UNITED STATES DEPARTMENT OF THE INTERIOR

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URANIUM, THORIUM, AND OTHER METAL ASSOCIATIONS IN SILICIC VOLCANIC COMPLEXES OF THE NORTHERN BASIN AND RANGE

A PRELIMINARY REPORT

By

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INTRODUCTION

Abnormal concentration of metals associated with Cenozoic silicic volcanic rocks has been recognized for years in many parts of the western Cordillera; this relation is particularly well represented within and marginal to the Basin and Range Province. Within the northern Basin and Range, deposits of uranium, mercury, precious metals, as well as several other metallic elements, have been discovered associated with rocks of this type and age, and abundant evidence indicates a genetic association. Many of these deposits of metals have been exploited over the past several decades and, in recent years, have received considerable renewed exploration attention. Two areas within the region that have attracted special attention are the McDermitt area on the Oregon-Nevada border and the Lakeview area, Oregon, about 235 km ($\approx$145 mi) to the west-northwest of McDermitt. Both of these areas, which are known to contain substantial amounts of uranium and several other metals, occur within a vast region of the northern Basin and Range characterized by Cenozoic volcanism of diverse chemistry. The age of volcanism within this region ranges from Eocene or early Oligocene to Holocene; by far the largest outcrop areas consist of Miocene and Pliocene age rocks dominated by basalt and rhyolite or rhyodacite (Gay and Aune, 1958; Jennings, 1977; Walker, 1977; Stewart and Carlson, 1978; Bond, 1978). Most of the silicic rocks considered here reflect extensional tectonics and related bimodal volcanism rather than products related to subduction of crustal plates (Lipman, Prostka, and Christiansen, 1972).

Because of the considerable current interest in metallic mineral deposits of the northern Basin and Range and in the volcanic and tectonic development of the region, a study was initiated to determine the relations of selected metals to silicic volcanic rocks: specifically to the age and petrochemical type, relation of volcanism to regional tectonism, and ultimately the relation of silicic volcanism and tectonism to resource potential of selected metals. The study was further designed to evaluate the relations of these silicic volcanic rocks to different kinds of volcanic vents, principally calderas and domal or near-surface intrusive complexes, and the significance of these vents in both temporal and tectonic regimes. Fundamentally, the study was undertaken to determine whether systematic relations exist between different petrologic and chemical kinds of silicic volcanic rocks and selected metals, including principally U, Th, precious metals, As, Hg, Sb, Rb, Ba, and Mo. The study is not to document metal concentration or redistribution that results from hydrothermal or other secondary processes, but is to document the metal content of silicic magmas by analyzing samples of fresh obsidian, wherever obtainable.

This paper is an interim report that presents a preliminary review of compiled and collated petrochemical data on silicic volcanic rocks of the northern Basin and Range. The main purpose of the report is to make available a large volume of analytical data obtained by various investigators on these silicic volcanic rocks and to briefly examine some selected elemental and isotopic variations in terms of geography and petrochemistry. Compilation of data is only partly completed and to date most of the effort has been directed toward organizing existing petrochemical data, both published and unpublished, determining its geographic distribution, and relating this and mineral deposits data to known silicic vent complexes; as yet, the study has not been involved with a comprehensive review or evaluation of the geochemical and genetic relations of silicic volcanism to regional tectonism or to ore deposits.

For purposes of this study, geographic limits were placed on the area of investigation by arbitrarily selecting a segment of the northern Basin and Range bounded by 41° and 44° N. latitude and 116° and 122° W. longitude (fig. 1). Included in the study are data on rhyolite, rhyodacite, dacite, and quartz latite collected in southeast Oregon, southwest Idaho, northeast California, and northwest Nevada by a large number of investigators for a number of different purposes.

Acknowledgments

Many geologists, geochemists, geochronologists, and analytical chemists have contributed data for this study and an attempt has been made to identify and recognize all of them.

The largest body of data was collected by N. S. MacLeod, with the assistance of the author and E. H. McKee, in support of a program to evaluate the geothermal potential of southeast Oregon. The next two largest bodies of data originated from a study of the uranium deposits near Lakeview, Oregon (Walker, 1980) and the mercury and uranium deposits associated with the McDermitt caldera complex, currently under investigation by J. J. Rytuba and others (Rytuba and Glanzman, 1979; Rytuba and Conrad, 1981). Bart Ekron supplied partial analyses of several rhyolitic rocks from the Owyhee Mountains of southwestern Idaho and R. R. Coats supplied partial analyses of several rhyolitic rocks from western Elko County, Nevada. Others who have contributed samples and various kinds of published and unpublished analytical data include: R. E. Wells, R. C. Greene, D. R. Shawe, Irving Friedman, W. A. Duffield, L. C. Rowan, and D. C. Noble. Analyses extracted from the literature are referenced at appropriate places in the report; included are a number of analyses reported by Higgins, (1973), Beyers (1973), Condie and Hayslip (1975), Le Masurier (1965; 1968), and Mertzman (1981). For a number of partially analysed samples, the author obtained additional sample material from the collector in order to resubmit the sample to the U.S. Geological Survey's Analytical Laboratories for additional information, particularly to obtain Delayed Neutron analyses for uranium and thorium.

Potassium-argon age determinations were made mostly by E. H. McKee (McKee, MacLeod, and Walker, 1976) and by Parker and Armstrong (1972). A few age determinations were made by Jerry Von Essen and by J. C. Engel. The strontium and lead isotope determinations are largely the work of C. E. Hedge, W. P. Leeman, and D. C. Noble.

Analyses of samples has been performed by a large number of analysts, mostly associated with the Analytical Laboratories of the U.S. Geological Survey. Included are: J. M. Baldwin, M. Cremer, P. J. Lamothe, J. Kent,

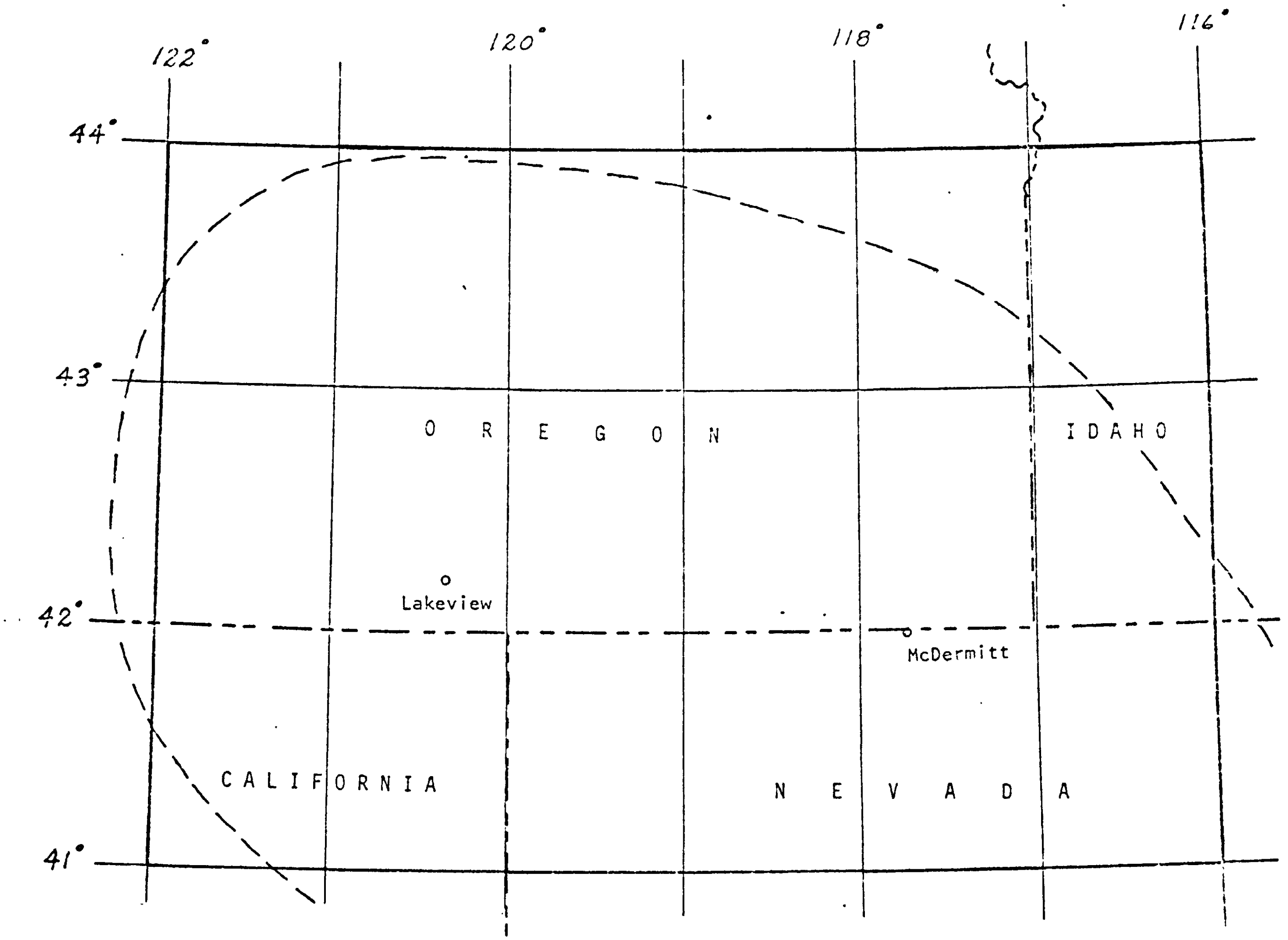

Figure 1.--Index to area covered in report. Dashed line shows approximate boundary of northern Basin and Range.

H. T. Millard, Jr., B. Vaughn, S. Lasater, B. Keaten, B. Lai, F. Brown, C. Jones, H. Smith, R. D. Bies, and Z. Hamlin. Some of the analyses made by professors and graduate students are reported in unpublished theses; these analyses are referenced in appropriate places throughout the report, particularly in individual sample descriptions accompanying tables of analytical data.

The study was initiated under the auspices of the U.S Geological Survey as an outgrowth of work on preparing a geologic map of eastern Oregon (Walker, 1977) and of geothermal investigations in the northern Basin and Range. Since 1979 the study has received partial financial support from the Department of Energy, as a part of its program on "World-Class" and "Intermediate-Grade" uranium deposits.

SAMPLES AND ANALYTICAL METHODS

This investigation is based largely on analyses of samples of silicic volcanic rocks collected throughout the northern Basin and Range during the past decade in support of studies related either to resource analyses for geothermal energy, uranium, mercury, and precious metals, or to fundamental problems of petrology. Some samples that originally had been collected by others only for isotopic dating, were recollected by the author for additional analytical work, including major-oxide and minor-element chemistry, and for a few samples, strontium-isotope determinations. Few of the data were collected specifically to look at uranium or other metal associations in silicic volcanic terranes and collectively they represent many kinds of analyses of different character and precision. Not only are the analyses themselves non-uniform in quality, but they also represent non-uniformity in regional coverage, inasmuch as many samples have been analyzed from Newberry Volcano, Medicine Lake Highlands, Lakeview area, Drake Peak complex and McDermitt caldera complex in contrast with single or only a very few analyses for most other areas. Because of the large body of data available for Newberry Volcano, only a few representative analyses are included here.

Suites of samples of silicic volcanic rocks collected at Newberry Volcano, McDermitt caldera complex, Medicine Lake Highlands, and the Drake Peak area, may each represent part of a comagmatic assemblage, with some of the chemical variations partly the result of eruption from zoned magma chambers. Selected age groups of samples from the Lakeview area of south-central Oregon may also represent comagmatic products, although the area from which silicic rocks of comparable age have been collected is very large and includes adjacent parts of Oregon and northeastern California. Most of the analyzed samples collected over this vast region of the northern Basin and Range are not comagmatic and represent eruptions from numerous completely separate magma chambers at different times throughout middle and late Cenozoic time.

Essentially all of the available analytical data, both published and unpublished, on major-oxide and minor-element chemistry, potassium-argon ages, and strontium and lead isotopes of intrusive and extrusive silicic rocks exposed within the region have been reviewed and collated. Initially, all rocks identified by collectors as being of dacitic or more silicic composition were considered in this compilation, and, ultimately those with SiO_2 contents greater than about 64 percent were incorporated into a series of tables that separate rocks into three age groups, those less than 5 m.y. old (table 1), those 5-10 m.y. old (table 2), and those older than 10 m.y. (table 3). For isotopically undated rocks, ages are inferred from geologic relations in order to place the data for these samples into one of the three tables. A few of the estimated geologic ages applied by the original collector may be in error and I have reinterpreted a few ages in light of current geologic and stratigraphic knowledge.

Emphasis was directed toward analytical data from silicic rocks of isolated dome complexes, as well as clearly identified intrusions or resurgent domes in caldera complexes. Wherever practical, analyses of fresh obsidian, or in a few places fresh pitchstone, from chilled marginal facies of intrusive or extrusive bodies, were selected and samples showing extensive weathering, devitrification, crystallization, hydration, or other evidence of alteration were rejected. As pointed out by Lipman (1965), devitrification and hydration of glassy phases of silicic volcanic rocks commonly results in transfer of components, particularly alkalies and silica. Noble, Smith, and Peck (1967) demonstrate that most of the halogens originally present in silicic volcanic glasses also are lost on crystallization. Studies by Rosholt, Prijana, and Noble (1971) and by Zielinski (1978) have shown further that co-existing obsidian and perlite have comparable uranium and thorium values whereas crystallization invariably results in depletion of these elements. Both in collecting samples and in selecting analytical data from the literature, every effort was made to minimize the effects of any of these processes that would alter the content of contained elements. A large number of analyses of samples collected by the author and by N. S. MacLeod were made on obsidian from apache tears collected in the chilled and highly perlitic marginal selvages of intrusive bodies; the largest of the apache tears were broken and only fresh, non-hydrated and non-perlitic obsidian from the cores of the tears was used for analysis. A few samples described in the literature only in very general terms by the original collector do not provide adequate information on the degree of crystallization or hydration. Analysis of a sample of rhyolite from the White King uranium mine near Lakeview has been included (table 2, column 19) even though it is obviously silicified and altered; its inclusion is for comparison only.

Every effort was made to exclude analyses of silicic ash-flow tuffs from the study, although a few analyses of rocks identified in the literature simply as rhyolite (or rhyolite intrusive or flow) may actually represent ash-flow tuffs that have undergone extensive secondary laminar flowage and, hence, are difficult to distinguish from rocks that have congealed directly from a melt without an intervening pyroclastic phase. Densely welded ash-flow tuffs with prominent flow-banding are common in parts of northern Nevada, southwest Idaho, and southeast Oregon, and some have been misidentified or, in places, lumped into packages of silicic volcanic rocks in which no distinction is made between flows and intrusives and remobilized pyroclastic deposits. Justification for excluding ash-flow tuffs from the study is two-fold: (1) most of the ash-flow tuffs show evidence of vapor-phase crystallization and some show extensive alteration, indicating that chemical components probably have been redistributed and possibly some elements have been leached; and (2) the vents for several analysed ash-flow tuffs are, as yet, unknown thus preventing chemical comparisons, by geographic position, with other known source areas. A few samples collected by the author in southern Malheur County, Oregon, and in Washoe County, Nevada, have been identified in the

Table 1.--Chemical analyses, isotopic ratios, and norms of rhyolites, rhyodacites, and dacites, less than 5 m.y. old or considered to be Pliocene or younger

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
K-Ar age	<0.1 m.y.	<1 m.y.	.58±0.10	.78±0.20	.84±0.04	1.10±0.05	2.29±0.32	3.59±0.07	3.9±0.4				2.7±	4.31±0.34
Geologic age										Holocene?	Pliocene	Pleistocene		
SiO_2	72.9	71.4	75.4	73.7	74.31	74.71	75.0	76.6	65.9	73.2	67.8	74.5	72.7	76.39
Al_2O_3	14.4	14.6	12.9	13.8	13.67	13.45	12.1	13.0	14.3	14.3	15.2	13.7	14.5	12.76
Fe_2O_3	.51	2.70	.36	2.37	.41	.36	.64	.24	1.6	.55	2.7	.16	1.0	.34
FeO	1.6		1.2		1.25	1.17	.28	1.3	2.8	1.5	.64	1.4		.81
MgO	.20	.41	.14	.19	.07	.07	.01	.04	1.3	.28	.99	.08	.5	.03
CaO	1.	1.16	.81	.81	.98	.89	.36	.68	3.1	1.	2.7	.87	1.9	.64
Na_2O	4.8	5.59	4.2	4.89	4.60	4.51	3.7	4.4	3.9	4.5	4:8	4.3	3.05	4.49
K_2O	4.	3.03	4.2	3.71	3.89	4.03	4.6	4.	3.	3.8	2.3	3.6	4.50	3.79
H_2O^+	.42	.28	.37	.63	.28	.27	2.2	.29	1.8	.54	.85	.37	—	.19
H_2O^-	.05		.06		.04	.03	.26	.06	.20	.06	.3	.06	—	.02
TiO_2	.21	.33	.16	.21	.11	.10	.05	.13	.68	.24	.53	.1	.13	.06
P_2O_5	.05	.04	.02	.01	.01	.01	.00	.01	.21	.04	.13	.01	—	.01
MnO	.04	.11	.03	.07	.04	.04	.00	.02	.08	.05	.06	.04	—	.04
CO_2	—	—	—	—	—	—	—	—	—	.05	.02	.05	—	—
Norms[1] (Water-free)														
Q	26.7	21.7	32.6	28.2	29.90	30.44	35.6	33.7	22.6	29.5	22.5	33.3	32.2	33.92
Or	23.6	17.9	24.8	22.0	22.99	23.87	27.8	23.6	18.3	22.5	13.6	21.3	26.6	22.45
Ab	40.6	49.9	35.5	41.6	38.92	38.24	32.2	37.4	33.8	38.1	41.5	37.2	25.8	38.08
An	4.6	4.4	3.9	4.	4.80	4.35	1.8	3.3	12.7	4.7	12.6	4.3	9.4	3.11
C	.6	—	.1	.3	.16	.1	.4	.2	—	1.2	.3	1.2	1.2	.13
Ac	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hs	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Wo	—	.5	—	—	—	—	—	—	.8	—	—	—	—	—
En	.5	1.	.4	.5	.17	.17	.0	.1	3.2	.7	5.6	.2	1.3	.07
Fs	2.1	2.7	1.5	2.5	1.72	1.61	.9	1.6	4.	2.	—	1.7	.9	1.26
Mt	.8	1.0	.6	.9	.62	.57	.3	.6	1.7	.8	1.3	.6	.4	.42
Il	.4	.6	.3	.4	.21	.19	.1	.3	1.3	.5	1.	.2	.3	.11
Ap	.1	.1	.1	.0	.02	.02	—	.0	.5	.1	.3	.0	—	.02
Hm	—	—	—	—	—	—	—	—	—	—	1.8	—	—	—
Q	29.	24.	35.	31.	33.	33.	37.	36.	30.	33.	29.	36.	38.	36.
Or	26.	20.	27.	24.	25.	26.	29.	25.	25.	25.	18.	23.	31.	24.
Ab	45.	56.	38.	45.	42.	41.	34.	39.	45.	42.	53.	41.	31.	40.
D.I.	91.	90.	93.	92.	92.	93.	96.	95.	75.	90.	78.	92.	85.	94.
Minor elements 2, 3, 4														
Cl	—	—	—	—	—	—	—	—	—	—	200.	—	—	—
F	—	—	—	—	—	—	—	—	800.	—	400.	—	—	—
Ag	—	—	—	—	—	N1.	<20.	—	<20.	<.1	<20.	<.1	—	—
As	—	—	—	—	—	—	4.2	—	4.9	<100.	3.6	<100.	—	—
Au	—	—	—	—	—	—	<.05	—	<.05	<6.81	<.05	<6.81	—	—
B	—	—	33.	40.	40.	40.	33.	28.	19.	30.6	N4.	44.3	—	40.
Ba	980.	950.	1100.	810.	877.	796.	100.	1030.	990.	983.	830.	654.	—	1210.
Be	—	—	3.	3.	2.	3.	3.	3.	N1.	3.4	N1.	2.33	—	2.
Bi	—	—	—	—	—	—	—	—	—	1.0	—	—	—	—
Cd	—	—	—	—	N50.	—	—	—	—	<14.7	—	<14.7	—	N50.
Co	—	—	N2	—	.35	.361	N2.	.438	N2.	1.	9.	<1.	<5.	.184
Cr	—	—	11.	—	.994	.50	N2.	N2.	9.	3.74	4.	1.7	10.	2.
Cs	—	—	—	—	5.6	5.5	—	4.6	—	5.3	—	—	—	3.5
Cu	—	—	13.	4.	4.	4.	4.	3.	17.	4.41	2.9	<1.	10.	3.
Hf	—	—	—	—	5.5	5.0	—	—	—	7.02	—	—	—	4.7
Hg	—	—	—	—	—	—	.035	—	.04	—	—	—	—	—
La	—	—	N20.	—	26.6	25.8	N20.	28.5	N20.	35.1	—	34.3	—	17.4
Li	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mo	—	—	N2.	—	L3.	L3.	N2.	N2.	N2.	3.78	—	2.31	—	L3.
Nb	—	—	N15.	—	L10.	—	23.	28.	N15.	13.6	N15.	6.8	—	L10.
Ni	—	—	N2.	—	N5.	N5.	N2.	N2.	10.	1.33	7.	<1.	10.	N5.
Pb	17.5	—	24.	17.8	19.8	21.1	30.	17.6	29.	15.5	N10.	13.	10.	17.
Rb	121.	71.	125.	118.	124.	123.	135.	115.	54.	122.	26.	—	—	89.4
Sb	—	—	—	—	.637	.579	.5	.528	<1.4	<68.1	<1.6	<68.1	—	.337
Sc	6.4	9.2	6.	7.	4.24	3.29	N1.5	3.90	14.	5.72	12.	2.9	—	4.02
Sn	—	—	—	—	—	—	—	—	—	4.99	—	3.84	—	—
Sr	53.	—	54.	66.	67.	52.	N2.	47.	140.	31.2	760.	76.4	—	34.
V	—	—	N3.	L7.	L7.	L7.	N3.	N3.	62.	8.62	50.	2.87	30.	—
W[4]	—	—	—	—	—	—	1.7	—	.78	<10.	.5	<10.	—	—
Y	—	—	47.	60.	60.	60.	79.	63.	55.	47.1	32.	43.	—	70.
Zn	133.	—	N30.	N300.	N300.	56.	67.	69.	120.	30.2	62.	40.8	10.	—
Zr	230.	296.	390.	230.	171.	166.	290.	209.	480.	487.	3.30	296.	—	115.
Ce	—	—	—	—	52.0	49.5	—	56.3	—	71.8	—	62.	—	36.1
Ga	—	—	19.	21.	25.	27.	22.	23.	21.	31.9	24.5	—	—	20.
Ge	—	—	—	—	N10.	N10.	—	—	—	1.	—	1.	—	N10.
In	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Re	—	—	—	—	—	—	—	—	—	—	—	10.	—	—
Tl	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Yb	4.7	5.3	5.	6.	4.55	4.27	60.	5.65	6.	7.74	3.	4.16	—	5.50
Th	12.1	7.6	11.	14.6	18.7	11.6	13.41	13.3	2.65	28.	4.8	21.5	—	11.3
U	4.9	—	4.94	3.85	4.3	4.56	5.33	3.52	2.51	4.	2.2	—	—	3.02
Th/U	2.47	—	2.30	3.79	4.35	2.54	2.52	2.52	1.06	6.95	2.18	—	—	3.74
Strontium and lead isotope data														
$Sr^{87/86}$	—	—	—	.7040	.7043	.7037	—	.7045	—	—	—	—	.7038	.7045
$Pb^{206/204}$	—	—	—	18.997	19.075	19.079	—	18.927	—	—	—	—	—	18.918
$Pb^{207/204}$	—	—	—	—	15.653	15.653	—	15.610	—	—	—	—	—	15.615
$Pb^{208/204}$	—	—	—	38.730	38.791	38.769	—	38.596	—	—	—	—	—	38.590

Table 1.--Chemical analyses, isotopic ratios, and norms of rhyolites rhyodacites, and dacites less than 5 m.y. old or considered to be Pliocene or younger--Cont.

	15	16	17	18	19	20	21	22	23	24	25	26	27	28
K-Ar age	4.43±0.18	4.67±0.17	4.88±0.59	4.9±0.7	4.91±0.73			300 y	300 y					
Geologic age						Holocene?	Holocene?			Pliocene?	Holocene	Holocene	2600 y	Quaternary?
SiO_2	70.2	66.2	73.0	75.7	76.18	73.7	73.15	72.75	73.59	74.10	73.43	69.88	72.5	72.38
Al_2O_3	14.7	16.0	13.8	13.4	13.01	14.	13.81	14.34	14.03	13.33	13.76	14.96	14.3	14.21
Fe_2O_3	2.1	2.8	1.7	.26	.30	.57	1.93	tr	.42	tr	.5	1.62	.33	1.97
FeO	.44	.36	.0	.56	.59	1.3		2.10	1.43	1.68	1.24	1.37	1.7	.51
MgO	.44	.49	.1	.09	.12	.32	.36	.43	.36	.38	.29	.53	.33	.18
CaO	1.8	2.1	.74	.90	.87	1.2	1.22	1.34	1.38	1.45	1.16	1.69	1.1	.80
Na_2O	4.1	5.7	4.7	3.8	3.88	4.	3.82	3.73	4.04	3.86	4.19	5.55	4.6	5.31
K_2O	3.9	2.7	4.	3.7	4.23	3.8	4.13	4.27	4.34	4.50	4.34	3.12	4.1	3.83
H_2O^+	.70	.77	.28	.39	.16	.23	—	.30	.12	.29	.32	.19	.43	.19
H_2O^-	.26	.51	.08	.04	.05	.04	—	.22	.06	.05	.12	.02	.03	.01
TiO_2	.36	.64	.19	.10	.11	.28	.3	.20	.31	.20	.26	.36	.23	.23
P_2O_5	.10	.17	.02	.0	.02	.04	.05	n	.09	n	.05	.09	.10	.04
MnO	.03	.08	.06	.06	.05	.04	.04	tr	.02	tr	.04	.09	.058	.07
CO_2	--	--	--	--	--	.05	--	—	—	—	.01	.06	<.05	.01
						Norms[1] (Water-free)								
Q	26.9	17.2	28.3	37.3	35.10	32.4	31.31	30.42	29.56	30.45	29.08	20.66	27.1	24.09
Or	23.15	16.	23.6	21.9	25.05	22.5	24.40	25.35	25.70	26.71	25.76	18.55	24.2	22.69
Ab	34.7	49.1	39.8	32.2	32.91	33.8	32.32	31.73	34.27	32.74	35.62	47.21	38.9	45.10
An	8.3	9.3	3.5	4.5	4.19	5.7	5.73	6.65	6.26	5.79	5.48	6.77	4.8	3.67
C	.8	.3	.5	1.61	.51	1.2	.96	1.15	.38	—	.17	—	.6	--
Ac	—	—	—	—	—	—	—	—	—	—	—	—	--	--
Ns	—	--	—	—	—	—	—	—	—	—	--	--	--	--
Wo	—	—	—	—	—	—	—	—	—	.59	—	.45	—	.02
En	1.1	1.2	.3	.2	.30	.8	.90	1.07	.90	.95	.72	1.32	.8	.45
Fs	2.1	2.4	1.5	.8	.88	1.7	1.77	2.06	1.58	1.58	1.57	2.79	2.0	2.34
Mt	.9	1.1	.6	.3	.33	.7	.74	.80	.68	.64	.65	1.09	.8	.87
Il	.7	1.2	.4	.2	.21	.5	.57	.38	.59	.38	.49	.68	.4	.44
Ap	.2	.4	.1	—	.05	.1	.12	—	.21	—	.12	.21	.2	.09
Hm	—	—	—	—	—	—	—	—	—	—	—	—	--	--
Q	32.	21.	31.	41.	38.	37.	36.	35.	33.	34.	32.	24.	30.	26.
Or	27.	19.	26.	24.	27.	25.	28.	29.	29.	30.	28.	21.	27.	25.
Ab	41.	60.	43.	35.	35.	38.	37.	36.	38.	36.	39.	55.	43.	49.
D.I.	85.	82.	92.	91.	93.	89.	88.	88.	90.	90.	90.	86.	90.	92.
						Minor elements[2, 3, 4]								
Cl	--	--	--	—	—	—	—							—
F	--	--	--	—	--	—	—							--
Ag	<20.	<20.	<20.	—	N1.	<.1	—							—
As	2.5	1.3	1.6	—	—	<100.	5.							--
Au	<.05	<.05	<.05	—	—	<6.81	—							—
B	7.	N4.	6.	—	N20.	29.9	—							--
Ba	700.	1000.	760.	—	1340.	796.	820.							1000.
Be	3.	3.	3.	—	2.	2.57	—							—
Bi	—	—	—	—	—	—	—							—
Cd	—	—	—	—	N50.	<14.7	—							--
Co	3.	5.	N2.	—	.454	1.87	—							—
Cr	5.	N2.	N2.	—	.982	4.21								5.
Ce	—	—	—	—	3.4	—	—							--
Cu	15.	7.	2.	—	2.	11.8	—							14.
Hf	—	—	—	—	3.5	—	—							--
Hg	—	.058	<.010	--	—	—	—							--
La	—	—	—	—	26.3	29.	—							—
Li	—	--	—	—	—	—	—							--
Mo	—	—	—	—	—	1.97	—							—
Nb	N15.	29.	22.	—	—	6.51	—							--
Ni	3.	N2.	N2.	—	N5.	2.35	12.							<4.
Pb	16.	12.	15.	—	18.1	<68.1	—							<20.
Rb	100.	41.	120.	—	98.5	—	156.							150.
Sb	--	—	<1.8	—	.214	<68.1	70.							
Sc	6.	13.	6.	—	2.78	4.6	8.							11.
Sn	—	—	—	—	—	<3.16	—							
Sr	160.	810.	80.	—	68.	148.	118.							79.
V	24.	30.	—	—	L7.	14.6	14.							9.
W[4]	--	—	1.	—	—	<10	—							
Y	22.	35.	39.	—	30.	—	—							80.
Zn	51.	86.	52.	—	—	27.9	29.							
Zr	130.	350.	170.	—	124.	—	215.							320.
Ce	—	—	—	—	48.	—	—							—
Ga	17.	23.	18.	—	14.	16.2	—							--
Ge	—	—	—	—	N10.	<1.0	—							—
In	—	—	—	—	—	—	—							--
Re	—	—	—	—	—	—	—							--
Tl	--	—	—	—	—	—	—							--
Yb	3.	3.	4.	—	2.85	—	—							--
Th	10.13	5.20	13.31	—	13.3	34.3	[5]13.1							--
U	4.13	2.35	4.60	—	3.52		5.85							—
Th/U	2.45	2.21	2.89	—	3.78	—	2.24							--
						Strontium and lead isotope data								
$Sr^{87/86}$	—	—	—	—	.7037	—	—							
$Pb^{206/204}$	—	—	—	—	18.823	—	—							
$Pb^{207/204}$	—	—	—	—	15.623	—	—							
$Pb^{208/204}$	—	—	—	—	38.539	—	—							

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Table 1.--Chemical analyses, isotopic ratios, and norms of rhyolites, and rhyodacites, and dacites less than 5 m.y. old or considered to be Pliocene or older--Cont.

	29	30	31	32	33	34	35	36	37	38	39
K-Ar age [4]		.58 m.y.	.58 m.y.	1350 y.					0.95±0.14	0.61±0.03	0.43±0.0.04
Geologic age	Holocene				Holocene	Holocene	Holocene	Holocene			
SiO_2	69.5	74.9	74.3	72.02	73.4	73.3	68.0	72.1	71.47	71.96	76.38
Al_2O_3	15.8	13.4	13.6	14.64	14.3	14.2	15.4	14.4	14.48	12.93	12.13
Fe_2O_3	1.7	1.63	1.79	2.46	[6]1.95	[6]2.07	[6]3.62	[6]2.45	1.63	.42	.38
FeO	.72				—	—	—	—	.91	.82	.70
MgO	.13	.18	.30	.164	.20	.28	1.11	.46	.51	.08	<.02
CaO	1.0	.83	1.06	.85	1.09	1.00	3.48	1.87	1.66	.86	.46
Na_2O	3.9	4.40	4.30	5.16	4.23	4.17	4.01	4.23	4.78	4.06	4.46
K_2O	3.2	4.17	4.04	3.89	4.12	4.50	3.24	3.83	3.18	4.63	4.42
H_2O^+	2.1	--	--	--	—	—	—	—	[7].87	[7].29	[7].44
H_2O^-	1.2	—	—	—	—	—	—	—			
TiO_2	.17	.25	.25	.24	.32	.33	.54	.37	.31	.21	.05
P_2O_5	.10	.02	.04	—	—	—	—	—	.09	.04	.01
MnO	.07	.04	.05	.064	—	—	—	—	.06	.04	.04
CO_2	<.05	—	—	—	—	—	—	—	—	—	—
					Norms[1] (water-free)						
Q	32.5	30.8	31.1	23.6	—	—	—	—	[8]27.68	[8]31.81	[8]32.92
Or	19.5	24.7	23.6	23.1	—	—	—	—	18.97	27.62	26.38
Ab	34.7	37.3	36.4	43.9	—	—	—	—	40.82	34.68	38.11
An	4.3	4.0	5.0	4.2	--	--	—	—	7.72	3.42	0.03
C	4.5	.2	.5	.4	—	—	—	—	.37	—	—
Ac	—	—	--	—	—	—	—	—	—	—	—
Ns	—	—	—	—	—	—	—	—	—	—	—
Wo	—	—	--	—	—	—	—	—	—	—	—
En	.3	.5	.8	.4	—	—	—	—	—	.55	1.83
Fs	2.5	1.5	1.7	3.6	—	—	—	—	1.28	.81	.07
Mt	.9	.6	.7	.4	—	—	—	—	2.25	.61	.56
Il	.3	.5	.5	.5	—	—	—	—	.59	.40	.10
Ap	.2	.1	.1	—	—	—	—	—	.21	.09	.02
Hm	--	—	—	—	—	—	—	—	0.09	—	—
Q	38.	33.	34.	26.	—	—	—	—	31.6	33.8	33.8
Or	22.	27.	26.	26.	—	—	—	—	21.7	29.3	27.1
Ab	40.	40.	40.	48.	—	—	—	—	46.7	36.9	39.1
D.I.	87.	93.	91.	91.	—	—	—	—	87.	94.	97.
					Minor elements[2, 3, 4]						
Cl	--	--	--	--	--	—	—	—	--	—	—
F	—	—	—	—	—	—	—	—	—	—	—
Ag	--	--	--	—	—	—	—	—	—	—	--
As	—	—	—	—	—	—	—	—	—	—	—
Au	—	—	--	--	—	--	—	—	—	—	—
B	—	—	—	—	—	—	—	—	—	—	—
Ba	--	1120.	1290.	980.	880.	856.	735.	—	729.	664.	85.
Be	--	—	—	—	—	—	—	—	—	—	—
Bi	--	--	--	--	—	—	--	—	—	—	—
Cd	—	—	—	—	—	—	—	—	—	—	—
Co	—	1.3	1.5	.9	2.7	2.6	8.2	5.9	—	—	--
Cr	—	2.	—	—	—	—	—	—	—	—	—
Cs	--	--	—	--	11.0	11.	8.6	9.4	--	--	--
Cu	—	—	—	--	20.	18.	21.	19.	—	—	--
Hf	--	--	--	--	—	—	—	--	--	--	--
Hg	—	—	—	--	—	—	—	—	—	—	—
La	—	23.	26.	--	29.	29.	21.	20.	—	--	--
Li	--	—	—	—	—	—	—	—	—	—	—
Mo	--	--	--	—	—	—	—	—	—	--	--
Nb	—	—	—	—	—	—	—	—	—	--	—
Ni	--	--	--	--	—	—	—	—	3.	—	--
Pb	—	—	—	—	—	—	—	—	—	—	—
Rb	—	119.	127.	153.	160.	157.	133.	153.	63.	128.	148.
Sb	—	—	—	—	—	—	—	—	—	—	—
Sc	—	5.	5.16	7.78	—	—	—	—	—	—	—
Sn	—	—	—	—	—	—	—	—	—	—	—
Sr	—	—	—	—	95.	95.	257.	144.	131.	70.	2.
V	—	—	—	—	—	—	—	—	10.	6.	—
W	—	—	—	—	—	—	—	—	—	—	—
Y	—	—	—	—	—	—	—	—	18.	54.	99.
Zn	—	—	—	—	—	—	—	—	—	—	—
Zr	—	200.	150.	133.	194.	192.	192.	185.	194.	189.	130.
Ce	—	51.	—	—	—	—	—	—	—	—	—
Ga	—	—	—	—	—	—	—	—	—	—	—
Ge	—	—	—	—	—	—	—	—	—	—	—
In	—	—	—	—	—	—	—	—	—	—	—
Re	—	—	—	—	—	—	—	—	—	—	—
Tl	—	—	—	—	—	—	—	—	—	—	—
Yb	—	3.4	3.6	—	2.4	2.5	1.8	2.4	—	—	—
Th	—	13.8	13.8	12.1	—	—	—	—	—	—	—
U	—	—	—	4.9	—	—	—	—	—	—	—
Th/U	—	—	—	2.47	—	—	—	—	—	—	—
					Strontium and lead isotope data						
$Sr^{87/86}$	—	—	—	.7035	—	—	—	—	—	—	—
$Pb^{206/204}$	—	—	—	19.048	—	—	—	—	—	—	—
$Pb^{207/204}$	—	—	—	15.609							
$Pb^{208/204}$	—	—	—	38.689							

Table 1 Footnotes

1. In normative calculations total Fe distributed according to ratio of Fe^{+3}/Fe^{+2} = (.31/.87), which was determined by average contents of Fe_2O_3 and FeO in 13 samples of fresh, nonhydrated obsidian.
2. Cl determined spectrophotometrically.
3. F determined with a specific-ion electrode.
4. W determined spectrophotometrically.
5. Th and U averages from Millard (1976, p. 64).
6. Total Fe reported as Fe_2O_3.
7. Loss on ignition.
8. Normative calculations as published by Mertzman (1981). Not corrected for H_2O or Fe^{+3}/Fe^{+2} ratio. Femic constituents reported as diopside and hypersthene.

Table 1 Sample information

1. Big Obsidian Flow, Newberry Volcano, Deschutes County, Oregon; lat 43°41.5' N., long 121°14' W.; Major oxides, average of 4 analyses (Higgins, 1973); minor elements (Beyers, 1973).
2. Paulina Peak dome; Newberry Volcano, Deschutes County, Oregon; lat 43°41.3' N., long 121°16' W.; Average from samples collected by Beyers, (1973).
3. East McKay Butte dome; Newberry Volcano, Deschutes County, Oregon; lat 43°43.9' N., long 121°21.6' W.; Samples M4-16 (collected by N. S. MacLeod).
4. China Hat dome; Deschutes County, Oregon; lat 43°41' N., long 121°2.3' W.; Average of 2 samples collected by Beyers (1973).
5. East Butte dome; Deschutes County, Oregon; lat 43°39.9' N., long 120°59.6' W.; Sample Mo73-29 (collected by N. S. MacLeod).
6. Quartz Mountain dome; Deschutes County, Oregon; lat 43°37.5' N., long 120°53.3' W.; Sample Mo73-31 (collected by N. S. MacLeod).
7. Long Butte dome; Lake County, Oregon; lat 43°33.5' N., long 120°49.8' W.; Sample M3-31 (collected by N. S. MacLeod).
8. Squaw Ridge dome; Lake County, Oregon; lat 43°31.8' N., long 120°46.8' W.; Sample M3-33 (collected by N. S. MacLeod).
9. Frederick Butte dome; Deschutes County, Oregon; lat 43°36.7' N., long 120°28.5' W.; Sample M3-42 (collected by N. S. MacLeod).
10. East Lake flow, Newberry Volcano, Deschutes County, Oregon; lat 43°45' N., long 121°15' W.; Sample 76-4C (Friedman and Long, 1976).
11. Burn Butte dome; Klamath County, Oregon; lat 43°19.2' N., long 121°53.3' W.; Sample M4-128 (collected by N. S. MacLeod).
12. Quartz Mountain dome; Deschutes County, Oregon; lat 43°45' N., long 121°10' W.; Sample 78-1-L (collected by Irving Friedman).
13. Iron Mountain dome; Harney County, Oregon; lat 43°16' N., long 119°27' W.; Sample DP-158 (Parker, 1974).
14. Cougar Mountain dome; Lake County, Oregon; lat 43°24.0' N., long 120°53.0' W.; Sample Mo73-32 (collected by N. S. MacLeod).
15. Stams Mountain dome; Klamath County, Oregon; lat 43°21.9' N., long 121°25.8' W.; Sample M4-84 (collected by N. S. MacLeod).

16. Yamsey Mountain dome; Klamath County, Oregon; lat 42°56.6' N., long 121°19.5' W.; Sample M4-131 (collected by N. S. MacLeod).
17. North Bald Mountain dome; Klamath County, Oregon; lat 43°19.2' N., long 121°22.5' W.; Sample M4-135 (collected by N. S. MacLeod).
18. Glass Buttes, Lake County, Oregon; lat 43°33.3' N., long 120°0.4' W.; Sample GB-1 (collected by G. W. Walker).
19. Glass Buttes dome; Lake County, Oregon; lat 43°33.3' N., long 120°0.4' W.; Sample Mo73-33 (collected by N. S. MacLeod).
20. Medicine Lake Glass Flow; Siskiyou County, California; lat 41°36' N., long 121°30' W.; Sample 3171-3A (Friedman and Long, 1976).
21. Glass Mountain, Siskiyou County, California; lat 41°30' N., long 121°22.5' W.; Sample RGM-1 (Tatlock and others, 1976; Millard, 1976).
22. Big Glass Mountain, Siskiyou County, California; lat 41°36.9' N., long 121°29.4' W.; Sample No. 19103 (Powers, 1932).
23. Little Glass Mountain, Siskiyou County, California; lat 41°34.3' N., long 121°41.0' W.; Sample No. 19033a (Powers, 1932).
24. Massive Lava Group, S. Slope Medicine Lake Highlands, Siskiyou County, California; lat 41°35.3' N., long 121°29.5' W.; Sample No 19007 (Powers, 1932).
25. Glass Mountain flow, Siskiyou County, California; lat 41°37.5' N., long 121°22.5' W.; Sample DBT No. 2 (collected by D. B. Tatlock).
26. Paulina Peak, Deschutes County, Oregon; lat 43°41.4' N., long 121°15.8' W.; Sample No. 26 (Higgins, 1973, Table 4).
27. East Lake Obsidian flow, Deschutes County, Oregon; lat 43°43.1' N., long 121°11.5' W.; Sample No. 40 (Higgins, 1973, Table 5).
28. Older rhyolite, Newberry Volcano, Deschutes County, Oregon; lat 43°42.6' N., long 121°13.3' W.; Sample No. 5 (Higgins, 1973, Table 3).
29. China Hat, Deschutes County, Oregon; lat 43°41.2' N., long 121°1.8' W.; Sample No. 70 (Higgins, 1973, Table 6).
30. McKay Butte dome, Deschutes County, Oregon; lat 43°44.4' N., long 121°21.3' W.; Sample MC-28 (Beyers, 1973).
31. McKay Butte, Deschutes County, Oregon; lat 43°44.4' N., long 121°21.3' W.; Sample MC-2A (Beyers, 1973).
32. Big Obsidian Flow, Newberry Volcano, Deschutes County, Oregon; lat 43°41.8' N., long 13.8' W.; Sample of early phase of Big Obsidian Flow (Laidley and McKay, 1971).
33. Rhyolite, Little Glass Mountain, Siskiyou County, California; lat 41°34' N., long 121°41' W.; Condie and Hayslip (1975).
34. Rhyolite, Big Glass Mountain, Siskiyou County, California; lat 41°40' N., long 121°29.5' W.; Condie and Hayslip (1975).
35. Dacite, Medicine Lake, Siskiyou County, California; Condie and Hayslip (1975).
36. Hoffman Rhyolite, Medicine Lake Highlands, Siskiyou County, California; Condie and Hayslip (1975).
37. Rhyolite dome, Medicine Lake Highlands, Siskiyou County, California; lat 41°39' N., long 121°42.5' W.; Sample No. 56B1 (Mertzman, 1981).
38. Rhyolite dome, Medicine Lake Highlands, Siskiyou County, California, lat 41°42' N., long 121°39' W.; Sample No. SM-51 (Mertzman, 1981).
39. Rhyolite dome, Medicine Lake Highlands, Siskiyou County, California, lat 41°41.5' N., long 121°28' W.; Sample ML-49 (Mertzman, 1981).

Table 2.—Chemical analyses, isotopic ratios, and norms of rhyolites, rhyodacites, and dacites, 5 to 10 m.y. old, or considered to be late Miocene in age

	1	2	3	4	5	6	7	8	9	10	11	12
K-Ar age	5.01±0.20	5.07±0.64	5.12±0.08	5.69±0.67	5.9±0.09	6.18±0.63	6.4±0.2	6.41±0.19	6.67±0.18	6.83±0.22		6.91±0.14
Geologic age											Late Miocene	
SiO_2	67.7	71.8	74.9	73.9	74.9	69.6	76.0	75.2	71.2	72.6	76.5	76.1
Al_2O_3	16.6	14.7	13.1	13.3	14.	15.7	12.9	13.6	13.5	11.3	11.	10.96
Fe_2O_3	3.1	1.9	.34	.67	.41	3.1	.75	.31	.47	.92	2.6	1.2
FeO	.0	.04	1.2	1.6	.88	.0		.68	.80	1.3	.26	1.53
MgO	.07	.14	.13	.07	.05	.6	.4	.07	.43	.02	.07	.00
CaO	1.2	1.0	.94	.46	.67	1.3	1.6	.53	1.5	.26	.27	.14
Na_2O	5.3	5.1	4.7	4.8	4.8	5.5	3.4	4.3	3.	4.1	4.2	4.73
K_2O	3.8	3.7	3.8	4.6	4.2	3.7	4.9	4.6	4.3	4.9	4.	4.50
H_2O^+	.97	.46	.37	.27	.34	.41	—	.25	2.9	2.8	.36	.23
H_2O^-	.26	.14	.07	.05	.06	.09	—	.13	.30	.18	.04	.08
TiO_2	.16	.25	.17	.24	.06	.17	.08	.13	.14	.21	.18	.17
P_2O_5	.04	.05	.02	.02	.02	.07	—	.02	.05	.01	.00	.01
MnO	.10	.06	.03	.06	.04	.10	—	.04	.03	.05	.08	.08
CO_2	—	—	—	—	—	—	—	—	—	—	—	—
Norms[1] (H_2O-free)												
Q	18.6	25.4	30.7	26.8	29.1	19.8	33.7	31.3	34.21	31.	35.5	34.
Or	22.5	21.9	22.5	27.2	24.8	21.9	29.	27.2	26.	30.1	23.6	26.7
Ab	45.7	43.2	39.8	40.6	40.6	46.5	28.8	36.4	26.23	31.8	34.1	31.5
An	5.7	4.6	3.7	1.2	3.2	6.0	5.5	2.5	7.61	—	—	—
C	1.7	.7	—	—	.5	.6	—	.7	1.35	—	—	—
Ac	—	—	—	—	—	—	—	—	—	1.7	1.1	2.
Ns	—	—	—	—	—	—	—	—	—	.4	—	1.5
Wo	—	—	.4	.4	—	—	1.	—	—	.5	.6	.3
En	.2	.4	.3	.2	.1	.2	1.	.2	1.10	.1	.2	—
Fs	3.1	1.7	1.5	2.2	1.4	3.1	.6	1.	1.26	2.6	3.1	3.4
Mt	1.1	.7	.6	.8	.5	1.1	.3	.4	.48	—	.4	—
Il	.3	.5	.3	.5	.1	.3	.2	.3	.27	.4	.3	.3
Ap	.1	.1	.1	.1	.1	.2	—	.1	.12	.0	—	.0
Hm	—	—	—	—	—	—	—	—	—	—	—	—
Q	21.	28.	33.	28.	31.	22.	37.	33.	40.	33.	38.	37.
Or	26.	24.	24.	29.	26.	25.	32.	29.	30.	32.	25.	29.
Ab	53.	48.	43.	43.	43.	53.	31.	38.	30.	34.	37.	34.
D.I.	87.	90.	93.	95.	95.	88.	91.	95.	86.	93.	93.	92.
Minor elements[2, 3, 4]												
Cl	—	—	—	—	—	—	—	—	—	—	—	—
F	—	—	—	—	—	—	—	—	—	—	—	—
Ag	<20.	<20.	—	—	<20.	<20.	—	—	<20.	<20.	—	.10
As	1.2	2.6	—	—	4.	1.2	—	—	2.4	9.5	—	10.
Au	<.05	<.05	—	—	<.05	<.05	—	—	<.05	<.05	—	.004
B	7.	11.	14.	18.	20.	8.	—	61.	65.	75.	—	60.
Ba	1100.	930.	1470.	1140.	530.	680.	—	1490.	1100.	410.	—	59.
Be	3.	3.	2.	4.	4.	4.	—	2.	1.5	4.	—	4.
Bi	—	—	—	—	—	—	—	—	—	—	—	—
Cd	—	—	—	—	—	—	—	—	—	—	—	—
Co	N2.	—	.810	.422	N2.	N2.	<5.	.478	3.	N2.	—	—
Cr	N2.	N2.	5.	N2.	3.	N2.	10.	1.4	4.	—	—	L1.
Cs	—	—	2.85	5.02	—	—	—	5.21	—	—	—	6.3
Cu	6.	3.	17.	14.	2.	8.	<5.	13.	9.	6.	—	6.
Hf	—	—	6.86	12.	—	—	—	5.29	—	—	—	16.6
Hg	<.010	.058	—	—	.010	.010	—	—	.065	.025	—	<.010
La	—	N20.	28.9	37.6	—	—	—	34.1	—	—	—	—
Li	—	—	—	—	—	—	—	—	—	—	—	—
Mo	—	N2.	N2.	N2.	—	—	—	N2.	—	—	—	5.
Nb	24.	36.	26.	84.	25.	N15.	—	24.	18.	34.	—	20.
Ni	N2.	N2.	5.	N2.	N2.	N2.	5.	N2.	3.	2.	—	L5.
Pb	23.	20.	19.2	22.7	21.	15.	10.	22.7	13.	21.	—	40.
Rb	37.	90.	95.	117.	100.	76.	—	112.	90.	100.	—	129.
Sb	<1.7	.4	.565	.604	.6	.3	—	2.41	.3	2.	—	2.4
Sc	4.	N1.5	4.76	6.88	N1.5	4.	—	3.98	N1.5	N1.5	—	N5.
Sn	—	—	—	—	—	—	—	—	—	—	—	N10.
Sr	100.	94.	70.	68.	50.	120.	—	41.	240.	23.	—	N5.
V	N3.	N3.	N3.	N3.	N3.	N3.	60.	N3.	—	N3.	—	N7.
W[4]	.37	—	—	—	1.8	—	—	—	—	1.9	—	2.1
Y	27.	29.	50.	70.	37.	39.	—	45.	N10.	110.	—	150.
Zn	80.	—	52.	95.	51.	77.	10.	45.	N30.	110.	—	—
Zr	1300.	400.	209.	435.	280.	980.	—	146.	110.	1100.	—	520.
Ce	—	—	56.	79.2	—	—	—	70.3	—	—	—	—
Ga	15.	18.	18.	22.	22.	13.	—	15.	14.	27.	—	32.
Ge	—	—	—	—	—	—	—	—	—	—	—	N10.
In	—	—	—	—	—	—	—	—	—	—	—	—
Re	—	—	—	—	—	—	—	—	—	—	—	—
Tl	—	—	—	—	—	—	—	—	—	—	—	—
Yb	3.	4.	4.96	7.22	4.	5.	—	4.66	N1.	11.	—	15.
Th	11.78	7.56	12.6	10.2	10.71	6.34	—	9.43	6.07	9.78	—	13.59
U	1.82	3.73	3.51	4.49	4.67	3.52	—	3.18	3.67	4.99	—	5.31
Th/U	6.47	2.02	3.59	2.27	2.29	1.80	—	2.97	1.65	1.96	—	2.56
Strontium and lead isotopic data												
$Sr^{87}/^{86}$	—	—	.7037	.7039	—	—	—	.7040	—	—	—	—
$Pb^{206}/^{204}$	—	—	18.844	18.846	—	—	—	18.777	—	—	—	—
$Pb^{207}/^{204}$	—	—	15.620	15.620	—	—	—	15.607	—	—	—	—
$Pb^{208}/^{204}$	—	—	38.520	38.538	—	—	—	38.479	—	—	—	—

Table 2.—Chemical analyses, isotopic ratios, and norms of rhyolites, rhyodacites, and dacites, 5 to 10 m.y. old, or considered to be late Miocene in age—Cont.

	13	14	15	16	17	18	19	20	21	22	23	24
K-Ar age	7.11±0.34		7.6	7.13±0.34	7.19±0.32		7.0±0.4	7.27±0.50				
Geologic age		Late Miocene				Late Miocene			Late Miocene	Late Miocene	Late Miocene	Late Miocene
SiO_2	72.28	73.1	70.2	76.75	76.27	76.7	81.4	74.75	75.1	75.7	74.6	76.9
Al_2O_3	13.60	14.1	14.4	12.56	13.48	13.3	10.5	13.41	13.3	13.	13.4	13.4
Fe_2O_3	.90	1.5	1.3	.28	.00	.29	.03	1.22	.60	.13	.89	.17
FeO	.63	.31		.45	.25	.08	.01	.25	.76	.24	.51	.25
MgO	.38	.22	.91	.03	.08	.04	.01	.19	.05	.01	.04	.01
CaO	1.25	1.1	1.9	.51	.56	.64	.05	1.06	.47	.28	.46	.3
Na_2O	3.38	3.5	3.2	4.07	3.09	3.3	2.6	3.62	4.9	4.3	4.8	4.4
K_2O	4.48	4.5	3.3	4.53	4.83	4.9	4.2	4.54	4.3	4.4	4.4	4.5
H_2O^+	2.88	1.0	3.2	.28	.98	1.1	.53	.37	.12	1.4	.32	.47
H_2O^-	.08			.06	.15		.67	.06	.08	.05	.02	.05
TiO_2	.19	.19	.08	.06	.06	.06	.07	.18	.06	.08	.06	.07
P_2O_5	.05	.04	—	.01	.01	.01	.11	.04	.04	.03	.04	.1
MnO	.06	.10	.11	.07	.02	.06	.01	.05	.05	.09	.05	.09CO_2
-	—	—	—	—	—	—	—	—	—	.01	—	.01
						Norms[1] (H_2O-free)						
Q	32.70	32.9	34.	34.37	38.8	37.8	—	33.43	28.8	33.3	28.5	33.9
Or	27.30	26.6	20.1	26.89	28.90	29.3	—	26.95	25.4	26.6	26.	26.6
Ab	29.44	29.6	27.9	34.52	26.48	27.9	—	30.80	41.5	37.2	40.6	37.2
An	6.08	5.2	9.9	2.47	2.76	3.2	—	5.	1.6	1.2	2.0	.8
C	.51	1.7	2.2	.06	2.15	1.5	—	.71	—	.7	—	1.1
Ac	—	—	—	—	—	—	—	—	—	—	—	—
Ns	—	—	—	—	—	—	—	—	—	—	—	—
Wo	—	—	—	—	—	—	—	—	.2	—	—	—
En	.97	.6	2.34	.07	.20	.1	—	.47	.1	—	.1	—
Fs	1.48	1.8	1.6	.84	.21	.4	—	1.33	1.5	.5	1.5	.5
Mt	.57	.6	.5	.26	.10	.1	—	.52	.5	.1	.5	.2
Il	.38	.4	.2	.11	.11	.1	—	.34	.1	.2	.1	.1
Ap	.12	.1	—	.02	.02	—	—	.09	.1	.1	.1	.2
Ne	—	—	—	—	—	—	—	—	—	—	—	—
Q	37.	37.	41.	36.	41.	40.	—	37.	30.	34.	30.	35.
Or	31.	30.	25.	28.	31.	31.	—	30.	27.	27.	27.	27.
Ab	33.	33.	34.	36.	28.	29.	—	34.	43.	38.	43.	38.
D.I.	89.	89.	82.	96.	94.	95.	—	91.	96.	97.	95.	98.
						Minor elements[2, 3, 4]						
Cl	610.	—	—	510.	190.	—	—	230.	1200.	190.	1100.	180.
F	170.	—	—	490.	50.	—	—	240.	1400.	730.	1400.	460.
Ag	.05	—	—	.04	.05	—	—	<.05	<20.	<20.	<20.	<20.
As	2.8	—	—	2.8	1.7	—	—	2.1	1.4	1.6	1.1	1.2
Au	<.001	—	—	<.001	<.001	—	—	<.001	<.05	<.05	<.05	<.05
B	20.	—	—	72.	20.	—	—	20.	120.	100.	130.	110.
Ba	1046.	—	—	51.	96.	—	—	899.	24.	6.	20.	10.
Be	N2.	—	—	4.	3.	—	—	N2.	2.	<.6	3.	.6
Bi	—	—	—	—	—	—	—	—	<14.	<6.	<14.	<6.
Cd	N50.	—	—	N50.	N50.	—	—	N50.	<14.	<14.	<14.	<14.
Co	2.1	—	—	<.3	<2.	—	—	1.8	<2.	<2.	<2.	<2.
Cr	2.4	—	—	<.8	<.5	—	—	2.2	4.	8.	<1.5	7.
Cs	3.4	—	—	4.2	3.3	—	—	3.9	—	—	—	—
Cu	10.	—	—	3.	1.	—	—	8.	10.	62.	11.	12.
Hf	3.4	—	—	3.6	3.4	—	—	4.	—	—	—	—
Hg	<.01	—	—	.045	.38	—	—	.05	.035	.065	.02	.022
La	29.5	—	—	19.	11.5	—	—	33.5	<14.	<14.	<14.	<15.
Li	—	—	—	—	—	—	—	—	—	—	—	—
Mo	L3.	—	—	L3.	N3.	—	—	L3.	<4.	3.	<4.	3.
Nb	L10.	—	—	L10.	L10.	—	—	L10.	14.	41.	14.	41.
Ni	L5.	—	—	N5.	L5.	—	—	L5.	3.	1.5	2.	2.
Pb	30.	—	—	40.	50.	—	—	40.	10.	49.	12.	35.
Rb	106.	—	—	127.	139.	—	—	111.	—	200.	125.	202.
Sb	.5	—	—	.6	.8	—	—	.4	.4	1.	.4	.9
Sc	2.9	—	—	3.16	3.07	—	—	2.79	<1.5	2.	<1.5	4.
Sn	N10.	—	—	N10.	N10.	—	—	N10.	<4.	20.	<4.	<4.
Sr	190.	—	—	8.	49.	—	—	190.	<2.	3.	<2.	4.
V	30.	—	—	N7.	L7.	—	—	20.	<2.	<2.	<2.	<2.
W	.92	—	—	1.1	1.2	—	—	.76	1.1	.5	1.2	.66
Y	20.	—	—	40.	20.	—	—	20.	140.	44.	120.	52.
Zn	32.	—	—	34.	15.	—	—	34.	120.	70.	150.	<30.
Zr	128.	—	—	88.	108.	—	—	154.	110.	110.	120.	100.
Ce	46.	—	—	37.	19.5	—	—	53.5	<100.	<100.	<100.	<100.
Ga	16.	—	—	15.	17.	—	—	14.	23.	19.	23.	20.
Ge	N10.	—	—	N10.	N10.	—	—	N10.	<10.	<14.	<10.	<14.
In	—	—	—	—	—	—	—	—	<3.	<3.	<3.	<3.
Re	—	—	—	—	—	—	—	—	<14.	<14.	<14.	<14.
Tl	—	—	—	—	—	—	—	—	<6.	<6.	<6.	<6.
Yb	2.	—	—	3.35	2.4	—	—	2.	7.	2.	8.	5.
Th	9.19	—	—	11.95	9.1	—	—	11.1	11.	15.2	10.3	15.2
U	3.97	—	—	8.2	6.5	—	—	4.5	3.4	8.3	3.3	9.7
Th/U	2.31	—	—	1.46	1.40	—	—	2.47	3.24	1.71	3.12	1.57
						Strontium and lead isotopic data						
$Sr^{87}/^{86}$	—	—	—	—	—	—	—	—	—	—	—	—
$Pb^{206}/^{204}$	—	—	—	—	—	—	—	—	—	—	—	—
$Pb^{207}/^{204}$	—	—	—	—	—	—	—	—	—	—	—	—
$Pb^{208}/^{204}$	—	—	—	—	—	—	—	—	—	—	—	—

Table 2.--Chemical analyses, isotopic ratios, and norms of rhyolites, rhyodacites, and dacites, 5 to 10 m.y. old, or considered to be late Miocene in age--Cont.

	25	26	27	28	29	30	31	32	33	34	35
K-Ar age			7.70±0.09	7.41±0.19	7.54±0.01	7.8 m.y.?		7.1±	9.24±0.3	9.6±0.6[5]	8.9±
Geologic age	Late Miocene	Late Miocene					Late Miocene				
SiO_2	76.8	76.68	75.87	76.06	74.7	71.0	75.1	74.8	72.0	69.1	75.6
Al_2O_3	13.4	12.95	13.33	13.21	13.5	12.9	11.5	13.5	12.6	13.7	13.0
Fe_2O_3	.2	.30	.15	.19	.44	2.4	1.8	.31	.74	.9	.44
FeO	.2	.31	.45	.49	1.0		.8	.44	.60	1.3	.66
MgO	.01	.04	.06	.06	.12	.6	.23	.04	.22	.85	.11
CaO	.26	.49	.89	.80	.59	1.45	.51	.79	1.1	1.6	.78
Na_2O	4.3	4.29	3.92	4.05	4.2	4.2	4.	4.5	2.9	3.2	3.8
K_2O	4.4	4.4	4.61	4.52	4.9	4.9	4.4	4.6	5.5	5.	4.9
H_2O^+	.65	.13	.21	.16	.39	--	.93	.18	2.8	2.3	.26
H_2O^-	.05	.03	.05	.04	.03	--	.47	.05	.17	.21	.08
TiO_2	.07	.06	.00	.05	.19	.40	.25	.11	.20	.37	.17
P_2O_5	.05	.01	.00	.00	.02	--	.04	.02	.05	.12	.03
MnO	.09	.10	.06	.07	.01	--	.01	.05	.05	.04	.04
CO_2	.01	.01	--	--	--	--	.05	.03	.01	.01	--
Norms[1] (H_2O-free)											
Q	34.8	33.15	33.17	33.09	29.9	24.	33.1	29.3	31.6	26.9	32.8
Or	26.0	26.59	27.30	26.77	29.	29.	26.6	27.2	33.7	30.1	29.
Ab	36.4	36.38	33.25	34.35	35.5	35.5	34.7	38.1	25.4	27.9	32.2
An	1.0	2.37	4.42	3.97	2.8	1.9	.2	3.1	5.2	7.2	3.7
C	1.3	.19	.28	.20	.4	--	--	--	--	.5	.1
Ac	--	--	--	--	--	--	--	--	--	--	--
Ns	--	--	--	--	--	--	--	--	--	--	--
Wo	--	--	--	--	--	2.2	.9	.3	.4	--	--
En	--	.10	.15	.15	.3	1.5	.6	.1	.6	2.2	.27
Fs	.5	.75	.80	.81	1.3	2.1	2.4	.8	1.3	2.	1.
Mt	.1	.22	.22	.25	.5	.9	.9	.3	.5	.8	.4
Il	.1	.11	--	.09	.4	.8	.5	.2	.4	.7	.3
Ap	.1	.02	--	--	.1	--	.1	.1	.1	.3	.1
Hm	--	--	--	--	--	--	--	--	--	--	--
Q	36.	34.	35.4	34.8	31.6	27.	35.	31.	34.8	31.7	34.9
Or	27.	28.	29.1	28.	30.7	33.	28.	28.8	37.2	35.5	30.8
Ab	37.	38.	35.5	36.	37.7	40.	37.	40.3	28.	32.9	34.2
D.I.	97.	96.	94.	94.	94.	89.	94.	95.	91.	95.	94.
Minor elements[2, 3, 4]											
Cl	180.	80.	470.	390.	--	--	--	350.	190.	200.	200.
F	500.	69.	830.	750.	--	--	--	300.	400.	500.	200.
Ag	<20.	<.05	.06	<.05	--	--	.87?	<.5	<.5	<.5	<.5
As	4.	5.4	2.1	2.	--	--	<100.	<300.	<300.	<300.	<300.
Au	<.05	<.001	<.001	<.001	--	--	<6.81	<14.	<14.	<14.	<14.
B	95.	70.	30.	30.	23.	--	15.2	32.	23.	<10.	69.
Ba	4.	77.	382.	313.	616.	--	165.	540.	840.	1700.	840.
Be	<.6	6.	4.	2.	4.	--	3.74	<2.	2.9	2.9	<2.
Bi	<6.	--	--	--	--	--	--	<14.	--	--	<14.
Cd	<14.	N50.	--	N50.	--	--	<14.7	<14.	<2.0	<2.	<14.
Co	<2.	.1	.2	.2	1.02	<5.	<1.	<2.	4.5	62.	<2.
Cr	7.	.6	<1.3	.7	.88	15.	3.74	<2.	<10.	<10.	<2.
Cs	--	8.2	4.2	4.4	3.3	--	--	--	--	--	--
Cu	12.	2.	2.	1.	13.	25.	<46.4	6.	4.7	9.	5.
Hf	--	4.1	2.8	3.	7.8	--	--	--	--	--	--
Hg	.03	.05	.058	.065	--	--	--	<20.	<20.	--	<20.
La	<14.	12.	31.8	45.5	41.1	--	124.	19.	35.	50.	20.
Li	--	--	--	--	--	--	--	--	<50.	<50.	--
Mo	3.	N3.	4.	L3.	N2.	--	1.97	6.	5.	6.	7.
Nb	37.	20.	L10.	L10.	62.	--	42.5	<20.	32.	<25.	20.
Ni	2.	N5.	N5.	N5.	N2.	10.	5.8	<2.	4.	6.	<2.
Pb	32.	50.	40.	40.	14.9	<10.	14.5	18.	21.	17.	<14.
Rb	204.	208.	94.	102.	120.	--	--	--	--	--	--
Sb	.9	1.	.4	<.6	.771	--	<68.1	<40.	--	--	<40.
Sc	3.	4.73	2.2	2.49	3.83	--	<1.	<2.	<10.	<10.	2.
Sn	<4.	N10.	N10.	N10.	--	--	3.85	<4.	<10.	<10.	<4.
Sr	2.	5.	85.	68.	25.	--	25.8	62.	180.	310.	91.
V	<2.	N7.	N7.	N7.	N.3	20.	12.	<2.	15.	32.	<2.
W	.86	.76	.88	.90	--	--	<10.	<20.	<20.	<20.	<20.
Y	43.	60.	30.	30.	51.	--	--	13.	21.	23.	17.
Zn	<30.	33.	28.	30.	N30.	--	106.	<30.	<50.	<50.	<30.
Zr	90.	138.	74.	76.	230.	--	600.	150.	150.	210.	230.
Ce	<100.	24.5	19.	27.	78.5	--	--	<100.	<100.	<100.	<100.
Ga	19.	20.	15.	14.	19.	--	28.8	10.	16.	18.	13.
Ge	<14.	N10.	N10.	N10.	--	--	<1.	<14.	--	--	<14.
In	<3.	--	--	--	--	--	--	<3.	--	--	<3.
Re	<14.	--	--	--	--	--	--	<14.	--	--	<14.
Tl	<6.	--	--	--	--	--	--	<6.	--	--	<6.
Yb	3.	5.3	2.7	2.9	4.95	--	--	2.	--	--	3.
Th	16.1	16.1	6.8	8.4	13.4	--	25.9	14.5	22.3	16.4	15.8
U	9.4	8.8	4.8	4.7	4.04	--	--	4.02	7.98	5.17	5.22
Th/U	1.71	1.83	1.42	1.79	3.32	--	--	3.61	2.80	3.18	3.03
Strontium and lead isotopic data											
$Sr^{87}/^{86}$	--	--	--	--	.7041	--	--	--	--	--	--
$Pb^{206}/^{204}$	--	--	--	--	18.836	--	--	--	--	--	--
$Pb^{207}/^{204}$	--	--	--	--	15.602	--	--	--	--	--	--
$Pb^{208}/^{204}$	--	--	--	--	38.597	--	--	--	--	--	--

Table 2 Footnotes

1. In normative calculations total Fe distributed according to ratio of Fe^{+3}/Fe^{+2}=(.31/.87), which was determined by average contents of Fe_2O_3 and FeO in 13 samples of fresh, nonhydrated obsidian.
2. Cl determined stectrophotometrically.
3. F determined with a specific-ion electrode.
4. W determined spectrophotometrically.

Table 2 Sample information

1. Partin Butte dome; Lake County, Oregon; lat 42 54.9' N., long 121 85' W.; Sample M4-130 (collected by N. S. MacLeod).
2. Bald Mountain dome; Klamath County, Oregon; lat 43 16.5' N., long 121 21.3' W.; Sample M4-112 (collected by N. S. MacLeod).
3. Squaw Butte dome; Harney County, Oregon; lat 43 30.0' N., long 119 46.7' W.; Sample M3-90 (collected by N. S. MacLeod).
4. Dome or flow south of Riley, Harney County, Oregon; lat 43 29.0' N., long 119 32.1' W.; Sample M3-70 (collected by N. S. MacLeod).
5. Hager Mountain dome; Lake County, Oregon; lat 43 0.6' N., long 121 1.2' W.; Sample M3-61 (collected by N. S. MacLeod).
6. Connley Mountain dome; Lake County, Oregon; lat 43 17.2' N., long 121 3.8' W.; Sample M4-42 (collected by N. S. MacLeod).
7. Palomino Butte dome; Harney County, Oregon; lat 43 29' N., long 119 18' W.; Sample DP-214 (Parker and Armstrong, 1972).
8. Egli Ridge dome; Harney County, Oregon; lat 43 22.8' N., long 119 51.0' W.; Sample M3-86 (collected by N. S. MacLeod).
9. Elk Mountain dome; Lake County, Oregon; lat 43 15.6' N., long 120 10.5' W.; Sample M3-60 (collected by N. S. MacLeod).
10. South Horse Mountain dome; Harney County, Oregon; lat 43 2.8' N., long 120 8.6' W.; Sample M3-57 (collected by N. S. MacLeod).
11. Horse Mountain dome; Harney County, Oregon; lat 43 9.1' N., long 120 7.7' W.; Sample HM-1 (collected by G. W. Walker).
12. Horse Mountain dome; Harney County, Oregon; lat 43 9.1' N., long 120 7.7' W.; Sample Mo73-41 (collected by N. S. MacLeod).
13. Owen Butte dome; Klamath County, Oregon; lat 42 19.7' N., long 120 51.9' W.; Sample Mo73-35 (collected by N. S. MacLeod).
14. Owen Butte dome; Klamath County, Oregon; lat 42 21' N., long 120 51.2' W.; Sample GWW-47-58 (collected by G. W. Walker).
15. Quartz Butte dome; Lake County, Oregon; lat 42 20.6' N., long 120 47.8' W.; Peterson and McIntyre (1970, p. 70).
16. Drews Ranch dome; Lake County, Oregon; lat 42 16.1' N., long 120 43.8' W.; Sample Mo73-34 (collected by N. S. MacLeod).
17. Thomas Creek dome; Lake County, Oregon; lat 42 23.8' N., long 120 36.0' W.; Sample Mo73-37 (collected by N. S. MacLeod).
18. Thomas Creek dome; Lake County, Oregon; lat 42 20' N., long 120 35' W.; Sample GWW-6-58 (collected by G. W. Walker).
19. Silicified and altered rhyolite intrusive, White King mine; Lake County, Oregon; lat 42 20' N., long 120 31.3' W.; Sample 26-77 (Walker, 1980). Isotopic age on unaltered perlite from overlying breccia.
20. Cougar Peak dome complex; Lake County, Oregon; lat 42 18.3' N.,

long 120 37.9' W.; Sample Mo-73-36 (collected by N. S. MacLeod).

21. Dome or flow on Cox Creek; Lake County, Oregon; lat 42 23.8' N., long 120 25.6' W.; Sample 126-77 (Walker, 1980).
22. Dome east of Cox Flat; Lake County, Oregon; lat 42 21.8' N., long 120 34' W.; Sample 74-77 (Walker, 1980).
23. Dome northeast of Paxton Meadow; Lake County, Oregon; lat 42 24.4' N., long 120 28.7' W.; Sample 107-77 (Walker, 1980).
24. Dome northeast of Cox Flat; Lake County, Oregon; lat 42 22.7' N., long 120 34.3'W.; Sample 9-77 (Walker, 1980).
25. Dome or intrusive between large Thomas Creek dome and Lucky Lass (U) mine; Lake County, Oregon; lat 42 20.2' N., long 120 33.5' W.; Sample 68-77 (Walker, 1980).
26. Dome exposed in borrow pit near USFS Thomas Creek Work Camp; Lake County, Oregon; lat 42 15' N., long 120 30' W.; Sample Mo73-38 (collected by N. S. MacLeod; Walker, 1980).
27. McComb Butte dome; Lake County, Oregon; lat 42 34.6' N., long 120 37.1' W.; Sample Mo73-39 (collected by N. S. MacLeod).
28. Tucker Hill dome; Lake County, Oregon; lat 42 34.6' N., long 120 25.3' W.; Sample Mo73-40 (collected by N. S. MacLeod).
29. Burns Butte dome, Harney County, Oregon; lat 43 34.1' N., long 119 8.2' W.; Sample M3-79 (collected by N. S. MacLeod).
30. Flow or dome at Double O Ranch, Harney County, Oregon; lat 43 17' N., long 119 19' W.; Sample DP-316D (Parker, 1974).
31. Rhyolite flow (?), Harney County, Oregon; lat 43 6' N., long 118 45' W.; Sample SA-49 (colleced by L. C. Rowan).
32. Rhyolite obsidian from dome near Boyd Creek, Modoc County, California; lat 41 42.8' N., long 120 11.5' W.; Sample BC-1 (collected by W. A. Duffield).
33. Perlitic rhyolite obsidian from dome S.E. of Crane, Harney County, Oregon; lat 43 20.1' N., long 118 26.5' W.; Sample M5-6 (collected by N. S. MacLeod).
34. Rhyolite from E. side of Duck Butte, Malheur County, Oregon; lat 43 8.6' N., long 118 7.0' W.; Sample M5-11 (collected by N. S. MacLeod).
35. Rhyolite obsidian, Modoc County, California; lat 41 51.2' N., long 120 19' W.; Sample OH-1 (collected by W. A. Duffield).

Table 3.--Chemical analyses, isotopic ratios, and norms of rhyolites, rhyodacites, anddacites, more than 10 m.y. old or considered to be Middle Miocene or older

	1	2	3	4	5	6	7	8	9	10	11	12
K-Ar age	10.36±0.53				16.0±0.4							
Geologic age		Late Miocene	Middle Miocene	Middle Miocene		Middle Miocene	Middle Miocene	Middle Miocene	Middle Miocene	Middle Miocene	Middle Miocene	Middle Miocene
SiO_2	74.00	66.21	75.2	74.7	76.1	69.3	70.2	72.3	74.6	76.5	72.9	74.1
Al_2O_3	13.91	15.74	13.2	13.0	13.1	14.3	14.8	14.6	13.4	13.6	14.7	11.8
Fe_2O_3	.40	1.53	.78	.77	.86	2.5	2.5	2.2	1.6	0.38	1.7	3.6
FeO	0.77	1.76	.78	.72	.24						.24	.2
MgO	0.21	0.93	.07	.06	.01	.88	.60	.74	.52	.21	.08	.19
CaO	1.15	2.85	.48	.42	.1	1.9	1.9	1.8	1.2	.81	.41	.13
Na_2O	3.75	3.75	4.6	4.6	4.1	3.8	4.0	4.0	3.5	3.9	4.7	3.3
K_2O	4.95	4.45	4.6	4.8	4.0	4.6	4.6	4.6	4.9	4.7	5.5	5.3
H_2O^+	.17	1.53	.27	.26	.51	2.2	.56	.85	.52	.56	.37	.83
H_2O^-	.08	.18	.12	.16	.31						.16	.27
TiO_2	.15	.55	.08	.08	.19	.40	.42	.40	.28	.10	.32	.26
P_2O_5	.03	.19	.04	.04	.1	.13	.14	.18	.08	.00	.04	.04
MnO	.00	.07	.05	.05	.02	.07	.06	.06	.05	.04	.05	.03
CO_2	--	--	--	.02	.01	--	--	--	--	--	.02	.02
					Norms[1] (H_2O-free)							
Q	30.18	19.42	29.4	28.5	[5]33.6	24.1	24.1	26.7	32.1	34.0	23.3	33.0
Or	29.31	26.77	27.2	28.4	29.6	27.8	27.2	27.2	29.0	27.8	32.5	31.9
Ab	31.81	33.32	38.9	38.9	34.7	33.	33.8	33.8	29.6	33.0	39.8	27.9
An	5.51	13.16	2.1	.9	.6	8.5	8.5	7.8	5.4	4.0	1.9	.4
C	.38	--	--	--	1.3	--	.2	.3	.5	.7	.3	.5
Ac	--	--	--	--	--	--	--	--	--	--	--	--
Ns	--	--	--	--	--	--	--	--	--	--	--	--
Wo	--	--	--	.4	--	.1	--	--	--	--	--	--
En	.52	2.37	.2	.2	--	2.2	1.5	1.8	1.3	.5	.2	.5
Fs	1.03	2.83	1.6	1.6	.9	2.4	2.3	2.0	1.5	.3	1.6	3.6
Mt	.43	1.22	.6	.5	.4	1.	1.0	.8	.6	.1	.7	1.3
Il	.28	1.06	.2	.2	.4	.8	.8	.8	.5	.2	.6	.5
Ap	.07	.45	.1	.1	.2	.3	.3	.4	.2	--	.1	.1
Hm	--	--	--	--	--	--	--	--	--	--	--	--
Q	33.	25.	31.	30.	34.	28.	28.	30.	35.	36.	24.	36.
Or	32.	34.	28.	30.	30.	33.	32.	31.	32.	29.	34.	34.
Ab	35.	41.	41.	41.	35.	39.	40.	39.	33.	35.	42.	30.
D.I.	91.	80.	95.	96.	98.	85.	85.	88.	91.	95.	96.	93.
					Minor elements[2, 3, 4]							
Cl	--	--	2500.	2800.	1000.	--	--	--	--	--	300.	--
F	--	--	2500.	700.	170.	--	--	--	--	--	500.	--
Ag	<.05	.06	<20.	<20.	<20.	--	--	--	--	--	<20.	--
As	2.	1.4	12.1	2.1	1.9	--	--	--	--	--	3.4	--
Au	<.001	<.002	<.05	<.05	<.05	--	--	--	--	--	<.05	--
B	20.	20.	180.	110.	.55	--	--	--	--	--	54.	20.
Ba	790.	880.	11.	16.	120.	--	--	--	--	--	400.	200.
Be	N2.	N2.	4.	3.	3.	--	--	--	--	--	5.	2.
Bi	--	--	<14.	--	<6.	--	--	--	--	--	--	--
Cd	N50.	N50.	<14.	<2.	<14.	--	--	--	--	--	--	--
Co	N5.	6.	--	--	<2.	--	--	--	--	--	2.	--
Cr	3.	3.	<1.5	<1.5	6.	--	--	--	--	--	N2.	--
Cs	2.8	1.9	--	--	--	--	--	--	--	--	--	--
Cu	6.	24.	25.	85.	13.	--	--	--	--	--	4.	1.5
Hf	--	--	--	--	--	--	--	--	--	--	--	--
Hg	.043	.01	.038	<.01	.022	--	--	--	--	--	.03	--
La	L50.	--	53.	53.	43.	--	--	--	--	--	--	--
Li	--	--	--	--	--	--	--	--	--	--	--	--
Mo	L3.	L3.	11.	7.	7.	--	--	--	--	--	--	--
Nb	L10.	L10.	24.	20.	35.	--	--	--	--	7.	38.	20.
Ni	N5.	L5.	<1.5	<15<15	--	--	--	--	--	--	N2.	--
Pb	30.	30.	10.	8.	27.	--	--	--	--	--	18.	20.
Rb	125.	102.	--	--	--	--	--	--	70.	100.	160.	--
Sb	.4	<.7	.8	.8	.8	--	--	--	--	--	<.05	--
Sc	N5.	11.	<1.5	<1.5	1.	--	--	--	--	--	6.	--
Sn	N10.	N10.	<4.0	<4.	7.	--	--	--	--	--	--	--
Sr	210.	320.	<2.	<2.	36.	--	--	--	165.	56.	71.	15.
V	20.	60.	<2.	<2.	<2.	--	--	--	--	--	3.	--
W	.90	.68	2.2	2.2	2.	--	--	--	--	--	1.6	--
Y	20.	30.	49.	45.	31.	--	--	--	--	18.	69.	50.
Zn	N200.	N300.	160.	63.	<30.	--	--	--	--	--	55.	--
Zr	140.	200.	120.	110.	210.	--	--	--	85.	60.	420.	300.
Ce	--	--	<100.	<100.	<100.	--	--	--	--	--	--	--
Ga	15.	21.	--	19.	21.	--	--	--	--	--	--	30.
Ge	N10.	N10.	--	--	<14.	--	--	--	--	--	--	--
In	--	--	--	--	<3.	--	--	--	--	--	--	--
Re	--	--	--	--	<14.	--	--	--	--	--	--	--
Tl	--	--	--	--	<6.	--	--	--	--	--	--	--
Yb	2.	3.	4.	3.	3.	--	--	--	--	--	7.	5.
Th	6.59	6.74	19.3	19.1	19.3	--	--	--	--	--	18.47	--
U	3.11	2.11	6.6	6.6	6.6	--	--	--	--	--	7.74	--
Th/U	2.12	3.19	2.92	2.89	2.92	--	--	--	--	--	2.39	--
					Strontium and lead isotope data							
$Sr^{87/86}$												

Table 3.--Chemical analyses, isotopic ratios, and norms of rhyolites, and rhyodacites, and dacites more than 10 m.y. old or considered to be middle Miocene or older--Cont.

	13	14	15	16	17	18	19	20	21	22	23	24
K-Ar age		10.9±1.0	14.2±0.2	14.3±0.3	15±0.3			21.4±4.0		25.0±0.8	27.5±0.8	
Geologic age	Middle Miocene					Miocene?	Miocene		Oligocene			Miocene
SiO_2	75.1	67.43	71.44	71.86	72.51	65.91	77.02	71.9	71.3	69.4	68.6	75.70
Al_2O_3	11.3	12.35	10.95	10.66	10.97	16.34	12.77	14.2	11.5	13.2	13.5	12.50
Fe_2O_3	2.9	1.46	1.75	2.36	1.72	.97	.42	1.7	4.1	3.2	3.1	1.02
FeO	.4	3.01	.88	1.06	.89	3.0	.76	.6	2.2	1.8	1.8	.10
MgO	.08	.15	<.08	.11	<.08	1.0	.02	.42	.02	.05	.03	<.02
CaO	.64	1.38	.74	.55	.54	3.19	.72	2.9	.3	.3	.52	.56
Na_2O	3.7	3.84	3.59	3.28	3.8	4.22	3.14	3.5	5.0	5.8	5.8	3.26
K_2O	4.8	4.32	4.27	5.09	4.32	3.60	5.09	2.7	4.5	4.6	4.7	5.15
H_2O^+	.5	2.91	4.14	4.79	3.62	.28	.20	.48	—	—	—	.34
H_2O^-	.09	.78	1.41	.47	.69	.16	.06	.72	—	—	—	.32
TiO_2	.3	.43	.23	.30	.21	.61	.11	.26	.5	.35	.37	.26
P_2O_5	.02	.02	.02	.05	.02	.25	.04	.28	.04	.05	.03	.03
MnO	.07	.147	.044	.07	.043	.10	.021	.02	.2	.18	.17	.007
CO_2	.02	.34	.1	.11	.03	.01	.05	.02	—	<.05	.05	.07
Norms[1] (H_2O-free)												
Q	33.5	24.97	33.86	32.39	33.50	18.4	37.38	34.2	24.2	17.8	15.9	35.76
Or	28.4	26.53	26.71	31.08	26.71	21.4	30.14	16.0	26.6	27.2	27.8	30.61
Ab	31.3	33.76	32.15	27.40	33.59	36.0	26.65	30.5	34.1	42.8	43.8	27.75
An	.3	3.84	1.25	—	.13	14.2	3.31	14.4	—	—	—	2.58
C	--	--	—	—	—	.3	.88	.3	—	—	—	.63
Ac	—	—	—	1.13	—	—	—	—	4.5	3.6	3.5	—
Ns	--	--	—	—	—	—	—	—	.7	.7	.5	—
Wo	1.1	1.31	1.04	1.05	1.05	—	—	—	.5	.5	1.	—
En	.2	.40	.20	.27	.20	2.5	.05	1.1	.1	.1	.1	.05
Fs	3.1	4.68	2.65	3.68	2.62	3.9	1.15	2.0	7.5	6.1	5.9	.76
Mt	1.2	1.71	.99	.69	.978	1.4	.43	.8	—	—	--	.39
Il	.6	.85	.46	.59	.42	1.2	.21	.5	1.0	.7	.7	.49
Ap	.1	.05	.05	.12	.05	.6	.09	.2	.1	.1	.1	.07
Hm	--	—	—	—	—	—	—	—	—	—	—	—
Q	36.	29.	37.	36.	36.	24.3	40.	42.	29.	20.	18.	38.
Or	30.	31.	29.	34.	28.	28.2	32.	20.	31.	31.	32.	33.
Ab	34.	40.	35.	30.	36.	47.5	28.	38.	40.	49.	50.	29.
D.I.	93.	85.	93.	91.	94.	79.	94.	81.	85.	88.	87.	94.
Minor elements[2, 3, 4]												
Cl	—	330.	430.	480.	470.	200.	360.	—	—	--	—	<200.
F	—	600.	600.	700.	600.	300.	900.	—	--	—	—	<10.
Ag	<1.	.25	.1	.19	.13	<.05	<0.5	—	—	<1.	<1.	—
As	--	7.	20.	10.	20.	—	300.	—	--	—	—	--
Au	—	<.05	<.05	<.05	<.05	<.05	<14.	—	—	—	—	—
B	20.	63.	73.	63.	88.	40.	26.	10.	—	16.	<10.	--
Ba	180.	1100.	114.	89.	57.	1400.	410.	1100.	—	850.	840.	—
Be	3.	3.7	4.4	4.4	4.4	2.	<2.	N1.	—	5.8	5.4	--
Bi	--	—	—	—	—	—	<14.	—	—	—	—	—
Cd	<2.	<2.	<2.	<2.	<2.	—	<14.	—	—	<2.	<2.	--
Co	2.1	—	—	—	—	7.	<2.	6.	—	2.9	3.	—
Cr	<10.	<10.	<10.	<10.	<10.	2.	<2.	11.	—	<10.	<10.	--
Cs	--	7.8	110.	8.7	37.6	—	--	—	—	—	—	—
Cu	7.	5.4	6.5	7.9	6.2	32.	2.	25.	—	4.3	3.6	--
Hf	—	--	—	—	—	—	--	—	—	—	--	--
Hg	—	.03	.07	.02	.03	—	<20.	—	—	—	--	--
La	39.	46.	47.8	48.1	46.4	—	30.	N20.	—	51.	100.	—
Li	--	13.	56.	53.	66.	—	—	—	—	—	—	--
Mo	20.	8.	3.	9.	4.	4.	<4.	N2.	—	<10.	<10.	—
Nb	15.	49.	32.	48.	34.	24.	<20.	N15.	—	<25.	<25.	--
Ni	4.6	5.8	6.2	5.5	5.7	2.	<2.	7.	—	8.5	9.6	—
Pb	<10.	19.	21.	13.	26.	20.	22.	24.	—	15.	15.	—
Rb	—	152.	370	158	225.	—	—	67.	—	—	—	—
Sb	--	2.26	3.37	2.69	3.15	—	<40.	—	—	—	—	—
Sc	<10.	10.	<2.	<2.	<2.	9.	2.	7.	—	<10.	<10.	—
Sn	<10.	18.	2.	24.	2.	—	<4.	—	—	<10.	<10.	--
Sr	7.	40.	86.	19.	47.	360.	53.	200.	—	16.	23.	—
V	<10.	<2.	<2.	<2.	<2.	84.	<2.	46.	—	<10.	<10.	--
W	—	<20.	<20.	<20.	<20.	—	<20.	—	—	—	—	—
Y	60.	72.	88.	92.	89.	30.	18.	25.	—	46.	56.	--
Zn	130.	98.	110.	120.	110.	—	<30.	70.	—	160.	170.	—
Zr	460.	490.	650.	540.	660.	160.	180.	260.	—	>1000.	>1000.	--
Ce	<100.	76.3	104.	98.	99.4	—	<100.	—	—	130.	160.	—
Ga	23.	23.	23.	23.	23.	—	15.	—	—	33.	34.	--
Ge	—	—	—	—	—	—	<14.	—	—	—	—	—
In	--	—	—	—	—	—	<3.	—	—	—	—	—
Re	—	—	—	—	—	—	<14.	—	—	—	—	—
Tl	—	—	—	—	—	—	<6.	—	—	—	—	--
Yb	7.	6.17	8.14	8.11	7.82	2.	3.	3.	—	—	—	--
Th	12.7	13.9	16.3	17.5	18.7	3.4	29.3	8.5	--	14.5	14.3	--
U	1.93	6.82	9.02	7.85	8.76	1.6	5.05	3.47	—	7.	5.16	—
Th/U	6.61	2.04	1.81	2.23	2.13	2.2	5.79	2.45	—	2.07	2.77	
Strontium and lead isotope Data												
$Sr^{87/86}$										[6].7034		

Table 3.--Chemical analyses, isotopic ratios, and norms of rhyolites, and rhyodacites, and dacites more than 10 m.y. old or considered to be middle Miocene or older--Cont.

	25	26	27	28	29	30	31	32	33	34	35	36
K-Ar age												
Geologic age	Middle Miocene	Middle Miocene	Middle Miocene	Middle Miocene	Middle Miocene	Middle Miocene	Middle Miocene		Miocene	Miocene	Miocene	Miocene
SiO_2	71.13	72.1	72.5	73.71	74.26	75.85	72.2	78.4	70.5	74.5	74.1	75.1
Al_2O_3	13.37	11.9	12.69	11.84	11.58	12.74	12.5	10.9	15.	11.7	11.4	13.6
Fe_2O_3	3.44	2.84	1.87	.76	1.99	.44	3.6	1.1	2.	2.5	2.9	.61
FeO	.49	1.3	.43	1.09	.76	.47	.2	.06		.76	.32	.72
MgO	.19	.13	.02	.05	.12	.13	.17	.02	.16	.04	.26	.09
CaO	1.16	.99	.56	.68	.85	.97	.56	.08	.50	.28	1.	.7
Na_2O	3.26	2.42	2.41	2.9	2.63	3.14	3.5	3.3	5.2	3.8	3.6	3.
K_2O	5.22	6.17	6.46	5.44	5.05	5.08	5.8	4.3	6.	5.2	5.1	5.5
H_2O^+	.54	2.44	2.46	2.44	2.25	.29	.63	.48	--	.41	.62	.64
H_2O^-	.57	.45	.65	.49	.36	.24	.37	.23	--	.27	.21	.14
TiO_2	.56	.37	.3	.14	.23	.33	.35	.18	.18	.43	.30	.13
P_2O_5	.1	.04	.04	.02	.06	.06	.04	.03	.44(?)	.02	.02	.05
MnO	.04	.04	.02	.03	.03	.01	.04	.05	.2	.04	.03	.01
CO_2	.02	.02	--	--	.08	.05	.02	<.05	--	.01	.06	.02
Norms[1] (H_2O-free)												
Q	28.53	31.6	32.7	34.66	37.65	37.08	27.4	42.8	[5]16.1	31.5	31.5	35.1
Or	31.20	37.5	39.4	33.09	30.61	30.20	34.9	25.4	35.5	30.7	30.1	32.5
Ab	27.92	21.1	21.1	25.38	22.85	26.14	29.6	27.9	43.8	31.7	30.5	25.4
An	5.16	3.5	2.6	3.28	3.93	1.94	1.3	.2	--	--	.2	3.2
C	.49	--	.8	--	.40	1.36	--	.8	--	--	--	1.7
Ac	--	--	--	--	--	--	--	--	.2	.4	--	--
Ne	--	--	--	--	--	--	--	--	--	--	--	--
Wo	--	.6	--	.02	--	--	.5	--	.2	.5	2.	--
En	.47	.3	.1	.12	.30	.32	.4	.1	.4	.1	.7	.2
Fs	3.27	4.	2.	1.89	2.63	.46	3.3	1.	2.5	2.9	2.9	1.3
Mt	1.38	1.5	.8	.70	1.	.33	1.3	.4	.7	1.	1.1	.5
Il	1.08	.72	.59	.27	.46	.63	.7	.3	.3	.8	.6	.3
Ap	.24	.1	.1	.05	.14	.14	.1	.1	1.	.1	.1	.1
Hm	--	--	--	--	--	--	--	--	--	--	--	--
Q	33.	35.	35.	37.	41.	39.	30.	44.	17.	33.	34.	38.
Or	36.	42.	42.	36.	34.	32.	38.	36.	37.	33.	33.	35.
Ab	32.	23.	23.	27.	25.	28.	32.	29.	46.	34.	33.	27.
D.I.	88.	90.	93.	93.	91.	93.	92.	96.	95.	94.	92.	93.
Minor elements												
Cl							--	--	--	--	--	--
F							--	--	--	--	--	--
Ag							<1.	<1.0	N2.	<1.	--	--
As							--	--	--	--	--	--
Au							--	--	--	--	--	--
B							80.	30.	80.	42.	20.	50.
Ba							280.	20.	230.	80.	100.	1000.
Be							5.	2.	L5.	5.	5.	5.
Bi							--	--	--	--	--	--
Cd							<2.	<2.	N50.	<2.	--	--
Co							2.7	1.4	N7.	--	--	--
Cr							<10.	<10.	54.	<10.	--	--
Cs							--	--	--	--	--	--
Cu							5.	26.	7.	5.	5.	1.
Hf							--	--	--	--	--	--
Hg							--	--	--	--	--	--
La							29.	70.	L70.	39.	--	--
Li							--	--	--	--	--	--
Mo							<10.	<10.	N10.	<10.	--	--
Nb							15.	15.	20.	15.	15.	20.
Ni							6.2	3.	L5.	5.6	--	--
Pb							11.	<10.	L20.	15.	15.	50.
Rb							--	--	--	--	--	--
Sb							--	--	--	--	--	--
Sc							<10.	3.	10.	<10.	--	10.
Sn							<10.	10.	L20.	<10.	--	--
Sr							15.	5.	N10.	7.	10.	50.
V							30.	<10.	N15.	<10.	15.	--
W							--	--	--	--	--	--
Y							60.	50.	70.	40.	46.	50.
Zn							130.	68.	N500.	150.	--	--
Zr							340.	500.	490.	300.	320.	200.
Ce							<100.	100.	--	--	--	--
Ga							23.	15.	21.	25.	--	30.
Ge							--	--	N20.	--	--	--
In							--	--	--	--	--	--
Re							--	--	--	--	--	--
Tl							--	--	--	--	--	--
Yb							5.	5.	11.	5.	5.	5.
Th							16.9	20.4	--	14.2	--	--
U							4.81	8.58	--	3.93	--	--
Th/U							3.52	2.38	--	3.60	--	--
Strontium and lead isotope data												
$Sr^{87/86}$												

Table 3.--Chemical analyses, and isotopic ratios, and norms of rhyolites, and rhyodacites, and dacites more than 10 m.y. old or considered to be middle Miocene or older--Cont.

	37	38	39	40	41	42	43	44	45	46	47
K-Ar age											
Geologic age	Miocene	Miocene			Eocene	Pliocene?		Miocene	Miocene	Miocene	
SiO_2	76.1	67.8	69.37	73.41	73.32	72.01	74.3	65.1	70.2	67.	63.3
Al_2O_3	12.2	13.5	14.59	12.54	12.52	12.53	15.	15.5	13.7	13.6	16.5
Fe_2O_3	.77	4.1	1.17	.9	.53	1.14	1.2	1.2	2.2	3.5	1.6
FeO	.08	1.8	2.33	.53	.18	1.09	.3	3.4	.87	1.1	2.2
MgO	.03	.13	.62	.43	.03	.2	.01	2.4	.71	1.1	1.7
CaO	.01	1.2	2.41	1.31	.44	.94	.6	3.8	1.1	2.1	3.7
Na_2O	3.3	4.2	3.92	2.82	3.61	2.83	3.4	3.3	3.7	3.7	3.7
K_2O	5.3	5.	2.9	4.95	4.58	5.71	4.8	3.4	4.2	3.5	2.9
H_2O^+	.58	.6	3.08	2.44	4.3	2.69	.25	.3	.4	.6	2.
H_2O^-	.33	.2	.42	.1	.11	.09	.05				—
TiO_2	.29	.57	.36	.17	.06	.28	.06	.62	.53	.78	.55
P_2O_5	.04	.11	.15	.04	.01	.03	.04	.32	.10	.27	.26
MnO	.03	.2	.06	.04	.09	.04	.04	.09	.05	.06	.08
CO_2	.02	.02	—	.01	.01	01	.05	tr	tr	tr	1.6
Norms[1] (H_2O-free)											
Q	[5]37.2	20.9	29.26	35.05	35.	31.46	34.5	20.4	28.7	25.4	19.8
Or	31.3	29.6	17.73	30.02	28.30	34.69	28.4	20.1	24.8	20.7	17.7
Ab	27.9	35.5	34.35	24.45	31.98	24.62	28.8	27.9	31.3	31.3	32.2
An	.0	3.5	11.37	6.39	2.22	4.62	2.7	16.8	4.8	8.7	17.2
C	1.2	—	1.02	.28	.88	.06	3.2	.2	1.4	.7	1.0
Ac	—	—	—	—	—	—	—	—	—	—	—
Ns	—	—	—	—	—	—	—	—	—	—	—
Wo	—	.7	—	—	—	—	—	—	—	—	—
En	.1	3.2	1.59	1.07	.07	.50	.0	6.0	1.8	2.7	4.2
Fs	.5	—	3.58	1.32	.86	2.06	1.6	4.23	2.5	3.7	3.4
Mt	.3	.5	1.38	.51	.26	.83	.52	1.7	1.1	1.6	1.4
Il	.6	1.1	.70	.32	.11	.55	.1	1.2	1.0	1.5	1.1
Ap	.1	.3	.38	.09	.02	.07	.1	.8	.2	.6	.6
Hm	—	3.8	—	—	—	—	—	—	—	—	—
Q	39.	24.	36.	39.	37.	35.	38.	30.	34.	33.	28.
Or	32.	34.	22.	34.	30.	38.	31.	29.	29.	27.	25.
Ab	29.	41.	42.	27.	34.	27.	31.	41.	37.	40.	46.
D.I.	96.	86.	81.	90.	95.	91.	92.	68.	85.	77.	70.
Minor elements[2, 3, 4]											
Cl	—	—	—	600.	500.	400.	—				
F	—	—	—	300.	800.	1200.	—				
Ag	—	<1.	—	—	—	—	<1.				
As	—	—	—	—	—	—	—				
Au	—	—	—	—	—	—	—				
B	20.	20.	—	50.	90.	L20.	70.				
Ba	500.	1400.	—	700.	50.	1000.	30.				
Be	2.	3.	—	L2.	4.	3.	10.				
Bi	—	—	—	—	—	—	—				
Cd	—	<2.	—	—	—	—	<2.				
Co	—	4.	—	L4.	L4.	L4.	1.4				
Cr	—	<10.	—	4.	L2.	L2.	<10.				
Cs	—	—	—	N5.	11.	N5.	—				
Cu	2.	7.	—	9.	7.	16.	3.				
Hf	—	—	—	—	—	—	—				
Hg	—	—	—	—	—	—	—				
La	—	25.	—	L60.	L60.	90.	50.				
Li	—	—	—	11.	28.	13.	30.				
Mo	—	7.	—	3.	—	3.	<10.				
Nb	20.	10.	—	L20.	L20.	30.	<25.				
Ni	—	5.3	—	L2.	L2.	L2.	<1.				
Pb	15.	20.	—	20.	40.	50.	44.				
Rb	—	—	—	120.	330.	250.	—				
Sb	—	—	—	—	—	—	—				
Sc	—	15.	—	L4.	L4.	L4.	3.				
Sn	—	<10.	—	—	7.	7.	10.				
Sr	15.	50.	—	180.	5.	50.	7.				
V	20.	50.	—	20.	L10.	—	<10.				
W	—	—	—	—	—	—	—				
Y	50.	40.	—	L20.	20.	60.	100.				
Zn	—	120.	—	—	—	—	56.				
Zr	200.	250.	—	100.	70.	420.	70.				
Ce	—	<100.	—	—	—	2300.	<100.				
Ga	30.	22.	—	12.	18.	20.	20.				
Ge	—	—	—	—	—	—	—				
In	—	—	—	—	—	—	—				
Re	—	—	—	—	—	—	—				
Tl	—	—	—	—	—	—	—				
Yb	5.	5.	—	L2.	2.	6.	10.				
Th	—	14.1	24.2	59.	64.	52.	42.6				
U	—	4.61	5.22	13.	17.8	7.88	8.77				
Th/U	—	3.05	4.63	4.47	3.58	6.61	4.86				
Strontium and isotope data											
$Sr^{87/86}$											

Table 3.—Chemical analyses, and isotopic ratios, and norms of rhyolites, and rhyodacites, and dacites more than 10 m.y. old or considered to be middle Miocene or older—Cont.

	48	49	50	51	52	53	54	55	56	57	58	59	60	61
K-Ar age	11.0±0.5	14.3±2.0	14.74±0.5	[7]15.7±										
Geologic age					Miocene	Miocene	Miocene	Miocene	Miocene	Miocene	Miocene	Miocene	Oligocene?	Oligocene
SiO_2	77.4	67.4	82.4	74.	69.2	72.1	76.5	68.5	69.1	73.1	75.9	75.8	76.1	77.3
Al_2O_3	11.6	14.	8.9	13.6	16.9	12.4	11.5	12.8	12.7	13.5	11.3	11.6	12.7	11.5
Fe_2O_3	.45	1.4	.74	.48	.8	1.4	1.4	2.6	1.3	.90	2.2	1.3	.85	1.2
FeO	.08	1.2	.08	.56	1.0	.80	.24	1.1	1.6	1.2	.0	.60	.04	.06
MgO	.0	.79	.0	.14	.57	.0	.01	.44	.29	.10	.04	.04	.01	.0
CaO	.47	1.9	.1	1.2	1.9	.53	.46	1.6	1.3	.53	.47	.09	.52	.05
Na_2O	3.4	4.0	2.3	4.0	3.2	1.	3.4	3.4	3.2	4.9	4.	4.6	3.6	.65
K_2O	5.3	4.9	4.6	4.4	4.5	4.5	4.7	5.2	5.4	4.7	4.4	4.9	5.	8.5
H_2O^+	.45	2.2	.26	.33	3.2	5.3	.43	2.1	2.9	.28	.39	.25	.37	.49
H_2O^-	.42	.25	.15	.10	.23	.77	.28	.18	.36	.08	.36	.10.	.20	.23
TiO_2	.09	.31	.09	.08	.24	.23	.09	.53	.42	.24	.12	.27	.14	.18
P_2O_5	.11	.14	.01	.03	.07	.02	.05	.01	.07	.03	.15	.02	.06	.03
MnO	.0	.01	.01	.08	.05	.02	.02	.08	.06	.08	.05	.10	.03	.02
CO_2	.02	.02	.02	.04	.01	.01	—	—	—	—	.02	—	—	—
							Norms[1] (H_2O)							
Q	37.5	20.6	51.2	31.	28.8	49.9	37.6	23.1	27.3	25.1	34.9	32.6	35.1	40.6
Or	31.3	29.6	27.2	26.	27.8	28.4	27.8	34.3	33.1	27.8	26.	29.	29.6	50.8
Ab	28.8	34.7	19.5	33.8	27.9	9.3	28.8	29.6	27.9	41.5	33.8	32.4	30.5	5.5
An	1.0	6.1	.4	5.8	9.5	2.7	2.	2.9	4.9	1.	.16	—	2.2	.1
C	—	—	—	.3	.4	5.2	.2	—	—	—	—	—	.7	1.2
Ac	—	—	—	—	—	—	—	—	—	—	—	1.5	—	—
Ns	—	—	—	—	—	—	—	—	—	—	—	1.1	—	—
Wo	.3	1.	—	—	—	—	—	1.8	.7	.6	.5	.1	—	—
En	—	2.	—	.4	1.5	—	.02	1.1	.8	.3	.1	.1	—	—
Fs	—	2.6	.8	1.2	1.8	2.3	1.8	3.6	2.9	2.1	2.4	2.3	.9	1.2
Mt	—	1.	.3	.4	.7	.9	.6	1.4	1.2	.8	.8	—	.3	.5
Il	.2	.6	.2	.2	.5	.5	.2	1.0	.8	.5	.2	.5	.3	.3
Ap	.3	.3	—	.1	.2	.1	.1	.2	.2	.1	.4	.1	.1	.1
Hm	.5	—	—	—	—	—	—	—	—	—	—	—	—	—
Q	38.4	24.2	52.3	34.1	34.1	57.	39.9	26.5	30.9	26.6	36.9	34.7	36.9	41.9
Or	32.1	34.8	27.8	28.6	32.9	32.4	29.5	39.4	37.5	29.5	27.4	30.8	31.1	52.5
Ab	29.5	40.9	19.9	37.3	33.1	10.6	30.6	34.1	31.6	44.	35.7	34.5	32.	5.7
D.I.	98.	85.	98.	91.	85.	88.	94.	87.	98.	94.	95.	94.	95.	97.
							Minor elements[2, 3, 4]							
Cl	70.	80.	<10.	240.	100.	500.	300.	200.	300.	400.	<100.	900.	<100.	<100.
F	200.	200.	<200.	400.	300.	1200.	600.	1100.	1000.	900.	300.	1100.	100.	100.
Ag	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
As	<300.	<300.	<300.	<300.		<300.	<300.	<300.	<300.	<300.	<300.	<300.	<300.	<300.
Au	<14.	<14.	<14.	<14.	<14.	<14.	<14.	<14.	<14.	<14.	<14.	<14.	<14.	<14.
B	<10.	24.	28.	14.	20.	27.	49.	13.	17.	23.	73.	150.	39.	19.
Ba	<20.	1600.	180.	1100.	2100.	680.	300.	1300.	1600.	920.	87.	76.	660.	780.
Be	4.6	<2.	2.5	2.6	2.1	6.	21.	3.	4.	4.	8.	7.	3.	<2.
Bi	—	<14.	—	—	—	<14.	<14.	<14.	<14.	<14.	<14.	<14.	<14.	<14.
Cd	<2.	<14.	<2.	<2.	<2.	<14.	<14.	<14.	<14.	<14.	<14.	<14.	<14.	<14.
Co	2.1	4.	2.2	2.5	6.	<2.	<2.	3.	<2.	<2.	<2.	<2.	<2.	<2.
Cr	<10.	<2.	<10.	<10.	<10.	<2.	<2.	<2.	<2.	<2.	<2.	<2.	<2.	<2.
Ce	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cu	4.4	13.	4.8	8.	15.	4.	4.	6.	8.	4.	9.	3.	4.	2.
Hf	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hg	<20.	<20.	<20.	<20.	<20.	<20.	<20.	<20.	<20.	<20.	<20.	<20.	<20.	<20.
La	26.	27.	<20.	<20.	31.	82.	53.	62.	73.	49.	47.	56.	36.	24.
Li	<50.	—	<50.	<50.	<50.	—	—	—	—	—	—	—	—	—
Mo	<4.	<4.	7.	8.	5.	7.	7.	7.	7.	8.	<4.	10.	5.	<4.
Nb	44.	<20.	<25.	<25.	<25.	47.	71.	34.	35.	34.	48.	38.	27.	26.
Ni	3.1	2.	3.6	2.2	7.5	2.	<2.	<2.	2.	2.	3.	3.	<2.	<2.
Pb	18.	17.	16.	18.	14.	25.	44.	22.	27.	21.	31.	28.	20.	<14.
Rb	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sb	—	<40.	—	—	—	<40.	<40.	<40.	<40.	<40.	<40.	<40.	<40.	<40.
Sc	<10.	4.	<10.	<10.	<10.	<2.	<2.	7.	7.	7.	<2.	9.	<2.	<2.
Sn	<10.	<4.	<10.	<10.	<10.	12.	16.	13.	13.	<4.	17.	12.	<4.	<4.
Sr	14.	260.	14.	160.	360.	65.	78.	120.	140.	72.	120.	87.	85.	74.
V	<10.	17.	<10.	<10.	29.	<2.	15.	15.	13.	<2.	<2.	<2.	<2.	<2.
W	<20.	<20.	<20.	<20.	<20.	<20.	<20.	< 20.	<20.	<20.	<20.	<20.	<20.	<20.
Y	22.	13.	16.	19.	18.	71.	93.	41.	43.	54.	140.	76.	21.	16.
Zn	<50.	<30.	<50.	<50.	<50.	125.	100.	68.	74.	99.	140.	140.	<30.	<30.
Zr	210.	230.	280.	120.	230.	1100.	350.	760.	830.	860.	1200.	1300.	220.	170.
Ce	<100.	<100.	<100.	<100.	<100.	<100.	<100.	<100.	<100.	<100.	<100.	<100.	<100.	<100.
Ga	16.	14.	11.	13.	17.	26.	32.	20.	25.	26.	28.	30.	14.	11.
Ge	—	14.	—	—	—	<14.	<14.	<14.	<14.	<14.	<14.	<14.	<14.	<14.
In	—	<3.	—	—	—	<3.	<3.	<3.	<3.	<3.	<3.	<3.	<3.	<3.
Re	—	<14.	—	—	—	<14.	<14.	<14.	<14.	<14.	<14.	<14.	<14.	<14.
Tl	—	<6.	—	—	—	<6.	<6.	<6.	<6.	<6.	<6.	<6.	<6.	<6.
Yb	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Th	18.1	5.2	10.2	6.4	8.1	18.9	40.7	27.	31.1	12.5	38.5	23.9	20.8	11.
U	5.45	1.16	3.48	2.65	2.64	6.14	12.8	6.27	6.60	3.81	12.2	10.8	6.31	2.37
Th/U	3.33	4.46	2.92	2.41	30.8	3.08	3.18	4.31	4.71	3.28	3.16	2.21	3.29	4.64
							Strontium and lead isotope data							

Table 3 Footnotes

1. In normative calculations total Fe distributed according to ratio of Fe^{+3}/Fe^{+2}=(.31/.87), which was determined by average contents of Fe_2O_3 and FeO in 13 samples of fresh, nonhydrated obsidian.
2. Cl determined spectrophotometrically.
3. F determined with a specific-ion electrode.
4. W determined spectrophotometrically.
5. Sample contains excess P_2O_5 over that used in normative calculations.
6. $Sr^{87/86}$ determined on alkali feldspar.
7. An additional age on this material is 15.4± m.y.

Table 3 Sample information

1. Beatys Butte dome complex, Harney County, Oregon; lat 42°25.5' N., long 119°18.8' W.; Sample Mo73-43 (collected by N. S. MacLeod).
2. Beatys Butte dome complex, Harney County, Oregon; lat 42°23.4' N., long 119°20.0' W.; Sample Mo73-42B (collected by N. S. MacLeod).
3. Large dome on Morgan Creek, Lake County, Oregon; lat 42°25.7' N., long 120°40.9' W.; Sample 80-77 (Walker, 1980).
4. Dome or intrusive on upper Morgan Creek, Lake County, Oregon: lat 42°25.2' N., long 120°41.8' W.; Sample 89-77 (Walker, 1980).
5. Drum Hill complex, Lake County, Oregon; lat 42°27.7 N., long 120°39' W., Sample 33-77 (Walker, 1980).
6. Drake Peak complex, Lake County, Oregon; lat 42°18.4' N., long 120°9.1'W., Sample DP-109A (Wells, 1980).
7. Drake Peak complex, Lake County, Oregon; lat 42°18.3 N., long 120°7.5' W.; Sample DP-125 (Wells, 1980).
8. Drake Peak complex, Lake County, Oregon; lat 42°20'10" N., long 120°8'25" W.; Sample DP-103A (Wells, 1980).
9. Drake Peak complex, Lake County, Oregon; lat 42°19'02" N.; long 120°06'45" W.; Sample DP-134 (Wells, 1980).
10. Drake Peak complex, Lake County, Oregon; lat 42°19'40" N., long 120°06'56" W.; Sample DP-149 (Wells, 1980).
11. Hawks Valley dome, Harney County, Oregon; lat 42°6.8' N., long 119°7.5' W.; Sample No. M4-117 (collected by N. S. MacLeod).
12. Rhyolite, Malheur County, Oregon; lat 42°00' N., long 117°56' W.; Sample MC-123 (Greene, 1976).
13. Rhyolite of McDermitt caldera area, Malheur County, Oregon; lat 42°0.5' N., long 117°58' W.; Sample MC-541 (Greene, 1976).
14. Obsidian on margin of intrusive, southwest part of Calavera caldera, Humboldt County, Nevada; lat 41°46' N., long 118°9' W.; Sample CC-78-130 (collected by J. J. Rytuba).
15. Vitrophyre on margin of intrusive, McDermitt caldera, Humboldt County, Nevada; lat 41°50' N., long 118°11' W.; Sample CC-143 (collected by J. J. Rytuba).
16. Intrusive, Double H Mountains, Humboldt County, Nevada; lat 41°45' N., long 118°0' W.; Sample CC 132A (collected by J. J. Rytuba).

17. Vitrophyre on margin of intrusive, McDermitt caldera, Humboldt County, Nevada; lat 41°49' N., 118°11' W.; Sample CC78-140 (collected by J. J. Rytuba).
18. Quartz latite dome, Lake County, Oregon; lat 42°44.8' N., long 119°58' W.; Sample QLO-1 (Walker and others, 1976).
19. Apache tears from rhyolite at Toy Pass, Owyhee County, Idaho; lat 42°54.1' N., long 116°32.75'W.; Sample BE-683 (collected by B. E. Ekren).
20. Pine Mountain dome, Deschutes County, Oregon; lat 43°51' N., long 120°59' W.; Sample M4-72 (collected by N. S. MacLeod).
21. Calculated composition of groundmass of Hart Mountain flow, Lake County, Oregon; lat 42°24.2' N., long 119°47.6' W.; (Noble, McKee, and Walker, 1974).
22. Flow on east flank Hart Mountain, Lake County, Oregon; lat 42°28.8' N., long 119°43.6' W.; Sample GWW-4-60 (Walker, 1961).
23. Intrusive, west base of Hart Mountain, Lake County, Oregon; lat 42°28.1' N., long 119°47.3' W.; Sample GWW-3-60 (Walker, 1961).
24. Rhyolite of Silver City, Owyhee County, Idaho; lat 43°06' N., long 116°36' W.; Sample BE-180 (collected by B. E. Ekren).
25. Rhyolite flow (or welded tuff?) of Idavada Formation, Owyhee County, Idaho, lat 42°36' N., long 116°33.6' W.; Sample OC-77-BE-25 (collected by B. E. Ekren).
26. Rhyolite flow (or welded tuff?) of Idavada Formation, Owyhee County, Idaho; lat 42°36.3' N., long 116°33' W.; Sample OC-77-BE-205B (collected by B. E. Ekren).
27. Rhyolite flow (or welded tuff?), Owyhee County, Idaho; lat 42°34.6' N., long 116°39.2" W.; Sample OC-77-BE-27 (collected by B. E. Ekren).
28. Silver City Rhyolite (flow?), Owyhee County, Idaho; lat 42°59' N., long 116°45' W.; Sample A98-3 (collected by W. P. Leeman).
29. Rhyolite flow of Idavada Formation, Owyhee County, Idaho; lat 43°01' N., long 116°28.5' W.; Sample OC-77-BE-160C (collected by B. E. Ekren).
30. Twin Peaks Rhyolite (flow), Owyhee County, Idaho; lat 43°05' N., long 116°50' W.; Sample 74-77 (collected by W. P. Leeman).
31. Alkali rhyolite of Reiser Creek, Humboldt County, Nevada; lat 41°58' N., long 118°04' W.; Sample MC-790-2 (collected by R. C. Greene).
32. Flow-banded rhyolite flow, Humboldt County, Nevada; lat 41°52.0' N., long 118°52' W.; Sample DRS-230B-62 (collected by D. R. Shawe).
33. Rhyolite obsidian, Humboldt County, Nevada; lat 41°24' N., long 118°48' W.; Sample N9-117-NG (collected by D. C. Noble).
34. Alkali rhyolite, Humboldt County, Nevada; lat 41°59.5' N., long 118°07' W.; Sample MC-618 (collected by R. C. Greene).
35. Alkali rhyolite (flow or ash-flow), Humboldt County, Nevada; lat 41°59' N., 118°03' W.; Sample MC-782 (collected by R. C. Greene).
36. Rhyolite flow, Humboldt County, Nevada; lat 41°50' N., long 117°48' W.; Sample MC-367-1 (collected by R. C. Greene).
37. Rhyolite flow (ash-flow?), Humboldt County, Nevada; lat 41°56'N., long 117°47' W.; Sample Unit F (collected by R. C. Greene).
38. Alkali rhyolite (ash-flow?), Humboldt County, Nevada; lat 41°47' N., long 117°54' W.; Sample MC-1139 (collected by R. C. Greene).
39. Dacite vitrophyre, Elko County, Nevada; lat 41°42' N., long 116°00' W.; Sample 71NC195 (collected by R. R. Coats).
40. Rhyolite vitrophyre (Ottawanah Rhyolite), Elko County, Nevada; lat 41°52' N., long 116°00' W.; Sample 64NC31 (collected by R. R. Coats).

41. Rhyolite vitrophyre (Ottawanah Rhyolite), Elko County, Nevada; lat 41°45' N., long 116°08' W.; Sample 62NC55 (collected by R. R. Coats).
42. Circle Creek Rhyolite, Elko County, Nevada; lat 41°52' N., long 116°22' W.; Sample 62NC134 (collected by R. R. Coats).
43. Porphyritic rhyolite flow, Humboldt County, Nevada; lat 41°00' N., long 117°30' W.; Sample DRS 211-62 (collected by D. R. Shawe).
44. Dacite, Humboldt County, Nevada; lat 41°46.2' N., long 117°33.3' W.; Le Masurier (1965).
45. Rhyodacite, Hinkey Summit, Humboldt County, Nevada; lat 41°40.1' N., long 117°31.7' W.; Sample 22 (Le Masurier, 1968).
46. Rhyodacite, Humboldt County, Nevada; lat 41°41.0' N., long 117°32.4' W.; Sample 18 (Le Masurier, 1968).
47. Intrusive dacite (andesite?) porphyry, Goughs Canyon, Humboldt County, Nevada;lat 41°9.1' N., long 117°20.0' W.; Hotz and Willden (1964, p. 50
48. Rhyolite dome at Stockade Mountain, Malheur County, Oregon; lat 43°27.4' N., long 118°07' W.; Sample M5-8 (collected by N. S. MacLeod).
49. Rhyolite flow in Drake Peak complex, Lake County, Oregon; lat 42°18' N., long 120°08.2' W.; Sample DP-73-109 (Wells, 1980; Walker, 1980).
50. Quartz-rich rhyolite in dome near Buchanan, Harney County, Oregon; lat 43°38.9' N., long 118°37.3' W.; Sample M4-114 (collected by N. S. MacLeod).
51. Rhyolite obsidian from dome near Venator, Harney County, Oregon; lat 43°21.4' N., long 118°17.8' W.; Sample M5-7 (collected by N. S. MacLeod).
52. Rhyolite flow at Owyhee dam, Malheur County, Oregon; lat 43°41.6' N., long 117°14.5' W.; Sample M3-75 (collected by N. S. MacLeod).
53. Vitrophyre, Ivanhoe Mercury district, Elko County, Nevada; lat 41°04' N., long 116°37.8' W.; Sample GWW-1-80 (collected by G. W. Walker).
54. Rhyolite flow or dome, Ivanhoe Mercury District, Elko County, Nevada; lat 41°09.7'N., long 116°34.4' W.; Sample GWW-4-80 (collected by G. W. Walker).
55. Vitrophyre from top of flow or remobilized ash-flow, Malheur County, Oregon; lat 42°05.6'N., long 117°35.2' W.; Sample GWW-6-80 (collected by G. W. Walker).
56. Vitrophyre from flow or remobilized ash-flow, Malheur County, Oregon; lat 42°31.7' N., long 117°10.2' W.; Sample GWW-12-80 (colleced by G. W. Walker).
57. Littlefield Rhyolite (of Kittleman, 1967), Malheur County, Oregon; lat 43°35' N., long 117°41.2' W.; Sample GWW-16-80 (collected by G. W. Walker).
58. Rhyolite "intrusive" (Rhyolite of Badger Mountain of Cathrall and others, 1978), Washoe County, Nevada; lat 41°45.6' N., long 119°21.8' W.; Sample GWW-21-80 (collected by G. W. Walker).
59. Rhyolite obsidian from chilled margin of flow or remobilized ash-flow, Washoe County, Nevada; lat 41°50' N., long 119°23.5' W.; Sample GWW-22-80 (collected by G. W. Walker).
60. Biotite rhyolite dome, Washoe County, Nevada; lat 41°48.5' N., long 119°39.1' W.; Sample GWW-24-80 (collected by G. W. Walker).
61. Rhyolite flow or intrusive within Pike Creek Formation, Harney County, Oregon; lat 42°40' N., long 118°33' W.; Sample GWW-9-80 (collected by G. W. Walker).

tables of analytical data as vitrophyre or rhyolite obsidian from glassy selvages on either flows or possibly ash-flow tuffs. These glassy selvages, which occur in places on the tops of flow units, are thought to represent chilled upper surfaces of flows, inasmuch as eutaxitic textures are not recognizable in thin section; however, they may be chilled parts of thick, thoroughly remobilized ash-flows in which vitro-clastic (eutaxitic) textures have been largely or completely destroyed through remelting and flowage.

The geographic distribution of sample localities within the northern Basin and Range is shown on Plate 1A. In most places an individual small circle on the map indicates a single sample locality, but in areas where analyses are clustered, as for example, at Newberry Volcano, Medicine Lake Highlands, Lakeview area, Drake Peak complex, and McDermitt, larger circles enclosing a spot represent several analysed samples. Outcrop areas of silicic volcanic rocks of dome complexes and related flows and intrusives are shown on Plate 1B, as well as the location of known and postulated calderas or caldera complexes. The location and age of rhyolite, rhyodacite, or dacite samples dated by potassium-argon methods also are shown. There are many additional published and unpublished potassium-argon ages on ash-flow tuffs and mafic flows of the region, some of which have been useful in establishing geologic ages of isotopically undated silicic domes and flows; none of these dates on ash-flow tuffs or mafic flows have been included or referenced in this report.

For areas along the Oregon-Idaho border and for much of northern Nevada, flows, dome complexes, and ash-flow tuffs are lumped on maps used as sources of information. Hence, within these areas individual domes and intrusions are distinguished on Plate 1B only where they have been mapped separately, as for example in the McDermitt caldera complex. Shown also on Plate 1B are locations of calderas with clearly defined surface manifestations, as well as those suspected or postulated to exist from surface distribution or isopaching of ash-flow tuffs, from evidence of regional structural collapse, directional flow phenomena, or from geophysical surveys.

Major-oxide chemistry on samples was determined largely either by conventional rock analysis (Peck, 1964) or by rapid rock analysis (Shapiro and Brannock, 1962; U.S. Geol. Survey, 1967), although X-ray florescence (XRF) methods were used on some samples analysed in university laboratories. Most of the determinations of minor elements were by quantitative spectrographic analysis, by instrumental neutron-activation analysis (INAA), and, for uranium and thorium, by the delayed neutron analysis. In some instances the level of concentration of some elements determined by INAA and quantitative spectrographic methods were at variance, infrequently by as much as a factor of 2 or more. In those few instances, the INAA values were given preference.

DISCUSSION OF DATA

Chemical data in tables 1-3 and geologic data presented in Plate 1B establish several fundamental relationships which may ultimately assist in resolving problems of silicic magma genesis and its relation to ore genesis and to tectonism. Although these relations are only briefly referred to here, several of them have been described elsewhere or are apparent from an empirical review of the data.

Potassium-argon dates

The rhyolitic rocks appear to form three age groups. The oldest group includes rocks 20 to 30 m.y. old which are about the same age as much more extensive rhyolitic rocks of the John Day Formation farther north. Only a few rocks of this age have been identified in the area of study, but they are likely much more abundant in the subsurface, buried by younger volcanic and sedimentary rocks. The second age group is composed of rhyolitic rocks about 13 or 14 to 17 m.y. old. They occur as dome and caldera complexes scattered broadly over the study area and many have associated widespread and voluminous ash-flow tuffs. The third group is formed of rhyolitic rocks younger than about 11 m.y. Within parts of the northern Basin and Range this younger group of silicic volcanic rocks forms part of a regional age progression in which the volcanism is systematically younger westward from Harney Basin and areas to the south of Harney Basin toward the Cascade Range (Walker, 1974; MacLeod, Walker, and McKee, 1976). The age progression is well defined in silicic rocks younger than about 10 to 11 m.y.; it may extend farther back in time, although the widespread silicic volcanism 14 to 17 m.y. ago obscures any projection of the progression to older rock units. Isotopic ages shown on Plate 1B show this age progression. A somewhat similar, but opposing age progression has been recognized for the Owyhee Mountains-eastern Snake River Plains (Armstrong, Leeman, and others, 1975), mostly to the east of the area shown on Plate 1B. These two opposing age progressions (fig. 2) span the same time interval and have a similar 3 cm/yr rate of advance (Walker and MacLeod, 1977), but the underlying mechanism (or mechanisms) remains to be fully explained.

Major-oxide chemistry

Major-oxide chemical data of silicic volcanic rocks of the northern Basin and Range demonstrate a considerable variation in contents of SiO_2, Al_2O_3, K_2O, Na_2O, and several other constituents. Some of these variations are fundamental, inasmuch as peraluminous and metaluminous and peralkaline rock types are represented; other variations are due to various stages of fractionation or evolution of these rocks as is indicated by differentiation index. Peraluminous silicic rocks (with normative corundum) appear to grade chemically into metaluminous rocks. The peralkaline rocks (small to moderate amounts of acmite) may form a separate group. The analytical data (tables 1, 2, and 3) suggest little correlation of changes in major oxide constituents with age and this lack of significant variation is further supported by plots of normative salic constituents (fig. 3). The younger rocks located in the western and northwestern part of the area consistently show lower $K_2O/Na_2O + K_2O$ than older rocks to the southeast and the older rocks show more scatter than do younger rocks. This regional decrease in K_2O to Na_2O is shown in Plate 1C, which was constructed by projecting data on the alkalies to a northwest-trending line partly parallel to the axis of the northwest-trending age progression in southeast Oregon and nearly perpendicular to the quartz diorite boundary line, summarized by Moore (1959). This variation in K_2O content with geographic position and, hence, to some degree with age, is further substantiated by comparing K_2O with SiO_2 content (fig. 4). The younger group of rocks, which represent those collected in areas just east of the Cascade Range at the west and northwest margins of the study area, show lower K_2O values for a given SiO_2 content than rocks of the intermediate or

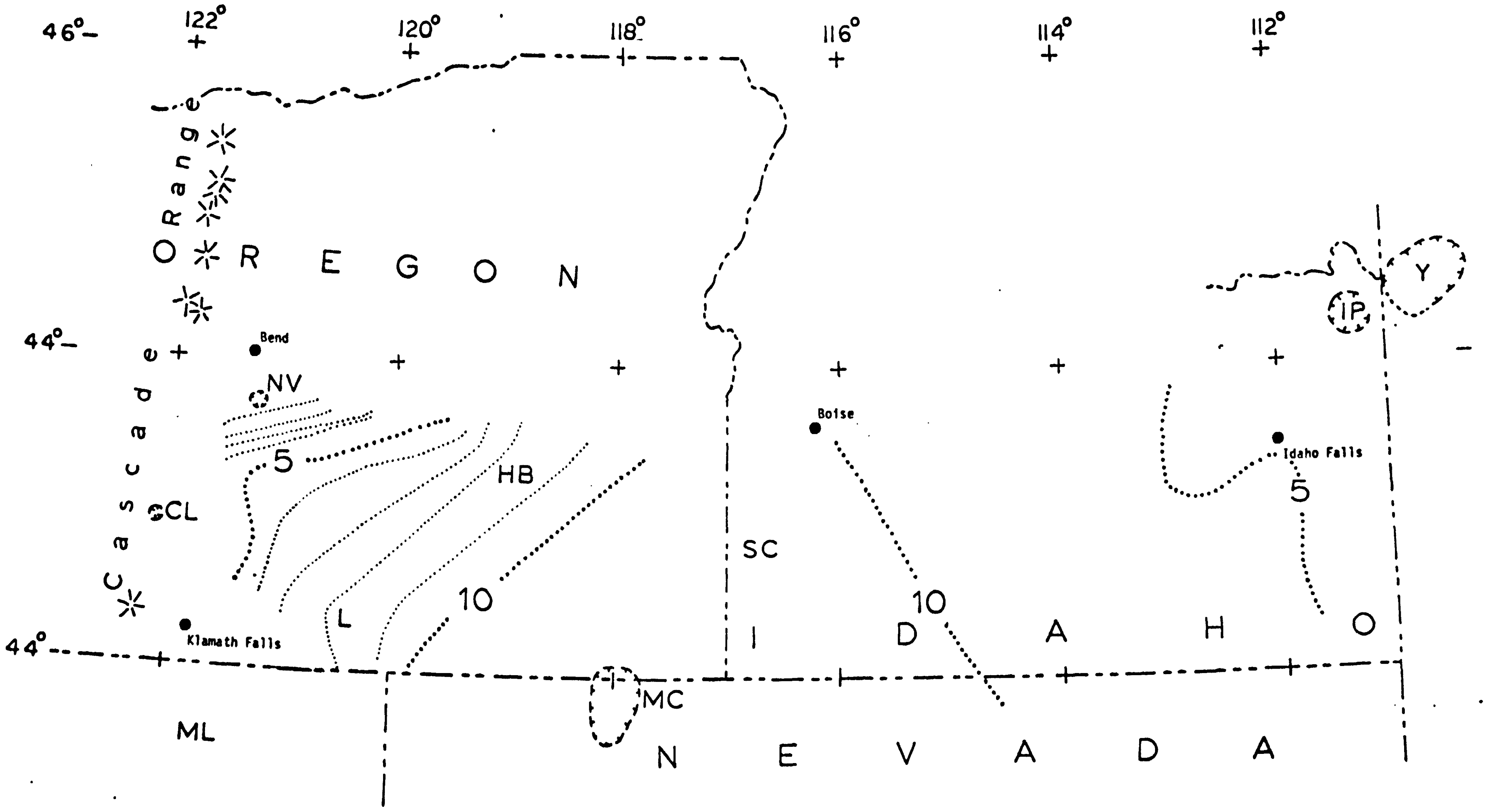

Figure 2.- Map of northern Basin and Range and adjoining areas showing opposing age progressions by isochrons. CL, Crater Lake; HB, Harney Basin; IP, Island Park; L, Lakeview area; MC McDermitt caldera complex; ML, Medicine Lake Highlands; NV, Newberry Volcano; SC, Silver City; Y, Yellowstone.

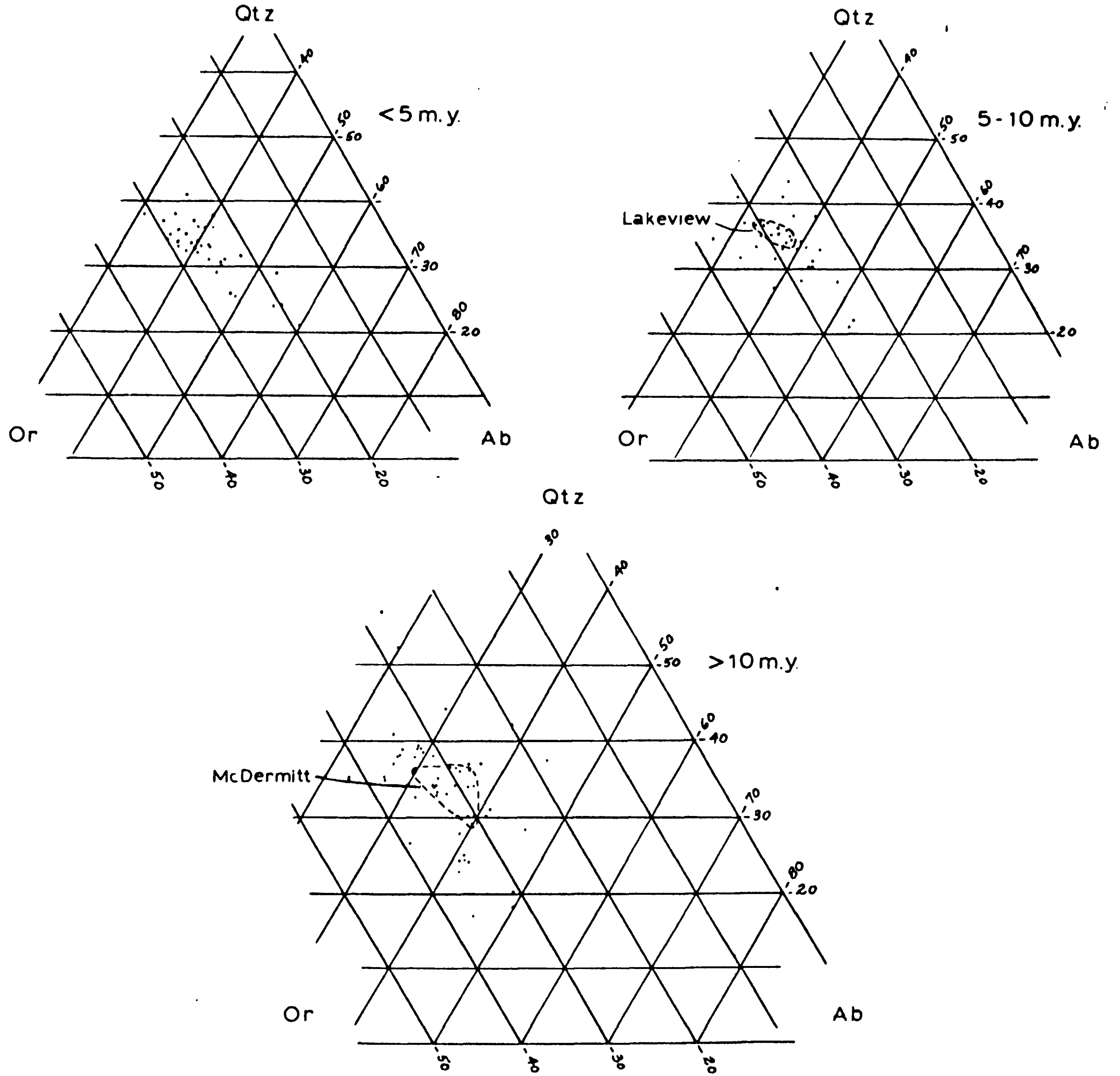

Figure 3.- Normative Q-or-ab plot, by age group, of analysed rhyolite, rhyodacite, and dacite.

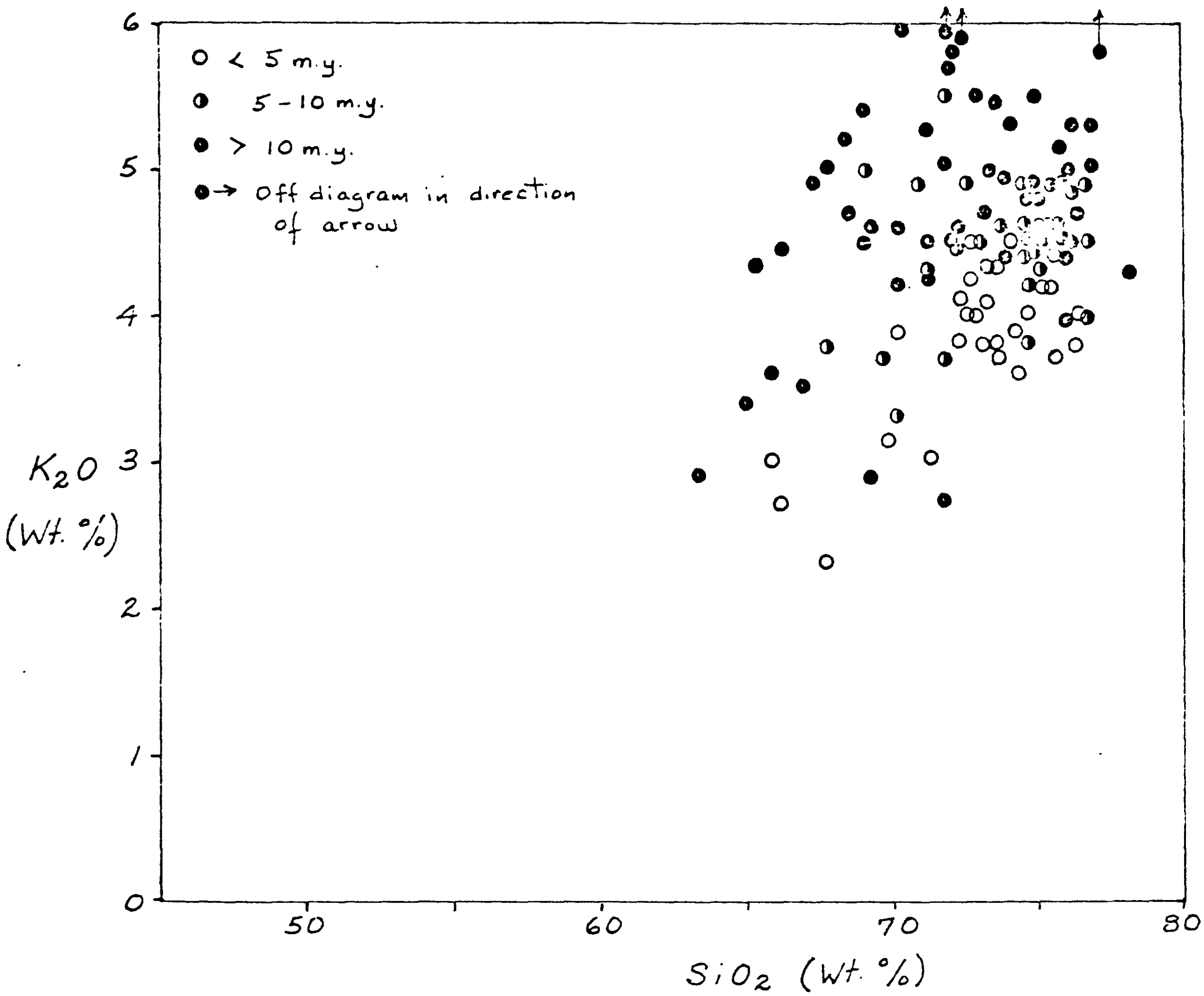

Figure 4.- Plot of K_2O versus SiO_2, by age group.

older age groups collected in areas far to the east and southeast of the Cascade Range.

In comparing the normative Q-Or-Ab fields for the McDermitt and Lakeview uranium areas, one plotted on the 5-10 m.y. diagram and the other on the diagram for rocks more than 10 m.y. old (fig. 3), it can be seen that the fields overlap but are not identical. The McDermitt field is larger and with more scatter to points, probably signifying fractionation under more diverse conditions in the complex caldera system; no caldera system is evident at Lakeview and the uranium appears to be largely associated with a cluster of rhyolite domes intruded into the axial parts of a faulted antiform (Walker, 1980). Lack of ash-flow tuffs and the presence of much sheared and brecciated fresh obsidian in the Lakeview area suggest also that the magma was relatively drier and more viscous, which also would inhibit fractionation.

Differentiation indices (D.I.) of all the rhyolitic to dacitic rocks that have been analyzed, except for the altered and silicified intrusive at the White King mine near Lakeview, for which no normative mineralogy has been calculated, are in the range of 68 to 98 (tables 1, 2, and 3) with over 70 percent of the rocks having indices of 90 or more, and 47 percent within the range of 92 through 96. Rocks with the highest differentiation indices (96 or more) are not geographically restricted, although domes and intrusions in the Lakeview area of the 7-8 m.y. age group (Walker, 1980) generally are some of the most highly differentiated rocks within the northern Basin and Range. Several rocks with high indices in areas other than Lakeview may be thoroughly remobilized ash-flow tuffs rather than domes, flows, or intrusives.

Minor-element chemistry

Comparisons of uranium and thorium abundances with differentiation index is shown by age group in figure 5. Those rocks with the highest uranium and thorium mostly have relatively high differentiation indices but the converse does not appear to be true, inasmuch as may rocks with relatively high differentiation indices have low uranium and thorium. Rhyolitic rocks of the Lakeview uranium area have exceptionally high indices (maximum 98) whereas those of the McDermitt area are lower (maximum 94); the McDermitt rocks contain more uranium and thorium for the same degree of differentiation, however. Several rhyolite samples from areas near the Humboldt-Elko County line contain anomalous amounts of both uranium and thorium and one sample from the Ivanhoe mercury district in southwestern Elko County is appreciably higher in both uranium and thorium than rocks with comparable indices from either Lakeview or McDermitt.

Plots of the abundances of barium, as well as barium plus strontium, were made to investigate whether depletion of these elements by alkali feldspar (Ba) and plagioclase (Sr) fractionation in the more highly differentiated rocks results in a corresponding enrichment in the content of uranium and thorium. Because the barium, strontium, and barium plus strontium plots showed similarity, only the variation diagram comparing uranium and thorium with barium plus strontium is reproduced here (fig. 6). In addition to the 3-fold age groupings of analyzed rocks, they are further segregated in the variation diagram into three groups based on silica content, one group with less than 70 percent SiO_2, another with 70-74 percent, and a final group with over 74 percent SiO_2. Preliminary review of these data show that of rocks of the different age groups, the 0-5 m.y. age group is characterized by

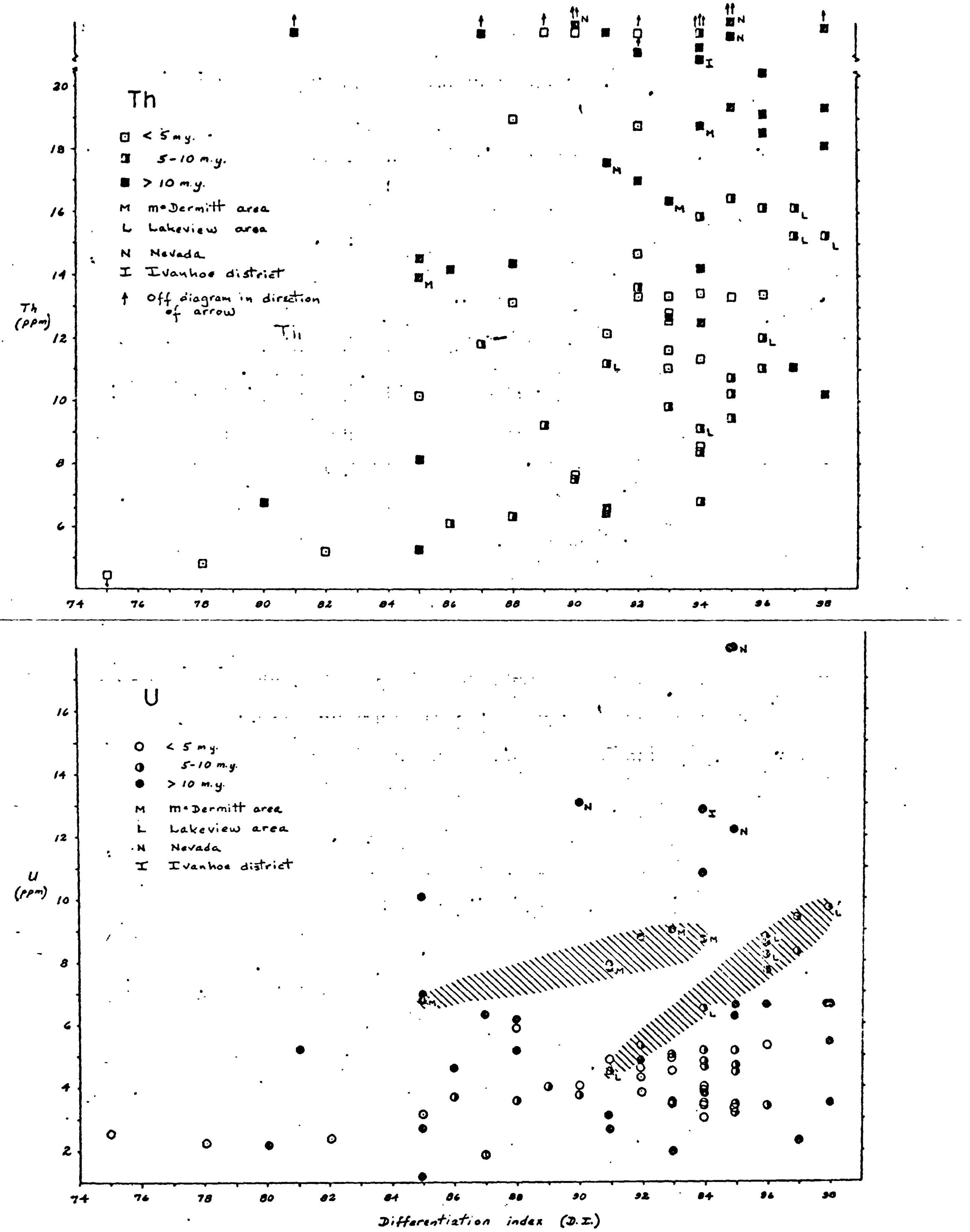

Figure 5.- Uranium- and thorium-differentiation index diagram.

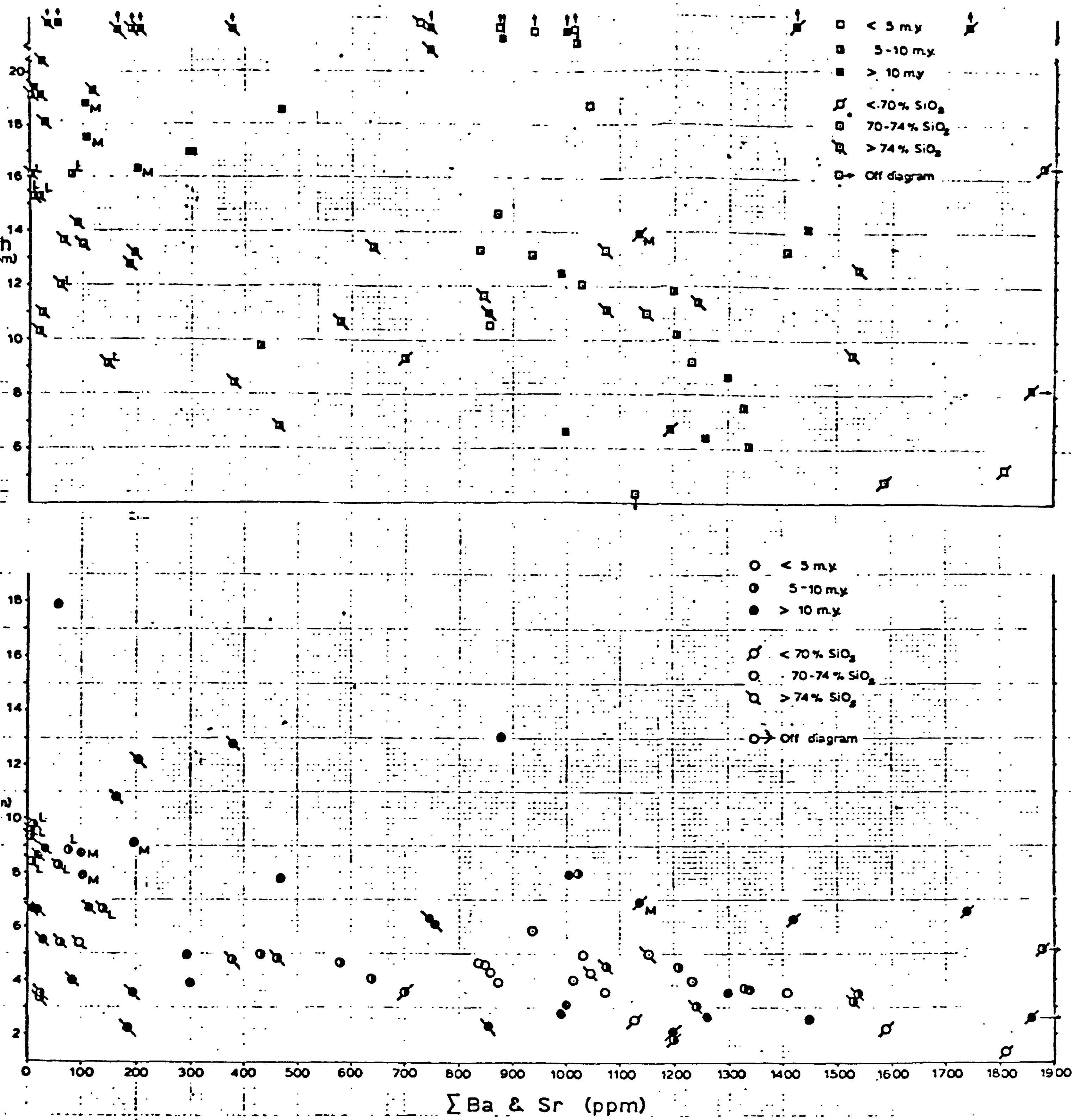

Figure 6.- Variation of uranium and thorium with barium plus strontium.

comparatively high total Ba and Sr (all but two have more than 800 ppm), mostly related to high Ba but for several samples high Sr, and that this young group tends to be low in uranium and generally contain only moderate amounts of thorium. Rocks of both the intermediate and older age groups show considerable scatter in total Ba and Sr contents; the U content is high only in rocks that have low total Ba and Sr. On the other hand, many rocks with low total Ba and Sr do not have high U. Included in the high U-low Ba plus Sr are rocks from the Lakeview and McDermitt uranium areas. The implications are that rocks that are both highly differentiated and that exhibit evidence of significant feldspar fractionation are those most likely to contain higher than normal amounts of both uranium and thorium.

Variation in uranium and thorium content with fluorine is shown in figure 7 and with chlorine in figure 8. The range in fluorine content in silicic rocks of the northern Basin and Range is from 50 ppm to 2500 ppm and at this level of concentration there seems to be little correlation with either uranium or thorium. Chlorine contents range from less than 10 ppm to 2,800 ppm, with the higher values of both uranium and thorium generally associated with the lower chlorine values (fig. 8). The highest chlorine values, however, were obtained on rhyolite collected from intrusions on Morgan Creek, 10-15 km northwest of the main part of the Lakeview uranium area; these rocks also are characterized by thorium contents ($\approx$19 ppm) and uranium contents (6-7 ppm) at about the same level of concentration as the intrusions associated with the Lakeview uranium deposits.

Cesium contents range from about 2 ppm up to 110 ppm, with most values at a level of 3-6 ppm. Abundances of cesium generally correlate with uranium abundances (fig. 9) in all three age groups of silicic volcanic rocks of the northern Basin and Range. The highest cesium contents (up to 110 ppm) are associated with intrusives in the McDermitt caldera complex characterized by comparatively high differentiation indices and by high uranium and thorium contents. The next highest cesium values were obtained on samples from the Lakeview area (8.2 ppm) and Horse Mountain (6.3 ppm) which also are characterized by high differentiation indices and comparatively high uranium and thorium contents. Both peralkaline (Horse Mountain; table 2, column 12) and peraluminous (Lakeview and McDermitt) petrochemical types are represented among these rocks with high cesium values.

Uranium and rubidium show a close correlation in the youngest and intermediate age groups of silicic volcanic rocks and a somewhat less well defined correlation in the older age group (fig. 10). Most of the high rubidium values were obtained on rocks from the McDermitt and Lakeview areas and the lowest values for both rubidium and uranium are in rocks exposed at the west or northwestern part of the study area; an exception to this geographic distribution pattern is the somewhat more mafic dacite at Beatys Butte in southern Harney County Oreg. (table 3, col. 2).

Comparisons of rubidium-strontium ratios with K_2O contents of these rocks by age groups are shown in figure 11. Within all age groups there is a major separation of those rocks with a Rb/Sr=5 or less and those with a ratio greater than 8; some of those with high ratios range up to about 65 or 70. In the 0 to 5 m.y. age group, there also appears to be a bimodal separation (fig. 11) into a group of rhyodacites or dacites with relatively low K_2O abundances and low Rb/Sr (less than 1) versus more silicic rhyolites with

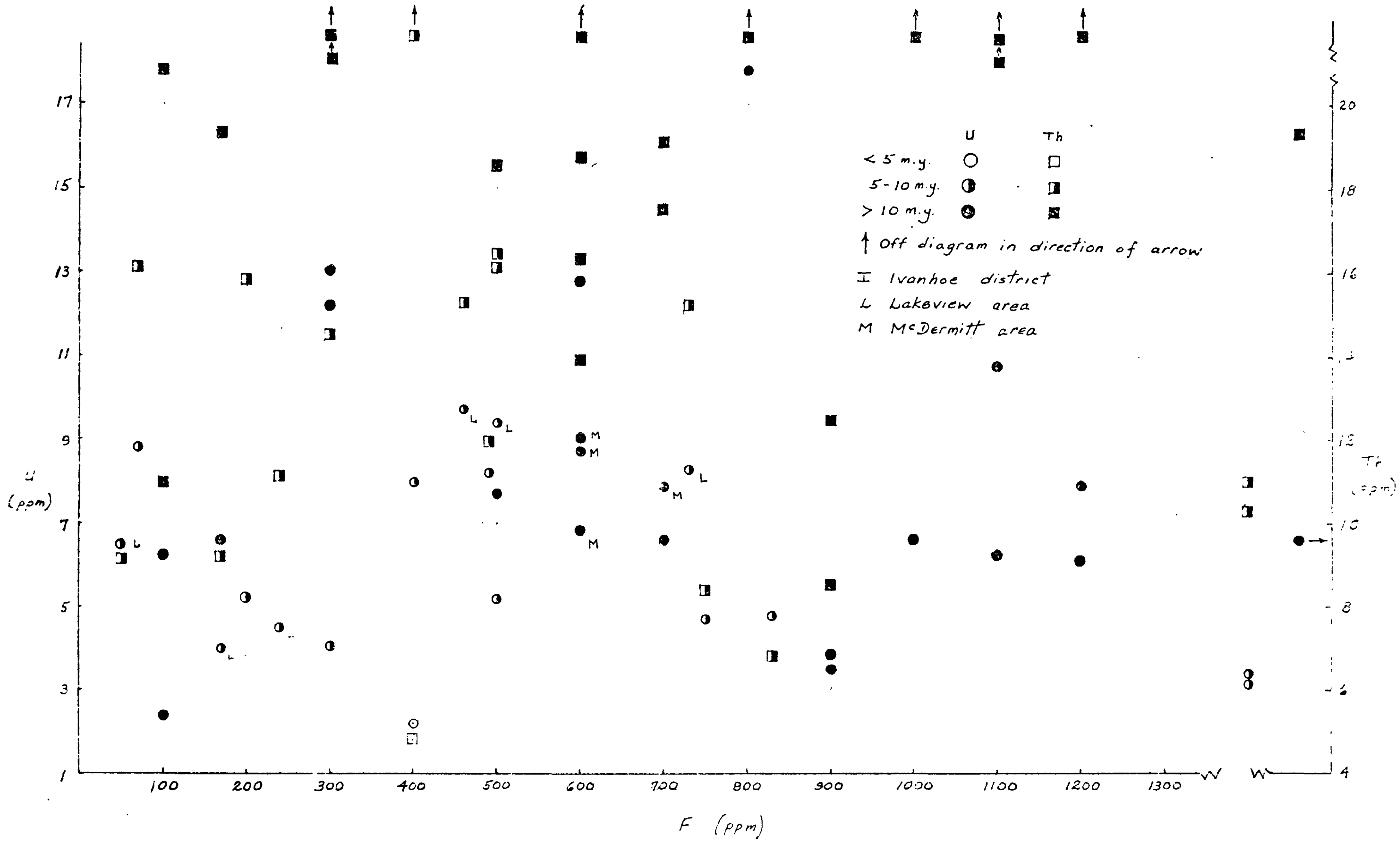

Figure 7.- Variation of uranium and thorium with fluorine

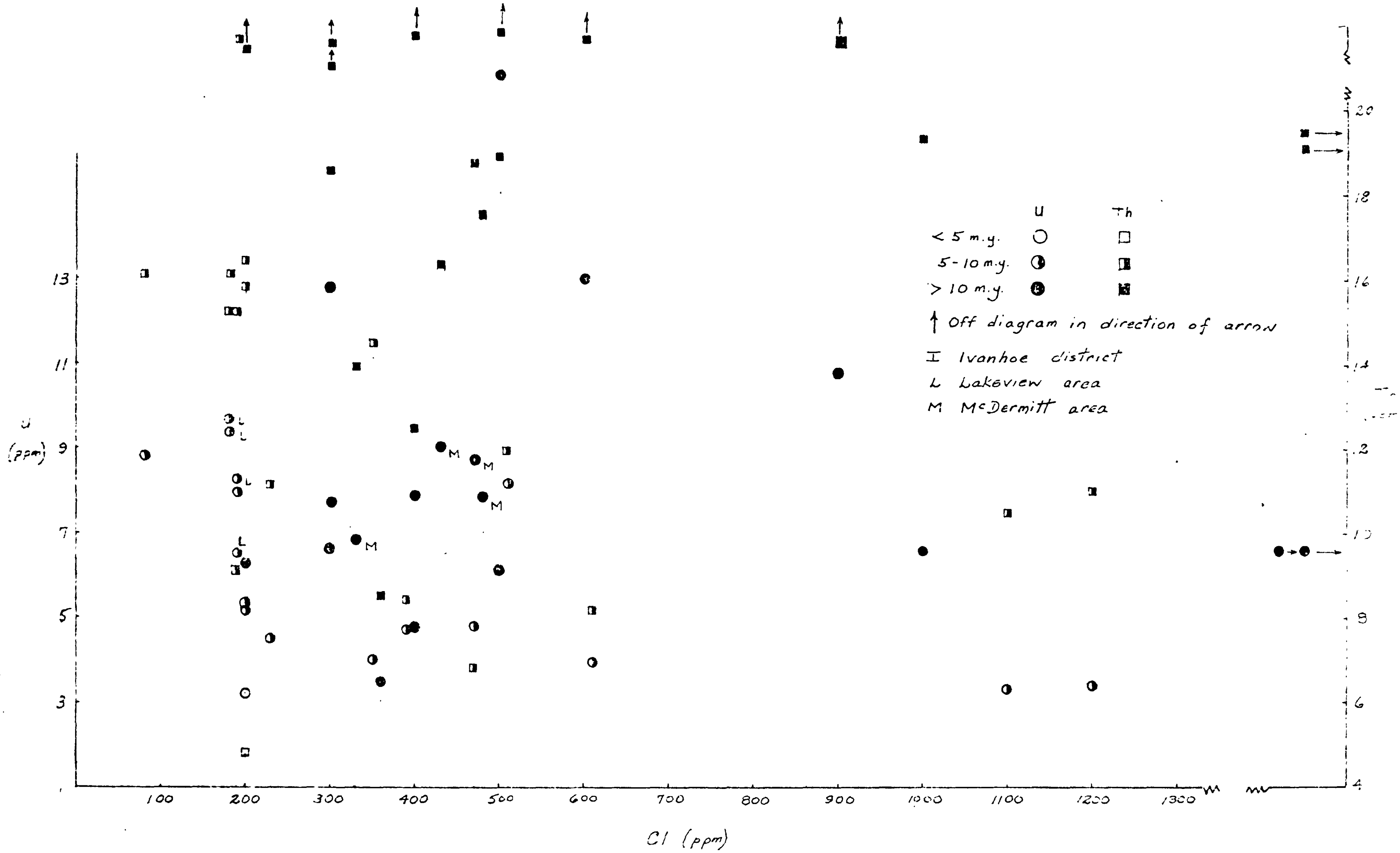

Figure 8.- Variation of uranium and thorium with chlorine

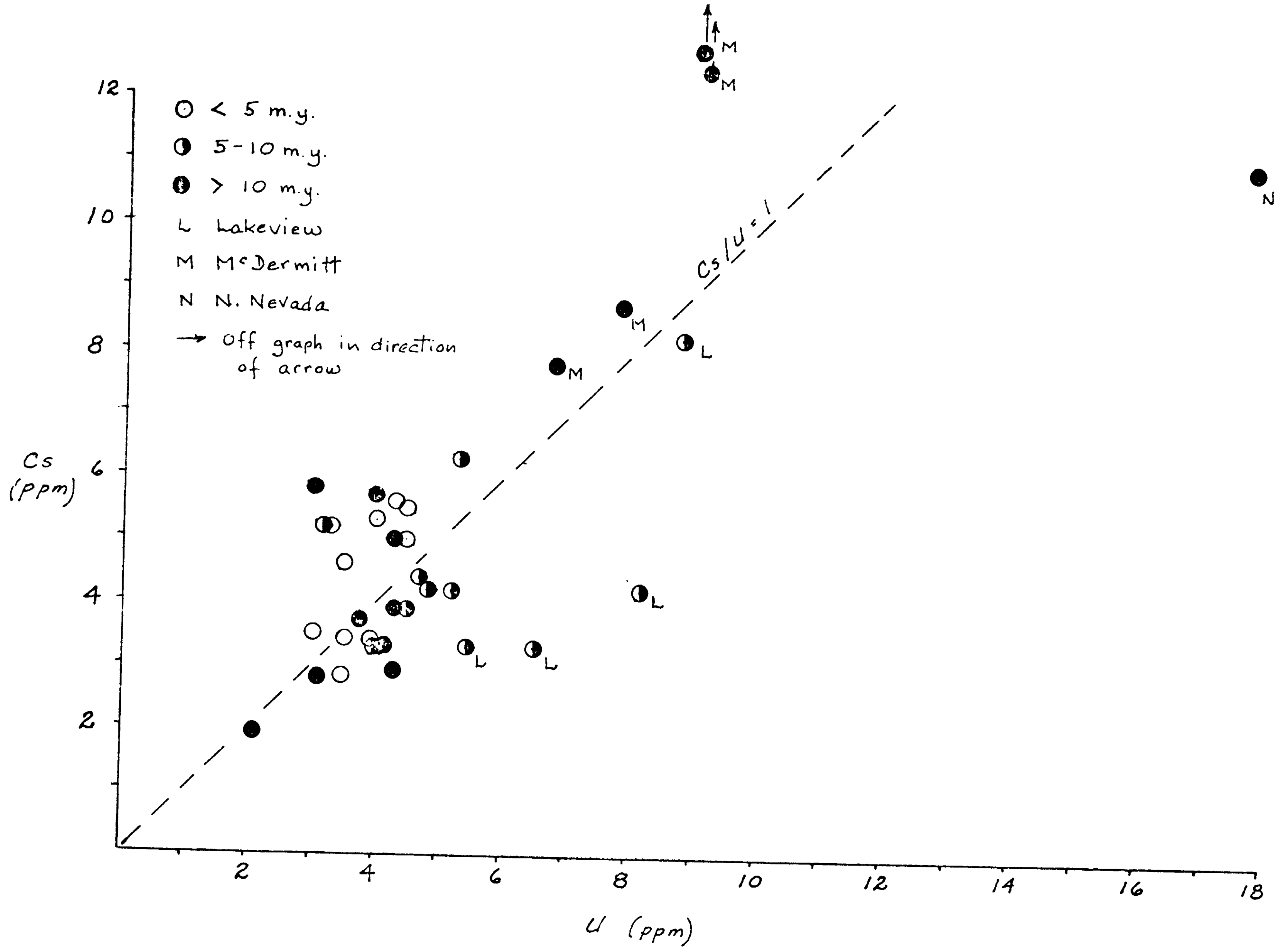

Figure 9.- Variation of cesium with uranium, by age group.

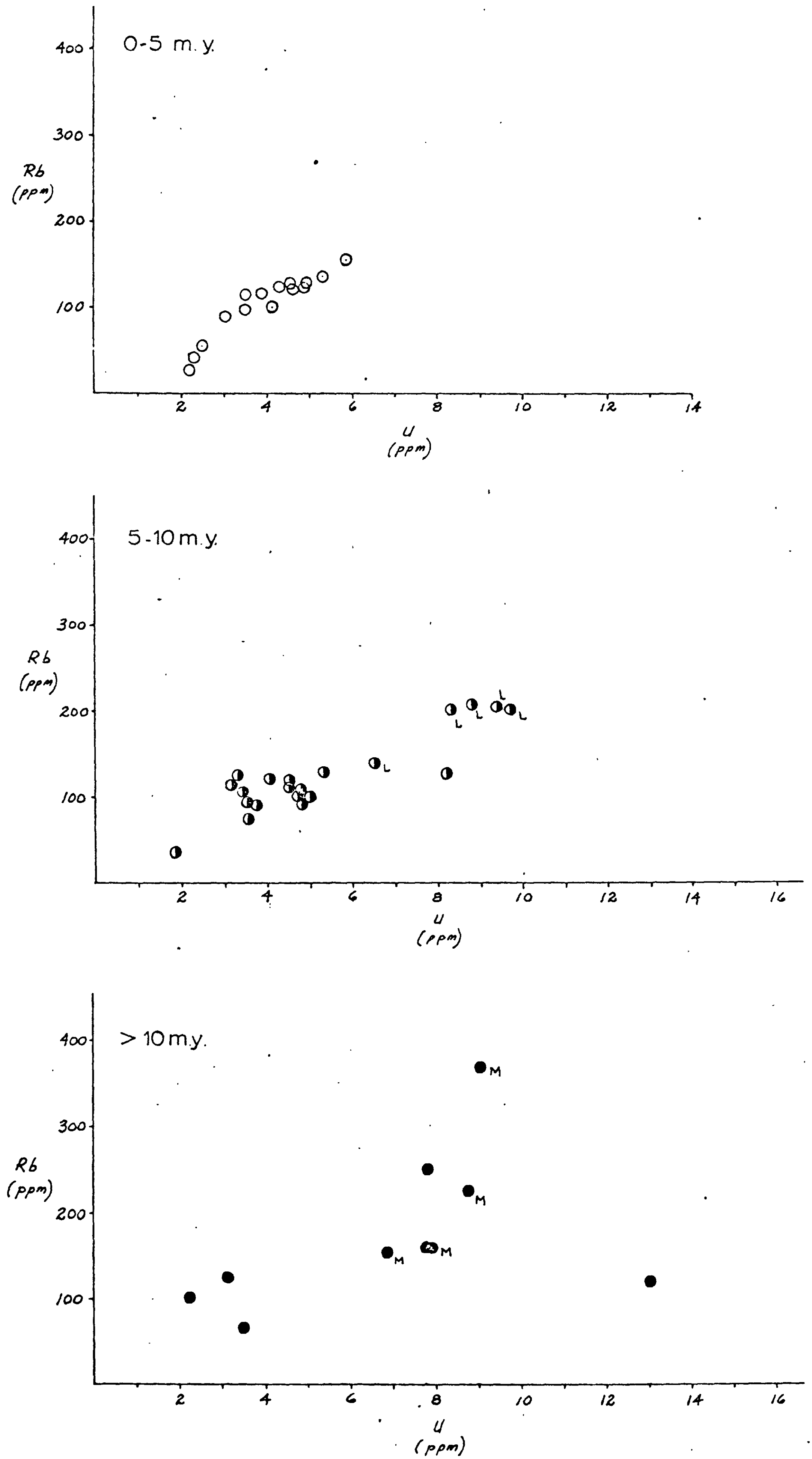

Figure 10.- Variation of uranium with rubidium, by age group

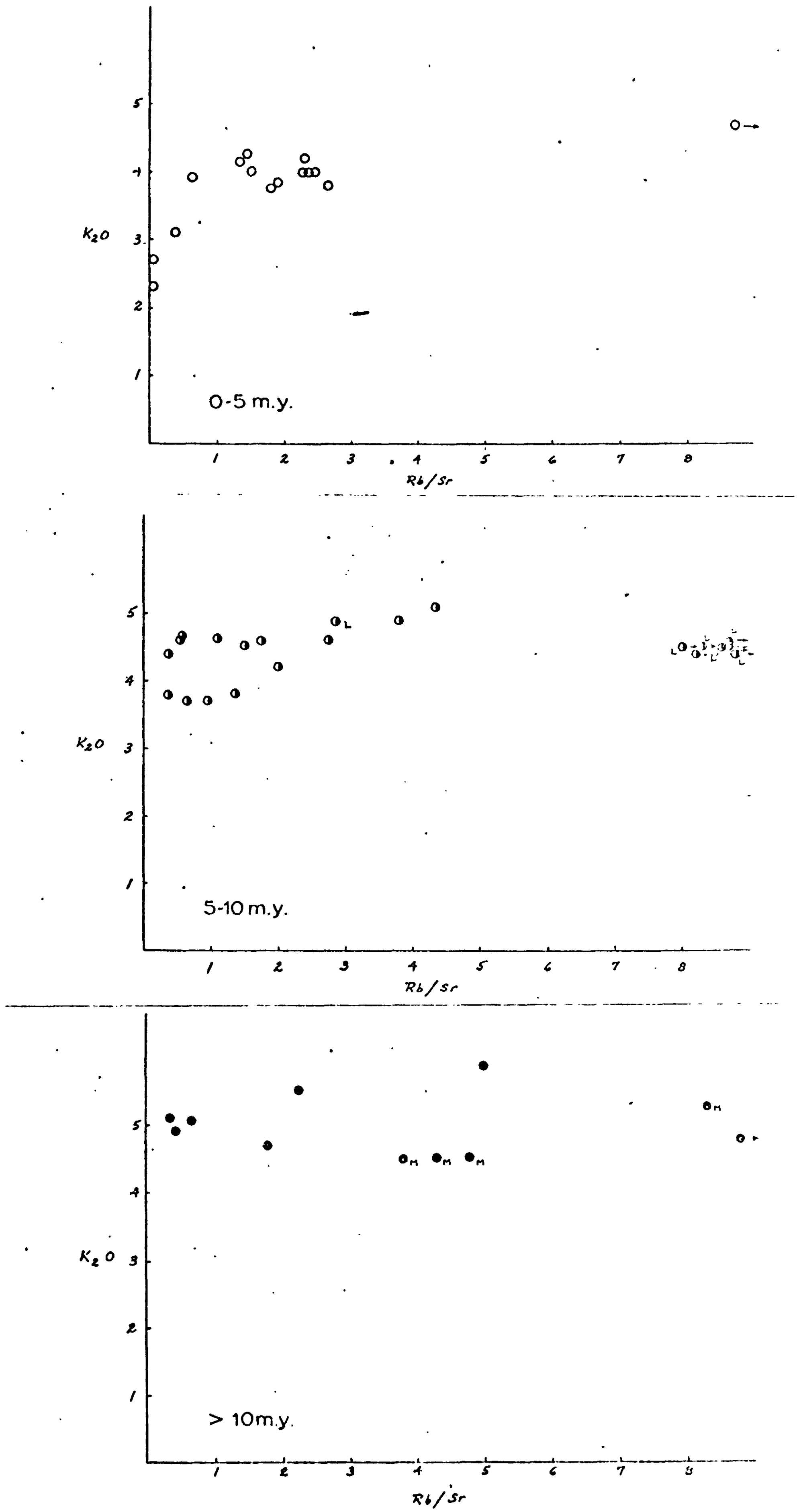

Figure 11-Variation in Rb/Sr with K_2O, by age group

higher K_2O abundances and Rb/Sr in the range of 1.5 to 3. The separation is even more pronounced in a plot of Rb/Sr as compared with SiO_2 contents (fig. 12). Rocks with low Rb/Sr, as well as with low K_2O, tend to be concentrated at the western margin of the study area, in and near the eastern margin of the Cascade province. The data suggest that there are two distinct types of silicic volcanic rocks near the western margin of the area and, although it is perhaps best exemplified in the youngest group of rocks, the distinction appears to apply to a few rocks in the two older age groups.

Both age data and geographic distribution of analyzed samples showing this bimodalism suggest that the rocks are not comagmatic and, further, that there are probably two different sources of these two groups of rocks. One group is characterized by low SiO_2, K_2O, and Rb/Sr as contrasted with the other group. Conceivably one group is a direct differentiate from basalt, which is very abundant in parts of this region characterized by a bimodal rhyolite-basalt association. The other group may be derived by anatexis resulting from the invasion of crustal rocks by large volumes of basalt, or, possibly all of the rocks with low K_2O and low Rb/Sr ratios are reflections of entirely different processes of magma generation related to the andesitic volcanism of the Cascade province.

All of the available data on strontium and lead isotopes of silicic volcanic rocks of that part of the northern Basin and Range represented by samples included in tables 1, 2, and 3, fall within rather narrow limits. The $Sr^{87/86}$ values range from 0.7034 to 0.7045, $Pb^{206/204}$ from 18.777 to 18.997, $Pb^{207/204}$ from 15.602 to 15.653, and $Pb^{208/204}$ from 38.479 to 38.791. There is no apparent variation consistent with differences in age, geographic position, or petrochemical differences of the analyzed rocks, although the amount of isotopic data available is limited. The entire area appears to straddle the line of initial $Sr^{87}/86 = 0.7040$, which, according to Kistler and Peterman (1973), is the eastern limit of principal exposures of ultramafic rocks and the western limit of Cretaceous granitic rocks for areas to the south and southwest in California. Lead isotope values are not unlike those obtained by Doe and Delevaux (1973) for Mesozoic granitic rocks of California. Both the strontium and lead values are similar to those found by Church and Tilton (1973) for basaltic and andesitic rocks of the Cascade Range.

The isotopic data suggest that the basement rocks throughout the region are quite homogeneous and that Precambrian cratonic rocks either are not present in the basement or have extremely low Rb/Sr and thus impart no isotopic evidence of their presence. Presumably the basement is composed entirely of late Paleozoic and younger rocks accreted from oceanic plates, in accordance with the concepts of Coney, Jones, and Monger (1980) and Stewart (1980, p. 9-11).

Some regional geographic variations in the uranium and thorium contents of silicic volcanic rocks of the northern Basin and Range were reviewed empirically by establishing a numeric ratio of these elements for each analyzed sample. The numeric values were projected to a west-northwest-trending, 500 km long section line that parallels the Brothers fault zone (Walker and Nolf, 1981) and is essentially perpendicular to the isochrons of the age progression in silicic volcanism in southeast Oregon. Some sample localities had to be projected for considerable distances (as much as 180 km)

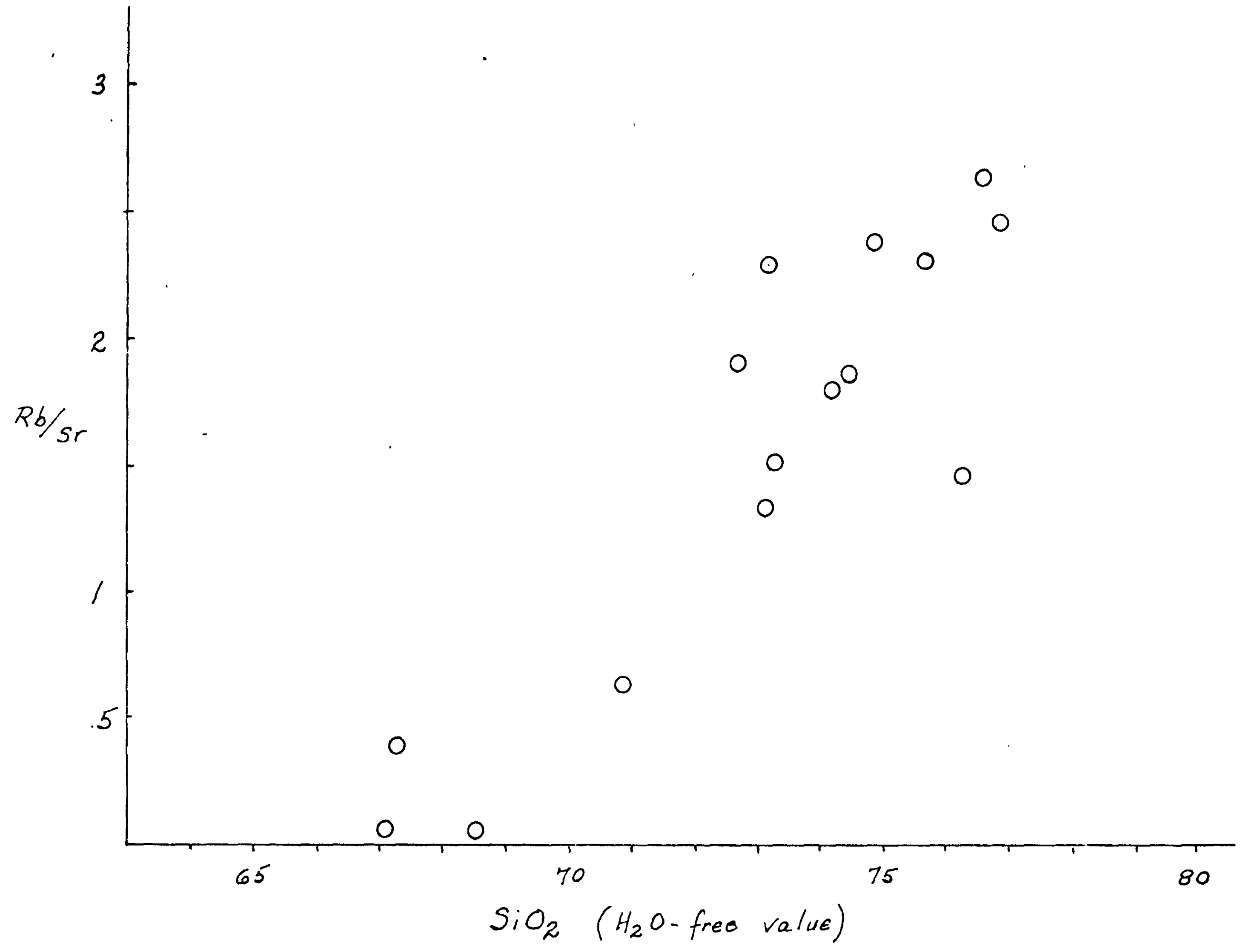

Figure 12.- Variation in Rb/Sr with SiO_2, in rocks of 0-5 m.y. age group.

to the section line, as for example those from Medicine Lake Highlands, which naturally induces some scatter to the data. Even with this scatter the projected points indicate little, if any, correlation in Th/U with geographic position (plate 1C). All of the analyses with thorium contents higher than 20 ppm come from specimens collected in western Elko County or adjacent parts of Humboldt County, except for analyses of a specimen of Medicine Lake Glass flow (34.4 ppm), another of East Lake flow (21.5 ppm) at Newberry Volcano, and one from Quartz Mountain (21.5 ppm), located 14 km east of Newberry. These anomalous analyses have higher Th contents than other analyses from the same rhyolite bodies and are therefore probably in error. Younger rhyolite bodies at the west-northwest end of the age progression generally have lower uranium values than those of either the middle or older age groups.

Analyses of rocks from both the Lakeview and McDermitt areas indicate similar patterns in the relation of uranium to thorium and data from both areas shows some divergence from regional trends. Both areas are characterized by closely grouped numeric values for Th/U and these ratios are consistently lower than those obtained on other geographically related rocks; this assumes that projection of data points to a single west-northwest-trending section line has not introduced the same or nearly identical systematic error to the data from both areas. This seems unlikely. Throughout the northern Basin and Range analysed samples show a fairly consistent correlation of high Th with high U values (fig. 13). The low Th/U values for McDermitt and Lakeview result from U enrichment in the silicic volcanic rocks rather than initial low Th values or depletion of Th.

Trace-element data in tables 1-3 are highly variable in type and precision and any attempt at establishing geochemically significant correlations of selected metals is subject to great uncertainty. Comparisions of these data with crustal abundances, such as presented by Turekian and Wedepohl (1961), for low calcium granitic rocks is further complicated by the differences in trace element abundances between intrusive granitic rocks and their extrusive equivalents. Crustal abundance data presented by Nockolds (1954), for volcanic rocks, requires modification in light of the vast amount of new chemical data now available. Even with these limitations some significant patterns of trace elements distribution can be recognized in silicic volcanic rocks of the northern Basin and Range and particularly for the Lakeview McDermitt areas. Silicic rocks of the Lakeview and McDermitt areas show appreciable enrichment in As, Cs, Rb, Sb, and U over average abundances in low-calcium granitic rocks (Turekian and Wedepohl, 1961, table 2). They also show enrichment in these elements over that found in similar rocks in adjoining parts of the northern Basin and Range. Also Mo and Ag are enriched in the McDermitt area and Mo possibly in the Lakeview area; Mo also seems to be enriched in rhyolite domes to the south of the Lakeview area, in the northeastern corner of California (see columns 32 and 35, table 2). These domes are about the same age as the domes associated with uranium deposits near Lakeview. Rocks in the McDermitt area also are anomalously high in Li (columns 14-17, table 3) and one sample in the Lakeview area is anomalously high in Hg. High Rb and U values, as well as high Th values, have been determined for silicic volcanic rocks exposed in western Elko County and eastern Humboldt County, Nevada (columns 40, 41, 42, and 43, table 3), and high Pb and U values are present in the Ivanhoe mercury district.

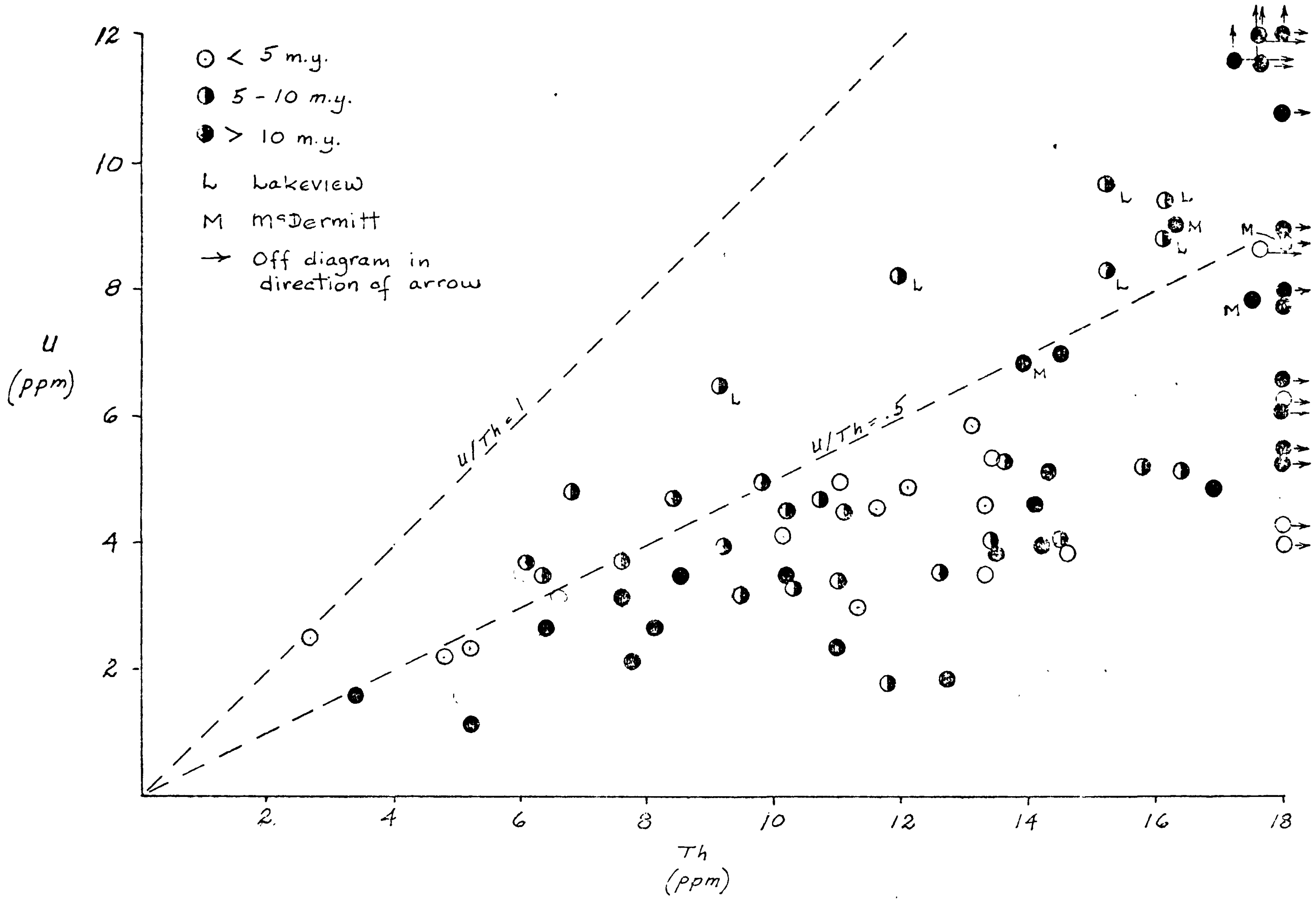

Figure 13.- Variation of uranium with thorium.

Except for the high Ag values reported on rocks from McDermitt, most Ag values are less than detection limits and do not permit establishing whether enrichment has or has not occurred. The 0.87 ppm value for Ag on either a rhyolite flow or ash-flow tuff collected in central Harney County, Oregon (column 31, table 2) is an order of magnitude greater than that obtained on any of the other rocks of the region; most likely the analysis is in error.

Based largely on the study of zoned ash-flow tuffs, Smith (1979) and Hildreth (1979) recognize that most magma chambers are zoned and that certain elements (U, Th, Cs, Rb, Li, Sn, Mo, W, F, Cl, and others) are strongly enriched in the upper parts of these magma chambers. Most of the metals that appear to be enriched in the silicic rocks of the northern Basin and Range are those commonly associated with highly differentiated rocks and are among those recognized as being enriched at the tops of zoned magma chambers.

REFERENCES CITED

Armstrong, R. L., Leeman, W. P., and Malde, H. E., 1975, K-Ar dating Quaternary and Neogene volcanic rocks of the Snake River Basin, Idaho: American Journal of Science, v. 275, p. 225-251.

Beyers, R. L., 1973, Magma differentiation at Newberry Crater in central Oregon: Eugene, Oregon University Ph. D. thesis, 93 p.

Bond, J. G., 1978, Geologic map of Idaho: Idaho Department of Lands, Bureau of Mines and Geology, scale 1:500,000.

Cathrall, J. B., Greene, R. C, Plouff, Donald, Siems, D. F., Crenshaw, G. L., Cooley, E. F., Tuchek, E. T., Johnson, F. J., and Conyac, M. D., 1978, Mineral resources of the Charles Sheldon Wilderness Study area, Humboldt and Washoe Counties, Nevada, and Lake and Harney Counties, Oregon: U.S. Geological Survey Open-File Report 78-1002.

Church, S. E., and Tilton, G. R., 1973, Lead and strontium isotopic studies in the Cascade Mountains; bearing on andesite genesis: Geological Society of America Bulletin, v. 84, p. 431-454.

Condie, K. C., and Hayslip, D. L., 1975, Young bimodal volcanism at Medicine Lake volcanic center, northern California: Geochimica et Cosmochimica Acta, v. 39, p. 1165-1178.

Coney, P. J., Jones, D. L., and Monger, J. W. H., 1980, Cordilleran suspect terranes: Nature, v. 288, p. 329-333.

Doe, B. R., and Delevaux, M. H., 1973, Variations in lead-isotopic compositions in Mesozoic granitic rocks of California: A preliminary investigation: Geological Society of America Bulletin, v. 84, p. 3513-3526.

Friedman, Irving, and Long, William, 1976, Hydration rate of obsidian: Science, v. 191, p. 347-352.

Gay, T. E, Jr., and Aune, Q. A., 1958, Geologic map of California, Olaf P. Jenkins edition, Alturas sheet: California Division of Mines, scale 1:250,000.

Greene, R. C., 1976, Volcanic rocks of the McDermitt caldera, Nevada-Oregon: U.S. Geological Survey Open-File Report 76-753, 80 p.

Higgins, M. W., 1973, Petrology of Newberry Volcano, Central Oregon: Geological Society of America Bulletin, v. 84, p. 455-488.

Hildreth, Wes, 1979, The Bishop Tuff: evidence for the origin of compositional zonation in silicic magma chambers: Geological Society of America Special Paper 180, p. 43-75.

Hotz, P. E., and Willden, Ronald, 1964, Geology and mineral deposits of the Osgood Mountains quadrangle, Humboldt County, Nevada: U.S. Geological Survey Professional Paper 431, 128 p.

Jennings, C. W., 1977, Geologic map of California: California Division of Mines and Geology, scale 1:750,000.

Kistler, R. W., and Peterman, Z. E., 1973, Variationsin Sr, Rb, K, Na, and initial Sr^{87}/Sr^{86} in Mesozoic granitic rocks and intruded wall rocks in central California: Geological Society of America Bulletin, v. 84, p. 3489-3512.

Laidley, R. A., and McKay, D. S., 1971, Geochemical examination of obsidians from Newberry caldera, Ore.; Contributions to Mineralogy and Petrology: Beitrage zur Mineralogie und Petrographie, v. 30, no. 4, p. 336-342.

Le Masurier, W. E., 1965, Volcanic geology of the Santa Rosa Range, Humboldt County, Nevada: Stanford University, Ph. D. thesis.

________1968, Crystallization behavior of basalt magma, Santa Rosa Range, Nevada: Geological Society of America Bulletin, v. 79, no. 8, p. 949-972.

Lipman, P. W., 1965, Chemical comparison of glassy and crystalline volcanic rocks: U.S. Geological Survey Bulletin 1201-D, p. D1-D24.

Lipman, P. W., Prostka, H. J., and Christiansen, R. L., 1972, Cenozoic volcanism and plate-tectonic evolution of the western United States, I. Early and middle Cenozoic: Philosophical Transactions of the Royal Society of London, A. 271, p. 217-248.

MacLeod, N. S., Walker, G. W., and McKee, E. H., 1976, Geothermal significance of eastward increase in age of upper Cenozoic rhyolitic domes in southeast Oregon: Second United Nations symposium on the development and use of geothermal resources, Proceedings, v. 1, p. 465-474.

McKee, E. H., MacLeod, N. S., and Walker, G. W., 1976, Potassium-argon ages of Late Cenozoic silicic volcanic rocks, southeast Oregon: Isochron/West no. 15, p. 37-41.

Mertzman, S. A., 1981, Pre-Holocene silicic volcanism on the northern and wesstern margins of the Medicine Lake Highland, California: U.S. Geological Survey Circular 838, p. 163-169.

Millard, H. T., Jr., 1976, Determination of uranium and thorium in USGS standard rocks by the delayed neutron technique: U.S. Geological Survey Professional Paper 840, p. 61-65.

Moore, J. G., 1959, The quartz diorite boundary line in the western United States: Journal of Geology, v. 67, no. 2, p. 198-210.

Noble, D. C., Smith, V. C., Peck, L. C., 1967, Loss of halogens from crystallized and glassy silicic volcanic rocks: Geochimica et Cosmochimica Acta, v. 31, p. 215-223.

Noble, D. C., McKee, E. H., and Walker, G. W., 1974, Pantellerite from the Hart Mountain area, southeastern Oregon. Interpretation of radiometric, chemical, and isotope data: U.S. Geological Survey Journal of Research, v. 2, p. 25-29.

Nockolds, S. R., 1954, Average chemical compositions of some igneous rocks: Geological Society of America Bulletin, v. 65, no. 12, p. 1007-1032.

Parker, D. J., 1974, Petrology of selected volcanic rocks of the Harney Basin, Oregon: Corvallis, Oregon State University, Ph. D. thesis, 119 p.

Parker, D. J., and Armstrong, R. L., 1972, K-Ar dates and Sr isotope ratios or volcanic rocks in the Harney Basin, Oregon: Isochron/West, no. 5, p. 7-12.

Peck, L. C. 1964, Systematic analysis of silicates: U.S. Geological Survey Bulletin 1170, 89 p.

Peterson N. V., and McIntyre, J. R., 1970, The reconnaissance geology and mineral resources of eastern Klamath County and Western Lake County, Oregon: Oregon Department of Geology and Mineral Industries, Bulletin 66, 70 p.

Powers, H. A., 1932, The lavas of the Modoc Lava-bed quadrangle, California: American Mineralogist, v. 17, no. 7, p. 253-294.

Rosholt, J. N., Prijana, and Noble, D. C., 1971, Mobility of uranium and thorium in glassy and crystallized volcanic rocks: Economic Geology, v. 66, p. 1061-1069.

Rytuba, J. J., and Conrad, W. K., 1981, Petrochemical characteristics of volcanic rocks associated with uranium deposits in the McDermitt caldera complex, Nevada-Oregon, in Goodell, P. C., ed., A.A.P.G. Studies in Geology No. 13, Uranium in Volcanic and Volcaniclastic rocks [in press].

Rytuba, J. J., and Glanzman, R. K., 1979, Relation of mercury, uranium, and lithium deposits to the McDermitt caldera complex, Nevada-Oregon: Nevada Bureau of Mines and Geology Report 33, p. 109-118.

Shapiro, Leonard, and Brannock, W. W., 1962, Rapid analysis of silicate, carbonate, and phosphate rocks: U.S. Geological Survey Bulletin 1144A, p. A1-A56.

Smith, R. L., 1979, Ash-flow magmatism: Geological Society of America Special paper 180, p. 5-27.

Stewart, J. H., 1980, Geology of Nevada: Nevada Bureau of Mines and Geology Special Publication 4, 136 p.

Stewart, J. H., and Carlson, J. E., 1978, Geologic map of Nevada; U.S. Geological Survey scale 1:500,000.

Tatlock, D B., Flanagan, F. J., Bastron, Harry, Berman, Sol, and Sutton, A. L., Jr., 1976, Rhyolite, RGM-1, from Glass Mountain, California: U.S. Geological Survey Professional Paper 840, p. 11-14.

Turekian, K. K., and Wedepohl, K. H., 1961, Distribution of the elements in some major units of the earth's crust: Geological Society of America Bulletin 72, no. 2, p. 175-192.

U.S. Geological Survey, 1967, Rapid analysis of rocks and minerals by a single-solution method: U.S. Geological Survey Professional Paper 575-B, P. B187-B191.

Walker, G. W., 1961, Soda rhyolite (pantellerite?) from Lake County, Oregon: U.S. Geological Survey Professional Paper 424-C, p. C142-C145.

________1974, Some implications of Late Cenozoic volcanism to geothermal potential in the High Lava Plains of south-central Oregon: The Ore Bin, v. 36, no. 7, p. 109-119.

______1977, Geologic map of Oregon east of the 121st meridian: U.S. Geological Survey Miscellaneous Investigations Map I-902, scale 1:500,000.

_______1980, Preliminary report on the geology of the Lakeview uranium area, Lake County, Oregon: U.S. Geological Survey Open-File Report 80-532, 33 p.,

Walker, G. W., Flanagan, F. J., Sutton, A. L., Jr., Bastron, Harry, Berman, Sol, Dinnin, J. I., and L. B. Jenkins, 1976, Quartz latite (dellenite), QLO-1, from southeastsern Oregon: U.S. Geological Survey Professional Paper 840, p. 15-20.

Walker, G. W., and MacLeod, N. S., 1977, Rhyolitic volcanism in southeastern Oregon and the Snake River Plain: similarities and contrasts (abs.): Geological Society of America, Abstracts with Programs, v. 9, no. 7, p. 1215-1216.

Walker, G. W., and Nolf, Bruce, 1981, High Lava Plains, Brothers fault zone to Harney Basin, Oregon: U.S. Geological Survey Circular 838, p. 105-111.

Wells, R. E., 1980, Drake Peak--A structurally complex rhyolite center in southeastern Oregon, in Shorter Contributions to Mineralogy and Petrology, 1979: U.S. Geological Survey Professional Paper 1124-E., E1-E16.

Zielinski, R. A., 1978, Uranium abundances and distribution in associated glassy and crystalline rhyolites of the western United States: Geological Society of America Bulletin, v. 89, p. 409-414.