U.S. DEPARTMENT OF THE INTERIOR

U. S. GEOLOGICAL SURVEY

Preliminary Geologic Map of the Lakeview Peak quadrangle, Cowlitz County, Washington

by

Russell C. Evarts[1] and Roger P. Ashley[1]

Open-File Report 91-289

Prepared in cooperation with the Washington Department of Natural Resources, Division of Geology and Earth Resources

[1]Menlo Park, California

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INTRODUCTION

The Lakeview Peak 7.5-minute quadrangle is on the western slope of the Cascade Range of southern Washington, centered about 25 km south-southwest of Mount St. Helens (fig. 1). Bedrock consists of volcanic and volcaniclastic rocks of late Eocene to middle Oligocene age, overlain by extensive late Pleistocene glacial deposits and locally by fine-grained tephra erupted from Mount St. Helens. The Kalama River valley contains thick deposits of glacial outwash as well as alluvium and minor laharic deposits derived from the Holocene volcano.

Natural bedrock exposures are limited owing to the dense vegetation of temperate coniferous rain forest as well as to the thick surficial cover. However, outcrops are common along the many small streams of the area. In addition, an extensive network of private logging roads constructed during the past two decades provides many roadcuts exposures as well as excellent access, allowing the stratigraphy of the quadrangle to be determined in considerable detail.

This is one of a series of 1:24,000-scale maps that cover the region near Mount St. Helens (Evarts and Ashley, 1990a, b; in press a,b,c,d; Swanson, 1989) in a program designed to produce a detailed geologic transect across the Cascade Range in order to elucidate the petrologic and structural evolution of the arc. The strata in this and the adjacent quadrangles to the north and east (Evarts and Ashley, 1990a, b) are older than those in mapped areas north and northeast of Mount St. Helens (fig. 1), and include some the oldest known products of the Cascades volcanic arc in Washington (Walsh and others, 1987; Phillips and others, 1989).

Acknowledgments

Our mapping program in the Cascade Range has been supported by the Washington Department of Natural Resources, Division of Geology and Earth Resources. Permission by Weyerhaeuser Paper Co. and Longview Fibre

Co. to work on their timberlands and use their road networks was essential to undertaking the work presented here. The enthusiasm and knowledge of William M. Phillips of the Division of Geology and Earth Resources, who spent several days in the field with us, were welcome and enlightening. Discussions about the geology of southwest Washington with Paul E. Hammond of Portland State University, and Donald A. Swanson, William E. Scott, and James G. Smith of the USGS helped place our mapping in a sound regional perspective. Helpful technical reviews were provided by James P. Calzia and Martin L. Sorensen.

SUMMARY OF GEOLOGY

Quaternary Deposits and Rocks

Surficial Deposits

Surficial deposits unconformably overlying Tertiary bedrock include middle Pleistocene olivine basalt and basaltic andesite, late Pleistocene glacial deposits and latest Pleistocene and Holocene eruptive products of Mount St. Helens volcano. Volcanic ash erupted from Mount St. Helens (chiefly the C and J tephra sets of Mullineaux (1986)) locally mantles gentle slopes in the northern half of the quadrangle, and reworked tephra forms local accumulations in valleys bottoms of the Kalama and North Fork Kalama River; these widespread but thin deposits were not mapped. Terraces along the Kalama River consist of glacial outwash deposits and younger alluvium and laharic deposits generated from Mount St. Helens.

Deposits of Mount St. Helens volcano

The Kalama River heads on the western slope of Mount St. Helens. Pyroclastic flows and lahars generated by eruptions of the volcano have moved down the valley many times during the past 40,000 years (Crandell (1987), but the Kalama River has received a significantly smaller volume of eruptive products than have most of the other streams that drain the volcano. None of the pyroclastic flows and few of the lahars that moved down the Kalama are known to have extended as far downvalley as the Lakeview Peak quadrangle; the deposits of Mount St. Helens debris that form low terraces along the river consist largely of fluvially reworked materials. The age of these deposits is not known. The absence of andesite and basalt clasts suggests they are mostly older than the Castle Creek eruptive period of Crandell (1987), when the volcano first erupted a substantial volume of mafic rocks. Exposures along the Kalama River about 10 km downstream from this quadrangle appear to belong largely to the early part of the Spirit Lake and possibly the Swift Creek eruptive stages according to Crandell (1987).

Glacial deposits

Drift in the area near Mount St. Helens (Evarts and Ashley, 1990a, b; in press a, b, c, d) has been correlated with similar deposits near Mount Rainier that represent the last two major advances of alpine glaciers in the Cascade Range (Crandell and Miller, 1974). Most glacial deposits in the Lakeview Peak quadrangle are considered correlative with the older deposits, the Hayden Creek Drift (Crandell and Miller, 1974), on the basis of similar weathering characteristics (Crandell, 1987). Hayden Creek till in this and adjacent quadrangles is overlain locally by biotite-bearing tephra of set C, erupted from Mount St. Helens during the Ape Canyon eruptive stage of Crandell (1987), approximately 40 ka. The till is present on gently sloping upland surfaces and the lower valley walls along the Kalama River and covers much of the gently south-dipping terrain of the Lewis River valley in the southern part of the quadrangle. These latter deposits include the Amboy drift of Mundorff (1984), which is considered correlative with the Hayden Creek drift by Crandell (1987). The distribution of till in the southern part of the quadrangle suggests a maximum elevation for the Lewis River glacier in this area of about 2200 feet, similar to that inferred by Mundorff (1984) and consistent with the preservation of weakly consolidated cinder beds near 3000 feet in the probable vent area for the basalt of Rock Creek. Some exposures of till in the Lewis River valley are much more deeply weathered than Hayden Creek Drift and apparently are remnants of a significantly older drift sheet, as has been observed in the lower Lewis valley by Crandell (1987).

Till in the southwestern part of the quadrangle contains clasts as much as 50 cm across of distinctive light-gray coarsely porphyritic hornblende-biotite dacite. The only known source for this lithology is the plug-dome of Goat Mountain in the Kalama River northeast of this quadrangle. Its presence in till here indicates that a lobe of the Kalama River glacier flowed southward across the drainage divide (probably at Merrill Lake in the Cougar quadrangle) and merged with the larger Lewis River glacier near Cougar.

The Kalama valley contains river terrace remnants that are probably outwash deposits of late Hayden Creek age. The terraces are composed of compact stratified gravels forming near-vertical cliffs as much as 45 m high along the north bank of the river. The clast population consists of Tertiary rocks and minor proportions of Quaternary volcanic rocks, but is devoid of Mount St. Helens lithologies, thus the deposits predate the volcano.

Deposits of the last major glaciation (Evans Creek Drift, formed during the Fraser glaciation) in the Washington Cascades (Crandell and Miller, 1974; Crandell, 1987) have not been recognized in the Lakeview Peak quadrangle. Minor till of this age may be present in and near the northeast-facing cirque below Lakeview Peak.

Pleistocene basalt and basaltic andesite

Light-gray, microporphyritic olivine basalt erupted during Pleistocene time from a vent in the south-central part of the quadrangle and flowed chiefly westward into Rock Creek. The vent area for the basalt of Rock Creek is indicated by roadcut exposures of south-dipping, reddish, oxidized cinder beds on hill 3217, about 3.3 km east of Rock Creek. A possible feeder dike trending N05W crops out on the north side of the hill.

Similar-looking flows are present at three localities southeast of the Kalama River and northeast of Wolf Creek. Basalt exposed along the eastern boundary of the quadrangle (basalt of Speelyai Creek) is the terminus of a flow erupted at about 800 ka from a vent about 2.7 km to the southeast in the adjacent Cougar quadrangle (Evarts and Ashley, 1990a). The other two areas of outcrop consist of the olivine-phyric basaltic andesite of Wolf Creek (table 1). Roadcut exposures of agglomerate in the western outcrop area suggest that a vent is located there. The eastern occurrence of basaltic andesite may represent a separate vent, but the rock is chemically identical to that near Wolf Creek and more likely is an erosional remnant of a flow or flows extruded from the same source.

Intense glaciation during late Pleistocene time has strongly modified all of the Quaternary volcanic edifices in the quadrangle. Much of the basalt of Rock Creek and the basalt of Speelyai Creek is covered by till (dominated by clasts of basalt) below about 2100 ft elevation. The two small patches of the basaltic andesite of Wolf Creek probably are remnants of a large flow, most of which was subsequently removed by the Kalama River glacier. The position of these remnants perched high above the valley floor suggests that the valley was filled with glacial ice at the time of eruption.

The chemistry of the Quaternary basalts and basaltic andesite differs substantially from that of underlying Tertiary mafic rocks, particularly in the much higher K_2O contents of the younger lavas (table 1; fig. 5). The basalt of Rock Creek is mildly alkalic, containing 1-2 percent nepheline in its CIPW norm. The primitive but diverse chemistry of the Quaternary lavas is characteristic of the southern Cascade Range (Leeman and others, 1990).

Tertiary Rocks

The Tertiary bedrock of the Lakeview Peak quadrangle is dominated by porphyritic basalt and lesser aphyric basalt flows (basalt of Kalama River) that are overlain by a more diverse group of volcanic and volcaniclastic rocks. The dominant structure in the quadrangle is the Lakeview Peak anticline (Phillips, 1987a), a broad, gently south-plunging fold which trends south-southeasterly across the center of the quadrangle. Rocks that overlie the basalt of Kalama River are found on both limbs of the anticline in the southern third and northeastern corner of the quadrangle. The Lakeview Peak quadrangle contains no intermediate to silicic phaneritic intrusive rocks such as those that are common in mapped areas to the east (Evarts and Ashley, 1990a). Fine-grained intrusive rocks emplaced at shallow levels, mostly basaltic andesite dikes, are widespread but sparse.

Basalt of Kalama River

The basalt of Kalama River underlies most of the northern half of the Lakeview Peak quadrangle as well as large areas to the east and north. (Evarts and Ashley, 1990a; R.C. Evarts, unpub. mapping). The unit has not been dated directly, but in the Cougar quadrangle it underlies volcaniclastic rocks with a K-Ar age of about 36 Ma and is therefore no younger than late Eocene. The base of the basalt of Kalama River is not exposed in the Lakeview Peak quadrangle, but to the north it abruptly but conformably overlies a sequence of interbedded mafic to intermediate lava flows, silicic tuffs, sedimentary rocks, and minor coal beds. The basalt of Kalama River contrasts sharply with the younger Tertiary rock units mapped to the east and northeast in the Mount St. Helens area in that it consists solely of basalt flows and lacks interbedded volcaniclastic beds. Black, strikingly plagioclase-phyric amygduloidal basalt constitutes approximately 75 percent of the unit. The remainder is composed of virtually aphyric but chemically similar basalt. Individual flows are typically 4 to 8 meters thick and sheetlike in form; many can be traced as low cliffs for distances exceeding 1 km with little variation in thickness. Typical flows exhibit massive, blocky-jointed interiors that grade up into highly vesiculated and commonly flow-brecciated tops. Beds of massive, indurated, brick-red hematitic siltstone, less than 1 m thick, are present between many flows. This siltstone appears to be a combination of fine-grained eolian sediment and lateritic soil that developed *in situ* on flow surfaces; no pumice, shards, or any other detritus indicative of active intermediate to silicic volcanism have been found. Palagonitic hyaloclastite and pillow breccia, some showing complicated contact relations with cryptocrystalline white clay (altered fine ash?), are exposed near the base of the unit in the valley of Elk Creek. The earliest lavas therefore erupted from or flowed into a shallow subaqueous environment, but the voluminous outpourings of basalt rapidly built up a broad subaerial shield volcano. The source of the basalt flows is unknown, as petrographically equivalent dikes have not been located. The sparse dikes scattered throughout the unit are more felsic in composition than the basalt of Kalama River, and probably fed some of the overlying basaltic andesite flows.

These basalts are petrographically and chemically unlike other known Tertiary mafic volcanic rocks in the southern Washington Cascade Range. They are mostly olivine-normative, low-potassium, high-alumina tholeiites (table 1; figs. 2, 3, 4, and 5) that closely resemble mid-ocean ridge basalt in their major and trace element geochemistry (Evarts, 1991). The abundant porphyritic flows contain conspicuous phenocrysts and glomerocrysts of blocky, weakly zoned plagioclase as large as 1 cm across accompanied by smaller phenocrysts of olivine. Augite phenocrysts are uncommon, and their modal abundance rarely exceeds 2 percent. A few flows in the area between Butler Butte and Bush Creek, however, contain 8 to 12 percent conspicuous black augite phenocrysts as large as 7 mm in diameter; these flows also carry small xenoliths of pyroxenite, gabbro, and troctolite. Groundmass textures are dominantly diktytaxitic-intergranular to subophitic. The abundant vesicles are invariably filled with secondary minerals, chiefly calcic zeolites and smectites. Aphyric lavas tend to be less vesicular and possess a finer-grained intergranular groundmass; many of them exhibit a pronounced flow-foliation.

In the northeastern corner of this quadrangle and in the Cougar quadrangle to the east, the top of the basalt of Kalama River is defined as the first appearance of intermediate lava flows or volcaniclastic sedimentary rocks derived from an intermediate to silicic volcanic source. In many locations this corresponds with the stratigraphically highest outcrop of basalt and the contact is therefore sharp, though conformable. In the southern part of the quadrangle, however, the upper contact is more difficult to locate precisely owing to extensive faulting and because in many locations the immediately overlying rocks are aphyric basaltic andesites that are indistinguishable in hand specimen from the aphyric flows of the basalt of Kalama River. The presence of volcaniclastic rocks and differences in chemical composition between the basalt of Kalama River and the overlying basaltic andesites (Table 1) were used jointly to define the contact in this area.

Other Tertiary volcanic and volcaniclastic rocks

The diverse strata overlying the basalt of Kalama River consist largely of volcaniclastic sedimentary and andesitic to dacitic pyroclastic rocks interstratified with lava flows of basalt and mafic andesite. On the southwestern limb of the Lakeview Peak anticline, sheetlike lava flows are intercalated with well-bedded volcaniclastic siltstone, sandstone, tuff, and minor conglomerate; these rocks probably were deposited low on the flanks of volcanoes or in intervent areas between major volcanic edifices. (Cas and Wright, 1987; Smith, in press). Rocks exposed on the northeast limb are similar but include thick lenticular bodies of very coarse-grained volcanic breccia, probably deposited in stream valleys by lahars, and a greater proportion of pumiceous lapilli tuff and other pyroclastic rocks.

Virtually all of the analyzed lava flows interbedded with the volcaniclastic strata that overlie the basalt of Kalama River in the Lakeview Peak quadrangle are basaltic andesite according to the IUGS classification (between 52 and 57 percent SiO_2) shown in Figure 2. Minor basalt also is present but the quadrangle is nearly devoid of more silicic rocks, which are common components of overlying strata to the east and north (Evarts and Ashley, 1990a, b; in press a, b, c, d). In general, the chemistry of these rocks is similar to that of Oligocene to early Miocene basaltic andesites in the Spirit Lake area to the northeast (Evarts and Ashley, in press a, b, c, d,). They straddle the tholeiitic versus calc-alkaline boundary on the classification diagrams of Irvine and Baragar (1971) and Miyashiro (1974) as shown in Figures 3 and 4, respectively, and tend to be lower in K_2O than Quaternary volcanic rocks of equivalent SiO_2 contents in southern Washington (fig. 5).

Structure

Strata in the Lakeview Peak quadrangle are deformed into a broad anticline, named the Lakeview Peak anticline by Phillips (1987a), the crest of which strikes north-northwesterly across the center of the quadrangle from Lakeview Peak to Butler Butte. The structure plunges to the southeast at approximately 10°; the limbs dip at low to moderate angles (generally less than 20°) to the east and south. According to Phillips (1987b), the Lakeview Peak anticline extends about 12 km to the southeast, where it is truncated by the Chelatchie Prairie fault zone.

A number of faults have been mapped within the quadrangle, mainly in its eastern half. Their orientations are diverse, but the most persistent structures strike northwest or northeast; all are relatively high-angle faults. Typically, these faults are marked by zones of brecciated and bleached, hydrothermally altered rock, and some of the inferred fault traces mapped are based primarily on the presence of semi-continuous outcrops of altered rock. Slickensides are rare, so the direction of movement for most of the faults is unknown. Displacement of stratigraphy in a few localities indicates vertical components of offset of as much as 25 m, but the amount and sense of horizontal movement cannot be determined in most places.

The age of faulting and folding are unknown. Intrusion of dikes along some faults shows that at least some of the faulting is Tertiary in age, but none of the dikes have been dated directly, so a more precise estimate is not possible. If the Lakeview Peak anticline was formed at the same time as folds elsewhere in the southern Washington Cascades, it is probably of Miocene age because folding to the northeast affects rocks as young as about 20 Ma (Evarts and others, 1987; Swanson, 1989).

Metamorphism and hydrothermal alteration

Tertiary rocks of the Lakeview Peak quadrangle have been subjected to zeolite-facies regional metamorphism, the general character of which is similar to that described from other areas in the southern Washington

Cascade Range (Fiske and others, 1963; Wise, 1970; Evarts and others, 1987). This metamorphism reflects burial beneath several kilometers of strata in the relatively high-heat-flow environment of an active volcanic arc. Neither the grade of metamorphism nor the extent of recrystallization increase with stratigraphic depth within the quadrangle. The oldest rocks, in the basalt of Kalama River, actually display a *lesser* degree of replacement of magmatic by secondary minerals than do stratigraphically higher Oligocene and early Miocene rocks to the northeast (Evarts and Ashley, in press a, b, c, d). The reasons for this are complex, but must relate in part to the virtual absence of intrusive bodies in the quadrangle compared to their widespread occurrence in strata to the east. The differences also suggest that the basalt of Kalama River was never buried as deeply as the aggregate thickness of younger volcanic rocks to the east might imply.

Metasomatic hydrothermal alteration is uncommon in the Lakeview Peak quadrangle, which is consistent with the lack of intrusive rocks. Zones of argillized rock, locally associated with silica veining, are found along faults, indicating that at least minor quantities of moderately heated water did move through the strata during or after faulting. The altered zones are composed entirely of poorly crystallized kaolinitic clay minerals with or without quartz and minor limonite; no relict sulfides have been detected in any of these zones.

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______in press c, Geologic map of the Spirit Lake West quadrangle, Cowlitz and Skamania Counties, Washington: U.S. Geological Survey Geologic Quadrangle Map GQ-1681, scale 1:24,000.

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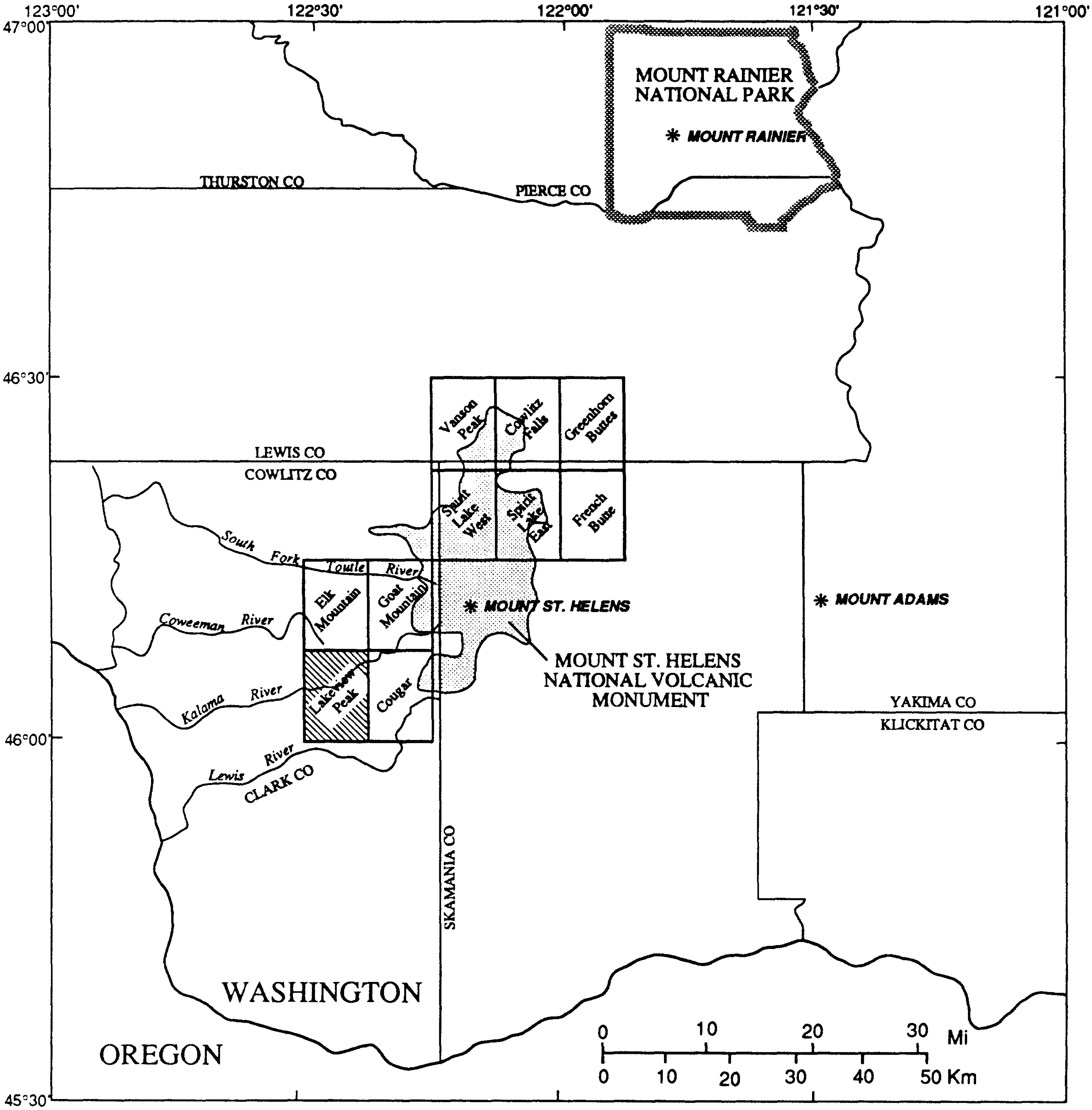

Figure 1.--Index map of southern Wasington showing location of Lakeview Peak quadrangle and other 7-1/2 minute quadrangles in which geologic mapping has been or is currently being conducted by the USGS.

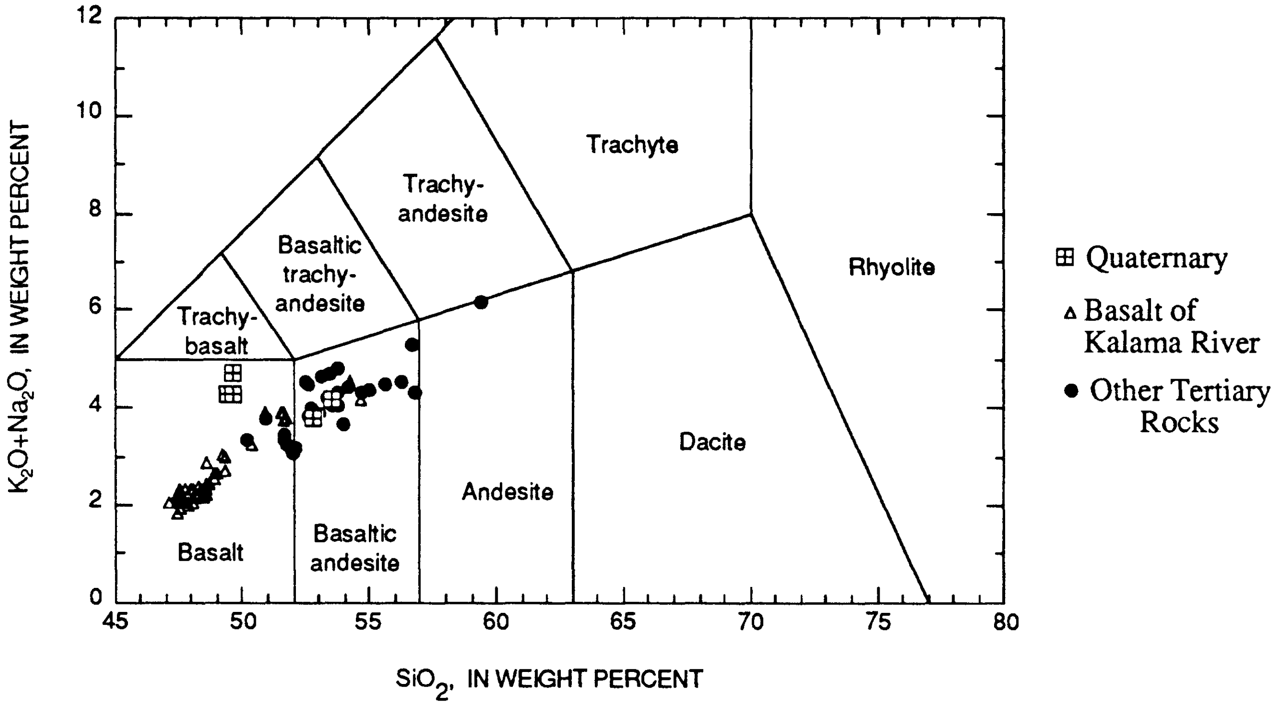

Figure 2.--K_2O+Na_2O versus SiO_2 (recalculated volatile-free) for Quaternary and Tertiary volcanic rocks from Lakeview Peak quadrangle showing classification according to I.U.G.S. (Le Bas and others, 1986).

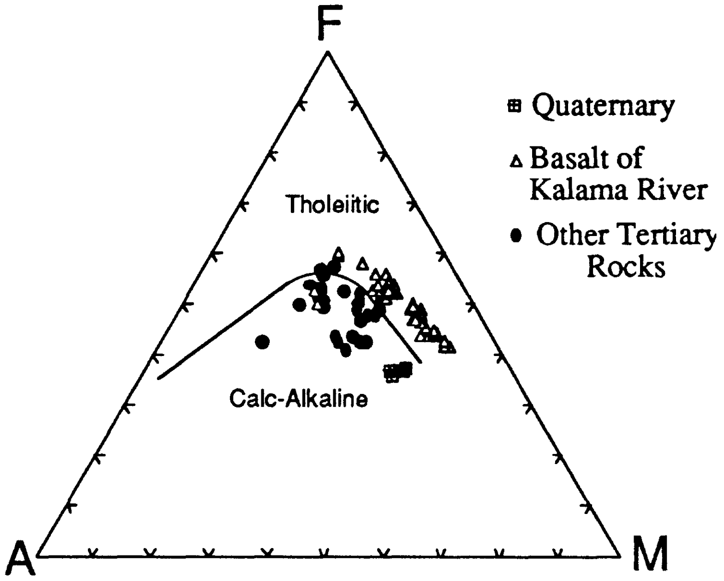

Figure 3.--AFM diagram for volcanic rocks from Lakeview Peak quadrangle. A, K_2O+Na_2O; F, FeO+Fe_2O_3+MnO; M, MgO. Line separating tholeiitic and calc-alkaline fields from Irvine and Baragar (1971).

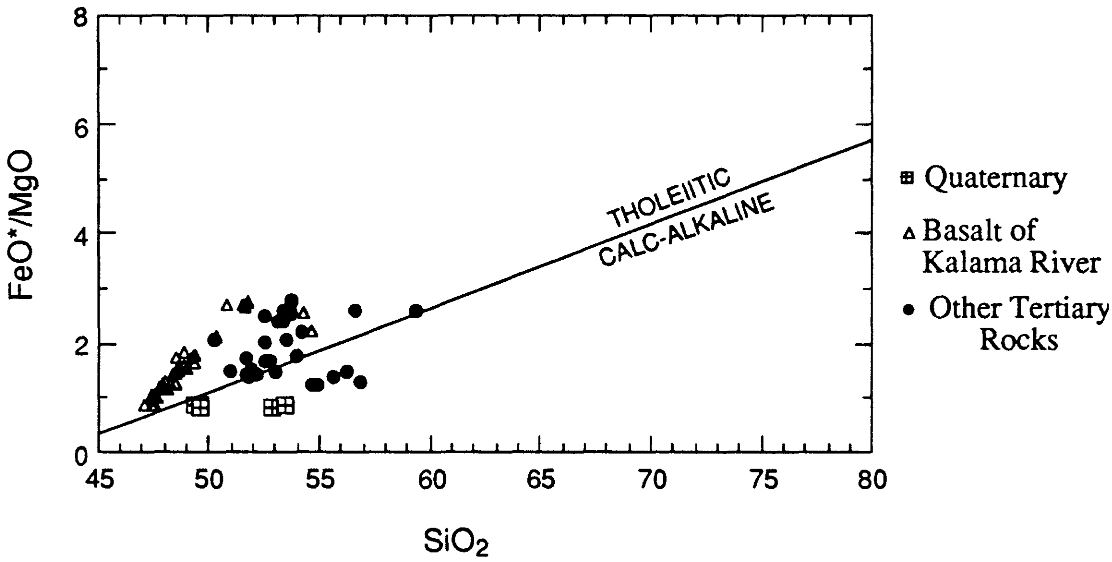

Figure 4.--FeO*/MgO versus SiO_2 (recalculated volatile-free) for volcanic rocks from Lakeview Peak quadrangle showing classification into tholeiitic and calc-alkaline rocks according to Miyashiro (1974). FeO*, total Fe as FeO.

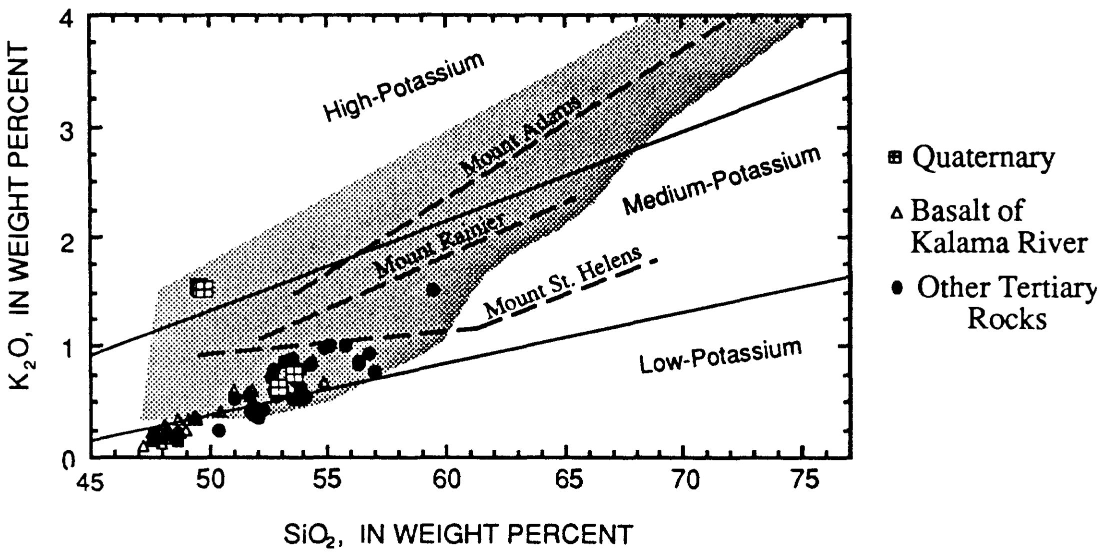

Figure 5.--K_2O versus SiO_2 (recalculated volatile-free) for volcanic rocks from Lakeview Peak quadrangle. Low-, medium-, and high-potassium fields from Gill (1981, p. 6). Shaded area encompasses compositions of Quaternary volcanic rocks, exclusive of major stratovolcanoes, of southern Washington Cascade Range from Hammond and Korosec (1983). Trendlines shown for Quaternary stratovolcanoes Mount Rainier, Mount St. Helens, and Mount Adams based on data in Condie and Swenson (1973), Hildreth and Fierstein (1985), and Smith and Leeman (1987).

Table 1.--*Chemical analyses of volcanic rocks, Lakeview Peak quadrangle*

[Oxides in weight percent. Rock type assigned in accordance with I.U.G.S. scheme of Streckeisen (1976) for plutonic rocks and I.U.G.S. system of Le Bas and others (1986) applied to analyses recalculated volatile-free for volcanic rocks. X-ray fluorescence analyses by methods described in Taggart and others, (1987); analysts, A.J. Bartel, D. Siems, K. Stewart, and J.E. Taggart; FeO, H_2O, and CO_2 determined using methods described by Jackson and others (1987); analysts, N. Elsheimer, L. Espos, K. Lewis, and S. Pribble.]

Map No.	1	2	3	4	5	6	7	8	9
Field sample No.	**87CG-V152A**	**89CG-V541**	**89CG-A185**	**88CG-V339**	**87CG-V249**	**89CG-V487**	**89CG-V475**	**89CG-A150**	**89CG-V476**
Latitude	46°02'59"	46°06'11"	46°06'33"	46°05'00"	46°04'18"	46°06'29"	46°07'12"	46°05'41"	46°07'11"
Longitude	122°23'53"	122°29'54"	122°29'33"	122°24'11"	122°24'25"	122°26'49"	122°29'53"	122°27'00"	122°29'25"
Map unit	Tbk	Tbk	Tbk	Tbk	Tbk	Tbk	Tbk	Tbk	Tbk
Rock type	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt
SiO_2	46.00	46.10	46.20	46.30	46.30	46.50	48.50	46.50	46.70
TiO_2	1.11	1.44	1.31	1.18	1.17	1.01	1.72	1.26	1.25
Al_2O_3	19.20	14.90	15.20	16.50	17.40	18.80	15.40	15.00	15.00
Fe_2O_3	3.06	2.91	2.57	3.18	2.39	1.70	3.65	3.14	2.70
FeO	5.20	7.38	7.41	6.23	6.64	6.44	7.25	6.81	7.21
MnO	0.13	0.16	0.16	0.15	0.14	0.13	0.18	0.16	0.16
MgO	6.21	10.50	11.50	9.50	8.83	7.87	6.45	11.10	10.90
CaO	13.10	11.50	11.50	12.70	12.20	13.10	12.10	11.90	12.00
Na_2O	1.83	1.98	1.90	1.61	1.82	1.92	2.57	1.88	1.87
K_2O	0.12	0.20	0.1	0.17	0.17	0.20	0.34	0.16	0.20
P_2O_5	0.12	0.15	0.15	0.11	0.13	0.12	0.19	0.12	0.12
H_2O^+	2.60	1.81	1.41	1.42	1.95	1.55	1.05	1.34	1.50
H_2O^-	1.59	1.42	0.81	0.76	1.03	0.69	1.09	0.94	0.52
CO_2	<0.01	0.07	0.12	0.12	<0.01	0.01	0.02	0.03	0.01
Total	100.27	100.52	100.34	99.93	100.17	100.04	100.51	100.34	100.14

Table 1.--*Chemical analyses of volcanic rocks, Lakeview Peak quadrangle,* continued

Map No.	10	11	12	13	14	15	16	17	18
Field sample No.	**89CG-A144**	**89CG-V489**	**89CG-A147**	**89CG-V467**	**88CG-V382**	**88CG-V378**	**89CG-V434**	**89CG-V459**	**89CG-V490**
Latitude	46°05'23"	46°06'27"	46°05'15"	46°07'05"	46°04'09"	46°03'42"	46°06'02"	46°05'52"	46°06'52"
Longitude	122°29'40"	122°27'27"	122°26'32"	122°26'29"	122°27'58"	122°26'20"	122°24'31"	122°26'40"	122°28'23"
Map unit	Tbk	Tbk	Tbk	Tbk	Tbk	Tbk	Tbk	Tbk	Tbk
Rock type	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt
SiO_2	46.70	46.70	46.80	46.80	46.80	46.80	46.80	46.90	46.90
TiO_2	1.24	1.25	1.22	1.26	1.16	1.02	1.41	1.24	1.20
Al_2O_3	16.30	15.00	16.90	16.80	17.60	19.40	15.90	16.70	17.50
Fe_2O_3	2.84	3.52	2.45	2.49	3.14	3.63	2.83	2.90	2.31
FeO	6.72	6.47	7.07	7.22	5.89	4.92	7.54	6.94	6.83
MnO	0.16	0.16	0.15	0.16	0.14	0.13	0.17	0.16	0.15
MgO	9.30	10.90	8.80	8.84	7.52	7.56	7.81	9.14	7.80
CaO	12.20	12.00	12.70	12.50	12.90	13.00	12.50	12.20	13.00
Na_2O	2.12	1.87	2.11	2.03	1.75	1.78	2.05	2.10	2.04
K_2O	0.17	0.20	0.20	0.23	0.25	0.15	0.22	0.16	0.25
P_2O_5	0.13	0.12	0.12	0.13	0.12	0.10	0.15	0.13	0.13
H_2O^+	1.60	1.38	1.55	1.46	2.25	1.72	1.73	1.03	1.50
H_2O^-	0.87	0.86	0.50	0.66	0.84	0.59	0.86	1.09	0.64
CO_2	0.02	0.03	0.02	0.01	0.07	0.09	0.03	0.03	0.03
Total	100.37	100.46	100.59	100.59	100.43	100.89	100.00	100.72	100.28

Table 1.--*Chemical analyses of volcanic rocks, Lakeview Peak quadrangle,* continued

Map No.	19	20	21	22	23	24	25	26	27
Field sample No.	**88CG-V443**	**88CG-V331**	**88CG-V345A**	**87CG-V247**	**88CG-V341C**	**87CG-V228B**	**88CG-V377**	**88CG-V336**	**88CG-V406**
Latitude	46°06'58"	46°03'10"	46°05'19"	46°05'24"	46°04'19"	46°05'30"	46°03'20"	46°04'34"	46°03'17"
Longitude	122°24'31"	122°29'40"	122°24'36"	122°23'22"	122°25'15"	122°22'33"	122°26'11"	122°24'52"	122°28'42"
Map unit	Tbk	Tbk	Tbk	Tbk	Tbk	Tbk	Tbk	Tbk	Tbk
Rock type	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt
SiO_2	47.00	47.10	47.10	47.20	47.20	47.30	47.30	47.30	47.30
TiO_2	1.20	1.54	1.20	1.44	1.37	1.78	1.46	1.41	1.39
Al_2O_3	17.50	17.20	17.80	15.90	17.60	14.70	16.40	16.50	17.30
Fe_2O_3	2.43	4.55	2.80	4.04	2.83	4.55	3.93	3.37	2.94
FeO	7.18	5.99	6.27	6.54	6.73	7.25	6.64	6.96	7.08
MnO	0.15	0.18	0.14	0.16	0.15	0.19	0.17	0.17	0.17
MgO	7.80	5.84	7.52	8.10	6.47	7.18	6.97	6.51	6.43
CaO	12.90	12.20	12.80	12.00	12.80	11.00	12.40	12.80	12.50
Na_2O	1.81	2.09	1.92	2.13	1.92	2.33	2.09	1.97	2.04
K_2O	0.17	0.15	0.20	0.18	0.18	0.23	0.20	0.19	0.24
P_2O_5	0.12	0.16	0.13	0.15	0.14	0.19	0.15	0.14	0.13
H_2O^+	1.92	1.26	2.38	1.39	1.91	1.55	1.99	2.33	2.25
H_2O^-	0.63	1.73	0.63	1.12	0.56	1.78	0.95	0.55	0.65
CO_2	0.01	0.13	0.11	<0.01	0.10	<0.01	0.09	0.14	0.06
Total	100.82	100.12	101.00	100.35	99.96	100.03	100.74	100.34	100.48

Table 1.--*Chemical analyses of volcanic rocks, Lakeview Peak quadrangle,* continued

Map No.	28	29	30	31	32	33	34	35	36
Field sample No.	**88CG-V294B**	**87CG-V229**	**88CG-V439**	**88CG-V444**	**88CG-V341B**	**88CG-V386A**	**89CG-A160**	**88CG-V349B**	**88CG-V350B**
Latitude	46°02'56"	46°05'33"	46°07'05"	46°06'36"	46°04'40"	46°03'34"	46°02'51"	46°04'21"	46°04'15"
Longitude	122°25'22"	122°23'30"	122°24'39"	122°24'05"	122°24'59"	122°26'49"	122°27'52"	122°25'27"	122°25'47"
Map unit	Tbk	Tbk	Tbk	Tbk	Tbk	Tbk	Tbk	Tbk	Tbk
Rock type	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt
SiO_2	47.40	47.40	47.50	47.50	47.60	47.60	47.60	48.00	48.00
TiO_2	1.26	1.54	1.36	1.34	1.55	1.21	1.48	1.49	1.60
Al_2O_3	16.50	16.50	16.40	17.90	15.60	18.30	16.40	17.00	17.50
Fe_2O_3	3.20	3.41	2.75	3.10	4.70	3.07	2.86	3.56	3.36
FeO	6.76	7.02	7.43	6.58	6.58	6.22	7.69	6.70	6.88
MnO	0.16	0.19	0.16	0.15	0.18	0.15	0.18	0.17	0.17
MgO	7.78	6.26	8.66	6.41	6.89	7.53	6.86	6.34	5.32
CaO	12.30	12.70	12.30	12.70	11.30	12.70	11.90	12.80	12.70
Na_2O	2.00	2.13	1.96	2.01	2.23	2.05	2.49	2.15	2.27
K_2O	0.18	0.22	0.17	0.21	0.34	0.28	0.32	0.23	0.25
P_2O_5	0.12	0.16	0.13	0.13	0.16	0.12	0.16	0.16	0.16
H_2O^+	1.74	2.12	1.68	2.02	2.21	1.25	1.75	1.85	1.91
H_2O^-	0.65	0.70	0.33	0.57	0.91	0.45	0.71	0.19	0.45
CO_2	0.14	0.04	0.04	0.04	0.13	0.08	0.01	0.09	0.09
Total	100.19	100.39	100.87	100.66	100.38	101.01	100.41	100.73	100.66

Table 1.--*Chemical analyses of volcanic rocks, Lakeview Peak quadrangle*, continued

Map No.	37	38	39	40	41	42	43	44	45
Field sample No.	**89CG-A162**	**89CG-V521**	**89CG-V477A**	**88CG-A132**	**89CG-V552A**	**88CG-V405**	**89CG-V537**	**87CG-V251**	**87CG-V147**
Latitude	46°05'37"	46°06'42"	46°07'29"	46°04'37"	46°00'30"	46°03'20"	46°00'26"	46°03'14"	46°04'04"
Longitude	122°29'13"	122°28'26"	122°29'15"	122°28'14"	122°25'49"	122°29'28"	122°22'51"	122°24'19"	122°24'07"
Map unit	Tbk	Tbk	Tbk	Tbk	Tba	Tbk	Tba	Tbk	Tbka
Rock type	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt
SiO_2	48.20	48.40	48.50	48.60	48.90	49.60	50.00	50.20	50.50
TiO_2	1.78	1.76	1.80	1.75	1.41	1.97	0.99	2.19	2.14
Al_2O_3	16.30	16.50	16.30	16.20	19.30	14.80	16.70	15.10	14.90
Fe_2O_3	3.89	3.84	4.58	4.40	5.01	5.73	5.11	5.12	4.23
FeO	6.77	6.72	6.23	6.49	3.76	6.91	4.50	8.09	8.62
MnO	0.18	0.17	0.17	0.18	0.14	0.21	0.14	0.23	0.22
MgO	5.84	5.90	5.84	6.32	3.98	5.73	6.21	4.68	4.60
CaO	11.70	11.80	11.70	11.70	11.40	10.20	10.70	8.93	8.75
Na_2O	2.61	2.62	2.60	2.33	3.01	2.78	3.19	3.29	3.25
K_2O	0.36	0.34	0.35	0.34	0.22	0.40	0.50	0.59	0.56
P_2O_5	0.22	0.21	0.21	0.20	0.22	0.22	0.13	0.27	0.27
H_2O^+	0.95	0.57	0.64	1.00	1.02	0.88	0.94	0.49	0.51
H_2O^-	1.30	1.13	1.31	1.03	1.86	1.42	1.06	1.04	1.18
CO_2	0.02	0.02	0.02	0.03	0.02	0.07	0.11	<0.01	<0.01
Total	100.12	99.98	100.25	100.57	100.25	100.92	100.28	100.22	99.73

Table 1.--*Chemical analyses of volcanic rocks, Lakeview Peak quadrangle,* continued

Map No.	46	47	48	49	50	51	52	53	54
Field sample No.	**89CG-V530**	**88CG-V367A**	**88CG-A129A**	**88CG-V409**	**87CG-V256**	**87CG-V250**	**88CG-V293**	**89CG-V538**	**89CG-V548**
Latitude	46°01'29"	46°02'54"	46°06'47"	46°02'00"	46°02'01"	46°03'05"	46°02'18"	46°00'15"	46°02'11"
Longitude	122°24'26"	122°26'22"	122°23'06"	122°27'08"	122°24'02"	122°24'37"	122°25'41"	122°24'30"	122°28'09"
Map unit	Tba	Tbk	Tbk	Tba	Tba	Tbk	Tba	Tba	Tba
Rock type	Basalt	Basalt	Basalt	Basaltic Andesite	Basalt	Basalt	Basaltic Andesite	Basaltic Andesite	Basaltic Andesite
SiO_2	50.80	51.10	51.20	51.30	51.30	51.40	51.40	51.50	51.50
TiO_2	1.24	2.20	2.19	1.11	1.10	2.15	1.14	1.07	1.00
Al_2O_3	17.30	14.90	14.80	16.00	17.40	15.10	16.40	16.60	16.70
Fe_2O_3	5.11	5.56	5.15	4.23	4.45	4.61	4.16	4.37	3.63
FeO	4.33	7.60	7.97	5.65	4.46	8.37	5.12	4.37	5.46
MnO	0.15	0.22	0.25	0.18	0.15	0.22	0.15	0.17	0.16
MgO	5.12	4.63	4.59	6.16	5.87	4.69	6.09	5.67	6.23
CaO	10.70	8.85	8.78	10.90	11.00	8.89	10.80	9.44	11.40
Na_2O	2.99	3.16	3.16	2.66	2.86	3.32	2.71	3.19	2.85
K_2O	0.39	0.55	0.59	0.35	0.45	0.58	0.42	0.60	0.38
P_2O_5	0.18	0.27	0.28	0.16	0.17	0.27	0.20	0.20	0.16
H_2O^+	0.56	0.63	0.63	0.57	0.40	0.31	0.59	1.07	0.32
H_2O^-	1.17	1.02	0.71	1.19	0.68	0.42	0.86	1.78	0.56
CO_2	0.02	0.08	0.02	0.05	<0.01	<0.01	0.13	0.05	0.02
Total	100.06	100.77	100.32	100.51	100.29	100.33	100.17	100.08	100.37

Table 1.--*Chemical analyses of volcanic rocks, Lakeview Peak quadrangle,* continued

Map No.	55	56	57	58	59	60	61	62	63
Field sample No.	**88CG-V333B**	**89CG-V532**	**89CG-V510B**	**89CG-V505**	**89CG-V502B**	**88CG-V313B**	**87CG-V253B**	**87CG-V254**	**88CG-V328**
Latitude	46°02'01"	46°00'05"	46°00'55"	46°01'52"	46°00'22"	46°01'22"	46°01'32"	46°01'50"	46°01'52"
Longitude	122°29'36"	122°23'51"	122°28'31"	122°29'16"	122°28'43"	122°26'14"	122°24'36"	122°25'40"	122°26'20"
Map unit	Tbig	Tba	Tba	Tbig	Tba	Tiba	Tba	Tba	Tba
Rock type	Basaltic	Basaltic Andesite	Basaltic Andesite	Basaltic Andesite	Basaltic Andesite	Basaltic Andesite	Basaltic Andesite	Basaltic andesite	Basaltic andesite
SiO_2	51.70	51.70	51.90	52.00	52.20	52.60	52.70	52.80	52.80
TiO_2	1.84	1.78	1.56	1.58	1.94	1.89	1.57	1.59	2.16
Al_2O_3	16.00	17.10	18.20	16.50	16.50	16.20	15.60	15.00	15.30
Fe_2O_3	5.96	4.24	4.46	4.12	4.59	3.46	6.44	4.59	3.43
FeO	3.91	5.55	4.20	5.39	5.41	6.88	4.02	7.22	7.54
MnO	0.13	0.17	0.12	0.15	0.19	0.17	0.16	0.18	0.18
MgO	5.62	3.75	4.05	5.52	3.95	3.83	4.82	4.43	3.82
CaO	8.87	9.26	9.50	8.98	8.59	9.03	8.86	8.16	8.38
Na_2O	3.20	3.77	3.65	3.42	3.75	3.62	3.32	3.38	3.73
K_2O	0.58	0.71	0.76	0.53	0.84	0.51	0.68	0.60	0.51
P_2O_5	0.49	0.34	0.27	0.43	0.34	0.35	0.24	0.23	0.33
H_2O^+	0.77	0.65	0.40	0.42	0.44	0.97	0.82	0.62	1.26
H_2O^-	1.38	0.78	0.88	0.82	0.99	0.72	1.07	1.34	0.70
CO_2	0.16	<0.01	0.02	0.03	0.01	0.12	<0.01	<0.01	0.09
Total	100.61	99.80	99.97	99.89	99.74	100.35	100.30	100.14	100.23

Table 1.--*Chemical analyses of volcanic rocks, Lakeview Peak quadrangle,* continued

Map No.	64	65	66	67	68	69	70	71	72
Field sample No.	**89CG-V516**	**88CG-V329B**	**89CG-V552B**	**89CG-A188**	**88CG-V334A**	**89CG-A189**	**89CG-V512A**	**89CG-V506**	**89CG-V512D**
Latitude	46°00'01"	46°02'31"	46°00'26"	46°05'18"	46°01'56"	46°05'50"	46°01'30"	46°01'24"	46°01'20"
Longitude	122°27'54"	122°27'06"	122°25'49"	122°29'59"	122°29'53"	122°29'56"	122°29'32"	122°28'57"	122°29'31"
Map unit	Tba	Tba	Tba	Tbk	Tba	Tbk	Tbig	Tbig	Tbig
Rock type	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite
SiO_2	52.80	52.90	53.00	53.20	53.40	53.50	53.60	53.80	54.80
TiO_2	1.92	1.29	1.94	1.61	1.59	1.19	1.27	1.24	1.25
Al_2O_3	16.70	15.20	15.80	17.00	17.20	18.40	14.60	14.60	14.80
Fe_2O_3	4.86	4.64	3.95	4.64	4.34	3.91	3.03	3.76	3.20
FeO	4.99	5.37	6.53	4.92	4.59	4.01	5.47	4.79	5.22
MnO	0.18	0.17	0.18	0.17	0.15	0.12	0.15	0.13	0.15
MgO	3.87	5.36	3.65	3.57	3.83	3.40	6.72	6.52	5.95
CaO	8.52	9.20	8.34	8.21	8.79	9.05	8.64	8.47	8.42
Na_2O	3.76	3.05	3.99	3.63	3.58	3.42	3.29	3.32	3.43
K_2O	0.87	0.53	0.76	0.85	0.81	0.66	0.96	0.97	0.98
P_2O_5	0.34	0.21	0.39	0.25	0.29	0.20	0.26	0.25	0.26
H_2O^+	0.28	0.69	0.60	0.63	0.67	0.77	0.50	0.59	0.57
H_2O^-	0.71	1.36	0.90	1.15	0.83	1.15	1.31	1.46	1.07
CO_2	0.02	0.14	0.01	0.01	0.09	0.20	0.04	0.02	0.01
Total	99.82	100.11	100.04	99.84	100.16	99.98	99.84	99.92	100.11

Table 1.--*Chemical analyses of volcanic rocks, Lakeview Peak quadrangle*, continued

Map No.	73	74	75	76	77	78	79	80	81	82
Field sample No.	**89CG-V517A**	**88CG-V415**	**88CG-V313A**	**88CG-V332**	**89CG-V512B**	**88CG-V312**	**87CG-V253A**	**89CG-V551C**	**88CG-V348**	**88CG-A114**
Latitude	46°00'38"	46°01'00"	46°01'21"	46°02'12"	46°01'25"	46°01'03"	46°01'31"	46°00'24"	46°03'48"	46°05'04"
Longitude	122°28'53"	122°27'39"	122°26'15"	122°29'53"	122°29'49"	122°26'28"	122°24'33"	122°26'49"	122°25'50"	122°24'50"
Map unit	Tba	Tiba	Tba	Tba	Ta	Qbr	Qbr	Qbr	Qbaw	Qbaw
Rock type	Basaltic andesite	Basaltic andesite	Basaltic andesite	Andesite	Andesite	Basalt	Basalt	Basalt	Basaltic andesite	Basaltic andesite
SiO_2	55.00	55.30	55.40	56.00	58.40	49.10	49.30	49.40	52.30	53.00
TiO_2	2.00	1.10	1.11	0.99	1.41	1.14	1.14	1.06	0.91	0.99
Al_2O_3	16.00	17.00	17.00	17.10	16.80	15.40	15.60	15.50	16.00	16.40
Fe_2O_3	4.38	3.85	4.17	3.31	2.92	3.82	3.46	3.18	2.69	2.48
FeO	4.55	3.66	3.46	3.59	3.94	4.74	5.08	5.12	5.22	5.17
MnO	0.19	0.12	0.11	0.09	0.13	0.14	0.14	0.14	0.13	0.12
MgO	3.31	4.85	4.87	5.06	2.56	9.60	9.42	9.67	9.06	8.42
CaO	6.16	7.81	7.69	7.93	5.67	10.80	10.60	10.40	8.72	8.13
Na_2O	4.25	3.64	3.62	3.53	4.59	2.73	2.79	3.20	3.17	3.40
K_2O	0.89	0.81	0.83	0.74	1.48	1.52	1.48	1.48	0.61	0.73
P_2O_5	0.35	0.22	0.22	0.18	0.45	0.37	0.37	0.36	0.19	0.21
H_2O^+	0.72	0.62	0.76	0.71	0.33	0.49	0.32	0.17	0.82	0.81
H_2O^-	1.66	0.90	0.91	0.71	0.78	0.21	0.26	0.08	0.11	0.39
CO_2	0.02	0.07	0.09	0.19	0.01	0.13	<0.01	0.05	0.11	0.03
Total	99.48	99.95	100.24	100.13	99.47	100.19	99.96	99.81	100.04	100.28

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Alluvial and Mass Wastage Deposits

Qa **Alluvium (Holocene)**--Unconsolidated, poorly to moderately sorted deposits of silt, sand, and gravel in valleys of active streams, chiefly the Kalama River and its tributaries

Qt **Talus (Holocene)**--Unsorted accumulations of loose, angular blocks of rock forming steep unvegetated to brushy slopes beneath cliffs; largest talus deposits are those along lower cirque headwall north and east of Lakeview Peak

Qls **Landslide deposits (Holocene and Pleistocene)**--Diamicton of unsorted, angular, mixed bedrock and surficial material transported down-slope *en masse*. Includes more-or-less coherent slumps and internally disrupted rockslide, earthflow, and debris-avalanche deposits. Most slides head at theatre-shaped scars and exhibit subhorizontal tops, bulbous toes, and hummocky, poorly-drained surfaces. Landslides in western part of quadrangle commonly developed on south-facing dip slopes owing to failure along clayey interflow paleosols

Qoa **Older alluvium (Pleistocene)**--Unconsolidated, poorly to moderately sorted deposits of silt, sand, and gravel in abandoned southwest-trending stream valley east of North Fork Kalama River and in and near Brooks Creek in southeastern part of quadrangle. Deposited by streams flowing along north margins of Kalama River and Lewis River glaciers during Hayden Creek time

Glacial Deposits

Hayden Creek Drift (Pleistocene)--Divided into:

Qht **Till deposits**--Unsorted, unstratified diamicton composed of angular to rounded clasts up to boulder size in compact matrix of sand, silt, and clay; locally includes glaciofluvial sand and gravel deposits, postglacial colluvium (especially along lower slopes of Kalama

River valley), probable loess, and areas of modern alluvium too small to map separately; deposits near the confluence of the Kalama River and North Fork Kalama River locally include as much as 3 m or more of variably oxidized and weathered Mount St. Helens ash. Forms discontinuous blanket on areas of low relief, mainly south of the Kalama River, but shown only where thick and extensive enough to obscure bedrock. Overlain by biotite-bearing tephra of set C of Mullineaux (1986) erupted from Mount St. Helens during the Ape Canyon eruptive stage approximately 40 ka (Crandell, 1987). Till typically is intensely weathered to depth of 1 m, oxidized to depth of 1 to 2 m or more, and contains clasts of Tertiary volcanic rock in the upper part of the weathering profile that exhibit weathering rinds 1 to 2 mm thick. Till deposited by Lewis River glacier in southern part of quadrangle (Mundorff, 1984) is locally dominated by clasts of Quaternary basalt; minor but conspicuous clasts of coarsely porphyritic biotite-hornblende dacite identical to the dacite of Goat Mountain (Evarts and Ashley, 1990b) are present in several till exposures near Indian George Creek. Correlated with the Hayden Creek Drift of the Mount Rainier region, which possesses similar weathering characteristics (Crandell and Miller, 1974; Colman and Pierce, 1981); some areas mapped as Hayden Creek till deposits, especially in Lewis River basin, may locally include older till. Age of the Hayden Creek Drift is controversial; it may be as young as about 60 ka (Crandell and Miller, 1974; Crandell, 1987) or greater than 300 ka (Dethier, 1988); 140 ka is preferred age of Colman and Pierce (1981) based on weathering-rind thicknesses

Qho **Outwash deposits**--Compact, crudely stratified, clast-supported gravel deposits forming terrace remnants along north side of Kalama River valley west of Kalama Falls; forms well-indurated, near-vertical exposures as much as 45 m high along banks of Kalama River. Consist of subangular to well-rounded pebbles, cobbles, and boulders, as large as 2 m across, of Tertiary volcanic and volcaniclastic rocks in a sandy matrix; locally includes clasts of light-gray microporphyritic Quaternary basalt and biotite-hornblende dacite identical to that which constitutes the plug-dome at Goat Mountain, 7 km northeast of quadrangle (Evarts and Ashley, 1990b), but lacks clasts of typical Mount St. Helens lithologies

VOLCANIC AND SEDIMENTARY ROCKS

Deposits of Mount St. Helens Volcano

Qspc **Deposits of Mount St. Helens volcano older than Castle Creek eruptive period, undivided (Holocene and Pleistocene)--** Unconsolidated laharic and alluvial deposits forming low terrace remnants in the Kalama River valley; relations upvalley in adjacent Cougar quadrangle (Evarts and Ashley, 1990a) indicate that these deposits are older than the basalt of Kalama Falls, which was erupted during the Castle Creek eruptive period of Crandell (1987); virtually all clasts are dacites like those erupted during the early history of the volcano, and clasts of typical Castle Creek-age andesite and basalt are absent, suggesting these deposits are older than the Castle Creek eruptive period. Exposures downvalley described by Crandell (1987) include products of the Castle Creek and Pine Creek eruptive periods of the Spirit Lake eruptive stage and possibly deposits as old as the Swift Creek eruptive stage

Basalt and basaltic andesite

Qbs **Basalt of Speelyai Creek (Pleistocene)**--Light- to medium-gray microporphyritic to seriate olivine basalt; in this quadrangle, exposed only beneath till (Qht) on west-facing slope about 1.8 km east of confluence of Kalama and North Fork Kalama Rivers, but underlies an extensive area in the adjacent Cougar quadrangle (Evarts and Ashley, 1990a). Consists of 5-10 percent olivine phenocrysts 1 mm across, accompanied in some samples by microphenocrysts of plagioclase and augite, in an intergranular groundmass of plagioclase, pyroxene, and Fe-Ti oxide. A whole-rock K-Ar age of 779±32 ka was obtained from a sample collected near the inferred vent in the Cougar quadrangle (Evarts and Ashley, 1990a)

Qbr **Basalt of Rock Creek (Pleistocene)**--Light-gray microporphyritic to seriate basalt underlying area east of Rock Creek. Contains microphenocrysts and rare phenocrysts of olivine (5 percent; generally <1 mm across but a few as large as 2 mm across; with tiny inclusions of chromian spinel) and augite (5 percent; < 1 mm long; strongly zoned and commonly displaying pronounced sector zoning) in an intergranular groundmass of plagioclase, augite, Fe-Ti oxide, and minor but ubiquitous interstitial brown biotite and apatite. Roadcut exposures of stratified agglomerate (scoria beds) on hill 3217 about 3 km east of Rock Creek probably mark vent for flows which moved predominantly westward into Rock Creek drainage. Below about 2100 ft, basalt is largely mantled by till (Qht) composed almost exclusively of clasts derived from the underlying basalt

Qbaw **Basaltic andesite of Wolf Creek (Pleistocene)**--Light-gray, microvesicular, porphyritic basaltic andesite underlying two small areas northeast of Wolf Creek. Presence of red oxidized agglomerate containing sparse angular fragments of Tertiary basalt in outcrops nearest to Wolf Creek suggest that basalt erupted explosively from vent located there. Consists of pale green olivine phenocrysts (4-8 percent; 1-2 mm across; contain abundant inclusions of minute chromian spinel octahedra) and augite microphenocrysts in an intergranular groundmass of plagioclase, augite, and Fe-Ti oxide. Locally overlain by till (Qht)

Tba **Basaltic andesite (Oligocene)**--Flows and flow-breccia of porphyritic to aphyric basaltic andesite and minor basalt. Porphyritic varieties typically contain phenocrysts of plagioclase (as much as 35 percent; 1 to 4 mm long; locally as long as 7 mm; containing abundant minute inclusions of altered glass), olivine (as much as 5 percent; as large as 3 mm across; commonly partly resorbed and rimmed by fine-grained granular pyroxene±magnetite; contains minute chromite inclusions in some samples; generally pseudomorphed by smectite and (or) quartz or by calcite), and, in most flows, augite (0-6 percent; 0.5 to 3 mm across; locally as large as 5 mm across) and Fe-Ti oxide (<1 percent; <0.5 mm across) in an intergranular groundmass of the same minerals plus interstitial glass (largely altered to smectite±quartz); phenocrysts or microphenocrysts of hypersthene (0-3 percent; 0.5 to 2 mm long) present in some basaltic andesite flows . Aphyric varieties commonly exhibit pronounced flow-foliation. Slight to moderate alteration, especially in flow-breccia zones, to zeolite-facies assemblages including albite, laumontite, stilbite, smectites, quartz, prehnite, titanite, hematite, and, rarely, calcite, epistilbite, heulandite, mesolite, pumpellyite

Tvs **Volcaniclastic sedimentary rocks (Oligocene)**--Diverse assemblage of continental volcaniclastic rocks of inferred epiclastic origin. Consists of generally well-bedded, well- to poorly sorted siltstone, sandstone, conglomerate, and breccia, all composed of volcanic debris. Locally includes thin beds of pumiceous pyroclastic rocks and lava flows too small or poorly exposed to map. Typically light green to olive green or greenish gray but also white, tan, brown, or maroon. Virtually all lithic clasts are volcanic rocks petrographically identical to interbedded mafic to intermediate flows; minor components include pumice, felsite, plagioclase, olivine, and pyroxene crystals, vitric ash, fine-grained plutonic rocks (most commonly dioritic), and plant remains. Interpreted as predominantly fluvial and lacustrine deposits deposited in low-lying intervolcano areas. Intense low-grade alteration to zeolites, smectite, kaolinite, carbonate, quartz, leucoxene, and hematite is typical; prehnite, pumpellyite present in a few samples; laumontite and heulandite or clinoptilolite are common cements. In northeast corner of quadrangle, includes:

Tvbc **Volcanic breccia and conglomerate facies**--Massive, very poorly sorted, clast-supported to matrix-supported, polylithologic diamictite forming lenticular bed as much as 100 m thick exposed in south-facing cliff. Composed of angular to subangular clasts of volcanic rock as much as 3 m across; clasts vary in composition but the largest are slabby aphyric basaltic andesite similar to flows exposed immediately north of unit in Elk Mountain quadrangle (R.C. Evarts, unpub. map)

Ta **Andesite (Oligocene)**--Scarce flows and flow-breccia of gray, porphyritic, hypersthene-augite andesite and aphyric microvesicular andesite; restricted to Indian George and Rock Creeks in southwestern part of quadrangle; alteration similar in mineralogy and intensity to that described for basaltic andesite

Tbig **Basaltic andesite of Indian George Creek (Oligocene)**--Light- to medium-gray to brownish gray, porphyritic to seriate, basalt and mafic basaltic andesite flows underlying headwaters area of Indian George Creek in southwestern part of quadrangle; generally highly weathered and fractured. Contain phenocrysts of olivine (2-5 percent; 0.5 to 2 mm across; some containing inclusions of chromian spinel) with or without plagioclase (2-3 percent; 1 to 3 mm) and augite (4-5 percent; 0.5 to 2 mm) in an intergranular to trachytic groundmass of plagioclase, augite, Fe-Ti oxide, and minor local interstitial glass (altered to smectite). In most outcrops, olivine, which is totally altered to orange smectite, stands out prominently from its gray matrix. Several samples contain embayed xenocrysts of quartz surrounded by granular reaction rims of clinopyroxene. Unit locally includes beds of brick-red, zeolitized, olivine-bearing agglomerate (scoria deposits)

Tbk **Basalt of Kalama River (Eocene)**--Sequence of black, blocky-jointed, strikingly plagioclase-phyric basalt flows and lesser slabby, virtually aphyric, basalt flows underlying northern two-thirds of quadrangle. Porphyritic flows make up 70 to 80 percent of unit and consist of 10-35 percent plagioclase phenocrysts and glomerocrysts typically 3 to 10 mm across, and 0-6 percent olivine phenocrysts 1 to 3 mm (rarely 5 mm) across in an intergranular to subophitic to ophitic, diktytaxitic groundmass of plagioclase, olivine, augite, and Fe-Ti oxide; some samples contain <2 percent equant augite phenocrysts or microphenocrysts, and a few of these are basaltic andesites (Table 1). Aphyric to sparsely phyric lavas (0-5 percent plagioclase, olivine, ± augite phenocrysts) display intergranular to subophitic textures similar to those of groundmasses of porphyritic flows, but commonly show strong flow-alignment of plagioclase. A few flows in the area between Butler Butte and Bush Creek contain 8-12 percent conspicuous black augite phenocrysts as large as 7 mm across, commonly accompanied by small pyroxenite, troctolite, and gabbro inclusions. Flows range between 3 and 25 m thick; most are 5 to 8 m thick; tops and bottoms of flows composed of highly vesiculated and zeolitized flow-breccia; vesicles, rendered conspicuous by fillings of ubiquitous white zeolites, are much less abundant in flow centers but persist throughout. Negligible interbedded volcaniclastic material except for local brick-red hematitic siltstone beds less than 1 m thick. Some plagioclase phenocrysts partly replaced by smectites, albite, laumontite, stilbite, and calcite; olivine partly to completely replaced by smectite; smectite, prehnite, pumpellyite, calcite, analcime, and a variety of calcic zeolites including scolecite, stilbite, mesolite, thompsonite, natrolite, levyne, and heulandite fill vesicles and numerous interstitial voids; in general, however, basalts of this unit are noticeably fresher than overlying rocks to the east and south. Thicker and more traceable aphyric lavas shown separately as $\mathbf{Tbk_a}$

INTRUSIVE ROCKS

Tia **Intrusive andesite (Oligocene or Eocene)**--Sill of dark-gray, aphanitic, amygduloidal, zeolitized andesite intruding basalt of Kalama River (Tbk) in upper Wolf Creek drainage. Composed of plagioclase, augite, hypersthene, Fe-Ti oxide, and interstitial zeolites and smectite; intergranular texture; pyroxenes and oxide relatively fresh but plagioclase much altered to zeolites, chiefly stilbite; stilbite also fills vesicles

Tiba **Intrusive basaltic andesite (Oligocene or Eocene)**--Plug of dark-gray, massive, seriate, pyroxene basaltic andesite in Rock Creek and scarce, widely scattered dikes of gray to greenish gray, aphyric to sparsely phyric, commonly amygduloidal, basaltic andesite intruding basalt of Kalama River (Tbk), chiefly south of Kalama River and west of Wolf Creek. Petrographically similar to and possibly feeders for basaltic andesite flows (Tba) in south part of quadrangle, but commonly coarser-grained and more highly altered to assemblages dominated by albite, smectite, and zeolites

Contact--Dashed where approximately located; short-dashed where inferred; dotted where concealed

Fault--Dashed where inferred; dotted where concealed. Ball and bar on downthrown side. Arrows show relative horizontal movement

Crestline of Lakeview Peak Anticline--Approximately located; dotted where concealed; showing direction of plunge

Strike and dip of beds:

27 Inclined

Horizontal

16 Strike and dip of compaction foliation in pumiceous lapilli tuff

32 Strike and dip of platy parting in lava flows

15 Sample locality for chemical analysis--See table 1

CORRELATION OF MAP UNITS