Selenium Content of Some Volcanic Rocks From Western United States and Hawaiian Islands

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Selenium Content of Some Volcanic Rocks From Western United States and Hawaiian Islands

By D. F. DAVIDSON, *and* H. A. POWERS

CONTRIBUTIONS TO GEOCHEMISTRY

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Geology and geochemistry of selenium based on analysis of volcanic rocks from selected localities

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SELENIUM CONTENT OF SOME VOLCANIC ROCKS FROM WESTERN UNITED STATES AND HAWAIIAN ISLANDS

By D. F. Davidson, and H. A. Powers

ABSTRACT

Eighty-one analyses for selenium of volcanic rocks from southern Alaska, the Aleutian Islands, the Hawaiian Islands, and several Western States have been made as a part of a study of the geology and geochemistry of selenium.

Of 15 samples from southern Alaska and the Aleutian Islands, none contained more than 1 ppm (part per million) selenium; of 15 samples from the Hawaiian Islands, only 1, a crystal tuff, contained 3 ppm selenium, the others contained less than 2 ppm selenium. Of 52 samples from California, Colorado, Idaho, New Mexico, and Wyoming, only 6 contained 1 or more ppm selenium. Four of these were trachyte tuffs from Wyoming. The most seleniferous of these samples contained 40 ppm selenium, although analyses of this material have been reported as high as 500 ppm.

All seleniferous samples were of volcanic ash or rocks derived from volcanic ash. The writers suggest that crystalline volcanic rocks have lost, during crystallization, the selenium contained in the magma from which they are derived. Some noncrystalline volcanic rocks (for the most part ash) have retained at least a part of the selenium.

INTRODUCTION

The products of volcanism have long been presumed sources of selenium found in geologically younger materials. This is, at least in part, a result of studies of the selenium content of volcanic gases and volcanic sulfur (Byers, Miller, Williams, and Lakin, 1938, p. 51–55). These investigations demonstrated that selenium is unquestionably a product of some volcanism; although it is not known whether there is any marked difference in the selenium content of the volatile products from different eruptions of the same volcano, or in similar products from different volcanos.

New information of the selenium content of some samples of volcanic rocks from the Hawaiian Islands and several Western States is presented here. These data have been collected as a part of a continuing study by the U.S. Geological Survey of the geology and geochemistry of selenium.

Most of the samples whose selenium analyses are presented were collected by H. A. Powers in his studies of volcanism for the Geological Survey; the remainder were collected by other members of the Geological Survey.

The samples analyzed for selenium were selected from the large number available to give as much of a stratigraphic and geographic spread as possible, and to represent all major chemical categories of extrusive rocks. Flow rocks, ash, and rocks derived from ash are included. Where possible, selenium analyses were made of samples of rocks already identified by complete rock analyses; however, the rock names of many samples are based on field identification.

Selenium analyses of samples were made by personnel of the U.S. Geological Survey. Two analytical methods for determination of selenium were employed: the field and the laboratory methods.

The laboratory method is that used for the determination of selenium in foods and is described in "Official Methods of Analysis of the Association of Official Agricultural Chemists" (Lepper and others, 1950). The field method is identical except that for the final step of the laboratory method, a visual estimation of selenium content as described by Franke, Burris, and Hulton (1936, p. 435) has been substituted. Results provided by the laboratory method are considered to be correct within an error of ± 10 percent of the reported value; those provided by the field method within an error of ± 35 percent (H. W. Lakin, oral communication, 1957).

PREVIOUS WORK

During the 1930's, considerable work was done, principally by chemists and soil scientists of the U.S. Department of Agriculture, and several State organizations of the Rocky Mountain region, on the occurrence of selenium in plants and soils, and the rocks from which seleniferous soils have been derived. A few analyses of samples of volcanic rocks are given in publications which resulted from this work. Most of these analyses, together with descriptions of the materials constituting the samples, and the publications in which the analyses were presented are listed in table 1.

The work by the U.S. Department of Agriculture and the State organizations of the Rocky Mountain region indicated that many geologic formations are at least locally seleniferous. Igneous rocks considered highly seleniferous are without exception of volcanic origin, and many seleniferous sedimentary formations probably have received large contributions of the products of volcanism, either ash, dust, or gas, or detritus derived from the breaking down of preexisting seleniferous volcanic rocks. The Cretaceous Pierre and Niobrara formations, both seleniferous, were studied in great detail,

TABLE 1.—*Selenium content of samples of volcanic rocks reported in geologic literature*

Sample locality	Rock type	Geologic formation	Age	Selenium content (ppm)	Reference
Colorado:					
Delta County	Bentonite	Mancos shale	Cretaceous	0.8	Byers (1936, p. 21).
Fremont County	do	Pierre shale	do	3	Byers, Miller, Williams, and Lakin (1938, p. 22).
Pueblo County	Bentonite and gypsum.	Greenhorn limestone.	do	1	Byers, Miller, Williams, and Lakin (1938, p. 40).
Do	Bentonite	do	do	.3	Do.
Do	do	do	do	3	Do.
Idaho:					
Hammett, Elmore County.	Lava	Unidentified	(?)	.6	Lakin and Byers (1948, p. 24).
Bliss, Gooding County.	do	do	(?)	.05	Do.
Mexico:					
Texcoco	Ash	do	(?)	.1	Williams, Lakin, and Byers (1940, p. 40).
Toluca	do	do	(?)	.1	Do.
Do	do	do	(?)	.1	Do.
Do	do	do	(?)	.1	Do.
Coahuila	Tuff	"Caracol"	(?)	.1	Williams, Lakin, and Byers (1940, p. 43).
Durango	Tuff and breccia.	Unidentified	Tertiary	.1	Do.
Do	Breccia	do	(?)	.2	Do.
Montana:					
Teton County	Bentonite	do	(?)	3	Williams, Lakin, and Byers (1941, p. 58).
Do	do	do	(?)	2.5	Do.
Nebraska:					
Boyd County	Bentonite and gypsum.	Pierre shale	Cretaceous	22	Byers (1935, p. 8).
Do	Bentonite	do	do	9	Do.
Do	do	do	do	76	Do.
Do	do	do	do	26	Do.
Dawes County	do	do	do	10	Byers (1936, p. 6).
North Dakota:					
Cavalier County	do	do	do	1.6	Lakin and Byers (1948, p. 5).
South Dakota:					
Custer County	do	do	do	2	Byers (1936, p. 9).
Do	do	do	do	5	Do.
Do	do	do	do	2	Do.
Utah:					
Juab County	Lava	Unidentified	(?)	.2	Lakin and Byers (1948, p. 21).
Wyoming:					
Albany County	Ash	do	Oligocene	0	Trelease and Beath (1949, p. 101).
Laramie Mountains	Pumice	(?)	(?)	.61	Beath, Hagner, and Gilbert (1946).
Sweetwater County	"Leucite rock."	Unidentified	(?)	.1	Trelease and Beath (1949, p. 100).
Cokeville, Lincoln County.	Bentonite	Bear River	Cretaceous	5.0	Trelease and Beath (1949, p. 99).
Lysite, Fremont County.	Tuff	Tepee Trail	Eocene	5–227	Trelease and Beath (1949, p. 100).

and two views as to the source of the selenium in these sedimentary formations were advanced.

Beath and others (1935) and Trelease and Beath (1949, p. 95) suggest that the selenium contained in these formations was a "primary constituent of the magmas that were introduced into or poured out upon the old Central Cordilleran land mass from which the Cretaceous rocks were derived." These authors suggest further that "Erosion of the extrusive selenium-bearing igneous rocks produced by volcanism and subsequent deposition in the Cretaceous seas could account for the primary occurrence of selenium in sedimentary rocks of Cretaceous age."

Byers and others (1936, p. 821–823; 1938, p. 61) believe, on the other hand, that the Pierre and Niobrara formations may have acquired their selenium content from gaseous emanations and dust which accompanied volcanic activity. These authors presume that rainfall would bring these volcanic products into the Cretaceous seas, and believe that the rocks from which the Pierre and Niobrara sediments were derived probably did not contain selenium in sufficient quantities to account for the concentrations of selenium in these two formations.

A trachytic crystal tuff of middle to late Eocene age (Tourtelot and others, 1946) exposed near Lysite, Wyo., has been much studied because of its high selenium content. Beath, Hagner, and Gilbert (1946, p. 6–13) sampled and described rock from this formation and report that selenium content ranges from about 5 to 227 ppm. More recently the U.S. Bureau of Mines investigated this material as a potential source of selenium and reported that the selenium content of more than 600 samples ranged from less than 40 to 500 ppm (Everett and Bauerle, 1957).

RESULTS OF ANALYSES OF VOLCANIC ROCKS FOR SELENIUM

In tables 2–4, 82 analyses for selenium in volcanic rocks are presented. Sample data have been grouped geographically: those from southern Alaska are presented in table 2; those from the Hawaiian Islands in table 3; and those from California, Colorado, Idaho, New Mexico, and Wyoming in table 4.

ALASKAN VOLCANIC ROCKS

Of 15 samples from southern Alaska, ranging in age from Tertiary to Recent, none contained more than 1 ppm selenium (table 2). Of the 15 samples 2 were of ash, and 13 of flow rocks (5 vitrophyre and 8 crystalline). The rocks sampled were, as a whole, of mafic types. The geographic localities from which the samples came are shown on figure 9.

HAWAIIAN VOLCANIC ROCKS

Selenium analyses of 15 samples of volcanic rock from the Hawaiian Islands are presented in table 3. These samples of mafic volcanic rocks range in age from Tertiary to Recent, and all but one contained less than 2 ppm selenium. A crystal tuff of the upper Tertiary(?) Kula volcanic series, contained 3 ppm; the selenium was apparently contained in the noncrystalline part of the tuff, for a sample consisting of augite and olivine crystals separated from the tuff, contained less than 2 ppm selenium. The localities at which the samples from the Hawaiian Islands were collected are shown on figure 10.

TABLE 2.—*Selenium content of samples of some volcanic rocks from southern Alaska*

Sample locality	No. on fig. 9	Rock type [1]	Age	Selenium content [2] (ppm)	Field sample	Laboratory sample
Alaska:						
Valley of Ten Thousand Smokes.	1	Pumice, white, eruption 1912.	Recent	<1	52-Wilcox-17.	55-3516
Aleutian Islands:						
Amchitka	2	Andesite, hornblende augite.	Tertiary	<1	49-Am-46	55-3511
	2	Glass breccia, zeolitic	do	<1	51-P-27	55-3512
Attu	3	Tuff, basaltic	do	<1	50-P-245	55-3501
	3	Quartz keratophyre	do	<1	50-P-280	55-3502
	3	Basalt	do	<1	50-P-293	55-3503
Little Sitkin	4	Rhyodacite	Recent	<1	Sn-155-51	55-3507
	4	Dacite	do	<1	Sn-111-51	55-3508
	4	do	do	<1	Sn-111A-51	55-3509
	4	Andesite, pigeonite-labradorite.	do	<1	Sn-208-51	55-3500
	4	Andesite, labradorite	do	<1	Sn-338-51	55-3504
	4	Andesite, pigeonite-labradorite.	Pliocene(?)	<1	Sn-364-51	55-3505
	4	Dacite	Recent	<1	Sn-324-51	55-3506
Segula	5	Andesite, pyroxene	do	<1	51-N-28	55-3514
	5	Basalt, olivine	do	<1	51-N-29	55-3515

[1] Complete rock analyses by L. Kehl, E. J. Tomasi, S. M. Berthold, H. F. Phillips, R. H. Stokes, E. E. Engleman, and H. M. Hyman.
[2] Laboratory method analyses by W. A. Bowles.

TABLE 3.—*Selenium content of samples of some volcanic rocks from the Hawaiian Islands*

Sample locality	No. on fig. 10	Rock type	Geologic formation	Age	Selenium content [1] (ppm)	Field sample	Laboratory sample
Maui	1	Basalt, picrite, augite-olivine.[2]	Kula volcanic series.	Tertiary(?)	<2	53-P-18	55-3566
	1	Tuff, crystal	do	do	3	6-HAP	55-2567
	1	Augite and olivine crystals from tuff, crystal above.	do	do	<2	6a-HAP	55-3569
	1	Andesite [2]	do	do	<2	1-HAP	55-2571
Hawaii	2	Basalt, 1801 flow [2]	Hualalai volcanic series.	Pleistocene and Recent.	<2	53-P-19	55-3504
	3	Basalt, olivine, 1950 flow.[2]	Kau volcanic series.	Pleistocene(?) and Recent.	<2	53-P-396	55-3563
	3	Basalt, 1940 eruption.[2]	do	do	<2	4-HAP	55-3570
	4	Basalt, glass skin, 1919 flow.	Puna volcanic series.	do	<2	53-W-1	55-3574
	4	Basalt, glass skin, 1919 flow.	do	do	<2	53-W-18	55-3576
	4	Basalt, crystalline core, 1919 flow.[2]	do	do	<2	53-W-1A	55-3575
	4	Basalt, crystalline core, 1919 flow.	do	do	<2	53-W-1C	55-3577
	4	Pumice, 1952 eruption.[2]	do	do	<2	1952-A	55-3565
	5	Andesite, oligoclase.[2]	Hawi volcanic series.	Pleistocene	<2	3-HAP	55-3573
Oahu	6	Basalt, nepheline.[2]	Honolulu volcanic series.	Pleistocene and Recent.	<2	2-HAP	55-3572
Kauai	7	Basalt, olivine [2]	Waimea Canyon volcanic series.	Pliocene(?)	<2	5-HAP	55-3568

[1] Field method analyses by H. E. Crowe.
[2] Complete rock analyses by F. A. Gonyer, H. S. Washington, L. Trumbull, L. N. Tarrant, George Steiger, and F. H. Neuerburg.

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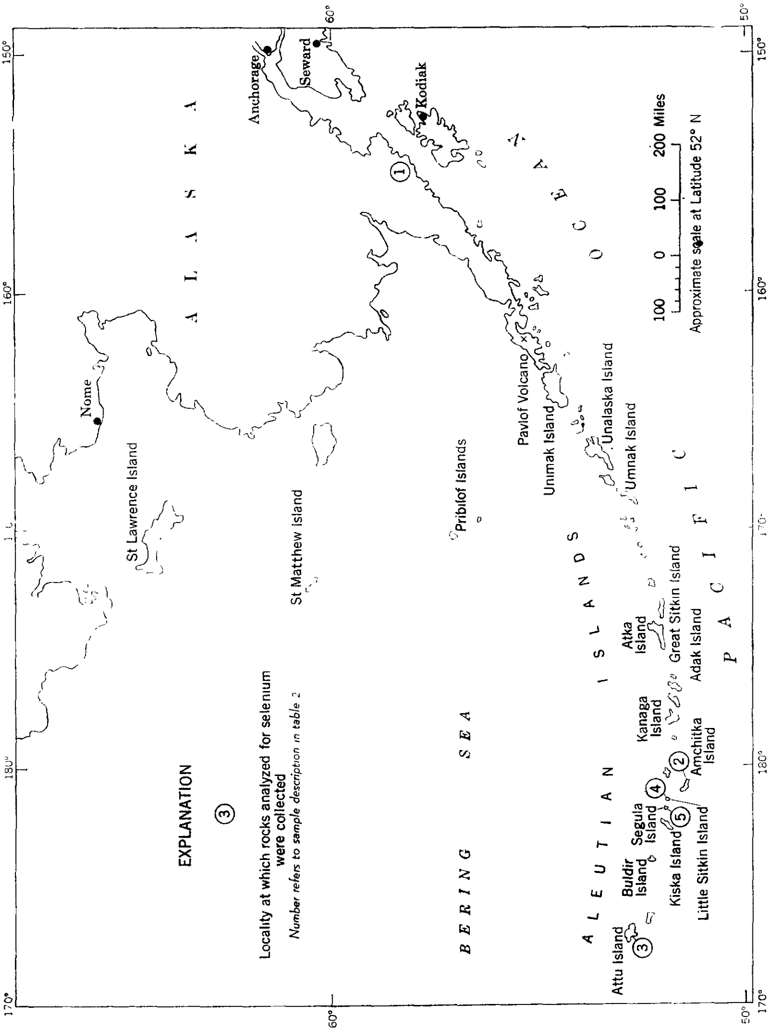

FIGURE 9.—Map of part of southern Alaska and the Aleutian Islands showing localities where volcanic rocks were sampled.

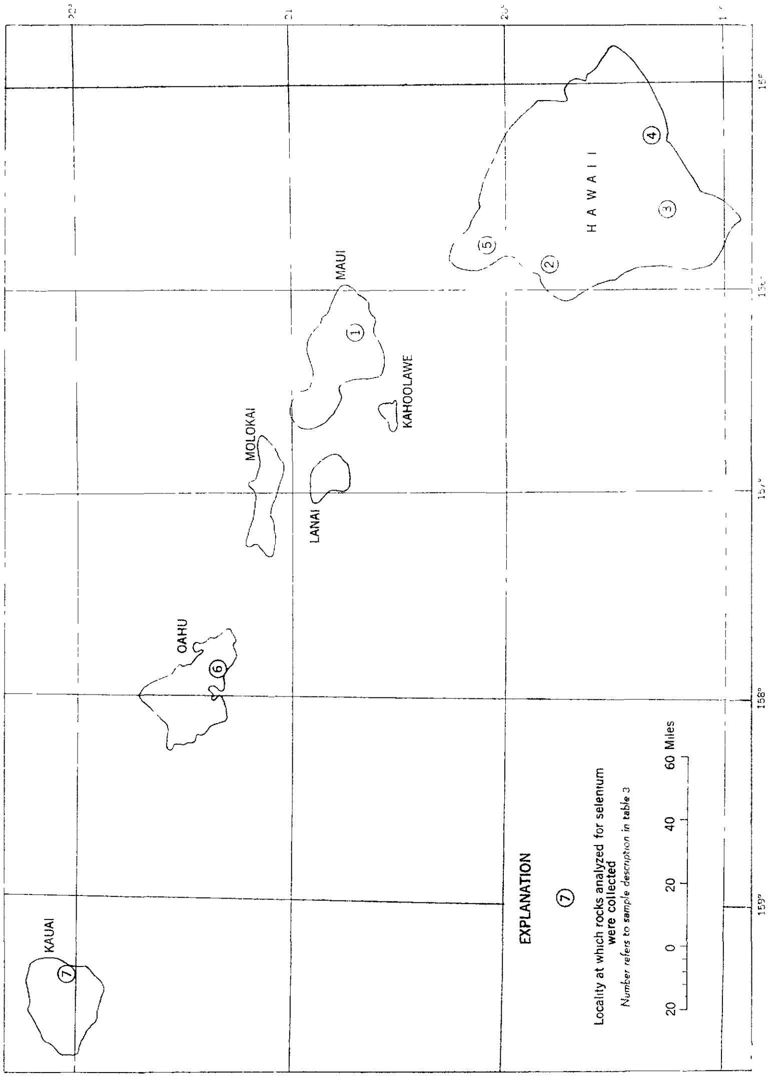

FIGURE 10.—Map of Hawaiian Islands showing localities where volcanic rocks were sampled.

VOLCANIC ROCKS FROM CALIFORNIA, COLORADO, IDAHO, NEW MEXICO, AND WYOMING

Selenium analyses of 52 samples of mafic to silicic volcanic rocks from several Western States are presented in table 4. The rocks sampled range in age from early Tertiary to Recent. Of the 52 samples 23 were of ash, and rocks composed of ash, and 29 were of flow rocks (7 vitrophyre and 22 crystalline). Localities at which the samples were collected are shown on figure 11. Of the 52 samples 6 contained

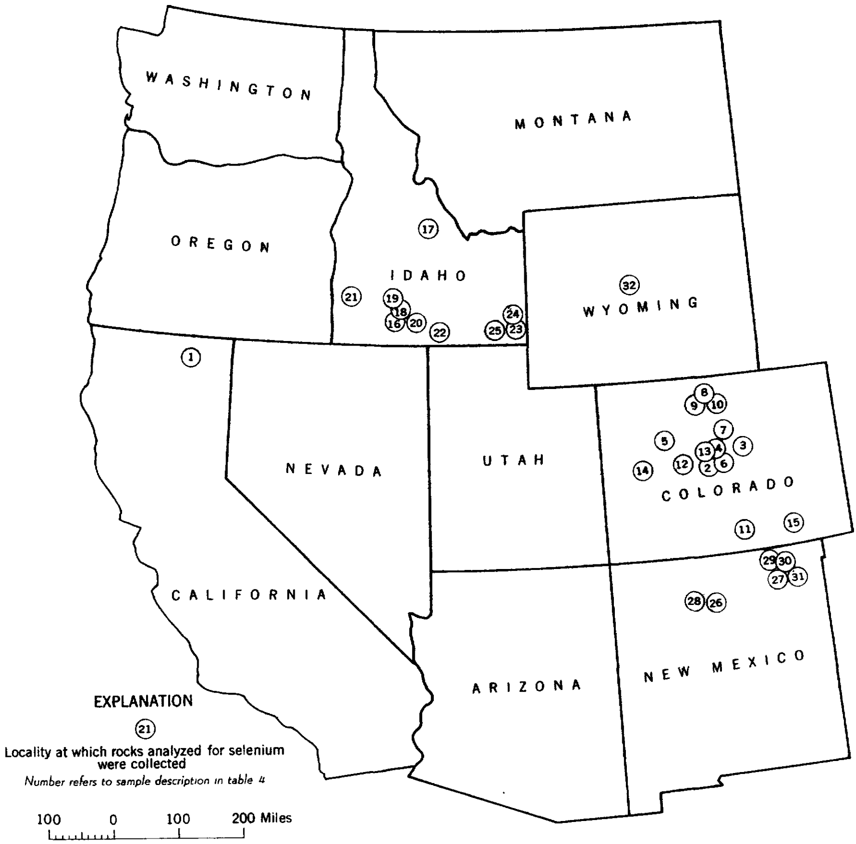

FIGURE 11.—Map of the Western United States except Alaska, showing localities where volcanic rocks were sampled.

1 or more ppm. selenium; 1 of them contained 40 ppm. Of the 6 seleniferous samples 5 were composed of volcanic ash and 1 was welded tuff. All seleniferous ash samples were of silicic type, as was the 1 sample of welded tuff.

TABLE 4.—*Selenium content of samples of some volcanic rocks from California, Colorado, Idaho, New Mexico, and Wyoming*

Sample locality	No. on fig. 11	Rock type	Geologic formation	Age	Selenium content (ppm)	Field sample	Laboratory sample
California:							
Medicine Lake	1	Dacite	(1)	Recent	[2] <1	52-P-124	55-3551
Little Glass Mountain.	1	Pumice, rhyolite.	(1)	do	[2] <1	52-P-123	55-3552
Colorado:							
Antero Reservoir, Park County.	2	Trachyte, brown phase.	Antero formation as used by Stark and others (1949).	Oligocene	[2] 5	52-P-106	55-3517
Do	2	Trachyte, green phase.	do	do	[2] <1	52-P-107	55-3518
Castle Rock, Douglas County.	3	Tuff, rhyolite	Dawson arkose	Late Cretaceous and Paleocene.	[2] <1	52-P-84	55-3519
Do	3	Tuff, rhyolite, silicified.	do	do	[2] <1	52-P-86	55-3520
Tarryall Creek Narrows, South Park, Park County.	4	Andesite porphyry.	Basin Ridge group of Stark and others (1949).	Tertiary	[2] <1	52-P-91	55-3521
Eagle River, Dotsero, Eagle County.	5	Basalt	(1)	Recent	[2] <1	52-P-152	55-3522
Basin Ridge, South Park, Park County.	6	Rhyolite	Basin rhyolite of Stark and others (1949).	Tertiary	[2] <1	52-P-100	55-3523
North Table Mountain, Golden, Jefferson County.	7	Basalt	Denver formation.	Late Cretaceous and Paleocene.	[2] <1	52-P-81	55-3524
Cameron Pass, North Park, Larimer County.	8	Tuff, rhyolite	(1)	Tertiary	[2] <1	53-P-44	55-3525
North Park, Jackson County.	9	Dacite porphyry(?)	(1)	do	[2] <1	53-P-40	55-3526
Specimen Mountain, Rocky Mountain National Park, Park County.	10	Quartz latite	(1)	do	[2] <1	52-P-119	55-3527
Fort Garland, Costilla County.	11	Basalt	Los Pinos gravel	Miocene and Pliocene(?)	[2] <1	52-P-77	55-3528
Twin Lakes, Lake County.	12	Rhyolite	Red Mountain rhyolite of Howell (1919).	Tertiary	[2] <1	52-P-112	55-3529
Do	12	Tuff, rhyolite	Grizzly Peak rhyolite of Howell (1919).	do	[2] <1	52-P-111	55-3532
East Hall Butte, Buffalo Peaks, South Park, Park County.	13	Andesite	Buffalo Peaks andesite as used by Stark and others (1949).	do	[2] <1	52-P-101	55-3531
Grand Mesa, Delta County.	14	Basalt	(1)	do	[2] <1	54-P-151	55-3533
Carrizo Mesa, Las Animas County.	15	do	Raton basalts as used by Collins, 1949.	Quaternary	[2] <1	54-P-163	55-3534
Idaho:							
Deep Creek Canyon, Twin Falls County.	16	do.[3]	Snake River basalt.	Pliocene to Recent.	[4] <1	54-P-23	55-3535
Twin Falls, Twin Falls County.	16	Quartz latite [3]	Shoshone Falls andesite.	Miocene(?)	[4] <1	53-P-85	55-3545
Challis, Custer County.	17	Tuff, rhyolite, welded.[3]	Challis volcanics, Yankee Fork rhyolite member.	Tertiary	[4] <1	53-P-73	55-3536
Do	17	Tuff, rhyolite	do	do	[4] <1	53-P-72	55-3542
Mill Creek, Northwest of Challis, Custer County.	17	Rhyolite	do	do	[4] <1	53-P-77	55-3543

See footnotes at end of table.

TABLE 4.—*Selenium content of samples of some volcanic rocks from California, Colorado, Idaho, New Mexico, and Wyoming*—Continued

Sample locality	No. on fig. 11	Rock type	Geologic formation	Age	Selenium content (ppm)	Field sample	Laboratory sample
Idaho—Continued							
Bliss quadrangle, Twin Falls County.	18	Basalt [3]	Banbury volcanics.	Late Pliocene.	[4] <1	54-P-3	55-3538
Thousand Springs quadrangle, Twin Falls County.	18	do.[3]	do	do	[4] <1	54-P-5	55-3537
Bliss quadrangle, Gooding County.	18	do.[3]	Bliss basalt	Pleistocene	[4] <1	55-P-95	55-3540
Do	19	Basalt, olivine.[3]	Madson basalt	do	[4] <1	54-P-61	55-3539
Twin Falls, Jerome County.	20	Basalt	Sand Springs basalt.	do	[4] <1	55-P-5	55-3541
Oreana quadrangle, Owyhee County.	21	Rhyolite	"Old Rhyolite" of Schrader (1923).	Middle Tertiary.	[4] <1	55-P-299	55-3544
Goose Creek, Cassia County.	22	Ash, siliceous [3]	Payette formation.	Miocene and Pliocene(?)	[4] <1	55-P-216	55-3547
Sulfur Canyon, Caribou County.	23	Tuff	Salt Lake formation.	Tertiary	[5] 1	D-51-57	256121
Vicinity China Hat, Caribou County.	24	Basalt	([1])	Pleistocene	[5] 0.5	D-53-57	256123
Oneida Narrows, Franklin County.	25	Tuff	Salt Lake formation.	Tertiary	[5] 0.5	D-55-57	256125
New Mexico:							
12 miles southwest of Espanola.	26	Basalt, olivine.	([1])	do	[2] <1	52-P-14	55-3530
Chico, Colfax County.	27	Trachyte	Slagle trachytes as used by Collins (1949).	Quaternary	[2] <1	54-P-165	55-3553
Do	27	Phonolite	([1])	Tertiary	[2] <1	54-P-167	55-3558
Bear Springs Canyon, Sandoval County.	28	Rhyolite	([1])	do	[2] <1	52-P-30	55-3554
Do	28	Tuff, welded, quartz-latite.	Bandelier rhyolite tuff of Smith (1938).	Quaternary	[2] <1	52-P-15	55-3555
Vicinity Los Alamos, Sandoval County.	28	Pumice, quartz-latite [3]	([1])	Recent	[2] <1	52-P-17	55-2556
Do	28	Tuff, welded, quartz-latite.	([1])	Late Pleistocene or Recent.	[2] <1	52-P-23	55-3557
Raton, Colfax County.	29	Basalt	Raton basalts as used by Collins. (1949)	Quaternary	[2] <1	54-P-170	55-3559
Do	30	Basalt, quartz-nepheline.	Yankee volcano of Clayton basalts as used by Collins (1949).	do	[2] <1	53-P-90	55-3560
Do	30	Dacite, hornblende.	([1])	Tertiary	[2] <1	53-P-94	55-3562
Capulin, Union County.	31	Basalt, porphyritic.	([1])	Recent	[2] <1	54-P-153	55-3561
Wyoming:							
Vicinity Lysite, Fremont County.	32	Tuff, trachyte	Tepee Trail	Middle(?) and late Eocene.	[6] <2	T-Se-18	55-3016
Do	32	do	do	do	[6] 5	T-Se-14a	55-3012
Do	32	do	do	do	[6] <2	T-Se-18a	55-3017
Do	32	do	do	do	[6] <2	T-Se-19	55-3018
Do	32	do	do	do	[6] 40	T-Se-15	55-3013
Do	32	do	do	do	[6] 7	T-Se-16	55-3014
Do	32	do	do	do	[6] 5	T-Se-17	55-3015

[1] No recognized formation name.
[2] Field method analysis by W. R. Weston.
[3] Complete rock analysis by L. N. Tarrant and L. Trumbull.
[4] Field method analysis by H. E. Crowe, and W. A. Bowles.
[5] Laboratory method analysis by G. T. Burrow.
[6] Field method analysis by H. E. Crowe and C. E. Thompson.

MODE OF OCCURRENCE OF SELENIUM IN VOLCANIC ROCKS

The mode of occurrence of selenium in volcanic rocks is little known, partly because the level of selenium content in these materials is very low, as shown by the analytical data presented in this report.

Some information is available of the mode of occurrence of selenium in one atypical volcanic deposit, a water-laid ash, called the "Lysite tuff." The tuff properly called the "Green and Brown member of the Tepee Trail formation" is of Eocene age and is well exposed near Lysite, Wyo. (Tourtelot, 1957).

Unlike the selenium contained in most volcanic rocks the selenium in Lysite tuff is readily removed by water. For example, Beath, Hagner, and Gilbert (1946, p. 11) state that in 3 samples of tuff, 84 percent, 96 percent, and 87 percent of the total selenium was water soluble, and most of the selenium was in the selenate state. The selenium content of the samples was, respectively, 112 ppm, 187 ppm, and 175 ppm. Extensive sampling and analytical work by the U.S. Bureau of Mines (Everett and Bauerle, 1957) has established that selenium is distributed erratically in small irregular bodies, and is not confined to any particular bed or beds. This distribution pattern suggests localization by ground water, rather than the even distribution one would expect if selenium vapor, or seleniferous dust, were collected by falling rain and brought to earth. Selenium in samples of other seleniferous volcanic rocks is so tightly held that it can only be liberated by destruction of the rock by nitric acid or a similar strong solvent.

DISCUSSION

In spite of the paucity of new and positive information to be derived from study of the selenium analyses of volcanic rocks reported here, some discussion of the meaning of the analytical data is justified.

Examination of the analyses presented in this report indicates no particular correlation between selenium content of samples and the areas from which the samples came, or the rock type (from the point of view of the rock name) of the samples, but there is a hint of a physical correlation. Bentonites and tuffs—volcanic rocks composed of ash—seem to contain more selenium than the vitrophyres and crystalline rocks analzyed. Information published by earlier workers (table 1) caused the writers to hold this opinion before the new analytical data presented here were compiled, and the new data have strengthened the opinion that volcanic rocks composed of ash are more seleniferous than crystalline ones.

It is probable that the selenium content of the magmas from which the ash samples were derived was as high as the selenium content of the magmas from which the flow rock samples were derived. It is the writers' opinion that the observed lower selenium content of the flow rocks may be attributed to loss of selenium during crystallization. Evidence that such a process may take place is indicated by the presence of selenium in fumarolic incrustations (Zies, 1929). This loss presumably did not take place during the rapid solidification of the material making up the ash samples.

The new data also support the hypothesis (Byers and others, 1936, 1938) that highly seleniferous sediments may have acquired their selenium chiefly from dust and gases, carried directly into the sediments by rain, as opposed to the hypothesis (Beath and others, 1935, and Trelease and Beath, 1949) that the selenium in sedimentary rocks is derived by normal processes from the erosion of a highly seleniferous upland composed of crystalline volcanic rocks.

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