Geology of the Anlauf and Drain Quadrangles Douglas and Lane Counties, Oregon

By LINN HOOVER

CONTRIBUTIONS TO ECONOMIC GEOLOGY

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A study of the mineral resources in Tertiary and Quaternary deposits in west-central Oregon

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GEOLOGY OF THE ANLAUF AND DRAIN QUADRANGLES, DOUGLAS AND LANE COUNTIES, OREGON

By Linn Hoover

ABSTRACT

The Anlauf and Drain quadrangles, Oregon, lie about 20 miles south of the city of Eugene, in Douglas and Lane Counties. They constitute an area of about 435 square miles that includes parts of both the Cascade Range and Coast Range physiographic provinces.

A sequence of lower Tertiary sedimentary and volcanic rocks with a maximum thickness of about 20,000 feet is exposed in the area. The oldest part of this sequence is the Umpqua formation of early Eocene age consisting of a lower member of vesicular and amygdaloidal olivine basalt flows, a middle member of water-laid vitric and lapilli crystal tuff, and an upper member of interbedded fissile siltstone and basaltic sandstone which contains a 300-foot tongue of massive to thick-bedded basaltic sandstone near its top. These rocks are predominantly of marine origin, although the general absence of pillow structures which are common in basaltic lavas of equivalent age elsewhere in the Coast Ranges suggests that some of the flows were poured out subaerially. The overlying tuff member, however, contains Foraminifera and in places has a lime content slightly in excess of 10 percent. Mollusca and Foraminifera indicate that the Umpqua formation is of early Eocene age and is a correlative of the Capay formation of California.

The Tyee formation of middle Eocene age overlies the Umpqua formation and consists of more than 5,000 feet of rhythmically deposited sandstone and siltstone in beds 2 to 30 feet thick. The basal part of each bed consists of medium- to coarse-grained sandstone that grades upward into fine-grained sandstone and siltstone. The principal constituents of the sandstone are quartz, partly altered feldspar, mica, clay, and fragments of basalt, fine-grained argillaceous rocks, and mica schist. Other detrital minerals include epidote, garnet, blue-green hornblende, tourmaline, and zoisite. The depositional environment of the Tyee formation is poorly known, although the rhythmic-graded bedding suggests turbidity currents.

About 500 feet of sandstone and siltstone assigned to the Spencer formation of late Eocene age unconformably overlies the Tyee formation. The Spencer formation, better exposed in the east-central part of the Coast Ranges, contains marine fossils but also has thin impure coal beds, indicative of strand-line accumulation. The sandstone in the Spencer formation is very similar to that in the Tyee formation, from which it was probably derived.

The Fisher formation contains about 5,500 feet of nonmarine pyroclastic and volcanic rocks that are related to the volcanic rock sequences of the western Cas-

cade Range. The formation is characterized by a wide variety of rock types, including conglomerate, tuffaceous sandstone and siltstone, vitric and crystal tuff, waterlaid and mudflow breccia, and andesitic lava flows. These rocks generally occur in lenticular beds that have little stratigraphic significance. The rocks apparently accumulated on a plain slightly above sea level that was subjected alternately to flooding by running water and to desiccation. Fossil leaves from the lowermost part of the Fisher formation are of late Eocene age; the upper part of the formation is of early, and possibly middle, Oligocene age.

A few exposures of olivine basalt were mapped in the extreme northern part of the Anlauf quadrangle. The flows, more extensively exposed to the north, overlie the Fisher formation, and, therefore, are tentatively considered to be post-Oligocene in age.

All these stratigraphic units, but principally the Fisher formation, are cut by dikes, sills, and stocklike bodies of porphyritic basalt, diabase, and norite. Contemporaneously with the emplacement of most of these rocks, in late Miocene(?) time, hydrothermal solutions locally altered the sedimentary and extrusive igneous rocks and deposited cinnabar and other sulfide minerals, carbonates, and silica.

Three parallel northeastward-trending anticlines in the older marine rocks are the most conspicuous structural features in the area. These folds plunge both to the northeast and southwest and expose in their central parts basalt flows of the Umpqua formation. The rocks along the west margin of the area dip westward into a structural basin in the adjacent Elkton quadrangle, whereas to the east the Fisher formation generally has an easterly dip typical of the nonmarine rocks in the western Cascade Range.

Geologic studies in the Anlauf and Drain quadrangles were undertaken principally to evaluate the petroleum possibilities of the area. Available data indicate that source beds and reservoir rock suitable for the formation and accumulation of petroleum are absent in this part of the Coast Ranges, but because of the lack of subsurface information, this evaluation is only tentative. Mineral deposits of economic value in the area include quicksilver and alumina clay.

INTRODUCTION

LOCATION AND EXTENT OF AREA

The Anlauf and Drain quadrangles, Oregon, lie about 20 miles south of the city of Eugene, in Douglas and Lane Counties. They constitute an area of about 435 square miles which includes parts of both the Cascade Range and the Coast Ranges and which is bounded by lat 43°30′ and 43°45′ and long 123° and 123°30′. The location of the area is shown on the index map (fig. 1).

PURPOSE AND SCOPE OF REPORT

During World War II the U.S. Geological Survey began an investigation of the geology and the petroleum potential of the Coast Ranges in Oregon. To complete this assignment, of which this report is a partial result, basic data have been obtained on the distribution, thickness, lithology, age, and structural setting of the marine Tertiary rocks that crop out in the Coast Ranges. Stratigraphic and foram-

FIGURE 1.—Index map showing location, by number, of the Anlauf and Drain quadrangles. Other areas mapped by the U.S. Geological Survey and the Oregon Department of Geology and Mineral Industries are:

1. Warren and others (1945).
2. Baldwin and Roberts (1952).
3. Baldwin and others (1955).
4. Snavely and Vokes (1949).
5. Baldwin (1947).
6. Vokes and others (1954).
7. Baldwin (1955).
8. Vokes and others (1954).
9. Baldwin (1956).
10. Vokes and others (1951).
11. Baldwin (1961).
12. Diller (1901); Allen and Baldwin (1944)
13. Diller (1898).
14. Diller (1903).

iniferal studies also have been undertaken to assist in understanding the geology of western Oregon.

The results of nine parts of this investigation, including geologic maps for all or parts of forty-eight 15-minute quadrangles, have been published previously and are included in the list of references.

PREVIOUS WORK AND PUBLICATIONS

The most comprehensive report previously published on the geology of the Anlauf-Drain area is that of Wells and Waters (1934). Their report, which dealt primarily with the quicksilver deposits of southwestern Oregon, contains a brief discussion of the stratigraphy and structure and a reconnaissance geologic map of the southeastern part of the area mapped for this report. In 1935 Wells and Waters also published a detailed study of the basalt flows and intrusive rocks in the Umpqua formation. Sanborn (1937) discussed an Eocene flora collected near Comstock, in the northwestern part of the Anlauf quadrangle, and Turner (1938) included a description of the sedimentary rocks exposed between Comstock and Drain in his report on the Eocene stratigraphy of western Oregon. Mining methods and a summary of the geology of the quicksilver deposits at the Black Butte and Elkhead mines in the eastern part of the mapped area were described by Schuette (1938). Reports by Denning (1943), Allen and Nichols (1945), and Allen and others (1951) described the high-alumina clay deposit at Hobart Butte.

J. S. Diller's many contributions to an understanding of the geology of western Oregon deserve acknowledgment in any geologic report on that region. His reconnaissance study of northwestern Oregon (1896) and description of the Roseburg quadrangle (1898) were particularly helpful in preparing this report.

FIELDWORK AND ACKNOWLEDGMENTS

Geologic field studies in the Anlauf and Drain quadrangles began in September 1954 and continued throughout most of the following summer months until September 1957. Geologic data obtained in the field were compiled on aerial photographs at a scale of about 1:47,-000 and subsequently were transferred to a 1:48,000 base map of the Anlauf and Drain quadrangles prepared by the U.S. Geological Survey.

The author was assisted during parts of the field seasons of 1956 by Norman V. Peterson and Jan A. Cummings and of 1957 by John S. Fryberger. Parke D. Snavely, Jr., contributed many helpful suggestions in the field and during the preparation of this report. The author also benefited from advice in the field by Dr. Charles M. Gilbert of the Department of Geology, University of California, and by Dr.

Ewart M. Baldwin of the Department of Geology, University of Oregon.

Foraminifera collected in the map area were identified by Raymond C. Douglass and Weldon W. Rau. Ellen J. Trumbull and F. Stearns MacNeil identified the molluscan faunas, and Roland W. Brown identified the fossil plants.

The Weyerhaeuser Timber Co. granted access to company land in the eastern part of the Anlauf quadrangle.

GEOGRAPHY

TOPOGRAPHY AND DRAINAGE

The Anlauf and Drain quadrangles lie at the south end of the Willamette Valley and also include parts of both the Cascade Range and the Coast Ranges (fig. 2). A spur of the Cascade Range known as the Calapooya Divide extends into the area and merges imperceptibly with the Coast Ranges. Farther north in Oregon the physiographic distinction between the Cascade Range and the Coast Ranges is made apparent by the intervening Willamette Valley, but in the map area this distinction is based more on geology than on topography; the Cascade Range and its western extensions consist predominantly of nonmarine volcanic and pyroclastic rocks, whereas the Coast Ranges consist predominantly of marine sedimentary rocks.

Except for the open valleys south and east of Yoncalla and the relatively broad valley of the Coast Fork of the Willamette River, most of the Anlauf-Drain area is characterized by well-dissected topography with narrow steep-walled valleys and rounded brush- or timber-covered interstream areas. The altitudes of the interstream areas show a remarkable uniformity, as may be seen in figure 3. This observation led Diller (1898, p. 4) to postulate the existence of a late Tertiary Coast Range peneplain. The maximum relief within the area is about 3,200 feet; the highest altitude, 3,346 feet, is at the summit of Harness Mountain and the lowest, about 150 feet, is at the west edge of the area, on the Umpqua River and on Elk Creek.

About three-fourths of the map area is drained by the Umpqua River, which flows northwestward in deeply entrenched meanders along the west edge of the area. At the town of Elkton, about 4 miles west of the area mapped, the Umpqua River turns westward and cuts directly across the Coast Ranges, and thus provides a water-level route to the coast. The major tributary to the Umpqua River in the Anlauf-Drain area is Elk Creek, which rises in the southeastern part of the area and flows northwestward to Drain and thence westward alternately through narrow canyons cut in basaltic rocks and through relatively open valleys underlain by sedimentary rocks. The southward-

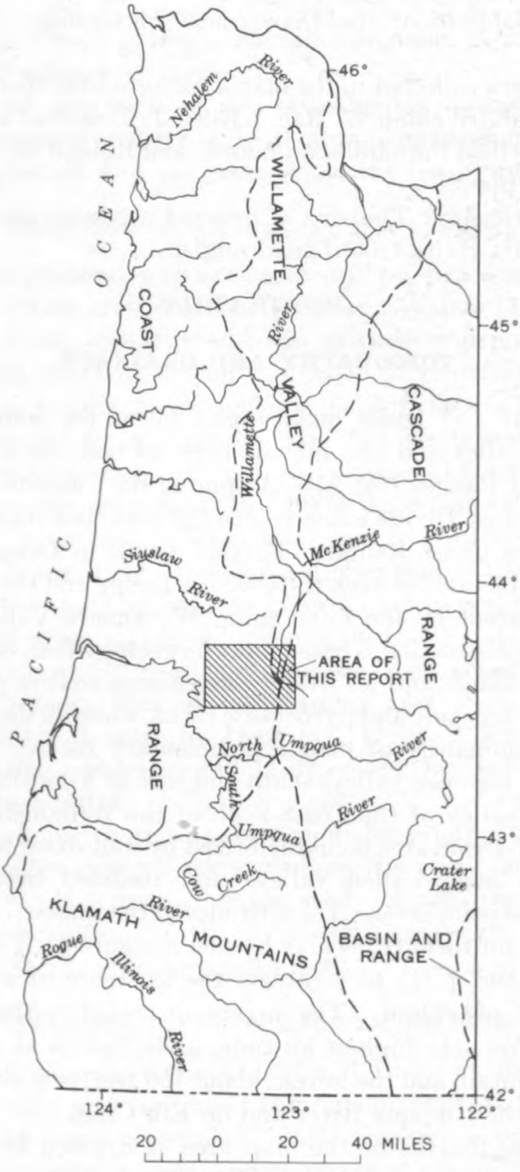

FIGURE 2.—Physiographic provinces of western Oregon (after Dicken, 1950).

flowing streams that originate near the south margin of the area are tributaries to Calapooya Creek, which is itself a tributary to the Umpqua River.

The Calapooya Divide (or Calapooya Mountains), a spur of the Cascade Range, trends westward to Harness Mountain and then north-northwestward to the vicinity of Comstock. It separates the drainage basin of the Umpqua River from that of the Coast Fork of the Wil-

FIGURE 3.—Westward view of the even crest of the Coast Ranges from the Calapooya Divide.

lamette River. The latter stream flows northward through the eastern part of the Anlauf quadrangle and joins the main branch of the Willamette River about 20 miles north of the area.

Because the drainage route to tidewater via the Umpqua River is much shorter and, consequently, steeper than by way of the Willamette River, the tributaries to the Umpqua River are eroding headward and encroaching upon the Willamette River and its tributaries. The more rapid erosion by the Umpqua River system, furthermore, has caused its tributaries to have a generally lower elevation than those that flow into the Coast Fork of the Willamette River. For example, the altitude of Elk Creek in Scotts Valley is about 425 feet, whereas at London Springs, only 5 miles to the east, the Coast Fork is at an altitude of 880 feet. Diller (1915, p. 39) suggested, from physiographic evidence, that the headwaters of the Umpqua River at one time flowed northward through the valley now occupied by Pass Creek and joined the Willamette River near the site of Cottage Grove. In support of this hypothesis, one might expect to find in Pass Creek valley scattered pebbles of rock types common to the upper Umpqua River drainage basin, but such evidence has not been found.

CLIMATE AND VEGETATION

The climate of the Anlauf and Drain quadrangles is temperate and moist; it is characterized by warm dry summers and cool winters with abundant rain and some snow. Records of the U.S. Weather Bureau show that for a 10-year period beginning in 1943 the average precipitation at Drain was 50.1 inches and the average temperature was 39.5° in January and 68.2° in July.

The abundant rainfall favors the growth of a dense forest cover, which consists principally of Douglas fir, with smaller stands of grand fir, western red cedar, western hemlock, and other coniferous trees. A matted growth of low shrubby plants, such as Oregon grape, rhododendron, and salal, together with vine maple and western sword fern, is usually found beneath the conifers. Cut-over areas have a tangled cover of blackberry, salmonberry, and bracken fern. Red alder, big leaf maple, and black cottonwood grow along open streams. Although the vegetation commonly has no relation to the type of bedrock, the well-indurated siltstone in the Umpqua formation more often supports a white oak, poison oak, and grass cover than a coniferous forest. In some places, such as on the northeast side of Halo Valley, the contact between the Umpqua formation and the overlying Tyee formation is clearly marked by a change in vegetation. South-facing slopes commonly have less vegetation and, consequently, better rock exposures than have north-facing slopes.

Another effect of the moist climate is the deep weathering of the sedimentary and volcanic rocks, which in most places are concealed beneath a thick mantle of soil. Locally, the weathering is so deep and the decomposition of the bedrock so complete that one cannot rely even on soil types to distinguish igneous from sedimentary rocks.

The thick vegetation and deep weathering limit geologic observations chiefly to road cuts and other artificial excavations and to the channels of perennial streams; the underbrush also impedes foot travel.

ACCESSIBILITY AND SETTLEMENT

The map area lies astride the Pacific Highway (U.S. 99) midway between the cities of Eugene and Roseburg. A hard-surfaced road (State Highway 38) connects Anlauf with the coast at Reedsport via Drain and the lower Elk Creek Valley, and another extends southward from Cottage Grove, 3 miles north of the area, to London Springs. Well-maintained graveled roads follow most of the larger valleys, and an extensive network of private logging roads provides access to other parts of the area. Except for the southwestern part of the Drain quadrangle, most places are within a mile of a passable road. The Siskiyou line of the Southern Pacific Co. also extends across the area.

Drain (population 1,200) and Yoncalla (population 710) are the only towns within the area. Smaller settlements are at Anlauf, Curtin, and London Springs.

Logging is the principal industry, although its importance has declined with the cutting of much of the virgin timber. Sawmills are operated at Anlauf, Drain, and Yoncalla. Ranching and farming also are of economic importance. In the past, quicksilver was mined near Black Butte and Elkhead.

STRATIGRAPHY

A sequence of lower Tertiary sedimentary and volcanic rocks with an aggregate thickness of about 20,000 feet is exposed in the Anlauf-Drain area. This sequence is graphically represented in plate 2. About two-thirds of the sequence consists of marine Eocene sedimentary and volcanic rocks, whose correlatives are widely exposed throughout the Oregon Coast Ranges; on the other hand, the pyroclastic and volcanic rocks of terrestrial origin that predominate in the upper one-third of the sequence are characteristic of the rock sequences found in the western Cascade Range. A few dikes, sills, and stocklike intrusive bodies of diabase, basalt, and norite occur in the eastern part of the area.

The nonmarine volcanic rocks that crop out in the eastern part of the Anlauf quadrangle for the most part are not folded and they dip gently to the east, whereas the older marine rocks to the west are folded into northeastward-trending anticlines. The thickness of individual units in both the marine and nonmarine rocks can be only approximated, owing to inadequate exposures and to the absence of subsurface data.

TERTIARY ROCKS

UMPQUA FORMATION

The oldest rocks exposed in the map area are referred to the Umpqua formation of early Eocene age, which was first described by Diller (1898) from outcrops in the vicinity of Roseburg. In that area, the formation has a total exposed thickness of about 12,000 feet and "is composed of an extensive series of conglomerates, sandstones, and shales, with traces here and there of calcareous siliceous beds * * *" (Diller, 1898, p. 2); these calcareous rocks were mapped separately as the Wilbur tuff lentil. Diller also separated from the Umpqua formation several masses of "diabase," which he considered to be partly intrusive and partly extrusive, but Wells and Waters (1935, p. 964–966) showed that most, if not all, of Diller's "diabase" consists of subaqueous basalt flows interbedded with the sedimentary rocks of the Umpqua formation. This conclusion was confirmed by Turner (1938, p. 10–11) on the basis of an examination of the Umpqua rocks exposed along the North Umpqua River near Glide.

The Umpqua formation can be divided into three members: (1) A lowermost member consisting of flows of vesicular and amygdaloidal olivine basalt, (2) a thin discontinuous belt of fine vitric tuff and lapilli tuff, and (3) well-indurated shaly siltstone containing a 300-foot tongue of massive to thick-bedded tuffaceous basaltic sandstone, in addition to many thin beds of fine-grained basaltic sandstone. The distribution of these members locally is affected by facies changes, as shown by the lateral gradation of basalt flows into tuff beds in the Jack Creek area and on the southeast flank of the Red Hill anticline northeast of the Elkhead mine (pl. 1).

Basalt member.—The oldest exposed member of the Umpqua formation consists of a sequence of olivine basalt flows that are generally amygdaloidal or vesicular. This member crops out in the axial parts of the Drain and Red Hill anticlines and is less well exposed in the Jack Creek anticline. Because of its relative resistance to erosion, the basalt forms prominent topographic features, such as Mount Yoncalla, Red Hill, and Dickinson Mountain; on the other hand, it commonly is deeply weathered to a dark reddish-brown clayey soil, so that outcrops of basalt are found mainly in stream channels, road cuts, and quarries.

Quarry exposures show the basalt in distinct flows, usually 20 to 30 feet thick (fig. 4), although their thickness ranges from about 5 feet to more than 50 feet. Individual flows generally are amygdaloidal or vesicular, particularly in their upper parts, but otherwise they are

FIGURE 4.—Amygdaloidal basalt flows in the Umpqua formation in a quarry 2 miles south of Yoncalla.

normally masive. In places, however, as in the quarries at the mouth of Bear Creek, 1½ miles southwest of Drain, and in the bed of Pollock Creek in sec. 3, T. 24 S., R. 5 W., poorly developed columnar structure is present. Rudimentary pillow structures, indicative of submarine extrusion, can be seen in a few exposures, but this type of structure is less common in the map area than it is reported to be in the Nonpareil-Bonanza area, a few miles to the south (Wells and Waters, 1934, p. 9).

The basalt is dark gray (N3) [1] to greenish black (5GY2/1) and is generally aphanitic. Phenocrysts of plagioclase as much as 15 mm in length and nearly equidimensional crystals of pyroxene are visible in some hand specimens. Vesicles and amygdules of very light gray (N8) to moderate orange-pink (10R7/4) zeolite minerals and calcite are common in the basalt; locally they constitute as much as 20 percent of the rock. Most of the amygdules are oval and about 2 mm long, but some samples of basalt contain irregular patches of zeolite minerals more than 3 cm long.

Microscopic study shows that the basalt is hypocrystalline to holocrystalline with an intersertal, intergranular, or, in places, a trachytic texture. Labradorite (about An_{52-62}) [2] and augite are present as phenocrysts and in the groundmass and together constitute 55 to 75 percent of the rock; generally plagioclase is nearly twice as abundant as augite. Many of the labradorite phenocrysts, which are as much as 3.5 mm long, have an outer zone of more sodic plagioclase and a few are poikilitic, with inclusions of clinopyroxene and serpentine. In a few thin sections the plagioclase and pyroxene phenocrysts form glomeroporphyritic clots. Olivine, which once constituted from 5 to 15 percent of the rock, is generally represented by pseudomorphs of serpentine (fig. 5) or of a clear golden-yellow slightly pleochroic alteration product rimmed with antigorite and of associated hematite and magnetite. Unaltered olivine is rare. Small subhedral crystals of magnetite form as much as 12 percent of the basalt, and skeletal crystals of ilmenite were seen in some thin sections. Hypersthene is present in a few samples and apatite generally is a minor constituent. The mesostasis of the intersertal basalt is colorless to nearly opaque dark-brown glass, commonly altered to chloritic material and palagonite. The amygdaloidal basalt also contains cavity fillings of zeolites and fibrous chalcedony. Some amygdules are composed partly of zeolites and partly of magnetite, and most of them have a thin jacket of chloritic material. Calcite occurs in vesticles and in fractures, and in at least one thin section it is pseudomorphous after plagioclase.

[1] The rock-color terms and reference numbers used in this report are from the Rock Color Chart prepared by the National Research Council, 1948.

[2] Plagioclase determinations in this report are based on maximum extinction angles of albite twins in sections cut normal to (010).

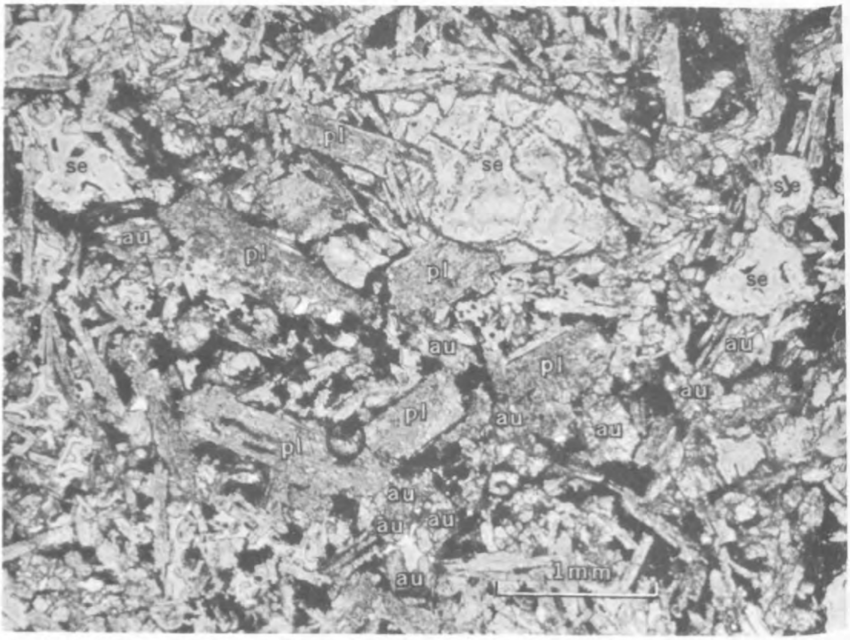

FIGURE 5.—Thin section of olivine basalt from the Umpqua formation. Pseudomorphs of serpentine (se) after olivine, saussuritized plagioclase (pl), and augite (au) in a groundmass of dark glass and iron ore. Ordinary light, × 20.

Secondary alteration has affected not only the olivine and basaltic glass, but also some of the plagioclase, which now appears as saussurite. Only the plagioclase in the groundmass is thus changed; the labradorite phenocrysts are fresh and clear. Other secondary minerals in the basalt include chlorophaeite, celadonite, limonite, and leucoxene.

Wells and Waters (1935, p. 970) published a chemical analysis (col. 1 in following table) of a sample of basalt from a flow in the Umpqua formation about 2 miles south of the map area. They stated (p. 964) that results of this analysis correspond closely to Daly's (1933, p. 17) average of analyses of plateau basalts. The analysis may also be compared with an average of two analyses (col. 2 in following table) of pillow basalt in the Siletz River volcanic series, a correlative of the Umpqua formation in the central part of the Coast Ranges (Snavely and Baldwin, 1948, p. 812).

In some places the basalt is intensely fractured and sheared and grades laterally into flow breccia. This type of rock is well exposed in a small quarry along State Highway 38, west of Jack Creek, and in a quarry on the east side of Elk Creek at Drain. The flow breccia usually is weathered to grayish red (10R4/2) and contains secondary minerals in cavities and veins and as thin films on shear surfaces. Locally a greenstone has resulted from chloritization.

Chemical analyses, in percent, of basalt from the Umpqua formation and the Siletz River volcanic series

[Column 1, Umpqua formation (Wells and Waters, 1935, p. 970); column 2, Siltez River volcanic series (Snavely and Baldwin, 1948, p. 812)]

Constituent	1	2	Constituent	1	2
SiO_2	47.51	42.82	H_2O-	2.33	4.04
Al_2O_3	12.81	11.38	TiO_2	1.75	2.57
Fe_2O_3	6.28	4.72	P_2O_5	.76	.37
FeO	6.86	6.10	MnO	.19	.16
MgO	6.58	8.42	Cr_2O_3	.02	
CaO	10.84	10.52	CO_2	.05	1.28
Na_2O	2.09	1.76	F		.06
K_2O	.31	2.40			
H_2O	1.91	3.40	Total	100.29	100.00

Geologic studies in the southern part of the Coast Ranges indicate that volcanic rocks occur at different stratigraphic positions in the Umpqua formation and that they vary in thickness from place to place; the thickest sequences presumably mark the sites of volcanic vents. In the map area the base of the basalt member is not seen, but the member appears to have a maximum exposed thickness of about 3,800 feet in the vicinity of Red Hill. The fact that in the Jack Creek anticline the basalt flows are interbedded with and in places grade laterally into beds of siltstone and tuff suggests that the volcanic rocks thin toward the northwest. They may also decrease in thickness in other directions away from the Red Hill area, but at present there is insufficient subsurface data to verify this possibility.

Tuff member.—The basalt flows in the Umpqua formation are discontinuously overlain by or, in a few places, interbedded with waterlaid pyroclastic rocks that consist predominantly of fine vitric tuff and of a smaller amount of lapilli crystal tuff. Some of the exposures of the pyroclastic rocks are too small to be shown on the geologic map, but they are relatively extensive in the Jack Creek-Hardscrabble Creek area and on the periphery of the mass of basalt that forms the core of Red Hill anticline. Tuff overlies basalt on the southeast side of Mount Yoncalla near Boswell Spring, and a few beds of altered tuff, each about 20 feet thick, are interbedded with partly brecciated basalt flows in a quarry on the north side of Bear Creek, in the SE¼ sec. 24, T. 22 S., R. 6 W. Only in a few places can the contact between the basalt flows and the overlying pyroclastic rocks be clearly seen. One such exposure is just east of the Southern Pacific Co.'s tracks, in the SE¼ D.L.C. (donation land claim) 46, T. 23 S., R. 5 W., where the tuff is conformable on the basalt, and another is along State Highway 38, west of Parker Creek. The small rounded fragments of basalt that compose about 20 percent of the lowermost beds of tuff exposed along State Highway 38 suggest that, in this area at least, the contact is erosional. In the Jack Creek area both tuff and siltstone are interbedded with basalt flows, and a few thin beds of tuff are intercalated with flows in the Drain anticline, but neither pyroclastic nor sedimentary rocks were observed within the basalt in the Red Hill-Dickinson Mountain area, even though some of the streams that drain this area, such as Adams and Elk Creeks, have cut deep canyons in the volcanic rocks.

Bedding is well defined in the water-laid fine tuff, in which strata range in thickness from 6 inches to about 6 feet. The lapilli tuff in the Jack Creek-Hardscrabble Creek area is more massive, but stratification is often apparent in the form of ill-defined graded bedding. Many outcrops of the pyroclastic rocks have conspicuous joints that trend in a northeasterly direction. In most areas the tuff is well exposed and has only a thin soil cover. The rock disintegrates into moderate yellowish-brown (10YR5/4) blocky fragments. A typical outcrop of fine vitric tuff, on the east side of old U.S. Highway 99, in the SE¼ D.L.C. 46, T. 23 S., R. 5 W., is shown in figure 6.

Greenish-gray (6G6/1) to greenish-black (5G2/1) fine vitric tuff is the most common type of pyroclastic rock in the Umpqua formation, although in the Jack Creek area lapilli crystal tuff predominates. Vitric tuff is extremely brittle and breaks with a subconchoidal fracture into sharp-edged fragments. On the basis of examination of some hand samples, it might easily be mistaken for chert. Generally this rock is too fine grained for its constituents to be identified with a hand lens, although small feldspar crystals and a few fragments of

FIGURE 6.—Fine vitric marine tuff in the Umpqua formation 3 miles south of Yoncalla. Beds range in thickness from 6 inches to 3 feet.

basalt occasionally can be seen. Most samples contain calcite, either as a cement or as very thin layers that are approximately parallel to bedding planes. Small irregular masses of an earthy grayish-blue-green choritic material are common and make up as much as 20 percent of the tuff that crops out along Goodrich highway west of the railroad, in the SE¼ D.L.C. 47, T. 23 S., R. 5 W.

As viewed through the microscope, the fine tuff contains abundant curved shards of clear colorless to dark-brown glass and small tabular crystals of plagioclase (An_{33-56}), some of which are embedded in small fragments of scoria. Some augite is usually present, and one thin section contains a few subhedral crystals of pigeonite (2V about 35°). Small grains of olivine and magnetite are sparingly present. The groundmass consists of medium-brown glass, crystallites, and minute fragments of colorless glass. Commonly, both the clear glass shards and the brown glass in the groundmass are partly devitrified to a yellowish-brown weakly birefringent palagonitic material. Calcite is ubiquitous in the fine tuff, occurring in foraminiferal tests, in irregular cracks and fissures, and in the groundmass. Chlorite minerals, including pennine, compose as much as 20 percent of the rock, and spherulitic chalcedony, tridymite, and zeolite minerals as much as 10 percent.

The tuff that crops out on the east side of Hardscrabble Creek, in the E½ sec. 36, T. 21 S., R. 6 W., contains abundant euhedral crystals of plagioclase 15 by 30 mm and nearly euhedral crystals of augite. The rock also contains about 15 percent of angular to subrounded fragments of basalt. Most of the tuffaceous rock elsewhere in the Jack Creek-Hardscrabble Creek area is sufficiently coarse grained for its constituents to be recognized with a hand lens. A small canyon on the west side of Hardscrabble Creek, in the SW¼ sec. 1, T. 22 S., R. 6 W., has good exposures of massive medium bluish-gray (5B5/1) augite tuff, in which the augite crystals attain a maximum length of 15 mm, and farther west, on Jack Creek, the typical pyroclastic rock is a varicolored calcareous lithic tuff with subangular fragments of basalt that average 2 mm in maximum diameter.

Diller (1898, p. 4) stated that some of the tuffaceous rocks in the Roseburg area were quarried at one time for lime but that the venture was unsuccessful because of the low percentage of CaO, as shown in the analysis on page D–16. According to local residents, there have been attempts to obtain lime from a lapilli crystal tuff that crops out on the east side of Hardscrabble Creek. An analysis by R. F. Gantnier shows that this rock contains 9.1 percent CaO and 2.9 percent MgO. The lime may be a primary constituent of the rock or may have been deposited from sea water following agitation and a rise in temperature caused by submarine flows. A similar mechanism was postulated by Park (1946) to explain the limy rocks associated with spilitic lavas on the Olympic Peninsula, Wash.

Chemical analysis, in percent, of fine tuff from the Umpqua formation

[Diller, 1898, p. 4; collected "a few miles northeast of Wilbur, Oreg.," in the Sutherlin quadrangle. Analyst unknown]

SiO_2	55.15	MgO	2.22
CO_2	3.64	K_2O	.50
Al_2O_3, TiO_2, P_2O_5	9.75	Na_2O	1.00
		H_2O (lost at 110 °C)	2.70
		H_2O (lost above 110 °C)	6.59
Fe_2O_3	7.76		
CaO	10.48	Total	99.79

The pyroclastic rocks in the Roseburg area mapped by Diller (1898) as the Wilbur tuff lentils are lithologically identical to the water-laid fine vitric tuff in the Anlauf-Drain area. His map shows that the Wilbur tuff lentils occur in discontinuous beds that are interbedded with or lie upon flows of basalt or are interbedded with Umpqua sedimentary rocks. This relation indicates that the tuff does not occupy the same stratigraphic position everywhere and suggests further that it was deposited primarily as a result of local and intermittent explosive volcanic eruptions.

Siltstone member.—The basalt flows and pyroclastic rocks of the Umpqua formation are overlain by and, in places, interbedded with as much as 5,000 feet of fine-grained marine sedimentary rocks that include well-indurated siltstone, sandy siltstone, and basaltic sandstone. Within this sedimentary sequence is a tongue of well-bedded sandstone about 300 feet thick. The sandstone unit has been differentiated on the geologic map (pl. 1) from the finer grained sedimentary rocks in the Umpqua formation.

The fine-grained sedimentary rocks are well exposed on the northwest flank of the Red Hill anticline and on the southeast flank in the drainage areas of Bachelor and Pollock Creeks. They are poorly exposed in a narrow belt on both flanks of the Drain anticline and also crop out in the Jack Creek-Hardscrabble Creek area, where they are interbedded in places with volcanic and pyroclastic rocks. Elsewhere, the siltstone member overlies these rocks. In an exposure of the contact between basalt and siltstone in Pollock Creek, in the SE¼ sec. 3, T. 24 S., R. 5 W., the uppermost 5 to 10 feet of volcanic rock is a breccia composed of angular blocks of basalt as much as 18 inches long. Filling the interstices of the basalt rubble is fine-grained basaltic sandstone and fossiliferous calcareous siltstone containing small crystals of pyrite. Graded beds of basaltic sandstone 2 to 10 inches thick lie above the breccia.

Well-indurated fissile siltstone is the most common rock in this member of the Umpqua formation. The rock is generally well bedded, so that observations of structure are more readily obtained in the siltstone member than in any other rock unit in the map area. The beds range in thickness from a few inches to more than 5 feet; the average thickness is about 1 foot. The rock when fresh is dark gray (N3); when weathered, light olive gray (5Y5/2) to moderate olive brown (5Y4/4). It weathers spheroidally to form blocky iron- and manganese-stained fragments 1 inch or less in diameter. Carbonaceous material occurs in some beds of thinly laminated siltstone and locally may be in sufficient concentration to constitute impure coal. Ellipsoidal or sticklike limy concretions are distributed sporadically in the siltstone, but the siltstone itself is generally noncalcareous.

Beds 1 inch to 3 feet thick of moderately well-indurated fine-grained basaltic sandstone are very common in the siltstone member of the Umpqua formation. Much of this sandstone, because of its high percentage of basaltic debris (as much as 65 percent) and fine-grained matrix (as much as 25 percent), may be called a volcanic wacke (Williams and others, 1954, p. 303). The basalt fragments are generally subrounded and attain a maximum diameter of about 3 mm, although most of them are less than 0.5 mm in diameter. In addition to the volcanic debris, the sandstone is composed of subangular to subrounded grains of quartz, partly altered plagioclase (generally andesine), and fragments of chert. Accessory minerals include augite, biotite, clinozoisite, epidote, and muscovite. In some beds the rock fragments and mineral grains are cemented with calcite, but commonly they are in a very fine grained tuffaceous chloritic matrix.

On the northwest flank of Red Hill anticline the siltstone member of the Umpqua formation contains a sequence of basaltic sandstone beds about 300 feet thick. This sandstone unit, which on the geologic map (pl. 1) is differentiated from the siltstone member, is well expressed topographically by a ridge that trends southwestward from the vicinity of Scotts Valley (fig. 7). Ambrose Hill and Rice Hill are formed by this unit, which thins southwestward and disappears about 1 mile north of the south edge of the Drain quadrangle.

Characteristically the basaltic sandstone is greenish gray (5GY6/1), well indurated, and fine to medium grained; it weathers to grayish-brown (5YR3/2). The unit is well bedded; beds range in thickness from about 2 inches to 6 feet and average about 2 feet. Dark-gray sandy siltstone in beds 1 to 2 inches thick sometimes is present between the sandstone beds.

Mineralogically, the sandstone that crops out on Rice Hill resembles the sandstone exposed elsewhere in the Umpqua formation. Quartz and chert predominate over basaltic debris in the sandstone on Rice Hill, and in places the rock has an opalescent cement. Heavy minerals in the sandstone include garnet, green hornblende, ilmenite, tourmaline, and zircon; they form a small percentage of the rock and occur so sporadically that most of them are not seen in thin sections.

FIGURE 7.—View southwestward from the west side of Scotts Valley. Wooded ridge in center foreground and right-center background is formed by the sandstone in the siltstone member of the Umpqua formation. Siltstone of the Umpqua underlies the valleys on each side of this ridge. Hills in right background are in the Tyee formation, and basalt flows of the Umpqua form the dip slope in left background.

Age and correlation.—Despite the marine origin of the sedimentary rocks in the Umpqua formation, in the map area they yielded only one small molluscan fauna, collected on Jack Creek, in the NW¼ D.L.C. 37, T. 21 S., R. 6 W. (pl. 1, loc. M–1). The following forms, of probable middle Eocene age but not specifically indicative of the Umpqua formation, were identified by Ellen J. Trumbull:

Gastropods:
- *Globularia*? sp. cf. *G. hannibali* (Dickerson)
- *Turritella* sp. cf. *T. buwaldana coosensis* Merriam
- *Scaphander*? sp.

Pelecypods:
- *Glycymeris*? sp. cf. *G. crescentensis* Weaver and Palmer
- *Crassatella uvasana* (Gabb), subsp.?
- *Pitar* (*Calpitaria*?) sp. cf. *P.* (*C.*) *uvasana coquillensis* Turner
- *Venericardia*? sp., immature
- *Teredo*? sp.

More extensive collections of Umpqua megafossils were obtained by Turner (1938) south of the area along the Middle Fork of the Coquille River, along the South Umpqua River west of Roseburg, and on the North Umpqua River near Glide. He believed that two paleontologic zones could be recognized in the Umpqua formation and that a corresponding lithologic division could be made in the Coquille River area, but not in the rocks exposed near Glide. Although some of the fossils that Turner collected resemble forms from either the Meganos or the Domengine formation of California, most are common to the Capay formation (Crook and Kirby, 1935) of California, and on this evidence the Umpqua formation is assigned an early Eocene age (Turner, 1938, p. 5–16; see also Weaver and others, 1944, chart 11).

Additional information on the age of the Umpqua formation in the mapped area is obtained from foraminiferal assemblages, which are fairly abundant in the siltstone member and, to a lesser extent, in the waterlaid pyroclastic rocks. The table shows the frequency of foraminiferal species in samples from 10 localities, most of which are near the top of the formation. Regarding these faunas W. W. Rau stated (written communication, 1957):

> The 10 assemblages included in this checklist, when taken as a group, compare exceedingly well with faunas assigned to the C zone, the lower B zones, and the lower part of the A–2 zone of Laiming (1940). Although most of the significant species are known both in Laiming's C zone and in the lower part of his A–2 zone, a few forms, such as *Silicosigmoilina californica* Cushman and Church, *Vaginulinopsis vacavillensis* (G. D. Hanna), and *Globorotalia membranacea* (Ehrenburg), are not recorded above the B zones of Laiming. This fact, together with the preponderance of species that occur in Laiming's C zone, suggests that the foraminiferal faunas from the Umpqua formation in the Anlauf and Drain quadrangles best compare with those previously referred to Laiming's C zone and possibly to his lower B zones. An early Eocene age, therefore, is inferred for the Umpqua formation in the mapped area.

Foraminifera from the Umpqua formation, showing frequency of occurrence of species

[C, common; F, few; R, rare; ?, identification doubtful]

Species (arranged taxonomically)	USGS locality									
	11991	11992	11993	11994	11995	11996	11997	11998	11999	12000
	Map locality (pl. 1)									
	F–1	F–2	F–3	F–4	F–5	F–6	F–7	F–8	F–9	F–10
Involutina sp							R			
Cyclammina sp	R									
Textularia cf. *T. mississippiensis* (Cushman)	C		R		R			F	R	
Gaudryina cf. *G. coalingensis* Cushman and G. D. Hanna						F				
?*Gaudryina* sp							R			
?*Clavulinoides* sp								R		
Dorothia principensis Cushman and Bermudez	R	R		?		R	R			
Tritaxilina colei Cushman and Siegfus	C	C	F	R		?				
Silicosigmoilina californica Cushman and Church	R	F	R				F			
Quinqueloculina sp	R						R			
Sigmoilina sp		R								
?*Cornuspira* sp		R								
Robulus holcombensis Rau	C	C	C	R	C	C	C	C	F	F
cf. *R. pseudocostata* Plummer	R		R							
Vaginulinopsis cf. *V. asperuliformis* (Nuttall)	R	R	?	R	R		R	R		
vacavillensis (G. D. Hanna)			?		R	F	?	?		R
Marginulina subbullata Hantken										R
sp			R							
Dentalina cf. *D. approximata* (Reuss)	R		F	?		R	R	R		
communis d'Orbigny		R			R					
consobrina d'Orbigny	F	?	?	?					F	

Foraminifera from the Umpqua formation, showing frequency of occurrence of species—Continued

Species (arranged taxonomically)	USGS locality 11991	11992	11993	11994	11995	11996	11997	11998	11999	12000
	Map locality (pl. 1) F–1	F–2	F–3	F–4	F–5	F–6	F–7	F–8	F–9	F–10
?*Dentalina globulicauda* Gümbel	----	R	F	----	----	----	----	----	----	----
Dentalina cf. *D. jacksonensis* (Cushman and Applin)	----	----	F	----	----	----	----	----	----	----
?*Nodosaria boffalorae* Martinotti	----	----	----	R	----	----	----	----	----	----
Nodosaria cf. *N. deliciae* Martin	F	?	?	----	----	----	F	----	----	----
latejugata Gümbel	F	F	C	R	----	F	R	F	F	R
cf. *N. longiscata* d' Orbigny	----	----	----	----	----	----	F	----	----	----
Rectoglandulina cf. *R. nallpeensis* (Rau)	----	----	----	----	R	----	----	R	----	----
sp	----	----	----	----	----	----	R	R	R	----
Lagena conscripta Cushman and Barksdale	----	----	----	----	R	----	----	----	----	----
Guttulina sp	----	R	----	----	----	----	----	----	----	----
Globulina landesi (Hanna and Hanna)	----	----	----	----	----	----	R	----	----	----
Nonion cf. *N. applini* Howe and Wallace	----	----	----	----	F	----	?	----	----	----
planatum Cushman and Thomas	----	----	----	----	----	R	----	----	----	----
?*Nonionella* sp	----	----	----	----	----	----	----	----	----	R
?*Plectofrondicularia* sp	R	----	----	----	----	----	----	----	----	----
Amphimorphina sp	----	----	R	----	----	----	R	----	----	----
Bulimina corrugata Cushman and Siegfus	F	R	----	----	----	----	----	----	----	----
cf. *B. guayabalensis* Cole	R	R	----	----	?	----	R	----	----	----
lirata Cushman and Parker	R	F	R	----	----	R	F	R	----	----
Bolivina applini Plummer	R	----	R	----	----	----	R	R	----	----
Bifarina nuttalli Cushman and Siegfus	----	R	----	----	----	----	F	----	----	----
Pleurostomella acuta Hantken	R	----	----	R	----	----	----	----	----	----
cf. *P. nuttalli* Cushman and Siegfus	R	----	----	R	----	----	----	----	----	----
?*Gyroidina childsi* Martin	R	F	R	R	----	----	R	R	----	----
Gyroidina soldanii octocamerata Cushman and G. D. Hanna	R	F	F	----	----	R	F	R	----	----
sp	----	----	R	----	----	----	----	R	----	----
Eponides aff. *E. mexicanus* (Cushman)	----	R	----	?	----	R	R	?	----	F
umbonatus (Reuss)	C	?	F	----	----	----	F	----	----	----
Höglundina eocenia (Cushman and Hanna)	----	F	----	----	R	----	----	----	----	----
Cancris cf. *C. malloryi* Smith	----	----	----	R	----	----	----	----	----	----
Asterigerina crassaformis Cushman and Siegfus	R	----	----	F	----	F	C	----	----	----
Alabamina sp	----	----	----	----	R	----	----	----	----	----
Chilostomella oolina Schwager	R	----	----	----	----	----	----	R	----	----
Pullenia sp	R	----	R	----	----	----	F	----	----	----
Globigerina cf. *G. triloculinoides* Plummer	C	C	F	F	F	----	C	R	R	----
Globorotalia cf. *G. aragonensis* Nuttall	----	R	----	----	----	----	----	----	----	----
membranacea (Ehrenberg)	----	R	----	----	----	----	F	----	----	----
Anomalina cf. *A. canimarensis* Palmer and Bermudez	----	----	----	R	----	----	----	----	----	----
cf. *A. dorri aragonensis* Nuttall	----	----	----	----	----	----	----	----	----	----
Cibicides cf. *C. hodgei* Cushman and Schenck	----	----	----	----	R	----	----	----	----	----
cf. *C. martinezensis malloryi* Smith	C	----	F	----	----	R	----	?	----	----
cf. *C. ouachitaensis alhambrensis* Smith	C	F	F	----	----	----	C	C	----	----
cf. *C. pachecoensis* Smith	----	----	----	----	F	F	----	----	----	----
sassei Cole	----	----	----	----	F	----	----	----	----	F
Cibicidoides coalingensis (Cushman and G. D. Hanna)	----	----	----	----	----	R	----	----	----	----
venezuelanus (Nuttall)	F	----	R	----	F	R	----	----	----	----
Discocyclina sp	----	----	----	----	----	----	----	----	F	----

An unusual assemblage of larger Foraminifera was collected from calcareous argillaceous siltstone at the base of the siltstone member in the stream bed of Pollock Creek, in the SE¼ sec. 3, T. 24 S., R. 5 W. (pl. 1, loc. F–11). The interest attached to this assemblage is derived from the inclusion of representatives of the Nummulitidae, a family previously unreported from the west coast, according to R. C. Douglass (written communication, 1957) who studied this fauna. The genus present has been tentatively identified as *Miscellanea*, which ranges from early to late Eocene in age but is most common in lower and middle Eocene rocks. Douglass also stated that a shallow-water tropical or subtropical environment is generally suggested for the accumulation of these forms.

Rocks equivalent in age to the Umpqua formation crop out in a number of places in the Coast Ranges in Oregon and Washington. The Umpqua formation itself extends southwesterly perhaps as far as the vicinity of Agness, on the Rogue River, and it also has been recognized in the Coos Bay area (Allen and Baldwin, 1944, p. 13–19). North of Reedsport a well drilled in 1957 by General Petroleum Corp. penetrated, below a depth of 4,375 feet, sedimentary and volcanic rocks that are correlated on the basis of lithology and stratigraphic position with the Umpqua formation.

In the central part of the Oregon Coast Ranges the Siletz River volcanic series contains molluscan faunas that show it to be a correlative of the Umpqua formation and of early Eocene (Capay) age (Snavely and Baldwin, 1948, p. 808–812).

Berthiaume (1938) correlated the Crescent formation of northwestern Washington with the Umpqua formation on the basis of Foraminifera.

TYEE FORMATION

The Tyee formation of middle Eocene age, a sequence of rhythmically bedded sandstone and siltstone with a maximum thickness of about 5,000 feet, is the most widespread unit in the Anlauf and Drain quadrangles. It crops out extensively and forms rugged topography to the west of the Calapooya Divide, and it is particularly well exposed in cuts on State Highway 38 between Drain and Elkton. From the vicinity of Yoncalla southwestward about 40 miles to the Coquille River, the limit of outcrop of the Tyee formation is marked by a prominent east-facing escarpment 800 to 1,700 feet high. About 8 miles south of the map area this escarpment forms Tyee Mountain, the type locality of the formation (Diller, 1898, p. 3).

The relation of the Tyee to the Umpqua formation has been problematical since the time of Diller. In 1896, he said (p. 463):

> The relationship of this [Tyee] sandstone to the underlying Eocene shales is not yet definitely known. While at some points there appears to be no reason to suspect that they are discordant, at others, as for example on the Umpqua, at the base of Tyee Mountain, and near the Nineteen Mile House on the old stage road from Roseburg to Coos Bay, there is a decided unconformity suggested. It is not known, however, that the underlying strata are in all cases of the same age.

Several years later Diller apparently was still uncertain as to the nature of this contact, for he remarked (1898, p. 3) that the Tyee sandstone "immediately overlies" the Umpqua formation, although a structure section in the same report shows these two formations separated by a high-angle fault. More recent workers have had

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diverse opinions as to whether or not the Tyee and Umpqua formations are separated by an unconformity. Turner (1938, p. 16–18) reviewed Diller's work and pointed out that data on the structure of the Tyee Mountain area suggest that the Tyee formation might be thrust over beds of the Umpqua formation. However, with respect to a section of Tyee and Umpqua rocks that he measured between Drain and Comstock, Turner noted (p. 21) that there is no sign of a stratigraphic break between the two formations. Allen and Baldwin (1944, p. 20–21) found no evidence of erosion or folding between the Umpqua and Tyee formations in the Coos Bay area, although Baldwin (oral communication, 1957) believed that south of the Middle Fork of the Coquille River an unconformity may be present at the base of the Tyee formation. The possibility of an angular unconformity of small magnitude at the base of the Tyee formation has been reported from the Corvallis area (Vokes and others, 1954). Farther west the relation between units equivalent to the Umpqua and Tyee formations appears to be conformable, except in areas adjacent to structural highs in the older volcanic rocks (P. D. Snavely, Jr., written communication, 1959).

Geologic mapping in the Anlauf-Drain area has not shown conclusively the nature of the contact between the Umpqua and the Tyee formations. Dips in the sedimentary rocks of the Umpqua formation locally are a few degrees steeper than those in the Tyee formation but are not sufficiently divergent to indicate a definite unconformity. The relation of the Tyee formation to the ridge-forming sandstone in the siltstone member of the Umpqua formation southwest of Yoncalla suggests that at least in some areas the contact is conformable. At other places, such as on the northwest flank of the Jack Creek anticline and on the southeast flank of the Drain anticline, a local unconformity appears to be the result either of pre-Tyee faulting or of truncation of the Umpqua formation by the Tyee formation (pl. 1). Probably the basalt flows in the Umpqua formation were in part poured out above sea level, or at least they may have formed topographic highs on the sea floor. It also is probable that in places in the vicinity of these highs the Tyee formation onlaps the Umpqua formation but elsewhere is conformable.

An additional problem regarding the Tyee formation concerns the type of environment in which it was deposited and the cause of its rhythmic graded bedding. Because of the presence of mud cracks and thin beds of coal, Allen and Baldwin (1944, p. 20) believed that the Tyee formation in the Coos Bay area represents nonmarine or shallow-water conditions. Some evidence from the Anlauf-Drain area, however, points to marine deposition in moderately deep water. The rhythmic graded bedding, the lateral uniformity of the strata, the lack of desiccation features and of well-developed crossbedding, and the presence, albeit sporadic, of marine molluscan and foraminiferal faunas suggest that the sediments of the Tyee formation were deposited in sea water too deep for them to be disturbed by waves or shallow currents. The rhythmic graded bedding and absence of crossbedding, together with the fact that much of the sandstone in the Tyee formation is actually a feldspathic or lithic wacke, further suggest that the sediments may have been transported by submarine turbidity currents, in a manner postulated by Kuenen and Migliorini (1950). According to Stanislaw Dzulynski (oral communication, 1958), the Tyee formation is similar in appearance to the Oligocene flysch of the Carpathian geosyncline, which he considers to have been deposited by density currents.

Lithology.—In the Anlauf-Drain area and elsewhere in the Coast Ranges the Tyee formation has an almost uniform appearance. It consists of rhythmically deposited sandstone and siltstone in graded beds that generally range in thickness from 1 to 5 feet but may be several tens of feet thick. The lower part of each bed consists of medium- to coarse-grained sandstone that grades upward into sandy siltstone and ultimately into siltstone. The sandstone part of each bed is from two to five times as thick as the upper silty part, which has an abrupt contact with the sandstone in the next overlying bed (fig. 8). Flow casts, current ripple marks, scour and fill channels,

FIGURE 8.—Graded beds of sandstone and siltstone in the Tyee formation along State Route 38, 0.1 mile west of Drain. For scale, note hammer in circle.

and other bedding features are visible on the underside of some strata where the upper silty part of the next lower bed has been eroded. Crossbedding generally is absent; where present, it is on a small scale and poorly developed. Spheroidal calcareous concretions 8 to 12 inches in diameter locally are present in the sandstone, and a few thin beds of sandstone are cemented with calcite. In the upper part of the formation some beds consist of 20 or more feet of sandstone and only an inch or two of siltstone. This type of bedding, poorly exposed east of Anlauf, is best seen in cuts on the road that follows the west bank of the Umpqua River, just west of the map area. Farther west, Baldwin (1961) has mapped at the top of the Tyee formation a sequence of strata about 800 feet thick that consists almost entirely of siltstone. This Elkton siltstone member and a nearly equivalent thickness of siltstone that crops out in the same stratigraphic position west of the city of Eugene (Vokes and others, 1951; 1954), appear to be equivalent to the uppermost strata in the Tyee formation exposed along the Pacific Highway just south of Comstock. The beds at Comstock, however, contain a higher percentage of sandstone than the Elkton siltstone member and cannot be mapped separately. Individual beds in the Tyee formation appear to persist over relatively broad areas, but poor exposures and the lack of stratigraphic horizon markers make it impossible to place an isolated exposure in its proper stratigraphic position within the formation.

In fresh outcrops the sandstone in the Tyee formation is medium gray (N5) to greenish gray (5GY6/1) and well indurated, but after prolonged exposure it becomes more friable and its color changes to moderate yellowish brown (10YR5/4) and dark yellowish orange (10YR6/6). In most places the rock weathers spheroidally and eventually breaks down ito small blocky fragments and loose sand.

As much as 2 inches of very coarse or coarse-grained standstone forms the base of some graded beds, and a few beds have a thin basal layer of granule-sized sand, but the maximum grain size in most beds is not more than 0.5 mm (medium sand). There is no apparent relation between the maximum grain size in a particular bed and the thickness of the bed.

The upper fine-grained part of each bed consists of moderately well indurated dark-gray (N4) to olive-black (5Y2/1) sandy micaceous siltstone and mudstone. Fragments of reedy plants are common in this rock, some of which contains so much carbonaceous matter that it can be classified as impure coal. The siltstone part of each graded bed is less resistant to erosion than the underlying sandstone part, and in weathered outcrops this difference in rate of erosion emphasizes the bedding.

Thin beds of intraformational conglomerate are present locally in the Tyee formation; examples can be seen in exposures along the Pacific Highway (U.S. Highway 99). At the west end of the Cox Creek road overpass, several strata, each about 6 inches thick, are composed of disc-shaped fragments of thin-bedded or, less commonly, massive siltstone embedded in a matrix of fine- to medium-grained sandstone. These fragments range from ½ to 6 inches in maximum diameter and most of them are alined nearly parallel to the bedding of the outcrop, but the bedding within the individual siltstone fragments may be nearly normal to their maximum length. Farther north on U.S. Highway 99, at the top of the hill south of Buck Creek, preconsolidation slump features can be seen in thin-bedded sandstone and siltstone. The strata are intricately swirled and contorted and contain a few 2-inch blocks of coarse-grained sandstone.

Petrographic studies show that much of the sandstone in the Tyee formation consists of 65 to 90 percent clastic material and a matrix of 10 to 35 percent clay minerals and chloritic material. Most of the mineral grains and rock fragments are subangular to subrounded and have a maximum diameter of about 0.3 mm (fig. 9). Quartz, in part strained, is the predominant detrital mineral; it constitutes

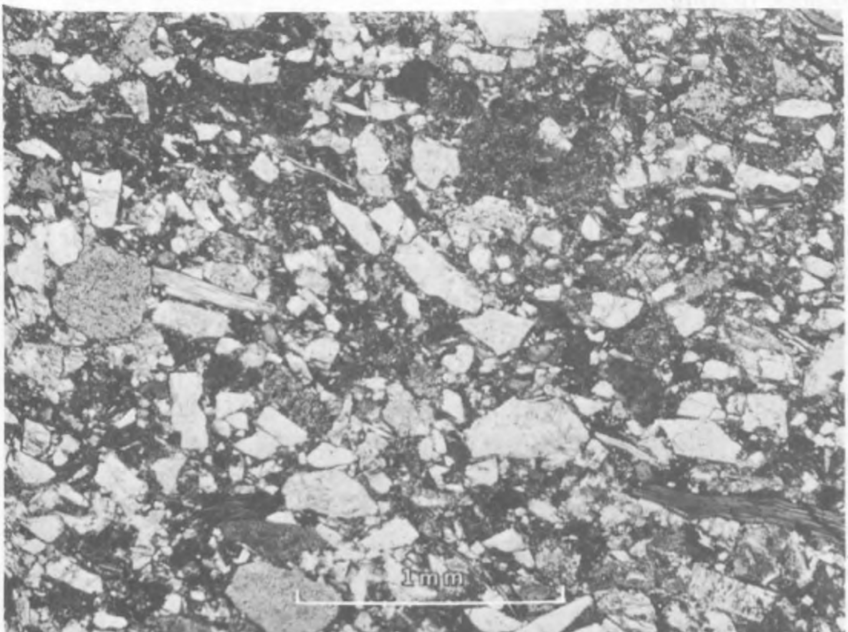

FIGURE 9.—Thin section of sandstone from the Tyee formation. Light grains are predominantly quartz, feldspar, and muscovite; darker areas are biotite, hornblende, and rock fragments. Ordinary light, × 35.

as much as 60 percent of some thin sections. Plagioclase is present in nearly all samples, the maximum being 25 percent. It is usually andesine (about An_{32-38}) but includes oligoclase and labradorite. Commonly the plagioclase grains are cloudy as a result of incipient alteration. A distinctive feature of the sandstone is the abundance of large flakes of muscovite, which may be 3 mm long, and of somewhat smaller flakes of biotite. Muscovite is more plentiful than biotite; it constitutes as much as 7 percent of the sandstone, whereas the amount of biotite is not more than about 3 percent. The mica flakes usually are sharply bent or wrinkled and some are molded around quartz grains. Much of the biotite is bleached and shredded and partly altered to chloritic material. Accessory minerals in the sandstone, listed in order of decreasing abundance, include magnetite, garnet, microcline, perthite, hornblende, zircon, epidote, tourmaline, hypersthene, sphene, augite, and clinozoisite. All but the first four are so sparingly present that they are seldom visible in thin sections. The sandstone of the Tyee also contains 10 to 25 percent lithic fragments of andesite and basalt, chert, fine-grained argillaceous rocks, and quartz-mica schist. As at least 10 percent of most thin sections consists of a matrix of argillaceous chloritic material, the sandstone can be classified as a lithic or feldspathic wacke (Williams and others, 1954, p. 292).

The heavy minerals in the Tyee formation, in association with the fragments of chert and mica schist and grains of quartz, mica, microcline, and perthite observed in thin sections, point to source areas underlain predominantly by metamorphic and silicic igneous rocks. Amphibolite schist and chert crop out in the Roseburg area (Diller, 1898) and extensive exposures of mica, schist and dark-colored slate are present a few miles farther south, in the Riddle area (Diller and Kay, 1924). Probably at least some of the sediments in the Tyee formation were derived from these rocks. The nearest exposures of granitic rocks are in the Klamath Mountains of southern Oregon (Wells, 1955). According to Diller (1898, p. 2), these rocks contributed sediments to the Myrtle formation of Cretaceous age, which is exposed in the Roseburg area, and they may well have continued to supply detritus throughout Eocene time.

Age and correlation.—A middle Eocene age is assigned to the Tyee formation, partly on the basis of a diagnostic molluscan fauna formerly exposed at the east end of the old highway overpass at Comstock, in the NE¼ sec. 20, T. 21 S., R. 4 W. (pl. 1, loc. M–2). This is the locality mentioned by Diller (1896, p. 460) and from which Turner (1938, p. 19) collected an invertebrate fauna of more than 20 species. A study by F. Stearns MacNeil of collections obtained at Comstock by members of the U.S. Geological Survey has modified Turner's check list, as indicated below:

Pelecypods:

Acila decisa (Conrad)[1]
Brachidontes cowlitzensis (Weaver and Palmer)
Cardiomya comstockensis Turner
Corbula parilis Gabb
Crassatella uvasana mathewsoni (Gabb)
Glycymeris sagittata (Gabb)[1]
Nemocardium linteum (Conrad)
Nuculana aff. *N. parkei* (Anderson and Hanna)[2]
Plagiocardium cf. *P. brewerii* (Gabb)[1]
Solena (*Eosolen*) *coosensis* Turner
Venericardia hornii calafia Stewart

Gastropods:

Amaurellina (*Euspirocrommium*) *clarki* Stewart
Bittium sp.[2]
Globularia (*Eocernina*) *hannibali* (Dickerson)[3]
Ancilla gabbi Cossmann
Calyptraea diegoana (Conrad)
Conus remondii Gabb var. *comstockensis* Turner
Cylichnina tantilla (Anderson and Hanna)
Cypraea sp. B
n. sp. (sp. B of Turner?)[1]
Ficopsis remondii crescentensis Weaver and Palmer
Pleurofusia sp.[2]
Polinices hornii (Gabb)
P. (*Euspira*) *nuciformis* (Gabb)
Scaphander (*Mirascapha*) *costatus* (Gabb)[1]
Ranellina pilsbryi Stewart[4]
Sinum sp.[1]
Turritella andersoni comstockensis Merriam
buwaldana coosensis Merriam
uvasana hendoni Merriam, var. A

Many of these species, together with additional forms, were also collected by Turner (a) from the Tyee formation at Basket Point on the Umpqua River (NE¼ sec. 30, T. 24 S., R. 7 W.), (b) from rocks on the North Umpqua River near Glide (sec. 17, T. 26 S., R. 3 W.) that have been mapped as the uppermost part of the Umpqua formation by R. D. Brown, Jr. (written communication, 1956), and (c) along the Middle Fork of the Coquille River east of Remote. He stated (1938, p. 18) that of the species listed above *Venericardia hornii calafia* and *Turritella uvasana hendoni* are especially characteristic of the Tyee formation and that comparison of these faunas with mol-

[1] Species not reported by Turner from Comstock.
[2] Species not reported by Turner from the Tyee formation.
[3] Listed as *Cernina* (*Eocernina*) *hannibali* (Dickerson) by Turner.
[4] Species reported by Turner but not recognized in the U.S. Geol. Survey's collections.

luscan faunas from California indicates that the Tyee formation is best correlated with the Domengine formation of middle Eocene age.

Although the Tyee formation usually does not contain microfossils, the following species of Foraminifera from the Comstock overpass locality (pl. 1, loc. F–12; USGS loc. F–11990) were identified by W. W. Rau:

Gaudryina cf. *G. coalingensis* Cushman and G. D. Hanna
Quinqueloculina sp.
Robulus holcombensis Rau
sp.
Vaginulinopsis vacavillensis (G. D. Hanna)
Nodosaria latejugata Gümbel
Gyroidina cf. *G. simiensis* Cushman and McMasters
Eponides cf. *E. mexicanus* (Cushman)
Cibicides cf. *C. haydoni* (Cushman and Schenck)
hodgei Cushman and Schenck
Cibicdoides coalingensis (Cushman and G. D. Hanna)

According to Rau, this fauna is similar to that of the Elkton siltstone member of the Tyee formation in the lower Umpqua River area, to that from the uppermost part of the Umpqua formation at Glide, and to that designated by Laiming (1940) as typical of his B–1 zone in California. Tyee Foraminifera from Basket Point on the Umpqua River, about 3 miles southwest of the map area, were considered by R. E. Stewart to be middle Eocene in age and in general to be equivalent to Foraminifera from Laiming's B–1 zone (Baldwin, 1955).

Fossil plant material is very abundant in the Tyee formation, but it consists only of carbonized fragments of reedlike plants that are neither identifiable nor indicative of age.

The Tyee formation in the southern part of the Oregon Coast Ranges has been correlated on the basis of stratigraphic position and lithologic similarity with the Burpee formation of northwestern Oregon (Vokes and others, 1949), and it is possible that the lower part of the Yamhill formation in the Sheridan-McMinnville area (Baldwin and others, 1955) is also equivalent in age to the Tyee formation. Foraminiferal faunas from the lowermost part of the McIntosh formation in southwestern Washington (Snavely and others, 1958, p. 21) are similar to those of Laiming's B–1 zone and to assemblages from the Tyee formation in the Corvallis area.

SPENCER FORMATION

In the northern half of the Anlauf quadrangle the Tyee formation is separted from the younger continental rocks of the Fisher formation by a narrow outcrop belt consisting predominantly of massive friable arkosic sandstone that is assigned to the Spencer formation. This name was proposed by Turner (1938, p. 23) for fossiliferous marine sandstone and shale of undetermined thickness exposed along

Spencer and Coyote Creeks, about 10 miles southwest of Eugene. However, the rocks in the Anlauf-Drain area herein referred to the Spencer formation were included by Turner in his Comstock formation, which, he said (1938, p. 21) consists of about 1,000 feet of nonmarine sandstone, tuff, and shaly siltstone. Turner added that, in its type section along the Pacific Highway north of Comstock, the Comstock formation rests unconformably on the Tyee formation and, in turn, is overlain unconformably by the Fisher formation. Subsequent geologic mapping in the Eugene area by Vokes and others (1951) demonstrated that Turner's Comstock formation is equivalent to the Spencer formation, for they found that the Comstock formation, in addition to being similar lithologically to the Spencer formation, in places contains marine megafossils identical to those in strata assigned by Turner to the Spencer formation.

In this report, the rocks included in Turner's type Comstock formation are distributed among the Tyee, Spencer, and Fisher formations. The thickness of the Comstock formation at its type section (see Turner, 1938, p. 21, including fig. 5) is estimated to be about 1,400 feet, rather than 1,000 feet as stated by Turner. The lower 900–1,000 feet is lithologically similar to and is herein included in the Tyee formation, and the uppermost several hundred feet, consisting of nonmarine plant-bearing strata, is referred to the overlying Fisher formation. The thickness of the Spencer formation in the vicinity of Comstock is about 250 feet, and its maximum exposed thickness, along the London Springs-Shoestring Valley road, is approximately 500 feet. A rapid thickening of the Spencer formation northward along the west side of the Willamette Valley is indicated by data given by Vokes and his coworkers. In the vicinity of Eugene they estimated (Vokes and others, 1951) a thickness of 2,100 to 2,800 feet, not including the Lorane shale member, and in the Corvallis area a thickness of more than 4,500 feet (Vokes and others, 1954).

An unconformity between the Tyee and Spencer formations has been observed in the Corvallis area (Vokes and others, 1954), and an unconformity at an equivalent stratigraphic position exists in the Dallas quadrangle (Baldwin, 1947, p. 25), in the Coos Bay area (Allen and Baldwin, 1944, p. 21–23), in the coastal area between Waldport and Cape Kiwanda (Vokes and others, 1949; Snavely and Vokes, 1949), and in the Sheridan-McMinnville area (Baldwin and others, 1955). Vokes and others (1951) noted that the unconformity between the Tyee and Spencer formations in the Eugene area "has but minor time significance," but the contact mapped by these authors is within the Tyee formation as mapped elsewhere by others. These formations are separated by a slight unconformity of about 7° at Comstock, but elsewhere in the Anlauf quadrangle the contact appears to be conformable.

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The Spencer formation crops out continuously in a narrow belt from the north boundary of the map area southward to a point about 1 mile north of the London Springs-Shoestring Valley road, where it is overlapped by the Fisher formation. Just north of this road a fault brings the formation to the surface, but about a mile to the south it is again overlapped by the volcanic rocks. The Spencer formation is not exposed in the southern part of the area.

Lithology.—Massive to poorly bedded fine- to medium-grained sandstone predominates in the lower part of the Spencer formation, and thin-bedded light-colored platy sandy siltstone and fine tuff in the upper part. The base of the formation is exposed only along the Pacific Highway northeast of Comstock (fig. 10), where it is marked by a bed of pebble conglomerate 14 to 18 inches thick. The pebbles are chiefly quartz, platy andesite or basalt, and chert, and are set in a matrix of poorly sorted arkosic granule sandstone. About 50 feet of poorly sorted calcareous granule sandstone overlies the pebble conglomerate and is overlain, in turn, by several hundred feet of massive or faintly crossbedded, moderately well indurated micaceous carbonaceous sandstone, thin-bedded carbonaceous siltstone, and a few thin beds of impure coal. Elsewhere, the lowermost exposed beds of the Spencer formation consist of massive or poorly bedded sandstone with a few thin beds of sandy siltstone and thin lenses of sandy tuff. Most of these sediments are fine to medium grained, but coarse-grained

FIGURE 10.—Contact between the Spencer (Ts) and Tyee (Tt) formations along the Pacific Highway, 0.5 mile northeast of Comstock.

sandstone with interbedded thin layers of pebbly sandstone is common in the area between Bear and Lees Creeks, east of Anlauf.

In areas of poor exposures it is difficult to map a contact between the Tyee and Spencer formations because the standstone in the Spencer formation closely resembles sandstone of the underlying Tyee from which it was probably derived. The most reliable criteria by which the Spencer formation may be distinguished are a lesser content of mica, some bleached biotite flakes, a large percentage of partly altered feldspar grains, and no rhythmic graded bedding.

In nearly all exposures the sandstone of the Spencer formation is dark yellowish orange (10YR6/6), deeply weathered, and very friable. A few outcrops of calcite-cemented sandstone, from which samples were taken for thin sections, showed that clastic material makes up about 70 percent of the rock. Well-sorted subrounded grains of clear quartz constitute about 40 percent of the rock, partly altered sodic plagioclase about 10 percent, and lithic fragments, including chert and altered volcanic rocks, about 15 percent (fig. 11). Muscovite, bleached and shredded biotite, microcline, and magnetite are present as accessory minerals. Polysynthetic twinning is very pronounced in the calcite cement. The interbedded siltstone is medium gray (N5) to light olive gray (5Y6/1), firm, and sandy, and locally is carbonaceous. Along the London Springs-Shoestring Valley road west of the

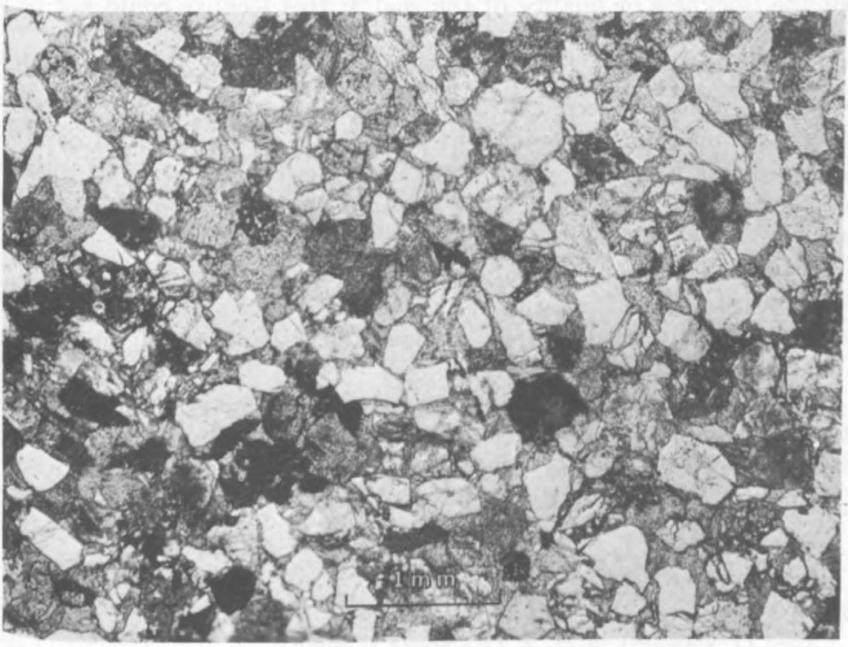

FIGURE 11.—Thin section of sandstone from the Spencer formation. Note the good sorting in this rock as compared with sandstone in the Tyee formation (fig. 9). Ordinary light, × 20.

Lane County line, thin-bedded platy siltstone occurs as clasts 2 to 6 inches long arranged in definite layers within thick beds of sandstone. Most of these siltstone fragments are oriented parallel to the bedding in the sandstone, but some are inclined as much as 25° from the plane of the bedding. They probably represent a siltstone bed of the Spencer broken by currents or by submarine slumping and redeposited as intraformational conglomerate. Sporadic, nearly spherical calcareous concretions about 8 inches in diameter occur below the siltstone clasts.

Weathered thin-bedded yellowish-gray (5Y8/1) to grayish-orange (10YR7/4) sandy siltstone and fine tuff compose the upper part of the Spencer formation. The change from sandstone to siltstone and tuff results from a lateral interfingering of these rock types, rather than from a gradual upward decrease in grain size. The fine-grained rocks are soft and punky and commonly occur in thin laminae. Some beds consist entirely of clay derived from the alteration of fine tuff. Carbonaceous material is relatively abundant in the upper part of the Spencer formation and locally forms beds of impure coal. A 30-foot section exposed on the south side of Bear Creek, in the NW¼ sec. 34, T. 21 S., R. 4 W., consists of 2- to 4-inch beds of carbonaceous siltstone and impure coal with many thin lenses of bright coal. An abandoned coal prospect in about the same stratigraphic position was found on the west side of Pass Creek, in the NW¼ sec. 16, T. 21 S., R. 4 W., but the thickness or quality of the coal at this locality could not be determined.

Age and correlation.—Turner (1938, p. 23–24) stated that the invertebrate faunas collected in its type area indicate that the Spencer formation represents "a portion of the Tejon-Cowlitz epoch of deposition" of late Eocene age, and that the species characteristic of these faunas include *Turritella uvasana stewarti* Merriam, *Ficopsis cowlitzensis* Weaver, *Crassatella dalli* (Weaver), and *Pitar eocenica* (Weaver and Palmer). The age assigned to additional faunas from the type area of the formation near Eugene (Vokes and others, 1951) and from the Corvallis area (Vokes and others, 1954) supports Turner's statement.

In the map area the Spencer formation yielded invertebrate fossils at only one locality (pl. 1, loc. M–3). The species obtained here (all poorly preserved) include:

Gastropods:

Turritella sp. cf. *T. uvasana olequahensis* Weaver and Palmer
Unidentified muricid?

Pelecypods:

Acila (*Truncacila*) sp. cf. *A.* (*T.*) *decisa* (Conrad)
"*Nuculana*" sp. cf. "*N.*" *cowlitzensis* (Weaver and Palmer)
Brachiodontes sp. cf. *B. cowlitzensis* (Weaver and Palmer)
Pitar (*Calpitaria*) sp. cf. *P.* (*C.*) *eocenica* (Weaver and Palmer)

Ellen Trumbull, who identified this fauna, reported that it indicates a late Eocene age and that it suggests a moderately shallow water environment. The species listed above are similar to forms recorded from the Spencer formation in its type area and from the Cowlitz formation of southwestern Washington.

Fossil plants were collected from the Spencer formation along a Bonneville Power Adm. right-of-way south of Bear Creek, in the NW¼ sec. 34, T. 21 S., R. 4 W. (pl. 1 loc. P-1). This flora was assigned a late Eocene age by Roland W. Brown, who identified the following species:

Typha sp. (cattail)
Ulmus oregoniana Knowlton
Alnus sp.
Caesalpinia pacifica (Knowlton) Brown
Fragments of other dicotyledonous leaves

As stated previously, the Spencer formation can be traced from the map area into its type area near Eugene and northward beyond Corvallis, and throughout this outcrop area it contains invertebrate fossils of late Eocene age. Correlatives of the Spencer formation in northwestern Oregon include the unnamed rocks of late Eocene age mapped by Baldwin (1947) in the Dallas area, the Helmick formation in the Salem quadrangle (Cushman, Stewart, and Stewart, 1947), the Moody shale member of the Toledo formation (Vokes and others, 1949), the Nestucca formation (Snavely and Vokes, 1949), and the upper part of the Yamhill formation as exposed along Mill Creek, south of Sheridan (Baldwin and others, 1955). The Coaledo formation in the Coos Bay area (Turner, 1938; Allen and Baldwin, 1944) and in the lower Umpqua River area (Baldwin, 1961) is also correlated with the Spencer formation.

In southwestern Washington the Cowlitz formation (Weaver, 1937), the Skookumchuck formation (Snavely and others, 1958), and locally the upper part of the McIntosh formation (Pease and Hoover, 1957) can be correlated with the Spencer formation on the basis of their contained faunas.

FISHER FORMATION

In the eastern half of the Anlauf quadrangle the marine Eocene rocks are succeeded by volcanic and pyroclastic rocks whose appearance indicates that they were deposited in fresh water or on land. Similar rocks in the Eugene area were named the Fisher formation by Schenck (1927, p. 451), and Vokes and others (1951) subsequently mapped the Fisher formation to the north boundary of the Anlauf-Drain area. The name Calapooya formation was proposed by Wells and Waters (1934, p. 11) for the nonmarine rocks exposed in the vicinity of Black Butte and London Springs, but mapping for this report has shown that the rocks composing the Calapooya formation are a southerly extension of the rocks named earlier by Schenck.

Wells and Waters (1934, p. 13–15) described the Calapooya formation as having a "lower or dominantly sedimentary facies" and an "upper or dominantly igneous facies," separated by a "comparatively narrow zone of transition." On their map (1934, pl. 7), the upper facies is restricted to the area south of Big River and east of Brauti Creek, in T. 23 S., R. 3 W. Additional exposures, made during recent logging operations, indicate that lava flows make up less than half of the exposed rocks in this area; the two-fold lithologic subdivision proposed by Wells and Waters for the Calapooya formation, therefore, does not seem to be valid.

The thickness of the Fisher formation in its type area west of Eugene was originally stated as 1,500 feet (Schenck, 1927, p. 451), but in later work Vokes and others (1951) increased this figure to about 7,000 feet. In the southeastern part of the Anlauf quadrangle the rocks now mapped as the Fisher formation were considered by Wells and Waters (1934, p. 11) to be more than 5,000 feet thick. A precise determination of the thickness of the Fisher formation in the map area is difficult to obtain because of the lack of structural data; its approximate thickness within the area is 5,500 feet. The Fisher formation is nearly conformable on the underlying rocks, although its southward overlap of the Spencer formation indicates a slight unconformity between marine and nonmarine rocks.

Lithology.—The Fisher formation in the Anlauf-Drain area is marked by a diversity of pyroclastic and volcanic rock types. The pyroclastic rocks, which constitute most of the formation, consist of massive to well-bedded fine to lapilli tuff, tuffaceous sandstone and siltstone, pebble to boulder conglomerate, and both water-laid and mudflow breccias. The lava flows, which are separated from the pyroclastic rocks on the geologic map (pl. 1), are predominantly hypersthene-augite andesite but range from basalt to dacite in composition. Most of the lithologic units in this heterogeneous sequence have a restricted lateral extent and thus very little stratigraphic significance.

Conglomerate is abundant in the lower part of the formation, although the basal beds are generally finer grained rocks. Good exposures of conglomerate in lenticular beds 20 to 50 feet thick can be seen on the south side of Bear Creek, in the SW¼ sec. 27, T. 21 S., R. 4 W., along the London Springs-Shoestring Valley road near the Douglas County line, and east of Elkhead, in sec. 35, T. 23 S., R. 4 W. Conglomerate also is common higher in the formation, but generally it is composed of smaller clasts and occurs in thinner beds. In most places the conglomerate is massive, but in some outcrops stratification is made apparent by a change in the average diameter of the clasts. The clasts are well rounded but have poor sphericity; they range in diameter from less than 1/4 inch to 30 inches and have an average diameter of about 4 inches. Most of the clasts are dark greenish-gray (5GY4/1) platy porphyritic andesite and are set in a matrix of coarse-grained tuffaceous sandstone. Other clasts consist of light brownish-gray (5YR6/1) dacite, chloritized basalt, and lapilli crystal tuff. When fresh, the conglomerate is olive gray (5Y4/1) to dark greenish gray (5GY4/1); when weathered, it is moderate brown (5YR3/4) to dark yellowish orange (10YR6/6). Generally the conglomerate is deeply weathered, and in some outcrops, such as those on the Weyerhaeuser Timber Co.'s road along the west side of Cottage Grove Reservoir, it contains completely decomposed pebbles that can be cut with a knife; the original texture of the conglomerate, however, is well preserved (fig. 12). In some outcrops false bedding results from subparallel iron-stained joints.

Massive or thick-bedded water-laid breccia and mudflow breccia are common in the Fisher formation but are less abundant than casual observation would indicate, for they are relatively resistant to erosion and thus form prominent outcrops. Some of the rock described here as breccia could as well be called conglomerate, for there are all grada-

FIGURE 12.—Weathered conglomerate in the Fisher formation in a road cut on the west side of Cottage Grove Reservoir. Most of the clasts in this rock are so completely decomposed that they can be cut with a knife.

tions between rocks containing exclusively angular clasts and those with exclusively rounded clasts.

Breccia occurs at all stratigraphic positions in the Fisher formation but is most common in the upper part, east of the Coast Fork of the Willamette River. It is well exposed at the east end of Cottage Grove Dam, in cuts on the Laurel Butte truck road, and in the channel of Big River east of Martin Creek. Imperfect graded bedding and a slight rounding of some clasts suggest that some of the breccia was deposited in water. In other places, the breccia is a mudflow deposit and consists of angular blocks of andesite 2 to 24 inches in diameter, smaller fragments of volcanic rock, and a matrix of poorly sorted clastic debris (fig. 13). The lithic fragments in the breccia are predominantly hypersthene-augite andesite, but locally they consist chiefly of subrounded fragments of tuffaceous rocks.

Petrographic examination of the breccia exposed on the northeast side of Cottage Grove Reservoir shows that it contains lithic fragments of porphyritic andesite with phenocrysts of zoned plagioclase (mainly andesine, An_{32}), abundant subhedral crystals of more calcic andesine (An_{42}), a few crystals of clinopyroxene and magnetite, and a matrix of fine vitric tuff.

FIGURE 13.—Mudflow breccia in the Fisher formation in a cut on the Laurel Butte truck road.

Fine-grained tuffaceous rocks in the Fisher formation rarely form conspicuous outcrops, but they probably make up the bulk of the formation. These rocks vary from tuffaceous siltstone to lapilli tuff, medium-grained tuffaceous sandstone being most common. They are massive to moderately well bedded and are various shades of green, gray, red, and purple; they are composed mainly of subangular granule-size fragments of andesitic and dacitic rocks and subhedral crystals of plagioclase and clinopyroxene, all in a matrix of very fine grained tuffaceous sandstone or tuffaceous siltstone. A few cuts on the Laurel Butte truck road reveal massive grayish-yellow (5Y8/4) crystal tuff in which feldspar crystals as much as 5 mm long are the predominant constituent. Dusky-brown (5YR2/2) pebbly claystone and soft white to yellowish-gray (5Y8/1) tuffaceous siltstone crop out locally. These rocks are massive and break with a subconchoidal fracture. Carbonized wood and leaf impressions are fairly common in the fine-grained rocks.

In the extreme northeastern part of the map area a small southeastward-plunging syncline contains in its central part massive to thick-bedded greenish-gray (5GY6/1) to yellowish-gray (5Y7/2) well-indurated fine-grained tuffaceous arkosic sandstone in which bedding is indicated by a few 3-inch beds of basaltic pebble conglomerate. Although this sandstone is mapped as a part of the Fisher formation, its lithology and stratigraphic position suggest that it may be equivalent to the Eugene formation, a fossiliferous marine unit of early and middle Oligocene age, which has been traced discontinuously southeastward from its type area at Eugene to the vicinity of the Dorena Reservoir, about 3 miles northeast of the area (Vokes and others, 1951).

A thin section shows that the tuffaceous sandstone consists of 25 percent fresh subhedral crystals of plagioclase (chiefly labradorite), 10 percent volcanic rock fragments, 10 percent accessory minerals (quartz, muscovite, biotite, and opaque minerals), 5 percent secondary calcite, and 50 percent fine tuff, which forms the matrix. The mineral grains and rock fragments are well sorted and have an average maximum dimension of 0.15 mm.

The pyroclastic rocks of the Fisher formation in places are interbedded with or overlain by lava flows that vary in composition from basalt to dacite but are predominantly hypersthene-augite andesite. Discontinuous outcrops of one flow are present along the crest of the Calapooya Divide north of Harness Mountain. North of the map area, in the vicinity of Cottage Grove and Eugene, the Fisher formation is capped in places by extrusive rocks which Vokes and others (1951) described as olivine basalt. A few flows of glassy olivine-bearing basalt that occur north of the Cottage Grove Reservoir are tentatively correlated with the post-Oligocene basalt flows mapped by Vokes and others. Most of the lava flows in the Anlauf quadrangle, however, are hypersthene-augite andesite and, with the exception noted above, do not contain olivine. Furthermore, no petrographic distinction can be made between the interbedded flows and those overlying the pyroclastic rocks; hence they are all considered part of the Fisher formation.

A typical lava flow in the Fisher formation consists of dark greenish-gray (5GY4/1) to dark-gray (N3) basaltic rock of an aphanitic to porphyritic texture. Some porphyritic flows contain phenocrysts of feldspar and pyroxene as much as 3 cm long. The rapid decomposition of the pyroxene crystals causes exposed surfaces of the rock to have a pitted appearance. A thin iron-stained rind is common on weathered outcrops. Where fresh, the rock is hard and brittle and breaks with a subconchoidal fracture. Imperfect columnar structure is present in some of the flows (fig. 14).

The flows in the Fisher formation are mainly hypocrystalline basaltic andesite, usually porphyritic, with an intersertal texture. The phenocrysts, which may make up as much as 20 percent of the rock, are augite, hypersthene, and plagioclase; the plagioclase may be as calcic as labradorite (An_{56}), although the abundant laths of feldspar in the groundmass normally are andesine (An_{44-50}). About 50 per-

FIGURE 14.—Andesite flow in the Fisher formation in a quarry near the head of Curtis Creek, in sec. 14, T. 22 S., R. 4 W. A thin section of this rock is shown in figure 15.

cent of the rock is plagioclase, 8 percent hypersthene, 22 percent clinopyroxene, 13 percent magnetite, and 7 percent partly devitrified brown glass with an index of refraction slightly less than 1.54. Crystallites and magnetite dust are common in the glass. A thin section of a typical andesite flow in the Fisher formation is shown in figure 15.

Age and correlation.—Although the Fisher formation does not contain marine fossils, at several localities in and adjacent to the map area it has yielded fossil plants that indicate a late Eocene age. In 1943, V. T. Allen and R. S. Nichols of the U.S. Geological Survey collected fossil leaves at Hobart Butte, in the NE¼ sec. 1, T. 23 S., R. 4 W. (pl. 1, loc. P–2). The late Roland W. Brown (written communication, 1943) identified the following species in this previously unpublished flora:

Anemia delicatula Brown
Hemitelia pinnata MacGinitie
Equisetum sp.
Potamogeton sp., probably new
Populus sp., probably new
Quercus nevadensis Lesquereux
Cercidiphyllum cf. *C. crenatum* (Unger) Brown
Liquidambar californicum Lesquereux
Cinnamomum dilleri Knowlton
Cryptocarya praesamarensis Sanborn
Rhus mixta Lesquereux

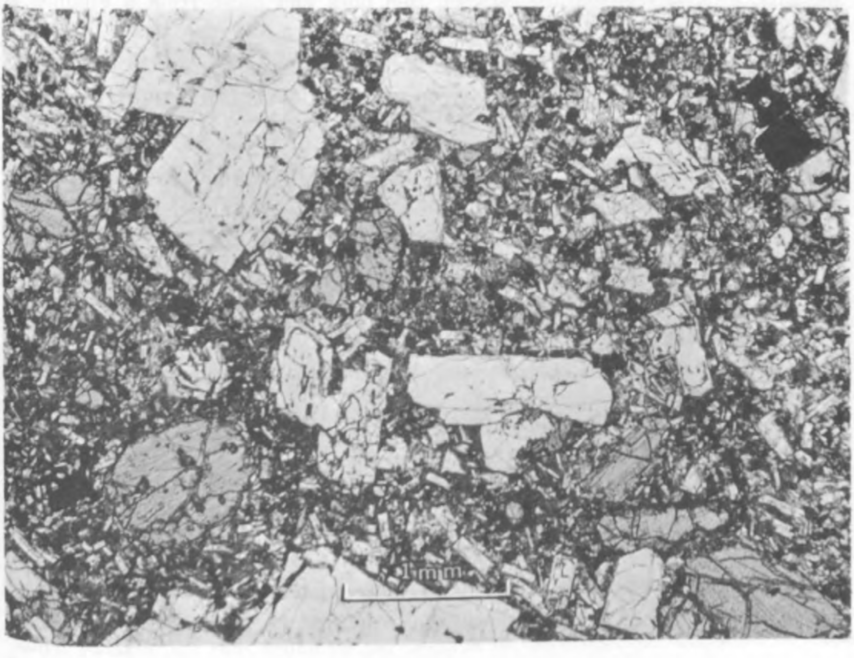

FIGURE 15.—Thin section of porphyritic andesite from the Fisher formation. The phenocrysts are labradorite, twinned augite, and hypersthene. Ordinary light, × 20.

Thouinopsis myricaefolia (Lesquereux) MacGinitie
Platanophyllum angustiloba (Lesquereux) MacGinitie
?*Cercis* sp., probably new
Unidentified dicotyledonous fragments
Unidentified fruit

Concerning this collection, Brown wrote:

> As some of the species listed here are represented by only one specimen, which, like most of the material, may be fragmentary and poorly preserved, definite or complete identifications cannot be given. Many of these species occur in the Chalk Bluffs flora of the Sierra Nevada in California, said by MacGinitie to be of middle Eocene age. Others occur in the late Eocene or early Oligocene of western Oregon and Washington. My inclination, pending receipt of more definite stratigraphic data, is to call the collection late Eocene.

Fossil leaves were found less than 100 feet above the base of the Fisher formation in the NW¼ sec. 2, T. 24 S., R. 4 W. (pl. 1, loc. P-3); Brown identified the following forms from this locality:

Equisetum sp.
Caesalpinia pacifica (Knowlton) Brown
Cinnamomum dilleri Knowlton
Magnolia sp.
Tetracera or *Quercus* sp.
Fragments of undetermined dicotyledonous leaves

Brown's comment on this collection is:

> The presence of *Caesalpinia pacifica* and *Cinnamomum dilleri* in this collection indicates a close relationship between this flora and those from a number of other localities, notably Comstock, Hansen coal mine, and Van Dyke Cliffs near Grizzly Peak, Ashland, Oregon. All these belong in the later half of the Eocene.

Species from the southeastern part of the Anlauf quadrangle on Coon Creek, in the NE¼ sec. 4, T. 24 S., R. 3 W. (pl. 1, loc. P-4), identified by Brown include:

Polypodium fertile MacGinitie
Lygodium kaulfussi Heer
Alisma sp.
Typha lesquereuxi Cockerell
Sabalites sp.
Aristolochia triangularis MacGinitie
Chaetoptelea pseudofulva (Lesquereux) MacGinitie
Alnus operia MacGinitie
?*Astronium oregonum* Chaney and Sanborn
Idesia cordata MacGinitie
Aleurites americana Potbury
Cryptocarya praesamarensis Sanborn
Columbia occidentalis Potbury
Terminalia estamina MacGinitie
Other dicotyledonous leaves and seeds, not determined

A late Eocene age for this flora was suggested by Brown:

> An analysis of this list shows that the majority of species is found in middle to late Eocene floras elsewhere, particularly in California. A few species, such

as *Polypodium fertile*, *Aristolochia triangularis*, and *Idesia cordata*, may have ranged into the early Oligocene, if the age of the flora from Weaverville, Trinity County, California, is of that age (see H. G. MacGinitie, Carnegie Inst. Washington Pub. 465, p. 83–151, 1937). However, the presence of *Lygodium kaulfussi*, which has never been reported from strata younger than Eocene in the western United States, indicates a late Eocene age as most likely for this flora. The aspect of the flora suggests a warm temperate to subtropical climate.

Fossil leaves also have been collected by members of the U.S. Geological Survey northeast of Cottage Grove Reservoir, in the NW¼ sec. 22, T. 21 S., R. 3 W., and along the Little River road, in the NW¼ sec. 27, T. 23 S., R. 3 W. They are not clearly identifiable, but Brown said (written communication, 1956) that the Little River collection, in his opinion, is of the same age as the Hobart Butte flora.

A sparse flora was obtained by Wells and Waters from a thin layer of tuff interbedded with conglomerate on the road between London Spring and Shoestring Valley, in the SE¼ sec. 35, T. 22 S., R. 4 W. This locality could not be found during the present study; however, Wells and Water (1934, p. 15–16) have quoted Brown's comments on the specimens obtained by them:

> The leaves are *Aralia*, probably *Aralia whitneyi*, a species described from the Yellowstone National Park and the auriferous gravel of California. The fossils described from those regions have been considered Miocene in age; but the tendency among recent students of these materials is to regard them as Oligocene, if not late Eocene. The fossil woods are sycamore (*Platanus*) and poplar (*Populus*). Much work needs to be done with fossil woods before they can by themselves be used as stratigraphic and time markers.

Along the Southern Pacific tracks about 1 mile northeast of Comstock and immediately north of the Anlauf quadrangle (mislocated by Vokes and others, 1951) there is a well-known fossil flora that was reported by Diller (1900, p. 34–35). The leaves he collected were identified by F. M. Knowlton, who assigned them to six species and stated that they "point unmistakably to the Miocene age of these beds" (Knowlton, 1900, p. 52). A more detailed study of the Comstock flora was made by Sanborn (1937); she found similar fossil leaves at a second locality 1¾ miles northeast of Comstock. The following quotation is the summary of her report on this flora (Sanborn, 1937, p. 14–15):

> The Comstock flora, from two localities in Douglas County, Oregon, on the west side of the Cascades, comprises 4 species of pteridophytes and 25 species of dicotyledons. These latter fall into 16 families, all but one of which are more characteristic of tropical than of temperate parts of the world. The modern species which they resemble are distributed almost equally in the warmer parts of both hemispheres, with several which range into middle latitudes. A warm, moist climate like that found on the borders of the tropics is indicated by these plants.

With 10 of the fossil species described as new, there remain 19 which have been previously recorded from other localities. All but one of these are known from the Eocene of North America, including such geographically wide-ranging and typical species as *Allophylus wilsoni*, *Aralia angustiloba*, *Aralia taurinensis*, *Laurus princeps*, *Magnolia californica*, *Persea pseudo-carolinensis*, *Platanus aceroides* and *Trochodendroides zaddachi*. The upper Eocene age of the Comstock flora is established by its systematic and climatic indications and by the stratigraphic relations of the Comstock formation.

Following the nomenclature of Turner, Sanborn placed the southern of these two localities within the uppermost part of the Comstock formation, but as Vokes and others (1951) pointed out, most of the rocks assigned by Turner to the Comstock formation are indistinguishable from those of the Spencer formation, and they believed the Comstock flora to be in the Fisher formation. Concerning this problem they said:

So far as can be determined from the original definition of the Comstock formation, Turner placed the top of that formation at a horizon falling between those of the two floral localities. As the floras from the two localities are so similar as to leave little doubt as to their essential contemporaneity, both would seem to require assignment to the same formational unit. The close association of mudflow breccia, cobble conglomerate, and lapilli tuff with the plant-bearing strata suggests the assignment of Sanborn's Comstock flora to a position near the base of the Fisher formation.

Reconnaissance mapping in the vicinity of the Comstock fossil plant localities indicates that Vokes and his coworkers have correctly interpreted the stratigraphy in this area and that both floras are near the base of the Fisher formation, in a stratigraphic position similar to the floras collected in the map area to the south.

There is no disagreement concerning a late Eocene age for the lower part of the Fisher formation, but no data are at hand regarding the age of the upper part of the formation. However, Vokes and others (1951) concluded that all but the lowermost part of the Fisher formation is a nonmarine equivalent of the Eugene formation, which is early and middle Oligocene in age. The Eugene formation, they believed, represented a period of marine transgression, which extended as far south as the Dorena Reservoir, about 3 miles northeast of the map area. The presence of unfossiliferous sandstone lithologically similar to the sandstone of the Eugene formation in the northeastern part of the Anlauf quadrangle, in secs. 22 and 23, T. 21 S., R. 3 W., together with the fact that more than 5,500 feet of nonmarine rocks overlies the Upper Eocene marine beds, suggests that the upper part, in fact perhaps most, of the Fisher formation is of early to middle Oligocene age.

POST-OLIGOCENE(?) BASALT FLOWS

North of the Anlauf quadrangle the Fisher and Eugene formations locally are concealed beneath basal flows that are of Miocene age or younger, according to Vokes and others (1951). These authors added that the flows are "predominantly an olivine basalt, occasionally porphyritic, with phenocrysts of olivine and plagioclase feldspar." Extrusive rocks in a similar stratigraphic position also are exposed in the map area, but most of them are included in the Fisher formation because they consist of hypersthene-augite andesite and cannot be distinguished petrographically from flows clearly interbedded in that formation. However, a few exposures of basalt similar to the olivine basalt flows mapped by Vokes and others were mapped in the valley of the Coast Fork of the Willamette River north of the Cottage Grove Dam; these rocks are therefore tentatively assigned a post-Oligocene age.

Microscopic examination shows that the post-Oligocene(?) basalt is hypocrystalline and has hyalo-ophitic or, less commonly, a variolitic texture. Most specimens contain at least a few phenocrysts as much as 3.5 mm long of zoned plagioclase (An_{44-54}) and twinned augite. Feldspar constitutes 25 percent of the basalt, clinopyroxene 20 percent, magnetite 8 percent, and olivine 7 percent. Clear light-brown glass, locally altered to palagonite, usually makes up about 40 percent of the rock.

QUATERNARY DEPOSITS

LANDSLIDE DEBRIS

The geologic map (pl. 1) shows the location and extent of the principal areas of landslide debris. Many landslides have occurred on dip slopes in the Tyee formation, the result of slippage within beds of water-lubricated micaceous siltstone. Landslide areas also are extensive in the tuff of the Fisher formation northeast of London Springs and on the west side of the Coast Fork north of the Cottage Grove Reservoir.

Most of the mapped landslides are of recent origin and may be recognized by the presence of landslide scarps, sag ponds, and hummocky topography. The landslide debris generally consists of yellowish- to reddish-brown clay in which are embedded blocks of locally derived rock types. Some blocks of sandstone of the Tyee are large enough to be mistaken for bedrock unless it is noted that they are in a landslide area.

An older landslide was recognized on the east side of Shoestring Valley, where an area of nearly 2 square miles is partly covered with rubble of volcanic rocks that are exposed on the mountain to the east. Erosion by Walker Creek has modified the landslide topography by stripping away much of the landslide debris and exposing small patches of bedrock.

ALLUVIUM

Alluvial deposits cover the valley floors of the larger streams and are widespread in the valley of Yoncalla Creek and in Hayhurst, Putnam, and Scotts Valleys. These extensive bottom lands, most of which are underlain by siltstone of the Umpqua formation, are the result of lateral planation and deposition of sediments at a time when basaltic or hard sedimentary rocks downstream created temporary base levels. Scotts Valley, especially, shows evidence of having been the site of a former flood plain, for the valley floor has a nearly uniform altitude and is covered by a layer of dark loamy soil. Elsewhere, the alluvial deposits consist of silt, pebbly sand and numerous lenses of poorly sorted pebbles and cobbles. Most of the streams have incised the alluvial deposits to a depth of 3 to 6 feet.

Small remnants of a terrace about 20 feet above the present valley floor occur on the northwest and northeast sides of Putnam Valley. Siltstone of the Umpqua formation crops out on the terrace slope. The sandy terrace deposits are not separated on the geologic map from the Recent alluvium.

INTRUSIVE ROCKS

FORM AND DISTRIBUTION

Dikes, sills, and stocklike bodies of igneous rock are present in the Anlauf-Drain area. Most of these intrusive bodies are in the outcrop area of the Fisher formation, although a few dikes and sills have been mapped in the Umpqua and Tyee formations.

Two small dikes of basalt cut the sedimentary rocks of the Umpqua formation on the northwest flank of the Red Hill anticline, just west of Scotts Valley. Where exposed in roadcuts they are about 20 feet wide and dip steeply to the southwest. The enclosing fine-grained sedimentary rocks have a narrow and poorly defined baked zone adjacent to the dikes. Two other basalt dikes intrude the Tyee formation, one near Comstock and the other north of Scotts Valley. Each of these dikes is about 35 feet wide and consists of porphyritic basalt. Baking is not discernible in the adjacent sandstone.

Sills occur in the Tyee formation south and east of Elkhead. Ben More Mountain, in T. 24 S., R. 4 W., is formed by a sill 350 to 400 feet thick that dips eastward with the enclosing sedimentary rocks. An indeterminate thickness of Tyee rocks both above and below the sill have been hardened and mottled with small circular patches of a brownish-black filmy material. This sill also is exposed in a small area about half a mile east of the crest of Ben More Mountain, where the headwaters of Elk Creek have stripped away the overlying sandstone.

Several miles northeast of Ben More Mountain another sill about 100 feet thick has intruded the Tyee formation. Although structural data for the immediate vicinity of this intrusive body are not available, field observations indicate that it cuts obliquely beds of the Tyee formation. In this respect the Elkhead sill is similar to some of the "sill-like bodies" in the west-central part of the Coast Ranges (Snavely and Vokes, 1949). Baking and alteration were not observed in the sedimentary rocks beneath this sill but have affected about 10 feet of fine-grained sandstone and siltstone above the intrusive.

Along the crest of the Calapooya Divide a series of stocklike bodies of intrusive rock form prominent peaks that rise 300 to 1,000 feet above the general level of the divide; these include Buck Mountain, Harness Mountain, an unnamed peak northeast of Shoestring Valley, and Wards Butte. The outcrop pattern of these bodies suggests that they are small stocks or volcanic necks. Each consists of medium dark-gray (N4) diabasic rock with columnar jointing. The orientation of the columns varies from nearly vertical in the central part of the intrusive bodies to nearly horizontal along the margins. The rock weathers spheroidally and usually forms a talus of blocky fragments.

Other smaller igneous bodies intrude the upper part of the Fisher formation east of the Coast Fork of the Willamette River. These include dikes, sill-like bodies, and small irregularly shaped plugs.

COMPOSITION

The intrusive rocks in the Anlauf-Drain area are similar in composition, but there are some differences in texture and mineral content. The principal difference, as pointed out by Wells and Waters (1935), is the olivine in the basalt dikes associated with the extrusive rocks of the Umpqua formation, and the hypersthene in the intrusive rocks that cut the Fisher formation. The only olivine-bearing intrusive rocks in the map area are the two small basalt dikes that cut the Umpqua formation west of Scotts Valley. The dike rock has an ophitic texture and consists of about 70 percent randomly oriented laths of cloudy plagioclase, 15 percent augite, 7 percent magnetite, 5 percent olivine, and 3 percent chloritic material. Olivine is much less abundant in these dikes than in the olivine basalt dikes described by Wells and Waters (1935, p. 967), but it is completely absent in the other intrusive rocks.

The dikes in the Tyee formation are composed of porphyritic hypocrystalline basalt that has an intersertal feature. Zoned phenocrysts of plagioclase, with cores of labradorite (An_{54-57}) and slightly more sodic rims, constitute 5 to 15 percent of the rock. The groundmass consists of plagioclase (labradorite?), clinopyroxene, magnetite, and choritic material. The color index of the rock is about 45.

A medium-gray (N5), moderately coarse grained porphyritic rock comprises the sills on Ben More Mountain and east of Elkhead. Wells and Waters (1935, p. 968) described this rock as a norite, but although it does contain abundant hypersthene as phenocrysts and in the groundmass, in only one thin section is this mineral as abundant as augite. Labradorite (An_{60}) constitutes about 50 percent, and chloritic material about 4 percent. Large anhedral plates of magnetite enclose smaller grains of plagioclase and pyroxene. The rock has a subhedral-granular texture.

The intrusive rocks in the Fisher formation are sufficiently uniform to be described together, although there are differences in texture between the small dikes and the large stocklike bodies. Labradorite (An_{54-62}), augite, and hypersthene, listed in order of decreasing abundance, are the predominant constituents of these rocks and together make up more than 90 percent of each thin section. Magnetite, apatite, and some biotite are accessories. Wells and Waters (1935, p. 968) reported fine-grained aggregates of quartz and orthoclase in the Buck Mountain plug, but these minerals were not recognized in the thin sections studied. The stocklike bodies generally have a hypidiomorphic-granular texture, whereas the smaller intrusives commonly are hypocrystalline and have an intersertal texture. Depending on the texture and the color index, which ranges from about 38 to 45, the intrusive rocks in the Fisher formation can be called hypersthene-augite andesitic basalt or diabase.

AGE

The geologic setting of the intrusive bodies in the map area indicates that most of them are probably post-Fisher and, therefore, Oligocene or younger in age, but an exact determination of the time of their emplacement cannot be made. Wells and Waters (1935, p. 968) noted a chemical similarity between some of the intrusive rocks in the Anlauf quadrangle and an augite diorite plug in the Bohemia mining district, about 20 miles to the east. Buddington and Callaghan (1936, p. 425) suggested that the intrusive rocks in the Bohemia district may be late Miocene in age. This correlation and age assignment appear tenuous, however, and in view of the lack of other evidence the intrusive rocks in the Fisher formation are considered to range in age from late Eocene to late Miocene.

The age of some of the dikes and sills that cut the Tyee and Umpqua formations can be estimated. At least one of the dikes in the Umpqua formation, in sec. 31, T. 22 S., R. 4 W., clearly antedates the Tyee formation, and because of the close mineralogic and geographic relation of these dikes to the basalt flows in the Umpqua formation, the dikes are considered to be early Eocene in age. The sill-like bodies south and east of Elkhead are confined to the Tyee formation, but mineralogically they are closely related to flows of the Fisher formation and to post-Fisher intrusive rocks, and, therefore, may range in age from late Eocene to late Miocene.

STRUCTURAL GEOLOGY

The Anlauf and Drain quadrangles lie on the east flank of the Coast Range anticlinorium south of the Willamette trough. In the latitude of the map area this anticlinorium consists of two upwarps and an intervening downwarp. The northeastward-trending folds in the central and western parts of the area represent the eastern upwarp, which extends in a northerly direction across the Sutherlin, Drain, Crow, and Elmira quadrangles.

The outcrop area of the oldest rocks, assigned to the Umpqua formation, is limited to the central parts of three northeastward-trending folds, whereas the overlying Tyee formation crops out on the flanks of these folds and elsewhere over a broad area. The westerly dips in the Tyee formation along the west margin of the Drain quadrangle represent the east edge of an elliptical structural basin mapped by Baldwin (1961) in the adjacent Elkton quadrangle. In the eastern part of the area the Tyee formation is overlain by the Spencer and Fisher formations. A few folds were mapped in these younger rocks, which for the most part have a variable but gentle easterly dip.

FOLDS

The most conspicuous structural features in the Anlauf-Drain area are three subparallel anticlines in the older marine Eocene rocks. These are doubly-plunging folds or elongated domes that trend about N. 45°–50° E. They are similar in many respects, yet each has its own individual characteristics which are chiefly the results of stratigraphic rather than structural variations.

The Red Hill anticline, to the southeast, is the largest of these folds. Its axis trends from the south edge of the area about N. 45° E. to the east end of Scotts Valley. The basalt member of the Umpqua formation crops out in the central part of the anticline and extends from just south of the area to the east end of Scotts Valley, about 11 miles northeastward; this member has a maximum outcrop width of about 4 miles. East of Scotts Valley the northeasterly plunge of the Red Hill anticline is accentuated by a normal fault perpendicular to its axis. The narrow width of outcrop of the basalt member near the south edge of the area probably is the result of a southwesterly plunge of the fold axis, but inasmuch as the Tyee formation does not close to the south, this apparent plunge may be due to a facies change between basalt and siltstone in the Umpqua formation. The Red Hill anticline is a nearly symmetrical feature, the dips on each flank averaging about 25°, although locally they are as steep as 60°. A northeastward-trending high-angle reverse fault can be seen in the

Elkhead mine, and several normal faults perpendicular to the axis cut both flanks of the anticline.

The Drain anticline lies northwest of the Red Hill anticline, from which it is separated by the Yoncalla syncline. The Drain anticline is a relatively uncomplicated doubly-plunging fold, whose axis trends about N. 60° E. The basalt flows in its core have an outcrop area about 6½ miles long and about 2½ miles wide. These extrusive rocks are separated from the Tyee formation by a narrow but apparently continuous belt of sedimentary rocks of the Umpqua formation. Sparse structural data indicate that the northwest flank of the Drain anticline is slightly steeper than the southeast flank. The axis of the structure plunges to the southwest at an angle of about 20° and to the northeast at about the same angle. A northwestward-trending normal fault cuts the northwest flank of the anticline in the vicinity of Lost Cabin Creek.

The Drain anticline is succeeded to the northwest by the Hardscrabble Creek syncline and then by the Jack Creek anticline, the most complex of the three anticlinal folds. Its complexity results principally from a pre-Tyee fault (see structure section *B–B′*, pl. 1), which, in conjunction with post-fault sedimentation, conceals much of the Umpqua formation on the southeast flank of the anticline and creates a local unconformity between the Umpqua and Tyee formations. The interbedding of igneous and pyroclastic rocks in the central part of this fold also increases the difficulty of interpreting the structure. The axis of the Jack Creek anticline plunges both to the northeast and southwest. The axis as plotted on the geologic map (pl. 1) refers only to the structure expressed by the Tyee formation and not to that of the Umpqua formation.

Southeast of Harness Mountain the northeastward-plunging Coon Creek anticline exposes both the Tyee and Umpqua formations in its central part and deforms strata of the Fisher formation along its flanks. This fold extends southwestward several miles into the Glide quadrangle, where the fault parallel to its steeply dipping northwest flank becomes the contact between the Fisher formation and the older marine sedimentary rocks (R. D. Brown, Jr., written communication, 1956). A broad downwarp separates the Coon Creek anticline from the Red Hill anticline to the northwest. The surface trace of the axis of this synclinal fold is not well marked, but it appears to trend northeastward just east of Harness Mountain and Black Butte.

A southeastward-plunging syncline in the northeastern corner of the Anlauf quadrangle is significant because it trends across the structural grain of the remainder of the area and because of the presence in its trough of rocks possibly equivalent to the Eugene formation. The dips on both flanks of this fold are less than 15°.

FAULTS

Most of the faults mapped in the Anlauf and Drain quadrangles are northwestward-trending normal faults that have displacement downward on the northeast side. Because of poor exposures, the faults can be located only by noting anomalous stratigraphic relations in association with local topographic expression. Several other faults are known but cannot be recognized at the surface. Wells and Waters (1934, p. 28) reported that a conspicuous northwestward-trending fault, along which hydrothermal alteration has taken place, can be seen in the Black Butte mine, but they could not trace this fault on the ground. Faults are also associated with the hydrothermally altered rocks at Hobart Butte (Allen and others, 1951, p. 9) and at the Elkhead mine.

Four northeastward-trending high-angle reverse faults are shown on structure section *B–B′* (pl. 1). The fault on the southeast flank of the Jack Creek anticline can be traced discontinuously on the ground, but the only evidence for the fault on the southeast flank of the Drain anticline is the difference in thickness of sedimentary rocks of the Umpqua formation on the opposite sides of the Yoncalla syncline. Alternate but less likely explanations for this anomalous relation are a northwestward thickening of the basalt at the expense of the siltstone member and a sharp unconformity between the Umpqua and Tyee formations.

AGE OF DEFORMATION

The rocks exposed in the Anlauf-Drain area have preserved a record of intermittent crustal deformation since early Eocene time. The record begins with submarine and, possibly in part, subaerial extrusion of basaltic lavas and with some contemporaneous faulting during the early part of the Eocene, after which these rocks and the overlying marine sedimentary rocks of the Umpqua formation in places were folded and cut by normal faults to produce local unconformities between the Umpqua and Tyee formations. The middle Eocene was a time of relative crustal stability; during this time the sediments of the Tyee formation accumulated in a broad marine basin, which probably subsided at a rate almost equal to the rate of sedimentation. Prior to deposition of the Spencer formation in late Eocene time the older Tertiary rocks were deformed into a series of northeastward-trending folds; subsequent erosion of sandstone of the Tyee formation from these topographic highs furnished the sediments for the Spencer formation. Following this episode of erosion and sedimentation, the sea withdrew from the area and nonmarine volcanic rocks accumulated for a long period. Paleobotanical evidence indicates that the lower part of this nonmarine sequence is of late Eocene age, and an Oligocene age is inferred for the upper part. According to Callaghan and

Buddington (1938, p. 21–22), who summarized the geologic history of the Cascade Range, the sequence of lavas and pyroclastic rocks, of which the Fisher formation is a part, accumulated from Eocene to Miocene time, although deposition was not necessarily continuous at any one place. Probably near the end of the Miocene the volcanic rocks were moderately deformed, intruded by calcic igneous rocks, and locally altered by hydrothermal solutions. Although Pliocene(?) to Recent lava flows are found farther east in the Cascade Range, there is no record in the Anlauf and Drain quadrangles of this volcanic episode. The late Tertiary and Quaternary structural history of the map area consists only of possible slight deformation, of which there is no evidence, and, as indicated by the entrenchment of the Umpqua River near the west edge of the area, of regional uplift.

ECONOMIC GEOLOGY

OIL AND GAS POSSIBILITIES

The possibilities of finding commercial quantities of oil and gas in western Oregon have intrigued oil operators for many years, but to date there has been no production. The general absence of surface indications of oil and of favorable source beds and reservoir rocks for petroleum was noted in early reports on the oil and gas possibilities of the western part of the State (Washburne, 1914; Harrison & Eaton, 1920), and more recent work in the Coast Ranges in Oregon has not disclosed new geologic data to modify these findings. However, western Oregon may still be regarded as virtually an untested area, for by 1954 only 61 wells, considerably less than one well per 300 square miles, had been drilled in that part of the State west of the Cascade Range (Stewart, 1954). No test wells for oil and gas have been drilled in the Anlauf-Drain area.

The only rock unit in the map area that might be considered as a source of oil and gas is the siltstone member of the Umpqua formation. This sequence of predominantly fine-grained rocks, which overlies flows of olivine basalt, attains a maximum thickeness of about 5,000 feet. Basalt flows also are present in the subsurface a few miles northeast of Reedsport, as shown by General Petroleum Corp.'s well Long-Bell 1, in the SE¼ SW¼ sec. 27, T. 20 S., R. 10 W. This well penetrated partly brecciated basalt flows about 4,000 feet below the top of sedimentary rocks of the Umpqua formation. There is a possibility, however, that these basalt flows are absent in the central part of the Coast Ranges and that a considerably thicker section of siltstone underlies the Tyee formation in this area.

Possible reservoir rocks include the Umpqua, Tyee, and Spencer formations. The Tyee formation, consisting predominantly of fine-to medium-grained sandstone in beds as much as 50 feet thick, blankets the western part of the Anlauf-Drain area and extends westward nearly to the coast. It thus overlies the siltstone member of the Umpqua formation in the area where that rock sequence is most likely to include source beds. Analyses of 12 samples of sandstone from the Tyee formation show that its effective porosity ranges from 6.2 to 19.4 percent, which according to Levorsen (1954, p. 98) is adequate for a reservoir rock; however, the same 12 samples, when tested for permeability, had values from less than 0.1 to as much as 9.2 millidarcies, and three-fourths of the samples had the lower value. As the samples tested were all obtained from surface outcrops, it is possible that in the subsurface the sandstone of the Tyee has substantially different values of porosity and permeability.

Two samples from the sandstone tongue in the siltstone member of the Umpqua formation and one from a lower stratigraphic position in the same member had effective porosities that range from 9.7 to 16.5 percent and permeabilities that range from less than 0.1 to 11.8 millidarcies. Although sandstone locally predominates in the siltstone member of the Umpqua formation, it generally is in beds that probably are too thin to be satisfactory reservoirs for petroleum.

The Spencer formation has been considered as a possible reservoir rock (Vokes and others, 1954). In the Anlauf-Drain area it is mainly concealed beneath the nonmarine volcanic rocks of the Fisher formation, and its eastward limit is not known. The sandstone in the Spencer formation was not tested for porosity and permeability, but generally it is less well cemented than sandstone of the Tyee.

In some areas of western Oregon, potential source beds are associated with suitable reservoir rocks, but the petroleum possibilities of these areas generally are abridged by the lack of structural features favorable for the accumulation of oil. Such features, however, are present in the map area, namely, the Red Hill, Drain, and Jack Creek anticlines, several of which seem to have closure. Although the rocks exposed in the central parts of these folds consist of basalt flows estimated to be as much as 4,000 feet thick, marine Eocene and possibly Cretaceous sedimentary rocks may underlie the volcanic rocks.

In summary, the surface geology does not lead one to anticipate substantial accumulations of oil in the Anlauf and Drain quadrangles, but subsurface data from exploratory wells are required to determine the petroleum potential of the area.

QUICKSILVER

The quicksilver deposits in the Anlauf-Drain area occur at the north end of a discontinuous belt of quicksilver mineralization that extends for some 55 miles south to the Rogue River. These deposits of cinnabar have been the subject of reports by Wells and Waters (1934) and by Schuette (1938). As the primary purpose of this investigation was to study the petroleum possibilities of the area, no attempt was made to supplement or revise the work of the authors cited above; the reader is referred to their reports for additional information. The following summary of the geology of the quicksilver deposits in the mapped area is based chiefly on the work of Wells and Waters.

Quicksilver has been mined at two localities in the Anlauf and Drain quadrangles: at Black Butte, in T. 23 S., R. 3 W., and about 1½ miles northeast of Elkhead, in sec. 21, T. 23, S., R. 4 W. The Black Butte mine has the larger ore body, and since its discovery about 1892, it has been one of the chief quicksilver producers in Oregon. The ore deposits at Black Butte are in andesitic lavas and breccia of the Fisher formation that have been altered by quicksilver-bearing hydrothermal solutions that migrated upward along fault planes. Poor exposures and the lack of contrasting lithology on opposite sides of these faults prevent them from being mapped on the surface, but Wells and Waters (1934, p. 28) reported that a large fault trending N. 69° W. can be seen underground. There has been some post-ore movement on this fault.

The hydrothermal solutions have so altered the host rocks that the original lithology can scarcely be determined from examination of hand specimens, although microscopic study reveals relic textures of andesite flows. A distinctive surface feature in the area of alteration is a series of conspicuous iron-stained ribs of silicified rock that form crags more than 100 feet high. These ribs or veins are composed chiefly of siderite and chalcedony, with some quartz; they are surrounded by a softer type of altered rock consisting of carbonate (mainly calcite), sericite, and silica. Mining operations have shown that in places calcite constitutes as much as 25 percent of the rock, and some of it has been mined, crushed, and sold for agricultural purposes. The altered rocks at Black Butte have been oxidized and leached to depths of as much as 1,000 feet.

The early history of the Black Butte mine was summarized by Wells and Waters (1934, p. 28–29) and by Schuette (1938, p. 81–83). Mining operations by the Quicksilver Syndicate continued until the spring of 1942, when the mine was shut down. It was reopened in the fall of 1955 by the Mercury and Chemicals Corp., which installed a 100-ton rotary furnace and new ore bins; however, operations were discontinued in July 1957, and the mine has since remained idle. The Black Butte mine has been noteworthy for operating on ore averaging about 3 pounds of quicksilver per ton (Schuette, 1938, p. 145); its total production is estimated from various published sources to be about 15,500 flasks.

At the Elkhead mine the cinnabar occurs in hydrothermally altered fine to lapilli tuff and tuffaceous sandstone in the Umpqua formation.

These rocks overlie amygdaloidal basalt flows that are not mineralized where they are exposed west of the mine, although they are reported to be altered at depth (Wells and Waters, 1934, p. 35). A high-angle reverse fault that trends N. 40° E. and dips 63° NW. brings the altered tuffaceous rocks in contact with unaltered siltstone of the Umpqua to the east. The type of rock alteration at Elkhead is similar to that at Black Butte.

The Elkhead quicksilver deposit has been mined intermittently since its discovery about 1870, but neither Wells and Waters (1934) nor Schuette (1938) were able to find reliable production figures for the mine.

Hydrothermal alteration also has occurred at other localities in the map area, principally in andesitic lava and tuff adjacent to Black Butte, in pebble conglomerate and tuff at Hobart Butte, and in basalt flows of the Umpqua formation at the northeast end of the Red Hill anticline north of Shoestring Valley (pl. 1). Numerous prospects in these altered rocks have revealed little or no cinnabar; either the hydrothermal solutions were not everywhere quicksilver-bearing, or else conditions prevented the deposition of cinnabar.

No reliable criteria are available to determine precisely the time of hydrothermal alteration, but an approximate age can be estimated. The alteration is at least post-Eocene, for uppermost Eocene and possibly Oligocene rocks have been subject to alteration. Callaghan and Buddington (1938, p. 22–23) stated that in the Bohemia mining district, about 20 miles east of the Anlauf quadrangle, the mineralization is associated with dioritic intrusive rocks of probable late Miocene age. Intrusive rocks of similar composition crop out in the Anlauf quadrangle, and on the 900-foot level of the Black Butte mine an almost unaltered basalt dike of Miocene(?) age cuts altered andesitic lavas (Wells and Waters, 1935, p. 969–970). The period of hydrothermal activity, therefore, probably was not later than Miocene(?).

HIGH-ALUMINA CLAY

High-alumina clay is found in the Fisher formation at several localities in the eastern part of the Anlauf quadrangle, but only the deposit at Hobart Butte, in sec. 31 T. 22 S., R. 3 W., and sec. 36, T. 22 S., R. 4 W., is large enough to be of economic interest. This deposit was discovered in 1930, and for a number of years thereafter was quarried for refractory clay (Wilson and Treasher, 1938, p. 69–71). Increased demand for aluminum during World War II led the U.S. Geological Survey, in conjunction with the U.S. Bureau of Mines, to examine the Hobart Butte deposit; the results of this investigation were reported by Allen and Nichols (1945) and by Allen, and others (1951).

The rocks at Hobart Butte, chiefly nonmarine clayey tuff, pebble conglomerate, and microbreccia, have been altered by hydrothermal solutions, so that their original composition is not always apparent. Mineralogical studies have shown that most of the clay is kaolinite of sedimentary origin, but minor amounts of hydrothermal kaolinite and dickite also are present. Other hydrothermal minerals at Hobart Butte include mansfieldite, pyrite, quartz, realgar, scorodite, siderite, and stibnite (Allen and others, 1951, p. 4–5). Evidence as to the time of hydrothermal alteration is summarized on page D–54.

The amount of available Al_2O_3 in the clay at Hobart Butte varies from about 26.7 to 34.3 percent and constitutes from 75 to 100 percent of the total alumina, according to Allen and others (1951, p. 5–7). The following analysis in percent, of a composite sample of high-alumina clay from Hobart Butte is taken from their report (p. 5; analysis by U.S. Bureau of Mines):

SiO_2	51. 2	V_2O_5	. 05
Al_2O_3	30. 4	Sb_2O_3	0. 08
Fe_2O_3	3. 6	As_2O_3	. 27
MgO	0. 0	WO_3	0. 0
CaO	. 2	Hg	0. 0
Na_2O	. 2	Organic C	. 1
K_2O	. 1	Co_2	. 7
TiO_2	2. 4	Ignition from loss at 700°C	11. 5
ZrO_2	0. 0	Ignition from loss at 950°C	11. 8
P_2O_5	. 25		

The clay quarry on the southeast side of Hobart Butte exposes several types of altered rock that cannot be seen in surface outcrops. One of the more unusual varieties consists of abundant white to very light gray oval pellets of clay as much as 15 mm in length in a matrix of medium-gray to light brownish-gray clay. Several hypotheses concerning the origin of the clay-pellet conglomerate were proposed before Allen and Nichols (1945) showed that the pellets of kaolinite are in a kaolinite matrix containing abundant black carbonaceous material and some diatoms. This fact eliminates all theories but those involving sedimentation, and of these the most tenable is that the rock is an intraformational conglomerate containing clasts formed by the desiccation, fragmentation, erosion, and redeposition of thin layers of clay. The clay fragments were rounded during transportation and were deposited in a plastic condition, as shown by the molding of pellets against each other and against lithic fragments and quartz grains (Allen and Nichols, 1945, p. 30–32).

CRUSHED ROCK

At least 25 quarries have been operated in the Anlauf-Drain area to supply crushed rock for public highways and private logging roads. Three types of igneous rock have been used: (1) amygdaloidal basalt flows in the Umpqua formation, (2) andesite flows in the Fisher formations, and (3) intrusive gabbroic rock. The rocks are widely distributed except in the western part of the area. Locally, however, basalt of the Umpqua is too vesicular and brecciated to use as road rock, because it tends to break down under heavy loads.

Burned waste rock from the Black Butte quicksilver mine has been used extensively for road metal in the southeastern part of the area. It provides a smooth, well-drained road surface that requires a minimum of maintenance.

MINERAL SPRINGS

Two mineral springs in the Anlauf-Drain area have been exploited. The larger of the two is Boswell Spring, in sec. 21, T. 22 S., R. 5 W. This spring, said to have been discovered in 1874, is on the southeast flank of the Drain anticline, near the contact between basalt flows of the Umpqua formation and the overlying sedimentary rocks of the Umpqua. The flow of Boswell Spring is reported to fluctuate and to range from less than 100 to about 1,000 gpm (gallons per minute); the minimum figure is considered to be more nearly correct. The temperature of the spring water is about 60°F.

London Springs lie about 10 miles east of Boswell Spring, in D.L.C. 41, T. 22 S., R. 3 W. The surrounding rocks are a part of the Fisher formation and consist of tuff, conglomerate, breccia, and andesitic lava flows. The combined flow of the springs is estimated to be 10 gpm. This estimate may be too low, however, because the springs are adjacent to the Coast Fork of the Willamette River and a part of their flow may be discharged directly into the river.

Samples of water from Boswell and London Springs were analyzed by J. P. Schuch with the following results:

	(Parts per million) Boswell Spring	*(Parts per million)* London Springs		*(Parts per million)* Boswell Spring	*(Parts per million)* London Springs
SiO_2	17	19	HCO_3	6	76
Fe[1]	.00	.00	SO_4	2.1	1.2
Al[1]	.32	.12	Cl	18,800	2,100
Mn[1]	.00	.00	F	----------	.00
As	----------	.13	NO_3	.0	9.3
Li	.00	.00	B	7.8	3.0
NH_4	1.3	.00	PO_4	----------	.34
Ca	7,080	480	NO_2	.02	.02
Mg	.00	29	Cu	----------	.00
Na	3,900	810	Pb	----------	.00
K	13	8.2	Zn	----------	.00
Br	45	3.7			
I	7.5	.2	Total	29,880	3,540
CO_3	.00	.00			

[1] In solution when analyzed.

According to D. E. White (oral communication, 1958), the water from Boswell Spring closely resembles connate water of the Na-Ca-Cl type and has a composition similar to some chloride-type oil-field brines (White, 1957). Despite the fact that it issues from nonmarine rocks, the London Springs water also is thought to be fossil sea water, which has been extensively diluted by meteoric water and altered by the chemical composition of the andesitic lava flows and pyroclastic rocks through which it must have migrated.

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