland accounts for the use of a local name.

RECOMMENDATIONS FOR FURTHER STUDY

Of considerable value to the further completion of the geology of the Willamette Valley and the Cascade area would be the mapping and study of certain quadrangles bordering the east side of the Willamette Valley.

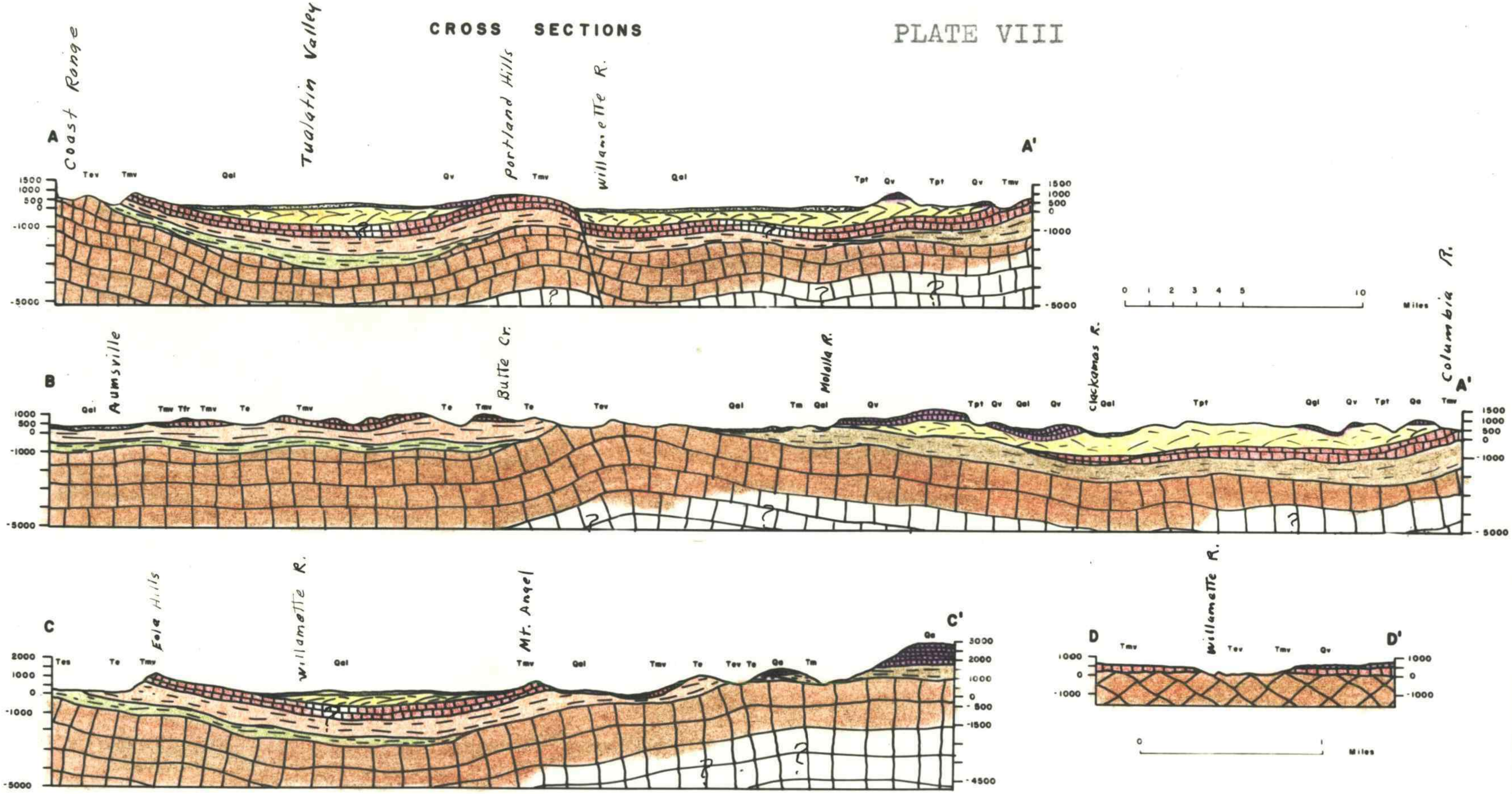
A detailed geologic study in the southwest quarter of the Estacada quadrangle would possibly prove the equivalency of the Troutdale gravels in the Boring quadrangle to the north with those in the Molalla quadrangle to the west. Evidence as to the position of the ancestral Columbia River in mid-Pliocene time in this area might be revealed (see p. 47).

The Lyons and Snow Peak topographic quadrangles, lying east of the Stayton and Lebanon quadrangles respectively, have been published recently. Study in these areas which link the high Cascade formations with those in the Valley may provide the information necessary to a better understanding of the geology of the Cascade Range.

Detailed mapping in the Vernonia and surrounding quadrangles would establish whether or not the Scappoose formation is a valid mappable unit.

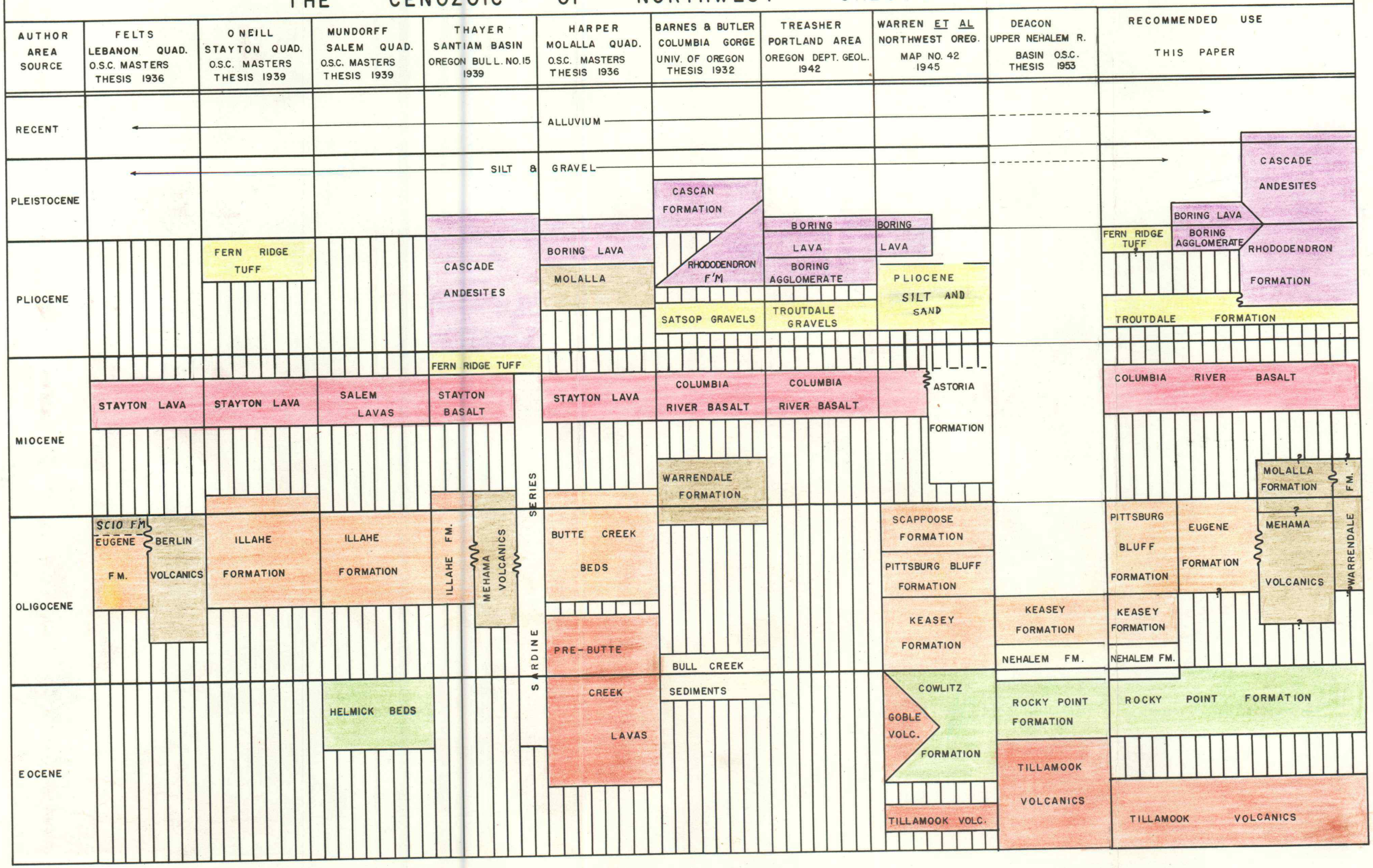
CROSS SECTIONS

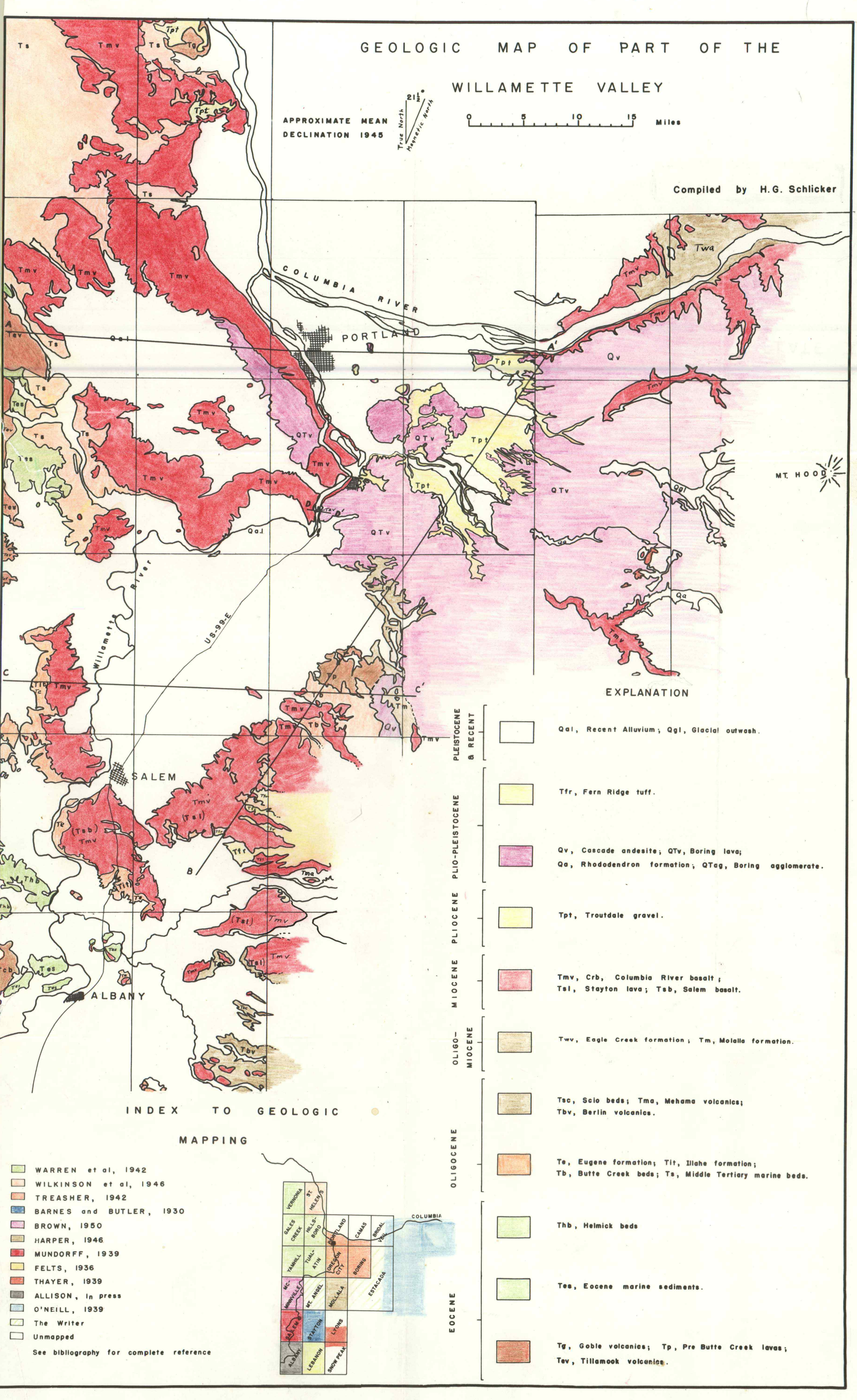
PLATE VIII



CORRELATION TABLE OF THE CENOZOIC OF NORTHWEST OREGON

Plate IX




GEOLOGIC MAP OF PART OF THE
WILLAMETTE VALLEY
APPROXIMATE MEAN
DECLINATION 1945
True North
Magnetic North
21½°
0 5 10 15 Miles
Compiled by H.G. Schlicker
COLUMBIA RIVER
PORTLAND
SALEM
ALBANY
MT. HOOD
Willamette River
US-99-E
EXPLANATION
PLEISTOCENE & RECENT
Qal, Recent Alluvium; Qgl, Glacial outwash.
PLIO-PLEISTOCENE
Tfr, Fern Ridge tuff.
Qv, Cascade andesite; QTv, Boring lava;
Qa, Rhododendron formation; QTag, Boring agglomerate.
PLIOCENE
Tpt, Troutdale gravel.
MIOCENE
Tmv, Crb, Columbia River basalt;
Tsl, Stayton lava; Tsb, Salem basalt.
OLIGO-MIOCENE
Twv, Eagle Creek formation; Tm, Molalla formation.
OLIGOCENE
Tsc, Scio beds; Tma, Mehama volcanics;
Tbv, Berlin volcanics.
Te, Eugene formation; Tit, Illahe formation;
Tb, Butte Creek beds; Ts, Middle Tertiary marine beds.
EOCENE
Thb, Helmick beds
Tes, Eocene marine sediments.
Tg, Goble volcanics; Tp, Pre Butte Creek lavas;
Tev, Tillamook volcanics.
INDEX TO GEOLOGIC
MAPPING
WARREN et al, 1942
WILKINSON et al, 1946
TREASHER, 1942
BARNES and BUTLER, 1930
BROWN, 1950
HARPER, 1946
MUNDORFF, 1939
FELTS, 1936
THAYER, 1939
ALLISON, In press
O'NEILL, 1939
The Writer
Unmapped
See bibliography for complete reference
COLUMBIA
VERNONIA
ST. HELENS
GALES CREEK
HILLSBORO
PORTLAND
CAMAS
BRIDAL VEIL
YAMHILL
TUALATIN
OREGON CITY
BORING
McMINNVILLE
MT. ANGEL
MOLALLA
ESTACADA
SALEM
STAYTON
LYONS
ALBANY
LEBANON
SNOW PEAK

BIBLIOGRAPHY

1. Allen, John Eliot. Contributions to the structure and stratigraphy of the lower Columbia River Gorge, Oregon. Master's thesis. Eugene, University of Oregon, 1932. 143p.

2. _____, and Ralph S. Mason. Brick and tile industry in Oregon. Portland, Oregon, 1949. 28p. (Oregon department of geology and mineral industries. Short paper 19)

3. Allison, Ira S. Geology of the Albany quadrangle, Oregon. Portland, Oregon, 1953. 18p. (Oregon department of geology and mineral industries. Bulletin 37)

4. Baldwin, Ewart M. Geology of the Dallas and Valsetz quadrangles, Oregon. Portland, Oregon, 1947. 61p. (Oregon department of geology and mineral industries. Bulletin 35)

5. Barnes, Ferrall F., and John W. Butler. Structure and stratigraphy of the Columbia River Gorge and the Cascade Mountains in the vicinity of Mt. Hood. Master's thesis. Eugene, University of Oregon, 1930. 137p.

6. Bogue, Richard G. Petrographic study of Mt. Hood and Columbia River basalt formations. Master's thesis. Eugene, University of Oregon, 1932. 88p.

7. Bretz, J. H. The Satsop formation of Oregon and Washington. Journal of geology 25:446-458. 1917.

8. _____. The Spokane flood beyond the channeled scablands. Journal of geology 33:249-252. 1925.

9. Brown, Robert David. Geology of the McMinnville quadrangle, Oregon. Master's thesis. Eugene, University of Oregon, 1950. 54p.

10. Chaney, Ralph W. Flora of the Eagle Creek formation, Washington and Oregon. Chicago University, Walker museum, contribution 2(5):115-181, July 1920.

11. _____, Carlton Condit, and Daniel I. Axelrod. Pliocene floras of California and Oregon, 1944. 407p. (Carnegie institution of Washington. Publication 553)

12. Clapp, C. H. Preliminary report on southern Vancouver Island. Canada department of mines, geology survey branch, memoir 13:86-96. 1912.

13. Cushman, Joseph A., and Roscoe E. and Katherine C. Stewart. Eocene formaninifera from Helmick Hill, Polk county Oregon. Portland, Oregon, 1947. 110p. (Oregon department of geology and mineral industries. Bulletin 36)

14. Deacon, Robert Julian. A revision of upper Eocene and lower Oligocene stratigraphic units in the upper Nehalem River basin, northwest Oregon. Master's thesis, Corvallis, Oregon state college, 1953. 83p.

15. Diller, J. A. Structure and age of the Cascade Range, Oregon. American geologist 18:61. 1896 (abstract)

16. Effinger, W. L. The Gries Ranch fauna of western Washington. Journal of paleontology 12(4):355-390. 1938.

17. Felts, Wayne Moore. Geology of the Lebanon quadrangle, Oregon. Master's thesis. Corvallis, Oregon state college, 1936. 83p.

18. Harper, Herbert Ewing. Preliminary report on the geology of the Molalla quadrangle, Oregon. Master's thesis. Corvallis, Oregon state college, 1936. 29p.

19. Hodge, Edwin T. Age of the Columbia River and lower canyon. Geological society of America bulletin 44(1):157. 1933. (abstract)

20. _____. Geology of the lower Columbia River. Geological society of America bulletin 49:831-930. 1938.

21. LeConte, Joseph. On the great lava flood of the northwest: and the structure and age of the Cascade Mountains. American journal of science, 3rd series, 7:176-180. 1874.

22. Lesquereux, Leo. Recent determinations of fossil plants from Kentucky, Louisiana, Oregon, California, etc. United States national museum proceedings 11:11-38. 1888.

23. Libby, F. W., W. D. Lowry, and R. S. Mason. Ferruginous bauxite deposits in northwestern Oregon. Portland, Oregon, 1945. 97p. (Oregon department of geology and mineral industries. Bulletin 29)

24. Lowry, W. D. The extent of the Oligocene sea in northwestern Oregon. Geological society of the Oregon country. News letter 13(1):1-7. 1947.

25. _____, and E. M. Baldwin. Late Cenozoic geology of the lower Columbia River Valley, Oregon and Washington. Geological society of America bulletin 63:1-24. 1952.

26. Mundorff, Maurice John. The geology of the Salem quadrangle, Oregon. Master's thesis. Corvallis, Oregon state college, 1939. 79p.

27. Nichols, Robert Leslie. Preliminary report on the Molalla high alumina clay deposit near Molalla, Clackamas county, Oregon. U. S. geological survey. Strategic minerals investigations, April 1944. (A typewritten report prepared in cooperation with the Oregon department of geology and mineral industries, Portland, Oregon, as a U. S. geologic survey, strategic minerals investigation, April 1944)

28. O'Neill, Thomas Francis. The geology of the Stayton quadrangle, Oregon. Master's thesis. Corvallis, Oregon state college, 1939. 83p.

29. Packard, E. L., and W. D. Smith. Salient features of the geology of Oregon. Journal of geology 27:79-120. 1919.

30. Sanborn, Ethel I. The Scio flora of western Oregon. Corvallis, Oregon state college, 1947. 47p. Oregon state college. Monograph studies in geology no. 4)

31. _____. The prehistoric forests of Oregon. Geological society of the Oregon country. News letter 2(20): 3-8. 1936.

32. Sheets, Meredith M. Contributions to the geology of the Cascade Mountains in the vicinity of Mt. Hood. Master's thesis. Eugene, University of Oregon, 1932. 141p.

33. Schenck, Hubert G. Marine Oligocene of Oregon. University of California. Publications bulletin of the department of geological sciences 16(12):449-460. 1927.

34. Thayer, Thomas P. Geology of the Salem Hills and North Santiam River basin, Oregon. Portland, Oregon, 1939. 40p. (Oregon department of geology and mineral industries. Bulletin 15)

35. Treasher, Ray C. Geologic history of the Portland area. Portland, Oregon, 1942. 17p. (Oregon department of geology and mineral industries. Short paper 7)

36. _____. Geologic map of the Portland area. Portland, Oregon, 1942. 1p. (Oregon department of geology and mineral industries. Map series)

37. (Turner, F. E.) Stratigraphy and mollusca of the Eocene of western Oregon. Geological society of America, Special papers 10. 130p. 1938.

38. Warren, W. C., and Hans Norbisrath. Stratigraphy of the upper Nehalem basin, northwestern Oregon. American association of petroleum geologists, Bulletin 30(2):213-237. 1946.

39. _____, _____, and R. M. Grivetti. Geology of northwestern Oregon. (U. S. geological survey. Oil and gas investigations, preliminary map 42). 1945.

40. Weaver, Charles Edwin. Tertiary stratigraphy of western Washington and northwestern Oregon. Seattle, University of Washington, 1937. 266p. (University of Washington publications in geology. Vol. 4)

41. _____. Geology of Oregon and Washington and its relation to the occurrence of oil and gas. American association of petroleum geologists bulletin 29(10):1377-1415. 1945.

42. Wentworth, Chester K., and Howel Williams. Classification and terminology of the pyroclastic rocks. National research council Washington bulletin 84: 19-35, 1932.

43. Wilkinson, W. D., W. D. Lowry, and E. M. Baldwin. Geology of the St. Helens quadrangle, Oregon. Portland, Oregon, 1946. 39p. (Oregon department of geology and mineral industries. Bulletin 31)

44. Williams, I. A. The Columbia River Gorge: Its geologic history interpreted from the Columbia River highway. Mineral resources of Oregon 2(3):1-130. 1916.

APPENDIX

APPENDIX

Notes on Map

Under the index to geologic mapping on Plate X Allison "in press" should be read Allison 1953 since the publication was in print prior to the completion of this thesis.

"Tcb" area on the west side of the Albany quadrangle colored as Eocene lava should be listed in the "Explanation" of Plate X as Coffin Butte volcanics.

"Ts" used along the left border near the top of Plate X and shown in the Explanation as Oligocene is that of Warren _et al_ (39) which on their map of northwest Oregon includes upper Eocene to Miocene marine sediments. The orange color symbolizing an Oligocene age is utilized on Plate X since the area represented by "Ts" on this map is almost entirely Oligocene comprised of the Keasey, Pittsburg Bluff and Scappoose formations.

In the text (p. 47) it was stated that part of the lavas mapped as Eocene by Harper in the Molalla quadrangle are actually Pliocene. The writer has not re-mapped these lavas but has indicated by color and a dotted line where the contact presumably occurs. Note: Eocene lavas are red-brown while Pliocene lavas are purple. (See map, Plate X)