MAP GQ-1680

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

GEOLOGIC MAP OF THE VANSON PEAK QUADRANGLE, LEWIS, COWLITZ, AND SKAMANIA COUNTIES, WASHINGTON

By Russell C. Evarts and Roger P. Ashley

EVARTS AND ASHLEY—GEOLOGIC MAP, VANSON PEAK, LEWIS, COWLITZ, AND SKAMANIA COUNTIES, WASHINGTON 1:24,000 MAP GQ-1680

GEOLOGIC QUADRANGLE MAP
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INTRODUCTION

The Vanson Peak quadrangle is situated on the western slope of the Cascade Range in southern Washington approximately 25 km north of Mount St. Helens. Bedrock consists of Oligocene volcanic and volcaniclastic rocks and Oligocene to early Miocene shallow-level plutonic rocks forming the core of the Tertiary Cascade volcanic arc. Surficial deposits include drift representing at least two episodes of alpine glaciation and, in the southern part of the quadrangle, tephra erupted from Mount St. Helens during the past 40,000 years (Mullineaux and Crandell, 1981; Mullineaux, 1986). Bedrock exposures are generally limited owing to the extensive and heavily vegetated surficial cover, but stratigraphic sections are commonly well exposed in stream beds.

The southernmost part of the quadrangle lies within the area devastated by the May 18, 1980 eruption of Mount St. Helens (Lipman and Mullineaux, 1981). A laterally directed pyroclastic-blast-surge leveled old-growth forest in this area and buried it under a stratigraphically complex blanket, as thick as 1 m, of ash, lapilli, and blocks (Hoblitt and others, 1981; Waitt, 1981; Moore and Sisson, 1981). However, much of this cover has been stripped by subsequent rapid erosion of the deforested slopes.

ACKNOWLEDGMENTS

Champion International Corporation and Weyerhaeuser Corporation freely allowed access to their timberlands in the northern and western parts of the quadrangle. We were ably assisted in the field during the early stages of mapping by Walt Avramenko, Rick Bishop, Mike Covey, Matt Evarts, Jerry Infeld, Mike Lukk, Scott Petersen, and Carolyn Peterson. Proficient laboratory support was provided by Joe Ash, Mary Caress, Mike Covey, Jerry Infeld, Rick Pietropaoli, Scott Petersen, Carolyn Peterson, and especially Rick Bishop. LedaBeth Gray, Brent D. Turrin, and James G. Smith provided the K-Ar and $^{40}Ar/^{39}Ar$ ages. We have also benefitted from logistical support provided by Bobbie Myers and the staff of the David A. Johnston Cascades Volcano Observatory. Discussions with Donald A. Swanson, Paul E. Hammond, James G. Smith, William M. Phillips, Michael A. Korosec, Virgil A. Frizzell, Donal R. Mullineaux, and William E. Scott during the course of this work contributed much to our understanding of the regional geology.

SUMMARY OF GEOLOGY

The strata exposed in the Vanson Peak quadrangle are part of a thick section of middle Tertiary subaerial volcanic rocks that underlies the Mount St. Helens area (Evarts and others, 1987). This section strikes approximately north-south and dips eastward at low to moderate angles, forming the gentle western limb of a major regional syncline whose axis lies about 15 km to the east (Walsh and others, 1987; Swanson, 1989). The strata are lithologically heterogeneous and stratigraphically complex. Distinctive marker units are absent, and, although unconformities have been recognized, their regional significance is unknown; therefore, construction of a formal stratigraphic framework was not attempted, and only lithologic or local informal units are shown on this map.

The most valuable data for regional correlation are the isotopic age determinations (table 1). Data from this and adjacent areas (Phillips and others, 1986; Evarts and others,in press) indicate that most of the volcanic rocks in the Vanson Peak quadrangle erupted during Oligocene time. Multiple age determinations indicate that the strata in the western part of the quadrangle that underlie the basalt of Goat Creek (Tgc) were deposited between 33 Ma and 27 Ma (Evarts and others, in press). The basalt of Goat Creek is approximately 25 Ma based on K-Ar and $^{40}Ar/^{39}Ar$ determinations from outcrops north of the Cowlitz River (table 1). $^{40}Ar/^{39}Ar$ analyses from the adjacent Cowlitz Falls quadrangle (Evarts and Ashley, 1993a) indicate that the age of the flat-lying section east of Goat Creek is about 24 Ma to 23 Ma, and thus extends into earliest Miocene time.

Many of the rocks of the quadrangle appear to represent near-source depositional environments characterized by abundant lava flows, pumiceous pyroclastic rocks, coarse-grained epiclastic deposits, fine-grained subvolcanic intrusions, and zones of hydrothermal alteration (Cas and Wright, 1987; Smith, in press). Remnants of a large Oligocene mafic volcano are preserved as the basalt of Goat Creek. The eroded center of this volcano is exposed in Goat Creek, where mafic flows, flow-breccia, and agglomerate (volcanic bomb) beds cut by abundant basaltic feeder dikes, gabbro plugs, and associated zones of hydrothermal alteration. The hills north of the Cowlitz River consist of thick sections of basaltic flows that formed the original flanks of the volcano. In the valley of Goat Creek, hydrothermally altered and dike-ridden rock of the volcanic core is unconformably overlain by flat-lying unaltered strata free of dikes, suggesting deep erosion of the edifice prior to deposition of the overlying strata. However, analytically indistinguishable radiometric ages of 25 Ma from the basalt of Goat Creek and an overlying andesite flow indicate that this unconformity developed during a relatively short time, probably no more than a million years. The summit of Vanson Peak is underlain by a stack of porphyritic two-pyroxene andesite flows possibly derived from an andesitic cone similar to the Miocene Tieton volcano southeast of Mount Rainier described by Swanson (1966). Epiclastic rocks in the quadrangle are predominantly coarse conglomerate and breccia that probably filled valleys on and adjacent to the lower flanks of Tertiary volcanoes.

Chemical analyses (table 2) show that the quadrangle contains a variety of volcanic rocks, but that basalt (less than 52 weight percent SiO_2) and basaltic andesite (between 52 and 57 weight percent SiO_2) are dominant (I.U.G.S. nomenclature of Le Bas and Streckeisen, 1991; see fig. 1). More than half of the samples are classified as calc-alkaline on the AFM plot (fig. 2) of Irvine and Baragar (1971) whereas most are tholeiitic according to the FeO*/MgO versus SiO_2 plot (fig. 3) of Miyashiro (1974). The Tertiary rocks tend to be lower in K_2O than Quaternary volcanic rocks of equi-valent SiO_2 contents in southern Washington (fig. 4).

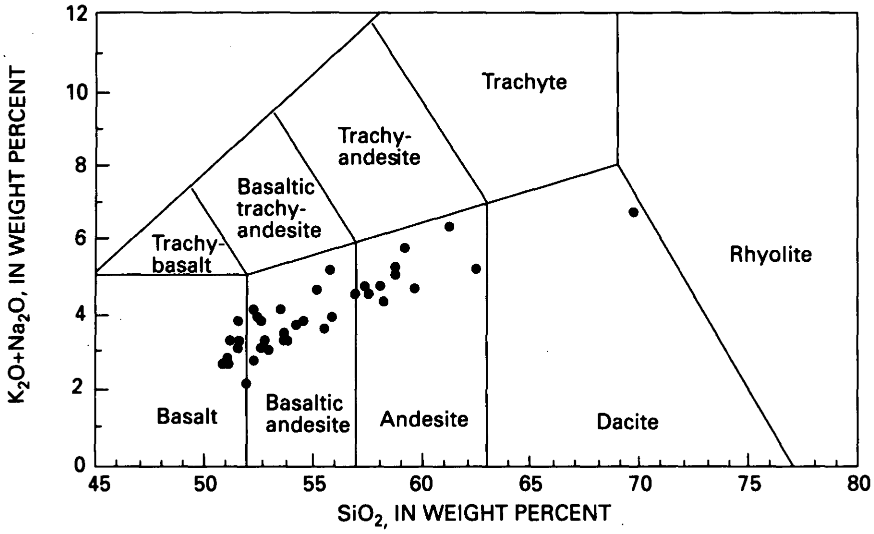

Figure 1. Na_2O+K_2O versus SiO_2 (recalculated volatile-free) for volcanic and hypabyssal intrusive rocks from Vanson Peak quadrangle showing classification according to International Union of Geological Sciences (Le Bas and Streckeisen, 1991.)

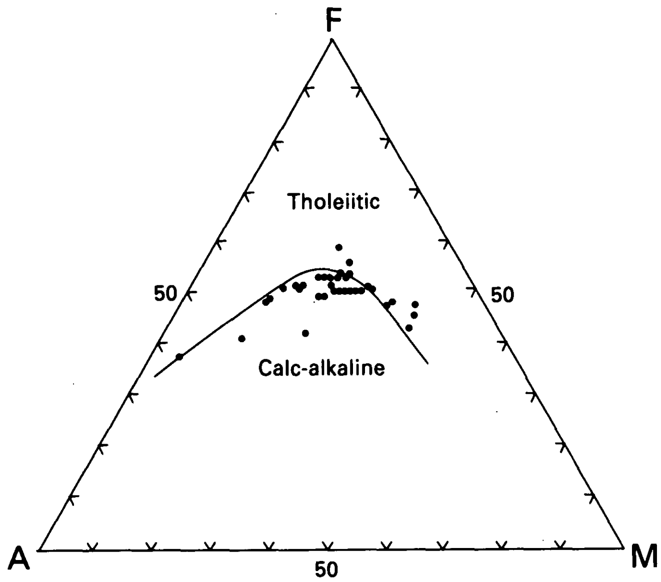

Figure 2. AFM diagram for volcanic and hypabyssal intrusive rocks from Vanson Peak quadrangle. A, Na_2O+K_2O; F, $FeO+Fe_2O_3$; M, MgO. Line separating tholeiitic and calc-alkaline rocks from Irvine and Barager (1971).

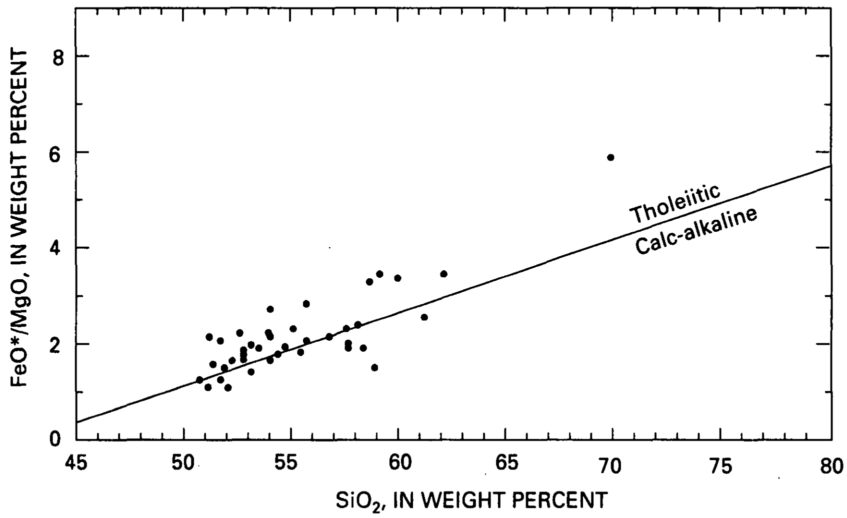

Figure 3. FeO*/MgO versus SiO_2 (recalculated volatile-free) for volcanic and hypabyssal intrusive rocks from Vanson Peak quadrangle showing classification into tholeiitic and calc-alkaline rocks according to Miyashiro (1974). FeO*, total Fe as FeO.

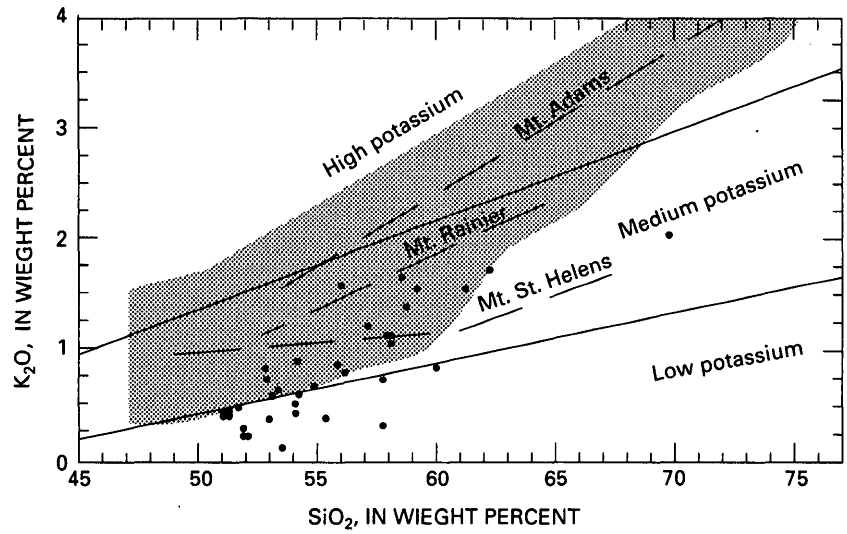

Figure 4. K_2O versus SiO_2 (recalculated volatile-free) for voncanic and hypabyssal intrusive rocks from Vanson Peak quadrangle. Low-, medium-, and high-potassium fields from Gill (1981, p. 6). Shaded area encompasses compositions of Quaternary volcanic rocks, exclusive of major stratovolcanoes, of southern Washington Cascade Range from Hammond and Korosec (1938). 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).

A general westward coarsening of textures in the Spirit Lake pluton (informal name) suggests that it has been tilted to the east along with its host rocks, so folding of the Tertiary section must postdate crystallization of the pluton at 21 Ma (Evarts and others, 1987). The age of folding is otherwise poorly constrained, and folding may have taken place over an extended period (Evarts and others, 1987).

Faults and shear zones are scarce. Those that have been observed are subvertical and typically exhibit offsets of only a few meters. Generally, the rocks on both sides of faults are identical and the sense of offset cannot be determined. Most faults are flanked by zones of hydrothermally altered rocks. Many of the faults are probably relatively old and may represent local small-scale adjustments to movements of magma within Tertiary volcanic centers rather than responses to regional tectonic stresses.

SPIRIT LAKE PLUTON

The Spirit Lake pluton is one of several large, epizonal, multiphase, granitic intrusions of Miocene age in the Washington Cascade Range (Fiske and others, 1963; Tabor and Crowder, 1969; Hammond, 1979; Evarts and others, 1987). It underlies an area of about 120 km^2, most of which lies east and south of the Vanson Peak quadrangle (Evarts and Ashley, 1993a, b, c). The pluton consists of three phases, all of which have yielded radiometric ages between 20 and 23 Ma. In the upper reaches of Goat Creek, the quartz diorite phase (Tsqd) forms a complex of altered porphyritic dikes and sills separated by screens of black recrystallized volcanic rocks. Field relations suggest that this is the oldest part of the pluton. This inference is supported by a 23.2-Ma K-Ar age for hydrothermal alteration which overprints the quartz diorite phase but not the main or granite phases. The slightly younger fission-track age of 22.0±0.6 Ma obtained from a quartz diorite in Goat Creek (table 1) is believed to reflect reheating during emplacement of the main phase and consequent partial annealing of tracks. The coarser grained and more massive main phase (Tsm), which is texturally and modally variable but has an average composition of granodiorite, constitutes most of the pluton. The granite phase (Tsgr) crops out chiefly near the top of the pluton in the Cowlitz Falls and Spirit Lake East quadrangles to the east and southeast (Evarts and Ashley, 1993a, b).

METAMORPHISM

Tertiary volcanic and intrusive rocks throughout the southern Washington Cascade Range have been overprinted by zeolite-facies burial metamorphism (Fiske and others, 1963; Wise, 1970; Hammond, 1980). Volcanic glass is nearly everywhere replaced by iron-bearing smectites that give the rocks their characteristic green colors. Olivine phenocrysts are generally replaced by clots of limonite+smectite, microcrystalline quartz, and (or) carbonate. Orthopyroxene is commonly converted to smectite+titanite, but clinopyroxene typically remains fresh. Recrystallization of plagioclase is more variable both in extent and mineralogy; partial replacement by albite, calcite, laumontite, stilbite, and various clay minerals is widespread.

A contact-metamorphic aureole extends as far as 4 km beyond the Spirit Lake pluton. Despite thorough mineralogic reconstitution, primary macroscopic textures are commonly well preserved and permit identification of protoliths. The aureole can readily be subdivided in the field into an inner zone of black, flinty, aphanitic amphibole-bearing hornfels and an outer zone of green epidote-bearing hornfels (see sketch map).

HYDROTHERMAL ALTERATION AND MINERALIZATION

The effects of hydrothermal alteration and mineralization directly related to volcanism or to later plutonic activity are present throughout the Vanson Peak quadrangle. The most conspicuous type of alteration in the volcanic and sedimentary rocks consists of local areas (<1 km^2) that contain erratically distributed bleached limonitic rocks. These altered areas tend to occur chiefly along faults, shear zones, and dikes; in detail, the alteration was controlled by fractures and permeable clastic beds, and some unaltered rock remains within the areas of hydrothermal alteration shown on this map. Primary igneous minerals in the altered rocks have been totally replaced by carbonate+clay assemblages composed of some combination of kaolinite, montmorillonite, illite, calcite, siderite, dolomite, ankerite, quartz, and limonite. The distribution and mineralogy of these intensely altered areas suggest that they are products of low-temperature, shallow-level, acidic geothermal systems penecontemporaneous with Tertiary volcanism.

Pervasive silicification and argillic to advanced argillic alteration are found inand adjacent to the Spirit Lake pluton along the east edge of the quadrangle, contiguous with a much larger altered area in the Cowlitz Falls quadrangle to the east (Evarts and Ashley, 1993a). The altered rocks range in appearance from dense and massive to brecciated to porous; most are white or pale gray, but orange to brown limonite is common along fractures. They have been intensely leached by acidic solutions that destroyed most primary textures and produced assemblages of fine-grained quartz, pyrophyllite or sericite, limonite, rutile, and minor local andalusite, alunite, diaspore, and topaz(?). Pyrite is generally absent from outcrops of these rocks but its former presence is indicated by bright-red limonite that forms surficial crusts and cements modern gravels in streams draining this area. The iron in this limonite is probably being liberated by oxidation of abundant sulfides in the shallow subsurface. The intense alteration obscures the protolith, but vague porphyritic textures suggest volcanic or quartz diorite phase (Tsqd) precursors. A K-Ar age of 23.2±0.4 Ma was determined on alunite collected from the altered area in the Cowlitz Falls quadrangle (Evarts and Ashley, 1993a).

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———1993c, Geologic map of the Spirit Lake West quadrangle, Skamania and Cowlitz Counties, Washington: U.S. Geological Survey Geologic Quadrangle Map GQ-1681, scale 1:24,000.

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Table 1. Summary of fission-track (FT) and isotopic age determinations, Vanson Peak quadrangle
[Source from Evarts and others (in press) except where otherwise noted]

Map No.	Field sample no.	Location Latitude	Location Longitude	Map unit	Rock type	Material dated	Method	Age (Ma) ± 1σ error	Comments
1	S82-A3-E32	46°23'44"	122°14'22"	Ta_1	Basaltic andesite	Plagioclase	K-Ar	35.0±2.0	———————
						Plagioclase	K-Ar	28.5±1.1	———————
						Plagioclase	$^{40}Ar/^{39}Ar$	33.5±0.4	Laser-fusion age
2	S80-A1-S02	46°27'56"	122°13'26"	Tt_1	Dacitic ash-flow tuff	Plagioclase	K-Ar	28.5±0.9	———————
3	S78-A1-E209A	46°27'01"	122°13'21"	Tvs_1	Hornblende andesite	Hornblende	K-Ar	27.1±2.0	———————
4	S78-B2-R46	46°26'30"	122°09'40"	Tgc	Basaltic andesite	Plagioclase	$^{40}Ar/^{39}Ar$	22.9±3.6	Laser incremental heating age; large error
5	S80-BI-L28	46°29'55"	122°08'16"	do	Porphyritic basalt	Plagioclase	$^{40}Ar/^{39}Ar$	25.0±1.4	Laser-fusion age
6	BP0516851	46°29'07"	122°10'52"	do	Basaltic andesite	Whole-rock	K-Ar	24.4±1.2	From Phillips and others (1986); mean of two concordant determinations
						Whole-rock	K-Ar	25.2±0.6	Determined on split of above sample at U.S.G.S., Menlo Park, Calif.
7	S78-B2-E49A	46°24'45"	122°09'19"	Ta_2	Pyroxene andesite	Plagioclase	K-Ar	24.7±3.5	———————
						Plagioclase	$^{40}Ar/^{39}Ar$	25.1±0.4	Laser-fusion age
8	S78-A2-R128	46°26'18"	122°12'45"	Tia	——do——	Whole-rock	K-Ar	8.6±0.3	Probable Ar loss; minimum age
9	S79-B3-E149D	46°24'04"	122°08'02"	Tsqd	Porphyritic granodiorite	Zircon	FT	22.0±0.6	Partially reset by main phase of pluton; minimum age

Table 2. Chemical analyses and modes of volcanic and hypabyssal intrusive rocks, Vanson Peak quadrangle

[Oxides in weight percent. For modal analyses, secondary minerals counted as primary mineral replaced except for interstitial chlorite (chl) in 5E36; tr: trace. Rock-type names assigned in accordance with I.U.G.S. system of Le Bas and Streckeisen, 1991; (applied to recalculated analyses for volcanic rocks.) Methods: RR, single-solution rapid rock analysis as described by Shapiro (1975); analysts, J. Gillison, and H. Smith. XRF, X-ray fluorescence analysis using methods described by Taggart and others (1987), analysts: J. Baker, A.J. Bartel, D. Fey, D. Siems, K. Stewart, J.E. Taggart, and J.S. Wahlberg; FeO, H_2O, and CO_2 determined by methods detailed in Jackson and others (1987); analysts, E. Engelman, L. Espos, S. Neil, H. Neiman, and S. Pribble. Texture: first term describes overall rock texture; second term (where appropriate) describes groundmass.

Map No.	1	2	3	4	5	6	7	8	9
Field sample number	3E64	5E36	0E59	8M44	0E14	8R132A	5E10	5E55B	0L28
Latitude	46°27'33"	46°26'46"	46°26'57"	46°26'42"	46°27'52"	46°26'13"	46°23'28"	46°25'38"	46°29'56"
Longitude	122°11'00"	122°09'34"	122°08'49"	122°08'41"	122°07'32"	122°11'49"	122°12'22"	122°09'05"	122°08'16"
Map unit	Tgc	Tgb	Tgc	Tb_2	Tgb	Tgc	Tib	Tia	Tgc
Rock type	Basalt	Gabbro	Basaltic andesite	Basalt	Gabbro	Basalt	Basalt	Basaltic andesite	Basalt
Method	XRF	XRF	RR	RR	RR	RR	XRF	XRF	RR
SiO_2	48.3	49.4	49.9	50.1	50.2	50.3	50.4	50.7	50.8
TiO_2	1.03	0.92	1.1	0.95	1.2	1.2	1.41	0.78	1.0
Al_2O_3	16.9	17.4	17.4	15.6	17.9	18.0	18.5	16.3	17.1
Fe_2O_3	3.81	2.93	3.7	4.2	3.8	3.7	3.3	3.52	3.8
FeO	5.54	5.27	4.8	5.0	5.7	6.3	6.76	4.82	5.1
MnO	0.14	0.11	0.12	0.16	0.16	0.15	0.15	0.12	0.18
MgO	6.86	7.48	4.9	7.4	5.8	4.6	4.58	7.20	6.7
CaO	9.46	10.00	10.4	10.6	9.7	9.2	10.4	11.50	10.4
Na_2O	2.29	2.41	2.6	2.1	2.9	3.4	2.7	2.06	2.7
K_2O	0.40	0.30	0.17	0.15	0.42	0.24	0.33	0.20	0.40
P_2O_5	0.15	0.13	0.20	0.16	0.18	0.27	0.18	0.14	0.16
H_2O+	2.07	1.67	0.90	0.60	0.76	0.73	1.36	1.46	0.10
H_2O-	2.84	2.07	1.8	2.1	0.64	0.97	0.53	1.12	1.4
CO_2	0.06	0.13	0.91	0.36	0.08	0.21	0.04	0.52	0.88
Total	99.85	100.22	98.90	99.48	99.44	99.27	100.64	100.44	100.72
Analyses recalculated volatile-free and normalized to 100 percent									
SiO_2	50.91	51.27	52.37	51.96	51.25	51.66	51.06	52.09	51.66
TiO_2	1.09	0.95	1.15	0.99	1.22	1.23	1.43	0.80	1.02
Al_2O_3	17.81	18.06	18.26	16.18	18.27	18.49	18.74	16.75	17.39
Fe_2O_3	4.02	3.04	3.88	4.36	3.88	3.80	3.34	3.62	3.86
FeO	5.84	5.47	5.04	5.19	5.82	6.47	6.85	4.95	5.19
MnO	0.15	0.11	0.13	0.17	0.16	0.15	0.15	0.12	0.18
MgO	7.23	7.76	5.14	7.67	5.92	4.72	4.64	7.40	6.81
CaO	9.97	10.38	10.91	10.99	9.90	9.45	10.54	11.81	10.58
Na_2O	2.41	2.50	2.73	2.18	2.96	3.49	2.74	2.12	2.75
K_2O	0.42	0.31	0.18	0.16	0.43	0.25	0.33	0.21	0.41
P_2O_5	0.16	0.13	0.21	0.17	0.18	0.28	0.18	0.14	0.16
Modes									
Plagioclase	18.3	57.2	18.8	15.2	62.7	36.8	33.0	20.8	23.7
Clinopyroxene	---	15.0	0.2	3.2	12.5	---	---	7.4	0.4
Orthopyroxene	---	13.7	---	---	8.2	---	---	1.8	---
Olivine	8.2	1.3	0.3	5.7	1.7	2.9	1.3	4.4	6.4
Fe-Ti oxide	---	1.8	---	---	2.6	---	---	---	---
Hornblende	---	---	---	---	---	---	---	---	---
Quartz	---	4.7	---	---	0.7	---	---	---	---
Groundmass	73.5	chl 6.3	80.7	75.9	11.6	60.3	65.7	65.6	69.5
No. of points counted	813	625	637	778	767	731	630	630	739
Texture	porphyritic/ intergranular	hypidiomorphic/ granular	seriate/ intergranular	porphyritic/ intergranular	hypidiomorphic/ granular	seriate/ intergranular	porphyritic/ intergranular	seriate/ intergranular	porphyritic/ intergranular

Table 2. Chemical analyses and modes of volcanic and hypabyssal intrusive rocks, Vanson Peak quadrangle--Continued

Map No.	10	11	12	13	14	15	16	17	18
Field sample number	3E57	2E18	8R107	5E03B	2E32	5E37	6N42A	8R46	2E34
Latitude	46°28'08"	46°22'33"	46°25'53"	46°27'49"	46°23'44"	46°26'51"	46°29'08"	46°26'30"	46°23'34"
Longitude	122°11'36"	122°14'02"	122°14'26"	122°12'26"	122°14'21"	122°09'08"	122°10'53"	122°09'40"	122°14'03"
Map unit	Tgc	Ta_1	Ta_1	Ta_1	Ta_1	Tgc	Tgc	Tgc	Ta_1
Rock type	Basalt	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite
Method	XRF	XRF	RR	XRF	XRF	XRF	XRF	XRF	XRF
SiO_2	51.0	51.1	51.3	51.3	51.6	51.7	51.8	51.9	52.6
TiO_2	1.37	1.55	1.5	1.27	1.58	1.14	1.51	0.85	1.27
Al_2O_3	17.3	16.0	17.	17.9	16.8	18.1	17.9	19.5	16.5
Fe_2O_3	3.32	3.33	3.8	4.31	2.80	2.76	4.68	3.67	3.36
FeO	6.20	6.28	5.6	3.97	5.87	5.42	4.18	3.39	5.55
MnO	0.16	0.17	0.13	0.14	0.13	0.13	0.12	0.11	0.14
MgO	5.99	4.77	4.0	4.12	3.71	4.93	4.68	4.70	5.04
CaO	9.46	9.24	9.6	10.10	8.74	10.00	9.16	10.30	9.12
Na_2O	2.87	2.66	3.3	3.17	3.21	2.80	3.14	2.81	2.97
K_2O	0.44	0.63	0.84	0.74	0.86	0.35	0.55	0.36	0.49
P_2O_5	0.22	0.38	0.48	0.10	0.28	0.19	0.25	0.14	0.20
H_2O^+	0.70	1.72	0.52	0.81	0.84	1.25	0.66	1.02	1.10
H_2O^-	0.75	0.44	1.2	1.32	0.46	1.48	1.69	1.46	1.45
CO_2	0.06	1.50	0.02	0.93	3.50	0.15	0.13	0.11	0.05
Total	99.84	99.77	99.29	100.18	100.38	100.40	100.45	100.32	99.84

Analyses recalculated volatile-free and normalized to 100 percent

SiO_2	51.87	53.17	52.59	52.82	53.98	53.01	52.87	53.11	54.09
TiO_2	1.39	1.61	1.54	1.31	1.65	1.17	1.54	0.87	1.31
Al_2O_3	17.59	16.65	17.43	18.43	17.58	18.56	18.27	19.95	16.97
Fe_2O_3	3.38	3.46	3.90	4.44	2.93	2.83	4.78	3.76	3.46
FeO	6.31	6.53	5.74	4.09	6.14	5.56	4.27	3.47	5.71
MnO	0.16	0.18	0.13	0.14	0.14	0.13	0.12	0.11	0.14
MgO	6.09	4.96	4.10	4.24	3.88	5.06	4.78	4.81	5.18
CaO	9.62	9.61	9.84	10.40	9.14	10.25	9.35	10.54	9.38
Na_2O	2.92	2.77	3.38	3.26	3.36	2.87	3.21	2.88	3.05
K_2O	0.45	0.66	0.86	0.76	0.90	0.36	0.56	0.37	0.50
P_2O_5	0.22	0.40	0.49	0.10	0.29	0.19	0.26	0.14	0.21

Modes

Plagioclase	30.5	1.6	---	13.9	31.2	30.3	9.6	36.8	17.7
Clinopyroxene	---	0.4	---	1.2	0.7	2.1	0.1	0.8	3.4
Orthopyroxene	---	0.5	---	---	2.3	---	tr	0.7	0.4
Olivine	5.7	3.8	---	2.0	0.4	5.6	1.0	2.8	2.5
Fe-Ti oxide	---	---	---	---	---	---	---	---	---
Hornblende	---	---	---	---	---	---	---	---	---
Quartz	---	---	---	---	---	---	---	---	---
Groundmass	63.8	93.7	100.0	82.9	65.4	62.0	89.3	58.9	76.0
No. of points counted	770	771	---	584	725	630	700	707	797
Texture	seriate/ intergranular	porphyritic/ hyaloophitic	aphyric/ intersertal	porphyritic/ intergranular	porphyritic/ intergranular	seriate/ intergranular	porphyritic/ pilotaxitic	seriate/ intergranular	porphyritic/ pilotaxitic

Table 2. Chemical analyses and modes of volcanic and hypabyssal intrusive rocks, Vanson Peak quadrangle--Continued

Map No.	19	20	21	22	23	24	25	26	27
Field sample number	9E125	5E74	7E18B	8W21	5E03A	7E15B	9E133	8R128	7E10
Latitude	46°24'16"	46°27'52"	46°24'04"	46°25'54"	46°27'49"	46°25'26"	46°24'35"	46°26'18"	46°27'04"
Longitude	122°13'56"	122°09'56"	122°13'06"	122°08'37"	122°12'26"	122°13'59"	122°14'46"	122°12'45"	122°08'17"
Map unit	Tia	Tgc	Ta_1	Tgc	Ta_1	Ta_1	Tia	Tia	Ta_2
Rock type	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite
Method	RR	XRF	XRF	RR	XRF	XRF	RR	RR	XRF
SiO_2	52.7	52.8	53.2	53.3	53.9	54.0	54.5	54.7	55.1
TiO_2	1.3	1.15	1.28	1.0	1.53	1.16	1.0	1.5	1.2
Al_2O_3	16.4	19.2	17.6	18.2	16.5	19.2	17.2	15.8	16.0
Fe_2O_3	3.2	3.56	3.06	3.2	2.82	2.96	2.9	3.3	3.62
FeO	7.5	4.78	6.08	5.1	6.56	4.34	5.3	6.1	5.63
MnO	0.19	0.15	0.18	0.15	0.15	0.07	0.16	0.19	0.15
MgO	3.9	4.12	4.06	4.4	3.90	3.45	4.2	3.3	4.28
CaO	8.4	9.65	9.57	8.7	7.31	9.04	8.7	7.4	8.54
Na_2O	2.9	2.98	2.87	3.2	3.70	3.20	3.3	3.5	3.2
K_2O	0.46	0.13	0.36	0.56	0.88	0.65	0.38	1.5	0.79
P_2O_5	0.3	0.17	0.20	0.18	0.29	0.18	0.32	0.55	0.16
H_2O^+	0.97	0.67	1.02	0.50	0.65	0.73	1.1	1.5	0.66
H_2O^-	0.89	1.04	0.65	0.90	0.84	1.06	0.81	0.64	0.72
CO_2	0.02	0.07	0.37	0.32	0.84	0.04	0.02	0.06	0.22
Total	99.13	100.47	100.50	99.71	99.87	100.08	99.89	100.04	100.27
Analyses recalculated volatile-free and normalized to 100 percent									
SiO_2	54.19	53.50	54.03	54.39	55.26	54.96	55.59	55.91	55.84
TiO_2	1.34	1.17	1.30	1.02	1.57	1.18	1.02	1.53	1.22
Al_2O_3	16.86	19.45	17.88	18.57	16.92	19.54	17.58	16.15	16.22
Fe_2O_3	3.29	3.61	3.11	3.27	2.89	3.01	2.96	3.37	3.67
FeO	7.71	4.84	6.18	5.20	6.73	4.42	5.42	6.23	5.71
MnO	0.20	0.15	0.18	0.15	0.15	0.07	0.16	0.19	0.15
MgO	4.01	4.17	4.12	4.49	4.00	3.51	4.29	3.37	4.34
CaO	8.64	9.78	9.72	8.88	7.49	9.20	8.89	7.56	8.66
Na_2O	2.98	3.02	2.91	3.27	3.79	3.26	3.37	3.58	3.24
K_2O	0.47	0.13	0.37	0.57	0.90	0.66	0.39	1.53	0.80
P_2O_5	0.31	0.17	0.20	0.18	0.30	0.18	0.33	0.56	0.16
Modes									
Plagioclase	7.2	26.4	23.9	18.3	35.9	36.8	30.4	0.7	0.3
Clinopyroxene	0.4	---	1.9	---	1.9	1.2	5.4	0.1	0.2
Orthopyroxene	0.6	1.1	---	---	1.3	3.3	3.2	---	---
Olivine	---	2.0	2.2	4.0	---	1.2	1.4	---	---
Fe-Ti oxide	---	---	---	---	---	0.2	0.5	---	---
Hornblende	---	---	---	---	---	---	---	---	---
Quartz	---	---	---	---	---	---	---	---	---
Groundmass	91.8	70.5	72.0	77.7	60.9	57.3	59.1	99.2	99.5
No. of points counted	791	658	649	776	776	674	776	610	576
Texture	porphyritic/ pilotaxitic	porphyritic/ intergranular	porphyritic/ intergranular	porphyritic/ pilotaxitic	porphyritic/ intergranular	porphyritic/ hypidiomorphic	porphyritic/ intersertal	aphyric/ pilotaxitic	aphyric/ intergranular

Table 2. Chemical analyses and modes of volcanic and hypabyssal intrusive rocks, Vanson Peak quadrangle--Continued

Map No.	28	29	30	31	32	33	34	35	36
Field sample number	8E49A	8E211	5E02	7E14	8M24	5E39	2E35B	7E11	5E05A
Latitude	46°24'45"	46°26'32"	46°29'39"	46°27'11"	46°26'58"	46°26'45"	46°23'31"	46°27'02"	46°26'22"
Longitude	122°09'20"	122°12'53"	122°12'53"	122°14'06"	122°08'44"	122°08'45"	122°14'25"	122°08'18"	122°13'51"
Map unit	Ta_2	Ta_1	Tia	Tia	Ta_2	Ta_2	Tia	Ta_2	Ta_1
Rock type	Basaltic andesite	Andesite	Andesite	Andesite	Andesite	Andesite	Andesite	Andesite	Andesite
Method	RR	RR	XRF	XRF	XRF	XRF	XRF	XRF	XRF
SiO_2	55.7	55.7	56.2	56.5	56.6	57.1	57.2	57.4	57.6
TiO_2	1.1	1.1	1.42	1.50	1.14	1.12	1.63	1.23	1.83
Al_2O_3	16.7	16.4	16.9	16.1	16.1	15.8	15.1	15.7	15.3
Fe_2O_3	4.5	3.9	3.01	4.70	3.03	2.93	2.46	4.37	4.28
FeO	3.8	3.9	4.93	3.62	5.07	5.12	5.62	4.57	4.21
MnO	0.14	0.13	0.13	0.13	0.14	0.14	0.14	0.15	0.11
MgO	3.6	3.6	3.14	2.49	3.88	3.87	2.36	3.40	2.38
CaO	7.7	7.2	7.33	6.32	8.47	7.54	5.74	7.18	5.44
Na_2O	3.1	3.1	3.67	3.54	3.06	3.13	3.76	3.46	4.06
K_2O	1.2	1.1	0.69	1.31	0.29	0.98	0.77	1.11	1.48
P_2O_5	0.22	0.32	0.26	0.31	0.18	0.18	0.41	0.18	0.40
H_2O^+	0.70	1.1	1.96	1.09	1.76	0.36	3.14	0.43	0.86
H_2O^-	1.1	1.5	0.91	2.31	0.45	1.26	1.06	0.64	1.35
CO_2	0.25	0.04	0.04	0.05	0.03	0.21	0.07	0.01	0.57
Total	99.81	99.09	100.59	99.97	100.20	99.74	99.46	99.83	99.87
Analyses recalculated volatile-free and normalized to 100 percent									
SiO_2	56.98	57.75	57.53	58.54	57.78	58.32	60.09	58.13	59.33
TiO_2	1.13	1.14	1.45	1.55	1.16	1.14	1.71	1.25	1.88
Al_2O_3	17.08	17.00	17.30	16.68	16.44	16.14	15.86	15.90	15.76
Fe_2O_3	4.60	4.04	3.08	4.87	3.09	2.99	2.58	4.43	4.41
FeO	3.89	4.04	5.05	3.75	5.18	5.23	5.90	4.63	4.34
MnO	0.14	0.13	0.13	0.13	0.14	0.14	0.15	0.15	0.11
MgO	3.68	3.73	3.21	2.58	3.96	3.95	2.48	3.44	2.45
CaO	7.88	7.47	7.50	6.55	8.65	7.70	6.03	7.27	5.60
Na_2O	3.17	3.21	3.76	3.67	3.12	3.20	3.95	3.50	4.18
K_2O	1.23	1.14	0.71	1.36	0.30	1.00	0.81	1.12	1.52
P_2O_5	0.23	0.33	0.27	0.32	0.18	0.18	0.43	0.18	0.41
Modes									
Plagioclase	29.2	23.2	7.7	8.9	10.3	9.9	0.2	3.1	---
Clinopyroxene	5.1	3.4	0.2	---	4.9	5.2	tr	---	---
Orthopyroxene	5.1	4.2	0.4	---	2.9	2.5	tr	0.5	---
Olivine	---	0.5	---	---	0.2	tr	---	---	---
Fe-Ti oxide	0.6	0.4	---	0.4	0.1	0.2	tr	---	---
Hornblende	---	---	---	---	---	---	---	---	---
Quartz	---	---	---	---	---	---	---	---	---
Groundmass	60.0	68.3	91.7	90.7	81.6	82.2	99.8	96.4	100.0
No. of points counted	811	805	505	530	814	629	562	672	---
Texture	porphyritic/ hyalopilitic	porphyritic/ hypidiomorphic	seriate/ intersertal	seriate/ intersertal	porphyritic/ hyalopilitic	porphyritic/ pilotaxitic	aphyric/ felty	microporphyritic/ mircrogranular	aphyric/ pilotaxitic

Table 2. Chemical analyses and modes of volcanic and hypabyssal intrusive rocks, Vanson Peak quadrangle—Continued

Map No.	37	38	39	40
Field sample No.	8R124	0E52	6E02	9M20A
Latitude	46°27'09"	46°29'55"	46°26'34"	46°29'48"
Longitude	122°14'58"	122°14'46"	122°07'54"	122°12'19"
Map unit	Tia	Ta_1	Td_2	Td_1
Rock type	Andesite	Andesite	Andesite	Dacite
Method	RR	RR	XRF	XRF
SiO_2	57.9	59.6	60.7	67.4
TiO_2	1.1	1.0	1.24	0.61
Al_2O_3	16.2	16.6	14.8	13.9
Fe_2O_3	3.8	3.5	2.17	1.73
FeO	3.4	2.8	5.17	2.95
MnO	0.13	0.06	0.14	0.11
MgO	4.2	2.3	2.06	0.76
CaO	6.6	4.7	5.46	2.28
Na_2O	3.6	4.7	3.50	4.47
K_2O	1.6	1.5	1.73	1.99
P_2O_5	0.25	0.53	0.35	0.14
H_2O^+	0.60	1.1	1.91	0.71
H_2O^-	1.2	1.6	0.94	0.29
CO_2	0.09	0.06	<0.10	2.69
Total	100.67	100.05	100.17	100.03
	Analyses recalculated volatile-free and normalized to 100 percent			
SiO_2	58.62	61.26	62.37	69.96
TiO_2	1.11	1.03	1.27	0.63
Al_2O_3	16.40	17.06	15.21	14.43
Fe_2O_3	3.85	3.60	2.23	1.80
FeO	3.44	2.88	5.31	3.06
MnO	0.13	0.06	0.14	0.11
MgO	4.25	2.36	2.12	0.79
CaO	6.68	4.83	5.61	2.37
Na_2O	3.64	4.83	3.60	4.64
K_2O	1.62	1.54	1.78	2.07
P_2O_5	0.25	0.54	0.36	0.15
	Modes			
Plagioclase	26.5	0.8	6.3	3.3
Clinopyroxene	4.2	---	0.8	0.7
Orthopyroxene	8.3	---	0.6	---
Olivine	---	---	---	---
Fe-Ti oxide	1.0	tr	0.2	0.1
Hornblende	---	---	---	---
Quartz	---	---	---	---
Groundmass	60.0	99.2	92.1	95.9
No. of points counted	695	566	635	674
Texture	porphyritic/ hyalopilitic	aphyric/ felty	porphyritic/ hyalopilitic	porphyritic/ hyalopilitic

* U.S. G.P.O.:1993-301-077:80033