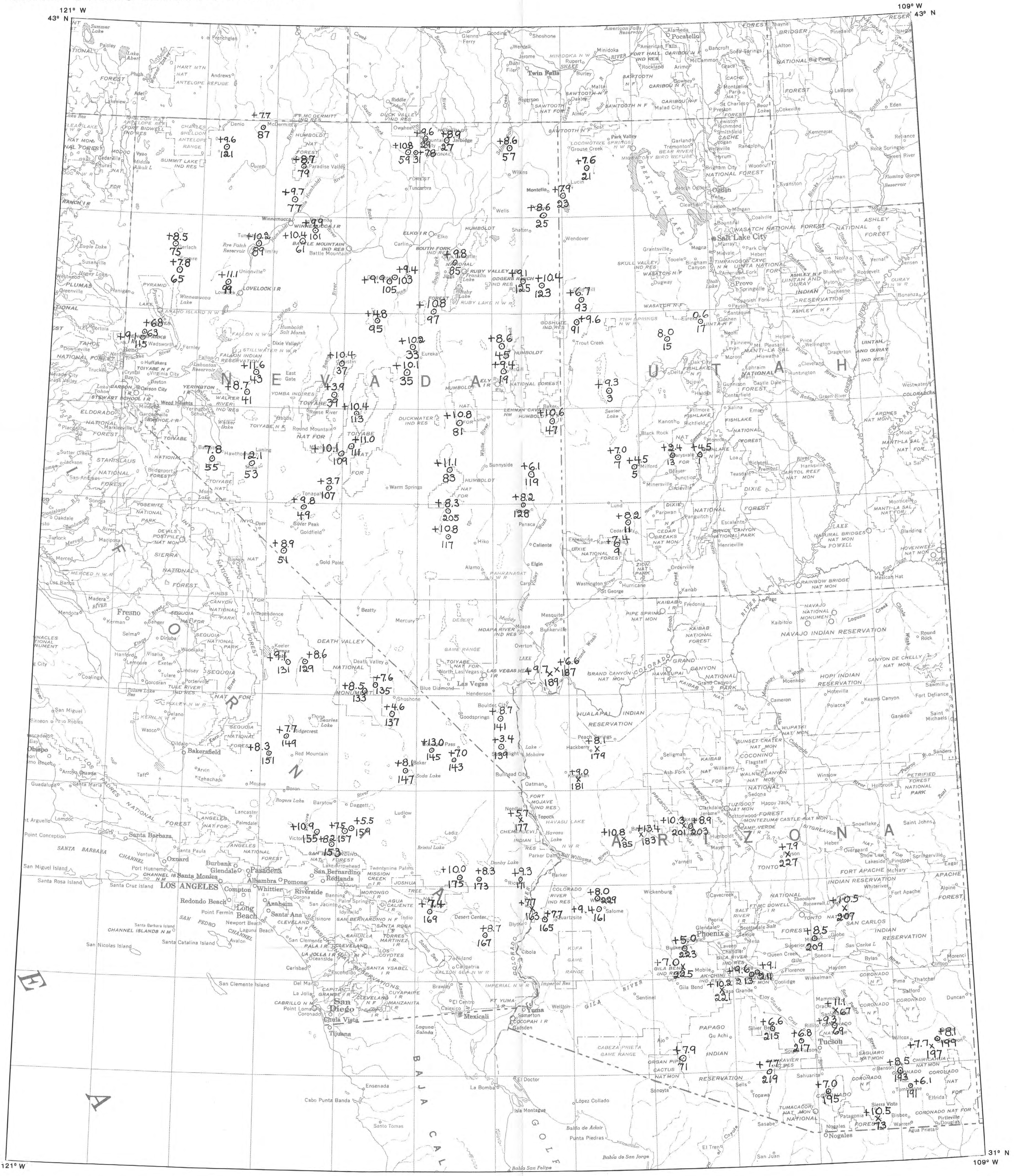
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF-1305
BASIN RANGE PROVINCE



Base from U.S. Geological Survey, United States planimetric base

SCALE 1:3 168 000

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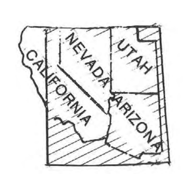

MAP LOCATION

MAP SHOWING THE OXYGEN ISOTOPE COMPOSITION OF GRANITOID ROCKS OF THE BASIN-RANGE PROVINCE

By

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1981

EXPLANATION

SAMPLE LOCALITIES--All sample numbers have prefix of GR. $\delta^{18}O$ value shown above localities

+2.4 ⊙ 13 Tertiary-Mesozoic intrusive

+7.9 X 227 Precambrian intrusive

DISCUSSION

This map presents oxygen isotope data for a suite of granitoid rocks from the Basin and Range Province of Nevada, Utah, California, and Arizona. Two random samples were collected from each of two randomly selected plutons within each 1° x 1° area. For this study, only the odd-numbered sample was analyzed except in one instance when sample GR-128 was substituted for its odd-numbered counterpart (GR-127), which was lost.

About 80 percent of the samples were collected by Lee alone, and about 20 percent were collected by Lee with the assistance of R. E. Van Loenen. Thus, for practical purposes, terrane not accessible to a single worker with a reasonable degree of safety was not amenable to sampling. In addition to being chosen at random, the samples were both fresh (zones of alteration, iron staining, and friable rock were avoided) and typical of the main intrusive phase in the area of the sample site (xenolithic material, dike rocks, and other minor intrusive variants were rejected).

Usually a minimum of four hours was spent on study of each pluton sampled. Samples that could not be broken out with a 5 kg sledge hammer were essentially inaccessible because no drilling or blasting was done. In the study area many plutons display an erosion pattern of large rounded monoliths, impossible to break open with a sledge hammer. In such terrane road cuts and rock falls often provided the only access to fresh material.

Because we sampled only fresh material, the sample suite as a whole is no doubt biased in favor of those igneous materials that were originally relatively impermeable. Few of the plutons in the study area appear in outcrop as uniformly fresh and coherent rock. Commonly the area properly mapped as intrusive igneous rock contains monoliths ranging in size from a few to a few tens of meters across surrounded by igneous rubble; in other words, the monoliths appear as large raisins floating in a pudding of igneous rubble. In deep road cuts and in canyons exposing a vertical section, the same relationship between coherent rock and grus commonly was seen to persist for tens of meters below the surface. The different susceptibility to weathering from place to place within a pluton must result from original differences in permeability and access to surface waters.

Sample localities and $\delta^{18}O$ values of the 115 samples analyzed as part of this study are listed in table 1. The $\delta^{18}O$ values were determined using the method described by Friedman and others (1974) and range from extremely light (+0.6) to very heavy (+13.4). Frequency distribution within that range is shown on figure 1. The average value of $\delta^{18}O$ for all 115 samples is 8.48 and the mean is 8.6. To our knowledge there are no Paleozoic plutons in the study area, and we distinguish here between two main age groupings, Precambrian and Mesozoic-Tertiary. As a group the 16 samples of Precambrian plutons have higher average (9.14) and mean (9.0<mean<9.7) values than do the 99 Mesozoic-Tertiary, which have average and mean values of 8.37 and 8.6, respectively.

Although we have determined only one $\delta^{18}O$ value for each of the plutons included in this suite, there is evidence to indicate that the range of $\delta^{18}O$ within any one of these plutons may be somewhat restricted. In the Snake Creek-Williams Canyon area of the southern Snake Range, Nevada, the equivalent of a large part of the classic differentiation sequence ranging from 63 to 76 percent SiO_2 is exposed; and major element oxides as well as many other parameters vary systematically across this igneous mass (Lee and Van Loenen, 1971). We have determined a total of 25 $\delta^{18}O$ values for rocks representing this entire range (from 63 to 76 percent SiO_2) of composition. Our unpublished data show that the $\delta^{18}O$ values range from 10.2 in the most mafic of these rocks to 12.2 in the most felsic. In view of the diversity of chemical types represented by this exposure, this range of $\delta^{18}O$ (2.0 per mil) probably is greater than one would expect in a more homogeneous mass. None of the 115 plutons included in the present study was recognized as being as systematically variable in composition as the Snake Creek-Williams Canyon intrusive mass.

Before we compare our results with those of some other regional studies, we will discuss briefly the classification of granites into S-types and I-types (Chappell and White, 1974). Those granites derived from predominantly sedimentary (weathered) materials are S-types, while those derived from igneous materials are I-types. Based on studies of a number of granite suites from the New England batholith of Australia, O'Neil and others (1977) concluded that $\delta^{18}O$ can be used to discriminate the major granite protoliths. O'Neil and others found $\delta^{18}O$ values consistently higher in the S-type granites (10.4-12.5) than in the spatially related I-type plutons (7.7-9.9), with what appears to be a systematic variation in $\delta^{18}O$ from the most S-type to the most I-type intrusives. The dividing line between the two granite types occurs at a $\delta^{18}O$ value of about 10.

The lower limit of $\delta^{18}O$ values for I-type granites appears to be about 6 (Beckinsale, 1979, p. 37), the probable value of $\delta^{18}O$ for mantle-derived starting materials (Shieh and Schwarcz, 1978, p. 1773). Extremely low values of ^{18}O, (<6.0) probably result from isotopic exchange between the magma and ground water low in ^{18}O; this has been shown to be true for the Yellowstone Plateau rhyolites (Friedman and others, 1974), and the ash-flow sheets of southern Nevada (Lipman and Friedman, 1975).

The relationship between $\delta^{18}O$ values and SiO_2 contents for the 115 samples included in the present study is shown on figure 2. Those samples with $\delta^{18}O$ values less than 6.0 range in SiO_2 from 57.4 to 74.1, and the point locations on figure 2 are random. This is consistent with the fact that magma of any chemical type might undergo isotopic exchange with ground water low in $\delta^{18}O$. The I-type granites, those with $\delta^{18}O$ values greater than 6.0 and less than 10.0, range in SiO_2 from 53.4 to 77.8. Again, there is no particular relationship between $\delta^{18}O$ and SiO_2 on figure 2, for the SiO_2 of an I-type magma will depend upon the amount of differentiation it has undergone. The S-type granites, those with $\delta^{18}O$ values greater than 10.0, have a minimum SiO_2 content of 64 percent (fig. 2) and as a group are more felsic than the I-type granites, which is not surprising considering the chemical nature of the respective protoliths of the two granite types.

There is of course the possiblity that a strongly S-type magma (with a very high content of ^{18}O) might undergo isotopic exchange with ground water low in ^{18}O, and crystallize with a $\delta^{18}O$ value in the range of I-type granites. In such a case, however, the S-type affinity of the rock might still be apparent from its other characteristics, as summarized for example by Beckinsale (1979, p. 37, 38). Moreover, the usual sequence of ^{18}O enrichment among coexisting minerals (Taylor, 1968) might be modified by isotopic exchange between meteoric water and a crystallizing magma. We have not yet studied individual mineral phases from any of the samples described here.

In general the $\delta^{18}O$ values determined here (table 1; figs. 1, 2) are similar to those reported for granites from other regions. The average $\delta^{18}O$ value for granitic rocks of the Canadian Precambrian shield is about 8.1 (Shieh and Schwarcz, 1978, p. 1780). The $\delta^{18}O$ values of 140 plutons in the Peninsular Ranges batholith of southern California and Baja California, Mexico, range from 6.0 to 7.0 in the west to 12.8 in the east (Taylor and Silver, 1978). The New England batholith of Australia, a large upper Paleozoic calc-alkaline mass, has $\delta^{18}O$ values (39 samples) that range from 6.39 to 12.49 (O'Neil and others, 1977).

Our findings differ from those of most other regional studies in two respects, the extreme range (0.6-13.4) of $\delta^{18}O$ values found, and the apparent lack of any systematic distribution of values. As noted above the $\delta^{18}O$ values of the Peninsular Ranges batholith of California increase from west to east (Taylor and Silver, 1978). On the northeastern coast of Baffin Island quartzo-feldspathic rocks (20 samples) show higher $\delta^{18}O$ values (>9.0) concentrated in the northwest, lower values (<7.7) in the southeast over an area about 600 km long (Shieh and Schwarcz, 1978, p. 1779). In the large New England batholith of Australia, each of four different granite suites is characterized by a particular range of $\delta^{18}O$ values (O'Neil and others, 1977). The extreme range and haphazard geographic distribution of the $\delta^{18}O$ values determined during our study probably result from the complex history and tectonic framework of the area sampled.

Table 1.--Locations and $\delta^{18}O$ values for a suite of random samples representing 115 plutons in the Basin-Range Province of Nevada, Utah, California, and Arizona

Sample Number	State[1] and County	Lat. N. ° ' "	Long. W. ° ' "	$\delta^{18}O$	Sample Number	State[1] and County	Lat. N. ° ' "	Long. W. ° ' "	$\delta^{18}O$
Gr-1	U-Piute	38 30 17	112 11 12	+4.5	GR-115	N-Washoe	39 43 20	119 42 35	9.1
3	U-Millard	39 11 15	113 23 05	9.3	117	N-Lincoln	37 39 10	115 37 45	10.8
5	U-Beaver	38 21 30	113 04 40	4.5	119	N-Lincoln	38 18 25	114 27 55	6.1
7	U-Beaver	38 27 50	113 17 35	7.0	121	N-Humboldt	41 41 35	118 42 10	9.6
9	U-Iron	37 34 00	113 21 15	7.4	123	N-Elko	40 15 55	114 17 10	10.4
11	U-Iron	37 46 10	113 10 10	8.2	125	N-Elko	40 20 30	114 33 30	9.1
13	U-Beaver	38 26 00	112 33 00	2.4	128	N-Lincoln	37 59 20	114 36 45	8.2
15	U-Juab	39 43 00	112 35 35	8.0	129	C-Inyo	36 20 15	117 28 30	8.6
17	U-Juab	39 53 55	112 06 40	0.6	131	C-Inyo	36 19 25	117 41 10	9.1
19	N-White Pine	39 23 48	114 51 45	9.4	133	C-Inyo	36 02 20	116 40 35	8.5
21	U-Box Elder	41 31 55	113 45 35	7.6	135	C-Inyo	36 06 55	116 32 30	7.6
23	U-Box Elder	41 14 00	113 59 35	7.9	137	C-San Bernardino	35 47 25	116 20 00	4.6
25	N-Elko	41 00 20	114 17 40	8.6	139	N-Clark	35 27 45	114 54 50	3.4
27	N-Elko	41 47 47	115 38 04	8.9	141	N-Clark	35 43 00	114 55 25	8.7
29	N-Elko	41 49 16	115 55 37	9.6	143	C-San Bernardino	35 18 00	115 32 20	7.0
31	N-Elko	41 40 45	116 04 11	7.8	145	C-San Bernardino	35 24 30	115 48 10	13.0
33	N-Eureka	39 38 48	116 04 40	10.2	147	C-San Bernardino	35 11 10	116 08 40	8.1
35	N-Eureka	39 22 53	116 08 42	10.1	149	C-Kern	35 32 30	117 41 35	7.7
37	N-Lander	39 29 38	117 03 34	10.4	151	C-Kern	35 22 20	117 54 35	8.3
39	N-Nye	39 08 09	117 07 54	3.9	153	C-San Bernardino	34 27 30	117 03 35	8.2
41	N-Churchill	39 08 25	118 20 35	8.7	155	C-San Bernardino	34 32 35	117 16 35	10.9
43	N-Chruchill	39 39 44	118 12 40	11.6	157	C-San Bernardino	34 33 25	116 54 30	7.5
45	N-White Pine	39 37 55	114 54 20	8.6	159	C-San Bernardino	34 34 30	116 49 00	5.5
47	N-White Pine	38 51 28	114 12 24	10.6	161	A-Yuma	33 44 20	113 40 15	9.4
49	N-Esmeralda	37 57 15	117 31 10	9.8	[2]163	C-Riverside	33 44 35	114 30 45	7.7
51	N-Esmeralda	37 31 45	117 48 15	8.9	165	A-Yuma	33 39 40	114 19 25	7.7
53	N-Mineral	38 24 04	118 14 00	12.1	167	C-Riverside	33 27 20	115 08 00	8.7
55	N-Mineral	38 26 45	118 45 25	7.8	169	C-Riverside	33 42 40	115 48 20	7.4
57	N-Elko	41 44 55	114 46 10	8.6	171	C-Riverside	34 03 55	114 39 15	9.3
59	N-Elko	41 42 06	116 09 00	10.8	173	C-San Bernardino	34 04 50	115 11 05	8.3
61	N-Humboldt	40 45 26	117 36 56	10.4	175	C-San Bernardino	34 05 40	115 24 35	10.0
63	N-Washoe	39 47 35	119 40 20	6.8	[2]177	C-San Bernardino	34 40 20	114 41 40	5.7
65	N-Pershing	40 26 05	119 15 45	7.8	[2]179	A-Mohave	35 25 20	113 39 00	8.1
[2]67	A-Pinal	32 35 10	110 44 45	11.1	[2]181	A-Mohave	35 06 00	113 52 35	9.0
69	A-Pima	32 26 45	110 46 10	9.3	[2]183	A-Yavapai	34 31 25	113 07 15	13.4
71	A-Pima	32 09 15	112 38 50	7.9	[2]185	A-Yavapai	34 28 15	113 19 05	10.8
[2]73	A-Cochise	31 27 10	110 18 20	10.5	[2]187	N-Clark	36 16 25	114 11 35	6.6
75	N-Washoe	40 40 35	119 23 05	8.5	[2]189	N-Clark	36 13 50	114 15 25	9.7
77	N-Humboldt	41 10 19	117 44 28	9.7	191	A-Cochise	31 45 20	109 52 25	6.1
79	N-Humboldt	41 29 30	117 38 35	8.7	193	A-Cochise	31 55 15	109 57 55	8.5
81	N-Nye	38 50 46	115 28 52	10.8	195	A-Pima	31 44 40	110 53 15	7.0
83	N-Nye	38 20 55	115 34 40	11.1	[2]197	A-Cochise	32 10 05	109 35 15	7.7
85	N-Elko	40 19 34	115 30 30	9.8	199	A-Cochise	32 14 00	109 29 45	8.1
87	N-Humboldt	41 55 45	118 12 00	7.7	[2]201	A-Yavapai	34 35 05	112 34 00	10.3
89	N-Pershing	40 41 48	118 14 46	10.2	203	A-Yavapai	34 34 20	112 30 00	8.9
91	U-Juab	39 51 20	113 48 25	9.6	205	N-Lincoln	37 56 25	115 36 00	8.3
93	U-Tooele	40 08 45	113 45 12	6.7	[2]207	A-Gila	33 39 00	110 34 45	10.5
95	N-Eureka	39 55 12	116 33 20	4.8	209	A-Gila	33 21 50	110 58 10	8.5
97	N-Eureka	40 00 50	115 50 15	10.8	211	A-Pinal	33 02 20	111 43 45	9.1
99	N-Pershing	40 17 20	118 37 25	11.1	213	A-Pinal	33 01 50	111 46 20	9.6
101	N-Humboldt	40 49 05	117 26 00	9.9	215	A-Pima	32 25 55	111 32 55	6.6
103	N-Eureka	40 21 50	116 21 05	9.4	217	A Pima	32 17 30	111 09 45	6.8
105	N-Eureka	40 19 50	116 24 10	9.9	219	A-Pima	31 59 10	111 36 00	7.7
107	N-Nye	38 09 50	117 12 10	3.7	[2]221	A-Pinal	32 50 15	112 08 50	10.2
109	N-Nye	38 30 30	117 01 15	10.1	223	A-Maricopa	33 18 00	112 37 45	5.0
111	N-Nye	38 34 24	116 53 05	11.0	[2]225	A Maricopa	33 11 50	112 38 55	7.0
113	N-Nye	38 57 10	116 50 35	10.4	[2]227	A-Gila	34 15 00	111 16 15	7.9
					229	A Yuma	33 50 40	113 40 55	8.0

[1]A, Arizona; C, California; N, Nevada; U, Utah.
[2]Precambrian, other rocks are Mesozoic or Tertiary in age.

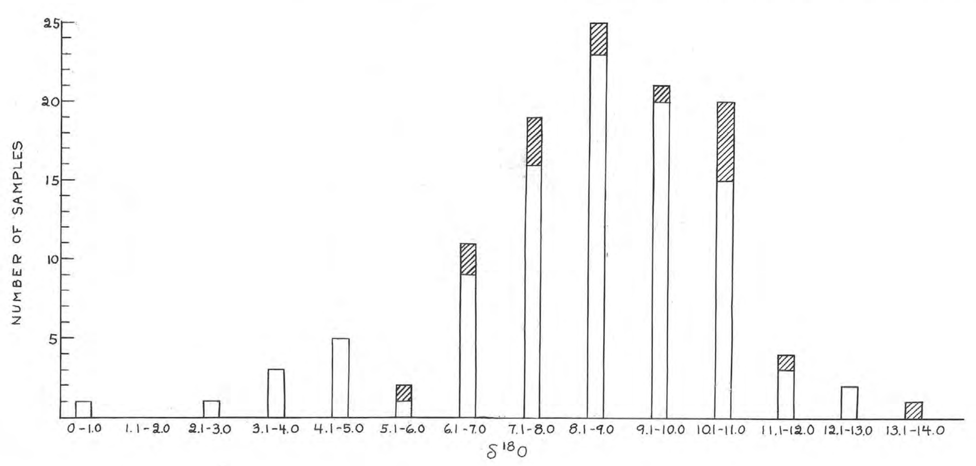

Figure 1.--Histogram showing range and frequency of $\delta^{18}O$ values for samples from 115 plutons in the Basin-Range Province of Nevada, Utah, California, and Arizona. Precambrian age rocks are patterned; all other intrusives are Mesozoic or Tertiary in age.

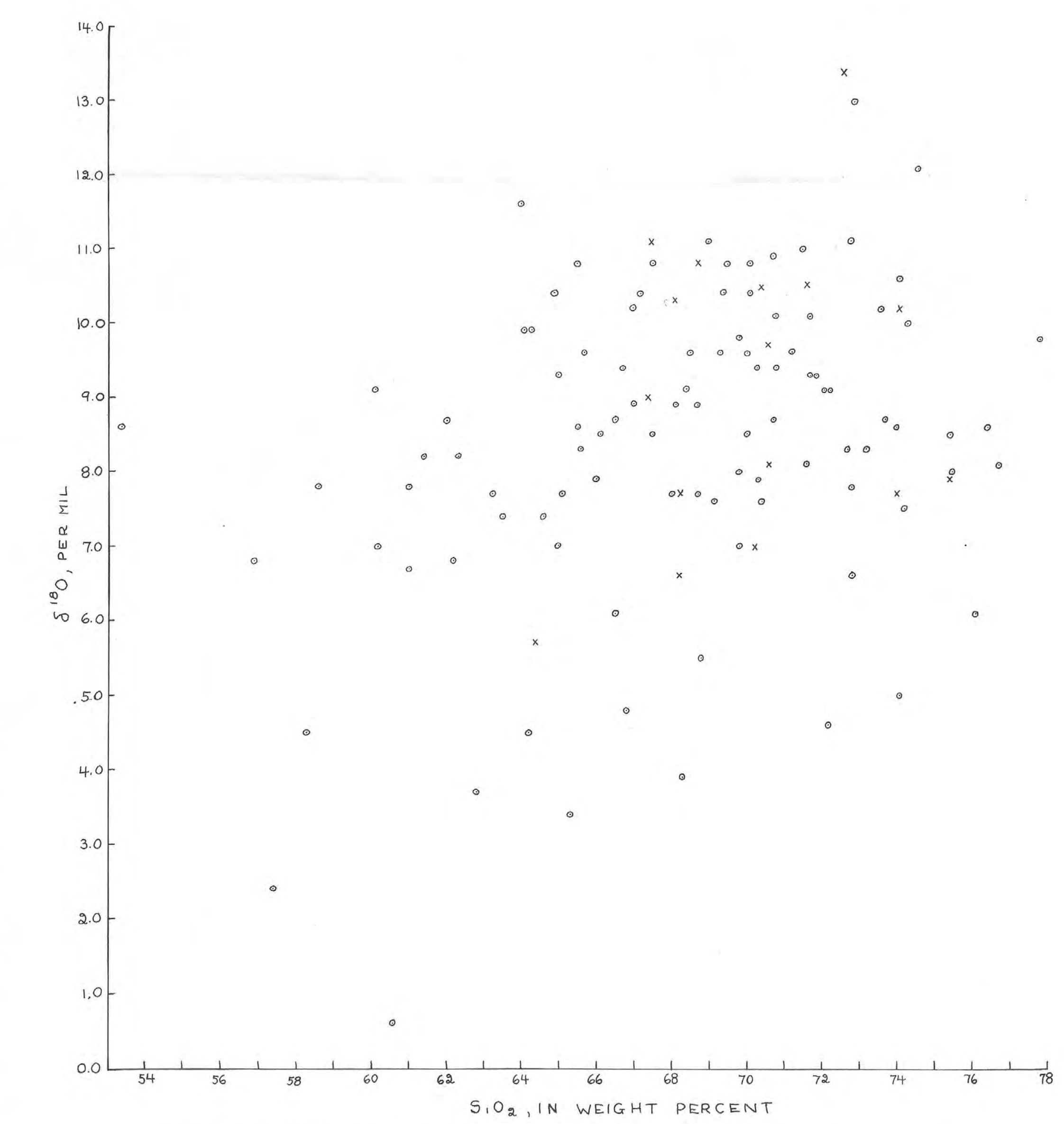

Figure 2.--Relationship between $\delta^{18}O$ values and SiO_2 contents of granitoid rocks of the Basin-Range Province. X, Precambrian rocks; 0, Mesozoic-Tertiary rocks.

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INTERIOR--GEOLOGICAL SURVEY, RESTON, VA.--, REPRINTED, 1984

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