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GEOCHEMICAL ANALYSES, AGE DATES, AND FLOW-VOLUME ESTIMATES FOR QUATERNARY VOLCANIC ROCKS, SOUTHERN CASCADE MOUNTAINS, WASHINGTON

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Introduction

This report presents data collected over the last three years as part of a continuing study of the Quaternary volcanic rocks of the southern Cascade Mountains.

Whole-rock chemical analyses, selected trace element geochemistry, volume approximations, specific gravity determinations, and locations are provided for most of the 103 samples collected, and 21 radiometric age dates are included. In addition, partial information, including names and flow-volumes, are presented for 98 additional samples, collected for related studies.

The study area, shown in figure 1, extends from the Columbia River north to the Cowlitz River and Goat Rocks Wilderness area, and from the Klickitat River west to the Puget-Willamette Trough. The volcanic rocks are all younger than 3 million years and consist primarily of tholeiitic and high-alumina basalts and basaltic-andesites erupted from numerous shield volcanoes and cinder cones. A few analyses of more silicic rocks, including hornblende and/or pyroxene andesites and dacites characteristic of the stratovolcanoes of the region, are also presented. However, systematic sampling of the stratovolcanoes in the study area, Mount Adams and Mount St. Helens, was not conducted.

A map of the areal extent of Quaternary volcanic units and sample locations is included (Plate 1). It has been based on the 1:125,000 reconnaissance geologic map of the southern Cascade Range by Hammond (1980).

Descriptions of the tables.

The first part of Table 1 contains information pertaining to sample location, geologic unit symbol, and informal geologic unit name for the first 103 samples. The second part of Table 1 includes sample numbers, map unit

Figure 1. — Index map showing zones of volcanism and project area in southern Washington Cascade Range.

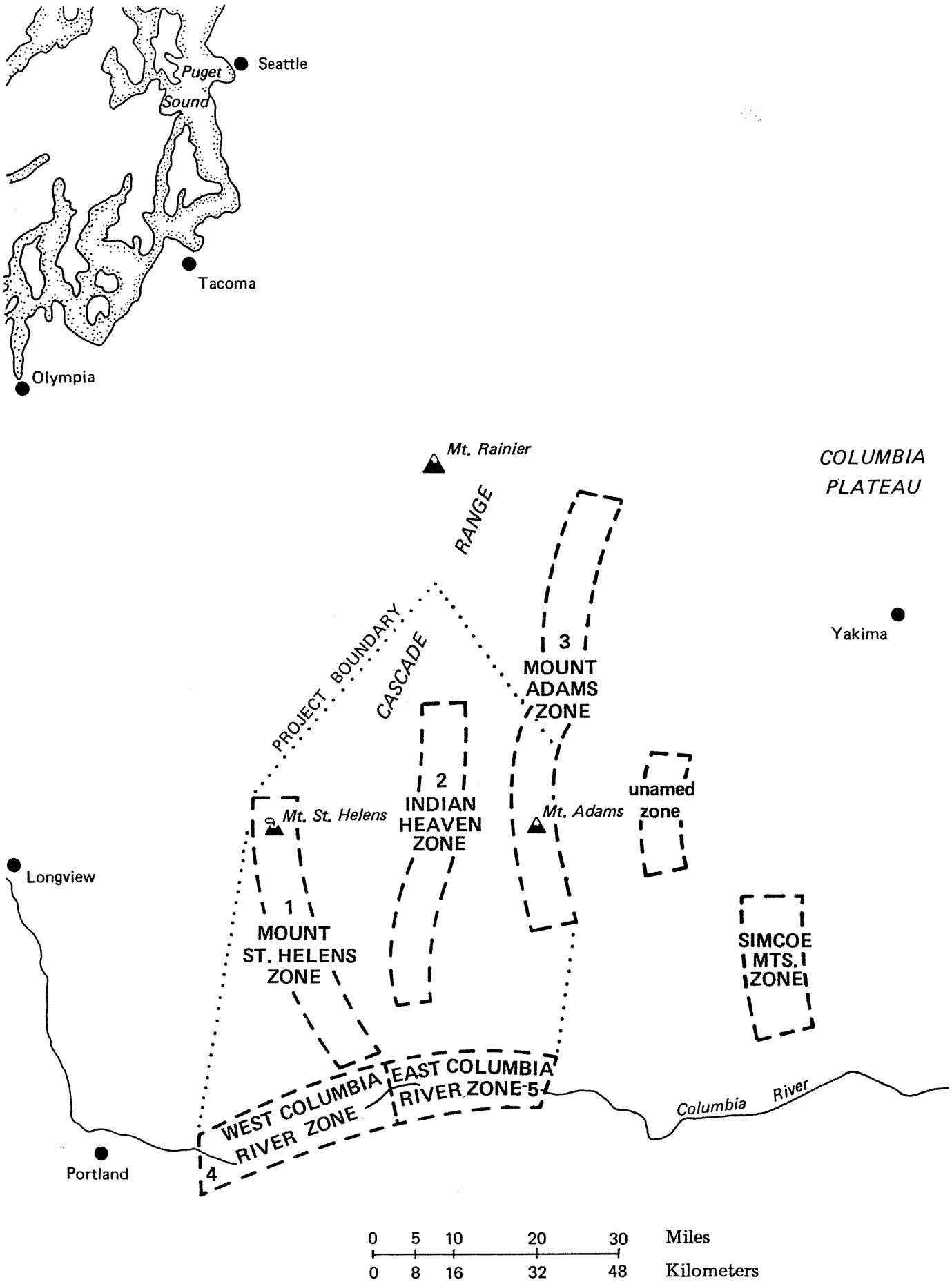

Table 1

SAMPLE NUMBER	LATITUDE	LONGITUDE	VOLCANIC ZONE	MAP UNIT	UNIT DESCRIPTION
1	4610.53	12138.24	3	QSM	ANDESITE OF SWAMPY MEADOWS
2	4612.53	12137.82	3	QAA	ANDESITE OF MOUNT ADAMS
3	4613.04	12137.62	3	QAA	ANDESITE OF MOUNT ADAMS
4	4618.58	12132.58	3	QSC	BASALT OF SPRING CREEK
5	4623.18	12131.97	3	QTLS	BASALT OF TWO LAKES
6	4625.31	12128.82	3	QWL	BASALT OF WALUPT LAKE
7	4604.01	12156.31	2	QTL	BASALT OF THOMAS LAKE
8	4604.18	12156.79	2	QTL	BASALT OF THOMAS LAKE
9	4603.75	12158.03	2	QLC	BASALT OF LAKE COMCOMLY
10	4604.22	12158.40	2	QTL	BASALT OF THOMAS LAKE
11	4604.77	12154.47	2	QIH	BASALT OF INDIAN HEAVEN
12	4605.11	12154.77	2	QTL	BASALT OF THOMAS LAKE
13	4603.15	12150.78	2	QLB	BASALT OF LONE BUTTE
14	4606.14	12147.83	2	QSL	BASALT OF SURPRISE LAKE
15	4605.80	12145.74	2	QSL	BASALT OF SURPRISE LAKE
16	4608.61	12146.35	2	QTC	BASALT OF TILLICUM CREEK
17	4553.61	12150.04	2	QBC	ANDESITE OF BLACK CREEK
18	4558.47	12143.29	2	QLC	BASALT OF LAKE COMCOMLY
19	4556.93	12143.17	2	QDC	BASALT OF DRY CREEK
20	4555.74	12146.05	2	QPM	BASALT OF PAPOOSE MOUNTAIN
21	4553.86	12149.49	2	QBC	BASALT OF BLACK CREEK
22	4554.03	12149.95	2	QBC	ANDESITE OF BLACK CREEK
23	4551.90	12149.55	2	QBC	ANDESITE OF BLACK CREEK
24	4601.28	12131.91	3	QGCY	BASALT OF GREEN CANYON
25	4602.98	12133.32	3	QGCY	BASALT OF GREEN CANYON
26	4606.82	12141.31	3	QWSC	BASALT WEST OF SKULL CREEK
27	4604.69	12139.59	3	QWSP	BASALT WEST OF SLEEPING BEAUTY
28	4604.09	12138.98	3	QWSC	BASALT WEST OF SKULL CREEK
29	4603.49	12136.70	3	QDH	BASALT OF DEADHORSE CREEK
30	4605.45	12141.80	2	QTLC	BASALT OF TROUT LAKE CREEK
31	4603.41	12137.75	3	QB	BASALT, UNDIVIDED
32	4601.02	12131.54	3	QCPK	BASALT OF COUNTY PARK
33	4603.03	12130.49	3	QSMB	ANDESITE OF SMITH BUTTE
34	4558.25	12125.00	3	QQB	ANDESITE OF QUIGLEY BUTTE
35	4558.04	12124.09	3	QQB	ANDESITE OF QUIGLEY BUTTE
36	4559.06	12121.34	3	QCP	BASALT OF CAMAS PRAIRIE
37	4559.06	12203.48	1	QSDP	BASALT OF SODA PEAK
38	4552.50	12205.30	1	QWC	ANDESITE OF WEST CRATER
39	4554.72	12205.61	1	QPC	BASALT OF PUNY CREEK
40	4554.97	12203.78	1	QBRM	BASALT OF BARE MOUNTAIN
41	4554.89	12141.52	2	QLC	BASALT OF LAKE COMCOMLY
42	4548.24	12141.52	2	QBL	BASALT OF BIG LAVA BED
43	4547.13	12137.80	2	QBL	BASALT OF BIG LAVA BED
44	4556.85	12138.66	3	QIM	RHYOLITE OF MANN BUTTE
45	4556.63	12135.73	2	QLC	BASALT OF LAKE COMCOMLY
46	4606.99	12207.62	1	QMMB	BASALT OF MARBLE MOUNTAIN
47	4552.76	12131.10	2	QIC	BASALT OF ICE CAVE
48	4554.55	12130.15	3	QGM	BASALT OF GULER MOUNTAIN
49	4551.73	12129.57	3	QGC	BASALT OF GILMER CREEK
50	4551.48	12129.82	3	QGC	BASALT OF GILMER CREEK
51	4551.26	12130.00	3	QGC	BASALT OF GILMER CREEK
52	4548.54	12128.05	3	QRS	ANDESITE OF RATTLESNAKE CREEK
53	4545.12	12130.73	3	QNW	BASALT OF NORTHWESTERN LAKE
54	4550.11	12123.48	3	QTDS	DACITE OF SNOWDEN
55	4544.49	12128.84	5	QMF	ANDESITE OF MCCOY FLAT

Table 1 (contd.)

SAMPLE NUMBER	LATITUDE	LONGITUDE	VOLCANIC ZONE	MAP UNIT	UNIT DESCRIPTION
56	4543.13	12128.84	5	QWS	BASALT OF WHITE SALMON
57	4543.13	12129.15	5	QWS	BASALT OF WHITE SALMON
58	4543.89	12130.58	5	QWS	BASALT OF WHITE SALMON
59	4544.62	12131.52	5	QUW	BASALT OF UNDERWOOD MOUNTAIN
60	4544.45	12132.99	5	QUW	BASALT OF UNDERWOOD MOUNTAIN
61	4543.72	12136.34	5	QUW	BASALT OF UNDERWOOD MOUNTAIN
62	4540.61	12156.19	4	QCLS	BASALT OF CASCADE LANDSLIDE
63	4537.84	12201.05	4	QBR	BASALT OF BEACON ROCK
64	4538.22	12201.23	4	QBR	BASALT OF BEACON ROCK
65	4537.59	12208.24	4	QMCC	BASALT OF MCCLOSKEY CREEK
66	4537.67	12213.65	4	QBPR	BASALT OF BEAR PRAIRIE
67	4533.95	12214.02	4	QMP	BASALT OF MT. PLEASANT
68	4535.08	12228.72	4	QPRH	BASALT OF PRUNE HILL
69	4536.95	12217.95	4	QMN	BASALT OF MT. NORMAY
70	4538.01	12212.79	4	QBM	BASALT OF BOBS MOUNTAIN
71	4534.27	12228.72	4	QMZ	ANDESITE OF MT. ZION
72	4604.35	12208.85	1	QMMA	ANDESITE OF MARBLE MOUNTAIN
73	4551.31	12202.15	1	QWC	ANDESITE OF WEST CRATER
74	4604.43	12208.48	1	QMMB	BASALT OF MARBLE MOUNTAIN
75	4555.31	12146.72	2	QPB	BASALT OF PAPOOSE MOUNTAIN
76	4559.62	12144.51	2	QLC	BASALT OF LAKE COMCOMLY
77	4600.17	12144.08	2	QLC	BASALT OF LAKE COMCOMLY
78	4607.07	12146.11	2	QTB	BASALT OF TWIN BUTTES
79	4609.46	12144.02	2	QWSB	BASALT OF WEST STEAMBOAT MOUNTAIN
80	4608.95	12146.17	2	QWSB	BASALT OF WEST STEAMBOAT MOUNTAIN
81	4603.41	12141.56	2	QLG	BASALT OF LITTLE GOOSE CREEK
82	4603.32	12144.88	2	QIVP	BASALT OF INDIAN VIEWPOINT
83	4603.28	12140.20	2	QIC	BASALT OF ICE CAVE
84	4619.60	12129.38	3	QSC	BASALT OF SPRING CREEK
85	4621.82	12132.71	3	QPH	BASALT OF POTATO HILL
86	4548.15	12141.65	2	QLVC	BASALT OF LAVA CREEK
87	4600.43	12126.13	3	QCP	BASALT OF CAMAS PRAIRIE
88	4605.58	12115.61	3	QCP	BASALT OF CAMAS PRAIRIE
89	4613.30	12159.88	1	QPF	BASALT OF PARADISE FALLS
90	4635.20	12137.44	2	QTSM	DACITE OF SNYDER MOUNTAIN
91	4601.28	12136.58	3	QFM	BASALT OF FLATTOP MOUNTAIN
92	4620.41	12144.51	2	QSRP	BASALT OF SUNRISE PEAK
93	4621.52	12143.52	2	QSC	BASALT OF SPRING CREEK
94	4620.88	12142.60	2	QECC	BASALT OF EAST CANYON CREEK
95	4547.22	12142.66	3	QLOC	BASALT OF LOST CREEK
96	4601.53	12145.37	2	QHL	BASALT OF HIDDEN LAKE
97	4600.26	12149.36	2	QEL	ANDESITE OF EUNICE LAKE
98	4605.11	12147.46	2	QRL	BASALT OF RED LAKE
99	4547.34	12137.07	3	QLPC	BASALT OF LAPHAM CREEK
100	4603.45	12150.16	2	QLB	BASALT OF LONE BUTTE
101	4547.56	12202.80	1	QMB	BASALT OF MOWICH BUTTE
102	4552.67	12131.10	2	QIC	BASALT OF ICE CAVES
103	4608.01	12210.39	1	QSHI	BASALT OF MOUNT ST. HELENS

Table 1 (Cont'd)

Sample Number	Map Unit Symbol	Unit Name
104	Qbp	Basalt of Burnt Peak
105	Qbp	Basalt of Burnt Peak
106	Qbp	Basalt of Burnt Peak
107	Qih	Basalt of Indian Heaven
108	Qih	Basalt of Indian Heaven
109	Qtl	Basalt of Thomas Lake
110	Qsl	Basalt of Surprise Lakes
111	Qsl	Basalt of Surprise Lakes
112	Qmc	Andesite of Meadow Creek
113	Qoc	Basalt of Outlaw Creek
114	Qlc	Basalt of Lake Comcomly
115	Qgp	Basalt of Gifford Peak
116	Qbl	Basalt of Big Lava Bed
117	Qbl	Basalt of Big Lava Bed
118	Qbl	Basalt of Big Lava Bed
119	Qbl	Basalt of Big Lava Bed
120	Qpm	Basalt of Papoose Mountain
121	Qbc	Andesite of Black Creek
122	Qih	Basalt of Indian Heaven
123	Qtch	Basalt of Trout Creek Hill
124	Qtch	Basalt of Trout Creek Hill
125	Qrkb	Basalt of Rock Creek
126	Qrkb	Basalt of Rock Creek
127	Qjc	Andesite of Juice Creek
128	Qih(?)	Basalt of Indian Heaven(?)
129	Qfl	Andesite of Forlorn Lakes
130	Qcc	Basalt of Cedar Creek
131	Qby	Basalt of Berry Mountain
132	Qcb	Cave Basalt
133	Qcb(?)	Cave Basalt
134	Qcb	Cave Basalt
135	Qcb(?)	Cave Basalt (?)
136	Qmmb	Basalt of Marble Mountain
137	Qsh_2	Andesite of Mount St. Helens
138	Qsh_3	Andesite of Mount St. Helens
139	Qrp	Basalt of Ruthon Point
140	Qrp	Basalt of Ruthon Point
141	Qaa_3	Andesite of Mount Adams
142	Qaa_3	Andesite of Mount Adams
143	Qaa_3	Andesite of Mount Adams
144	Qaa_3	Andesite of Mount Adams
145	Qaa_2	Andesite of Mount Adams
146	Qaa_3	Andesite of Mount Adams
147	Qaa_3	Andesite of Mount Adams
148	Qaa_3	Andesite of Mount Adams
149	Qaa_3	Andesite of Mount Adams
150	Qaa_2	Andesite of Mount Adams

Table 1 (Cont'd)

Sample Number	Map Unit Symbol	Unit Name
151	Qaa_1	Andesite of Mount Adams
152	Qaa_1	Andesite of Mount Adams
153	Qjc	Andesite of Juice Creek
154	Qfl	Andesite of (lower) Forlorn Lakes
155	Qtch	Basalt of Trout Creek Hill
156	Qlc	Basalt of Little Goose Creek
157	Qmc	Andesite of Lake Comcomly
158	Qlg	Basalt of Little Goose Creek
159	Qhl	Basalt of Hidden Lakes
160	Qtp	Basalt of Timbered Peak
161	Qb	Basalt, undivided
162	Qb	Basalt, undivided
163	Qern	Basalt of Ecklandt Ridge, N.
164	Qsl	Basalt of Surprise Lakes
165	Qchc	Andesite of Chinook Creek
176	Qtl	Basalt of Thomas Lake
177	Qmc	Andesite of Meadow Creek
178	Qsl	Basalt of Surprise Lakes
179	Qbc	Andesite of Black Creek
180	Qlg	Basalt of Little Goose Creek
181	Qhl	Basalt of Hidden Lakes
182	Qgl	Basalt of Goose Lake
183	Qjc	Andesite of Juice Creek
184	Qpl	Basalt of Placid Lake
185	Qsbm	Basalt of SE Bird Mountain
186	Qecr	
187	Qser	Basalt of SE Red Mountain
188	Qpm	Basalt of Papoose Mountain
189	Qspl	Basalt of Sheep Lakes
190	Qner	Andesite of NE Red Mountain
191	Qstm	Basalt of Sawtooth Mountain
192	Qnbm	Basalt North of Bird Mountain
193	Qfl	Andesite of Forlorn Lakes
194	Qby	Basalt of Berry Mountain
195	Qspl	Basalt of Sheep Lakes
196	Qlc	Basalt of Lake Comcomly
197	Qtw	Basalt of The Wart
198	Qflu	Andesite of Forlorn Lakes

symbols, and unit names for samples 104-198. Descriptions of most of these units are presented in Hammond (1980). In addition to longitude and latitude, location by zone is given, referring to the zones shown in figure 1. Quaternary volcanic centers in the south Cascades concentrate roughly into 3 north-south oriented belts and one east-west belt.

The Mount St. Helens zone, number 1, extends from Mount St. Helens on the north to Trout Creek Hill on the south. It includes the Marble Mountain, Soda Peak, and West Crater volcanic centers. Some of the youngest volcanic activity in the study area is included in this zone.

To the east, the Indian Heaven zone extends from the Burnt Peak basalt at Lone Butte and Steamboat Mountain on the north, to the Big Lava Bed on the south. It includes the numerous basalt flows, shield volcanoes, cinder cones, and fissure zones known collectively as Indian Heaven. The basalt flows near Spud Hill may be a northern extension of this belt and have therefore been assigned to zone 2.

The Mount Adams zone, which falls between Indian Heaven and the Simcoe Mountains volcanic area, is the largest belt in terms of flow area and total length. It extends from the volcanoes of the White Pass-Tumac Mountain area south to the King Mountain fissure zone, and includes the Goat Rocks volcanic complex and the Mount Adams stratovolcano. Only the volcanics occurring south of Goat Rocks were considered in this study.

A fourth belt extends east-west, roughly parallel to the Columbia River, and has been divided into a western section (zone 4) and an eastern section (zone 5). The Columbia River belt consists of scattered volcanic centers, including the Boring basalts and Skamania volcanics in the western zone, and the basalts of Underwood Mountain and White Salmon to the east. The volcanics of the Mount Defiance-Hood River area in Oregon may also be a part of the Columbia River zone.

Table 2 presents unnormalized major and minor oxide data for the study area. Analyses were carried out by A. N. Baxter, using x-ray fluorescence and Table 3 consists of the oxide data normalized to a volatile-free (H_2O and CO_2 free) basis, Table 4 presents the concentrations of 13 trace elements in parts per million (p.p.m.) for the volcanic rocks. These values were also determined by A. N. Baxter. Table 5 gives the specific gravity values for samples 1 through 71.

Radiometric age dates and the results of remanent magnetic polarization studies are contained in Table 6. The age dates, which have been determined by four different labs (identified in Table 6), include 19 K-Ar and 2 ^{14}C dates.

Flow volume estimates for 63 separate flows, representing most of the major flows which had been sampled, are presented in Table 7. The summation of volumes reported for each zone only includes studied flows. The actual total volume for a zone may be significantly greater. Table 8 is an alphabetical reference list of the symbols and informal names for all volcanic flows within the study area.

Descriptions of Figures

Variation diagrams for major element oxides versus silica are presented in figures 2 through 11, using normalized data from Table 3. Figure 12 diagrams CaO vs. MgO, and K_2O vs. TiO_2 is plotted in figure 13.

Figure 14 is a plot of the ratio of Fe total/ (Fe total + MgO) vs. the Larson Index (1/3 SiO_2 - Ca) - MgO + K_2O).

Figure 15 and 16 present two different classification systems based on the variation diagrams.

Table 2

UNNORMALIZED MAJOR AND MINOR OXIDE DATA

SAMPLE NUMBER	% SIO2	% AL2O3	% FE (TOTAL)	% TIO2	% MNO	% MGO	% CAO	% NA2O	% K2O	% P2O5	% H2O	% CO2	UNNORMALIZED TOTAL
1	58.80	16.30	6.60	1.34	0.11	3.20	6.00	4.00	1.85	0.30	1.51	.	100.010
2	60.80	17.20	5.20	1.20	0.08	1.80	5.10	4.60	2.70	0.34	0.66	.	99.680
3	60.80	16.80	5.20	1.16	0.08	1.80	5.00	4.44	2.60	0.35	1.07	.	99.300
4	49.20	16.70	10.00	1.48	0.18	7.60	9.90	3.12	0.40	0.15	0.91	.	99.640
5	53.50	16.80	8.60	1.24	0.15	6.15	8.85	3.40	0.80	0.11	0.18	.	99.780
6	50.60	16.80	9.00	1.52	0.17	7.00	9.90	3.16	0.80	0.23	0.78	.	99.960
7	48.90	17.00	9.80	1.30	0.18	8.10	9.85	2.96	0.30	0.11	0.66	.	99.160
8	47.05	16.78	10.01	1.23	0.17	8.79	11.02	2.91	0.33	0.10	0.08	.	98.470
9	50.60	17.30	9.00	1.22	0.17	6.95	9.65	3.20	0.55	0.16	0.89	.	99.690
10	48.00	17.40	9.80	1.26	0.18	7.95	9.90	3.12	0.25	0.12	0.36	0.180	98.520
11	50.40	17.00	9.80	1.14	0.17	7.75	9.60	3.00	0.50	0.13	0.18	.	99.670
12	50.40	16.70	9.60	1.50	0.18	7.10	9.60	3.28	0.50	0.17	0.73	0.030	99.790
13	52.60	16.30	7.60	1.40	0.14	7.40	8.30	3.52	1.10	0.32	1.32	.	100.000
14	52.00	15.70	8.40	1.32	0.14	7.35	8.45	3.52	1.40	0.38	0.99	.	99.650
15	51.60	16.55	8.80	1.23	0.16	7.50	9.00	3.16	0.90	0.27	0.19	.	99.360
16	46.50	16.32	11.48	1.67	0.20	8.79	11.03	3.00	0.24	0.10	1.03	.	100.360
17	57.40	17.00	6.20	1.03	0.11	5.30	6.50	3.84	1.00	0.20	1.04	.	99.620
18	50.40	17.20	9.80	1.11	0.18	7.70	9.35	3.04	0.50	0.14	0.84	.	100.260
19	50.20	16.70	9.40	1.20	0.17	7.85	9.20	3.20	0.55	0.17	1.16	.	99.800
20	51.60	17.40	8.80	1.20	0.17	6.65	9.55	3.12	0.65	0.18	0.60	.	99.920
21	52.90	16.80	8.20	1.43	0.14	6.40	7.65	3.72	0.95	0.34	0.82	.	99.350
22	56.70	16.72	6.65	0.98	0.11	5.24	6.98	4.13	1.16	0.36	0.71	.	99.740
23	54.90	16.30	6.60	1.12	0.12	6.35	7.40	3.84	1.25	0.33	0.65	.	98.860
24	57.60	17.30	6.60	1.18	0.12	4.70	6.00	3.80	1.00	0.28	1.64	.	100.220
25	51.80	16.40	7.60	1.60	0.14	7.70	8.10	3.68	1.05	0.39	0.65	.	99.110
26	51.35	15.30	8.00	1.61	0.15	9.00	9.15	3.28	1.30	0.40	0.78	0.050	100.370
27	54.65	15.75	6.65	1.27	0.10	6.03	7.97	3.76	2.07	0.48	0.25	0.050	99.030
28	50.80	16.70	9.00	1.33	0.16	7.45	8.90	3.04	0.70	0.21	1.37	0.080	99.740
29	52.80	16.20	9.20	1.64	0.16	5.80	7.95	3.40	1.10	0.29	0.45	.	98.990
30	50.40	17.60	9.00	1.16	0.17	7.50	9.60	3.08	0.40	0.27	0.85	.	100.030
31	54.20	17.00	6.80	1.23	0.13	6.05	8.00	3.92	1.10	.	1.05	.	99.480
32	51.40	16.70	9.40	1.70	0.17	6.05	8.75	3.52	0.90	0.28	0.62	0.080	99.570
33	56.60	17.30	6.60	1.50	0.11	4.00	6.80	3.88	1.45	0.35	1.26	.	99.850
34	55.00	16.90	7.40	1.34	0.13	4.55	7.80	3.80	1.10	0.22	1.26	.	99.500
35	54.30	16.40	7.60	1.38	0.14	6.05	7.40	3.80	1.35	0.27	0.95	0.030	99.670
36	52.50	16.55	8.00	1.44	0.15	5.90	8.45	3.48	0.80	0.29	1.29	.	98.850
37	53.20	16.20	6.60	1.20	0.12	6.75	7.80	4.00	1.35	0.44	1.19	0.080	98.930
38	55.90	16.90	5.80	1.14	0.10	3.70	7.60	4.40	1.70	0.55	1.91	.	99.700
39	54.10	16.40	6.20	1.14	0.11	7.40	7.25	4.00	1.45	0.34	0.89	.	99.280
40	51.80	16.00	7.80	1.74	0.13	6.75	8.25	4.00	1.40	0.35	0.91	.	99.130
41	50.70	16.90	9.40	1.20	0.16	7.85	8.85	3.16	0.45	0.14	1.14	.	99.950
42	50.10	17.30	9.40	1.36	0.17	7.85	8.85	3.16	0.50	0.18	0.77	.	99.640
43	49.20	17.30	9.80	1.38	0.17	8.35	9.45	3.16	0.50	0.16	0.89	.	100.360
44	74.80	14.20	0.60	0.10	.	.	0.65	3.60	4.10	0.02	0.98	0.030	99.080
45	49.80	16.90	9.60	1.27	0.17	8.00	9.60	3.12	0.55	0.19	0.11	.	99.310
46	52.00	15.80	8.20	1.48	0.13	7.05	8.05	3.68	1.35	0.37	0.98	0.030	99.120
47	48.40	17.40	10.80	1.14	0.18	8.00	9.70	3.08	0.25	0.10	0.84	0.030	99.920
48	49.10	17.30	9.60	1.42	0.17	7.70	9.70	3.08	0.50	0.16	0.31	.	99.040
49	49.40	17.10	10.20	1.40	0.18	7.05	10.05	3.08	0.55	0.21	0.70	0.030	99.950
50	49.60	17.80	10.00	1.42	0.17	7.05	9.50	3.24	0.70	0.24	0.60	0.050	100.370
51	50.88	16.19	9.72	1.39	0.15	7.14	9.87	3.67	0.61	0.23	0.17	.	100.020
52	56.40	17.85	7.11	1.12	0.12	3.74	6.95	4.31	1.36	0.25	0.72	0.075	100.005
53	51.06	17.16	9.75	1.65	0.15	5.41	8.82	3.71	1.06	0.28	0.76	0.075	99.885

Table 2 (contd.)

UNNORMALIZED MAJOR AND MINOR OXIDE DATA

SAMPLE NUMBER	% SIO2	% AL2O3	% FE (TOTAL)	% TIO2	% MNO	% MGO	% CAO	% NA2O	% K2O	% P2O5	% H2O	% CO2	UNNORMALIZED TOTAL
54	62.89	19.82	4.48	0.56	0.07	0.57	3.84	3.92	0.60	0.14	3.04	0.025	99.955
55	57.40	17.52	6.76	1.06	0.11	3.62	7.17	4.44	1.24	0.25	0.41	.	99.980
56	50.57	17.13	10.19	1.22	0.15	6.98	10.60	3.11	0.42	0.19	.	.	100.560
57	51.51	16.83	9.11	1.22	0.15	7.05	9.64	3.20	0.44	0.20	0.35	0.100	99.800
58	48.80	15.80	10.85	1.39	0.13	7.58	10.03	2.88	0.51	0.18	0.57	0.025	98.745
59	48.92	16.90	9.97	1.06	0.14	7.87	10.34	3.26	0.65	0.20	0.17	0.050	99.530
60	52.46	17.08	8.98	1.25	0.12	5.45	9.52	3.35	0.71	0.20	0.55	0.025	99.695
61	51.54	16.45	9.16	1.16	0.13	6.29	10.05	3.07	0.57	0.19	0.85	0.100	99.560
62	53.82	17.00	7.36	1.06	0.11	5.75	8.78	3.63	0.86	0.19	.	0.075	98.635
63	54.52	17.43	7.38	1.16	0.09	4.74	8.50	4.19	0.88	0.25	0.68	0.050	99.870
64	51.70	17.00	8.04	1.22	0.12	6.79	9.55	3.63	0.89	0.25	0.31	0.025	99.525
65	52.63	17.33	7.62	1.12	0.11	6.79	7.24	3.60	0.90	0.25	1.95	.	99.540
66	51.00	17.21	8.65	1.55	0.13	6.72	8.78	3.94	1.04	0.29	1.04	0.025	100.375
67	53.80	17.70	7.77	1.19	0.11	5.43	8.25	3.99	1.08	0.31	0.43	.	100.060
68	53.20	16.56	8.02	1.22	0.11	6.28	7.94	4.56	1.02	0.28	0.21	.	99.400
69	52.55	17.04	8.20	1.49	0.13	5.96	8.22	4.01	1.01	0.30	0.78	0.025	99.715
70	53.65	16.53	7.88	1.25	0.11	6.66	8.78	3.44	0.70	0.23	0.92	.	100.150
71	55.11	17.33	6.82	1.06	0.10	5.70	7.39	4.22	1.02	0.24	0.78	.	99.770
72	58.41	17.07	6.29	1.02	0.08	3.86	6.65	4.23	1.52	0.27	0.39	.	99.790
73	55.60	18.64	6.60	0.99	0.10	3.52	7.06	4.90	0.83	0.27	0.39	.	98.900
74	52.15	15.51	9.07	1.35	0.13	7.57	8.39	3.55	1.15	0.33	0.55	.	99.750
75	50.00	18.01	9.46	1.29	0.16	7.28	9.29	3.11	0.60	0.23	0.63	.	100.060
76	48.71	16.97	10.24	1.06	0.15	8.05	10.11	3.39	0.50	0.18	0.43	.	99.790
77	50.02	16.80	9.03	1.12	0.15	8.31	9.56	3.08	0.65	0.19	0.57	.	99.480
78	50.26	16.62	9.77	1.39	0.15	7.38	9.80	3.13	0.80	0.23	0.51	.	100.040
79	49.00	15.95	9.96	1.49	0.15	7.81	10.52	3.01	1.40	0.35	0.41	.	100.050
80	49.07	16.26	9.63	1.62	0.14	7.24	10.37	3.36	1.05	0.33	0.80	.	99.870
81	50.00	16.01	9.08	1.72	0.13	8.21	9.42	3.76	1.15	0.31	0.23	0.050	100.070
82	52.40	16.16	6.88	1.02	0.10	7.45	8.35	3.91	1.85	0.35	0.26	0.025	98.755
83	48.34	17.75	10.06	1.09	0.15	7.67	10.16	3.36	0.25	0.17	0.40	.	99.400
84	47.65	16.35	10.27	1.39	0.16	7.86	10.43	3.20	0.30	0.18	0.49	.	98.280
85	53.75	15.95	8.19	1.32	0.13	6.19	7.98	3.88	1.40	0.24	0.29	0.025	99.345
86	47.54	17.66	10.03	1.16	0.16	8.22	10.36	2.66	0.25	0.16	1.46	.	99.660
87	51.46	16.29	8.87	1.35	0.13	6.77	9.05	3.85	0.70	0.23	1.22	.	99.920
88	48.69	16.77	10.76	1.55	0.17	6.83	10.48	3.26	0.65	0.25	0.59	.	100.000
89	49.34	16.84	9.19	1.19	0.16	8.24	9.89	3.42	0.45	0.20	0.15	.	99.070
90	65.24	15.59	4.37	0.66	0.07	1.88	4.01	4.28	2.80	0.15	0.81	.	99.860
91	50.00	15.56	9.40	1.95	0.15	8.29	8.59	3.46	1.20	0.34	1.19	.	100.130
92	48.95	17.02	8.34	1.25	0.14	8.15	9.68	3.45	1.30	0.34	0.44	.	99.060
93	47.83	16.41	11.08	1.65	0.18	7.22	10.35	3.51	0.30	0.19	0.33	.	99.050
94	49.45	15.76	8.26	1.35	0.13	8.56	9.40	3.76	1.40	0.35	0.42	0.050	98.890
95	53.61	17.20	7.64	1.35	0.13	6.18	7.53	4.14	1.20	0.29	0.83	.	100.100
96	52.64	17.72	7.93	1.16	0.13	5.59	8.87	3.91	0.80	0.19	1.07	.	100.010
97	57.06	18.34	7.10	1.19	0.11	5.14	7.09	.	1.00	0.25	1.29	.	98.570
98	56.00	16.41	9.05	1.42	0.13	8.15	8.59	3.42	1.70	0.33	1.30	0.025	106.525
99	51.51	18.57	8.47	1.32	0.13	6.75	7.57	3.71	0.35	0.28	1.59	.	100.250
100	51.10	16.69	8.31	1.39	0.13	7.78	8.73	3.58	1.05	0.26	0.75	.	99.770
101	53.80	16.90	7.33	1.12	0.11	6.86	7.56	4.22	1.50	0.28	0.73	0.025	100.435
102	48.89	16.41	8.17	1.42	0.12	9.56	10.58	3.45	0.25	0.27	0.54	0.050	99.710
103	51.00	17.11	9.47	1.68	0.14	5.42	8.81	3.79	0.90	0.26	1.05	.	99.630

Table 3

MAJOR AND MINOR OXIDE DATA NORMALIZED TO 100% ON VOLATILE-FREE BASIS

SAMPLE NUMBER	% SIO2	% AL2O3	% FE (TOTAL)	% TIO2	% MNO	% MGO	% CAO	% NA2O	% K2O	% P2O5
1	59.70	16.55	6.70	1.36	0.11	3.25	6.09	4.06	1.88	0.30
2	61.40	17.37	5.25	1.21	0.08	1.82	5.15	4.65	2.73	0.34
3	61.90	17.10	5.29	1.18	0.08	1.83	5.09	4.52	2.65	0.36
4	49.83	16.91	10.13	1.50	0.18	7.70	10.03	3.16	0.41	0.15
5	53.71	16.87	8.63	1.24	0.15	6.17	8.89	3.41	0.80	0.11
6	51.02	16.94	9.07	1.53	0.17	7.06	9.98	3.19	0.81	0.23
7	49.64	17.26	9.95	1.32	0.18	8.22	10.00	3.01	0.30	0.11
8	47.82	17.05	10.17	1.25	0.17	8.93	11.20	2.96	0.34	0.10
9	51.21	17.51	9.11	1.23	0.17	7.03	9.77	3.24	0.56	0.16
10	48.99	17.76	10.00	1.29	0.18	8.11	10.10	3.18	0.26	0.12
11	50.66	17.09	9.85	1.15	0.17	7.79	9.65	3.02	0.50	0.13
12	50.89	16.86	9.69	1.51	0.18	7.17	9.69	3.31	0.50	0.17
13	53.30	16.52	7.70	1.42	0.14	7.50	8.41	3.57	1.11	0.32
14	52.71	15.91	8.51	1.34	0.14	7.45	8.56	3.57	1.42	0.39
15	52.03	16.69	8.87	1.24	0.16	7.56	9.08	3.19	0.91	0.27
16	46.81	16.43	11.56	1.68	0.20	8.85	11.10	3.02	0.24	0.10
17	58.23	17.24	6.29	1.04	0.11	5.38	6.59	3.90	1.01	0.20
18	50.69	17.30	9.86	1.12	0.18	7.74	9.40	3.06	0.50	0.14
19	50.89	16.93	9.53	1.22	0.17	7.96	9.33	3.24	0.56	0.17
20	51.95	17.52	8.86	1.21	0.17	6.70	9.62	3.14	0.65	0.18
21	53.69	17.05	8.32	1.45	0.14	6.50	7.76	3.78	0.96	0.35
22	57.26	16.88	6.72	0.99	0.11	5.29	7.05	4.17	1.17	0.36
23	55.90	16.60	6.72	1.14	0.12	6.47	7.53	3.91	1.27	0.34
24	58.43	17.55	6.70	1.20	0.12	4.77	6.09	3.85	1.01	0.28
25	52.61	16.66	7.72	1.63	0.14	7.82	8.23	3.74	1.07	0.40
26	51.59	15.37	8.04	1.62	0.15	9.04	9.19	3.30	1.31	0.40
27	55.35	15.95	6.74	1.29	0.10	6.11	8.07	3.81	2.10	0.49
28	51.68	16.99	9.16	1.35	0.16	7.58	9.05	3.09	0.71	0.21
29	53.58	16.44	9.34	1.66	0.16	5.89	8.07	3.45	1.12	0.29
30	50.82	17.75	9.07	1.17	0.17	7.56	9.68	3.11	0.40	0.27
31	55.06	17.27	6.91	1.25	0.13	6.15	8.13	3.98	1.12	.
32	51.99	16.89	9.51	1.72	0.17	6.12	8.85	3.56	0.91	0.28
33	57.41	17.55	6.69	1.52	0.11	4.06	6.90	3.94	1.47	0.36
34	55.99	17.20	7.53	1.36	0.13	4.63	7.94	3.87	1.12	0.22
35	55.02	16.62	7.70	1.40	0.14	6.13	7.50	3.85	1.37	0.27
36	53.81	16.96	8.20	1.48	0.15	6.05	8.66	3.57	0.82	0.30
37	54.47	16.59	6.76	1.23	0.12	6.91	7.99	4.10	1.38	0.45
38	57.16	17.28	5.93	1.17	0.10	3.78	7.77	4.50	1.74	0.56
39	54.99	16.67	6.30	1.16	0.11	7.52	7.37	4.07	1.47	0.35
40	52.74	16.29	7.94	1.77	0.13	6.87	8.40	4.07	1.43	0.36
41	51.31	17.10	9.51	1.21	0.16	7.94	8.96	3.20	0.46	0.14
42	50.67	17.50	9.51	1.38	0.17	7.94	8.95	3.20	0.51	0.18
43	49.46	17.39	9.85	1.39	0.17	8.39	9.50	3.18	0.50	0.16
44	76.27	14.48	0.61	0.10	.	.	0.66	3.67	4.18	0.02
45	50.20	17.04	9.68	1.28	0.17	8.06	9.68	3.15	0.55	0.19
46	53.00	16.10	8.36	1.51	0.13	7.19	8.21	3.75	1.38	0.38
47	48.86	17.57	10.90	1.15	0.18	8.08	9.79	3.11	0.25	0.10
48	49.73	17.52	9.72	1.44	0.17	7.80	9.82	3.12	0.51	0.16
49	49.79	17.23	10.28	1.41	0.18	7.11	10.13	3.10	0.55	0.21
50	49.74	17.85	10.03	1.42	0.17	7.07	9.53	3.25	0.70	0.24
51	50.96	16.21	9.73	1.39	0.15	7.15	9.83	3.68	0.61	0.23
52	56.85	17.99	7.17	1.13	0.12	3.77	7.01	4.34	1.37	0.25
53	51.55	17.32	9.84	1.67	0.15	5.46	8.90	3.75	1.07	0.28

Table 3 (contd.)

MAJOR AND MINOR OXIDE DATA NORMALIZED TO 100% ON VOLATILE-FREE BASIS

SAMPLE NUMBER	% SIO2	% AL2O3	% FE (TOTAL)	% TIO2	% MNO	% MGO	% CAO	% NA2O	% K2O	% P2O5
54	64.91	20.46	4.62	0.58	0.07	0.59	3.96	4.05	0.62	0.14
55	57.65	17.60	6.79	1.06	0.11	3.64	7.20	4.46	1.25	0.25
56	50.29	17.03	10.13	1.21	0.15	6.94	10.54	3.09	0.42	0.19
57	51.85	16.94	9.17	1.23	0.15	7.10	9.70	3.22	0.44	0.20
58	49.72	16.10	11.05	1.42	0.13	7.72	10.22	2.93	0.52	0.18
59	49.26	17.02	10.04	1.07	0.14	7.92	10.41	3.28	0.65	0.20
60	52.93	17.23	9.06	1.26	0.12	5.50	9.60	3.38	0.72	0.20
61	52.27	16.68	9.29	1.18	0.13	6.38	10.19	3.11	0.58	0.19
62	54.61	17.25	7.47	1.08	0.11	5.83	8.91	3.68	0.87	0.19
63	54.99	17.53	7.44	1.17	0.09	4.78	8.57	4.23	0.89	0.25
64	52.12	17.14	8.11	1.23	0.12	6.85	9.63	3.66	0.90	0.25
65	53.93	17.76	7.81	1.15	0.11	6.96	7.42	3.69	0.92	0.26
66	51.35	17.33	8.71	1.56	0.13	6.77	8.84	3.97	1.05	0.29
67	54.00	17.77	7.80	1.19	0.11	5.45	8.28	4.00	1.08	0.31
68	53.63	16.70	8.09	1.23	0.11	6.33	8.00	4.60	1.03	0.28
69	53.13	17.23	8.29	1.51	0.13	6.03	8.31	4.05	1.02	0.30
70	54.07	16.66	7.94	1.26	0.11	6.71	8.85	3.47	0.71	0.23
71	55.67	17.51	6.89	1.07	0.10	5.76	7.47	4.26	1.03	0.24
72	58.76	17.17	6.33	1.03	0.08	3.88	6.69	4.26	1.53	0.27
73	56.44	18.92	6.70	1.00	0.10	3.57	7.17	4.97	0.84	0.27
74	52.57	15.64	9.14	1.36	0.13	7.63	8.46	3.58	1.16	0.33
75	50.29	18.11	9.51	1.30	0.16	7.32	9.34	3.13	0.60	0.23
76	49.02	17.08	10.31	1.07	0.15	8.10	10.18	3.41	0.50	0.18
77	50.57	16.99	9.13	1.13	0.15	8.40	9.67	3.11	0.66	0.19
78	50.50	16.70	9.82	1.40	0.15	7.41	9.85	3.14	0.80	0.23
79	49.18	16.01	10.00	1.50	0.15	7.84	10.56	3.02	1.41	0.35
80	49.53	16.41	9.72	1.64	0.14	7.31	10.47	3.39	1.06	0.33
81	50.11	16.04	9.10	1.72	0.13	8.23	9.44	3.77	1.15	0.31
82	53.21	16.41	6.99	1.04	0.10	7.57	8.48	3.97	1.83	0.36
83	48.83	17.93	10.16	1.10	0.15	7.75	10.26	3.39	0.25	0.17
84	48.73	16.72	10.50	1.42	0.16	8.04	10.67	3.27	0.31	0.18
85	54.28	16.11	8.27	1.33	0.13	6.25	8.06	3.92	1.41	0.24
86	48.41	17.98	10.21	1.18	0.16	8.37	10.55	2.71	0.25	0.16
87	52.14	16.50	8.99	1.37	0.13	6.86	9.17	3.90	0.71	0.23
88	48.98	16.87	10.82	1.56	0.17	6.87	10.54	3.28	0.65	0.25
89	49.88	17.02	9.29	1.20	0.16	8.33	10.00	3.46	0.45	0.20
90	65.87	15.74	4.41	0.67	0.07	1.90	4.05	4.32	2.83	0.15
91	50.54	15.73	9.50	1.97	0.15	8.38	8.68	3.50	1.21	0.34
92	49.63	17.26	8.46	1.27	0.14	8.26	9.82	3.50	1.32	0.34
93	48.45	16.62	11.22	1.67	0.18	7.31	10.48	3.56	0.30	0.19
94	50.24	16.01	8.39	1.37	0.13	8.70	9.55	3.82	1.42	0.36
95	54.00	17.33	7.70	1.36	0.13	6.23	7.59	4.17	1.21	0.29
96	53.20	17.91	8.01	1.17	0.13	5.65	8.97	3.95	0.81	0.19
97	58.66	18.85	7.30	1.22	0.11	5.28	7.29	.	1.03	0.26
98	53.23	15.60	8.60	1.35	0.12	7.75	8.17	3.25	1.62	0.31
99	52.21	18.82	8.59	1.34	0.13	6.84	7.67	3.76	0.35	0.28
100	51.61	16.86	8.39	1.40	0.13	7.86	8.82	3.62	1.06	0.26
101	53.97	16.95	7.35	1.12	0.11	6.88	7.58	4.23	1.50	0.28
102	49.32	16.56	8.24	1.43	0.12	9.64	10.67	3.48	0.25	0.27
103	51.73	17.36	9.61	1.70	0.14	5.50	8.94	3.84	0.91	0.26

Table 4

TRACE ELEMENT CONCENTRATIONS (PPM)

SAMPLE NUMBER	LI	RB	CU	SR	BA	ZN	SC	Y	LA	CE	V	CR	NI
1	20	55	55	380	370	88	16	31	27	55	137	90	19
2	20	75	41	380	420	80	13	.	34	70	87	40	9
3	27	75	38	370	420	76	13	42	36	72	85	45	.
4	10	10	87	300	80	89	32	29	7	26	201	335	97
5	15	25	52	300	130	80	29	28	9	26	170	260	40
6	11	15	71	460	220	82	33	31	16	42	197	265	52
7	9	10	69	345	70	87	31	25	5	22	183	320	82
8	9	15	73	340	100	83	32	23	7	24	240	246	167
9	10	15	63	325	160	86	32	29	10	30	190	245	40
10	9	10	74	330	50	88	31	25	5	21	197	350	4
11	9	15	61	335	100	90	28	22	8	26	172	330	82
12	8	10	80	380	90	89	31	29	8	25	227	275	59
13	12	25	63	565	250	84	22	22	17	36	169	360	100
14	11	20	70	840	430	97	21	21	29	60	160	320	120
15	11	15	63	740	320	89	26	24	19	43	174	360	90
16	9	10	98	287	84	89	34	30	8	25	273	225	168
17	13	15	32	660	320	89	16	19	18	36	124	225	73
18	10	10	60	400	120	88	30	25	9	26	176	325	62
19	10	15	60	380	130	89	30	26	10	27	172	365	86
20	10	10	54	385	190	82	33	28	13	32	192	255	34
21	13	15	60	540	280	99	21	24	18	39	158	230	69
22	16	20	72	958	366	94	15	19	25	53	128	197	130
23	14	15	63	990	380	90	17	20	24	50	145	310	108
24	14	20	46	550	270	90	17	22	19	39	142	205	56
25	17	15	63	630	260	93	23	25	20	45	175	400	120
26	12	20	76	1020	430	90	23	21	26	59	193	565	178
27	47	25	75	1246	407	151	17	20	37	87	151	160	142
28	11	10	68	470	180	93	28	26	12	33	182	375	69
29	17	25	71	360	220	99	24	31	18	42	190	230	44
30	10	10	60	345	120	81	31	26	8	24	182	195	42
31	16	15	63	930	370	92	20	22	24	50	167	245	76
32	15	25	80	360	180	97	27	33	16	38	202	185	46
33	13	35	65	510	390	90	18	27	26	52	161	60	23
34	18	25	52	450	250	91	24	28	17	38	167	100	20
35	17	30	73	450	260	88	22	28	20	45	163	250	59
36	13	15	82	500	230	91	26	26	16	39	173	260	56
37	16	15	121	860	440	99	18	20	29	63	160	290	100
38	20	20	115	920	640	120	16	22	43	87	128	85	32
39	18	20	65	230	480	81	17	19	30	61	149	340	144
40	15	20	43	1030	370	100	19	22	28	63	183	310	79
41	87	15	78	300	120	174	27	26	6	28	182	365	76
42	12	10	68	360	130	75	28	24	8	28	198	365	76
43	10	10	65	370	120	73	27	24	8	28	198	380	79
44	7	150	5	60	690	38	3	34	32	67	11	30	11
45	11	15	63	315	130	74	28	26	24	28	183	355	59
46	12	15	90	750	360	89	20	23	25	57	167	315	83
47	9	10	77	265	70	88	26	23	5	21	176	290	79
48	.	10	.	350	270	.	.	.	.	.	.	375	76
49	9	10	63	320	160	81	32	28	10	31	203	245	28
50	11	10	70	405	200	81	28	28	14	38	198	285	51
51	10	17	60	365	190	82	26	26	12	39	185	173	102
52	14	20	51	576	372	82	15	25	21	47	122	74	58
53	14	26	73	376	252	85	23	31	18	44	185	144	88

Table 4 (contd.)

TRACE ELEMENT CONCENTRATIONS (PPM)

SAMPLE NUMBER	LI	RB	CU	SR	BA	ZN	SC	Y	LA	CE	V	CR	NI
54	18	7	33	409	524	75	8	20	34	51	56	23	21
55	13	30	47	563	376	81	15	25	21	47	121	69	59
56	9	16	65	381	127	78	27	24	7	27	190	184	107
57	9	12	84	509	178	82	25	21	11	34	184	214	125
58	11	14	65	408	124	93	26	23	10	37	173	169	122
59	9	19	60	429	233	78	25	21	15	43	165	192	147
60	17	18	42	484	199	149	26	24	14	44	179	111	54
61	12	12	53	439	168	82	26	22	13	42	83	138	70
62	11	12	47	560	217	73	17	16	11	31	143	155	115
63	14	16	53	644	234	89	19	18	17	44	140	78	75
64	9	16	60	751	368	74	19	20	17	45	165	173	130
65	14	16	43	608	245	86	20	19	19	43	158	148	158
66	14	18	65	622	209	89	22	24	17	46	186	213	122
67	13	18	59	856	413	89	19	20	25	60	155	119	102
68	14	16	51	709	356	89	19	22	20	49	150	159	145
69	13	15	54	641	241	89	22	35	26	50	186	154	119
70	12	11	53	772	309	87	18	18	17	46	150	179	143
71	14	16	43	849	372	88	17	18	19	44	146	112	140
72	14	21	37	851	283	80	14	19	24	54	131	68	56
73	18	16	53	677	240	92	14	20	15	38	122	66	58
74	15	21	76	604	268	107	22	24	20	51	175	178	172
75	13	13	53	376	199	92	34	30	14	43	210	152	77
76	13	12	55	392	138	88	31	26	10	31	189	175	124
77	10	16	52	410	169	74	27	24	11	32	164	216	132
78	9	16	65	504	251	81	26	25	15	42	201	203	107
79	14	30	68	718	478	99	31	31	30	73	227	239	97
80	13	17	68	621	274	90	29	28	23	57	220	158	87
81	13	21	68	611	245	88	24	25	21	49	190	234	166
82	16	30	45	946	500	92	20	20	37	81	170	242	164
83	11	9	70	287	72	86	24	21	6	24	161	166	116
84	12	12	80	254	73	86	30	27	8	33	198	281	140
85	17	30	55	397	233	84	21	27	22	54	157	171	101
86	10	10	65	244	71	73	32	25	7	29	175	152	127
87	12	13	63	476	191	84	24	24	17	44	169	189	96
88	12	16	63	338	165	96	32	30	12	41	206	179	73
89	13	11	88	336	111	81	30	25	9	29	203	211	145
90	22	81	28	318	475	62	11	25	32	59	86	36	26
91	15	23	65	618	286	103	22	25	24	56	195	215	176
92	13	24	79	756	368	79	32	27	28	67	180	203	146
93	13	10	98	256	86	93	35	31	8	30	233	171	117
94	14	23	71	888	396	82	26	24	33	73	170	246	175
95	13	16	59	624	256	78	19	25	20	44	159	150	124
96	13	18	60	464	194	73	24	23	13	36	179	97	53
97	17	21	52	594	283	87	16	20	17	42	133	106	97
98	12	28	62	955	532	92	22	23	38	82	156	193	177
99	14	10	54	637	262	96	18	25	23	47	147	148	144
100	14	21	56	506	258	81	20	22	18	46	163	221	156
101	15	24	52	774	445	85	18	20	30	67	145	171	150
102	14	10	54	779	395	83	17	20	25	57	147	105	96
103	15	22	84	405	240	90	26	32	15	44	201	132	73

Table 5: Specific Gravity Determinations (gm/cm^3)

Sample No.	Specific Gravity	Sample No.	Specific Gravity
1	2.462	37	2.667
2	2.609	38	2.498
3	2.609	39	2.707
4	2.713	40	2.702
5	2.730	41	2.636
6	2.799	42	2.699
7	2.749	43	2.759
8	2.596	44	2.417
9	2.631	45	2.844
10	2.431	46	2.793
11	2.685	47	2.799
12	2.805	48	2.656
13	2.694	49	2.516
14	2.735	50	2.795
15	2.672	51	3.018
16	2.870	52	2.649
17	2.646	53	2.873
18	2.629	54	2.189
19	2.676	55	2.817
20	2.733	56	3.099
21	2.780	57	3.049
22	2.540	58	2.989
23	2.911	59	2.984
24	2.705	60	2.884
25	2.906	61	2.978
26	2.937	62	2.976
27	2.671	63	3.084
28	2.729	64	2.721
29	2.760	65	2.643
30	2.655	66	2.680
31	2.735	67	2.677
32	2.727	68	2.576
33	2.599	69	2.538
34	2.662	70	2.604
35	2.619	71	2.655
36	2.741		

Table 6 — Radiometric Age Dates

Sample*	Map Unit	RMP**	Age (million years)	Method
89	Qpf	N	0.04 ± 0.03 (4)	K-Ar
72	Qmma	N	0.16 ± 0.01 (4)	K-Ar
32	Qcpk	N	0.2 ± 0.034 (4)	K-Ar
32	Qcpk	N	0.24 ± 0.71 (2)	K-Ar
155	Qtch	N	0.34 ± 0.07 (4)	K-Ar
5	Qtls	N	0.35 ± 0.06 (4)	K-Ar
37	Qsdp	N	0.36 ± 0.01 (4)	K-Ar
1	Qsm	N	0.37 ± 0.01 (4)	K-Ar
16	Qtc	N	0.47 ± 0.04 (4)	K-Ar
61	Qum	N	0.85 ± 0.02 (4)	K-Ar
14	Qsl	N	0.85 ± 0.05 (3)	K-Ar
28	Qwsc	-	0.93 ± 0.82 (2)	K-Ar
28	Qwsc	-	1.34 ± 0.02 (4)	K-Ar
30	Qtlc	N	0.98 ± 0.12 (4)	K-Ar
128	Qjc	-	1.4 ± 0.06 (3)	K-Ar
66	Qbpr	R	1.53 ± 0.20 (2)	K-Ar
51	Qgc	R	1.76 ± 0.50 (2)	K-Ar
17	Qbc	N	3.3 ± 0.25 (3)	K-Ar
12	Qte	N	3.7 ± 0.5 (1)	K-Ar
39	Qpc	N	0.0077 ± 0.00028 (1)	^{14}C
42,43	Qbl	N	0.0082 ± 0.0001 (1)	^{14}C

NOTES:

*See sample numbers, Table 1.

**Remnant Magnetic Polarity. N = Normal R = Reversed

1. Date by H. W. Fairhall, University of Washington, Seattle.
2. Date by S. H. Evans, University of Utah Research Institute, Salt Lake City.
3. Date by E. H. McKee, U.S. Geological Survey, Menlo Park, California.
4. Date by R. A. Duncan, Oregon State University, Corvallis, Oregon.

Table 7: Flow Volume Estimates
Quaternary Volcanic Rocks
Southern Cascades Range, Washington

Volcanic Zone = 1

	Sample Number	Map Unit	Flow Volume (Km^3)
	27	QPC	0.24
	89	QPF	0.14
	132	QCB	0.12
	46	QMMB	0.68
	72	QMMA	0.07
	165	QCHC	0.05
	160	QTP	0.01
	40	QBRM	0.59
	37	QSDP	0.06
	38	QWC	0.03
	73	QWC	0.25
Sum of Zone 1:			2.24

Volcanic Zone = 2

Sample Number	Map Unit	Flow Volume (Km^3)
81	QLG + QHL	5.190
83	QIC	1.340
192	QUBM	0.070
185	QSBM	1.320
156	QLC	1.340
97	QCL	2.080
115	QGP	1.690
198	QFLU	0.120
194	QBY	1.550
193	QFLL	1.080
182	QGL	1.770
19	QDC	8.300
190	QNER	0.030
195	QSPL	0.080
187	QSER	2.650
183	QJC	2.030
197	QBC	0.040
	QCSR	0.030
118	QBL	0.880
22	QTW	8.160
130	QCC	0.030
79	QWSB	0.440
16	QTC	0.130

Table 7. (Cont.)

Volcanic Zone = 2 (Cont'd)

Sample Number	Map Unit	Flow Volume (Km^3)
26	QWSC	0.790
14	QSL + QMC	3.420
30	QTLC	1.630
98	QRL	0.004
12	QTL	5.030
11	QIH	0.490
106		1.710
13	QLB	0.330
82	QIVP	4.480
29	QDH	0.030
Sum of Zone 2:		58.264 (Km^3)

Volcanic Zone = 3

Sample Number	Map Unit	Flow Volume (Km^3)
6	QWL	0.590
5	QTLS	0.710
85	QPH	0.380
84	QSC	0.660
142	QAA3	0.260
1	QSM	0.230
88	QCP	3.620
25	QGCY	0.520
33	QSMB	0.110
32	QCPK	0.070
34	QQB	0.070
48	QGM	0.240
49	QGC	0.520
54	QTDS	0.080
52	QRS	0.020
53	QUW	0.004
Sum of Zone 3:		8.084

Volcanic Zone = 4 & 5

Sample Number	Map Unit	Flow Volume (Km^3)
70	QBM	0.230
66	QBPR	0.100
65	QMCC	0.480
61	QUW	0.750
Sum of Zone 4 & 5:		1.560
	TOTAL:	69.908

Table 8. Alphabetical Key to Map Unit Symbols

Map Unit Symbol	Map Unit Name	Corresponding Samples
Qaa	Andesite of Mount Adams	2, 3, 141-152
Qb	Basalt west of Sleeping Beauty	27, 31, 161,162
Qbc	Andesite of Black Creek	17, 21, 22, 23, 121, 179
Qbl	Basalt of Big Lava Bed	42, 43, 116, 117, 118, 119
Qbm	Basalt of Vogel Creek	70
Qbp	Basalt of Burnt Peak	104, 105, 106
Qbpr	Basalt of Bear Prairie	66
Qbr	Basalt of Beacon Rock	63, 64
Qbrm	Basalt of Bare Mountain	40
Qby	Basalt of Berry Mountain	131, 194
Qcb	Cave Basalt	132, 133, 134, 135
Qcc	Basalt of Cedar Creek	130
Qchc	Andesite of Chinook Creek	165
Qcls	Basalt of Cascade Landslide	62
Qcp	Basalt of Camas Prairie	36, 87, 88
Qcpk	Basalt of County Park	32
Qdc	Basalt of Dry Creek	19
Qdh	Basalt of Deadhorse Creek	29
Qecc	Basalt of East Canyon Creek	94
Qecr		186
Qel	Andesite of Eunice Lake	97
Qern	Basalt of Ecklandt Ridge, North	163
Qfl	Andesite of Forlorn Lakes	129, 154, 193
Qflu	Andesite of Forlorn Lakes	198
Qfm	Basalt of Flattop Mountain	91
Qgc	Basalt of Gilmer Creek	49, 50, 51
Qgcy	Basalt of Green Canyon	24, 25
Qgl	Basalt of Goose Lake	182
Qgm	Basalt of Guler Mountain	48
Qgp	Basalt of Gifford Peak	115
Qhl	Basalt of Hidden Lake	96, 159, 181
Qic	Basalt of Ice Cave	47, 83, 102
Qih	Basalt of Indian Heaven	11, 107, 108, 122, 128
Qim	Rhyolite of Mann Butte	44
Qivp	Basalt of Indian Viewpoint	82
Qjc	Andesite of Juice Creek	127, 153, 183
Qlb	Basalt of Lone Butte	13, 100
Qlc	Basalt of Lake Comcomly	9, 18, 41, 45, 76, 77,
	" " " "	114, 156, 196
Qlg	Basalt of Little Goose Creek	81, 158, 180
Qloc	Basalt of Lost Creek	95
Qlpc	Basalt of Lapham Creek	99
Qlvc	Basalt of Lava Creek	86
Qmb	Basalt of Mowich Butte	101
Qmc	Andesite of Meadow Creek	112, 157, 177
Qmcc	Basalt of McCloskey Creek	65
Qmf	Andesite of McCoy Flat	55
Qmma	Andesite of Marble Mountain	72
Qmmb	Basalt of Marble Mountain	46, 74, 136
Qmn	Basalt of Mt. Normay	69
Qmp	Basalt of Mt. Pleasant	67
Qmz	Andesite of Mt. Zion	71

Map Unit Symbol	Map Unit Name	Corresponding Samples
Qnbm	Basalt North of Bird Mountain	192
Qner	Andesite of NE Red Mountain	190
Qnw	Basalt of Northwestern Lake	53
Qoc	Basalt of Outlaw Creek	113
Qpb	Basalt of Papoose Mountain	75
Qpc	Basalt of Puny Creek	39
Qpf	Basalt of Paradise Falls	89
Qph	Basalt of Potato Hill	85
Qpl	Basalt of Placid Lake	184
Qpm	Basalt of Papoose Mountain	20, 120, 188
Qprh	Basalt of Prune Hill	68
Qqb	Andesite of Quigley Butte	34, 35
Qrkb	Basalt of Rock Creek	125, 126
Qrl	Basalt of Red Lake	98
Qrp	Basalt of Ruthon Point	139, 140
Qrs	Andesite of Rattlesnake Creek	52
Qsbm	Basalt of SE Bird Mountain	185
Qsc	Basalt of Spring Creek	4, 84, 93
Qsdp	Basalt of Soda Peak	37
Qser	Basalt of SE Red Mountain	187
Qsh	Basalt of Mount St. Helens	103, 137, 138
Qsl	Basalt of Surprise Lake	14, 15, 110, 111, 164, 178
Qsm	Andesite of Swampy Meadows	1
Qsmb	Andesite of Smith Butte	33
Qspl	Basalt of Sheep Lakes	189, 195
Qspr	Basalt of Sunrise Peak	92
Qstm	Basalt of Sawtooth Mountain	191
Qtb	Basalt of Twin Buttes	78
Qtc	Basalt of Tillicum Creek	16
Qtch	Basalt of Trout Creek Hill	123, 124, 155
Qtds	Dacite of Snowden	54
Qtl	Basalt of Thomas Lake	7, 8, 10, 12, 109, 176
Qtlc	Basalt of Trout Lake Creek	30
Qtls	Basalt of Two Lakes	5
Qtp	Basalt of Timbered Peak	160
Qtsm	Dacite of Snyder Mountain	90
Qtw	Basalt of The Wart	197
Quw	Basalt of Underwood Mountain	59, 60, 61
Qwc	Andesite of West Crater	38, 73
Qwl	Basalt of Walupt Lake	6
Qws	Basalt of White Salmon	56, 57, 58
Qwsc	Basalt West of Skull Creek	26, 28
Qwsb	Basalt of Tillicum Creek	79, 80
Qwsp	Basalt West of Sleeping Beauty	27

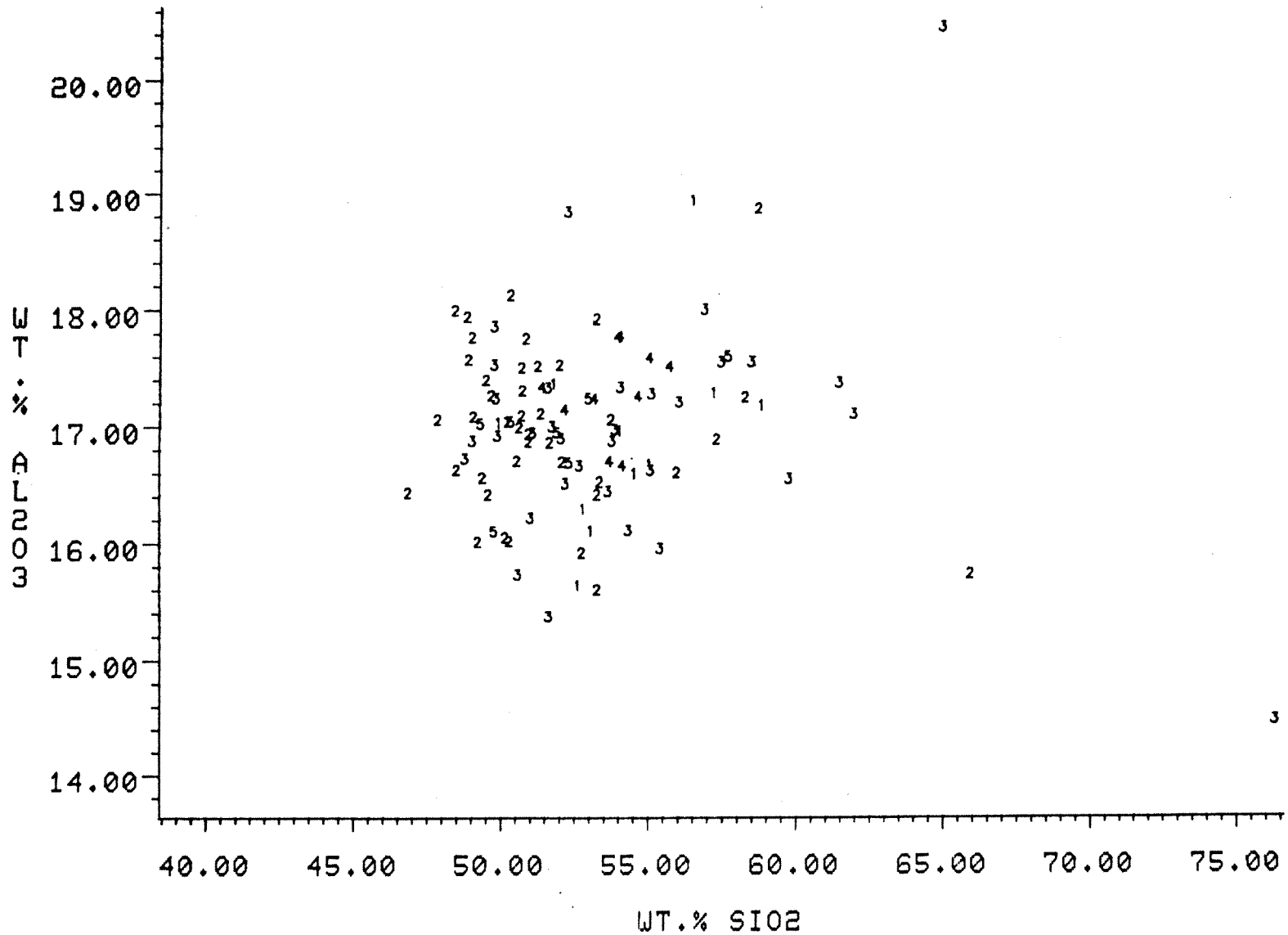

Figure 2. — Al_2O_3 vs. SiO_2 variation diagram for southern Cascade Range Quaternary volcanic rocks. Number refers to the volcanic zone of sample.

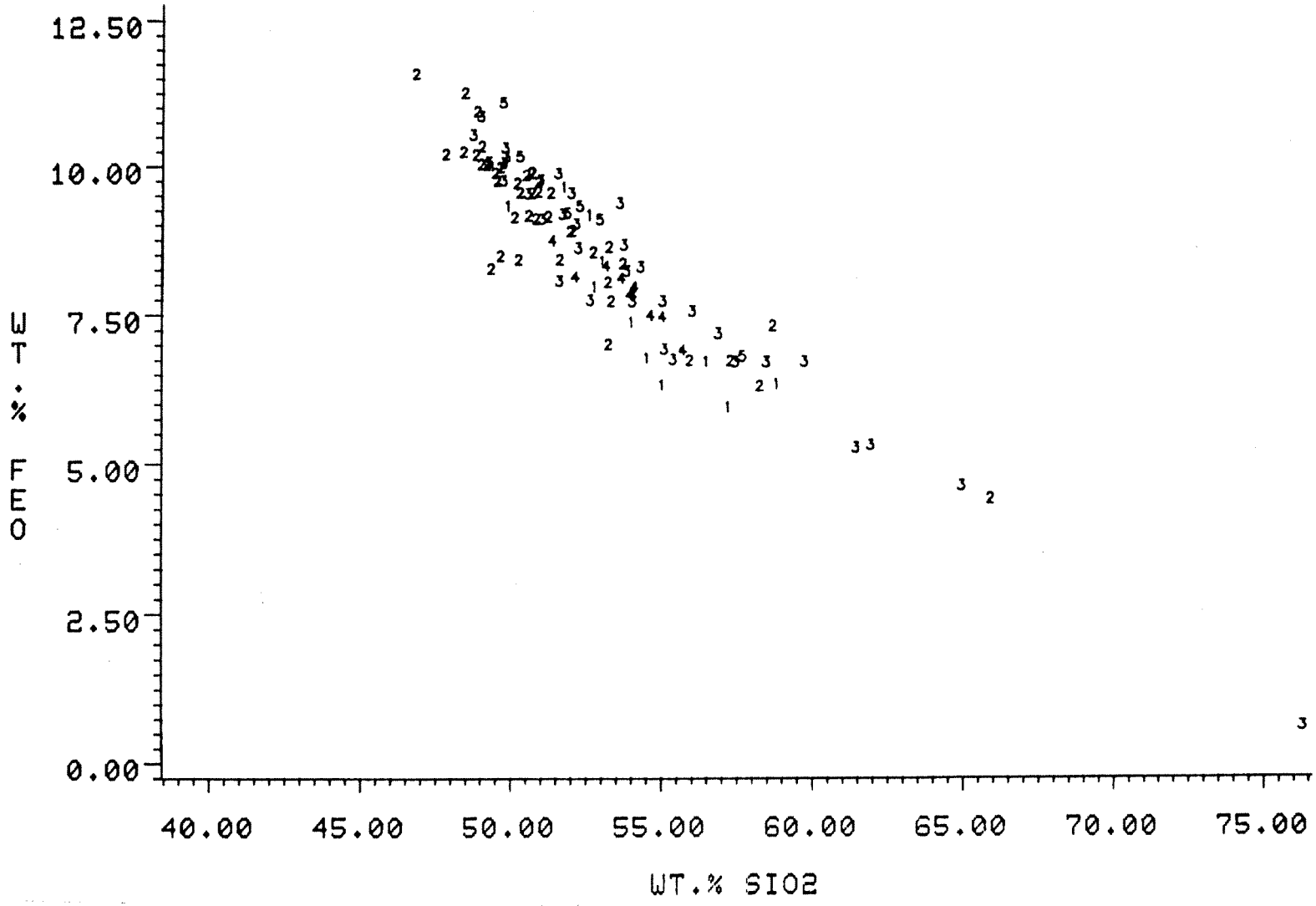

Figure 3. — Fe (total) vs. SiO_2 variation diagram. Number refers to the volcanic zone of sample.

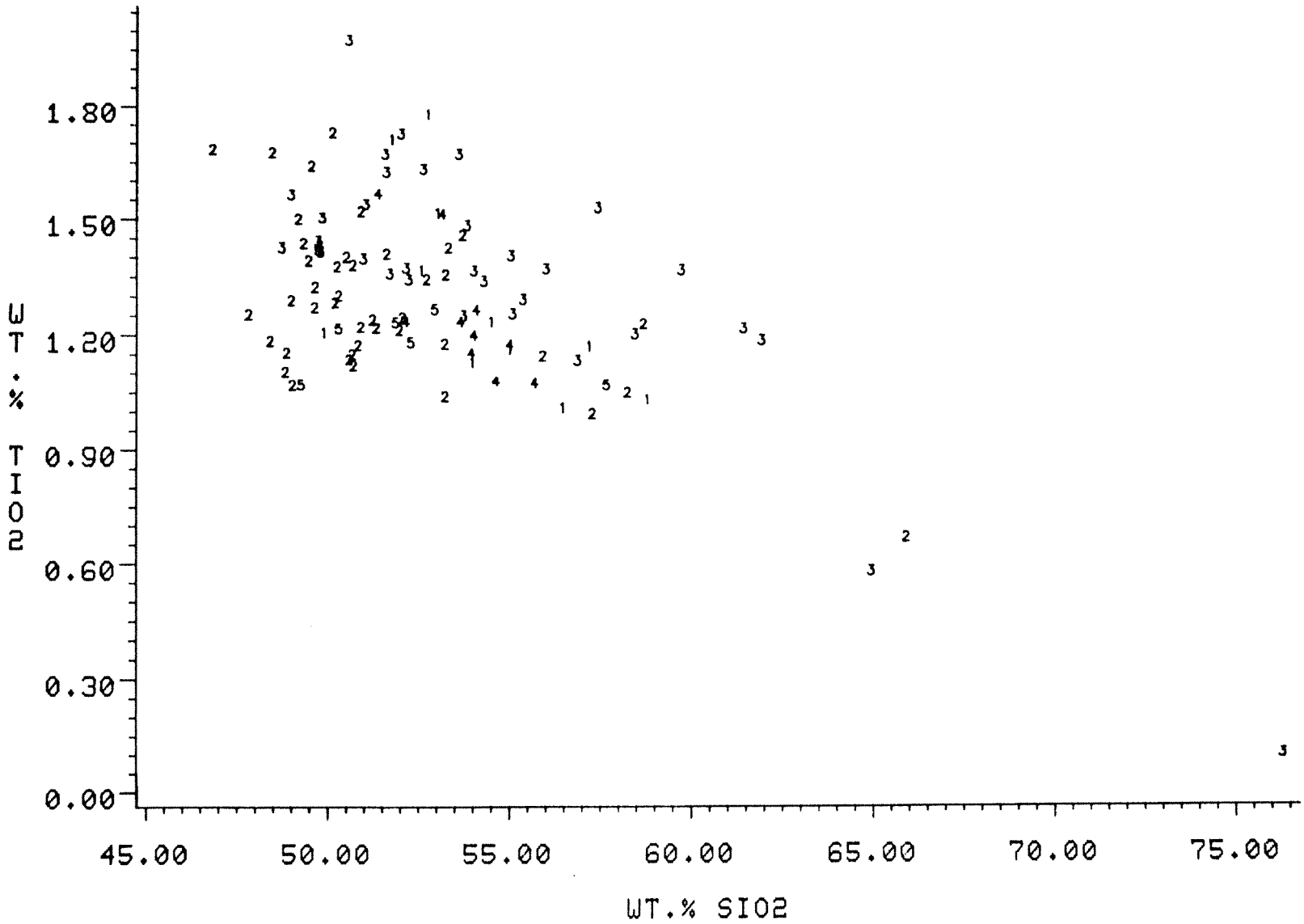

Figure 4. — TiO_2 vs. SiO_2 variation diagram. Number refers to the volcanic zone of sample.

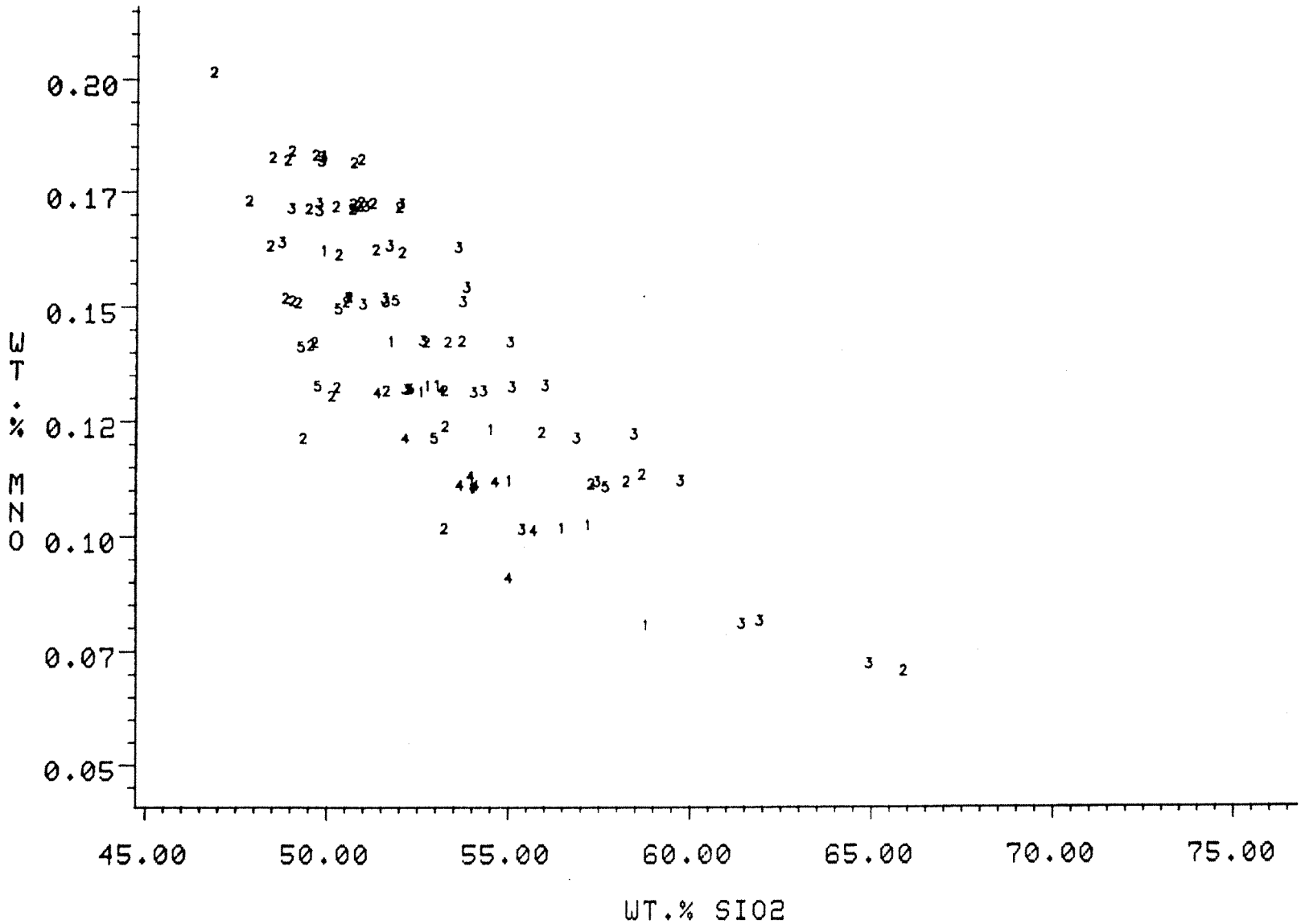

Figure 5. — MnO vs. SiO_2 variation diagram. Number refers to the volcanic zone of sample.

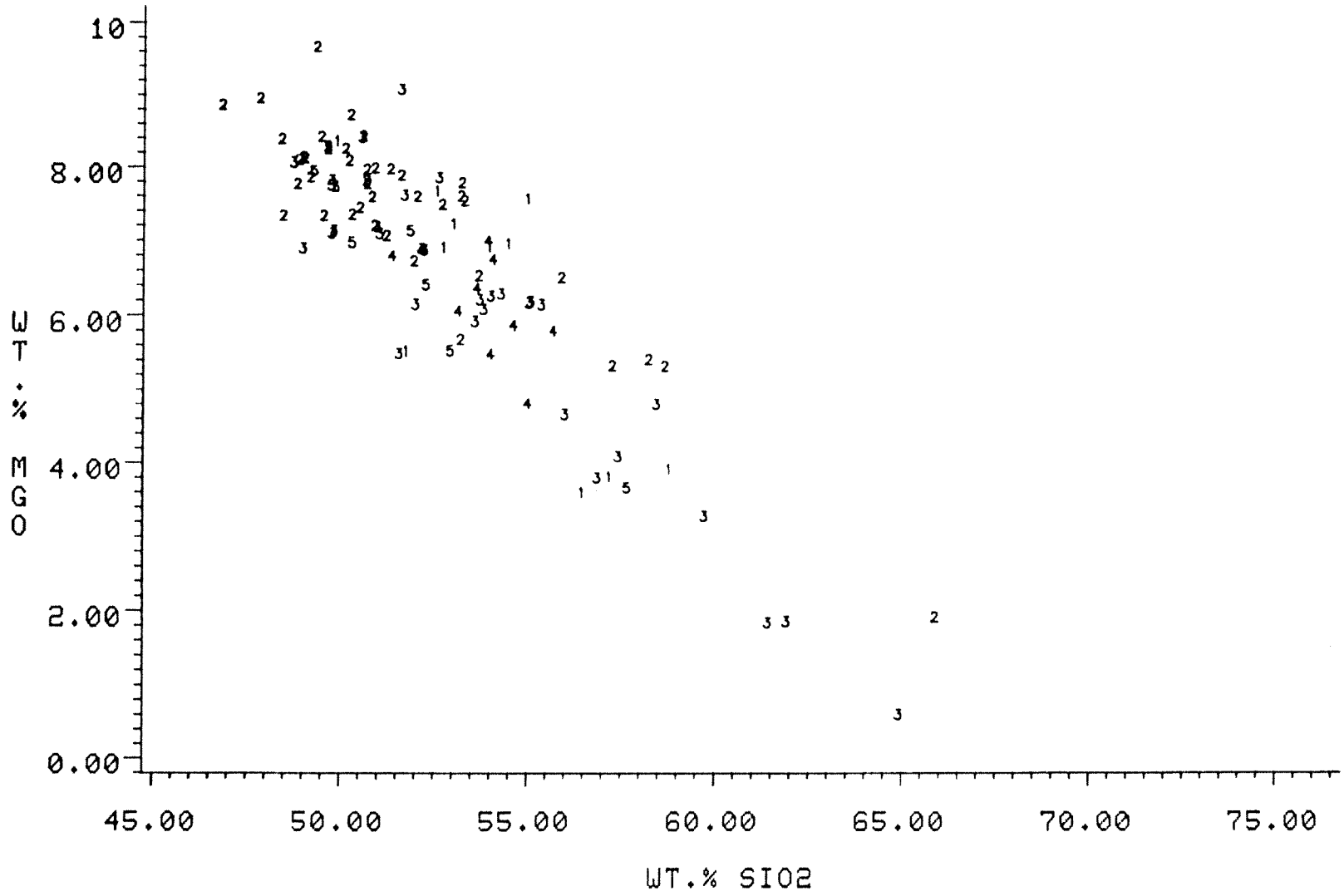

Figure 6. — MgO vs. SiO_2 variation diagram. Number refers to the volcanic zone of sample.

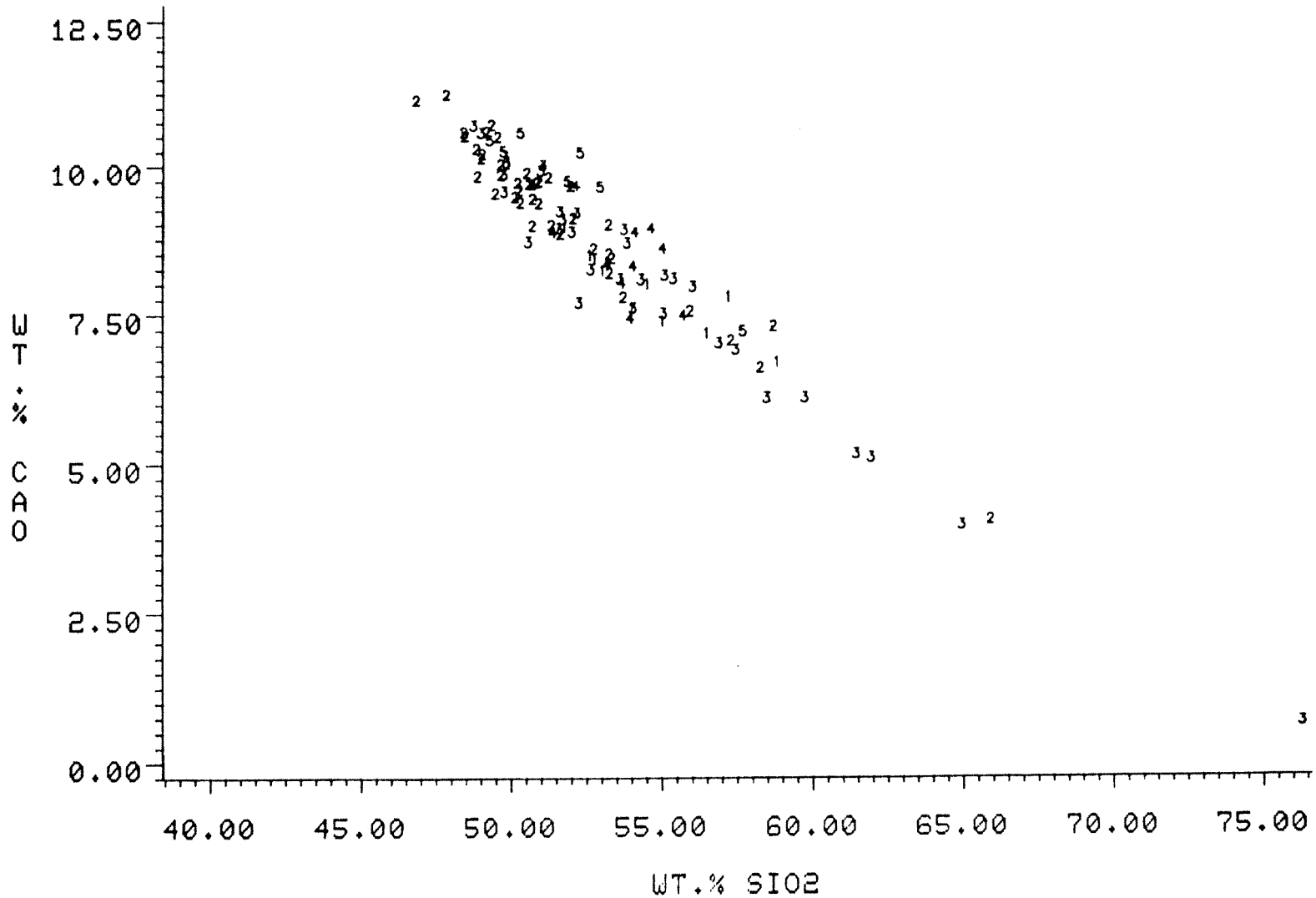

Figure 7. — CaO vs. SiO_2 variation diagram. Number refers to the volcanic zone of sample.

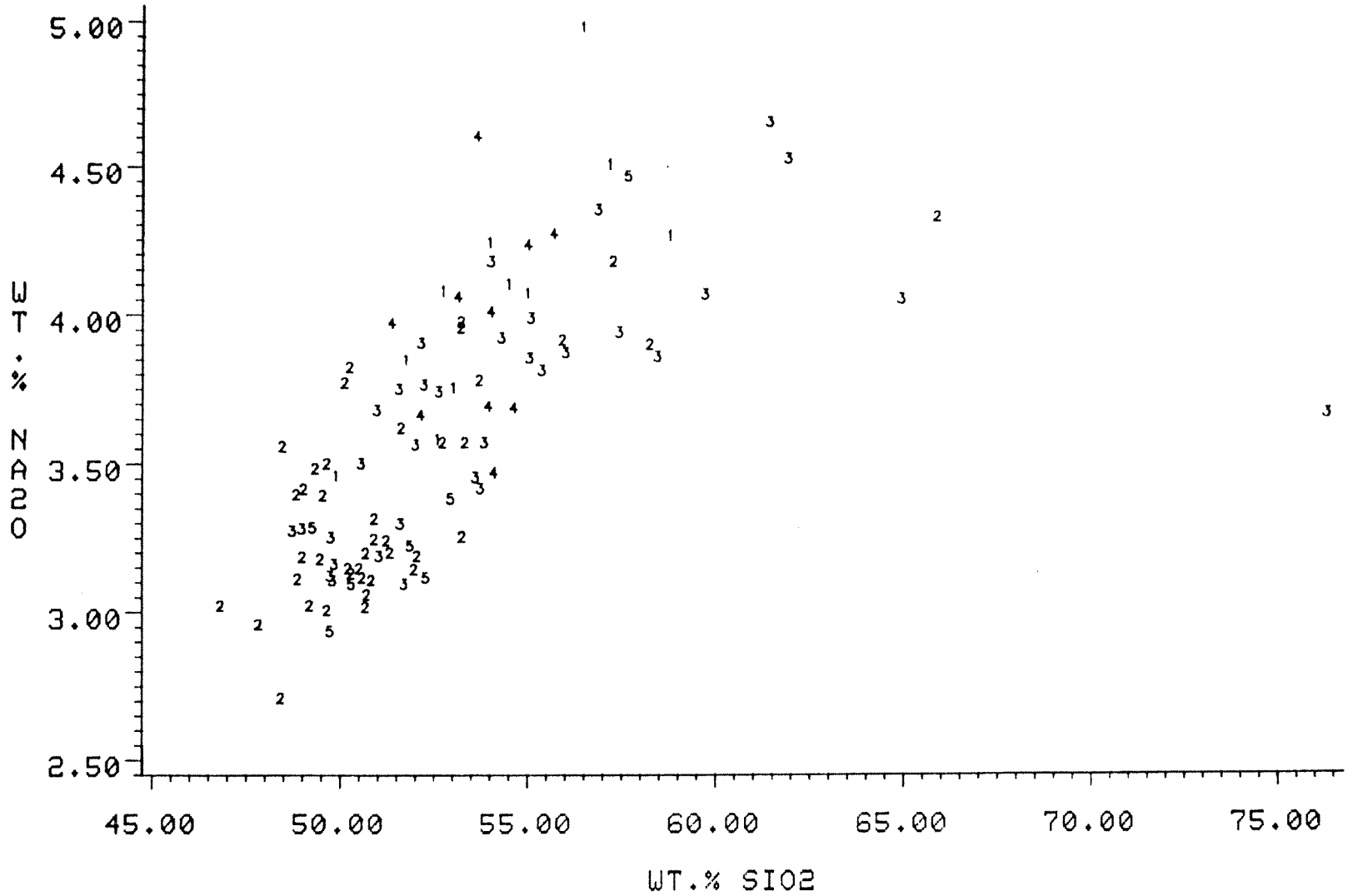

Figure 8. — Na_2O vs. SiO_2 variation diagram. Number refers to the volcanic zone of sample.

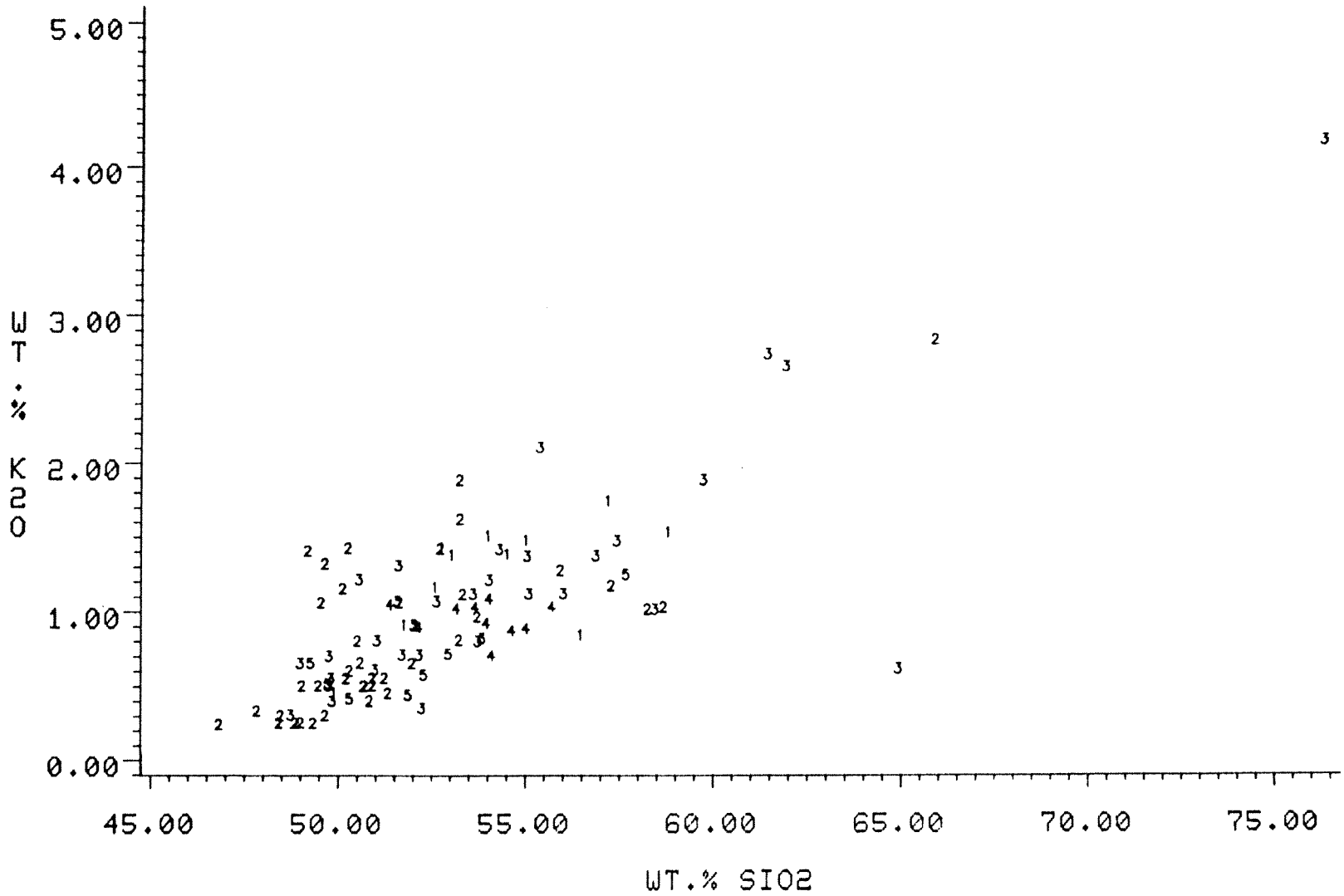

Figure 9. — K_2O vs. SiO_2 variation diagram. Number refers to the volcanic zone of sample.

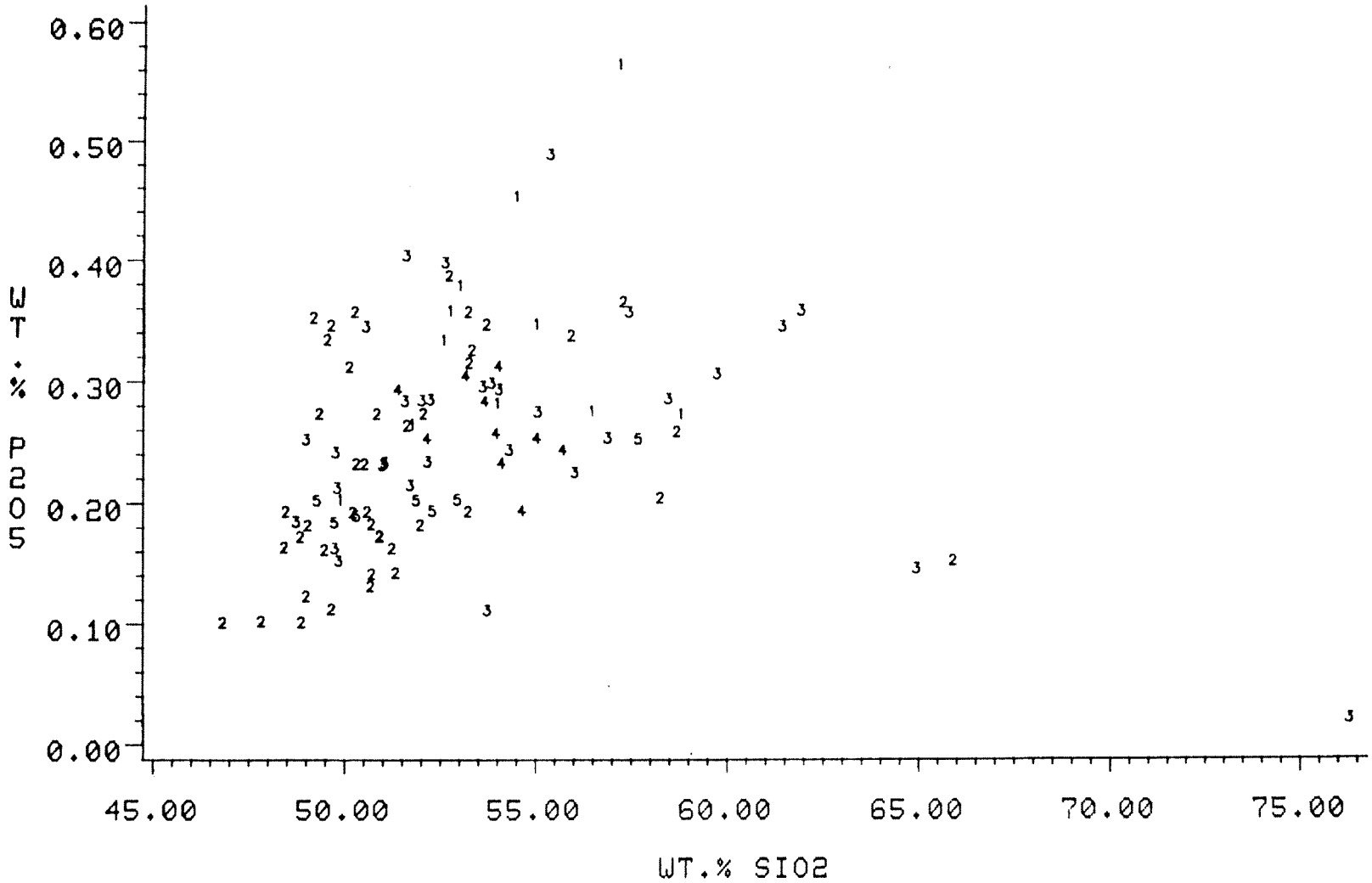

Figure 10. — P_2O_5 vs. SiO_2 variation diagram. Number refers to the volcanic zone of sample.

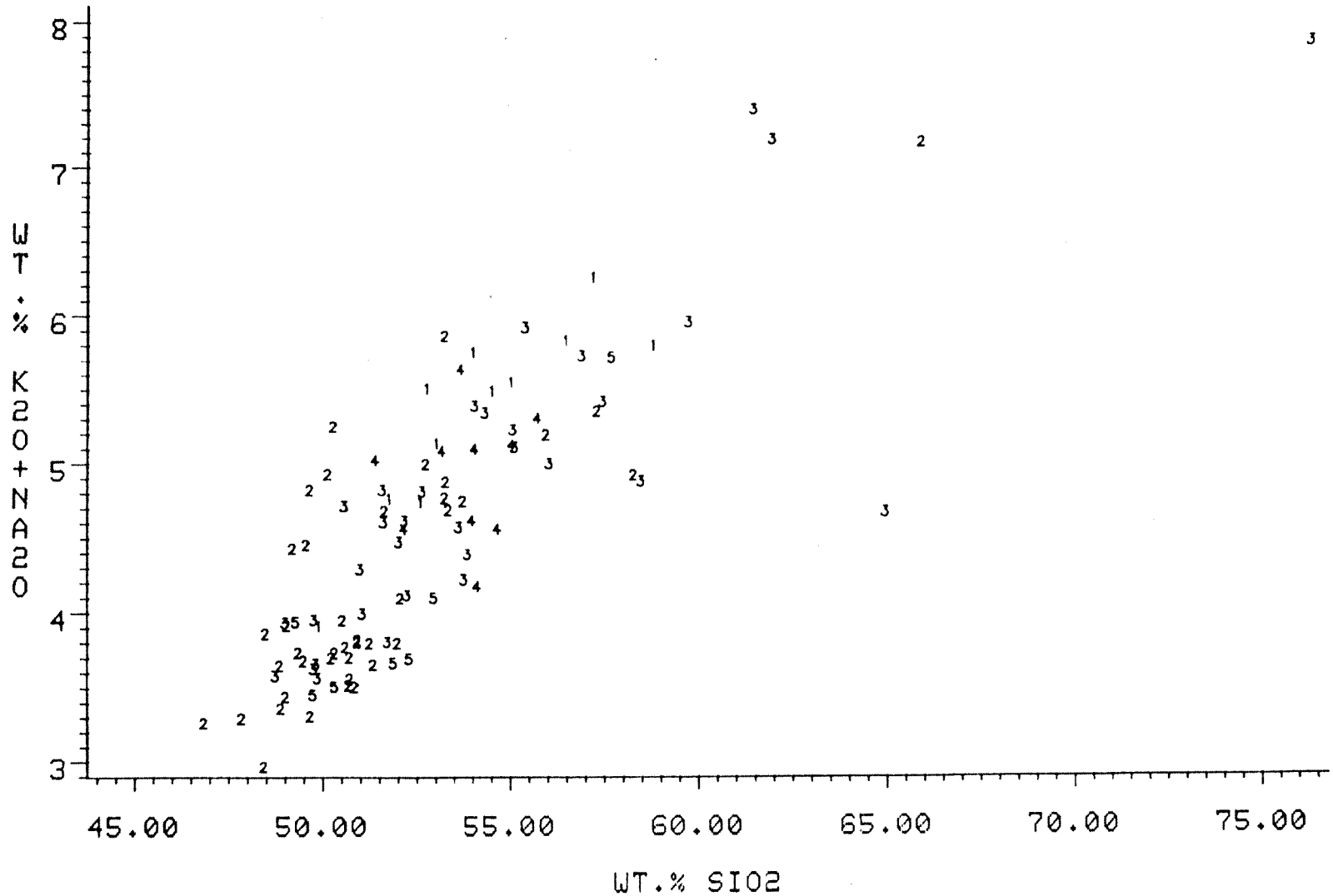

Figure 11. — Na2O+K_2O vs. SiO_2 variation diagram. Number refers to the volcanic zone of sample.

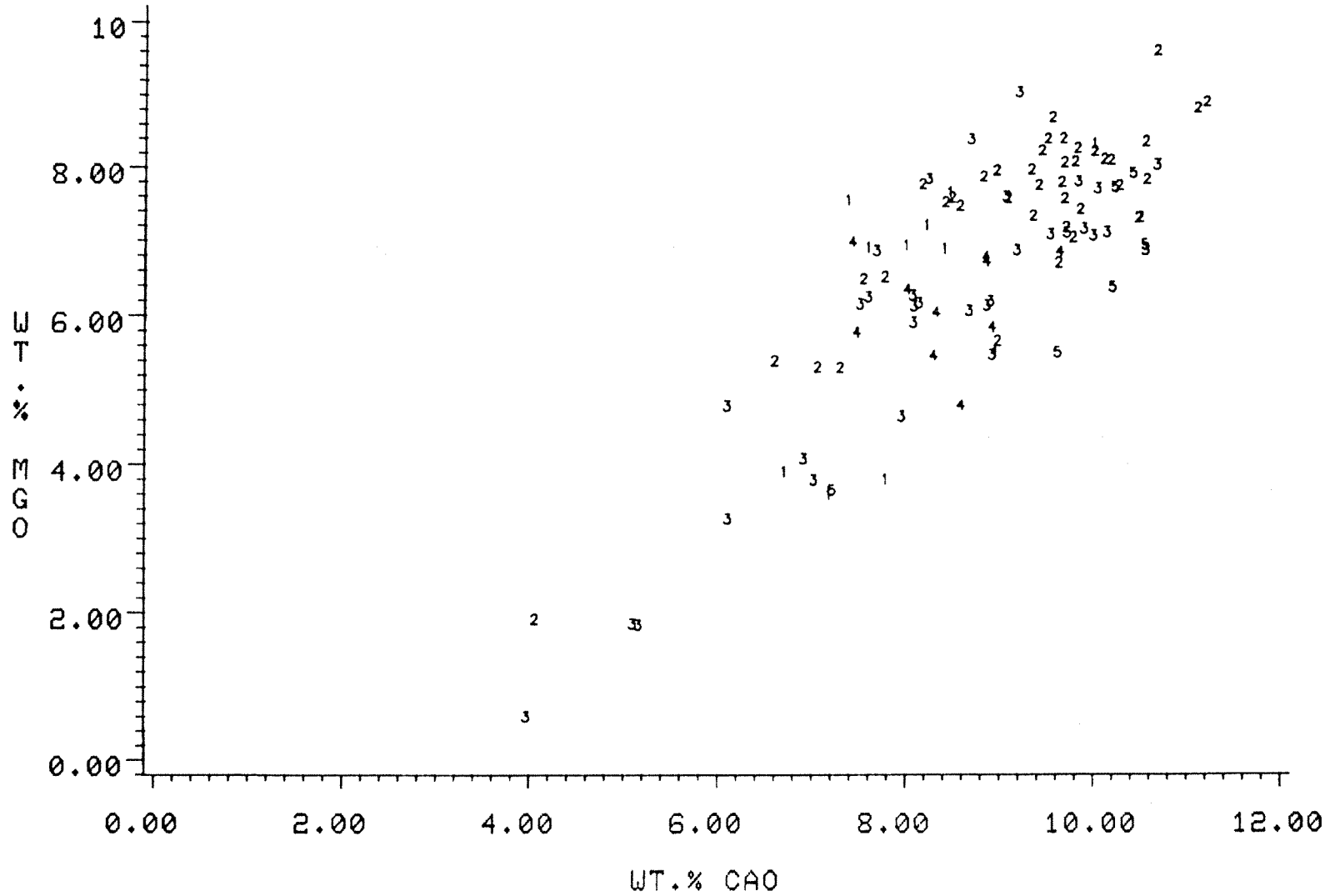

Figure 12. — Mg vs. CaO variation diagram. Number refers to the volcanic zone of sample.

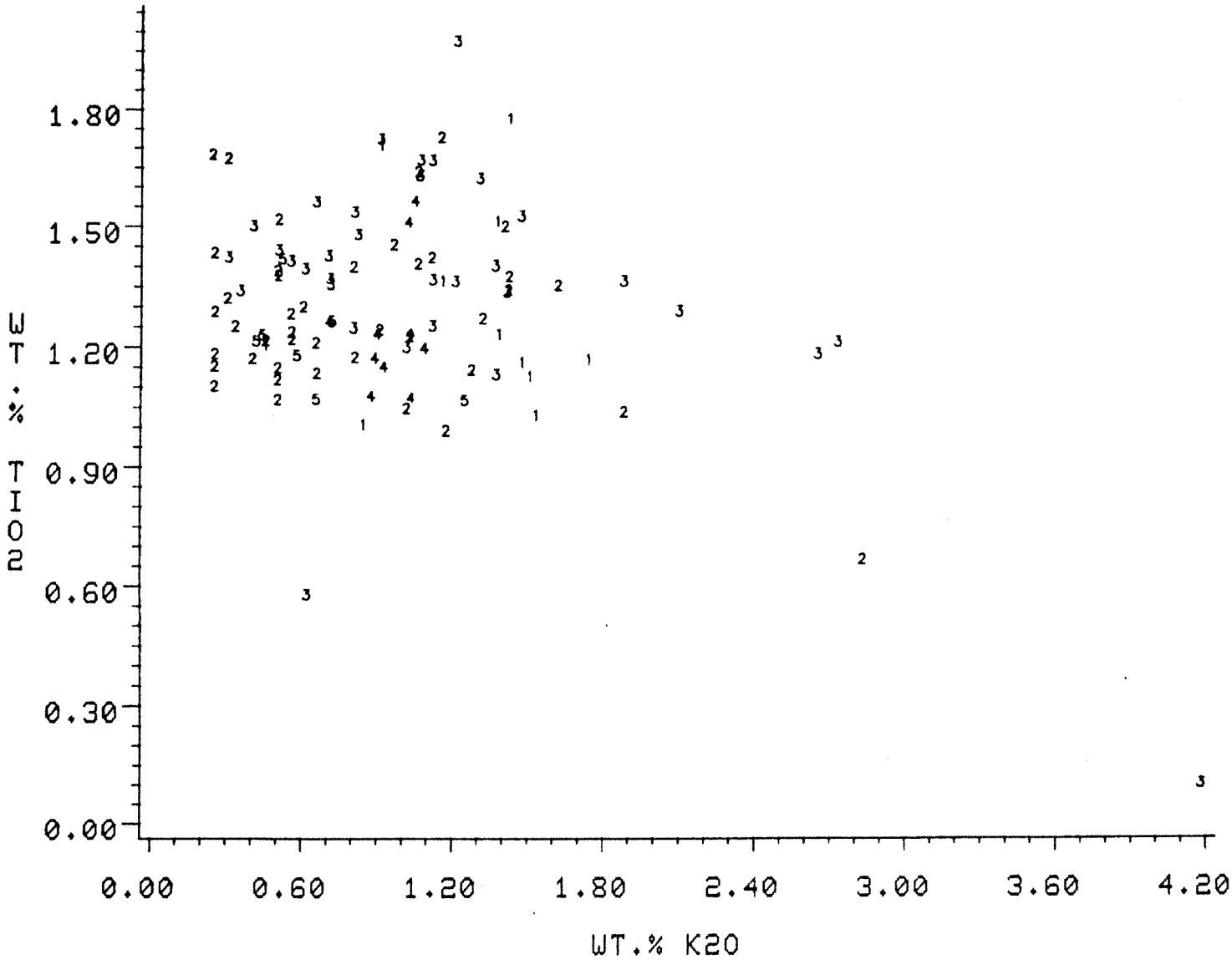

Figure 13. – TiO_2 vs. K_2O variation diagram. Number refers to the volcanic zone of sample.

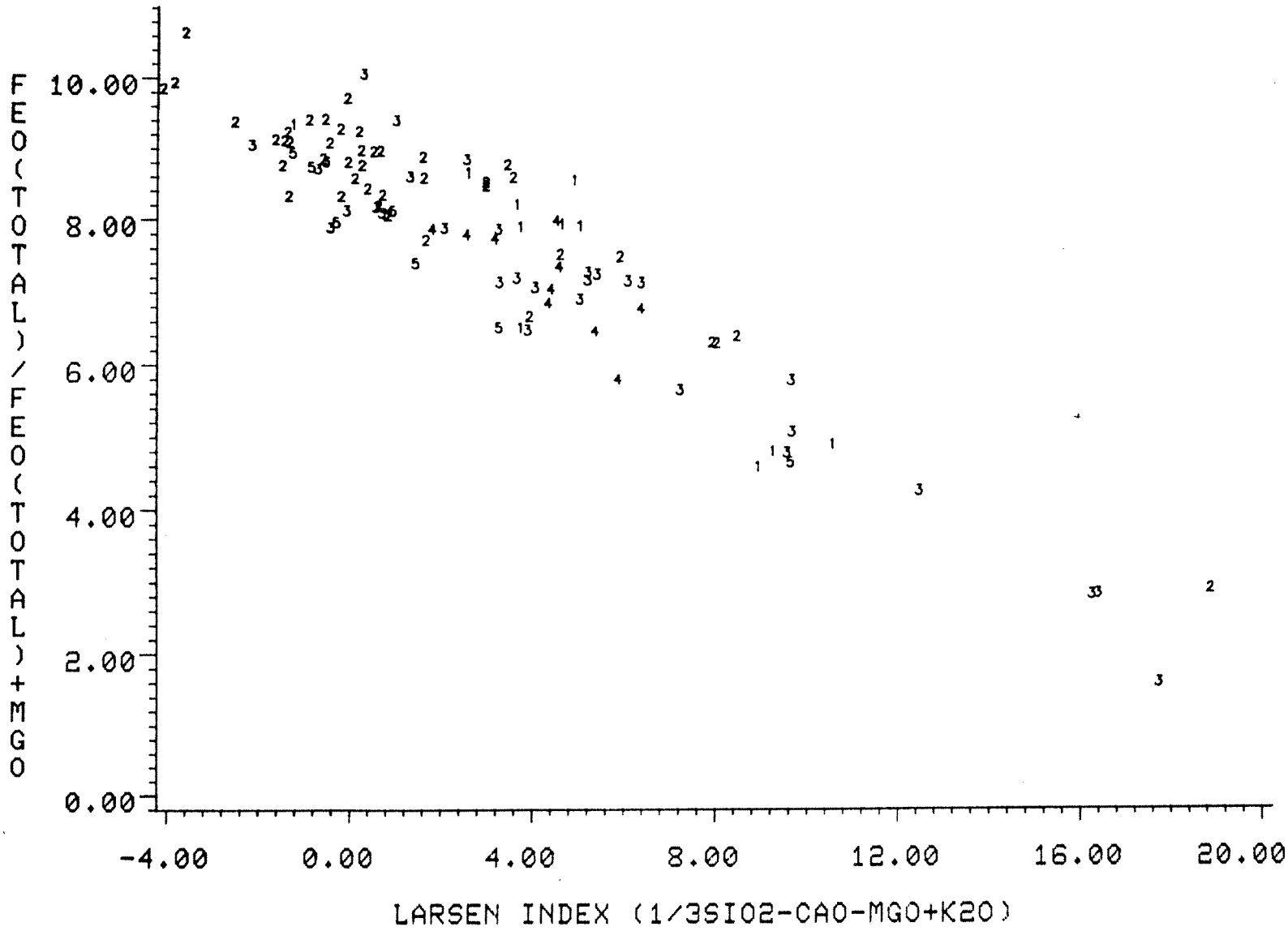

Figure 14. — The Fe(total)/Fe(total) + MgO ratio vs The Larson Index. Number refers to the volcanic zone of sample.

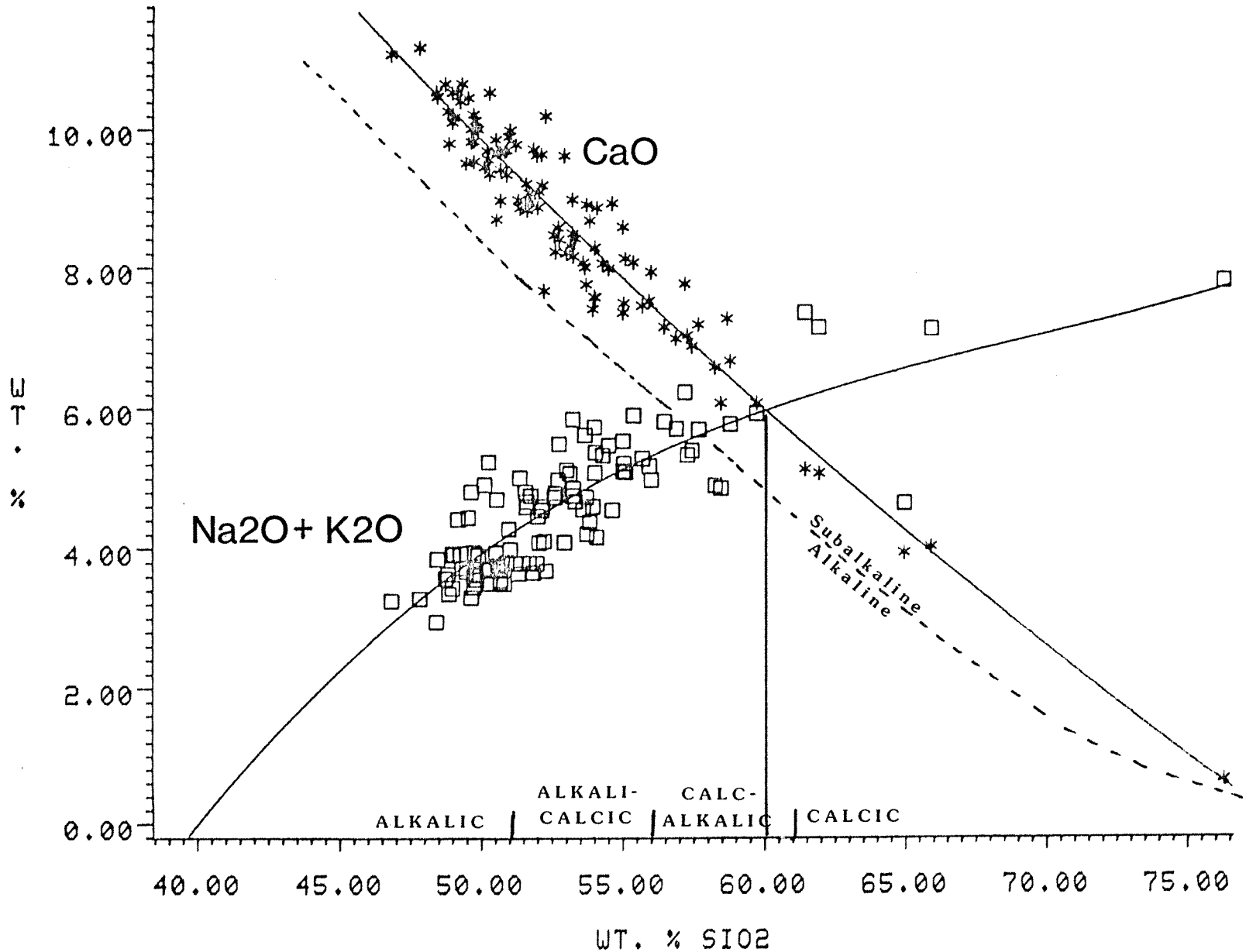

Figure 15. — Alkali-lime silica variation diagram classification system (Peacock, 1931) applied to Quaternary volcanic rocks of the southern Cascade Range. Also shown is the subalkaline-alkaline field boundary of CaO - SiO_2 plot.

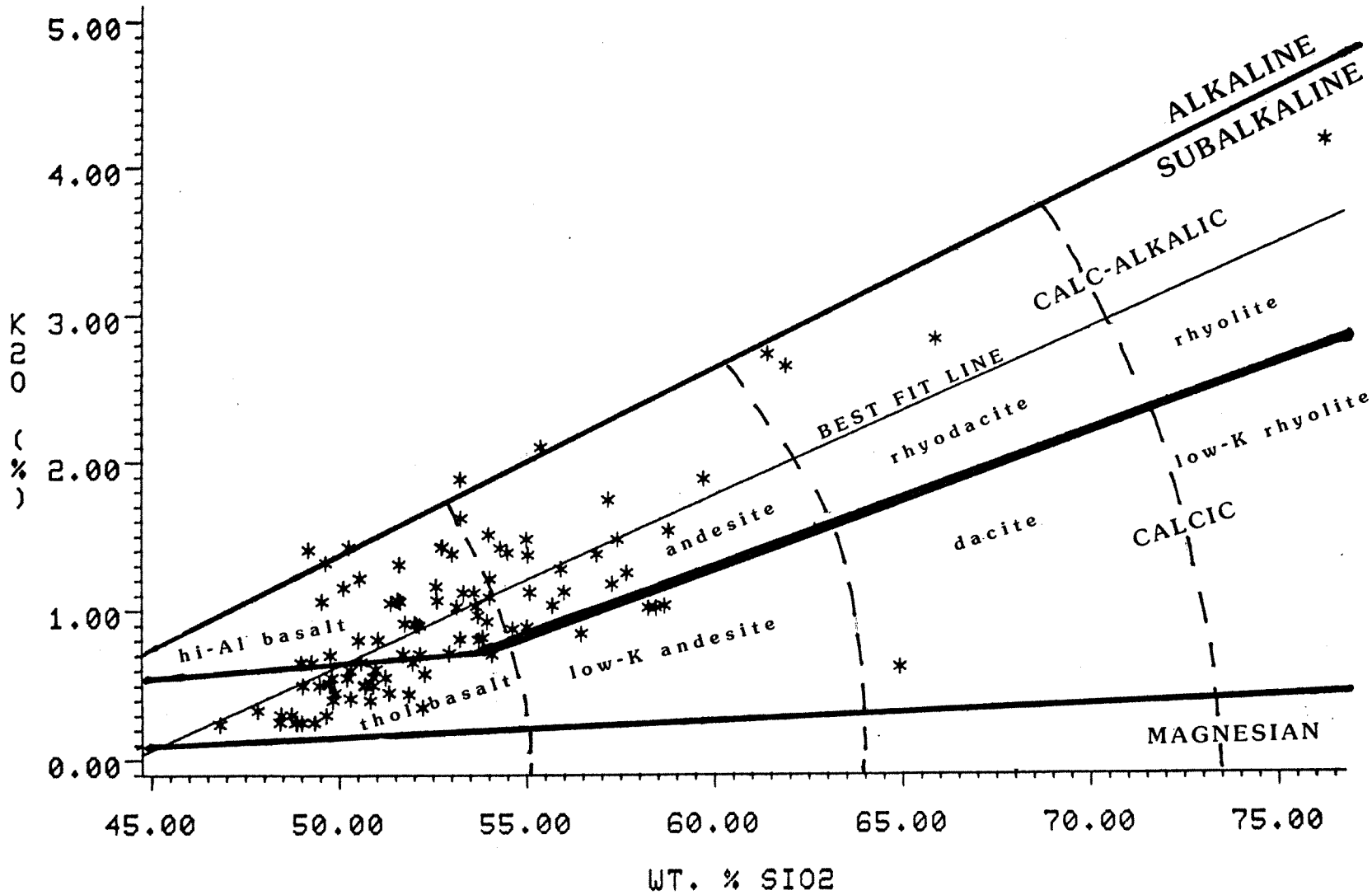

Figure 16. — Potassium-Silica variation diagram. Classification of southern Cascade Range Quaternary volcanic rocks using the classification system is from Keith (1983).

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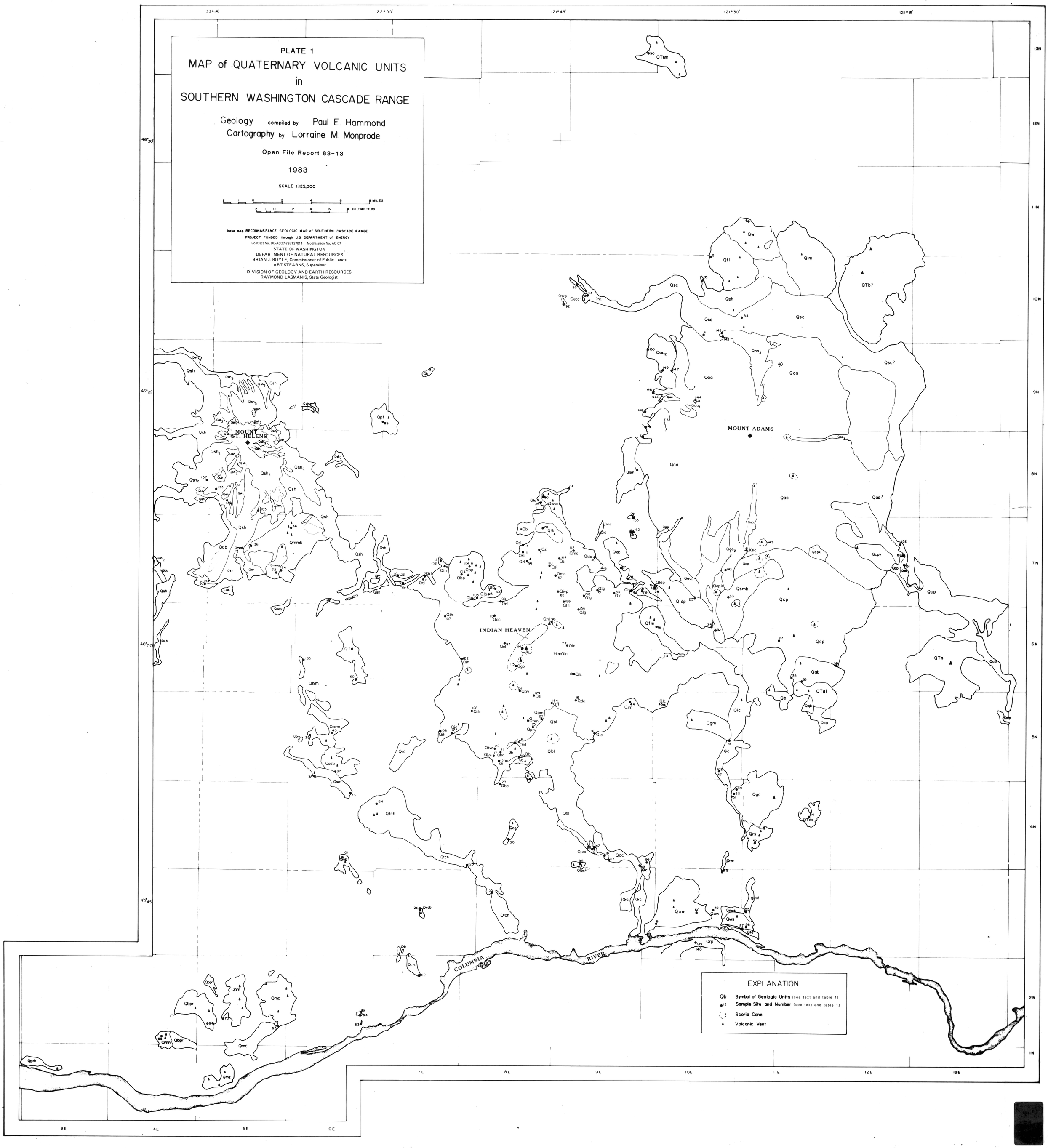
PLATE 1
MAP of QUATERNARY VOLCANIC UNITS
in
SOUTHERN WASHINGTON CASCADE RANGE
Geology compiled by Paul E. Hammond
Cartography by Lorraine M. Monprode
Open File Report 83-13
1983
SCALE 1:125,000
8 MILES
8 KILOMETERS
base map RECONNAISSANCE GEOLOGIC MAP of SOUTHERN CASCADE RANGE
PROJECT FUNDED through U.S. DEPARTMENT of ENERGY
Contract No. DE-AC07-79ET27014 Modification No. A0 07
STATE OF WASHINGTON
DEPARTMENT OF NATURAL RESOURCES
BRIAN J. BOYLE, Commissioner of Public Lands
ART STEARNS, Supervisor
DIVISION OF GEOLOGY AND EARTH RESOURCES
RAYMOND LASMANIS, State Geologist
MOUNT ST. HELENS
MOUNT ADAMS
INDIAN HEAVEN
COLUMBIA RIVER
EXPLANATION
Qb Symbol of Geologic Units (see text and table 1)
12 Sample Site and Number (see text and table 1)
Scoria Cone
Volcanic Vent