UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Analytical results and sample locality map of rock samples from the Devil's Garden Lava Bed (OR-1-2), Squaw Ridge Lava Bed (OR-1-3), and Four Craters Lava Bed (OR-1-22) Wilderness Study Areas, Lake County, Oregon

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine their mineral values, if any. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a geochemical survey of the Devil's Garden Lava Bed, Squaw Ridge Lava Bed, and Four Craters Lava Bed Wilderness Study Areas, Lake County, Oregon.

INTRODUCTION

In the spring and summer of 1986, the U.S. Geological Survey conducted a reconnaissance geochemical survey of the Devil's Garden Lava Bed (OR-1-2), Squaw Ridge Lava Bed (OR-1-3), and Four Craters Lava Bed (OR-1-22) Wilderness Study Areas, Lake County, Oregon.

The Devil's Garden Lava Bed, Squaw Ridge Lava Bed, and Four Craters Lava Bed Wilderness Study Areas, Lake County, Oregon, comprise about 44.0 mi^2 (114.4 km^2), 32.9 mi^2 (85.5 km^2), and 14.2 mi^2 (36.9 km^2), respectively in the north-central part of Lake County, Oregon. The Devil's Garden Lava Bed Wilderness Study Area lies about 6 mi (10 km) northeast of Fort Rock, Oregon; the Squaw Ridge Lava Bed Wilderness Study Area lies about 14 mi (23 km) northeast of Fort Rock and about 13 mi (21 km) north of Christmas Valley, Oregon; and the Four Craters Lava Bed Wilderness Study Area lies about 4 mi (6 km) north of Christmas Valley. Access to each of the three study areas is provided on all sides by unimproved and improved dirt roads which generally follow the peripheries of the study areas. These roads connect to improved dirt and paved roads leading out of Christmas Valley on the south and Fort Rock on the west (fig. 1).

The study areas are located in the southwestern part of the High Lava Plains physiographic province. The study areas are all underlain by Pleistocene or Holocene basalt flows that overlie older (Pliocene to Pleistocene) basaltic to more silicic lavas and basaltic ejecta. The study areas are within the area of a reconnaissance geologic map of the east half of the Crescent quadrangle at 1:250,000 scale by Walker and others (1967).

The topographic relief of most of the three study areas is generally low to moderate; relatively high relief is found on the flanks on volcanic cones. The lowest elevation is about 4,300 ft (1,311 m) along the southeast side of the Four Craters area; the highest elevation is 5,612 ft (1,710 m) at the peak of Lava Mountain in the Squaw Ridge area. The climate is semiarid.

METHODS OF STUDY

Sample Media

Analyses of unaltered or unmineralized rock samples provide background geochemical data for individual rock units. On the other hand, analyses of altered or mineralized rocks, where present, may provide useful geochemical information about the major- and trace-element assemblages associated with a mineralizing system.

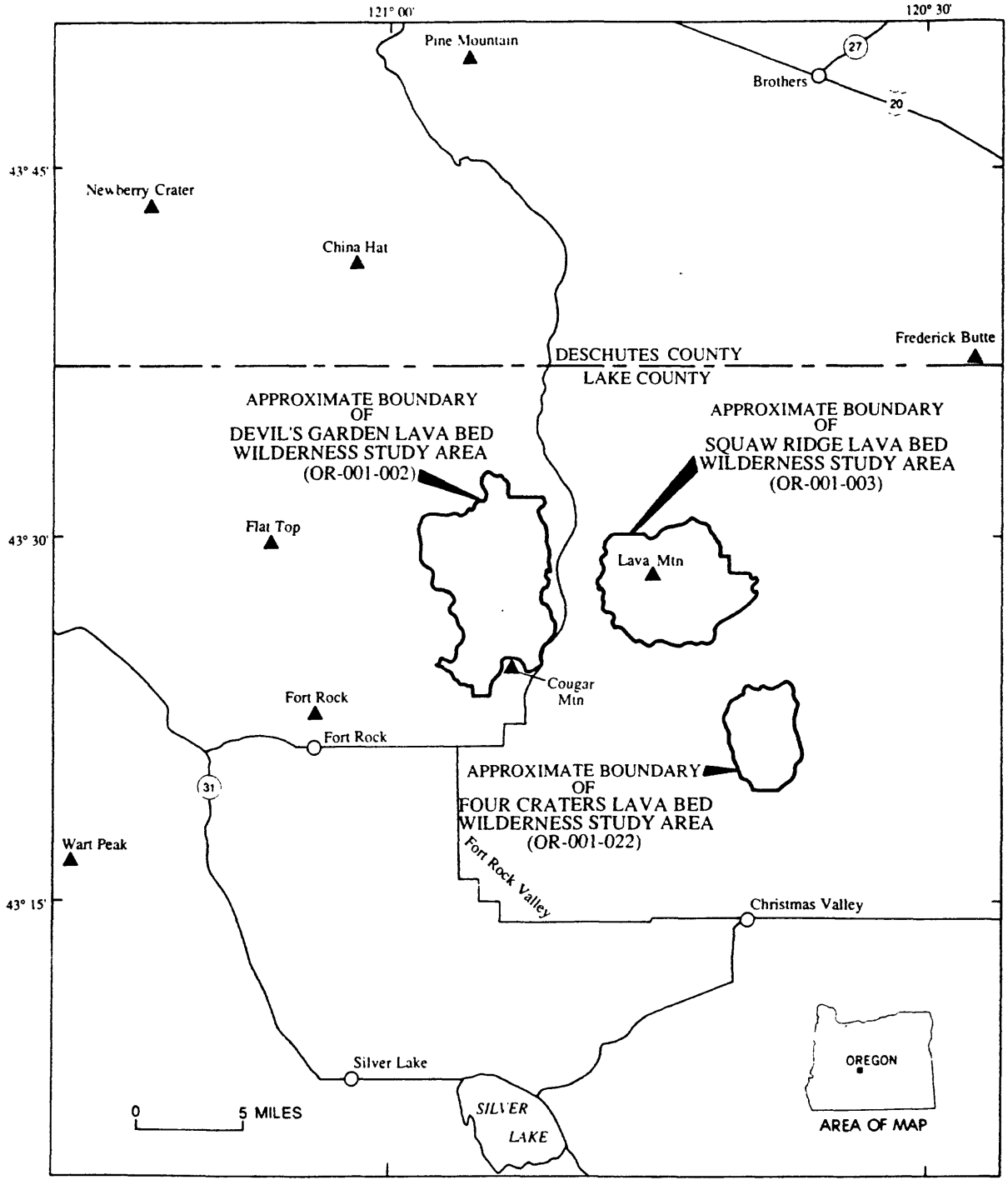

Figure 1. Index map showing location of the Devil's Garden Lava Bed, Squaw Ridge Lava Bed, and Four Craters Lava Bed Wilderness Study Areas, Lake County, Oregon.

Sample Collection

Rock samples were collected at 36 sites (pl. 1). Samples were collected from various types of occurrences in the vicinity of the plotted site location. Descriptions of rock samples are in table 4.

Samples were crushed and then pulverized to minus 0.15 mm with ceramic plates.

Sample Analysis

Spectrographic method

The rock samples were analyzed for 31 elements using semiquantitative, direct-current arc emission spectrographic methods. The analyses for rock samples were performed by analysts in the Branch of Exploration Geochemistry using the method of Grimes and Marranzino (1968). The elements analyzed and their lower limits of determination are listed in table 1. Spectrographic results were obtained by visual comparison of spectra derived from the sample against spectra obtained from standards made from pure oxides and carbonates. Standard concentrations are geometrically spaced over any given order of magnitude of concentration as follows: 100, 50, 20, 10, and so forth. Samples whose concentrations are estimated to fall between those values are assigned values of 70, 30, 15, and so forth. The precision of the analytical method is approximately plus or minus one reporting interval at the 83 percent confidence level and plus or minus two reporting intervals at the 96 percent confidence level (Motooka and Grimes, 1976). Values determined for the major elements, iron, magnesium, calcium, and titanium, are given in weight percent; all others are given in parts per million (micrograms/gram). Analytical data for samples from the Devil's Garden Lava Bed, Squaw Ridge Lava Bed, and Four Craters Lava Bed Wilderness Study Areas are listed in table 3.

Chemical methods

Other analytical methods used on samples from the Devil's Garden Lava Bed, Squaw Ridge Lava Bed, and Four Craters Lava Bed Wilderness Study Areas are summarized in table 2. The analytical method used for determining As, Bi, Cd, Sb, and Zn is a modification and adaptation for the inductively coupled plasma method (ICP) based on the method of O'Leary and Viets (1986).

DATA STORAGE SYSTEM

Upon completion of all analytical work, the analytical results were entered into a computer-based file called Rock Analysis Storage System (RASS). This data base contains both descriptive geological information and analytical data. Any or all of this information may be retrieved and converted to a binary form (STATPAC) for computerized statistical analysis or publication (VanTrump and Miesch, 1977).

DESCRIPTION OF DATA TABLES

Table 3 lists the results of analyses for the rock samples. For the table, the data are arranged so that column 1 contains the USGS-assigned sample numbers. These numbers correspond to the numbers shown on the site location map (plate 1). "DK" and "DG" indicate sample from Devil's Garden, "FK" and "FL" indicate sample from Four Craters, and "SK" and "SR" indicate

Squaw Ridge. Columns in which the element headings show the letter "s" below the element symbol are emission spectrographic analyses; "aa" indicates atomic absorption analyses; "icp" indicates inductively coupled plasma-atomic emission spectroscopy. A letter "N" in the tables indicates that a given element was looked for but not detected at the lower limit of determination shown for that element in table 1. For emission spectrographic analyses, a "less than" symbol (<) entered in the table in front of the lower limit of determination indicates that an element was observed but was below the lowest reporting value. For AA and ICP analyses, a "less than" symbol (<) entered in the table in front of the lower limit of determination indicates that an element was below the lowest reporting value. If an element was observed but was above the highest reporting value, a "greater than" symbol (>) was entered in the table in front of the upper limit of determination. If an element was not looked for in a sample, two dashes (--) are entered in the table in place of an analytical value. Because of the formatting used in the computer program that produced the table, some of the elements listed in the table (Fe, Mg, Ca, Ti, Ag, and Be) carry one or more nonsignificant digits to the right of the significant digits. The analysts did not determine these elements to the accuracy suggested by the extra zeros.

ACKNOWLEDGMENTS

A number of our colleagues also participated in the analyses of these samples: Paul Briggs, Kay Kennedy, F.W. Tippitt, P. Hageman, E. Welsch, T. McCollum, B. Anderson and C. Gent.

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TABLE 1.--Limits of determination for the spectrographic analysis of rocks based on a 10-mg sample

Elements	Lower determination limit	Upper determination limit
	Percent	
Iron (Fe)	0.05	20
Magnesium (Mg)	.02	10
Calcium (Ca)	.05	20
Titanium (Ti)	.002	1
	Parts per million	
Manganese (Mn)	10	5,000
Silver (Ag)	0.5	5,000
Arsenic (As)	200	10,000
Gold (Au)	10	500
Boron (B)	10	2,000
Barium (Ba)	20	5,000
Beryllium (Be)	1	1,000
Bismuth (Bi)	10	1,000
Cadmium (Cd)	20	500
Cobalt (Co)	5	2,000
Chromium (Cr)	10	5,000
Copper (Cu)	5	20,000
Lanthanum (La)	20	1,000
Molybdenum (Mo)	5	2,000
Niobium (Nb)	20	2,000
Nickel (Ni)	5	5,000
Lead (Pb)	10	20,000
Antimony (Sb)	100	10,000
Scandium (Sc)	5	100
Tin (Sn)	10	1,000
Strontium (Sr)	100	5,000
Vanadium (V)	10	10,000
Tungsten (W)	50	10,000
Yttrium (Y)	10	2,000
Zinc (Zn)	200	10,000
Zirconium (Zr)	10	1,000
Thorium (Th)	100	2,000

TABLE 2.--Chemical methods used

[AA = atomic absorption; ICP = inductively coupled plasma spectroscopy; S = spectrophotometry]

Element or constituent determined	Sample type	Method	Determination limit (micrograms/ gram or ppm)	Reference
Gold (Au)	Rocks	AA	.1	Modification of Thompson and others, 1968,
Mercury (Hg)	Rocks	AA	0.02	Koirtyohann and Khalil, 1976.
Arsenic (As)	Rocks and sediments	ICP	5	Crock and others, 1987.
Antimony (Sb)		ICP	2	
Zinc (Zn)		ICP	2	modification of O'Leary and Viets, 1986.
Bismuth (Bi)		ICP	2	
Cadmium (Cd)		ICP	0.1	

Table 3. Results of analyses of rock samples from the Devil's Garden Lava Bed, Squaw Ridge Lava Bed, and Four Craters Lava Bed Wilderness Study Areas, Lake County, Oregon

Sample	Latitude	Longitude	Fe-pct. s	Mg-pct. s	Ca-pct. s	Ti-pct. s	Mn-ppm s	Ag-ppm s	As-ppm s	Au-ppm s	B-ppm s	Ba-ppm s
86DK01	43 25 10	120 51 42	7.0	3.00	5.00	1.00	700	N	N	N	N	150
86DK02	43 29 10	120 51 13	5.0	1.50	3.00	1.00	700	N	N	N	<10	300
86DK03	43 30 40	120 51 40	7.0	3.00	5.00	1.00	700	N	N	N	N	150
86DK04	43 28 18	120 51 25	1.5	.15	.70	.30	300	N	N	N	30	500
86DK05	43 28 29	120 52 31	3.0	.50	1.00	.50	700	N	N	N	30	500
86DK06	43 28 18	120 53 30	10.0	3.00	5.00	1.00	700	N	N	N	N	150
86DK07	43 29 57	120 54 45	1.5	.07	.20	.07	200	N	N	N	30	500
86DK08	43 30 29	120 53 42	3.0	2.00	3.00	.70	700	N	N	N	N	150
86SK10	43 25 29	120 43 3	7.0	3.00	5.00	1.00	700	N	N	N	<10	200
86SK11	43 26 27	120 47 25	7.0	3.00	5.00	1.00	1,000	N	N	N	N	100
86SK12	43 26 17	120 47 27	2.0	.50	1.00	.50	500	N	N	N	20	700
86SK13	43 26 14	120 47 33	5.0	3.00	3.00	1.00	700	N	N	N	10	200
86DK15	43 28 16	120 51 38	3.0	.30	1.00	.30	300	N	N	N	50	500
86SK16	43 28 5	120 45 8	5.0	3.00	3.00	1.00	700	N	N	N	N	300
86FK17	43 20 50	120 39 37	7.0	3.00	5.00	1.00	700	N	N	N	10	200
86FK18	43 22 1	120 41 15	3.0	3.00	3.00	1.00	700	N	N	N	N	200
86FK20	43 22 32	120 37 48	5.0	3.00	5.00	1.00	1,000	N	N	N	N	150
86SK21	43 27 59	120 42 25	5.0	3.00	3.00	1.00	700	N	N	N	N	200
86DK22	43 25 5	120 53 20	1.0	.10	.30	.07	300	N	N	N	50	1,000
86FK23	43 22 23	120 38 3	5.0	3.00	5.00	1.00	1,000	N	N	N	N	200
86DK25	43 31 17	120 51 35	1.5	.07	.30	.10	300	N	N	N	30	1,000
86DK26	43 30 31	120 53 6	1.0	.05	.07	.07	150	N	N	N	30	300
86DK27	43 32 8	120 52 20	1.0	.05	.30	.07	150	N	N	N	50	300
86SK28	43 24 48	120 53 42	.7	.02	.20	.05	150	N	N	N	50	700
86DK29	43 26 58	120 49 43	5.0	3.00	3.00	.70	700	N	N	N	15	200
FL001JR	43 22 36	120 41 2	7.0	7.00	5.00	>1.00	1,000	N	N	N	<10	200
FL002SR	43 20 12	120 40 30	7.0	7.00	5.00	1.00	700	N	N	N	10	200
FL003JR	43 22 4	120 40 35	7.0	7.00	5.00	>1.00	700	N	N	N	<10	200
FL004SR	43 21 38	120 40 17	5.0	5.00	7.00	1.00	300	N	N	N	N	150
FL005JR	43 22 39	120 37 50	7.0	5.00	5.00	>1.00	1,000	N	N	N	<10	150
SR001JR	43 26 48	120 40 18	5.0	3.00	5.00	1.00	500	N	N	N	<10	200
SR003JR	43 30 1	120 47 28	7.0	7.00	5.00	>1.00	1,000	N	N	N	<10	150
DG003JR	43 24 10N	120 53 32	5.0	5.00	5.00	1.00	700	N	N	N	N	300
DG004SR	43 24 42	120 57 37	.3	.07	.70	.05	200	N	N	N	20	1,000
DG006SR	43 29 2	120 54 38	7.0	5.00	7.00	1.00	500	N	N	N	N	150
DG007JR	43 27 45	120 57 12	7.0	7.00	.70	>1.00	700	N	N	N	N	150

Table 3. Results of analyses of rock samples from the Devil's Garden Lava Bed, Squaw Ridge Lava Bed, and Four Craters Lava Bed Wilderness Study Areas, Lake County, Oregon--Continued

Sample	Be-ppm s	Bi-ppm s	Cd-ppm s	Co-ppm s	Cr-ppm s	Cu-ppm s	La-ppm s	Mo-ppm s	Nb-ppm s	Ni-ppm s	Pb-ppm s	Sb-ppm s	Sc-ppm s	Sn-ppm s
86DK01	N	N	N	70	300	70	N	N	<20	150	10	N	30	N
86DK02	<1.0	N	N	50	10	30	N	N	<20	5	<10	N	20	N
86DK03	N	N	N	70	300	50	N	N	<20	200	<10	N	30	N
86DK04	2.0	N	N	<5	10	20	20	N	N	<5	15	N	7	N
86DK05	1.5	N	N	<5	15	7	20	N	<20	<5	20	N	10	N
86DK06	N	N	N	70	500	70	<20	N	<20	150	<10	N	50	N
86DK07	1.5	N	N	N	<10	10	<20	N	N	<5	70	N	5	N
86DK08	<1.0	N	N	50	100	50	N	N	N	100	<10	N	20	N
86SK10	N	N	N	70	200	50	N	N	<20	150	10	N	30	N
86SK11	N	N	N	70	150	70	N	N	N	150	<10	N	30	N
86SK12	1.5	N	N	7	10	7	20	N	N	<5	20	N	7	N
86SK13	N	N	N	70	150	50	N	N	<20	100	10	N	30	N
86DK15	1.5	N	N	7	<10	15	20	N	<20	5	20	N	7	N
86SK16	N	N	N	70	200	70	N	N	N	100	<10	N	20	N
86FK17	<1.0	N	N	70	300	70	N	N	<20	150	10	N	30	N
86FK18	N	N	N	70	200	50	N	N	<20	100	<10	N	30	N
86FK20	N	N	N	70	100	50	N	N	N	70	<10	N	30	N
86SK21	N	N	N	50	200	70	N	N	N	70	10	N	30	N
86DK22	2.0	N	N	N	N	7	20	N	N	<5	30	N	5	N
86FK23	N	N	N	70	200	50	N	N	N	100	10	N	30	N
86DK25	2.0	N	N	N	N	10	20	N	N	<5	15	N	5	N
86DK26	2.0	N	N	N	<10	7	20	N	<20	<5	20	N	<5	N
86DK27	3.0	N	N	N	N	10	20	N	<20	5	30	N	<5	N
86SK28	2.0	N	N	N	N	7	<20	N	N	<5	20	N	<5	N
86DK29	N	N	N	70	300	50	N	N	N	150	10	N	20	N
FL001JR	<1.0	N	N	30	300	70	N	<5	<20	100	<10	N	30	N
FL002SR	<1.0	N	N	30	500	70	N	<5	N	100	<10	N	30	N
FL003JR	<1.0	N	N	30	300	50	N	<5	<20	100	<10	N	30	N
FL004SR	<1.0	N	N	20	100	100	N	<5	N	70	<10	N	20	N
FL005JR	<1.0	N	N	50	100	100	N	<5	N	100	<10	N	30	N
SR001JR	<1.0	N	N	30	200	50	N	<5	N	100	<10	N	20	N
SR003JR	<1.0	N	N	50	500	50	N	5	N	150	<10	N	20	N
DG003JR	<1.0	N	N	30	150	100	N	<5	N	50	<10	N	20	N
DG004SR	1.0	N	N	<10	10	5	N	<5	N	5	30	N	5	N
DG006SR	<1.0	N	N	30	300	70	N	<5	N	150	N	N	30	N
DG007JR	<1.0	N	N	30	300	100	N	<5	N	100	N	N	30	N

Table 3. Results of analyses of rock samples from the Devil's Garden Lava Bed, Squaw Ridge Lava Bed, and Four Craters Lava Bed Wilderness Study Areas, Lake County, Oregon--Continued

Sample	Sr-ppm s	V-ppm s	W-ppm s	Y-ppm s	Zn-ppm s	Zr-ppm s	Th-ppm s	Au-ppm aa	Hg-ppm aa	As-ppm icp	Bi-ppm icp	Cd-ppm icp	Sb-ppm icp	Zn-ppm icp
86DK01	300	150	N	30	N	150	N	--	--	<5	<2	.4	5	42
86DK02	300	150	N	30	N	150	N	--	--	<5	<2	.6	<2	65
86DK03	300	150	N	30	N	150	N	--	--	<5	3	.3	<2	40
86DK04	200	30	N	30	N	200	N	--	--	<5	<2	<.1	<2	45
86DK05	200	20	N	50	N	200	N	--	--	<5	<2	.2	<2	41
86DK06	300	150	N	30	N	100	N	--	--	<5	<2	.4	4	37
86DK07	N	<10	N	30	N	150	N	--	--	<5	<2	<.1	<2	56
86DK08	300	150	N	20	N	50	N	--	--	<5	<2	.8	3	63
86SK10	300	150	N	30	N	150	N	--	--	<5	<2	.5	<2	45
86SK11	300	200	N	30	N	30	N	--	--	<5	2	.7	<2	63
86SK12	200	30	N	30	N	150	N	--	--	<5	<2	.2	<2	46
86SK13	500	150	N	30	N	150	N	--	--	<5	<2	.3	<2	40
86DK15	200	30	N	50	N	300	N	--	--	<5	<2	.1	<2	43
86SK16	300	150	N	30	N	150	N	--	--	<5	<2	.3	<2	35
86FK17	500	150	N	30	N	150	N	--	--	<5	<2	.5	<2	46
86FK18	300	150	N	30	N	150	N	--	--	<5	<2	.5	4	47
86FK20	200	200	N	30	N	150	N	--	--	<5	<2	.6	<2	44
86SK21	500	150	N	30	N	150	N	--	--	<5	<2	.2	<2	21
86DK22	N	10	N	50	N	150	N	--	--	<5	<2	<.1	<2	6
86FK23	500	200	N	30	N	150	N	--	--	<5	<2	.5	<2	46
86DK25	<100	<10	N	70	N	300	N	--	--	<5	<2	.2	<2	84
86DK26	N	<10	N	30	N	150	N	--	--	<5	<2	<.1	<2	47
86DK27	N	<10	N	50	N	150	N	--	--	<5	<2	<.1	<2	52
86SK28	N	<10	N	30	N	100	N	--	--	<5	<2	<.1	<2	34
86DK29	300	150	N	30	N	150	N	--	--	<5	<2	.2	<2	28
FL001JR	500	150	N	30	<200	100	N	N	.04	<5	2	<.1	<2	33
FL002SR	500	100	N	20	<200	50	N	N	.02	<5	<2	<.1	<2	32
FL003JR	300	150	N	30	<200	100	N	N	.02	<5	3	<.1	<2	23
FL004SR	200	70	N	20	<200	100	N	N	.02	<5	2	<.1	<2	43
FL005JR	200	200	N	30	<200	100	N	N	.04	<5	2	<.1	<2	34
SR001JR	300	100	N	20	<200	100	N	N	.02	<5	<2	.3	<2	37
SR003JR	300	150	N	30	<200	70	N	N	.02	<5	<2	.3	<2	39
DG003JR	500	150	N	20	<200	100	N	N	.02	<5	<2	.2	<2	26
DG004SR	100	<10	N	50	<200	100	N	N	.02	<5	<2	<.1	<2	38
DG006SR	150	150	N	30	<200	70	N	N	.02	<5	<2	.2	<2	40
DG007JR	200	150	N	30	<200	70	N	N	.02	<5	<2	.3	<2	32

Table 4. Description of rock samples

Rock types from Devils Garden, Squaw Ridge, and Four Craters Lava Beds

86	DK01	basalt
	DK02	basalt
	DK03	basalt
	DK04	rhyolite
	DK05	basalt
	DK06	basalt
	DK07	rhyolite
	DK08	basalt
	SK10	basalt
	SK11	basalt
	SK12	basalt
	SK13	basalt
	DK15	rhyolite
	SK16	basalt
	FK17	basalt
	FK18	basalt
	FK20	basalt
	SK21	basalt
	DK22	rhyolite
	FK23	basalt
	DK25	rhyolite
	DK26	rhyolite
	DK27	rhyolite
	DK28	rhyolite
	DK29	basalt
	FL001JR	basalt
	FL002SR	basalt
	FL003JR	basalt
	FL004SR	basalt
	FL005JR	basalt
	SR001JR	basalt
	SRPP3JR	basalt
	DG003JR	rhyolite
	DG004SR	basalt
	DG006SR	basalt
	DG007JR	basalt