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Amounts of selected trace elements present in the Snake Creek-Williams Canyon intrusion, southern Snake Range, Nevada

By

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and statigraphic nomenclature.

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Abstract

This report presents quantitative data on the As, Cs, Hg, Li, Se, Sb, Tl, and Zn contents of representative samples collected from the most mafic to the most felsic parts of a zoned pluton in the southern Snake Range of eastern Nevada. Minor element values determined are compared with abundance figures for other granitoid rocks, and attention is paid to trends that might relate to the zoning in the Snake Range pluton. The zoned intrusion has resulted from in situ fractional crystallization. Within a horizontal distance of 5 km this well exposed pluton grades from 63 to 76 percent SiO_2, and other major element variations compare closely with Daly's average andesite-dacite-rhyolite.

Introduction

The purpose of this report is to present quantitative data on the As, Cs, Hg, Li, Se, Sb, Tl, and Zn contents of representative samples collected from the most mafic to the most felsic parts of the Snake Creek-Williams Canyon pluton. We also present similar data for three samples of a Cretaceous muscovite-phenocrystic two-mica granite (Lee and others, 1981) that is separated from the Snake Creek-Williams Canyon pluton by a septum of sedimentary rocks 1.6 km long and only about 300 m wide. The muscovite-phenocrystic two-mica granite crops out in the Pole Canyon-Can Young Canyon area, just northeast of the northeast corner of the pluton (fig. 1).

The Snake Creek-Williams Canyon intrusive mass is located in the southern Snake Range, Nevada, about 60 km southeast of Ely, Nevada. The intrusive rock is well-exposed in contact with chemically distinct host rocks, and the chemical and mineralogical trends are developed over large enough distances to be defined with assurance. Yet the distances are small enough to allow detailed field study of the concentration gradients. Within a horizontal distance of 5 km this well-exposed pluton grades from 4.5 percent CaO (63 percent SiO_2) where the host rock is limestone to less than 0.5 percent CaO (76 percent SiO_2) where the host rock is quartzite (fig. 1), and other major element variations compare closely with Daly's (Barth, 1962, p. 164) average andesite-dacite-rhyolite. When the large and systematic variation in the petrology of this pluton was recognized, it became apparent that this intrusive mass is ideal for a study of igneous processes.

The Snake Creek-Williams Canyon intrusive mass has been intensively studied. The locations of all of the samples mentioned in this discussion were given by Lee and Van Loenen (1971). A report by Lee and Christiansen (1983) summarized and integrated the information from some 30 papers on the petrology, age relations, and systematic mineralogy of the Snake Creek-Williams Canyon pluton and spatially related rocks. These writers list references to the earlier works on these rocks and conclude that the zonation in the Snake Creek-Williams Canyon pluton is the result of in situ fractional crystallization. Models of trace element and isotopic data indicate that relatively little assimilation took place at the level of crystallization.

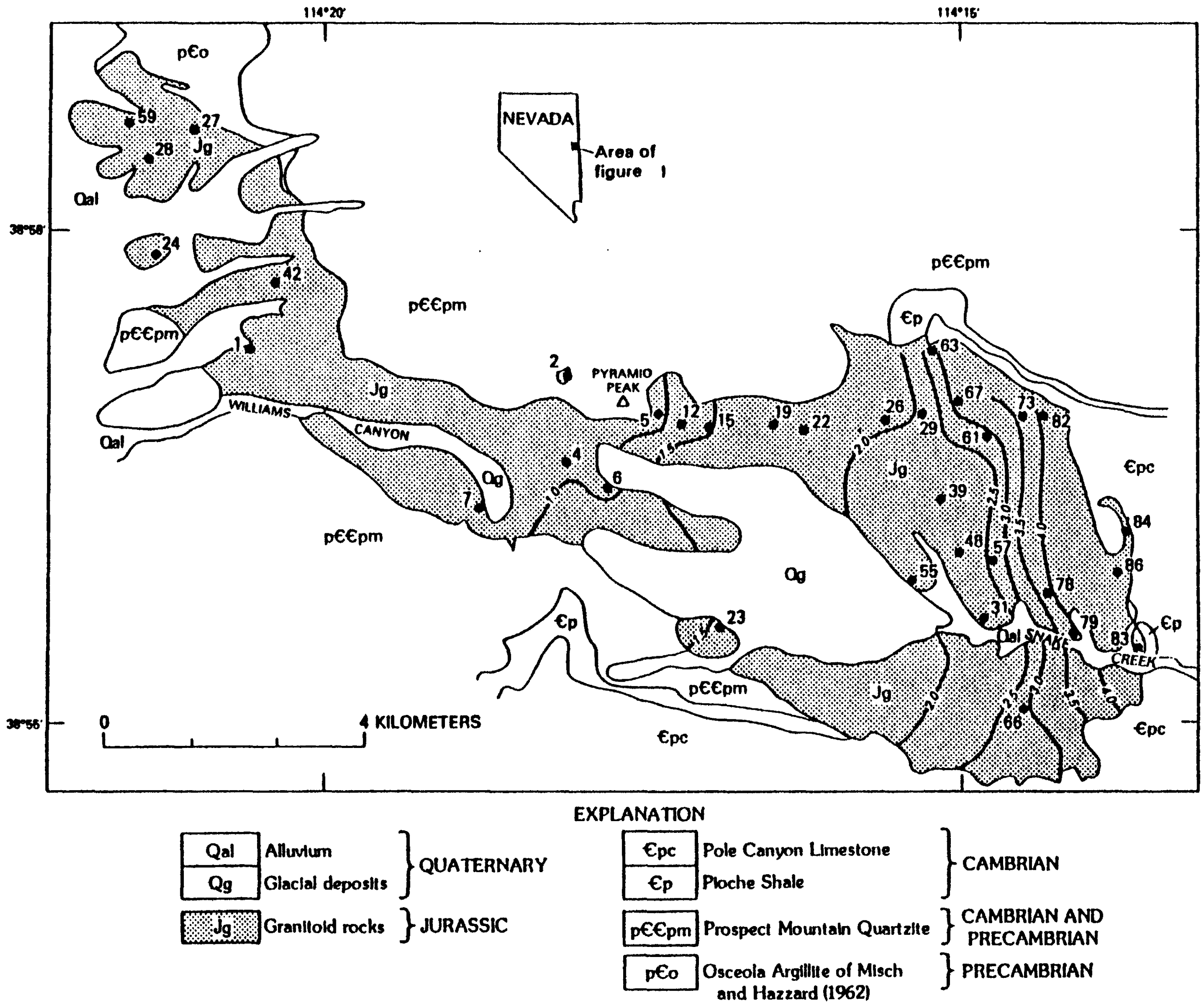

Figure 1.--Simplified geologic map of the Snake Creek-Williams Canyon pluton. The solid lines within the intrusion are CaO isopleths. Many sample locations omitted for the sake of simplicity; others are shown that are not included in Table 1.

Analytical data

General

Selected analytical data for the pluton of the Snake Creek-Williams Canyon area and for the two-mica granite of the Pole Canyon-Can Young Canyon area are listed in table 1, where samples are arranged in order of CaO content; that is, from most felsic to most mafic. Although many sample locations have been omitted from figure 1 for the sake of simplicity, the relation between each sample and the geology of the Snake Creek-Williams Canyon area can be deduced from the CaO isopleths shown.

For comparison table 2 lists world averages for intermediate and felsic intrusive rocks (Vinogradov, 1962), and table 3 lists data for a suite of 228 random samples of granitoid rocks collected from 114 plutons in the Basin and Range Province of Nevada, Utah, Arizona and California (Lee, 1984, table 10). Arithmetic means and standard deviations have been calculated (table 3) for those elements present in amounts above the limit of detection in at least half the samples analyzed. Qualified values, that is, those below the limit of detection, have been ignored in these calculations. These data (table 3) are based on methods of analysis described by Lee (1984, p. 1, 3). In the following discussion of the individual elements we will compare values in table 1 with those in tables 2 and 3, and also comment on trends in table 1 that might relate to the aforementioned compositional zoning in the Snake Creek-Williams Canyon pluton.

Arsenic

The arsenic values in table 1 were determined spectrophotometrically by E. J. Fennelly. Comparison of data in tables 1-3 indicate that the Snake Creek-Williams Canyon and the Pole Canyon-Can Young Canyon plutons are depleted in arsenic. A maximum of 28 ppm arsenic was found in 228 random samples of granitoid rocks from the Basin and Range province (table 3), and up to 40 ppm was found in 71 samples of Mesozoic plutonic rocks of the Sierra Nevada (Dodge, 1972).

Cesium

The cesium values in table 1 were determined by atomic absorption by Violet Merritt. A modeling of these cesium values by the method of Lee and Christiansen (1983) indicates that the initial concentration of cesium in the Snake Creek-Williams Canyon melt was 2-3 ppm, and that the bulk distribution coefficient of the element was 0.3-0.4. Cesium collected during the evolution of the liquid and is found in concentrations as high as 6-7 ppm in the most felsic parts of the Snake Creek-Williams Canyon intrusive outcrop area. The cesium values in the Snake Creek-Williams Canyon pluton are near the world average for felsic rocks (table 2), but they fall in the lower part of the range of cesium values found in 228 granitoid rocks of the Basin and Range province.

Table 1.--Analytical data for granitoid rocks of the southern Snake Range

[Methods of analysis given in text]

Sample No.	Weight CaO[1]	Percent SiO_2[1]	Parts per million							
			As	Cs	Hg	Li	Se	Sb	Tl	Zn
			Snake Creek-Williams Canyon pluton							
2	0.52	76.2	<0.1	7	0.006	18	<0.1	0.23	0.7	30
4	.61	75.2	< .1	5	.008	21	< .1	.19	1.3	18
8	.83	76.4	< .1	6	.006	33	< .1	.22	1.3	25
10	1.1	75.3	< .1	4	.007	16	< .1	.37	1.4	27
12	1.2	75.4	< .1	4	.020	31	< .1	.90	.6	28
14	1.4	74.7	< .1	3	.005	24	.2	.24	.7	27
16	1.6	73.7	< .1	3	.008	19	< .1	.18	.7	33
18	1.7	74.0	< .1	2	.036	51	< .1	.66	.5	39
25	1.8	73.5	.1	2	.003	23	< .1	.22	.7	35
26	1.9	73.0	< .1	3	.004	21	< .1	.14	.6	39
29	2.1	71.6	< .1	2	.008	28	< .1	.45	.3	46
30	2.2	71.7	< .1	3	.018	29	< .1	.70	.4	45
40	2.3	70.2	< .1	1	.003	20	< .1	.17	.3	45
47	2.4	72.2	.1	2	.007	31	.2	.58	.3	45
56	2.5	70.0	< .1	2	.022	28	< .1	1.30	.5	47
58	2.6	71.0	< .1	2	.030	35	< .1	1.37	.4	46
62	2.7	70.5	.1	2	.004	31	< .1	.19	.3	45
63	2.9	70.2	.1	4	.004	44	< .1	.24	.4	70
65	3.0	70.0	< .1	2	.003	35	< .1	.18	< .2	57
66	3.1	70.3	.1	<1	.017	29	< .1	.76	.3	52
67	3.2	71.1	.1	2	.017	25	< .1	.17	.3	47
68	3.3	68.5	< .1	2	.008	57	< .1	.52	.4	60
70	3.4	67.8	< .1	1	.011	55	< .1	.43	.3	60
73	3.5	67.2	< .1	2	.005	33	< .1	.23	.4	61
74	3.6	67.6	< .1	<1	.007	24	< .1	.18	.3	58
76	3.8	65.4	< .1	1	.004	32	.1	.15	.3	60
78	3.9	66.3	< .1	2	.047	29	.2	.85	.3	62
79	4.0	63.5	< .1	1	.013	46	< .1	.63	.4	70
80	4.1	65.2	< .1	2	.043	43	< .1	1.85	< .2	64
82	4.2	67.1	.1	3	.008	34	< .1	.17	< .2	67
83	4.3	63.7	< .1	3	.019	72	< .1	.20	1.0	85
84	4.3	61.9	< .1	2	.009	54	< .1	.20	.7	77
86	4.5	62.8	< .1	1	.010	31	< .1	.21	.4	72
			Pole Canyon-Can Young Canyon pluton							
88	0.87	73.8	< .1	4	.045	29	.2	.49	< .2	52
93	1.3	71.6	< .1	6	.012	68	< .1	.14	.4	67
95	1.6	72.5	< .1	6	.010	45	< .1	.19	.7	57

[1] CaO and SiO_2 data from Lee and Van Loenen (1971).

Table 2.--Average contents of selected minor elements in intermediate and felsic intrusive rocks[1]

Element	Average contents, parts per million Intermediate rocks	Felsic rocks
As	2.4	1.5
Cs	No Data	5.0
Hg	do.	0.08
In	do.	0.26
Li	20	40
Se	.05	.05
Sb	0.20	0.26
Tl	0.5	1.5
Zn	72	60

[1]World averages from A. P. Vinogradov (1962).

Table 3.--Contents, in ppm, of selected minor elements in a suite of 228 random samples of granitoid rocks from the Basin and Range province[1]

Element	Limit of detection	Detection ratio[2]	Range	Arithmetic mean	Standard deviation
As	1	88	<1-28	7.7	±5.9
Cs	5	34	<5-49	---	---
Li	1	100	2-175	29	±19
Sb	1	21	<1-4.8	---	---
Tl	1	50	<1-7	1.6	±0.8
Zn	1	100	2-180	49	±27

[1]Based on data from Lee (1984, table 10).
[2]Percent of samples in which element was detected.

Mercury

The mercury values in table 1 were determined by a wet oxidation-flameless atomic absorption method by V. E. Shaw. Amounts of mercury found in samples of the Snake Creek-Williams Canyon pluton range from 0.003 to 0.047 ppm, but values within this range are not obviously related to the major element chemistry of the pluton. If the world average content of mercury in felsic intrusive rocks (0.08 ppm) listed in table 2 is correct, the Snake Creek-Williams Canyon pluton may be depleted in mercury. Mercury is not listed in table 3, for practically all of the 228 random samples of granitoid rocks from the Basin and Range province contain mercury in amounts less than the limit of detection (0.5 ppm) of the analytical method.

Small amounts of mercury were detected in some of the zircons recovered from samples of the Snake Creek-Williams Canyon pluton (Lee and others, 1968).

Lithium

The lithium values in table 1 were determined by a total digestion and atomic absorption method by J. A. Thomas. Lithium is enriched in the most mafic samples and its concentration appears to decrease throughout the evolution of the liquid. A modeling of these lithium values by the method of Lee and Christiansen (1983) indicates that the initial concentration of lithium in the Snake Creek-Williams Canyon melt was 27-30 ppm, and that the bulk distribution coefficient ranged from 2.1 at $F = 1.0 - 0.8$ to 1.1 at $F = 0.8$ to 0.1, with F = fraction of liquid remaining.

Biotite is the main concentrator of lithium in these rocks. Based on semiquantitative emission spectrographic analyses, the lithium content of this biotite ranges from <700 ppm in the most mafic parts of the intrusion to 1,500 ppm in the most felsic parts (Lee and Van Loenen, 1970, table 1). Biotite comprises about 25 percent of the most mafic parts of the intrusion and decreases with decreasing CaO content until it makes up less than 3 percent of the most felsic parts of the pluton (Lee and Van Loenen, 1971, table 5). Next to biotite, plagioclase is probably the most important concentrator of lithium in these rocks.

Selenium

The selenium values in table 1 were determined by J. S. Wahlberg by an X-ray fluorescence method (Wahlberg, 1976). Both Vinogradov (1962, p. 646) and Leutwein (1972, p. 34-E-1) note that the selenium content of igneous rocks is small and not yet well known. The values listed by these writers are of the same order of magnitude as the selenium values found for the southern Snake Range plutons (table 1).

Antimony

The antimony values in table 1 were determined by D. R. Norton, using an unpublished rhodamine-B method. Values in table 1 range from 0.14 to 1.85 ppm and show no relation to petrologic type. Antimony values in table 1 are similar to those in tables 2 and 3 and to those for igneous rocks listed by

Onishi (1969). Zircon recovered from the felsic part of the Snake Creek-Williams Canyon pluton contains as much as 700 ppm antimony, as determined by semiquantitative spectrographic analysis (Lee and others, 1968, table 1).

Indium and thallium

All indium values for the samples in table 1 were determined to be <0.2 ppm. Although these values are slightly lower than the world average (0.26 ppm) for felsic igneous rocks (table 2), they are in agreement with the compilation of Linn and Schmitt (1972, figs. 49-E-4 and 49-E-5). The indium values (each <0.2 ppm) and the thallium values listed in table 1 were determined by A. E. Hubert by an atomic absorption technique described by Hubert and Lakin (1972).

The thallium values found in samples of the Snake Creek-Williams Canyon pluton (table 1) are of the same order of magnitude as those listed in tables 2 and 3. Evidence of the variation of the thallium contents in series of differentiates is inconclusive (de Albuquerque and Shaw, 1972, p. 81-E-9), with some examples showing higher thallium contents in the later differentiates, while other examples show lower contents. Thallium contents tend to be higher in the more felsic parts of the zoned Snake Creek-Williams Canyon pluton (fig. 2).

The geochemistry of thallium is dominated by a close coherence with potassium and rubidium. In igneous rocks de Albuquerque and Shaw (1972, p. 81-E-10) found that the values of K/Tl and Rb/Tl fall in the ranges 4,000-112,000 and 19-950, with averages close to 30,000 and 150, respectively. Most of the K/Tl and Rb/Tl values determined for the southern Snake Range granitoids (fig. 3) are consistent with the findings of de Albuquerque and Shaw (1972).

Zinc

The zinc values in table 1 were determined by J. A. Thomas, using a total digestion and atomic absorption method. These zinc values are in general agreement with those in tables 2 and 3 and with the world-wide data compiled by Wedepohl (1972). A modeling of the values in table 1 by the method of Lee and Christiansen (1983) indicates that the initial concentration of zinc in the Snake Creek-Williams Canyon melt was 32-38 ppm, and that the bulk distribution coefficient of the element was 1.2. As shown in fig. 4, zinc was depleted during the evolution of the liquid, and the most felsic parts of the pluton contain only about 20 ppm of the element. Wedepohl (1972, p. 30-E-13) cited several references reporting that zinc abundance in granitic rocks is controlled mainly by their biotite content. Data for the Snake Creek-Williams Canyon pluton are consistent with this idea. The most mafic parts of this pluton (63 percent SiO_2) contain as much as 25 percent biotite. The more felsic parts of the pluton contain less of the mineral until the most felsic parts (76 percent SiO_2) contain less than 3 percent biotite (Lee and Van Loenen, 1971, table 5). Biotites recovered from the Snake Creek-Williams Canyon pluton generally contain less than 500 ppm zinc, as determined by semiquantitative emission spectrographic analysis (Lee and Van Loenen, 1970, table 1). Thus probably less than half the 20 ppm zinc present in the most felsic parts of the Snake Creek-Williams Canyon pluton is contained in

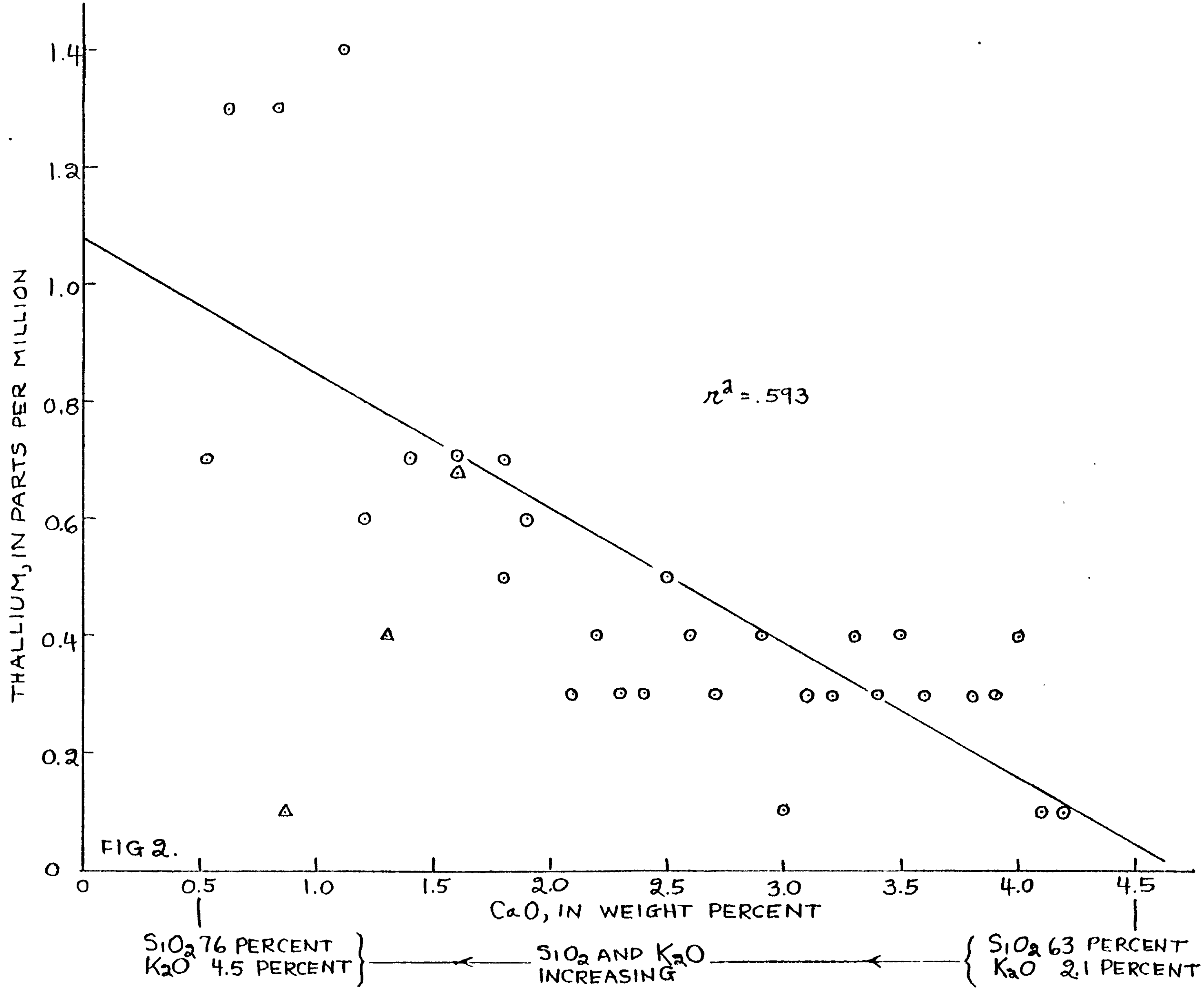

Figure 2.--Relation between CaO and Tl contents of granitoid rocks of the Snake Creek-Williams Canyon pluton (circles) and the Pole Canyon-Can Young Canyon pluton (triangles). CaO values are used instead of SiO_2 for a better point spread, and the equivalent ranges of SiO_2 and K_2O are indicated. The equation for the least squares fit regression line (based only on the samples from the Snake Creek-Williams Canyon pluton) is $Y = 1.078-0.23X$. Tl values listed as <0.2 ppm are arbitrarily assumed to be 0.1 ppm. Based on data in table 1, excluding samples 83, 84, and 86, which do not conform to the main trend, possibly because of contact effects.

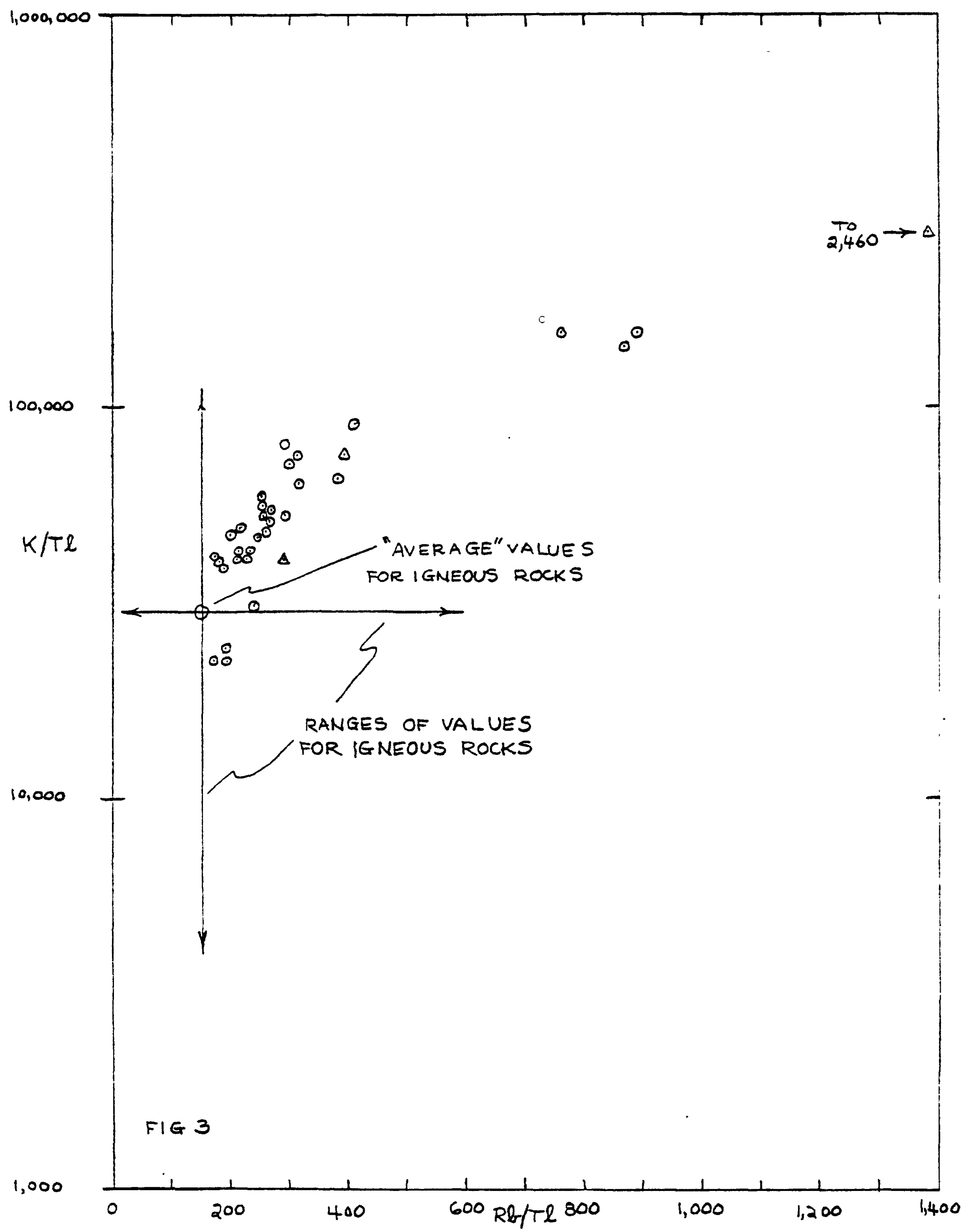

Figure 3.--Plot of Rb/Tl versus log K/Tl for samples of the Snake Creek-Williams Canyon pluton (circles) and the Pole Canyon-Can Young Canyon pluton (triangles), based on thallium values in table 1, K from the K_2O values listed by Lee and Van Loenen (1971, tables 5 and 6), and Rb values listed by Lee and Doering (1980). Ranges and "averages" from the data of de Albuquerque and Shaw (1972) are shown.

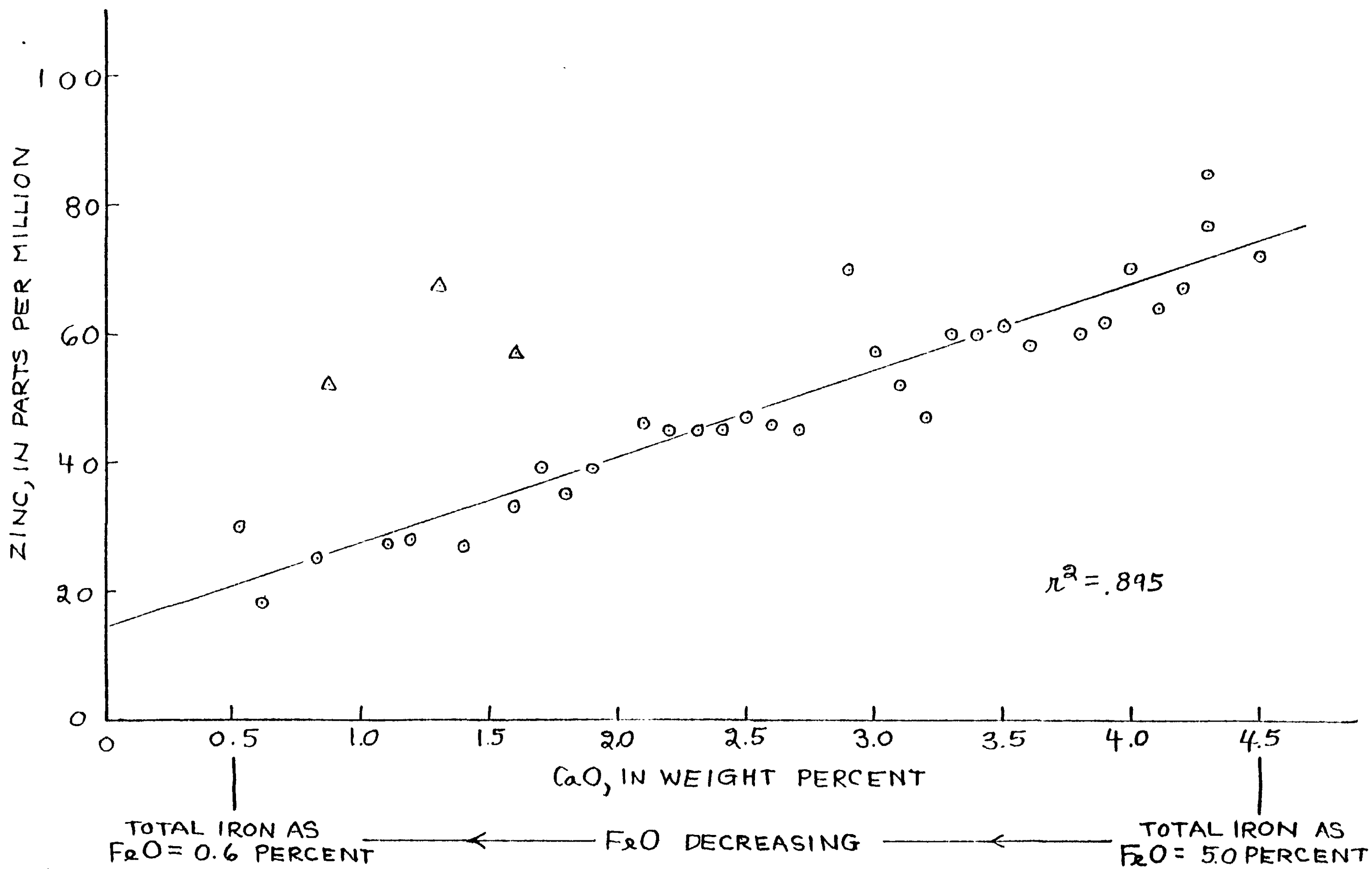

FIG 4

Figure 4.--Relation between CaO and Zn contents of granitoid rocks of the Snake Creek-Williams Canyon pluton (circles) and the Pole Canyon-Can Young Canyon pluton (triangles). The equivalent range of total Fe as FeO is indicated. The equation for the least square fit regression line is Y = 13.43+13.54X.

biotite, and the rest is probably present in plagioclase (Crecraft and others, 1981). The most felsic parts of this pluton contain about 35 percent plagioclase (Lee and Van Loenen, 1971, table 5).

Compared to the more felsic parts of the Snake Creek-Williams Canyon pluton, the muscovite-phenocrystic two-mica granite of the Pole Canyon-Can Young Canyon area contains relatively large amounts of zinc (fig. 4). The only mafic mineral present in the Pole Canyon-Can Young Canyon pluton is biotite, which is present as tiny euhedra within phenocrysts of muscovite. Each of the three samples of this pluton plotted (fig. 4, triangles) contains less than 4 percent biotite (Lee and Van Loenen, 1971, table 6). The biotite present in the Young Canyon-Can Young Canyon pluton contains as much as 1,500 ppm zinc (Lee and Van Loenen, 1970, table 1), and thus the zinc present in these constituent biotites could account for all of the zinc present in the rocks.

Summary

The zoned (63-76 percent SiO_2) intrusion of the Snake Creek-Williams Canyon area is depleted in arsenic and possibly in mercury. Cesium and thallium collected, and lithium and zinc were depleted, during the evolution of the liquid. Of the elements discussed, zinc concentration shows the most systematic change from the mafic to the felsic parts of the pluton. In agreement with earlier studies, our results indicate that biotite is the main reservoir for zinc in these granitoid rocks.

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