Descriptions and Analyses of Eight New USGS Rock Standards

GEOLOGICAL SURVEY PROFESSIONAL PAPER 840

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

Descriptions and Analyses of Eight New USGS Rock Standards

Compiled and edited by F. J. FLANAGAN

GEOLOGICAL SURVEY PROFESSIONAL PAPER 840

Twenty-eight papers present analytical data on new and previously described whole-rock standards

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1976

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, ***Secretary***

GEOLOGICAL SURVEY

W. A. Radlinski, ***Acting Director***

First printing 1976
Second printing 1978

Library of Congress Cataloging in Publication Data

Descriptions and analyses of eight new USGS rock standards.
(Geological Survey professional paper; 840)
Supt. of Docs. no.: I 19.16:840
1. Rocks--Analysis--Standards. 2. Geochemistry, Analytic--Standards. I. Flanagan, Francis James, 1915- II. Series: United States. Geological Survey. Professional paper; 840.
QE438.D37 552'.06 76-608172

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402
Stock Number 024-001-02866-2

CONTENTS

Page

Abbreviations ---------- VI

Introduction, by F. J. Flanagan ---------- 1

Nepheline syenite, STM-1, from Table Mountain, Oregon, by P. D. Snavely, Jr., N. S. MacLeod, F. J. Flanagan, Sol Berman, H. G. Neiman, and Harry Bastron ---------- 7

Rhyolite, RGM-1, from Glass Mountain, California, by D. B. Tatlock, F. J. Flanagan, Harry Bastron, Sol Berman, and A. L. Sutton, Jr ---------- 11

Quartz latite (dellenite), QLO-1, from southeastern Oregon, by G. W. Walker, F. J. Flanagan, A. L. Sutton, Jr., Harry Bastron, Sol Berman, J. I. Dinnin, and L. B. Jenkins ---------- 15

Cody Shale, SCo-1, from Natrona County, Wyoming, by L. G. Schultz H. A. Tourtelot, and F. J. Flanagan ---------- 21

Marine mud, MAG-1, from the Gulf of Maine, by F. T. Manheim, J. C. Hathaway, F. J. Flanagan, and J. D. Fletcher ---------- 25

Mica schist, SDC-1, from Rock Creek Park, Washington, D.C., by F. J. Flanagan and G. V. Carroll ---------- 29

Basalt, BHVO-1, from Kilauea Crater, Hawaii, by F. J. Flanagan, T. L. Wright, S. R. Taylor, C. S. Annell, R. C. Christian, and J. I. Dinnin ---------- 33

Mass spectrometric isotope dilution determinations of barium, by J. R. de Laeter, R. Date, and I. D. Abercrombie ---------- 41

The bismuth content of six new USGS standard rocks, by L. P. Greenland, E. Y. Campbell, and F. J. Flanagan ---------- 45

Molybdenum in USGS standard rocks, by E. G. Lillie and L. P. Greenland ---------- 47

Intercalibration of 17 standard silicates for 14 elements by instrumental neutron activation analysis, by Amitai Katz and Lawrence Grossman ---------- 49

Bismuth contents of USGS rock samples RGM-1 and BHVO-1, by P. M. Santoliquido and W. D. Ehmann ---------- 59

Determination of uranium and thorium in USGS standard rocks by the delayed neutron technique, by H. T. Millard, Jr ---------- 61

The determination of antimony, hafnium, and tantalum in the new USGS standard rocks, by L. J. Schwarz and J. J. Rowe ---------- 67

Gold content of USGS standard rocks, by L. J. Schwarz and J. L. Barker ---------- 71

The beryllium, fluorine, lithium, copper, zinc, and strontium contents of USGS standard rock samples STM-1, RGM-1, QLO-1, SCo-1, MAG-1, SDC-1, and SGR-1, by V. Macháček, I. Rubeška, V. Sixta, and Z. Šulcek ---------- 73

Instrumental analyses of major and minor oxides in USGS standard rocks BHVO-1, QLO-1, SDC-1, and RGM-1, by P. W. Weigand, K. Thoresen, W. L. Griffin, and K. S. Heier ---------- 79

The determination of selected elements in the USGS standard rocks STM-1 and RGM-1, by A. C. S. Smith and J. N. Walsh ---------- 83

Homogeneity of niobium content of eight USGS standard rocks, by E. Y. Campbell and L. P. Greenland ---------- 87

X-ray fluorescence analysis of 21 selected major, minor, and trace elements in eight new USGS standard rocks, by B. P. Fabbi and L. F. Espos ---------- 89

Titanium and trace element data in USGS standard rocks SCo-1 and SGR-1, by Isaac B. Brenner and A. Harel ---------- 95

Computerized spectrographic data for USGS standards, by F. G. Walthall, A. F. Dorrzapf, Jr., and F. J. Flanagan ---------- 99

Determinations of rare alkalis and alkaline earths in USGS standard rocks, by Sydney Abbey ---------- 117

Copper, lithium, manganese, strontium, zinc, sodium, potassium, and magnesium contents of eight new USGS standard rock samples, by J. A. Thomas, Wayne Mountjoy, and Claude Huffman, Jr ---------- 119

	Page
The carbon contents of USGS volcanic rock standards, by F. J. Flanagan, J. C. Chandler, I. A. Breger, C. B. Moore, and C. F. Lewis	123
Final compilation of K-Ar and Rb-Sr measurements on P-207, the USGS interlaboratory standard muscovite, by M. A. Lanphere and G. B. Dalrymple	127
1972 compilation of data on USGS standards, by F. J. Flanagan	131
Determination of gold, silver, and tantalum in the new USGS standards by neutron activation analysis, by G. N. Anoshin and G. A. Perezhogin	185
G-1 et W-1: Requiescant in Pace!, by F. J. Flanagan	189

ILLUSTRATIONS

			Page
FIGURES	1-4.	Maps showing:	
		1. Source of STM-1 on Table Mountain, Oreg	7
		2. Lava flow at Glass Mountain, Calif., with location of RGM-1	11
		3. Source of QLO-1 south of Juniper Mountain, Oreg	15
		4. Southwest corner of Edgerton quadrangle, Wyo., showing source of SCo-1	21
	5.	Plane table sketch map and diagrammatic cross section showing the rocks in the immediate area of the source of SCo-1	22
	6.	Sketch map showing location of the source of MAG-1 in the Wilkinson Basin, Gulf of Maine	25
	7.	Geologic sketch map of the Washington West quadrangle, District of Columbia-Maryland-Virginia, showing the source of SDC-1	29
	8.	Part of the geologic map of Kilauea Crater, Hawaii, with the source of BHVO-1	33
	9.	Scatter diagram of SiO_2 determinations in G-2 and GSP-1	190
	10.	Scatter diagram of SiO_2 determinations in AGV-1 and BCR-1	191

TABLES

			Page
TABLE	1.	Sieve analyses of STM-1	8
	2.	Chemical analyses and norms of STM-1	8
	3.	Spectrochemical determinations of elements in STM-1	9
	4.	Averages and standard deviations for spectrographic data for STM-1	10
	5.	Published determinations by neutron activation analysis of STM-1	10
	6.	Sieve analyses of RGM-1	12
	7.	Chemical analyses of RGM-1	12
	8.	Norms (CIPW) for RGM-1	13
	9.	Spectrochemical determinations of elements in RGM-1	13
	10.	Averages and standard deviations for spectrographic data for RGM-1	14
	11.	Sieve analyses of quartz latite, QLO-1	16
	12.	Chemical analyses of QLO-1	16
	13.	Norms (CIPW) of QLO-1	16
	14.	Spectrochemical determinations of elements in QLO-1	17
	15.	Averages and standard deviations for spectrographic data for QLO-1	17
	16.	Sieve analyses of quartz latite, QLO-γ	18
	17-22.	Determinations and analyses of variance of:	
		17. Uranium in QLO-1	18
		18. Thorium in QLO-1	18
		19. K_2O in QLO-1	18
		20. Uranium in QLO-γ	18
		21. Thorium in QLO-γ	19
		22. K_2O in QLO-γ	19
	23.	Estimates of the U, Th, and K_2O contents, and of the Th:U ratio, of QLO-1 and QLO-γ	19
	24.	Sieve analyses of SCo-1	23
	25.	Chemical analysis of SCo-1	23
	26.	Semiquantitative spectrographic estimates of some trace elements in SCo-1	23
	27.	Grain-size estimates of the marine mud MAG-1	26
	28.	Bulk mineralogy of MAG-1 determined by X-ray diffractometer	26

Page

TABLE 29. Mineralogy of the clay fraction of MAG-1 determined by X-ray diffractometer 26
30. Mineralogy of the sand fraction of MAG-1 26
31. Sieve analyses of MAG-1 26
32. Chemical analyses of MAG-1 26
33. Quantitative spectrographic determinations of trace elements in marine mud, MAG-1 27
34. Conclusions from the analysis of variance and estimates of the spectrographic data from MAG-1 28
35. Sieve analyses of SDC-1 30
36. Analyses of SDC-1 by rapid rock methods and by X-ray fluorescence 31
37. Norms (CIPW) for SDC-1, bottle 21/5 31
38. Semiquantitative spectrographic estimates of the trace element contents of SDC-1 31
39. Chemical analysis of a grab sample of BHVO-1 34
40. Sieve analyses of batches of BHVO-1 34
41. Quantitative spectrographic determinations of trace elements in Hawaiian basalt, BHVO-1 35
42. Determinations of the potassium content of BHVO-1 35
43. Determinations of the niobium content of BHVO-1 35
44. Determinations of the uranium content of BHVO-1 35
45. Instrumental neutron activation analyses of the chromium, scandium, and thorium contents of BHVO-1 35
46. X-ray fluorescence determinations of several oxides in BHVO-1 36
47. Spark source mass spectrometric determination of elements in BHVO-1 37
48. Means and standard deviations of data for BHVO-1 38
49. Isotopic composition of barium nitrate tracer and natural barium 42
50. Determinations of barium in USGS standard rock samples 42
51. Estimates of the barium contents of standard rocks 43
52. Bismuth content of USGS standard rocks 45
53. Summary of estimates for the bismuth content of six USGS standard rocks 46
54. Molybdenum content of USGS standard rocks 48
55. Nuclides, gamma-ray peaks, and half-lives of elements determined 50
56. Best values selected from literature for the "primary" standards 51
57. New data for the "primary" standards 52
58. Data for the new (1971 series) USGS silicate standards 53
59. Deviations between the new and the selected data of the "primary" standards 56
60. Neutron activation determinations and estimates of bismuth in USGS standard rocks RGM-1 and BHVO-1 59
61. Calibration of uranium and thorium monitors against a set of laboratory standard rocks by the delayed neutron technique 62
62. Neutron fluxes in the Geological Survey TRIGA reactor for pneumatic tube irradiations in the "G" ring 62
63. Analytical parameters for the determination of uranium and thorium using one cycle of two irradiations and countings with the delayed neutron system 63
64. Concentrations of uranium and thorium in USGS standard rocks 64
65. Estimates for uranium and thorium in USGS standard rocks 65
66. Determinations of antimony, hafnium, and tantalum in USGS standard rocks 68
67. Gold in standard rocks 72
68. Analytical data for seven USGS standard rock samples 75
69. Conclusions from the analysis of variance, averages, and standard deviations for USGS standard rock samples 76
70. Operating conditions for X-ray analyses 79
71. Determinations of oxides and summary of estimates for USGS standard rock samples BHVO-1, QLO-1, SDC-1, and RGM-1 80
72. Replicate data for minor oxides in RGM-1 and STM-1 83
73. Replicate data for trace elements in RGM-1 and STM-1 84
74. Results of analysis of variance of minor-oxide data for RGM-1 and STM-1 84
75. Results of analysis of variance of trace-element data for RGM-1 and STM-1 85
76. Niobium content of USGS standard rocks 87
77. X-ray Quantometer operating conditions 89
78. X-ray spectrograph operating conditions 90
79. X-ray fluorescence determinations and estimates for standard samples 90
80. Quantitative spectrographic determinations of trace and minor elements in Cody Shale, SCo-1 96
81. Quantitative spectrographic determinations of trace and minor elements in shale of the Green River Formation, SGR-1 97

Page

TABLE 82–96. Computerized spectrographic data for:
82. Diabase, W–1 ---- 101
83. Granite, G–2 ---- 102
84. Granodiorite, GSP–1 ---- 103
85. Andesite, AGV–1 ---- 104
86. Peridotite, PCC–1 ---- 105
87. Dunite, DTS–1 ---- 106
88. Basalt, BCR–1 ---- 107
89. Nepheline syenite, STM–1 ---- 108
90. Rhyolite, RGM–1 ---- 109
91. Quartz latite, QLO–1 ---- 110
92. Mica schist, SDC–1 ---- 111
93. Cody Shale, SCo–1 ---- 112
94. Green River Shale, SGR–1 ---- 113
95. Marine mud, MAG–1 ---- 114
96. Hawaiian basalt, BHVO–1 ---- 115
97. Estimates of the less common alkali and alkaline-earth contents of USGS samples ---- 117
98. Determinations and estimates of several elements and oxides in eight USGS samples ---- 120
99. Determinations of carbon and summary of estimates for USGS samples by Arizona State University ---- 124
100. Determinations of carbon and summary of estimates for USGS samples by USGS laboratory ---- 125
101. Potassium and argon analyses of P–207 ---- 128
102. Rubidium and strontium measurements of P–207 ---- 129
103. New rock analyses ---- 132
104. Determinations of major and minor constituents in eight USGS standard rock samples ---- 135
105. Determinations of trace elements in eight USGS standard samples ---- 145
106. Estimates of components normally determined in a rock analysis ---- 171
107. Estimates for trace elements in USGS samples ---- 171
108. Determinations of gold, silver, and tantalum in USGS standard rocks ---- 186
109. Particle-size distribution of six USGS samples ---- 192

ABBREVIATIONS

A	Angstrom
cm	centimeter
cm^3	cubic centimeter
cps	counts per second
cps/μg	counts per second per microgram
°F	degrees Farenheit
ft	foot
ft^2	square foot
ft^3	cubic foot
g	gram
g/kg	grams per kilogram
gal	gallon
gal/ton	gallons per ton
h	hour
in	inch
keV	kiloelectronvolts
kg	kilogram
km	kilometer
kp	kilopond force
kp/cm^2	kilopond force per centimeter squared
kV	kilovolt
kW	kilowatt
l	liter
l/min	liter per minute
lb	pound
m	meter
M	mole
mA	milliampere
MeV	megaelectronvolts
mg	milligram
mi	mile
mi^2	square mile
min	minute
ml/min	milliliters per minute
mm	millimeter
MW	megawatt
m.y.	million years
μg	microgram
μm	micrometer
μs	microsecond
neutrons cm^{-2} s^{-1}	neutrons per square centimeter per second
ng	nanogram
nm	nanometer
oz	ounce
ppb	parts per billion
ppm	parts per million
psi	pounds per square inch
yd^2	square yard
yr	year

DESCRIPTIONS AND ANALYSES OF EIGHT NEW USGS ROCK STANDARDS

INTRODUCTION

By F. J. FLANAGAN

Eight new whole-rock sample powders have been added to the U.S. Geological Survey's standard sample program. These samples supplement the first two samples, G–1 and W–1 (Fairbairn and others, 1951; Stevens and others, 1960; Fleischer and Stevens, 1962; Fleischer, 1965, 1969), and the more recent set of six samples, G–2, GSP–1, AGV–1, PCC–1, DTS–1, and BCR–1 (Flanagan 1967, 1969). The supply of G–1 became exhausted in 1965, but requests for the remaining samples will be considered as long as supplies last.

The new samples consist of six rocks—a nepheline syenite from Table Mountain, Oreg.; a rhyolite obsidian from Glass Mountain, Calif.; a quartz latite from Lake County, Oreg.; a mica schist from Rock Creek Park, Washington, D.C.; the Cody Shale from Natrona County, Wyo.; and a basalt from Kilauea Crater, Hawaii—and a marine sediment from Wilkerson Basin, Gulf of Maine. The marine sediment is probably the first standard sample of its kind and should be of substantial value to analysts dealing with such samples. A second portion of the quartz latite is intended for gamma ray spectrometry. Seven of the samples, collected by geologists familiar with the geologic settings, are described in separate sections in this report, and analyses of the contents for many of the elements are given for all eight standard rocks.

The samples were prepared primarily as reference materials for geochemical investigations. Although intended for use principally in our laboratories, they are available for distribution to investigators in geological surveys, other government organizations, universities, and research institutes whose problems and interests are similar to ours. Normally, 1-oz bottles are supplied, but requests for larger amounts may be considered.

Our laboratories have made preliminary chemical and spectrographic analyses of these new samples, and the data are included in the descriptive papers. Periodic compilations of data for all available USGS samples are planned. Because of the difficulties inherent in simultaneously compiling data for a dozen or more samples, analysts are requested to send us the references to papers in which they have published data on our samples.

The processing of these new samples, with only a few exceptions, follows without change the procedure previously described (Flanagan, 1967). An important part of the procedure consists of the selection, using random normal deviates, of (1) four bottles for sieve tests from each third of the entire batch of bottles; (2) three bottles from each third for spectrographic determinations in which one bottle from each third is given to each of our three spectrographic laboratories; and (3) two bottles from each third for the initial chemical analysis by our laboratories.

As these selections are made upon completion of bottling, sieve analyses are available for all samples. Chemical analysis by the methods of Peck (1964) and quantitative spectrographic analysis by the method of Bastron, Barnett, and Murata (1960) are available for the first three samples, STM–1, RGM–1, and QLO–1. The compositions of the remaining samples were determined by rapid rock analysis methods (Shapiro and Brannock, 1962; Shapiro, 1967) and by semiquantitative spectrographic analysis (Myers and others, 1961). Data on trace elements that had concentrations below the limits of detection for either spectrographic method have not been entered in the tables.

The quantitative spectrographic data for the minor and trace elements are entered as parts per million for ease in comparison of data and in computation in the analysis of variance. These data are significant to two figures (but only one near the limit of detection), and the zeros to the right of the significant digits are intended only to locate the decimal point. The two digits for some semiquantitative data serve only to indicate the midpoint of an interval because the data are reported as a number in the series 1.0, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, and so on, which represent midpoints of intervals on a geometric scale. The standard deviation of these semiquantitative data is one interval.

The analysis of variance was used with the quantitative spectrochemical determinations for the first three samples to determine if the samples are homogeneous for those elements for which the laboratories reported duplicate determinations on their three bottles. The data for each element are cast into the form of a two-way experimental design with duplicate determinations in which the laboratories and the bottles from the three thirds of the lot of samples are the variables of classification. As an example, the data for beryllium in STM-1 are shown below.

Beryllium determinations for STM-1, in parts per million

Thirds	Laboratory			Totals for thirds
	Menlo Park	Denver	Washington	
1	5	10	7	
	6	11	14	
Subtotal	11	21	21	53
2	6	17	11	
	6	12	10	
Subtotal	12	29	21	62
3	5	7	14	
	7	6	8	
Subtotal	12	13	22	47
Laboratory totals and grand total	35	63	64	162

Because of the relatively small number of determinations (18), it was not determined if the assumptions underlying the analysis of variance (Eisenhart, 1947) were tenable. On the assumption that they are valid, the calculations of the sums of squares for the sources of variation were made as shown in numerous texts, (for example, Dixon and Massey, 1951, p. 135–136), and the sums of squares and the degrees of freedom were entered in the analysis of variance table below.

Analysis of variance

[NS, not significant]

Source of variation	Sum of squares	Degrees of freedom	Mean sum of squares	F ratio
Thirds	19.00	2		
Laboratories	90.33	2		
Interaction	45.67	4	11.42	11.42/6.55=1.74 NS
Subtotal	155.00	8		$F_{0.95}(4,9)$ =3.63
Within	59.00	9	6.55	
Total	214.00	17		

The sum of squares for the interaction was obtained by the difference between the subtotal and the sums of squares for the thirds and laboratories, and that for the within, by the difference between the total variation and the subtotal.

The mean sums of squares (MSS) for the sources of variation are obtained by dividing the sums of squares by their degrees of freedom, and the significance of the interaction is tested by the ratio, $MSS_{interaction}/MSS_{within}$, shown in the table. For most elements in the first three samples the computed ratio does not exceed the allowable value, $F_{0.95}(4, 9) = 3.63$, and the interaction is judged to be not significant. The interaction and the within sums of squares and their degrees of freedom are then pooled to form an error sum of squares and degrees of freedom which are entered in the final analysis of variance table below. Ratios of the variation attributable to thirds and to laboratories are then formed with the error mean square, and if a ratio does not exceed the value of $F_{0.95}(2, 13) = 3.81$, as shown in F tables, it is not declared to be significantly larger than the error. When the variation due to the bottles randomly selected from the three thirds is not significant, the sample is declared to be homogeneous for that element by the spectrographic data of the three laboratories.

Analysis of variance

[S, significant; NS, not significant]

Source of variation	Sum of squares	Degrees of freedom	Mean sum of squares	F ratio
Thirds	19.00	2	9.50	9.50/8.05=1.18 NS
Laboratories	90.33	2	45.16	45.16/8.05=5.61 S
Error	104.67	13	8.05	$F_{0.95}(2,13)$=3.81
Total	214.00	17		

The standard deviations listed in the summary tables are the estimates for analytical error and for laboratory error. Other designs have been used in some papers that result in estimates of the bottle error and the analytical error. Bennett and Franklin (1954, table 7.14, p. 362) show that the average value for the mean square for subclasses (in this case, laboratories) is the sum of the mean square for error and *n* times the laboratory variance, where *n* is the number of determinations by each laboratory. If we subtract the error mean square from the mean square of the variation attributable to laboratories and divide this answer by 6, the number of determinations by each laboratory, we obtain the laboratory variance. The square root of the latter value and the square root of the error mean square are entered in the summary tables as their respective standard deviations.

For several *F* ratios of the mean sum of squares for the variation attributable to laboratories over the error mean square, we have obtained values less than, but not significantly less than, one. The resulting negative values for the estimates of the laboratory variance may be attributed to sample fluctuations about an average value of zero. We should anticipate this effect in half the tests in which our hypothesis, that the variation due to laboratories is not significantly greater than the error mean square, is true. These negative values have been indicated in the summary tables by the abbreviation "Neg."

With few exceptions, the first three samples are homogeneous for the several elements that were determined, whereas the laboratory variation was frequently significantly greater than the error mean square and the laboratories therefore estimate these elements differently. For several elements, the interaction mean square was significantly greater than the within mean square. There appears to be no physical reason for the significance of the interaction, and this significance may be due to chance, which may occur 5 percent of the time at the level of significance used. These significant interactions were used in the denominator of the *F* ratio to test the mean squares for thirds and for laboratories.

The data below for the significance of the variation due to laboratories for STM-1, RGM-1, and QLO-1 can furnish material for speculation. If the nepheline syenite, STM-1, is classified as crystalline, and the rhyolite obsidian, RGM-1, and the quartz latite, QLO-1, as noncrystalline (the very fine grain size and the minor glass content give the quartz latite a noncrystalline appearance), then the ratio of nonsignificant conclusions for the crystalline rock is 0.38 and for the noncrystalline, 0.56. The difference between these ratios lends slight support to the idea that the spectrographic determination of trace elements in noncrystalline materials is more precise than those in crystalline rocks, possibly because of the more uniform distribution of the elements in the noncrystalline rocks. The data also show that, as with G-1, W-1, and other standards, spectrographic laboratories can agree with only moderate differences on elements such as copper but that improvements in the technique are still necessary for elements such as barium, strontium and zirconium.

Significance of the variation due to laboratories for STM-1, RGM-1, and QLO-1

[S, significant; NS, not significant]

Element	STM-1	RGM-1	QLO-1
Ba	NS	NS	S
Be	S	------	------
Co	------	------	NS
Cu	NS	NS	NS
Ga	S	------	------
La	S	------	------
Mo	NS	------	------
Nb	NS	------	------
Pb	------	S	NS
Sc	------	NS	S
Sr	NS	NS	NS
V	------	S	S
Y	S	NS	S
Yb	S	NS	NS
Zr	S	S	S
Mn	S	S	NS
Ti	S	NS	S
NS/(S+NS)	5/13	7/11	6/12

The last two-thirds of this volume contain compilations of data on muscovite P-207 and on the USGS rocks that have been made available since 1951, as well as individual studies of the newer USGS standards by U.S. Geological Survey laboratories and by laboratories throughout the world. These studies of the newer samples report data obtained by using an experimental design with a single variable of classification. The use of this simple design was based on the argument below.

The user of a standard sample generally has a single unit of issue—for our rocks, a single bottle. If an analyst makes determinations on a number of portions of sample from the bottle, he can calculate a mean and a standard deviation of the data. These estimates adequately summarize the data obtained, but they apply only to the powder in the bottle that was analyzed and cannot be extrapolated to another bottle. Further, the standard deviation is of dubious value for estimating sample variability as it contains some estimate of the variability of the material in the bottle and of the variability due to the analyst and to the method. As each analyst has his own bottle, there is an obvious need for some measure of the bottle-to-bottle variation, and the simple experimental design with a single variable of classification is one of the least costly ways of achieving the desired goal.

The variable of classification for the design is the three or more bottles of a standard, randomly selected from the stock. Analysts were requested to make two or more determinations on each bottle (but the same number of determinations per bottle to preserve the simplicity of the arithmetic) and to make the determinations in random order. The analysis of variance allows us to calculate a mean sum of squares for the variation within bottles, which we equate to the analytical variance, and also allows us to separate the components of the mean sum of squares between bottles, so that we can estimate a bottle variance. Of at least equal importance, the *F* test involving the ratio of the two mean sums of squares, where the analytical error is used as the yardstick for measuring, affords us an objective test of the homogeneity of an element in the bottles of sample. Because of the random selection of the bottles, the conclusions may be extrapolated to the entire lot of bottles.

Many estimates of the bottle variance obtained in these studies are negative, and these negative estimates are clearly embarrassing because variance components are, by definition, positive. The problem of negative estimates of variances has been discussed by McHugh and Mielke (1968), Nelder (1954), Thompson (1961, 1962), and Searle (1971). Searle lists several possible steps, few of which are considered by him to be satisfactory, that may be taken when such estimates occur.

Bennett and Franklin (1954, p. 329) state that one can expect such negative estimates in about half of the tests on the type of data for which our hypothesis, that σ^2_B (the bottle variance) is zero, is true and that these negative estimates may be attributed to sample fluctuations about an average value of zero. We might, therefore, as a temporary expedient rewrite a negative estimate of the bottle variance, $-\sigma^2_B$, as $\sigma^2_B(-1)$, or as $\sigma^2_B i^2$, and table the negative estimate as a bottle standard deviation, $\sigma_B i$, where *i* is the conventional symbol for $\sqrt{-1}$. If such a convention were adopted, the *i*, especially if italicized, should be a sufficient warning that the tabled standard deviation was obtained from a negative bottle variance. We would then have a numerical but partly imaginary estimate that might be useful until a simpler, but rigorous, statistical solution to the problem is available.

Among the samples for which data are reported in the analytical papers is one of oil shale from the Mahogany zone of the Green River Formation. No descriptive paper is available for this sample. The rock was sent to the laboratory by G. U. Dinneen, Laramie Petroleum Research Center, U.S. Bureau of Mines, as a possible standard for the determination of shale oil yields and for use by the Organic Geochemistry Division of the Geochemical Society. Thirty determinations by several analysts yielded an average of 53.4 gal of oil per ton of shale, with a range of 52.2–55.7 gal/ton. This range does not necessarily indicate heterogeneity of the sample as the Fischer assay method for oil determinations, or modifications thereof, is an empirical method somewhat dependent on the analyst and on his specific technique.

The number of samples available or being prepared as standards (Flanagan, 1970) now threatens to tax the analysts of laboratories that can cooperate in the analysis of such samples. Invariably, the organization that prepares a proposed standard cannot afford the time and effort to make all determinations necessary for standardization, and it must depend on the generosity of cooperating laboratories. Despite the large size of our organization, we must also depend on such assistance.

Our gratitude is extended to collaborators who contributed analyses of our samples.

While this paper was in page proof, Kosiewicz and others (1974) published rare-earth data for STM–1 and SCo–1 from neutron activation.

REFERENCES CITED

Bastron, Harry, Barnett, P. R., and Murata, K. J., 1960, Method for the quantitative spectrochemical analysis of rocks, minerals, ores, and other materials by a powder d-c arc technique: U.S. Geol. Survey Bull. 1084–G, p. 165–182.

Bennett, C. A., and Franklin, N. L., 1954, Statistical analysis in chemistry and the chemical industry: New York, John Wiley and Sons, 724 p.

Dixon, W. J., and Massey, F. J., Jr., 1951, Introduction to statistical analysis: New York, McGraw-Hill Book Company, 370 p.

Eisenhart, Churchill, 1947, The assumptions underlying the analysis of variance: Biometrics, v. 3, p. 1–21.

Fairbairn, H. W., and others, 1951, A cooperative investigation of precision and accuracy in chemical, spectrochemical, and modal analysis of silicate rocks: U.S. Geol. Survey Bull. 980, 71 p.

Flanagan, F. J., 1967, U.S. Geological Survey silicate rock standards: Geochim. et Cosmochim. Acta, v. 31, p. 289–308.

——— 1969, U.S. Geological Survey standards—II. First compilation of data for the new U.S.G.S. rocks: Geochim. et Cosmochim. Acta, v. 33, p. 81–120.

——— 1970, Sources of geochemical standards—II: Geochim. et Cosmochim. Acta, v. 34, p. 121–125.

Fleischer, Michael, 1965, Summary of new data on rock samples G-1 and W-1, 1962-1965; Geochim. et Cosmochim. Acta, v. 29, p. 1263-1283.

——— 1969, U.S. Geological Survey standards—I. Additional data on rocks G-1 and W-1, 1965-1967: Geochim. et Cosmochim. Acta, v. 33, p. 65-79.

Fleischer, Michael, and Stevens, R. E., 1962, Summary of new data on rock samples G-1 and W-1: Geochim. et Cosmochim. Acta, v. 26, p. 525-543.

Kosiewicz, S. T., Schomberg, P. J., and Haskin, R. A., 1974, Rare earth analysis of USGS SCo-1 and STM-1—Evaluation of standards for homogeneity and of the precision and accuracy of a procedure for neutron activation analysis: Jour. Radioanal. Chemistry, v. 20, p. 619-626.

McHugh, R. B., and Mielke, P. W., Jr., 1968, Negative variance estimates and statistical dependence in nested sampling: Am. Statistical Assoc. Jour., v. 63, 1000-1003.

Myers, A. T., Havens, R. G., and Dunton, P. J., 1961, A spectrochemical method for the semiquantitative analysis of rocks, minerals, and ores: U.S. Geol. Survey Bull. 1084-I, p. 207-229.

Nelder, J. A., 1954, The interpretation of negative components of variance: Biometrika, v. 41, p. 544-548.

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

Searle, S. R., 1971, Topics in variance component estimation: Biometrics, v. 27, p. 1-76.

Shapiro, Leonard, 1967, Rapid analysis of rocks and minerals by a single-solution method: U.S. Geol. Survey Prof. Paper 575-B, p. B187-B191.

Shapiro, Leonard, and Brannock, W. W., 1962, Rapid analysis of silicate, carbonate, and phosphate rocks: U.S. Geol. Survey Bull. 1144-A, 56 p.

Stevens, R. E., and others, 1960, Second report on a cooperative investigation of the composition of two silicate rocks: U.S. Geol. Survey Bull. 1113, 126 p.

Thompson, W. A., Jr., 1961, Negative estimates of variance components: an introduction: Inst. Internat. Statistique (Rome) Bull., v. 34, p. 181-184.

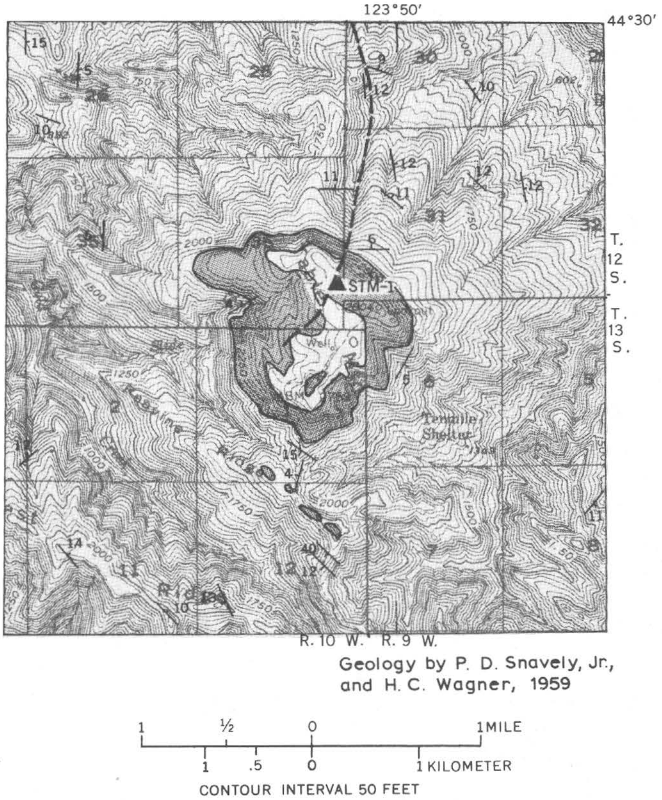
——— 1962, The problem of negative estimates of variance components: Annals Math. Statistics, v. 33, p. 273-289.

DESCRIPTIONS AND ANALYSES OF EIGHT NEW USGS ROCK STANDARDS

NEPHELINE SYENITE, STM-1, FROM TABLE MOUNTAIN, OREGON

By P. D. Snavely, Jr., N. S. MacLeod, F. J. Flanagan, Sol Berman,
H. G. Neiman, and Harry Bastron

A sample of peralkaline nepheline syenite for the reference sample program of the U.S. Geological Survey was collected from a sill that underlies Table Mountain (Georgia-Pacific quarry, SE¼ sec. 36, T. 12 S., R. 10 W., Tidewater 15-min quadrangle, lat. 44°28.6′ N.; long 123°50.2′ W. see fig. 1) in the Oregon Coast Range. The nepheline syenite sill is 250–400 ft thick, underlies an area of about 1½ mi², and intrudes graded sandstone and siltstone beds of the Tyee Formation (middle Eocene). The Table Mountain sill is a remnant of a much larger sill that may have underlain an area of more than 50 mi². Numerous small dikes of nepheline syenite, shonkinite, and camptonite that crop out in the Tidewater and adjoining quadrangles appear to be consanguineous with the nepheline syenite at Table Mountain.



Geology by P. D. Snavely, Jr., and H. C. Wagner, 1959

Figure 1.—Source of STM-1 on Table Mountain, Oreg. Shaded areas indicate outcrops of nepheline syenite. Base from U.S. Geological Survey, Tidewater 15-min quadrangle, 1942–56.

Nepheline syenite from a dike in Indian Creek, Mapleton quadrangle (approximately 18 miles south of Table Mountain), has a potassium-argon age of 33.6 m.y. (determined by R. W. Kistler, U.S. Geol. Survey) and this probably is also the age of the nepheline syenite at Table Mountain. The petrography, petrochemistry, and field relations of nepheline syenite in the central part of the Oregon Coast Range are briefly described by Snavely and Wagner (1961).

The fresh nepheline syenite is light to medium gray and has a glassy luster; weathered surfaces are pitted because of leaching of nepheline and analcime. The nepheline syenite is holocrystalline and very fine to fine grained and has a very pronounced trachytic texture. According to grain size and texture, it might more properly be termed phonolite, but, because it is intrusive and somewhat coarser grained in places, it is referred to as nepheline syenite. The rock is composed of alkali feldspar, nepheline, analcime, aegirine, riebeckite-arfvedsonite, biotite, olivine, opaque minerals, and apatite.

Alkali feldspar, about Ab_{90}–Or_{10}, constitutes 75–80 percent of the nepheline syenite and occurs as flow-alined laths. A more potassic feldspar, revealed by sodium cobaltinitrite staining, is interstitial to the albitic feldspar. Nepheline constitutes 5–10 percent of the nepheline syenite and occurs as euhedral to subhedral crystals and as smaller anhedral grains interstitial to feldspar. Analcime constitutes about 5 percent and is generally associated with nepheline.

The mafic minerals occur surrounding larger nepheline and analcime crystals and as anhedral grains ophiticaly intergrown with alkali feldspar. Aegirine makes up about 10 percent of the rock, and riebeckite-arfvedsonite about 3 percent. Olivine is less than 1 percent of the rock and has reaction rims of biotite surrounded by alkali amphibole. Biotite (less than 0.5 percent) also occurs ophitically intergrown with feldspar and rimming nepheline or analcime crystals. Opaque minerals and apatite make up less than 0.5 percent.

Sieve analyses of portions of the processed sample are given in table 1. Chemical analyses of two bottles of the sample and CIPW norms computed from these analyses are given in table 2. For calculation of the norms, total water was removed from the analyses, and the remaining oxides were recalculated to 100 percent.

TABLE 1.—*Sieve analyses of STM-1 (percent)*

Thirds	1	2	3	Avg
Sieve size:				
+100	0.1	0.1	0.1	0.1
—100+120	.1	.1	.1	.1
—120+170	.9	1.3	1.0	1.1
—170+200	1.9	2.3	2.2	2.1
—200	96.9	96.2	96.5	96.5
Total	99.9	100.0	99.9	99.9

TABLE 2.—*Chemical analyses and norms of STM-1*

[In weight percent. Chemical analyses by methods of Peck (1964). Analysts: bottle 9/17, E. L. Munson; bottle 29/31, V. C. Smith]

Bottle No	9/17	29/31
Chemical analyses		
SiO_2	59.62	59.46
Al_2O_3	18.61	18.60
Fe_2O_3	2.86	2.87
FeO	2.10	2.08
MgO	.10	.10
CaO	1.16	1.15
Na_2O	9.01	8.92
K_2O	4.27	4.21
H_2O+	1.41	1.38
H_2O-	.18	.19
TiO_2	.13	.14
P_2O_5	.16	.16
MnO	.23	.22
CO_2	.01	.02
Cl	.05	.05
F	.10	.10
S	.00	.00
BaO	.05	.05
Subtotal	99.95	99.70
Less O	.05	.05
Total	99.90	99.65

TABLE 2.—*Chemical analyses and norms of STM-1*—Continued

Bottle No	9/17	29/31
CIPW norm		
Orthoclase	25.65	25.35
Albite	50.75	52.43
Nepheline	12.13	11.48
Halite	.08	.08
Acmite	3.51	2.58
Wollastonite	1.74	1.70
Enstatite	.16	.18
Ferrosilite	1.77	1.70
Forsterite	.06	.05
Fayalite	.75	.54
Magnetite	2.46	2.95
Ilmenite	.25	.27
Apatite	.39	.39
Fluorite	.18	.18
$CaCO_3$	.02	.05
Total	99.90	99.93

Quantitative spectrographic determinations are presented in table 3. The data for the 13 elements for which our three spectrographic laboratories reported duplicate determinations on their three bottles were treated by the analysis of variance. These tests showed that without exception the variation attributable to samples selected from the three thirds was not significant. We may therefore conclude that the samples are homogeneous for the 13 elements. Because of the random selection of the bottles, the conclusions may be extended to the entire sample.

The variation due to laboratories was not significant for Ba, Cu, Mo, Nb, and Sr, and the laboratories may use the grand average to estimate these elements. The variation due to laboratory means for the remaining eight elements was significantly greater than the error mean square, and the laboratories estimate these elements differently. Inspection of the data in table 3 shows that the tests of significance for some elements served only to confirm visual judgments that significant differences might be attributed to laboratory means

Laboratory averages are given in table 4 for all elements for which quantitative determinations were reported, and grand averages, standard deviations and conclusions from the analysis of variance are given for the 13 elements for which tests were made. Although the variation due to laboratories was significant for eight elements, some differences among the laboratory means are not unduly large, and the grand average may be used as the estimate. The laboratories should use their own estimates for Zr and Ti.

Means of the La data for two laboratories agree well between themselves and both differ markedly

TABLE 3.—*Spectrochemical determinations of elements in STM-1*

[In parts per million. Method of Bastron and others (1960)]

Laboratory	Washington			Denver			Menlo Park		
Bottle No.	10/13	29/22	50/11	10/12	30/10	49/28	9/20	29/32	50/14
Ba	500	470	470	480	420	440	460	480	460
	370	390	420	760	620	620	480	440	440
Be	7	11	14	10	17	7	5	6	5
	14	10	8	11	12	6	6	6	7
Ce	800	400	600	----	----	----	----	----	----
	500	600	300	----	----	----	----	----	----
Cr	----	----	----	2	3	2	1	1	1
	----	----	----	3	3	3	1	1	1
Cu	4	3	2	5	3	2	2	2	2
	4	3	2	3	3	2	2	3	3
Ga	35	36	37	42	46	46	40	32	32
	35	29	31	41	45	45	26	26	26
La	260	260	300	110	150	160	190	160	150
	280	240	210	160	160	160	140	140	160
Mo	6	4	3	15	<5	7	5	6	6
	5	5	4	12	5	7	5	7	6
Nb	280	290	350	310	330	330	280	260	300
	290	240	250	310	340	300	300	320	280
Ni	----	----	----	----	----	----	3	2	2
	----	----	----	----	----	----	1	1	1
Pb	----	----	----	30	20	20	14	11	8
	----	----	----	20	20	20	10	8	9
Sn	----	----	----	----	----	----	13	12	12
	----	----	----	----	----	----	9	11	12
Sr	740	420	380	840	1,100	640	900	840	740
	400	500	590	1,400	1,000	900	800	880	740
Y	70	70	70	58	62	54	40	50	50
	80	60	50	52	60	67	60	40	40
Yb	5	5	5	5	4	4	4	4	4
	6	4	4	5	5	4	4	3	4
Zr	1,000	990	1,000	1,500	1,500	1,500	1,300	1,100	1,300
	960	1,000	900	1,500	1,500	1,500	1,100	1,200	1,300
Mn	1,600	1,600	1,700	1,700	1,700	1,800	1,600	1,500	1,400
	1,700	1,800	1,400	1,800	2,000	1,500	1,400	1,600	1,500
Ti	840	820	1,100	1,200	1,100	1,200	840	720	790
	940	860	690	1,200	1,100	1,200	800	840	830

from the third. These two laboratories may wish to recalculate a single estimate for their common use. Although the variation in the Sr data attributable to both thirds of the lot and to the laboratories were declared not significant, the pooled mean square for error is larger than those attributable to thirds and laboratories. After partitioning the variation due to laboratories into its two components of laboratory and error variance, the laboratory standard deviation was entered in the table as negative, but because of the poor precision for Sr, the laboratories might wish to estimate their own means and standard deviations.

Before the processing of this sample had been completed, a request was received for a portion, and two 1-oz bottles were dipped into the ground and partly mixed, but unbottled, bulk sample. Data for several trace elements obtained by neutron activation on these two unnumbered bottles are given in table 5 and lend further credence to the above claims of sample homogeneity.

TABLE 4.—*Averages and standard deviations for spectographic data for STM-1*

[In parts per million. S, significant. NS, not significant, when tested against $F_{0.95}$. d.f., degrees of freedom]

Element	Laboratory averages			Grand average	Conclusion from analysis of variance		Standard deviation	
	Washington	Denver	Menlo Park		Thirds	Laboratories	Laboratories (d.f.=2)	Error (d.f.=13)
Ba	437	557	460	484	NS	NS	53	86
Be	10.7	10.5	6.2	9.1	NS	S	2.2	2.6
Ce	530	----	----	----	----	----	----	----
Cr	----	2.6	1	----	----	----	----	----
Cu	3.0	3.0	2.3	2.8	NS	NS	.24	.74
Ga	34	44	30	36	NS	S	7.0	4.1
La	258	150	156	188	NS	S	60	25.6
Mo	4.5	8.5	5.8	6.3	[1] NS	[1] NS	1.3	3.9
Nb	283	320	290	298	NS	NS	15.6	28.8
Ni	----	----	1.6	----	----	----	----	----
Pb	----	22	10	----	----	----	----	----
Sn	----	----	12	----	----	----	----	----
Sr	505	980	817	767	NS	NS	Neg.	940
Y	67	59	47	57.4	NS	S	9.5	8.5
Yb	4.8	4.5	3.8	4.4	NS	S	.46	.51
Zr	975	1,500	1,217	1,230	NS	S	265	63.6
Mn	1,600	1,800	1,500	1,600	NS	S	110	120
Ti	875	1,166	803	948	NS	S	189	88.5

[1] The significant interaction was used to test the variation due to thirds and to laboratories.

TABLE 5.—*Published determinations by neutron activation analysis of STM-1*

[In parts per million, except where indicated]

Element	Determinations	Average	References
Ce	298, 286, 308	297	Brunfelt and Steinnes (1967a).
Cl	430, 432	431	Johansen and Steinnes (1967).
Co	<1	----	Brunfelt and Steinnes (1966).
Cr	----	1.4	Brunfelt and Steinnes (1967b).
Cu	2.0, 1.9, 2.1	2.0	Brunfelt, Johansen, and Steinnes (1967).
Eu	4.0, 3.9, 4.2	4.1	Brunfelt and Steinnes (1967a).
Ga	36, 39, 38	38	Brunfelt, Johansen, and Steinnes (1967).
In	0.0852, 0.0879	.087	Johansen and Steinnes (1966).
La	133, 155, 141	143	Brunfelt and Steinnes (1966).
Mn	1,420, 1,540, 1,440	1,470	Do.
Na (percent)	6.12, 6.56, 5.99, 5.76, 5.68, 6.39	6.08	Do.
P_2O_5 (percent)	[1] (0.178, 0.0180), [1](0.194, 0.176)	.182	Brunfelt and Steinnes (1968).
Sc	0.6, 0.6	.6	Brunfelt and Steinnes (1966).
Se	0.012, 0.008	.010	Brunfelt and Steinnes (1967c).
Sm	17.3, 18.3 16.6	17.4	Brunfelt and Steinnes (1966).
Zn	204, 206, 218	209	Brunfelt, Johansen, and Steinnes (1967).

[1] Two irradiations

REFERENCES CITED

Bastron, Harry, Barnett, P. R., and Murata, K. J., 1960, Method for the quantitative spectrochemical analysis of rocks, minerals, ores and other materials by a powder d-c arc technique: U.S. Geol. Survey Bull. 1084-G, p. 165-182.

Brunfelt, A. O., Johansen, O., and Steinnes, Eiliv, 1967, Determination of copper, gallium, and zinc in "standard rocks" by neutron activation: Anal. Chim. Acta, v. 37, p. 172-178.

Brunfelt, A. O., and Steinnes, Eiliv, 1966 Instrumental neutron activation analysis of "standard rocks": Geochim. et Cosmochim. Acta, v .30, p. 921-928.

——— 1967a, Cerium and europium content of some standard rocks: Chem. Geology, v. 2, no. 3, p. 199-207.

——— 1967b, Determination of chromium in rocks by neutron activation and anion exchange: Anal. Chemistry, v. 39, no. 7, p. 833-834.

——— 1967c, Determination of selenium in standard rocks by neutron activation analysis: Geochim. et Cosmochim. Acta, v. 31, no. 2, p. 283-285.

——— 1968, The determination of phosphorus in rocks by neutron activation: Ana. Chim. Acta, v. 41, p. 155-158.

Johansen, O., and Steinnes, Eiliv, 1966, Determination of indium in standard rocks by neutron activation analysis: Talanta, v. 13, p. 1177-1181.

——— 1967, Determination of chlorine in U.S.G.S. standard rocks by neutron activation analysis: Geochim. et Cosmochim. Acta, v. 31, p. 1107-1109.

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

Snavely, P. D., Jr., and Wagner, H. C., 1961, Differentiated gabbroic sills and associated alkalic rocks in the central part of the Oregon Coast Range, Oregon: U.S. Geol. Survey Prof. Paper 424-D, p. D156-D161.

DESCRIPTIONS AND ANALYSES OF EIGHT NEW USGS ROCK STANDARDS

RHYOLITE, RGM-1, FROM GLASS MOUNTAIN, CALIFORNIA

By D. B. Tatlock, F. J. Flanagan, Harry Bastron, Sol Berman,
and A. L. Sutton, Jr.

The rhyolite from Glass Mountain, Siskiyou County, Calif. (lat 41°37.2′ N., long 121°29.0′ W.), was selected for the U.S. Geological Survey standard sample program chiefly because it is a glass and is therefore less subject to the phase heterogeneities likely to be encountered in a crystalline rock. A sample weighing about 135 kg (300 lb) was broken from a single block of massive obsidian near the terminal front of a Holocene obsidian flow, about 2.7 km northeast of, and about 500 m lower than, its probable source vent on Glass Mountain proper. This youngest of the Glass Mountain flows and the sample location are shown in figure 2. The flow may be as young as 500 yr (Friedman, 1968).

Glass Mountain, altitude 2,323 m, is in the Medicine Lake Highland (Anderson, 1941; Peacock, 1931; Powers, 1932) on the eastern margin of the Cascade Range. It is about 63 km east-northeast of Mount Shasta and about 10 km south of Lava Beds National Monument.

The Medicine Lake Highland has a diameter of about 30 km and rises from an undulating plateau whose average altitude is about 1,500 m. The plateau is underlain chiefly by basalt and andesite of Miocene and Pliocene age. Silicic volcanic rocks of probable late Pliocene age are found at several places around the margin of the present highland.

The growth of the highland began with the eruption of olivine andesites which formed a broad shield volcano. According to Anderson (1941), the central part of the shield collapsed, forming a caldera some 10 km long and 6 km wide. At the same time, andesitic lava was squeezed upward along boundary fractures, forming rim volcanos that in time were high enough to discharge lava down the slopes of the original shield volcano. The inner walls of the original caldera were obliterated, leaving an enclosed central basin which is now occupied by Medicine Lake and is surrounded by a rampart of cones. Discharge of more silicic differentiates, ranging from dacites to rhyolites, began in the caldera area at this time.

In the vicinity of what is now Glass Mountain, flows of spherulitic obsidian and dacite terminated some 5 km east of the rim of the Medicine Lake basin. These flows and the surrounding area were

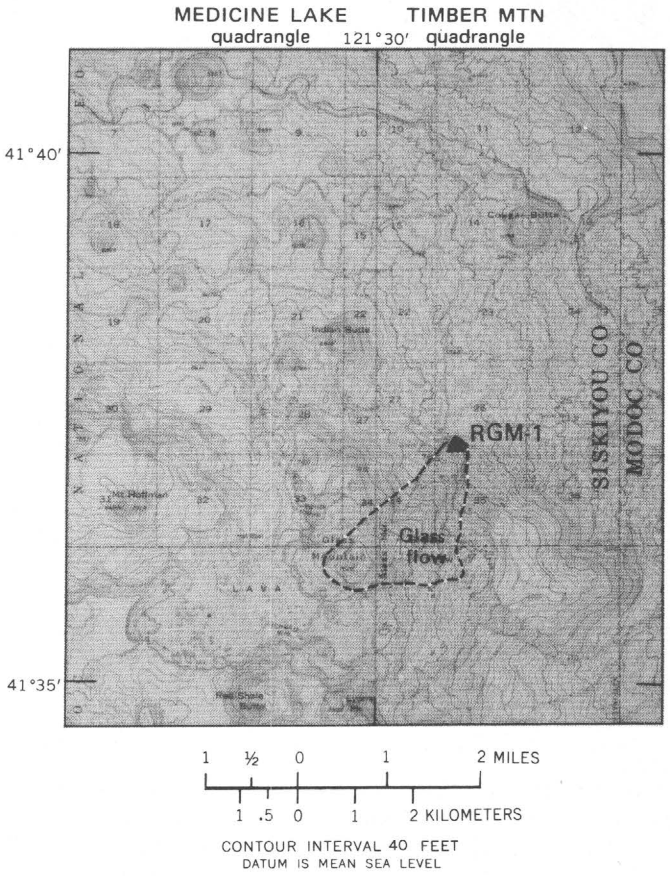


FIGURE 2.—Lava flow at Glass Mountain, Calif., with the source of RGM-1. Base from U.S. Geological Survey, Medicine Lake and Timber Mountain 15-min quadrangles, 1952.

then mantled by white rhyolitic pumiceous ejecta from vents along a fissure striking N. 30° W.; a large pumice cone formed at one of the vents on or near the site of Glass Mountain.

Following this explosive activity, dacite (rhyodacite) and rhyolite obsidian were discharged simultaneously and apparently from the same vent. Anderson (1933) termed this a composite flow, but with obsidian forming the major portion. It extends more than 5 km east of Glass Mountain, riding out over the older dacite and spherulitic obsidian flows. Locally, lenses and bands of obsidian are found cutting through the dacite, but there is no suggestion of diffusion of one rock type into the other. It is probable that two separate magma chambers existed but that explosive eruptions made it possible for the dacite to erupt from the rhyolite vent.

The last of the Glass Mountain flows, and the one from which the sample was taken, consists entirely of rhyolitic obsidian; it flowed predominantly to the east and northeast. It is smaller than, and stands out sharply from, the underlying composite flow. Chemically, however, it is indistinguishable from the older pumice ejecta and obsidian of the composite flow. The geology of Glass Mountain, including eight analyses of the various rhyolitic rocks, has been thoroughly discussed by Anderson (1933).

Pieces making up the sample displayed no phenocrysts or spherulites and no pumiceous or perlitic phases. The luster of the glass on freshly broken surfaces ranged from semiglossy to brilliant.

The obsidian appears to be black from a distance, but on close inspection it shows gray to very dark gray or black mottling and banding; the bands range in thickness from about a millimeter to several centimeters. The darker bands seem to result from a concentration of microlites, too small to polarize light appreciably, that are roughly parallel to the banding. Rare opaque crystallite, probably magnetite, may be seen in thin section.

The index of refraction of the glass ranges from about 1.491 to almost 1.494, with an average of 1.492±0.002. The bulk specific gravity of 14 pieces, varying in size from small chips to large band specimens, ranges from 2.380 to 2.385, with a mean of 2.383±0.003. The specific gravity of the small chips was determined by the sink-float method in solutions of zinc iodide, and that of the hand specimens was determined by the specific-gravity balance. The powder density of the ground sample is 2.45. No consistent appreciable differences in either the index of refraction or the specific gravity could be detected between the lighter and darker colored parts of the glass.

Sieve analyses of portions of the ground samples are given in table 6. Chemical analyses of portions from two randomly selected bottles of RGM-1 are given in table 7, and the CIPW norms calculated from the analyses are given in table 8.

TABLE 6.—*Sieve analyses of RGM-1, in percent*

[Tr., trace]

Thirds	1	2	3	Avg.
Sieve size:				
+100	Tr.	0.1	Tr.	Tr.
−100+120	Tr.	Tr.	Tr.	Tr.
−120+170	1.0	0.6	0.8	0.8
−170+200	1.5	1.7	1.9	1.7
−200	97.4	97.5	97.3	97.4
Sum	99.9	99.9	100.0	99.9

TABLE 7.—*Chemical analyses of RGM-1, in weight percent*

[Method of Peck, 1964, Analysts: bottle 31/14, E. L. Munson; bottle 52/32, V. C. Smith]

Bottle No.	31/14	52/32
SiO_2	73.43	73.44
Al_2O_3	13.76	13.72
Fe_2O_3	.50	.49
FeO	1.24	1.23
MgO	.29	.29
CaO	1.16	1.19
Na_2O	4.19	4.17
K_2O	4.34	4.34
H_2O+	.32	.35
H_2O-	.12	.11
TiO_2	.26	.27
P_2O_5	.05	.05
MnO	.04	.04
CO_2	.01	.00
Cl	.05	.06
F	.04	.04
S	.00	.00
BaO	.07	.09
Subtotal	99.87	99.88
Less O	.03	.03
Total	99.84	99.85
Total Fe as FeO	1.69	1.67

The low water content (reflecting the absence of any perlitic phase), the low ratio of ferric to ferrous iron, and the low excess alumina (normative corundum) suggest that the glass has undergone no appreciable alteration. The sample is classified as a rhyolite on the basis of its high silica and total alkali contents, and it is assigned to the calc-alkali series because of its high ratio of CaO to total iron and the relatively high (for a rhyolite) anorthite content of its normative plagioclase (An_{13-14}). Except for its lower ratio of potassium to sodium, the

TABLE 8.—*Norms (CIPW) for RGM-1, in weight percent*

Bottle No.	31/14	52/32
Quartz	28.99	29.06
Orthoclase	25.65	25.65
Albite	35.46	35.29
Anorthite	5.43	5.58
Corundum	.18	.12
Enstatite	.72	.72
Ferrosilite	1.51	1.48
Magnetite	.73	.71
Ilmenite	.49	.51
Apatite	.12	.12
Total	99.28	99.24
Niggli values:		
k	.41	.41
mg	.23	.23

Ratios averaged from two analyses:

Q:Or:(Ab+An) 30.4:26.8:42.8
Or:Ab:An 38.5:53.2:8.3
Alk:F:M (mol. percent) 78.4:16.6:5.0

rhyolite obsidian from Glass Mountain closely matches the average calc-alkali rhyolite of Nockolds (1954).

Quantitative determinations by our three spectrographic laboratories are shown in table 9. The data for those 11 elements for which the laboratories reported their six determinations were treated by the two-way analysis of variance with duplicate determinations. Significant mean squares for interaction for the copper and strontium data were used to test the significance of the variation due to thirds and laboratories, but the tests for the remaining nine elements were made in the normal fashion.

Estimates of the means and standard deviations and the conclusions from the analyses of variance are given in table 10. The standard deviations were calculated as described in the "Introduction," except those for the Cu and Sr data. Because of the significant interaction for these elements, the sums of squares and degrees of freedom for the interaction and the within sources of variation were pooled, and the standard deviation for error was obtained from this pooled estimate. The *F* tests for the sig-

TABLE 9.—*Spectrochemical determinations of elements in RGM-1*

[In parts per million. Method of Bastron and others (1960)]

Laboratory	Washington			Denver			Menlo Park		
Bottle No	10/28	31/5	56/26	10/3	31/15	52/29	10/27	31/25	52/11
B	30	30	40	----	----	----	30	30	40
	30	30	30	----	----	----	40	30	30
Ba	750	660	740	760	720	740	740	740	740
	590	690	700	660	720	640	680	680	740
Be	----	----	----	----	----	----	3	3	3
	----	----	----	----	----	----	3	3	2
Co	----	----	----	----	----	----	3	2	3
	----	----	----	----	----	----	2	2	2
Cr	----	----	----	3	2	3	4	2	3
	----	----	----	4	2	3	2	2	2
Cu	12	13	8	8	9	10	13	8	9
	12	14	7	8	8	8	11	10	15
Ga	10	12	11	17	12	14	----	----	----
	8	12	12	15	16	15	----	----	----
Mo	----	----	----	----	----	----	4	4	3
	----	----	----	----	----	----	3	3	3
Nb	----	----	----	----	----	----	18	18	18
	----	----	----	----	----	----	15	15	17
Pb	30	30	20	20	20	20	13	16	26
	30	30	30	20	20	20	12	12	13
Sc	5	6	6	5	5	6	6	6	5
	5	7	5	5	6	6	5	5	5
Sr	100	100	150	120	110	120	100	100	100
	96	120	170	120	110	110	80	100	100
V	10	13	15	10	10	10	19	19	18
	8	4	8	10	10	10	17	16	20
Y	30	30	30	20	20	30	30	30	30
	30	40	20	20	30	30	20	20	20
Yb	2	3	2	2	2	3	2	2	2
	3	3	2	2	3	2	2	2	2
Zr	210	190	200	180	190	210	240	210	200
	210	220	180	170	210	200	220	240	210
Mn	280	330	330	320	330	310	280	240	240
	330	300	310	330	310	290	220	200	220
Ti	1,600	1,700	1,800	1,200	1,500	1,500	1,500	1,600	1,400
	1,800	2,100	1,500	1,400	1,800	1,500	1,900	1,900	1,400

TABLE 10.—*Averages and standard deviations for spectrographic data for RGM-1*

[In parts per million. S, significant, NS, not significant, when tested against $F_{0.95}$.d.f., degrees of freedom]

Element	Laboratory averages			Grand average	Conclusions from analysis of variance		Standard deviation	
	Washington	Denver	Menlo Park		Thirds	Laboratories	Laboratories (d.f.=2)	Error (d.f.=13)
B	31.7	----	33.3	----	---	---	---	---
Ba	688	707	720	705	NS	NS	Neg.	49
Be	----	----	2.8	----	---	---	---	---
Co	----	----	2.3	----	---	---	---	---
Cr	----	2.8	2.6	----	---	---	---	---
Cu	11	8.5	11	10.2	[1] NS	[1] NS	1.1	2.4
Ga	10.8	14.8	----	----	---	---	---	---
Mo	----	----	3.3	----	---	---	---	---
Nb	----	----	16.8	----	---	---	---	---
Pb	28	20	15.3	21.2	NS	S	6.4	4.2
Sc	5.7	5.5	5.3	5.5	NS	NS	Neg.	.61
Sr	123	115	97	111	[1] NS	[1] NS	6.9	28
V	9.7	10	18.2	12.6	NS	S	4.7	2.5
Y	30	25	25	26.7	NS	NS	1.5	6.0
Yb	2.5	2.3	2.0	2.3	NS	NS	.19	.43
Zr	202	193	220	205	NS	S	11.8	16.4
Mn	313	315	233	287	NS	S	45.8	22.6
Ti	1750	1480	1680	1630	NS	NS	110	190

[1] The significant interaction was used to test the variation due to thirds and to laboratories.

nificance of the variation of the Ba and Sc data attributable to laboratories resulted in ratios of less than one (but not significantly so). The laboratory standard deviations for Ba and Sc are therefore negative and are so entered in table 10.

The variation attributable to the bottles randomly selected from the three thirds of the sample was not significant for the 11 elements for which there was complete data by the three laboratories, and the sample may be claimed to be homogeneous for these elements. The variation due to laboratories was not significant for Ba, Cu, Sc, Sr, Y, Yb, and Ti, and a single estimate can be used for the three laboratories. Conclusions of significant differences due to the laboratory means were obtained for Pb, V, Zr, and Mn. Of these, the laboratory means for Zr each fall within one standard deviation of the grand average, and it is appropriate to use the grand average as the single estimate for the laboratories. There are some fairly large differences among the laboratory means for Pb, V, and Mn, and the laboratories should estimate these elements by their own averages.

A study of the gold content of some volcanic rocks (Gottfried, and others, 1972) indicates that gold is also homogeneously distributed in both bottles and in chips from hand specimens of RGM-1. In contrast to the average of 16.8 ppm Nb by the Menlo Park spectrographic laboratory, Esma Campbell of the Washington laboratory obtained 9.51 ppm Nb for a single determination by the modified thiocyanate spectrophotometric method of Grimaldi (1960).

REFERENCES CITED

Anderson, C. A., 1933, Volcanic history of Glass Mountain, northern California: Am. Jour. Sci., 5th ser., v. 26, p. 485–506.

——— 1941, Volcanoes of the Medicine Lake highland, California: Calif. Univ. Dept. Geol. Sci. Bull., v. 25, no. 7, p. 347–422.

Bastron, Harry, Barnett, P. R., and Murata, K. J., 1960, Method for the quantitative spectrochemical analysis of rocks, minerals, ores, and other materials by a powder d-c arc technique: U.S. Geol. Survey Bull. 1084–G, p. 165–182.

Friedman, Irving, 1968, Hydration rind dates rhyolite flows: Science, v. 159, no. 3817, p. 878–880.

Gottfried, David, Rowe, J. J., and Tilling, R. I., 1972, Distribution of gold in igneous rocks: U.S. Geol. Survey Prof. Paper 727, 42 p.

Grimaldi, F. S., 1960, Determination of niobium in the parts per million range in rocks: Anal. Chemistry, v. 32, no. 1, p. 119–121.

Nockolds, S. R., 1954, Average chemical compositions of some igneous rocks: Geol. Soc. America Bull., v. 65, no. 10, p. 1007–1032.

Peacock, M. A., 1931, The Modoc lava field, northern California: Geog. Rev., v. 21, no. 2, p. 259–275.

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

Powers, H. A., 1932, The lavas of the Modoc Lava Bed quadrangle, California: Am. Mineralogist, v. 17, no. 7, p. 253–294.

QUARTZ LATITE (DELLENITE), QLO-1, FROM SOUTHEASTERN OREGON

By G. W. WALKER, F. J. FLANAGAN, A. L. SUTTON, JR., HARRY BASTRON,
SOL BERMAN, J. I. DINNIN, and L. B. JENKINS

As part of the U.S. Geological Survey rock standards program, a sample of dense black volcanic rock was collected in Lake County, Ore., about 21 km (13 miles) south of Juniper Mountain in sec. 35?, T. 32 S., R. 23 E. (lat 42°44.8′ N.; long 119° 58′ W.) (fig. 3). The sample was collected from outcrops about 10 m east of a poor road that heads south-southeast down a shallow unnamed desert wash.

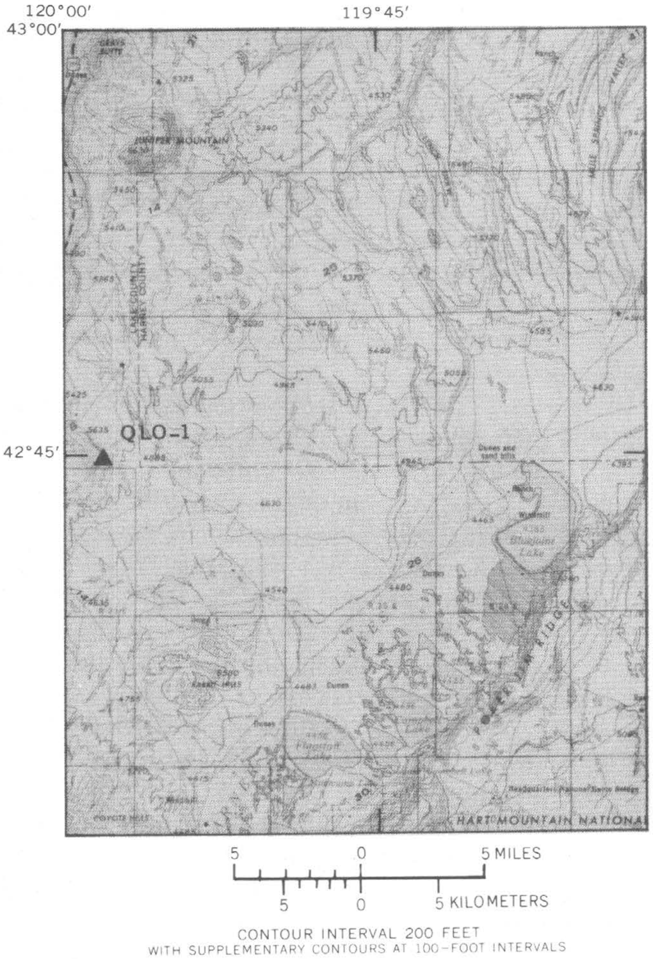


FIGURE 3.—Source of QLO-1 south of Juniper Mountain, Oreg. Base by U.S. Geological Survey, 1:250,000, Walker and Repenning (1965).

Although outcrops are poor in this area, the sample appears to represent part of a lava flow on the flanks of a low exogeneous dome that is composed dominantely of the same dense black volcanic rock. The dome is located on the northern extension of the large tilted fault block dominated on the west by Abert Rim. Correlation with adjacent volcanic units indicates that the exogeneous dome and related flow are either of late Miocene or possibly early Pliocene age. Most of the region adjacent to the dome is underlain by upper Miocene and lower Pliocene basalt, Pliocene ash flow tuff of rhyolitic composition, and Pleistocene lake sediments (Walker and Repenning, 1965).

Several more or less synonomous petrographic names can be applied to this rock, depending on which classification is used. According to the classification of Rittman (1952), this rock is a quartz latite, and in the classification of Nockolds (1954) and Wahlstrom (1955) it is a dellenite. Very similar volcanic rocks from south-central Nevada, but with slightly different $Na_2O:K_2O$ ratios, have been broadly classed as dellenite and more precisely as rhyodacite by O'Connor (1965).

Characteristically the rock is greasy black and is aphanitic with a conchoidal fracture. In hand specimen, a few small feldspar phenocrysts, mostly 1 or 2 mm in maximum dimension, can be recognized. A specific gravity of 2.553±0.003 was obtained by averaging measurements from 10 different hand specimens. The powder density of the processed sample is 2.60.

In thin section, the rock is finely porphyritic with an extremely fine grained trachytic to felted groundmass texture or, in places, a vitrophyric texture. Phenocrysts, representing less than 1 percent of the rock, consist of rounded and embayed, zoned and twinned plagioclase (about An_{60-70}), hypersthene, magnetite, and clinopyroxene?; the plagioclase phenocrysts contain abundant inclusions of pinkish-brown glass. The groundmass consists of abundant minute subparallel microlites of plagioclase (approximately An_{25-30}) in either a cryptocrystalline mesostasis or rarely in pinkish-brown glass.

Sieve analyses of portions of the processed sample are given in table 11, chemical analyses in table 12, and norms in table 13. In the calculation of the norms, total water, Cl, and F were omitted, and the remaining 12 oxides were recalculated to 100 percent.

TABLE 11.—*Sieve analyses of quartz latite, QLO-1, in percent*

[Tr., trace)]

Thirds	1	2	3	Avg
Sieve size:				
+100	0.1	Tr.	0.1	0.1
—100+120	.1	Tr.	.1	.1
—120+170	1.1	1.0	1.1	1.1
—170+200	2.3	1.9	2.2	2.1
—200	96.4	97.1	96.5	96.6
Total	100.0	100.0	100.0	100.0

TABLE 12.—*Chemical analyses of QLO-1*

[In weight percent. Method of Peck (1964). Analysts: bottle 9/23, V. C. Smith; bottle 51/6, E. L. Munson]

Bottle No	9/23	51/6
SiO_2	65.91	65.96
Al_2O_3	16.34	16.35
Fe_2O_3	.97	1.01
FeO	3.0	2.96
MgO	1.00	1.05
CaO	3.19	3.22
Na_2O	4.22	4.28
K_2O	3.60	3.61
H_2O+	.28	.25
H_2O-	.16	.21
TiO_2	.61	.60
P_2O_5	.25	.26
MnO	.10	.09
CO_2	.01	.01
Cl	.02	.03
F	.03	.03
Subtotal	99.69	99.92
Less O	.02	.02
Total	99.67	99.90

TABLE 13.—*Norms (CIPW) of QLO-1 in weight percent*

Bottle No	9/23	51/6
Quartz	18.4	17.9
Corundum	.3	.2
Orthoclase	21.4	21.5
Albite	36.0	36.4
Anorthite	14.2	14.3
Enstatite	2.5	2.6
Ferrosilite	3.9	3.8
Magnetite	1.4	1.5
Ilmenite	1.2	1.1
Apatite	.6	.6
Total	99.9	99.9

Spectrographic determinations of several elements, including Mn and Ti normally classified as minor elements and reported as oxides in a rock analysis, are given in table 14. The analysis of variance was used to determine the significance of the sources of variation in the data for the 12 elements for which the three laboratories reported duplicates on their bottles. Laboratory averages for all data reported, plus grand averages, standard deviations, and conclusions of significance from the analysis of variance, are given in table 15.

The data in table 15 indicate that, except for Sr, the variation attributable to the thirds of the lot from which the sample bottles were selected is not significantly larger than the error term against which they were tested. The variation of the Sr data attributable to thirds is significant at the upper 5 percent of the *F* distribution, but that due to laboratories is not.

The variation attributable to laboratories is not significant for Co, Cu, Pb, Sr, Yb, and Mn, but it is significantly larger than the pooled error mean square for the remaining elements in table 15 for which estimates are given. The significance of the laboratory variation at $F_{0.99}$ for barium confirms the often-noted observation that the determination of this element by optical emission spectroscopy is not too precise.

Estimates of the laboratory standard deviations, obtained after partitioning the mean square for laboratories into its variance components, have been entered in table 15. During testing of the significance of the variation attributable to laboratories, *F* ratios of less than 1 were obtained for the Co, Cu, and Pb data. The variance for the analytical error is obviously greater than the mean squares due to laboratories, resulting in negative values for the laboratory variance when the variance components are partitioned. The laboratory standard deviations for Co, Cu, and Pb have been entered as negative in table 15.

Preliminary determinations of uranium and thorium for another study yielded estimates of about 3.4 ppm Th and 1.6 ppm U, with a resultant Th:U ratio of about 2.2 These data are slightly higher than those for some selected reference igneous suites given by Tilling and Gottfried (1969) but they are fairly typical of similar volcanic rocks of the circumpacific region.

Data on the thorium, uranium, and potassium con-

TABLE 14.—*Spectrochemical determinations of elements in QLO-1*

[In parts per million. Method of Bastron and others (1960)]

Laboratory	Washington			Denver			Menlo Park		
Bottle No.	10/23	31/22	51/30	9/23	31/31	51/6	9/30	31/32	52/1
B	40	30	30	----	----	----	40	40	40
	30	30	40	----	----	----	50	40	40
Ba	1,400	1,400	1,100	1,400	1,300	1,300	1,600	1,500	1,400
	1,100	1,200	1,100	1,500	1,200	1.200	1,500	1,300	1,500
Be	----	----	----	----	----	----	2	2	2
	----	----	----	----	----	----	2	2	2
Co	7	8	5	6	7	7	7	6	8
	7	11	7	7	6	6	6	6	8
Cr	----	----	----	2	2	2	1	1	1
	----	----	----	2	2	2	1	1	4
Cu	28	33	29	32	32	32	28	28	28
	36	33	28	30	30	31	32	32	32
Ga	12	12	11	20	21	20	----	----	----
	14	17	12	19	18	18	----	----	----
Mo	----	----	----	----	----	----	4	3	4
	----	----	----	----	----	----	4	4	4
Nb	----	----	----	10	10	10	26	24	22
	----	----	----	10	10	10	22	20	18
Ni	----	----	----	----	----	----	3	2	3
	----	----	----	----	----	----	1	2	2
Pb	20	20	20	20	20	20	20	13	16
	10	40	10	20	20	30	20	14	18
Sc	11	11	9	9	9	9	9	9	9
	10	14	10	9	10	10	9	8	10
Sr	420	360	320	420	370	360	380	320	380
	380	280	320	430	360	330	380	320	320
V	60	42	40	84	79	73	64	46	56
	41	46	32	81	73	81	62	72	66
Y	40	40	30	20	20	20	40	40	40
	30	50	30	20	30	30	30	30	40
Yb	2	2	2	2	2	2	2	2	2
	2	3	2	3	3	3	2	2	2
Zr	130	150	110	160	160	160	180	170	200
	130	200	120	150	160	160	190	210	180
Mn	730	500	680	610	690	640	500	640	600
	720	790	740	640	650	650	600	500	700
Ti	4,400	4,000	3,400	2,800	3,100	3,100	3,700	3,500	3,800
	3,800	5,400	3,500	2,900	3,100	3,000	4,000	3,500	3,400

TABLE 15.—*Averages and standard deviations for spectographic data for QLO-1*

[In parts per million. S, significant, NS, not significant, when tested against $F_{0.95}$. d.f., degrees of freedom]

Element	Laboratory averages			Grand average	Conclusions from analysis of variance		Standard deviation	
	Washington	Denver	Menlo Park		Thirds	Laboratories	Laboratories (d.f.=2)	Error (d.f.=13)
B	33	----	42	----	---	---	---	---
Ba	1,210	1,320	1,460	1,330	NS	S	170	110
Be	----	----	2	----	---	---	---	---
Co	7.5	6.5	6.8	6.9	NS	NS	Neg.	1.4
Cr	----	2	1.5	----	---	---	---	---
Cu	31	31	30	30.8	NS	NS	Neg.	2.4
Ga	13	19	----	----	---	---	---	---
Mo	----	----	3.8	----	---	---	---	---
Nb	----	10	22	----	---	---	---	---
Ni	----	----	2	----	---	---	---	---
Pb	20.0	21.7	16.8	19.5	NS	NS	Neg.	7.3
Sc	10.8	9.3	9.0	9.7	NS	S	.86	1.1
Sr	347	378	350	358	S	NS	14	26
V	43.5	78.5	61.0	61.0	NS	S	17	7.7
Y	36.7	23.3	36.7	32.2	NS	S	7.2	6.3
Yb	2.2	2.5	2.0	2.2	NS	NS	.19	.41
Zr	140	158	188	162	NS	S	23	19.4
Mn	693	647	590	643	NS	NS	41	78.3
Ti	4.080	3.000	3.650	3,570	NS	S	160	440

tents of rocks are essential for the calculation of radiogenic heat production and heat flow, and as such data are frequently obtained by gamma-ray spectrometry for which samples of about 0.5 kg may be required, another portion of the quartz latite was obtained and processed for gamma counting. After being processed the bulk sample was divided in half, and the portions were poured into two large plastic bags for storage. Sieve analyses representing the two halves of the finished product, QLO–γ, are given in table 16.

TABLE 16.—*Sieve analyses of QLO–γ, in percent*

Halves of bulk sample	1	2	Avg
Sieve sizes:			
+100	0.2	0.3	0.2
—100+120	.4	.6	.5
—120+170	2.7	3.1	2.9
—170+200	3.5	4.2	3.9
—200	93.1	91.8	92.5
Sum	99.9	100.0	100.0

Because it is almost inevitable that comparisons will be made of the thorium, uranium, and potassium contents of the two samples, QLO–1 and QLO–γ, nine bottles of QLO–1 were randomly selected from the bottled stock, and nine portions of QLO–γ were taken at random intervals during the final mixing of the bulk stock.

Duplicate determinations of uranium were made by the fluorimetric method of Grimaldi, May, and Fletcher (1952), and of K_2O by atomic-absorption spectrometry. The experimental design was that for a one-way analysis of variance with duplicate determinations per bottle or portion. The data and the analysis of variance are given in tables 17, 19, 20, and 22. The estimates derived therefrom are summarized in table 23.

TABLE 17.—*Determinations and analysis of variance of uranium in QLO–1*

[In parts per million. Fluorimetric method of Grimaldi and others (1952)]

Bottle	Determination		Total
	First	Second	
1	1.6	1.6	3.2
2	1.6	1.6	3.2
3	1.4	1.5	2.9
4	1.4	1.4	2.8
5	1.8	1.5	3.3
6	1.6	1.6	3.2
7	1.8	1.5	3.3
8	1.6	1.8	3.4
9	1.6	1.5	3.1
Grand total			28.4
Average			1.58

Analysis of variance

Source of variation	Sum of squares	Degrees of freedom	Mean sum of squares	F ratio
Bottles	0.15	8	0.0188	0.0188/0.0133=1.41
Within	.12	9	.0133	NS at $F_{0.95}$
Total	0.27	17		

TABLE 18.—*Determinations and analysis of variance of thorium in QLO–1*

[In parts per million. Arenazo III method of May and Jenkins (1965)]

Bottle	Determination			Total
	First	Second	Third	
1	4.3	4.4	3.3	12.0
2	3.6	3.5	3.0	10.1
3	3.4	3.2	3.3	9.9
4	2.1	2.4	3.3	7.8
5	3.1	2.9	2.7	8.7
6	4.2	4.6	2.7	11.5
7	3.7	3.4	3.3	10.4
8	3.6	4.2	2.4	10.2
9	4.0	3.6	2.4	10.0
Grand total				90.6
Average				3.36

Analysis of variance

Source of variation	Sum of squares	Degrees of freedom	Mean sum of squares	F ratio
Bottles	4.32	8	0.540	0.540/0.388=1.39
Within	6.99	18	.388	NS at $F_{0.95}$
Total	11.31	26		

TABLE 19.—*Determinations and analysis of variance of K_2O in QLO–1*

[In weight percent. Determined by atomic absorption]

Bottle	Determination		Total
	First	Second	
1	3.60	3.58	7.18
2	3.59	3.60	7.19
3	3.61	3.58	7.19
4	3.58	3.58	7.16
5	3.58	3.56	7.14
6	3.58	3.56	7.14
7	3.58	3.58	7.16
8	3.57	3.59	7.16
9	3.58	3.58	7.16
Grand total			64.48
Average			3.582

Analysis of variance

Source of variation	Sum of squares	Degrees of freedom	Mean sum of squares	F ratio
Bottles	0.0012	8	0.00015	0.00015/ 0.000144=1.04
Within	.0013	9	.000144	NS at $F_{0.95}$
Total	.0025	17		

TABLE 20.—*Determinations and analysis of variance of uranium in QLO–γ*

[In parts per million. Method of Grimaldi and others (1952)]

Portions	Determination		Total
	First	Second	
1	1.8	1.6	3.4
2	1.3	1.4	2.7
3	1.6	1.6	3.2
4	1.5	1.8	3.3
5	1.6	1.6	3.2
6	1.8	1.7	3.5
7	1.3	1.6	2.9
8	1.5	1.8	3.3
9	1.3	1.6	2.9
Grand total			28.4
Average			1.58

TABLE 20.—*Determinations and analysis of variance of uranium in QLO–γ*—Continued

Analysis of variance

Source of variation	Sum of squares	Degrees of freedom	Mean sum of squares	*F* ratio
Portions	0.2812	8	0.03515	0.03515/ 0.02333=1.51 NS at $F_{0.95}$
Within	.2100	9	.02333	
Total	.4912	17		

TABLE 21.—*Determinations and analysis of variance of thorium in QLO–γ*

[In parts per million. Arsenazo III method of May and Jenkins (1952)]

Thirds	Determination First	Second	Third	Total
1st	3.0	2.3	4.2	9.5
2d	4.1	3.6	3.5	11.2
3d	3.2	3.9	3.9	11.0
Grand total				31.7
Average				3.52

Analysis of variance

Source of variation	Sum of squares	Degrees of freedom	Mean sum of squares	*F* ratio
Thirds	0.576	2	0.288	0.288/0.397= <1 NS
Within	2.380	6	.397	
Total	2.956	8		

TABLE 22.—*Determinations and analysis of variance of K_2O in QLO–γ*

[In weight percent. Determination by atomic absorption]

Bottle	Determination First	Second	Total
1	3.583	3.580	7.163
2	3.572	3.580	7.152
3	3.580	3.580	7.160
4	3.580	3.580	7.160
5	3.600	3.590	7.190
6	3.580	3.580	7.160
7	3.573	3.565	7.138
8	3.580	3.580	7.160
9	3.580	3.598	7.178
Grand total			64.461
Average			3.581

Analysis of variance

Source of variation	Sum of squares	Degrees of freedom	Mean sum of squares	*F* ratio
Portions	0.00087	8	0.000109	0.000109/ 0.0000311=3.50 S at $F_{0.95}$, NS at $F_{0.99}$
Within	.00028	9	.0000311	
Total	0.00115	17		

TABLE 23.—*Estimates of the U, Th, and K_2O contents, and of the Th:U ratio, of QLO–γ and QLO–1*

[See tables 17–22. Nonsignificant digits shown as subscripts]

Average and standard deviation	QLO–γ Estimate	QLO–γ Degrees of freedom	QLO–1 Estimate	QLO–1 Degrees of freedom	QLO–γ and QLO–1 Estimate	QLO–γ and QLO–1 Degrees of freedom
K_2O (percent)						
Average	3.58_1	----	3.58_2	----	3.58_2	----
Standard deviation:						
Bottles or portions	$.006_2$	8	.002	8	----	----
Analytical error	$.005_6$	9	.012	9	$.009_4$	18
U (ppm)						
Average	1.5_8	----	1.5_8	----	1.5_8	----
Standard deviation:						
Bottles or portions	$.02_4$	8	$.05_2$	8	----	----
Analytical error	.15	9	.12	9	.14	18
Th (ppm)						
Average	3.5_2	----	3.3_6	----	3.4_0	----
Standard deviation:						
Bottles	-----	----	.23	8	----	----
Analytical error	.63	6	.62	18	.62	24
Th:U ratio						
Average	2.23	----	2.13	----	2.15	----
Standard deviation (analytical error)	.42	15	.51	27	.48	42

Because of an oversight during the sampling for the determinations of thorium, three portions for analysis were taken from the bottles of QLO–1 but the nine portions of QLO–γ were sampled only once. The thorium determinations by the arsenazo III method of May and Jenkins (1965), the analysis of variance table, and the estimate of the thorium content of QLO–1 are given in table 18. During the random selection of bottles of QLO–1 or of portions of QLO–γ, the additional restraint was imposed that the bottles or portions herein numbered 1 to 3, 4 to 6, and 7 to 9 should also be selected from among the 1st, 2d, and 3d thirds, respectively, of the entire lot sampled. Because of this precaution, the nine single determinations of thorium in QLO–γ were treated as a one-way experimental design with the three thirds of the bulk sample as the variable of classification and with the single determinations on the nine portions considered as replicate analyses within their proper thirds. The data and the analysis of variance table are given in table 21.

The estimates for the thorium, uranium, and K_2O contents of the two samples are summarized in table 23 where nonsignificant digits are shown as subscripts. The source of variation termed "within" in the analysis of variance tables has been called analytical error in table 23 as it represents any variation not attributable to the main variable of classification of either bottles or portions. Most of the error so included probably represents the error of the analytical method, that associated with sampling heterogeneous material, and random error.

F ratios between the two samples for the comparable mean squares of the K_2O and of the uranium data, and of only the analytical error for the thorium data, yield one significant ratio, that of the analytical error for K_20, 0.000144/0.0000311=4.63, which is greater than $F_{0.95}$(d.f.=9, 9)=3.18 but less than $F_{0.99}$(d.f.=9, 9)=5.35. The same analyst made all K_2O determinations, and the slightly higher variance for the one set of data may reflect instrumental differences that cannot be separated by the simple design used. We have considered the tested mean squares homogeneous and have pooled the comparable pairs of sums of squares and degrees of freedom for analytical error to obtain the combined estimates in table 23. The standard deviations among bottles or portions are tabled separately as the sampling unit is different for QLO–1 and QLO–γ, and the necessary change in the experimental design for QLO–γ reduces further any comparability between the two sets of these Th data.

The uranium contents of the two samples are identical, the K_2O contents nearly so, and the thorium contents differ slightly but not significantly. The average ratios for Th:U are tabled with the analytical standard deviation and degrees of freedom. Analysts may wish to use our estimates for the samples to judge the appropriateness of their own data.

REFERENCES CITED

Bastron, Harry, Barnett, P. R., and Murata, K. J., 1960, Method for the quantitative spectrochemical analysis of rocks, minerals, ores, and other materials by a powder d-c arc technique: U.S. Geol. Survey Bull. 1084–G, p. 165–182.

Grimaldi, F. S., May, Irving, and Fletcher. M. H., 1952, U.S. Geological Survey fluorimetric methods of uranium analysis: U.S. Geol. Survey Circ. 199, 20 p.

May, Irving, and Jenkins, L. B., 1965, Use of arsenazo III in determination of thorium in rocks and minerals, in Geological Survey Research 1965: U.S. Geol. Survey Prof. Paper 525–D, p. D192–195.

Nockolds, S. R., 1954, Average chemical compositions of some igenous rocks. Geol. Soc. America Bull., v. 65, no. 10. p. 1007–1032.

O'Connor, J. T., 1965, A classification for quartz-rich igneous rocks based on feldspar ratios *in* Geological Survey Research 1965: U.S. Geol. Survey Prof. Paper 525–B, p. B79–B84.

Peck, L. C., 1964, Systematic analysis of silicates. U.S. Geol. Survey Bull. 1170, 89 p.

Rittman, Alfred, 1952, Nomenclature of volcanic rocks: Bull. Volcanol., ser. 2, v. 12, p. 75–102.

Tilling, R. I., and Gottfried, David, 1969. Distribution of thorium, uranium, and potassium in igneous rocks of the Boulder batholith region, Montana, and its bearing on radiogenic heat production and heat flow: U.S. Geol. Survey Prof. Paper 614–E, 29 p.

Wahlstrom, E. E.. 1955, Petrographic mineralogy: New York, John Wiley and Sons, Inc.. 408 p.

Walker, G. W., and Repenning, C. A., 1965, Reconnaissance geologic map of the Adel quadrangle, Lake, Harney, and Malheur Counties, Oregon: U.S. Geol. Survey Misc. Geol. Inv. Map I–446, scale 1:250,000.

CODY SHALE, SCo-1, FROM NATRONA COUNTY, WYOMING

By L. G. SCHULTZ, H. A. TOURTELOT, and F. J. FLANAGAN

Sample SCo-1 was collected in 1963 by J. R. Gill and R. E. Burkholder from a bulldozer cut in an abandoned road on the west side of Teapot Dome in the SE¼SE¼ sec. 4, T. 38 N., R. 78, W., Natrona County, Wyo. (fig. 4). It is from the upper part of the Cody Shale just above the base of the *Baculites perplexus* range zone in rocks stratigraphically equivalent to the Claggett Shale to the north and the Mitten Black Shale Member of the Pierre Shale to the east (Gill and Cobban, 1966, pl. 3, loc. 10). The exact location and stratigraphic relations of the sample are shown in figure 5.

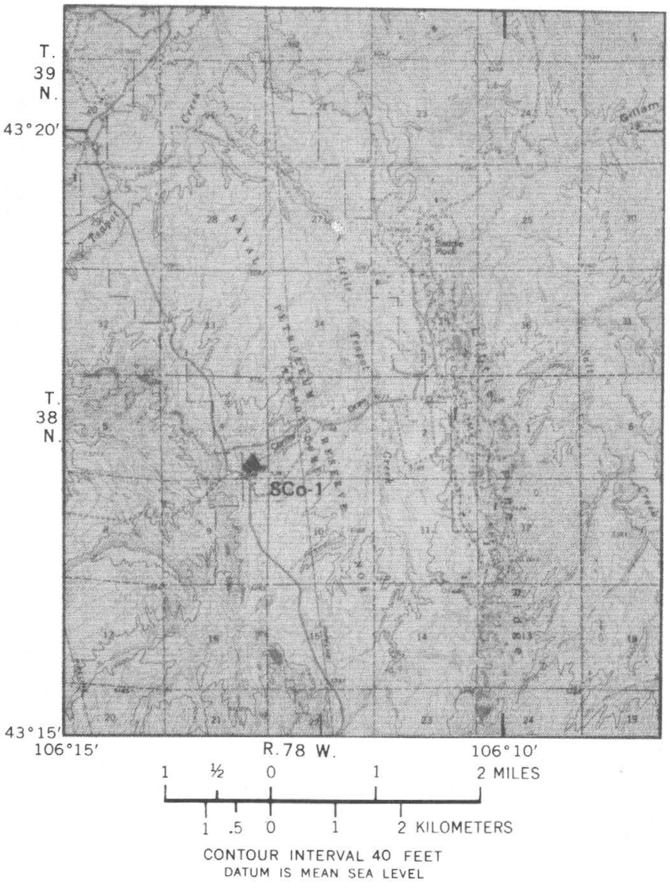


FIGURE 4.—Southwest corner of Edgerton quadrangle, Wyoming, showing source of SCo-1. Base from U.S. Geological Survey 15-min quadrangle, 1959.

Sample SCo-1 is typical of the Upper Cretaceous silty marine shales intermediate between the fine-grained offshore marine shales common farther to the east and the coarser nearshore marine siltstones and sandstone such as those in the Parkman Sandstone overlying it (fig. 5). The rock is a medium-dark-gray (Munsell N-4) silty shale having thin lighter colored silty laminations. Mineralogical composition, estimated from the X-ray diffractometer method of Schultz (1964), is (in percent) 29 quartz, 6 dolomite, 6 plagioclase, about 1 potassium feldspar, 5 kaolinite, 2 chlorite, 10 illite, and 40 of a mixed-layer clay mineral composed of about three-fourths nonexpanding illite-like layers and two fifths expanding montmorillonite-like layers. Judged from the chemical analysis (table 25), the sample also may contain pyrite, apatite, and gypsum in amounts too small to be detected in the diffractometer analysis.

Thin-section examination shows the shale to be made up of interlaminated clay and clayey silt in proportions of about 2 to 1. The clay laminae contain about 8 percent quartz and 1 percent each of muscovite and dolomite. Biotite is present in smaller amounts. Typical quartz grains measure about 0.02 by 0.01 mm, and the sharply angular elongated shape is characteristic. Several grains as large as 0.05 mm were noted. The dolomite grains are about 0.02 by 0.02 mm and are rudely euhedral with indistinct boundaries such as might be expected of grains of diagenetic origin. The sparse biotite grains are pale and frayed; a typical grain measures 0.05 by 0.01 mm. The muscovite is much more flaky; several grains measure about 0.025 by 0.002 mm.

The silty laminae contain 30-35 percent quartz, 10 percent dolomite, and minor amounts of mus-

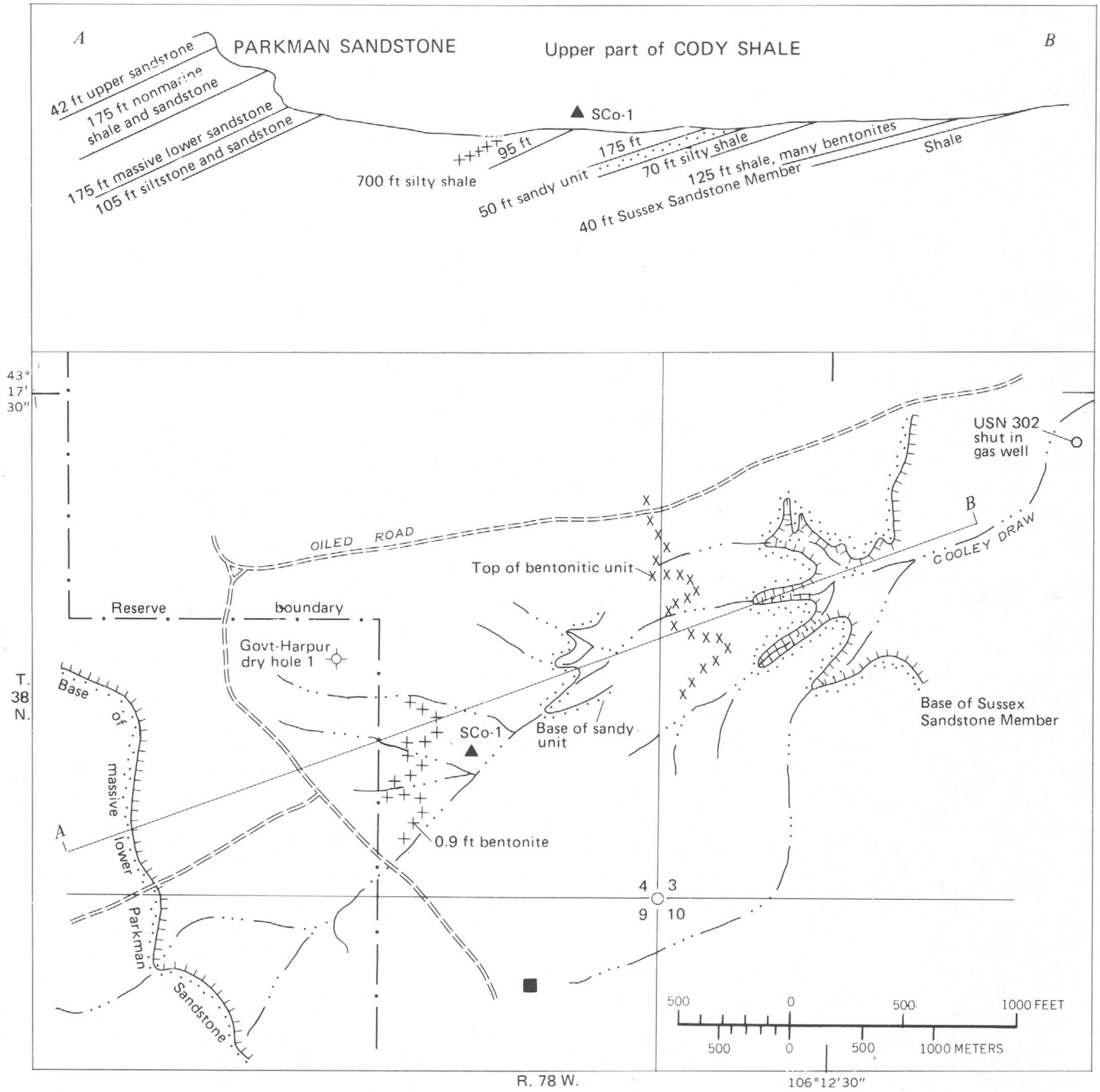


FIGURE 5.—Plane table sketch map and diagrammatic cross section showing the rocks in the immediate area of the source of SCo-1. Mapped by J. R. Gill and L. G. Schultz.

covite and biotite. The quartz grains are angular and elongate and average about 0.09 by 0.02 mm. Poorly formed dolomite rhombs measure about 0.04 by 0.04 mm. A very minor part of the dolomite seems to fill voids. Biotite measures about 0.075 by 0.01 mm, and the more flaky muscovite measures 0.15 by 0.01. A few greenish grains of indistinct character seem to represent alteration products of femic minerals. Several pellets of glauconite were noted.

Iron oxides in thin stringers seem to be oxidation products of pyrite, and pyrite may be present but obscured by the iron oxides. Particulate organic matter with high reflectance, and hence probably coaly in nature, forms films along bedding planes.

The clay is highly oriented parallel to bedding.

Recognizable compaction features consist of clay flakes wrapped around quartz grains in both the clay laminae and silt laminae. The clay matrix has a mass apparent birefringence of lower first order red, and individual clay minerals could not be recognized.

Feldspar grains could not be recognized in thin section.

The amount of quartz inferred from the X-ray analysis is nearly double that determined from the microscopic examination. Analyses by particle size of numerous samples similar to SCo–1 indicate that much of the quartz is in particles less than 2 μm equivalent settling diameter and therefore is unlikely to be identified microscopically.

Measured bulk and powder densities of 2.20 and 2.55, respectively, have been obtained by Paul Elmore.

The sample was processed in the normal fashion (Flanagan, 1967), and sieve analyses representing the three thirds of the finished product are shown in table 24. During ball milling a comparatively large amount of sample adhered to the balls and the liner of the mill, and probably the moisture content of the sample may be partly responsible. The material that was retained on the 100-mesh screen during sieve tests is readily friable and can easily be reduced to powder between the fingers. The material in the sealed bottles shows a tendency to "ball," and therefore the sample should be dried at 105°C before analysis. The chemical analysis and semiquantitative estimates of some trace elements are given in tables 25 and 26.

TABLE 24.—*Sieve analyses of SCo–1, in percent*

Thirds	1	2	3	Avg
Sieve size:				
+100	1.0	2.0	1.4	1.5
—100+120	0	.2	.3	.2
—120+170	.6	.5	.4	.5
—170+200	1.0	.8	1.4	1.1
—200	97.4	96.4	96.5	96.7
Total	100.0	99.9	100.0	100.0

TABLE 25.—*Chemical analysis of SCo–1*

[Analyst: Sarah M. Berthold]

Constituent	Weight percent
SiO_2	61.84
Al_2O_3	13.40
Fe_2O_3	3.83
FeO	1.15
MgO	2.69
CaO	2.68
Na_2O	.97
K_2O	2.8
H_2O+[1]	3.85
H_2O-	2.45
TiO_2	.83
P_2O_5	.44
MnO	.05
CO_2[2]	2.55
SO_3[3]	.44
Cl	.16
F	.15
S	.12
Organic material	.18
Subtotal	100.58
Less O=Cl	.04
Less O=F	.06
Less O=S	.06
Total	100.42

[1] Corrected for Organic $H \rightarrow H_2O+$, assuming organic material contains 5 percent hydrogen.
[2] Acid evolution.
[3] Sulfate soluble in HCl.

TABLE 26.—*Semiquantitative spectrographic estimates of some trace elements in SCo–1*

[Ag was detected but could not be estimated. Other elements were not detected. Analyst: Joseph J. Harris]

Element	Parts per million
B	70
Ba	300
Be	1
Ce	100
Co	10
Cr	70
Cu	30
Ga	10
La	50
Nb	15
Ni	30
Pb	15
Sc	10
Sr	200
V	100
Y	30
Yb	3
Zr	150

REFERENCES CITED

Flanagan, F. J., 1967, U.S. Geological Survey silicate rock standards: Geochim. et Cosmochim. Acta, v. 31, no. 3, p. 289–308.

Gill, J. R., and Cobban, W. A., 1966, The Red Bird section of the Upper Cretaceous Pierre Shale in Wyoming: U.S. Geol. Survey Prof. Paper 393–A, 69 p.

Schultz, L. G.. 1964, Quantitative interpretation of mineralogical composition from X-ray and chemical data for the Pierre Shale: U.S. Geol. Survey Prof. Paper 391–C, 31 p.

DESCRIPTIONS AND ANALYSES OF EIGHT NEW USGS ROCK STANDARDS

MARINE MUD, MAG–1, FROM THE GULF OF MAINE

By F. T. MANHEIM, J. C. HATHAWAY, F. J. FLANAGAN, and J. D. FLETCHER

Another sample for the standards program is MAG–1, a fine-grained gray-brown clayey mud from the Wilkinson Basin of the Gulf of Maine. The sample, collected by the Woods Hole Oceanographic Institution R/V *Gosnold,* Jobst Hülseman, scientist-in-charge, was obtained with a 125-l Campbell grab sampler (clamshell type) from a depth of 282 m at lat 42°34.6′ N., long 69°32.6′ W. (Loran A), about 125 km east of Boston, Mass. (fig. 6). The sample is from station 2197 of the joint U.S. Geological Survey-Woods Hole Oceanographic Institution continental margin program (Hathaway, 1971).

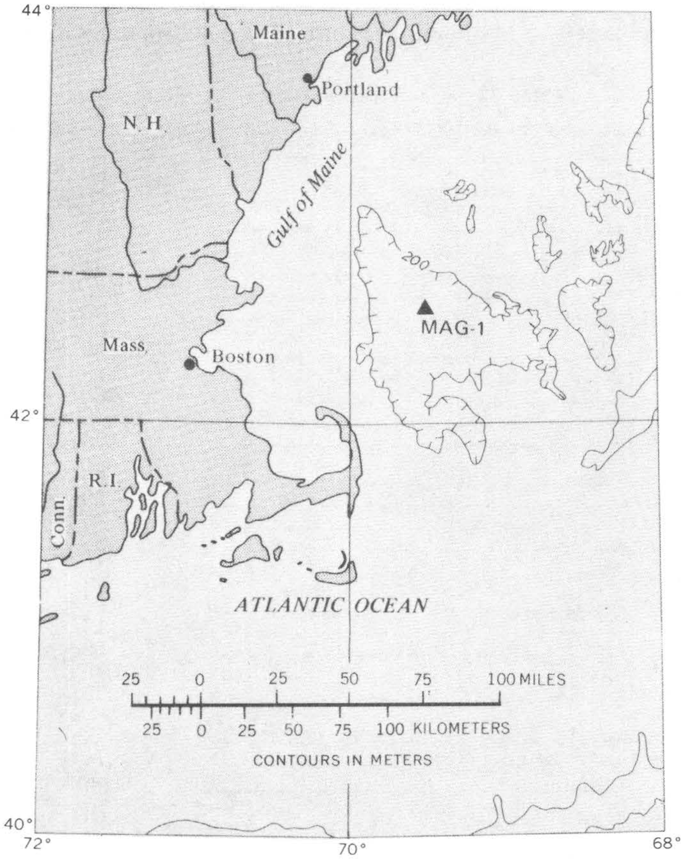


FIGURE 6.— Location of source of MAG–1 in the Wilkinson Basin, Gulf of Maine.

The bottom sediment is a gray-brown very fine-grained clayey mud with a low carbonate content. Benthonic fauna collected with the sample included mainly sparse worm tubes, scaphopods, and foraminifers; planktonic forms include sparse diatoms, spores and pollen, and foraminifers. The age of the sediment is Holocene, but it probably includes reworked Pleistocene sediments from surrounding areas. The sediment, as shipped, probably included more than 60 percent of its bulk weight as seawater having an estimated salinity of about 33–34 g/kg. The salts are assumed to be in essentially the same proportions as in seawater. Soluble constituents reported in analyses may partly reflect modifications of the original salts resulting from the action of the water on the sediment during the drying process.

The sample was shipped to the laboratory in 30-gal polyethylene containers, and the sediment was allowed to settle for several weeks. Because of the size of the sample, no attempt was made to leach the soluble salts. The water (about 4–5 l) then remaining above the sediment in each container was decanted, and portions of the mud were transferred to pyrex dishes and dried at 170° F. Lumps of sample formed during the drying process were broken every several hours to ensure complete drying. The dried sample was passed through a rolls crusher to ensure the absence of lumps and was then transferred to a ball mill to complete the normal processing previously described (Flanagan, 1967).

The grain-size characteristics of the sediment are given in table 27. The mineralogy of the bulk sample and of the clay fraction as determined by X-ray diffractometer analyses are given in tables 28 and 29, and the mineralogy of the sand fraction is given in table 30.

TABLE 27.—*Grain-size characteristics of the marine mud MAG–1*

[Wentworth scale unless otherwise indicated. Determinations made under supervision of J. S. Schlee]

Component	Weight percent
Gravel	0.0
Sand	.1
Silt (62–4 μm)	19.5
Clay (4–2 μm)	18.0
Clay (<2 μm)	63.4
Parameters of particle size distribution	
Mode	8.6 phi (about 4 μm)
Median	9.88 phi
Mean	9.92 phi
Standard deviation	2.2 phi
Skewness	0.02
Kurtosis	—0.32

TABLE 28.—*Bulk mineralogy of MAG-1 determined by X-ray diffractometer*

Constituent	Weight percent
Quartz	6
Potassuim feldspar	0
Plagioclase feldspar	7
Calcite	0
Layer silicates	83
Hornblende	0
Pyrite	1

TABLE 29.—*Mineralogy of the clay fraction (<2 μm) of MAG–1 determined by X-ray difractiometer*

Constituent	Concentration in units of parts per 10
Montmorillonite	Trace to 1
Chlorite	2
Illite	5
Kaolinite	1
Feldspar	1
Quartz	Trace
Hornblende	Trace

TABLE 30.—*Mineralogy of the sand fraction of MAG–1*

[Determinations by J. V. A. Trumbull]

Constituent	Weight percent
Rock fragments	3
Quartz and feldspar	63
Dark minerals	1
Glauconite	3
Mica	.1
Foraminifers	30

TABLE 31.—*Sieve analyses of MAG–1, in percent*

Thirds	1	2	3	Avg
Sieve size:				
+100	4.0	5.5	7.5	5.7
—100+120	.6	.5	.5	.5
—120+170	1.1	2.2	2.2	1.8
—170+200	.8	.8	1.0	.9
—200	93.4	91.0	88.8	91.1
Total	99.9	100.0	100.0	100.0

The size analyses of the processed sample (table 31) show that the proportion of +100–mesh material increases from the first to the last third of the lot of bottled samples. Much of the material consists of friable platy clay aggregates not present in the original sample (table 27). These aggregates were probably formed during the drying of the wet sample and did not disaggregate in the ball mill. Possibly the increase in coarse material occurs because the platy aggregates concentrated near the top of the bulk material being tumbled in the blender. Analysts may wish to make sure of sample homogeneity by hand-grinding the contents of bottles to reduce the platy aggregates to powder.

The chemical analysis of the sample is given in table 32, and quantitative spectrographic determinations of some trace elements are given in table 33. Because the sediment was processed without prior leaching of soluble salts, the powdered material may contain about 4 percent evaporated seawater salts. These salts, predominately NaCl, have an appreciable effect on the Na and S contents and contribute virtually all the Cl. If we can assume that the salinity was 33.5 g/kg, typical for bottom water from the Gulf of Maine, with a corresponding chlorinity of 18.7 g/kg, and that all Cl in the sample is derived from seawater, one can calculate that the seawater amounted to about 62 percent of the sediment. Other

TABLE 32.—*Chemical analysis of MAG–1*

[Analyst: S. M. Berthold. Organic constituents by J. H. Chandler]

Constituent	Weight percent
SiO_2	49.74
Al_2O_3	16.44
Fe_2O_3	2.64
FeO	3.65
MgO	2.98
CaO	1.50
Na_2O	3.9
K_2O	3.6
H_2O+[1]	5.22
H_2O-	2.58
TiO_2	.70
P_2O_5	.32
MnO	.10
CO_2[2]	.51
SO_3[3]	.15
Cl	2.86
F	.12
S	.52
Organic C	1.43
Organic N	.08
Organic H	.12
Organic remainder (=O?)	.74
Subtotal	(99.90)
Less O=Cl	.64
Less O=F	.05
Less O=S	.26
Total	(98.95)

[1] Corrected for Organic $H \rightarrow H_2O+$.
[2] Acid evolution.
[3] Sulfates soluble in HCl.

TABLE 33.—*Quantitative spectrographic determinations (in parts per million) of trace elements in marine mud, MAG–1*

Element	Spectral line	Thirds and bottle number (below)					
		1		2		3	
		4/21	18/23	35/31	38/20	59/22	60/10
B	I 2497.73	120	140	120	120	130	140
		130	130	120	140	140	130
Ba	II 4554.0	540	540	520	480	560	480
		440	420	400	420	520	600
Co	I 3453.50	16	19	19	18	15	17
		16	20	19	20	15	17
Cr	I 3021.56	130	120	120	100	120	120
		130	120	140	120	120	110
Cu	I 3273.96	46	50	44	46	50	48
		48	50	52	50	52	50
Ga	I 2943.64	22	19	18	22	20	24
		20	22	20	20	20	24
Ni	I 3413.94	42	52	50	44	50	52
		50	52	56	56	50	54
Sc	II 4246.83	19	19	19	17	19	19
		17	19	19	17	19	17
Sr	I 4607.33	180	150	170	170	170	140
		120	160	190	170	140	140
V	I 3183.41	120	130	130	120	140	130
		120	150	150	110	130	150
Y	II 3327.88	58	58	62	60	60	56
		58	58	56	50	58	52
Yb	3289.37	3.8	3.0	3.0	2.4	3.2	3.2
		3.2	3.0	3.2	3.0	3.6	4.0
Zr	II 3279.26	140	130	130	120	140	120
		130	120	130	120	130	120

constituents less influenced by the evaporated salts are Mg, Ca, K, and CO_2. The sediment-associated amounts of B and Sr may be slightly enhanced as a result of dried interstitial salt, but most other trace elements should not be appreciably affected.

J. Hülseman and coworkers (written commun., 1969) found 1.9 percent organic carbon, 1.8 percent calcium carbonate, and 0.27 percent Kjeldahl nitrogen in a portion of the sample taken before shipment to the laboratory, and these data yield a C:N ratio of 7.0. Differences between the above data for the organic carbon, the Kjeldahl nitrogen, and the CO_2 equivalent of the carbonate value, and their equivalents(?) in table 32 may be partly due to processing.

Defining processing as anything that happened to the sample between the time of collection and the end of drying, one can assume that two possible causes of such differences are the decantation of the supernatent seawater in the laboratory and the drying of the mud at 170° F (76° C). One should not ignore possible losses due to evaporation or steam distillation during the isolation of the organic material that was separated in the laboratory by repeated HF–HCl treatment, followed by washing with distilled water and drying at 110° C. One might also question the correction of H_2O+ for the contribution due to the assumed total conversion of the organic hydrogen to water. Because of these possible uncertainties, both the subtotal and the total of the analysis in table 32 are enclosed in parentheses. The total of the analysis for MAG–1 is below the range generally considered acceptable by rock analysts, and analyses of portions of the sample from which soluble salts have been leached will undoubtedly result in better data and in acceptable totals.

Salt residues such as $MgCl_2$ and some complex chlorides and sulfates are hygroscopic, and the powdered sample is probably even more hygroscopic now than it might ordinarily have been because of the high clay content alone. The processed sample showed a slight tendency to "ball" during and after the splitting and bottling operations, and it is recommended that determinations be made on dried (105° C) portions or that analyses on an "as received" sample also show hygroscopic moisture, separately determined. It is not anticipated that the "balling" of the powdered material will result in heterogeneity as the sample was well mixed during the ball milling and blending operations.

The mention of "balling" may raise doubts, and to determine if the homogeneity of the sample has been affected, a suite of 13 trace elements was determined spectrographically in six bottles of MAG–1. The first six bottles that fulfilled the requirement that two bottles should represent each third of the lot of samples were selected from the stock of bottles stored in random order. Two subsamples were

TABLE 34.—*Conclusions from the analysis of variance and estimates of the spectrographic data from MAG–1*

[In parts per million. Conclusions: S, significant; NS, not significant. Unless otherwise indicated, the calculated ratios were compared to $F_{0.95}$. d.f., degrees of freedom]

Element	Conclusions		Mean (ppm)	Standard deviation	
	Thirds	Bottles		Bottles (d.f. = 3)	Error (d.f. = 6)
B	NS	NS	130	([1])	8.2
Ba	NS	[2]S	493	Neg.	70
Co	S (0.99)	S (0.99)	17.6	1.6	.64
Cr	NS	NS	121	7.1	8.6
Cu	NS	NS	48.8	Neg.	2.8
Ga	NS	NS	20.9	1.6	1.3
Ni	NS	NS	50.7	Neg.	4.5
Sc	NS	NS (0.99)	18.3	.91	.57
Sr	NS	NS	158	Neg.	20.4
V	NS (0.99)	NS	132	10.8	10.8
Y	NS	NS	57	.55	3.6
Yb	NS	NS	3.2	.10	.36
Zr	NS	NS (0.99)	128	7.6	5.0

[1] Indeterminate. The mean sums of squares for the variation attributable to error and to bottles within thirds were equal, resulting in the indeterminate division, 0/2.

[2] The variation attributable to bottles within thirds was significantly less than that for error at $F_{0.995}$.

taken from each bottle and individually diluted 1:1 with a mixture of 10 percent Na_2CO_3 in quartz. An amount of carbon equal to one-fourth of the weight of this mixture was added to the previous dilution, and this new dilution was then mixed. The samples and standards prepared similarly were loaded into electrodes, and the exposures were made in random order on the plate, yielding the data in table 33. An analysis of variance of the data for each element was made, and a summary of the conclusions and estimates is given in table 34.

Several mean sums of squares in table 34 are significantly larger than the error mean square and one, the mean square for bottles within thirds for Ba, is significantly less than the error mean square. Inspection of the cobalt data in table 33 shows that the sums of the determinations for individual bottles cluster at two points, the lower at about 32 ppm and the higher at slightly over 38 ppm. There are techniques for comparing means in the analysis of variance but the differences among bottles sums, and the even smaller differences among bottle means, are not analytically significant. Similarly, the differences among the sums of thirds, and among the means, are statistically but not analytically significant, and the average of all determinations, 17.6 ppm may be used to estimate the cobalt content of the sample. The mean square for thirds for vanadium and the mean squares for bottles for scandium and zirconium are also not analytically significant. These spectrographic data therefore indicate that the bottles are generally homogeneous and that the "balling" has had little, if any, effect.

Conclusions about the thirds of the entire lot of bottles yield only gross estimates of the homogeneity of the entire lot whereas similar conclusions for the bottles randomly selected for the test are more valuable as the unit of standard samples with which all analysts deal is a bottle. In a manner similar to what was done for samples STM–1, RGM–1, and QLO–1, the mean sum of squares for the variation attributable to bottles may be shown to be composed of the analytical variance plus *n* times the bottle variance, where *n* is the number of determinations made on the individual bottle. The bottle and error standard deviations are given in table 34. Four standard deviations in the table are negative (the error mean square was greater than that for the variation due to bottles), and one is indeterminate (the two mean squares are equal).

REFERENCES CITED

Flanagan, F. J., 1967, U.S. Geological Survey silicate rock standards: Geochim. et Cosmochim. Acta. v. 31, no. 3, p. 289–308.

Hathaway, J. C., ed., 1971, Data file, continental margin program, Atlantic Coast of the United States V. 2, Sample collection and analytical data: Woods Hole Oceanog. Inst. Ref. 71–15, 496 p.

DESCRIPTIONS AND ANALYSES OF EIGHT NEW USGS ROCK STANDARDS

MICA SCHIST, SDC-1, FROM ROCK CREEK PARK, WASHINGTON, D.C.

By F. J. FLANAGAN and G. V. CARROLL

A 200-lb sample of mica schist excavated from a sewer tunnel in the northern part of Rock Creek Park, Washington, D.C., was collected during the summer of 1963 to be processed as part of a rock sample program of the U.S. Geological Survey. At the time of collection the working face of the tunnel was approximately 400 ft north of Rock Creek, as shown in figure 7, at an estimated depth below

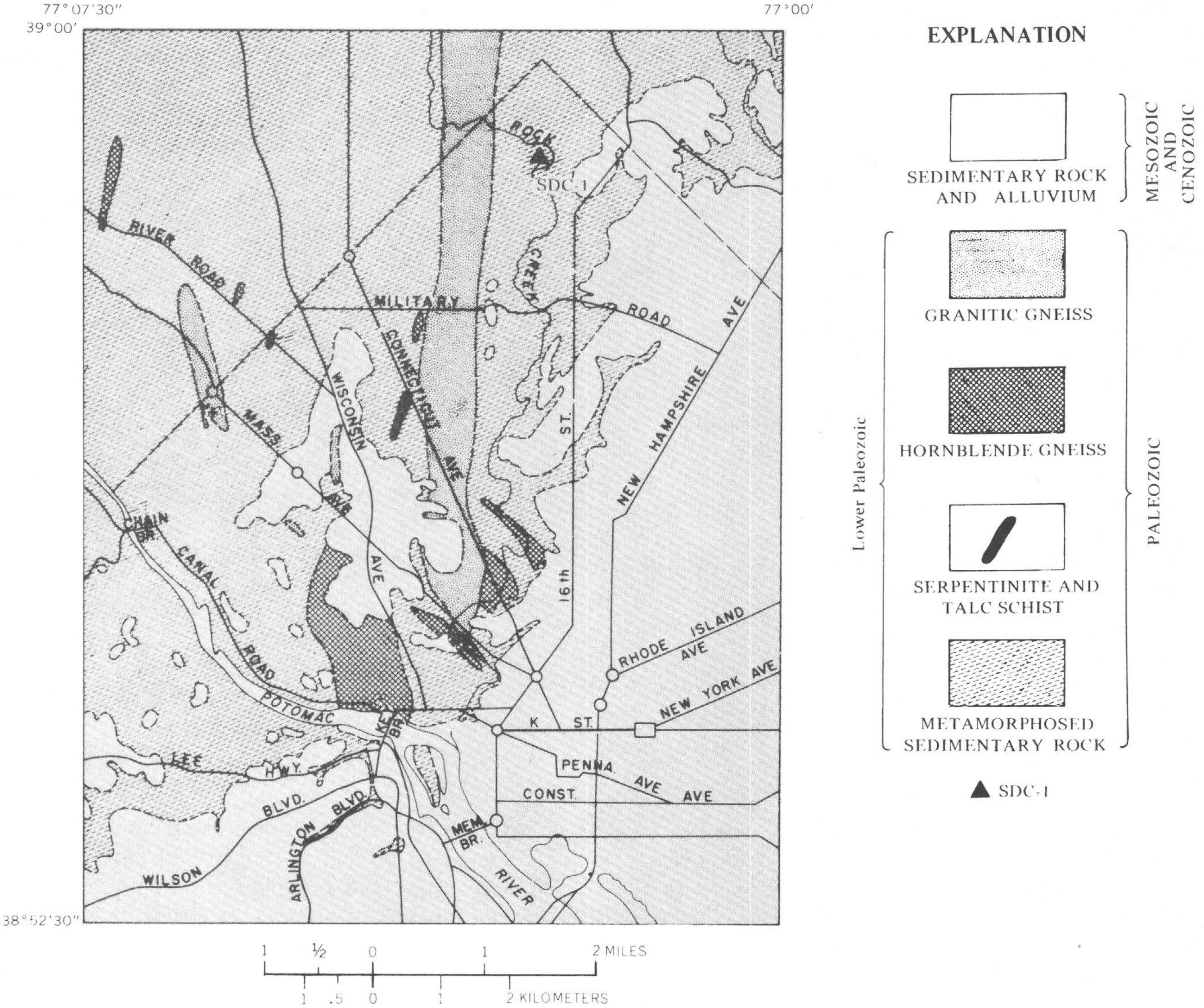


FIGURE 7.—Geologic sketch map of the Washington West quadrangle, District of Columbia-Maryland-Virginia, showing the source of SDC-1. Modified from Coulter and Carroll (1964).

the surface of 80 ft. The sample was selected from the freshest material on top of the dump and was assumed to have been the most recent increment directly from the existing working face. The entrance shaft was later covered during regrading, and the remaining material from the dump was used as riprap along Rock Creek.

The geology of the region was originally described by Darton and Keith (1901) and subsequently by Fellows (1950) and Cloos and Cooke (1953). Recent workers, Coulter and Carroll (1964) and Hopson (1964), assign these rocks to the Sykesville Formation which Southwick and Fisher (1967) refer to as the boulder gneiss lithofacies of the Wissahickon Formation of the Glenarm Series.

These rocks are probably of late Precambrian age and are probably no younger than Early Cambrian; the regional relations upon which these age assignments depend are well summarized by Hopson (1964) and Southwick and Fisher (1967).

The rock in hand specimen is a dark-grey pervasively foliated muscovite-quartz schist with a homogeneous thinly streaked texture, rather than one that is compositionally layered. Muscovite is conspicuous on foliation surfaces. Small ellipsoidal granules of quartz and feldspar, as much as 1–2 mm in diameter, make up 10–15 percent of the rock; individual pebbles of quartz 0.5–1 cm or larger are randomly scattered in the matrix at intervals of several centimeters. Inconspicuous grains of garnet as much as 2 mm in diameter are present in small amounts.

In thin section, quartz makes up about 45 percent of the matrix of the rock, plagioclase about 15, muscovite 20, biotite as much as 10, chlorite 2–3 and garnet 2–3. Very minor amounts of apatite, epidote, allanite, flaky ilmenite, pyrite, and magnetite(?) are present. Proportions are approximate and vary from one thin section to another. The percentage of quartz varies markedly among specimens, depending on the number and size of the quartz pebbles included.

The quartz pebbles are rounded and consist internally of several grains. Grains with straight boundaries display only weak undulose extinction whereas grains with sutured boundaries are characterized by strong undulose extinctions. Outer parts of the pebbles may be crushed to grain sizes like, and merging with, the matrix.

Plagioclase (An_{20-25}) is characteristically untwinned and has very weak zonal extinction. A minority of grains show close-set polysynthetic twinning much of which appears to be pericline twinning. The larger plagioclase grains are poikiloblastic and have strong amoeboid outlines. Some of the larger plagioclase grains, as much as 0.5 cm in diameter, have well-rounded cores densely crowded with finely divided muscovite. These cores are surrounded by inclusion-free jackets with amoeboid outlines against the matrix. Such pebbles are interpreted as original detrital grains surrounded by metamorphic overgrowths.

Mica and chlorite flakes are sharply outlined. The majority of flakes define the foliation, but many flakes cross foliation at higher angles. The larger flakes show minor kinking of cleavage, but no shredding. Garnet is subhedral to anhedral. In general, mineral grains have crystalloblastic textural relations to one another. This crystalloblastic texture postdates development of foliation. The few cataclastic features appear to be minor and incipient. Evidence presented elsewhere (Coulter and Carroll, 1964) indicates that foliation in these rocks, which originated as massive submarine slump deposits, is not mimetic to bedding.

A detailed petrologic study of correlative rocks in Howard and Montgomery Counties is presented by Hopson (1964).

The general procedure for the processing of samples for the standard sample program has been described by Flanagan (1967). The mica schist presented a challenge for grinding because of its mica content. The sieve analysis of sets of four bottles each, taken randomly around the midpoints of the three thirds of the entire lot of bottled samples, is shown in table 35. An average of 87 percent of the sample passes a 200-mesh screen, and this percentage exceeds the goal of at least 80 percent. At least 75 percent of the material retained on the larger screens consists of mica. This situation should cause no problems for techniques like the classical methods of rock analysis in which 0.5-g portions are used, but large subsamples taken from bottles should be reground before use in techniques like spectrochemical analysis in which sample portions are of the order of 25 mg or less.

TABLE 35.—*Sieve analyses of SDC–1, in percent*

Thirds	1	2	3	Avg
Sieve size:				
+100	1.9	.6	2.4	1.6
−100+120	1.0	2.4	2.0	1.8
−120+170	4.8	5.8	5.8	5.5
−170+200	3.8	3.5	4.9	4.1
−200	88.5	87.7	84.9	87.0
Total	100	100	100	100

Chemical analyses of the rock and X-ray fluorescence determinations of several constituents are given in table 36, and the norms are given in table 37. The rapid methods of Shapiro and Brannock (1962) were used for the chemical analysis, and a modification of the method of Rose, Adler, and Flanagan (1963) was used for the X-ray determinations. The modification consisted of the substitution of cerium oxide for lanthanum oxide as the heavy absorber to avoid interference with the magnesium determination by a higher order line of lanthanum (Leonard Shapiro, written commun., 1969). Semiquantitative spectrographic estimates of several detectable trace elements are shown in table 38. The semiquantitative method of Myers, Haven, and Dunton (1961) was used, and the data are reported in percent to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, and 0.1, which represent approximate midpoints of intervals on a geometric scale.

TABLE 36.—*Analyses of SDC–1, in weight percent, by rapid rock methods and by X-ray fluorescence*

[Analysts: Rapid rock: P. Elmore, S. Botts, G. Chloe, and L. Artis. X-ray fluorescence: L. Shapiro and H. Smtih]

Bottle -No	21/5	100/13
Rapid rock		
SiO_2	65.9	65.8
Al_2O_3	16.3	16.3
Fe_2O_3	2.9	2.7
FeO	3.7	3.9
MgO	1.6	1.7
CaO	1.4	1.3
Na_2O	2.1	2.1
K_2O	3.2	3.2
H_2O+	1.4	1.5
H_2O-	.17	.16
TiO_2	.98	.98
P_2O_5	.18	.19
MnO	.12	.12
CO_2	.05	.05
Total	100	100
X-ray fluorescence		
Fe_2O_3[1]	7.1, 6.8	6.9, 7.0
MgO	2.1, 1.6	1.9, 1.7
CaO	1.4, 1.4	1.3, 1.5
Na_2O[2]	2.1, 2.1	1.9, 2.1
K_2O	3.3, 3.1	3.4, 3.2
TiO_2	1.0, 1.0	1.0, 1.0
P_2O_5[2]	.20, .24	.24, .24
MnO	.13, .11	.13, .12

[1] Total Fe as Fe_2O_3.
[2] By chemical methods using the powder prepared for X-ray fluorescence.

TABLE 37.—*Norms (CIPW) for SDC–1, bottle 21/5*

Constituent	Weight percent
Quartz	35.33
Orthoclase	18.91
Albite	17.77
Anorthite	5.45
Corundum	7.38
Enstatite	3.99
Ferrosilite	3.00
Magnetite	4.20
Ilmenite	1.86
Apatite	.43
$CaCO_3$	.11
Total	98.43

TABLE 38.—*Semiquantitative spectrographic estimates of the trace element contents of SDC–1*

Element	Percent
Ag	0.00003
B	.003
Ba	.1
Be	.0003
Ce	.02
Co	.002
Cr	.007
Cu	.003
Ga	.003
La	.015
Nb	.0015
Nd	.01
Ni	.005
Pb	.003
Sc	.002
Sn	.0003
Sr	.02
V	.007
Y	.007
Yb	.0007
Zr	.05

The sample was originally intended for chemical analysis. It is inevitable, however, that the sample will be used with other techniques that require a much smaller sample size. The mica content will probably be the source of problems for elements such as Ba, K, Rb, Sr and Zr, and claims of heterogeneity of the sample, published with the data and test used, are anticipated.

REFERENCES CITED

Cloos, Ernest, and Cooke, C. W., 1953. Geologic map of Montgomery County and District of Columbia: Baltimore, Md., Maryland Dept. Geology, Mines and Water Resources, scale 1:62,500.

Coulter, H. W., and Caroll, G. V., 1964, Selected geologic localities in the Washington area: Washington Acad. Sci. Jour., v. 54, no. 5, p. 153–159.

Darton, N. H., and Keith, Arthur, 1901, Description of the Washington, D.C.-Md.-Va. quadrangles: U.S. Geol. Survey Geol. Atlas, Folio 70.

Fellows, R. E., 1950, Notes on the geology of Rock Creek Park, District of Columbia: Am. Geophys. Union Trans., v. 31, no. 2, p. 267–277.

Flanagan, F. J., 1967, U.S. Geological Survey silicate rock standards: Geochim. et Cosmochim. Acta, v. 31, no. 3, p. 289–308.

Hopson, C. A., 1964, The crystalline rocks of Howard and Montgomery Counties, *in* the geology of Howard and Montgomery Counties: Baltimore, Md.. Maryland Geol. Survey, p. 27–215.

Myers, A. T., Havens, R. G., and Dunton, P. J., 1961, A spectrochemical method for the semiquantitative analysis of rocks, minerals, and ores: U.S. Geol. Survey Bull. 1084–I, p. 207–229.

Rose, H. J., Jr., Adler, Isidore, and Flanagan, F. J., 1963, X-ray fluorescence analysis of the light elements in rocks and minerals: Appl. Spectroscopy, v. 17, no. 4, p. 81–85.

Shapiro. Leonard, and Brannock, W. W., 1962, Rapid analysis of silicate, carbonate, and phosphate rocks: U.S. Geol. Survey Bull. 1144–A, 56 p.

Southwick, D. L., and Fisher, G. W., 1967, Revision of the stratigraphic nomenclature of the Glenarm Series in Maryland: Maryland Geol. Survey Rept. Inv. 6, 19 p.

DESCRIPTIONS AND ANALYSES OF EIGHT NEW USGS ROCK STANDARDS

BASALT, BHVO-1, FROM KILAUEA CRATER, HAWAII

By F. J. Flanagan, T. L. Wright, S. R. Taylor,[1] C. S. Annell,
R. C. Christian, and J. I. Dinnin

A basaltic lava from Kilauea caldera, Kilauea volcano, Hawaii, was collected by Howard A. Powers and coworkers from the surface layer of the pahoehoe lava that overflowed from Halemaumau in the fall of 1919. The sample, BHVO–1, has been processed as one of the series of standard rock powders, and more than 100 lb of the powdered material has been shipped to the NASA Manned Spacecraft Center, where it is being used as simulated lunar material for such purposes as plant growth media, soil mechanics experiments, drilling experiments, and oxygen recovery technique development.

The sample locality (fig. 8) is 1,000 ft due east of the tic at lat 19°25′00″ N., long 155°17′30″ W., on the Kilauea Crater quadrangle, Hawaii Island and County of Hawaii, 7½-min topographic series, 1963. The flow is mapped on the geologic map of Kilauea Crater quadrangle (Peterson, 1967).

A strong overflow occurred from the north side of Halemaumau from April 20 through June 1919. After a period of quiescence, the strong overflow from the north resumed on August 16 and continued through September, covering the lavas emplaced in the spring. Thus, the sample collected is probably from the overflow that occurred in mid-September. This surface was later bombarded by falling blocks and small particles, from pebble to silt size, broken from the wall lavas of Halemaumau during phreatic explosions in May 1924. It was not buried under a cover of such debris, however, and has thus been exposed as surface rock since September 1919.

The surface cooling unit of the 1919 pahoehoe is usually from 6 in to 1 ft thick and is separated from the lower part of the flow by a zone of large vesicles or even by open flattened gas cavities perhaps several feet in diameter. Shrinkage cracks break these slabs into blocks with top surface areas of 1–2 ft^2. Several of these blocks, from different parts of the flow but all within an area of about 100 yd^2, con-

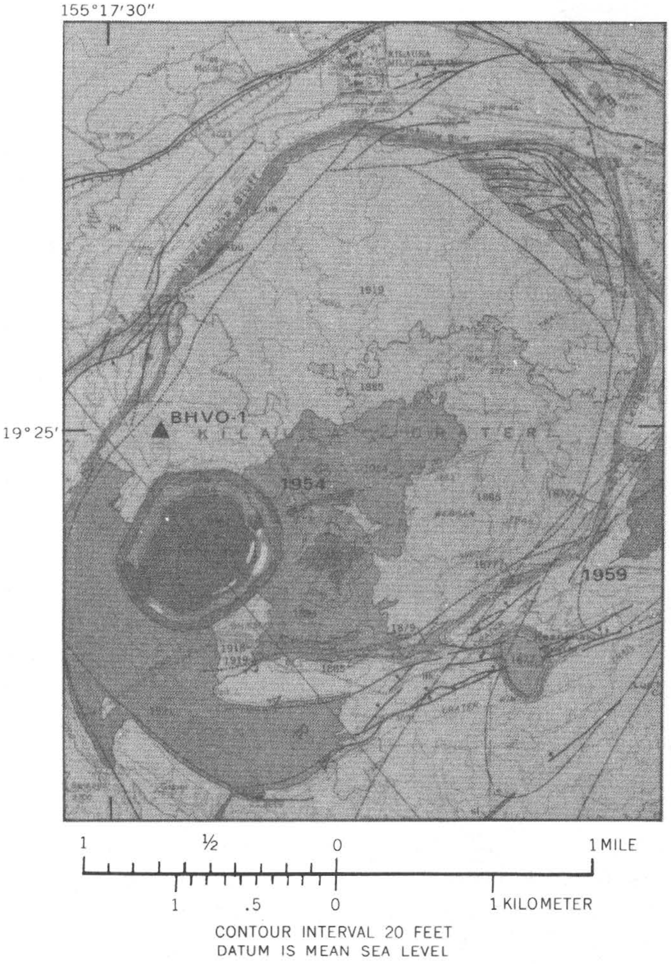


FIGURE 8.—Part of the geologic map (Peterson, 1967) of Kilauea Crater, Hawaii, with the source of BHVO–1 identified. Products of different eruptions are identified by year. Also shown are sl, splatter and lava cones; llk, lower lavas of Kilauea; bu, basalt of Uwekahuna laccolith; and ua, Uwekahuna ash.

---

[1] Department of Geophysics and Geochemistry, Australian National University, Canberra.

stituted the original bulk sample weighing nearly 700 lb.

The rock has a mildly oxidized zone, a few centimeters thick, separating the glassy rind from the denser crystalline interior, both of which are essentially unoxidized. There is no evidence of surface alteration due to weathering. The variation of chemical composition within this sample is probably not great and is caused mostly by the somewhat erratic distribution of olivine phenocrysts and by minor variations in the ratio of ferric to ferrous iron. A grab portion of the powdered and mixed sample was analyzed by the methods of Shapiro (1967), and this chemical analysis is shown in table 39.

TABLE 39.—*Chemical analysis of a grab sample of BHVO–1*

Constituent	Weight percent
SiO_2	49.8
Al_2O_3	14.0
Fe_2O_3	2.5
FeO	8.5
MgO	7.2
CaO	11.3
Na_2O	2.2
K_2O	.62
H_2O+	.25
H_2O-	.06
TiO_2	2.6
P_2O_5	.32
MnO	.18
CO_2	$<.05$
Total	100

The sample was received as eight large pieces ranging in weight from 60 to 120 lb. These pieces were first cleaned with a brush and water to remove any possible surface dirt and were then air dried over a weekend at about 90° F. The pieces were then broken on a steel bucking board with a hammer and chisel. The few pieces that dropped to the floor were inspected for traces of asphalt tile and were chipped clean, if necessary, before the crushing operations. The chips from the surfaces were discarded. As the material was reduced by a rolls crusher, it was continually passed down a stainless steel chute onto a large piece of 16- by 18-mesh aluminum screen to separate oversized particles before final powdering in a ball mill, and this oversize material was returned through the rolls crusher. The material was inspected as it passed to this screen, and several small pieces of wood from the shipping box that had escaped previous notice and a few small pieces of paper from the cardboard box in which broken pieces were stored before crushing were removed. Because traces of asphalt tile, wood, or paper may have escaped detection, it is not recommended that the sample be analyzed for organic constituents.

Nominal batch weights (125 lb) of the screened material were then processed in the ball mill until a sieve analysis of the pulverized product showed that at least 90 percent of the powder passed a 200-mesh screen. The second and succeeding batches were formed by replacing the amount of ground material taken from the ball mill by an equal weight of coarse material. Half-pint samples of the powder were taken at intervals while the batches were being processed, and these portions were sieved to determine if the minimum requirements for particle-size distribution had been reached. These sieved portions were then discarded. Sieve analyses of the powder immediately before the four batches were removed from the ball mill are given in table 40, and the average of these may be used to estimate the size distribution of the completed sample.

TABLE 40.—*Sieve analyses of batches of BHVO–1, in percent*

[Tr., trace]

Batch	1	2	3	4	Avg
Sieve sizes:					
+100	0.0	0.2	0.8	0.2	0.3
−100+120	Tr.	.1	Tr.	Tr.	.1
−120+170	2.1	1.9	1.3	.6	1.5
−170+200	4.1	5.6	3.3	.6	3.4
−200	93.8	92.2	94.6	98.6	94.8
Total	100.0	100.0	100.0	100.0	100.1

The ground sample was stored in eight 1-ft^3 cardboard boxes until the ball milling was completed. The contents of these boxes were then mixed in a V-blender (two boxes per batch) in a prearranged scheme to nominally ensure that one-eighth of the contents of any completely blended box could be attributed to each of the original eight boxes.

After filling every second set of bottles, the normal processing was halted to withdraw a half gallon (about 5 lb) of powder from the blender. These 5-lb portions were transferred to a large plastic bag, and the withdrawals continued until the bag contained about 50 lb. When such withdrawals during the bottling of the first, second, and last thirds of the estimated lot of bottled samples had been completed, the bags were shipped to NASA's Lunar Receiving Laboratory, Manned Spacecraft Center, Houston, Tex. Similar but smaller withdrawals were made simultaneously to reserve part of the powdered material for gamma ray spectrometric determinations of uranium, thorium, and potassium.

In anticipation that portions of this sample might be requested as frequently as had been portions of

USGS BCR-1 for use as a comparison standard for lunar analyses, several sets of six bottles were randomly selected from the stock of bottles. These sets, designed to test the homogeneity of the sample and to obtain error estimates, were distributed among several analysts who were to make their determinations in random order. The data by chemical, optical emission, atomic absorption, instrumental neutron activation, X-ray fluorescence and spark source mass specroscopic methods are given in tables 41–47.

TABLE 41.—*Quantitative spectrographic determinations, in parts per million, of trace elements in Hawaiian basalt, BHVO-1*

[Optical emission method of Annell and Helz (1970). Analyst, C. S. Annell]

Element	Spectral line	Bottle					
		11/11	10/14	31/23	32/15	52/2	51/17
Ba -------	II 4554.0	170, 190	190, 170	170, 150	190, 170	190, 150	170, 150
Co -------	3412.3	46, 44	50, 51	44, 44	42, 45	51, 38	44, 47
	3412.6	43, 41	48, 52	47, 44	43, 42	48, 39	44, 47
Cr -------	3005.05	340, 280	340, 350	310, 260	285, 270	480, 270	295, 305
	2985.9	335, 290	340, 350	320, 275	290, 290	450, 280	315, 325
Cs --------	8521.1	<1, 2.0	1.1, 1.1	<1, 1.1	3.5, 1.8	<1, 1.1	<1, <1
Cu -------	3247.5	150, 94	150, 150	74, 150	155, 150	150, 96	94, 150
	3273.96	170, 130	170, 130	150, 110	170, 160	150, 120	100, 61
Ga -------	2943.6	21, 18	21, 20	18, 18	20, 19	21, 16	18, 20
Li --------	6707.8	4.4, 4.6	4.3, 4.1	3.9, 4.0	4.2, 4.0	3.7, 3.8	4.1, 3.9
Mn -------	3256.1	1320, 1140	1300, 1320	1220, 1120	1370, 1290	1390, 1030	1180, 1320
Nb -------	II 3163.4	17, 17	17, 12	15, 17	19, 15	14, 15	14, 14
Ni -------	3050.82	120, 104	117, 122	112, 107	113, 112	157, 106	97, 106
Pb -------	2833.0	5.9, 6.9	6.5, 3.0	6.2, 6.2	5.5, 3.2	11.2, 7.2	5.5, 7.5
Rb -------	7800.2	7.4, 9.1	7.3, 7.3	8.3, 7.9	8.6, 8.8	7.2, 8.4	7.0, 8.2
Sc --------	II 3353.7	31, 31	32, 32	31, 31	32, 31	32, 31	31, 30
Sr --------	4607.3	390, 290	390, 300	390, 230	345, 250	360, 250	420, 300
V --------	3198.0	325, 280	310, 335	320, 235	260, 260	330, 280	315, 305
Y --------	II 3327.8	30, 30	29, 31	31, 28	29, 31	31, 27	29, 30
Yb -------	II 3289.37	3.3, 2.3	2.9, 3.3	2.8, 3.3	2.1, 3.1	2.3, 2.5	2.8, 3.0
Zn -------	3345.02	97, 107	98, 108	105, 107	95, 108	104, 94	105, 103
	3345.6	100, 106	97, 106	106, 99	97, 109	103, 96	104, 100
Zr --------	II 3279.26	153, 151	151, 138	147, 152	154, 158	148, 132	136, 120

TABLE 42.—*Determinations of the potassium content of BHVO-1, in percent*

[Atomic absorption method; Analyst, J. I. Dinnin]

Bottle					
9/9	11/12	30/6	30/25	51/16	51/25
0.440	0.440	0.438	0.443	0.437	0.440
.432	.433	.438	.438	.443	.436
.432	.438	.438	.432	.440	.434
.438	.440	.432	.434	.434	.432

TABLE 43.—*Determinations of the niobium content of BHVO-1*

[In parts per million. Isotope dilution-spectrophotometric method of Greenland and Campbell (1970). Analyst, E. Y. Campbell]

Bottle					
10/14	11/11	31/23	32/15	51/17	52/2
22.6	19.1	21.0	20.0	21.5	20.2
24.0	22.3	23.1	24.6	21.3	24.1

TABLE 44.—*Determinations of the uranium content of BHVO-1*

[In parts per million Fluorimetric method of Grimaldi and others (1952); uranium content is close to limit of estimation of the method. Analyst, Roosevelt Moore]

Bottle					
9/9	11/12	30/6	30/25	51/25	52/16
0.3	0.3	0.3	0.3	0.5	0.5
.3	.3	.3	.3	.5	.5

TABLE 45.—*Instrumental neutron activation analyses of the chromium, scandium, and thorium contents of BHVO-1*

[In parts per million. Analyst, L. P. Greenland]

Bottle -------------	9/9	11/12	30/6	30/25	51/16	51/25
Chromium -----	312	316	305	302	343	331
	295	317	338	313	300	313
Scandium ------	26	28	27	26	28	32
	27	30	26	28	27	25
Thorium -------	.84	.78	.81	.57	.77	.71
	.90	.94	.73	.65	.96	.74

TABLE 46.—*X-ray fluorescence determinations of several oxides in BHVO-1*

[In weight percent. Method of Rose and others (1970); Analyst, R. P. Christian]

Bottle	10/16	10/26	31/20	31/32	50/30	51/22
SiO_2	50.2	49.9	49.9	49.8	49.8	49.8
	49.8	50.2	49.7	50.0	49.8	49.9
Al_2O_3	14.0	13.8	13.9	14.0	14.0	13.8
	13.8	13.8	14.1	13.8	13.9	13.8
Total Fe as Fe_2O_3	11.99	11.89	11.95	11.94	11.94	11.97
	11.94	11.94	11.98	11.91	11.96	11.92
MgO	7.45	7.35	7.30	7.40	7.35	7.20
	7.40	7.45	7.40	7.35	7.30	7.20
CaO	11.48	11.49	11.39	11.34	11.35	11.39
	11.44	11.45	11.44	11.34	11.38	11.43
K_2O	.54	.54	.54	.57	.55	.55
	.53	.55	.55	.55	.56	.56
TiO_2	2.68	2.61	2.63	2.64	2.67	2.68
	2.65	2.67	2.64	2.62	2.72	2.68
P_2O_5	.26	.30	.27	.28	.26	.27
	.26	.30	.29	.28	.26	.29
MnO	.17	.16	.16	.17	.16	.16
	.16	.16	.17	.17	.17	.16

Calculations for a one-way experimental design with the six bottles of sample as the variable of classification were then made for the data reported. Four determinations for some bottles were made by the spark source method, and two observations were deleted from each set of four using random numbers. This procedure simplifies calculations by having the same number of observations per bottle. For the missing cesium observation by spark source, the average of the other 11 determinations was substituted to facilitate the analysis of variance, but the inserted value may have slightly changed conclusions and estimates that might have otherwise been obtained.

For the instrumental neutron activation determinations of chromium, scandium, and thorium, 100-mg samples were irradiated for 14 h in a thermal neutron flux of 5×10^{12} n/cm^2/sec at the Naval Research Laboratory reactor. After about 2 weeks decay, the samples were counted at least twice with a 40 cm^3 Ge(Li) detector coupled to a 1,024-channel analyzer. The gamma energies, in keV, for the analyses were: Sc^{46}, 889; Cr^{51}, 320; and $Th^{233} \rightarrow Pa^{233}$, 312. USGS sample G–1 was used as a standard for the thorium and scandium determinations with assumed values of 45 ppm Th and 2.73 ppm Sc. USGS DTS–1, with an assumed value of 4,190 ppm Cr, was used as a standard for the chromium determinations.

Conclusions resulting from the analysis of variance and our estimates of means and standard deviations are given in table 48. An extra significant digit has been retained in all estimates so that the user can round the data. For simplicity and for freedom of choice for future users, all conclusions are listed as NS (not significant) at some specified or unspecified level. Those conclusions for which no level is specified were obtained after comparing the calculated ratio of the bottle mean sum of squares (MSS bottles) to the error mean sum of squares (MSS error) with the table value for $F_{0.95}$(d.f.=5,6)=4.39. For those conclusions for which a fractile of the F distribution is specified, for example NS(0.99), the calculated ratio is significant at both $F_{0.95}$ and $F_{0.975}$, but is not significant at $F_{0.99}$. Twenty-seven of the 68 standard deviations for bottles are listed as negative, and the conclusions listed were reached by testing the inverse ratio of mean squares (MSS error:MSS bottles) to determine if the variation attributable to bottles was significantly less than the error mean square. No F test could be made, and therefore a conclusion was not reached for the chemical uranium data because the error mean square was identically zero.

The standard deviations for error in table 48 are the square roots of the mean sums of squares for error. Standard deviations for bottles were calculated by

$$\sqrt{\frac{MSS_{\text{bottles}} - MSS_{\text{error}}}{n}}$$

where n is the number of determinations per bottle (four for K by atomic absorption, two for all other determinations). Negative values for the bottle standard deviation may be expected in about half of such calculations as the variances are distributed as sample values of the variances around a mean of zero.

Inspection of the column of conclusions in table 48 shows that the bottle mean square was not significantly different from the error mean square for 53 of the 67 tests made against $F_{0.95}$. For these we can conclude that the element or oxide by the method used is homogeneously distributed among the bottles. The decision is left to the user whether to accept a declaration of homogeneity for the five conclusions that were not significant when tested against $F_{0.975}$, or for the eight tested against $F_{0.99}$. Comparisons of variances and means by the appropriate F and t tests could be made for elements and oxides between methods in table 48, but the general agreement of the data indicate that such tests would probably be arithmetic exercises to test analytical judgment.

Ilmenite has been added to a small portion of the bulk material shipped to the Manned Spacecraft Center. The addition of the ilmenite at the center raised the TiO_2 content of this portion to approxi-

TABLE 47.—*Spark source mass spectrometric determination of elements in BHVO-1*

[In parts per million. Method of Taylor (1965). Analysts, S. R. Taylor and A. L. Graham, Australian Nat. Univ.]

Element-isotope	Bottle					
	9/8	10/17	30/24	31/3	52/6	52/26
Y-89	21.3	29.4	24.8	29.2	28.9	26.7
	26.7	31.6	23.8	21.0	22.3	24.3
Nb-93	15.7	19.4	19.9	21.2	20.4	21.2
	15.6	20.7	16.9	17.8	18.6	19.3
Cs-133	.0776	.127	.100	---	.0505	.0784
	.0554	.0912	.0872	.126	.0406	.0827
Ba-135	121	121	144	144	134	130
	120	123	137	139	120	136
Ba-136	130	128	149	139	151	132
	114	134	149	145	111	139
Ba-137	121	115	126	124	133	126
	126	133	132	130	118	132
La-139	15.0	16.9	18.4	19.1	15.2	16.8
	19.0	17.3	19.5	18.4	17.2	17.2
Ce-140	30.0	30.5	31.8	35.2	33.5	31.3
	30.0	38.6	35.7	36.4	33.1	33.9
Pr-141	5.77	6.06	6.01	6.49	4.77	5.42
	5.62	5.60	6.40	5.33	5.35	5.17
Nd-143	23.8	24.8	26.9	22.1	18.3	21.2
	27.7	17.8	24.5	24.6	22.3	22.6
Nd-146	22.1	21.4	26.2	23.2	19.3	20.6
	25.6	16.5	25.3	22.3	21.6	21.8
Sm-147	6.12	5.47	5.09	5.18	3.96	5.45
	5.24	6.35	4.63	5.50	4.72	5.74
Sm-149	5.13	6.53	5.14	4.87	4.31	5.31
	5.51	4.18	5.20	5.64	4.91	5.53
Eu-151	1.70	1.82	1.64	1.67	1.33	1.52
	1.98	1.83	1.67	1.77	1.57	1.60
Eu-153	1.90	1.81	1.72	1.63	1.21	1.47
	1.62	1.49	1.67	1.76	1.63	1.58
Gd-155	6.84	6.00	5.45	5.82	4.10	4.95
	7.72	6.66	5.94	6.42	5.23	5.21
Gd-158	5.68	5.53	5.24	5.53	3.67	4.82
	4.83	4.38	5.69	5.11	5.35	5.40
Tb-159	.685	.752	.595	.683	.562	.648
	1.00	.756	.841	.765	.743	.720
Dy-161	4.65	4.94	4.06	4.18	3.34	4.64
	5.32	4.46	4.35	5.04	4.21	5.12
Dy-163	5.14	5.33	3.90	4.23	3.87	4.80
	5.69	4.53	5.00	4.75	4.46	4.93
Ho-165	1.07	1.17	.892	.788	.649	.870
	.862	.875	.971	.883	.732	.927
Er-166	2.65	1.86	1.70	1.62	1.26	1.76
	1.83	1.74	1.84	1.89	1.64	1.80
Er-167	2.21	1.87	1.61	1.65	1.28	1.63
	2.21	1.73	1.77	1.83	1.68	1.75
Tm-169	.300	.302	.251	.317	.206	.272
	.350	.222	.250	.335	.280	.302
Yb-172	1.72	1.77	1.40	1.36	1.15	1.62
	1.95	1.39	1.39	1.34	1.63	1.68
Yb-174	1.64	1.41	1.25	1.21	1.16	1.57
	2.28	1.86	1.30	1.33	1.57	1.61
Hf-177	4.27	4.28	3.71	3.34	3.39	3.60
	5.16	3.27	3.68	4.18	4.21	3.52
Hf-178	3.78	3.31	3.25	3.01	3.16	3.20
	3.65	4.44	3.40	3.99	4.13	3.27
Th-232	.672	.701	.726	.726	.611	.912
	1.15	.825	.814	1.07	.725	.857
U-238	.393	.394	.182	.328	.315	.332
	.316	.414	.186	.452	.327	.351

TABLE 48.—*Means and standard deviations of data for BHVO–1*

[In parts per million unless percent is indicated. Method: XRF, X-ray fluorescent; OS, optical emission; SSMS, spark source mass spectrometric; INA, instrumental neutron activation; AA, atomic absorption; Chem, chemical. Conclusions are from the analysis of variance. The calculated *F* ratio of MSS : $MSS_{bottles}:MSS_{error}$ was generally tested at $F_{0.95}$ except where the higher fractile of the *F* distribution is indicated in parentheses. Where the standard deviation for bottles is indicated as "Neg.," the inverse ratio, MSS_{error} : $MSS_{bottles}$, was tested to determine the significance. NS, not significant; d.f., degrees of freedom. See tables 41–47]

Element or oxide	Method	Spectral line or Isotope	Conclusion (bottles)	Mean	Standard deviation		Coefficient of variation for error (percent)
					(d.f.=5) Bottles	(d.f.=6) Error	
Al_2O_3 percent	XRF	------	NS	13.89	0.032	0.104	0.7
Ba	OS	II 4554.0	NS	171.7	Neg.	17.3	10.1
	SSMS	135	NS (0.99)	132.8	8.33	5.09	3.8
	SSMS	136	NS	135.6	2.62	12.8	9.4
	SSMS	137	NS (0.975)	127.5	Neg.	7.54	5.9
CaO percent	XRF	------	NS (0.99)	11.41	.048	.026	.2
Ce	SSMS	140	NS	33.4	.402	2.73	8.2
Co	OS	3412.3	NS	45.5	2.76	4.00	8.8
	OS	3412.6	NS	44.8	1.89	3.16	7.0
Cr	INAA	------	NS	315	Neg.	17.5	5.6
	OS	2985.9	NS	321.7	Neg.	52.5	16.3
	OS	3005.05	NS	315.4	Neg.	65.0	20.6
Cs	SSMS	133	NS (0.975)	.088	.022	.016	18.8
Cu	OS	3273.96	NS	135.1	23.8	24.7	18.3
	OS	3247.5	NS	130.2	Neg.	35.3	27.1
Dy	SSMS	161	NS	4.60	.323	.456	9.9
	SSMS	163	NS	4.83	.283	.482	10.0
Er	SSMS	166	NS	1.86	.159	.278	14.9
	SSMS	167	NS (0.975)	1.80	.219	.145	8.0
Eu	SSMS	151	NS	1.67	.130	.113	6.8
	SSMS	153	NS	1.64	Neg.	.180	11.0
Total Fe as Fe_2O_3 percent	XRF	------	NS	11.94	.004	.028	.2
Ga	OS	2943.6	NS	19.2	Neg.	1.82	9.5
Gd	SSMS	155	NS (0.99)	6.04	.862	.513	8.5
	SSMS	158	NS	5.18	Neg.	.682	13.2
Hf	SSMS	177	NS	3.97	.200	.516	13.0
	SSMS	178	NS	3.99	Neg.	.518	13.0
Ho	SSMS	165	NS	.90	.084	.114	12.7
K percent	AA	------	NS	.437	Neg.	[1].004	.9
K_2O percent	XRF	------	NS	.55	.007	.009	1.6
La	SSMS	139	NS	17.5	.534	1.35	7.7
Li	OS	6707.8	NS (0.99)	4.08	.239	.122	3.0
MgO percent	XRF	------	NS (0.975)	7.35	.072	.048	.6
Mn	OS	3256.1	NS	1250	Neg.	129	10.3
MnO percent	XRF	------	NS	.16	.001	.005	3.1
Nb	Chem [2]	------	NS	22.0	Neg.	2.10	9.5
	OS	II 3163.4	NS	15.5	Neg.	1.96	12.6
	SSMS	93	NS	19.0	1.31	1.56	8.2
Nd	SSMS	143	NS	22.7	1.16	2.80	12.3
	SSMS	146	NS	22.1	2.05	1.93	8.7
Ni	OS	3050.82	NS	114.4	Neg.	15.8	13.8
P_2O_5 percent	XRF	------	NS (0.99)	.28	.014	.008	.8
Pb	OS	2833.0	NS	6.23	1.15	1.79	28.7
Pr	SSMS	141	NS	5.54	.296	.341	6.2
Rb	OS	7800.2	NS	7.96	Neg.	.705	8.8
Sc	INAA	------	NS	27.5	Neg.	2.24	8.1
	OS	II 3353.7	NS	31.2	.387	.500	1.6
SiO_2 percent	XRF	------	NS	49.90	Neg.	.168	.3
Sm	SSMS	147	NS	5.28	.533	.459	8.7
	SSMS	149	NS	5.31	Neg.	.746	14.0
Sr	OS	4607.3	NS (0.975)	326.2	Neg.	81.2	24.9
Tb	SSMS	159	NS	.75	Neg.	.130	17.3
Th	INAA	------	NS	.783	.086	.081	10.3
	SSMS	232	NS	.871	Neg.	.179	20.6
TiO_2 percent	XRF	------	NS	2.66	.020	.025	.9
Tm	SSMS	169	NS	.289	.026	.036	12.4

TABLE 48.—*Means and standard deviations of data for BHVO-1*—Continued

Element or oxide	Method	Spectral line or Isotope	Conclusion (bottles)	Mean	Standard deviation: Bottles (d.f.=5)	Standard deviation: Error (d.f.=6)	Coefficient of variation for error (percent)
U	Fluorimetric	----	(3)	0.36	0.103	---	---
	SSMS	238	NS(0.99)	.34	.073	0.043	12.6
V	OS	3198.0	NS	296	3.47	32.2	10.9
Y	OS	II 3327.8	NS(0.99)	29.7	Neg.	1.68	5.6
	SSMS	89	NS	25.8	Neg.	3.55	13.8
Yb	OS	II 3289.37	NS	2.81	Neg.	.456	16.2
	SSMS	172	NS	1.59	.134	.190	11.9
	SSMS	174	NS	1.54	.196	.258	16.8
Zn	OS	3345.02	NS	102.6	Neg.	6.30	6.1
	OS	3345.6	NS(0.99)	101.9	Neg.	5.59	5.5
Zr	OS	II 3279.26	NS	145.0	8.40	7.78	5.4

[1] Degrees of freedom for error = 18.
[2] Isotope dilution and spectrophotometric.
[3] Indeterminate because the error MSS is identically zero.

mately that of the TiO_2 content of the Apollo 11 soil samples. Because of the widely differing TiO_2 contents, there seems little chance that this portion and USGS BHVO-1 will be confused.

REFERENCES CITED

Annell, Charles, and Helz, Armin, 1970, Emission spectrographic determination of trace elements in lunar samples: Science, v. 167, no. 3918, p. 521–523.

Greenland, L. P., and Campbell, E. Y., 1970, Determination of niobium in rocks by an isotope dilution-spectrophotometric method: Anal. Chim. Acta, v. 49, p. 109–114.

Grimaldi, F. S., May, Irving, and Fletcher, M. H., 1952, U.S. Geological Survey fluorimetric methods of uranium analysis: U.S. Geol. Survey Circ. 199, 20 p.

Peterson, D. W., 1967, Geologic map of the Kilauea Crater quadrangle, Hawaii: U.S. Geol. Survey Geol. Quad. Map GQ–667.

Rose, H. J., Jr., Cuttitta, Frank, Dwornik, E. J., Carron, M. K., Christian, R. P., Lindsay, J. R., Ligon, D. T., and Larson, R. R., 1970, Semimicro chemical and X-ray fluorescence analysis of lunar samples: Science, v. 167, no. 3918, p. 520–521.

Shapiro, Leonard, 1967, Rapid analysis of rocks and minerals by a single-solution method, *in* Geological Survey Research 1967: U.S. Geol. Survey Prof. Paper 575–B p. B187–B191.

Taylor, S. R., 1965, Geochemical analysis by spark source mass spectrograhy: Geochim. et Cosmochim. Acta, v. 29, p. 1243–1261.

MASS SPECTROMETRIC ISOTOPE DILUTION DETERMINATIONS OF BARIUM

By J. R. de Laeter,[1] R. Date,[1] and I. D. Abercrombie [1]

ABSTRACT

The eight new USGS standard rocks have been analyzed for barium by the stable isotope dilution technique. Duplicate portions from three bottles of the rocks were analyzed in random order. No departures from homogeneity for these randomly selected bottles of samples were observed. The average barium contents are, in parts per million: STM–1, 584; RGM–1, 822; QLO–1, 1,401; SDC–1, 641; MAG–1, 476; SCo–1, 570; SGR–1, 286; and BHVO–1, 132.5. The analytical error is generally less than 1 percent whereas the absolute accuracy of the technique for barium is approximately 2 percent.

INTRODUCTION

As part of a program to standardize a new series of rocks, the elemental abundance of barium in STM–1, RGM–1, QLO–1, SDC–1, MAG–1, SCo–1, SGR–1, and BHVO–1 was determined by the stable isotope dilution technique using solid-source mass spectrometry. Three bottles, randomly selected from the stock of each rock, were analyzed in duplicate to provide a one-way experimental design with the three bottles as the variable of classification.

The determination of barium in silicate samples is often imprecise and sometimes of doubtful accuracy by emission spectroscopy and other analytical techniques. Fleischer (1969) has summarized new data on the standard rocks G–1 and W–1 but is still unable to recommend a value for the barium content of these rocks with any confidence. Flanagan (1969) has provided a compilation of analytical data on the major, minor, and trace constituents of the new series of samples recently prepared by the U.S. Geological Survey. The barium determinations cover a wide range of abundances for each of the six rocks, and under the circumstances, the average values listed for barium are of questionable significance.

The stable isotope dilution technique is for some elements potentially more accurate and precise than many other analytical methods and has been adopted in this project in an attempt to provide accurate barium data for this new series of USGS standard rocks.

EXPERIMENTAL METHODS

The elemental abundance of barium in each rock sample was determined by using a barium nitrate tracer enriched to approximately 94 percent in the isotope of mass 135. The isotopic composition of this tracer as obtained from Oak Ridge National Laboratory (ORNL) is listed in table 49, together with the isotopic ratios as measured by the mass spectrometer used throughout the project. The isotopic composition of natural barium as measured in the Western Australian Institute of Technology (WAIT) laboratory is also listed. The measured ratios are uncorrected for mass spectrometer fractionation.

We have taken the atomic weight of natural barium to be 137.327 as calculated by Eugster, Tera, and Wasserburg (1969). The atomic weight of the Ba^{135} tracer has been calculated from the measured isotopic composition to be 135.04, using isotopic weights according to the $C^{12} = 12$ scale (Mattauch and others, 1965).

An accurately weighed sample of the $Ba^{135}(NO_3)_2$ tracer was used to prepare a gravimetric solution in 6 *M* HCl. The concentration of this solution was determined using the isotope dilution technique itself to calibrate the tracer against an accurate gravimetric standard made up from a spectroscopically pure sample of $BaCO_3$ (obtained from Johnson, Matthey & Co.). The measured concentration of the tracer solution agreed with the gravimetric value within experimental error. The adopted concentration was the average of a number of calibrations

---

[1] Department of Physics, Western Australian Institute of Technology, South Bentley, Western Australia.

determined on random occasions throughout the project. No significant variation was detected in the tracer concentration as a function of time.

TABLE 49.—*Isotopic composition of barium nitrate tracer and natural barium*

	$\frac{\mathrm{Ba}^{137}}{\mathrm{Ba}^{138}}$	$\frac{\mathrm{Ba}^{136}}{\mathrm{Ba}^{138}}$	$\frac{\mathrm{Ba}^{135}}{\mathrm{Ba}^{138}}$
Ba^{135} tracer (ORNL values)[1]	0.2444	0.4522	26.2921
Ba^{135} tracer (WAIT value)[2]	0.2456±0.0019	0.4565±0 0031	26.0720±0.078
Natural barium (WAIT value)[2]	0.1581±0.0003	0.1112±0.0003	0.09374±0.0003
	$\frac{\mathrm{Ba}^{134}}{\mathrm{Ba}^{138}}$	$\frac{\mathrm{Ba}^{132}}{\mathrm{Ba}^{138}}$	$\frac{\mathrm{Ba}^{130}}{\mathrm{Ba}^{138}}$
Ba^{135} tracer (ORNL values)[1]	0.1011	<0.028	<0.028
Ba^{135} tracer (WAIT value)[2]	0 1031 ±0.009	--------------	--------------
Natural barium (WAIT value)[2]	0.03449±0.00012	0.00147±0.00001	0.00154±0.00001

[1] Error estimated to be less than 1 percent, from known sources of systematic errors.

[2] Errors represent the 95-percent confidence limits.

An accurately weighed quantity of the Ba^{135} tracer was added to a known amount of a standard rock sample immediately before dissolution. Portions of an approximate weight of 0.2 g were taken, and sufficient tracer was added to ensure that the $\mathrm{Ba}^{135}/\mathrm{Ba}^{138}$ ratio of the mixture was approximately unity. Each portion was then dissolved with a $\mathrm{HF{-}HClO_4}$ mixture, and the barium was extracted as the chloride on a cation exchange column as described by de Laeter, Abercrombie, and Date (1969). Blank analyses of the complete extraction procedure were of the order of 0.1 μg, and the measured concentrations were corrected for this effect.

Portions of the barium as the chloride were mounted on a conventional triple-filament ion source and analyzed in a 12-in.-radius, 90° magnetic sector, solid-source mass spectrometer equipped with an electron multiplier. The resulting signals were amplified by a vibrating-reed electrometer with a 10^9-ohm input resistor whose linearity as a function of ion-beam intensity was carefully checked. A voltage-to-frequency converter, followed by an electronic counter, allowed digital presentation of the data, which was fed on-line to a small computer, The amplifying system was periodically calibrated for scale factors, linearity, and speed of response.

The magnetic field was successively switched from mass 135 to mass 138 and back again, until each isotope was measured approximately 40 times. The computer was programmed to select a number that was representative of the height of each peak, and this information was stored in memory until the mass spectrometer run was completed, after which the isotopic ratios were calculated. This system of data analysis enabled the mean and standard deviation of the $\mathrm{Ba}^{135}/\mathrm{Ba}^{138}$ ratio of the mixture of tracer and natural barium standard to be computed immediately after the completion of a run with a minimum of operator involvement, thus contributing significantly to the efficiency of the project as a whole.

RESULTS AND DISCUSSION

The concentration of barium in each of the standard rocks is given in table 50. Two portions from the three bottles of each standard rock sample were analyzed in random order. Every result listed in table 50 is an independent analysis. The mean of the two analyses for each bottle is given, together with the average of the six analyses for each rock. The average was calculated on the assumption that each bottle is representative of the relevant standard rock sample.

TABLE 50.—*Determinations of barium in USGS standard rock samples, in parts per million*

Standard rock and bottle No.	Analyses 1	Analyses 2	Mean
Nepheline syenite, STM-1:			
9/11	584	586	585
11/19	583	583	583
21/15	583	585	584
Average			584
Preliminary USGS value			[1] 465
Rhyolite, RGM-1:			
5/17	821	823	822
11/8	823	823	823
62/1	823	820	821.5
Average			822
Preliminary USGS value			[1] 732
Quartz latite, QLO-1:			
17/8	1,402	1,402	1,402
32/25	1,399	1,395	1,397
49/8	1,402	1,408	1,405
Average			1,401
Preliminary USGS value			[1] 1,380
Mica schist, SDC-1			
28/31	638	641	639.5
47/29	643	644	643.5
90/11	641	639	640
Average			641
Preliminary USGS value			[2] 1,000
Marine mud, MAG-1			
20/23	478	480	479
42/7	475	474	474.5
63/19	476	473	474 5
Average			476
Preliminary USGS value			[1] 493
Cody shale, SCo-1			
35/16	572	571	571.5
63/32	568	568	568
65/26	571	569	570
Average			570
Preliminary USGS value			[2] 300
Green River shale, SGR-1			
22/23	287	292	289.5
23/3	285	283	284
56/25	282	288	285
Average			286
Hawaiian basalt, BHVO-1			
1/7	132	134	133
8/1	132	132	132
17/4	132	133	132.5
Average			132.5
Preliminary USGS value			[1] 170

[1] Quantitative emission spectrographic data

[2] Semiquantitative emission spectrographic estimate

We have also listed in table 50 some barium concentrations for the rocks obtained by emission spectrography by the USGS during preliminary work on the samples. The average values from the present work are within 25 percent of the quantitative emission spectroscopic data for STM–1, RGM–1, QLO–1, MAG–1, and BHVO–1, although our value of 132.5 ppm for BHVO–1 is in excellent agreement with the spark-source mass-spectrometry value of about 130 ppm by S. R. Taylor (written commun., 1970). Our value of 641 ppm for SDC–1 is 44 percent lower and our value of 570 ppm for SCo–1 is 62 percent higher than the semiquantitative estimates for these two rocks. No preliminary value for SGR–1 has yet been determined, though we obtained a value of 286 ppm for this rock.

Table 51 summarizes the data and the conclusions from the analysis of variance for each standard rock. The standard deviations listed are the estimates for the "between bottles" and "within bottles" error, respectively. These have been calculated from the analysis of variance design described by Bennett and Franklin (1954, table 7.2, p. 323). The "within bottles" standard deviation has been equated with analytical error in this simple design, since, other than random error, it is the only error remaining after the effects of the bottle means are subtracted from the total variation.

TABLE 51.—*Estimates of the barium contents of standard rocks*

[All calculated *F* ratios were not significant when compared to $F_{0.95}$ (d.f.= 2, 3) = 9.55. d.f., degrees of freedom; Neg., negative bottle variance]

Sample	Average (ppm)	Standard deviation				*F* ratio
		Bottles (d.f.=2)		Error (d.f.=3)		
		ppm	percent	ppm	percent	
STM–1	584	0.6	0.10	1.2	0.21	1.5
RGM–1	822	Neg.	---	1.5	.18	.5
QLO–1	1,401	3.5	.25	2.9	.21	3.8
SDC–1	641	1.9	.30	1.5	.23	4.1
MAG–1	476	2.4	.50	1.5	.32	5.8
SCo-1	570	1.6	.28	.9	.16	7.4
SGR–1	286	1.8	.63	3.3	1.15	1.6
BHVO–1	132.5	Neg.	---	.9	.68	.6

For two *F* ratios of the mean sum of the squares for "between bottles" divided by the mean sum of the squares for "within bottles," we obtained values less than unity. The negative values that result for the estimate of the "between bottles" variance may be attributed to sample fluctuations about an average value of zero. This should be anticipated in half the tests in which our null hypothesis—that the variation "between bottles" is not significantly greater than the variation "within bottles"—is true. These negative values have been indicated in table 51 by the abbreviation "Neg."

A comparison of the calculated *F* ratios with the appropriate *F* values listed in statistical tables (Hoel, 1954, table V), indicates that there is no significant departure from the null hypothesis at the 95-percent level in any of the samples, and one can therefore conclude that the barium of the bottles is homogeneous for each of the standard rocks analyzed.

In fact, all samples, except perhaps SGR–1, show excellent "between bottles" and "within bottles" reproducibility. In the case of SGR–1, the measured barium content of bottle 22/23 is 1.7 percent greater than the average content of bottles 23/3 and 56/25. The reproducibility of duplicate analyses in bottles 22/23 and 56/25 are also considerably worse than in any of the other standard rocks. Some difficulty was experienced in the dissolution of SGR–1, and perhaps the relatively poorer reproducibility of the analyses of this rock reflects inconsistencies in the chemistry rather than real variations in the samples themselves.

An indication of the reproducibility of the stable isotope dilution technique for barium in the WAIT laboratory is exhibited by analyses of the USGS standard rock BCR–1. In a previous publication, de Laeter, Abercrombie, and Date (1969) reported a value of 678 ppm as the average of two analyses. During the present project, BCR–1 was reanalysed on three separate occasions and gave values of 676, 677, and 675 ppm, respectively. The average value of 676 ppm therefore compares favorably with the earlier result and is well within the limits imposed by experimental error.

ACKNOWLEDGMENT

This work was supported by the Australian Research Grants Committee.

REFERENCES

Bennett, C. A., and Franklin, N. L., 1954, Statistical analysis in chemistry and the chemical industry: New York, John Wiley, 724 p.

de Laeter, J. R., Abercrombie, I. D., and Date, R., 1969, Mass spectrometric isotope dilution analyses of barium in standard rocks: Earth and Planetary Sci. Letters, v. 7, no. 1, p. 64–66.

Eugster, O., Tera F., and Wasserburg, G. J., 1969, Isotopic analyses of barium in meteorites and in terrestrial samples. Jour. Geophys. Research,, v. 74, p. 3897–3908.

Flanagan, F. J., 1969, U.S. Geological Survey standards—II. First compilation of data for the new U.S.G.S. rocks: Geochim. et Cosmochim. Acta., v. 33, p. 81–120.

Fleischer, M., 1969, U.S. Geological Survey standards—I. Additional data on rocks G–1 and W–1, 1965–1967: Geochim. et Cosmochim. Acta, v. 33, p. 65–80.

Hoel, P. G., 1954, Introduction to mathematical statistics [2d ed.]: New York, John Wiley, Table V, 322 p.

Mattauch, J. H. E., Thiele W., and Wapstra, A. H.. 1965, 1964 atomic mass table: Nuclear Physics, v. 67, p. 1–31.

THE BISMUTH CONTENT OF SIX NEW USGS STANDARD ROCKS

By L. P. GREELAND, E. Y. CAMPBELL, and F. J. FLANAGAN

Bismuth was determined in replicate portions of three bottles of six new USGS standard rocks by a substoichiometric isotope dilution technique. The average, as parts per billion bismuth, were QLO-1, 66; BHVO-1, 19; MAG-1, 380; RGM-1, 280; SDC-1, 280; and STM-1, 250. One-way analysis of variance of the several sets of data showed no significant differences in the bismuth content among bottles of any specific rock, and these samples may be accepted as homogeneous for their bismuth contents by this method. The coefficient of variation calculated from the "within bottles" variation for STM-1, however, was much greater than that expected from instrumental error alone, and this rock powder is not suitable as a standard for bismuth determinations.

The use of rock powders as standards for chemical analysis entails the assumption that various bottles and portions from a given bottle all have the same approximate concentrations of the elements sought. This assumption has been challenged occasionally in the case of older USGS standard rocks, but never, to our knowledge, has heterogeneity been conclusively demonstrated for a reasonable sample size. Statistical designs are available for testing this assumption, and here we present data on the bismuth content of six new USGS standard rocks by one such simple procedure.

Three bottles of each of the six standard rocks were randomly selected. These bottles and appropriate portions therefrom were numbered and randomized. The portions, about 100 mg, were analyzed in batches of 12. Duplicate portions from the bottles of QLO-1 and BHVO-1, and triplicate portions from the bottles of the other four samples, were analyzed for their bismuth content.

Because of the lower bismuth contents of QLO-1 and BHVO-1, it was necessary to analyze portions of these samples separately from those of the other four rocks. Nevertheless, randomization was maintained throughout.

The analytical method has been described in detail elsewhere (Greenland and Campbell, 1972). In brief, samples were decomposed with HF-$HClO_4$ in the presence of Bi^{207} tracer. Bismuth was separated from the other constituents by extraction of its iodide complex and then reacted with a known substoichiometric amount of EDTA (ethylenediaminetetraacetic acid). After removal of the excess bismuth by extraction of the iodide, Bi^{207} was counted to determine the specific activity of the Bi-EDTA complex, from which the original bismuth content could be calculated.

The analytical data are given in table 52, and the statistical estimates are summarized in table 53. Most averages in table 53 are given to three significant figures even though the analytical precision (the square root of the mean sum of squares for within bottles) may indicate two figures, and the user may round or not at his discretion.

The calculations of the one-way analysis of variance of these data were made to determine if the differences in the bismuth content attributable to

TABLE 52.—*Bismuth content of USGS standard rocks, in parts per billion*

Rock sample	Bottle 1	Bottle 2	Bottle 3
QLO-1	68	65	60
	73	70	62
BHVO-1	24	18	16
	19	16	20
MAG-1	380	380	370
	380	370	410
	410	380	380
RGM-1	280	280	290
	270	300	320
	280	270	260
SDC-1	280	290	260
	280	260	290
	280	270	270
STM-1	330	170	220
	220	290	330
	230	240	220

TABLE 53.—*Summary of estimates for the bismuth content of six USGS standard rocks*

[In parts per billion. d.f., degrees of freedom. Neg., negative bottle variance]

Rock sample	Mean	Standard deviation		Coefficient of variation for error (percent)
		Bottles (d.f.=2)	Error (d.f.=3)	
QLO-1	66.3	4.4	3.0	4.5
BHVO-1	18.8	1.4	2.7	14.4
MAG-1	384	Neg.	[1]16.0	4.2
RGM-1	283	Neg.	[1]19.7	7.0
SDC-1	276	Neg.	[1]12.5	4.5
STM-1	250	Neg.	[1]62	24.8

[1] d.f.=6.

bottle means were significantly greater than the variation within bottles for any given standard rock. In no case was the mean sum of squares for bottles significantly greater (95-percent confidence level) than the variation within bottles. There is, then, no evidence to reject the hypothesis that the three bottles of a given standard rock contain the same concentration of bismuth, and, because of the random selection of the bottles for the experiment, this conclusion may be extrapolated to the entire lot of bottles for any given standard rock.

Although homogeneity of the average bismuth contents of the bottles is a necessary, but not a sufficient, condition for the use of these rock samples as standards, it is also necessary that portions selected from a given bottle should yield a fairly constant concentration of bismuth. The analytical precision (error) of the determinations is presented in table 53 as the coefficient of variation. Five of the six standard rock samples have coefficients of variation in accord with that to be expected from the analysis of pure solutions. The coefficient of variation for the determinations of bismuth in STM-1 is much greater than those of the other rock samples, and we cannot recommend the use of STM-1 as a standard for the determination of bismuth in rocks.

REFERENCE

Greenland, L. P., and Campbell, E. Y., 1972, Determination of nanogram amounts of bismuth in rocks by substoichiometric isotope dilution analysis: Anal. Chim. Acta, v. 60, p. 159–165.

MOLYBDENUM IN USGS STANDARD ROCKS

By E. G. Lillie and L. P. Greenland

Molybdenum was determined in three aliquots of three bottles of five standard rocks by a new isotope dilution spectrophotometric technique. The data were used both to determine the analytical errors of the method and to demonstrate that different bottles of these five rocks are homogeneous with respect to molybdenum content. Average molybdenum contents found, in parts per million, were: AGV–1, 1.6; BCR–1, 1.3; STM–1, 4.4; QLO–1, 2.3; BHVO–1, 0.92.

Analytical error can be subdivided into reproducible and random errors that determine the analytical accuracy and precision, respectively. The USGS standard rocks are used widely to detect reproducible errors, but their virtue for determining analytical precision generally has been overlooked. Our purpose here is to argue that descriptions of new analytical methods should include replicate analyses of several USGS standards with the data obtained from a statistical experimental design such that an analysis of the observed variance becomes possible. Data obtained from a new method for the determination of molybdenum in rocks are presented as an example.

The analytical method consists of three general steps; dissolution, separation, and determination. Errors, both reproducible and random, commonly occur at each of these steps. A further source of error arises from sampling the bottle of powdered rock for analysis: although this error is not inherent in a specific analytical method, it is a component of analytical error in that it affects the final analysis.

It is obvious that the frequently used measures of precision based on repetitive analyses of pure solutions are unduly optimistic in that they ignore variance components arising from sampling, dissolution, and incomplete separations from interfering elements. Replicate analyses of a single rock offers some improvement in estimating analytical precision but is still inadequate in that it represents only one specific case of problems associated with sampling, dissolution, and interfering elements. A useful measure of analytical precision can come only from replicate analyses of a number of rocks of widely differing composition; further, the replicate analyses must be performed at different times to preclude possible correlation of errors that can occur within a single analytical run.

The one-way analysis of variance experimental design used throughout this paper to demonstrate homogeneity of different bottles of the USGS standard rocks is ideal for studying analytical precision. This design provides for randomization of bottles and splits of a given rock powder and then subtracts the variance associated with differing contents of an element among bottles from the observed total variance of the analytical data to leave a valid estimate of the random component of the analytical error. Although any collection of rocks could be used in this way to estimate analytical precision, the USGS standard rocks offer several advantages: (1) Their compositions are relatively well known, permitting both a selection for various concentrations of interfering elements and an estimate of the reproducible component of analytical error; (2) the precision of a new analytical method can be compared directly with that obtained previously by other analysts with other methods; and (3) evidence of heterogeneity among bottles of a given standard rock, obtained as a byproduct of the analysis of variance, is necessary information for other analysts attempting to use these rocks as standards.

We have used this technique to determine the analytical precision of a recently developed method for the determination of molybdenum in rocks. As pointed out above, these data are also useful for demonstrating homogeneity of the molybdenum contents of the standard rocks.

Three portions (about 0.5 g) of three bottles of five of the USGS standard rocks were randomized and analyzed over a period of a week. The analytical method consists of decomposing the samples in the presence of Mo^{99} tracer with HF–HNO$_3$–HClO$_4$, separating Mo by sequential solvent extractions of the chloride and α-benzoinoxine complexes, and determining the amount of molybdenum present with thiocyanate. Losses of molybdenum through the procedure are corrected by counting Mo^{99} in the final fraction.

The analytical data and statistics are given in table 54. In no case is the F ratio significant at the 95-percent confidence level, and thus there is no evidence of differing Mo contents among the bottles.

The random analytical error, calculated from the within bottles mean sum of squares with six degrees of freedom, ranges from 6.2 to 14.4 percent. If only STM–1 had been used for the determination of precision we could conclude that the method was adequate for most geochemical purposes, whereas if only BHVO–1 were used we would conclude that the method was adequate only for semiquantitative work. We believe it to be significant that the two basalts show the poorest precision, and we are currently attempting to improve the method for routine use.

TABLE 54.—*Molybdenum content, in parts per million, of USGS standard rocks*

[d.f., degrees of freedom; Neg., negative bottle variance; NS, not significant]

Rock sample	Bottle	Mo	Mean	Standard deviation		Analytical relative deviation percent	*F* ratio
				Bottle (d.f.=2)	Error (d.f.=6)		
AGV–1	A	1.7, 1.4, 1.7	1.6	Neg.	0.137	8.3	<1(NS)
	B	1.7, 1.8, 1.5					
	C	1.7, 1.7, 1.6					
BCR–1	A	1.4, 1.5, 1.1	1.3	Neg.	0.183	13.7	<1(NS)
	B	1.4, 1.5, 1.1					
	C	1.4, 1.4, 1.2					
STM–1	A	4.0, 4.3, 4.1	4.4	0.306	.275	6.2	3.5(NS)
	B	4.4, 4.8, 4.8					
	C	4.6, 4.1, 4.8					
QLO–1	A	2.3, 2.4, 2.2	2.3	.108	.216	9.3	1.5(NS)
	B	2.3, 2.7, 2.5					
	C	2.5, 2.2, 1.9					
BHVO–1	A	1.1, 0.89, 0.81	.92	Neg.	.133	14.4	<1(NS)
	B	0.93, 0.74, 0.96					
	C	0.89, 1.1, 0.87					

INTERCALIBRATION OF 17 STANDARD SILICATES FOR 14 ELEMENTS BY INSTRUMENTAL NEUTRON ACTIVATION ANALYSIS

By AMITAI KATZ[1] and LAWRENCE GROSSMAN[2]

ABSTRACT

Iron and 13 trace elements (Ba, Ce, Co, Cr, Cs, Eu, Hf, Rb, Sb, Sc, Ta, Tb, Th) were determined by instrumental neutron activation analysis in 17 standard silicate rocks. The silicates analyzed comprise two groups: (1) eight of the older USGS standard silicate rocks and one standard pottery sample for all of which previous data are available, and (2) eight new (1971) USGS standard silicate rocks. Hereafter group 1 will be referred to as primary standards, and group 2 as new standards. The primary standards were intercalibrated for each element by calculating a mean specific activity (that is, a time-corrected activity per microgram of element), using least square linear correlation statistics. From the best mean specific activity obtained for the primary standards, new self-consistent data were obtained both for the primary and the new standards. Primary standards were analyzed in duplicate, whereas duplicate portions from each of three bottles of each new standard were analyzed in random order to test homogeneity. The samples of the new rocks are homogeneous for the elements analyzed, with but a few exceptions: Tb is heterogeneous at the 1-percent confidence level in both SCo–1 and STM–1, and Ta in SCo–1, Rb in MAG–1, Sc in QLO–1, Eu in SDC–1 and Cr in STM–1 are heterogeneous at the 5-percent level. These heterogeneities, except for Sc in QLO–1, occur for elements having relatively poor counting statistics.

INTRODUCTION

In recent years, several standard rock samples have been processed to serve as analytical reference materials in geochemical and petrological studies. (For a recently revised list, see Flanagan, 1970.) Various laboratories using many different analytical methods, as well as different reference materials, have contributed to the pool of data on these standard rocks. Despite this extensive effort, however, the wide range of concentrations of some trace elements between rock types has led to uncertainty about the accuracy, particularly for the lower concentration values. The establishment of a new (1971) series of standard silicate rocks by the USGS through the work of F. J. Flanagan, provided us with an opportunity to analyze the old and new standard rocks for 14 elements determinable by instrumental neutron activation analysis (INAA). The procedure involves the estimation of the best set of values for each element for each standard, starting with a method of assessing the reliability of the "recommended" values on the old standards. We believe that the results reported here provide a relatively large set of internally consistent standards for 14 elements in silicates to which future work in analytical geochemistry may be referred.

ANALYTICAL METHOD

INSTRUMENTATION

A 25-cm^3 coaxial Ge(Li) detector was used. Signals from the detector were passed through a transistorized preamplifier, then to a main amplifier coupled to a d-c restorer. The signal from the restorer was fed to an analog-to-digital converter and then to a 2,048-channel analyzer. The data from the multichannel analyzer were read out on a high-speed printer and also onto a high-speed paper tape punch through an interface.

The resolution of this system (full width at half maximum) for the Co^{60} 1,173 keV gamma-ray peak was typically 4.6–4.8 keV for the samples, and 4.4–4.6 keV for a pure Co^{60} source. The system was regularly checked and recalibrated using a pure Co^{60} source and the prominent Sc^{46}, Fe^{59}, and Eu^{152} lines as revealed in the spectra of most of the samples. The 1,173-keV Co^{60} peak never shifted by more than two channels and was generally within one channel from its value of the energy-channel calibration curve.

---

[1] Hebrew University, Jerusalem, Israel.

[2] Department of Geophysical Sciences, University of Chicago.

SAMPLE PREPARATION AND IRRADIATION

The eight older USGS standard rock samples (G–1, W–1, G–2, BCR–1, AGV–1, GSP–1, DTS–1, PCC–1), plus one standard pottery sample (SP–1) (Perlman and Asaro, 1969), were used to obtain the best mean specific activity for each nuclide analyzed by the method described below. For each of the old standards, one bottle was available. For the new USGS standards, three bottles of each sample were used.

Duplicate 50-mg portions from each bottle of sample were weighed (to the nearest 0.01 mg). No further homogenization or grinding was attempted after removal of the sample powders from the original bottles. The powders were poured directly onto glossy weighing paper and were immediately transferred, via a small Teflon funnel, into preweighed quartz vials (length, 30 mm; inside diameter, 3 mm) that had been cleaned by boiling in concentrated nitric acid for 10 hours followed by washing with high-purity distilled water and drying at 60°C in a vacuum. One empty quartz vial was run at the same time during these and the following steps and served as a blank.

The vials were heat sealed using an H_2–O_2 torch, were weighed again to obtain the net quartz-glass weight, and were again cleaned with nitric acid and water. Then the vials were packed, in random order, into a circular belt of a high-purity aluminum foil and were introduced into an irradiation cylinder 4 in. in diameter. In its final shape this cylinder contained one layer of vials, all of which were in essentially identical radial and vertical positions relative to the reactor core. During irradiation the cylinder was slowly rotated around its vertical axis to ensure a uniform neutron flux.

The vials were irradiated in the "swimming pool" reactor of the Union Carbide Co., Sterling Forest, N.Y., at a flux of 1×10^{13} neutrons $cm^{-2}s^{-1}$ for 3 days.

COUNTING

After irradiation, the samples in the vials were allowed to cool for 21 days. Thereafter, the vials were unpacked, boiled for 5 hours in concentrated nitric acid, washed in distilled water, and dried. For counting, the vials were placed vertically in a Perspex holder resting on top of the Ge(Li) detector. The distance between the upper surface of the detector and the bottom of the vials was 25 mm. This distance allowed for a maximum of 14 percent dead time for the hottest samples. The counting time was 5,000 seconds for all the samples except the quartz-vial blank which was counted for 40,000 seconds. The nuclides analyzed, their half-lives, and their gamma-ray peaks are listed in table 55.

TABLE 55.—*Nuclides, gamma-ray peaks, and half-lives of elements determined*

Element	Target isotope	Product nuclide	γ-ray peak (keV)	Half life (h)
Fe	Fe^{58}	Fe^{59}	1,100	1,080
Ba	Ba^{130}	Ba^{131}	496	288
Ce	Ce^{140}	Ce^{141}	145	792
Co	Co^{59}	Co^{60}	1,332	45,991
Cr	Cr^{50}	Cr^{51}	320	667
Cs	Cs^{133}	Cs^{134}	796	17,958
Eu	Eu^{151}	Eu^{152}	1,408	108,624
Hf	Hf^{180}	Hf^{181}	482	1,020
Rb	Rb^{85}	Rb^{86}	1,077	448
Sb	Sb^{123}	Sb^{124}	1,690	1,449
Sc	Sc^{45}	Sc^{46}	889	2,016
Ta	Ta^{181}	Ta^{182}	1,222	2,762
Tb	Tb^{159}	Tb^{160}	963+967	1,730
Th	Th^{232}	Pa^{233}	312	658

COMPUTER DATA REDUCTION

The spectra for the blank, the primary standards, and all the new standards were transferred from paper tape to the magnetic disc of an IBM 360/65 computer. The data were edited and reduced at the Yale Computer Center by means of the Conversational Yale Terminal Operating System. For each element, the same peak and background channels for every spectrum were selected by visual inspection. Since our data-reduction program calculates the slope of the background from any two sets of background counts in the vicinity of each peak, the "upper" and "lower" background regions need not be symmetrically placed about the peak or even on opposite sides of the peak. This flexibility circumvents small interfering peaks near the desired peak. For each blank, primary standard, and new standard, the program corrects for background and decay during counting for every element. All peak areas are corrected to the same point in time, and the blank correction is calculated from the relative masses of quartz in the blank and in the primary or new standards. The specific activity of each desired element in every standard is calculated, and the concentration of each element in every sample is computed relative to its specific activity in each standard. The 1-sigma counting statistics are propagated throughout the calculations.

INTERCALIBRATION OF THE PRIMARY STANDARDS

The data fed into the computer program for each element analyzed are shown in table 56. The values were selected from recent literature (Fleischer, 1969; Flanagan, 1969; Gordon and others, 1968; Schmitt and others, 1970; Perlman and Asaro, 1969). Whenever available, existing "mean" or "best" values were preferred. In other cases, the

TABLE 56.—*Best values, in parts per million selected from literature for the "primary" standards*

Element	W–1	G–1	BCR–1	G–2	AGV–1	SP–1	PCC–1	DTS–1	GSP–1
Fe	73,500	17,200	94,350	18,850	44,670	10,170	54,100	56,500	28,870
Ba	146	1,200	709	1,900	1,270	712	33.0	23.0	1,190
Ce	22.0	170	49.7	155	66.5	80.3	0.34	--------	472
Co	46.0	2.40	36.4	4.40	15.4	14.1	111	132	6.83
Cr	110	22.0	17.1	7.20	10.2	115	2,870	4,055	14.1
Cs	.91	1.50	1.20	1.45	1.25	8.31	.08	.05	1.25
Eu	1.08	1.36	1.95	1.37	1.58	1.45	--------	--------	3.10
Hf	2.50	5.75	4.78	7.65	5.25	6.23	.06	.03	13.8
Rb	20.5	220	55.3	178	78.6	70.0	.50	2.80	298
Sb	1.05	.40	.84	.05	4.64	1.71	.97	.48	3.43
Sc	33.9	3.00	33.5	3.63	12.3	20.6	8.30	3.55	7.13
Ta	.68	1.80	.89	.95	.83	1.55	--------	--------	1.25
Tb	.68	.60	1.05	.52	.77	--------	--------	--------	1.30
Th	2.50	52.0	6.76	25.6	6.98	14.0	.01	.01	118

final choice of data for a particular element was based on judgment of the most suitable analytical method by which it had been determined. When no clear-cut decision could be made, data from either neutron activation analysis or instrumental neutron activation analysis were selected. For each element in the nine primary (or old) standards, the computer calculated the time-corrected gamma activity and its amount in the sample analyzed. These data were fed into a least-square linear correlation program which calculated α_0, α_1 and Sy_0x, where α_0 is the intercept of the activity-weight line, α_1 is the mean specific activity or the slope of the activity-weight line, and Sy_0x is the standard error estimate.

The following sources of error were then considered to account for points deviating from the regression lines:

1. Errors in sample preparation,
2. Error due to sample geometry, and
3. Error due to radiation interference.

Errors of type 1 could be attributed to the loss of small amounts of material during the weighing of the samples and (or) during the sealing of the quartz vials. These cases were easily discerned by (1) irreproducible data for the same element between two duplicates, and (2) a similar difference between the two duplicates for all elements analyzed. When such an error was established, an appropriate correction factor, f_{corr}, was calculated from the activities of Co^{60}, Fe^{59}, and Sc^{46} in the duplicates:

$$f_{\text{corr}}=\frac{[A^H{}_{Co^{60}}/A^L{}_{Co^{60}}]+[A^H{}_{Fe^{59}}/A^L{}_{Fe^{59}}]+[A^H{}_{Sc^{46}}/A^L{}_{Sc^{46}}]}{3}$$

where A_i denotes the specific activity of nuclide i in the duplicate having the higher H or lower L activity. Co^{60}, Fe^{59}, and Sc^{46} were selected for this purpose because of their excellent counting statistics.

Errors due to sample (packing) geometry were distinguished from those of type 1 by counting the samples at a greater distance (80 mm) from the detector where such errors due to packing geometry become very small and a correction factor could be calculated. Except for one sample (GSP–1) in which a geometry effect was found, all others showed a variation within 1-sigma of the counting statistics.

For most elements, the gamma-ray peaks and the spectrum areas selected for background counting were reasonably free of interfering peaks. The computer program allowed for the subtraction of the Fe^{59} peak at 143 keV from the Ce^{141} gamma-ray line at 145 keV and of the interfering 964 keV line of Eu^{152} from the 963–967 keV Tb^{160} double peak.

Some of the regression lines thus obtained did not pass through the origin. In order to make them do so, they were offset by adding a constant increment to each data point. This phenomenon could have been brought about by any of the following reasons:

1. A systematic bias in the selection of the data from the literature,
2. A systematic radiation interference (postive or negative) that affected our data,
3. A similar interference that affected the data in the literature.

These offsets were very small for most elements, but for one element, Th, it was large enough to cause all our data to be higher than the literature values. This offset could have resulted from a positive interference, due to another nuclide, with the Th gamma-ray peak. The most likely interfering nuclide in this region is Cr^{51} at 320 keV. That this is not interference can be seen by the lack of correlation between the Cr concentrations and the size of the Th deviation in our samples. We have no explanation for this observation.

Finally, after correction of the aforementioned errors, data points that still deviated from the regression lines were attributed to poor initial data selection and were corrected accordingly. By this process, new estimates of the concentration of some elements in some standards were obtained to replace the commonly used published values.

The new intercalibrated "best" values for the suite of primary standards are listed in table 57.

TABLE 57.—*New data for the "primary" standards, in parts per million*

Sample	Fe	Ba	Ce	Co	Cr	Cs	Eu
W-1:							
1	74,500±317	--------	-------	40.9±0.29	105±3.1	0.29±0.46	1.08±0.08
2	74,700±316	--------	-------	41.0±0.29	100±3.1	0.97±0.46	1.28±0.08
Mean	74,600±316	--------	-------	41.0±0.29	102±3.1	0.63±0.46	1.18±0.08
G-1:							
1	15,300±156	1,470±52	188±1.7	2.48±0.12	-------	2.00±0.21	1.79±0.05
2	14,900±151	1,310±50	221±1.3	2.52±0.11	-------	1.72±0.21	1.60±0.05
Mean	15,100±154	1,390±51	204±1.5	2.50±0.11	-------	1.86±0.21	1.70±0.05
BCR-1:							
1	92,700±346	544±109	51.1±3.6	35.2±0.28	11.2±3.1	0.92±0.47	2.26±0.09
2	93,210±343	513±108	48.4±3.9	34.8±0.28	10.9±3.0	1.52±0.46	2.14±0.08
Mean	92,955±343	528±109	49.8±3.8	35.0±0.28	11.0±3.0	1.22±0.46	2.20±0.08
G-2:							
1	18,900±157	1,950±49	191±1.1	4.14±0.11	-------	1.43±0.20	1.68±0.05
2	18,700±152	1,890±47	187±1.0	4.12±0.10	-------	1.06±0.19	1.53±0.04
Mean	18,800±155	1,920±48	189±1.1	4.13±0.10	-------	1.24±0.19	1.60±0.05
AGV-1:							
1	45,900±235	1,140±72	72.7±1.4	14.3±0.17	18.4±2.0	1.34±0.29	1.88±0.06
2	46,300±250	1,040±79	75.0±1.7	14.3±0.18	16.8±2.0	1.20±0.39	1.81±0.06
Mean	46,100±243	1,090±76	73.8±1.5	14.3±0.18	17.6±2.0	1.27±0.35	1.85±0.06
SP-1:							
1	10,700±162	650±87	67.8±1.4	12.9±0.18	112±2.3	8.50±0.34	1.49±0.59
2	10,500±162	692±87	68.7±1.4	13.2±0.18	116±2.4	8.95±0.34	1.35±0.58
Mean	10,600±162	671±87	68.2±1.4	13.0±0.18	114±2.4	8.72±0.34	1.42±0.59
PCC-1:							
1	56,200±286	--------	-------	102±0.4	2,670±3.9	--------	--------
2	55,700±290	--------	-------	102±0.4	2,830±4.0	--------	--------
Mean	55,950±288	--------	-------	102±0.4	2,750±4.0	--------	--------
DTS-1:							
1	58,000±285	--------	-------	121±0.41	4,120±4.4	--------	--------
2	58,100±293	--------	-------	124±0.43	4,090±4.5	--------	--------
Mean	58,050±289	--------	-------	122±0.42	4,105±4.4	--------	--------
GSP-1:							
1	31,000±199	1,140±66	520±1.3	6.58±0.13	-------	0.81±0.24	2.82±0.06
2	29,400±241	1,210±87	496±2.0	7.48±0.18	-------	0.96±0.31	2.77±0.07
Mean	30,200±221	1,175±77	508±1.7	7.03±0.16	-------	0.88±0.28	2.80±0.07

Sample	Hf	Rb	Sb	Sc	Ta	Tb	Th
W-1:							
1	2.13±0.31	--------	1.15±0.33	35.4±0.06	-------	0.82±0.13	2.77±0.27
2	2.35±0.31	--------	1.06±0.33	35.3±0.06	-------	1.01±0.13	2.56±0.26
Mean	2.24±0.31	--------	1.10±0.33	35.4±0.06	-------	0.92±0.13	2.67±0.27
G-1:							
1	7.65±0.15	360±8.5	0.53±0.16	3.64±0.02	1.80±0.07	0.91±0.05	55.1±0.09
2	7.37±0.16	369±7.4	0.36±0.15	3.69±0.02	1.74±0.07	0.86±0.05	57.3±0.19
Mean	7.51±0.16	364±7.9	0.44±0.16	3.66±0.02	1.77±0.07	0.88±0.05	56.2±0.15
BCR-1:							
1	4.60±0.31	--------	0.48±0.33	33.1±0.06	0.52±0.12	0.94±0.11	6.97±0.28
2	4.14±0.31	--------	0.43±0.32	32.9±0.06	0.58±0.12	1.03±0.11	7.09±0.27
Mean	4.37±0.31	--------	0.46±0.33	33.0±0.06	0.55±0.12	0.98±0.11	7.03±0.28
G-2:							
1	8.14±0.14	240±7.8	--------	3.70±0.02	0.89±0.06	0.63±0.04	30.3±0.16
2	8.31±0.14	214±7.5	--------	3.67±0.02	0.73±0.05	0.70±0.05	31.0±0.16
Mean	8.22±0.14	227±7.7	--------	3.68±0.02	0.81±0.06	0.66±0.04	30.6±0.16
AGV-1:							
1	5.23±0.20	55.4±22	4.67±0.24	12.1±0.04	0.73±0.08	0.88±0.07	7.63±0.19
2	4.42±0.22	62.7±19	4.41±0.25	12.3±0.04	0.63±0.09	0.96±0.08	8.00±0.22
Mean	4.82±0.21	59.0±21	4.54±0.25	12.2±0.04	0.68±0.08	0.92±0.08	7.81±0.20
SP-1:							
1	6.13±0.24	72.9±9.3	1.40±0.23	19.9±0.05	1.51±0.08	1.33±0.13	16.6±0.23
2	6.07±0.24	76.7±9.5	1.53±0.23	19.8±0.05	1.54±0.08	1.20±0.12	16.8±0.23
Mean	6.10±0.24	74.8±9.4	1.46±0.23	19.8±0.05	1.52±0.08	1.26±0.13	16.7±0.23
PCC-1:							
1		--------	0.80±0.23	8.17±0.03	-------	--------	--------
2		--------	0.85±0.23	8.22±0.04	-------	--------	--------
Mean		--------	0.82±0.23	8.20±0.04	-------	--------	--------
DTS-1:							
1		--------	-------	3.54±0.03	-------	--------	--------
2		--------	-------	3.47±0.03	-------	--------	--------
Mean		--------	-------	3.51±0.03	-------	--------	--------
GSP-1:							
1	15.0±0.18	299±10.1	4.05±0.22	6.66±0.03	0.75±0.07	1.67±0.07	131±0.27
2	15.4±0.23	274±12.1	3.35±0.27	6.75±0.04	0.76±0.06	1.40±0.07	124±0.34
Mean	15.2±0.21	286±11.2	3.70±0.24	6.70±0.03	0.76±0.07	1.54±0.07	128±0.31

TABLE 58.—*Data for the new (1971 series) USGS silicate standards, in parts per million*

[NS, not significant at $F_{0.95}$; S, significant at $F_{0.95}$ or the fractile indicated; N.d., not determined; Neg., negative]

Rock Sample	SGR–1		SCo–1		MAG–1		SDC–1		BHVO–1		QLO–1		STM–1		RGM–1	
Duplcate No	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Antimony																
Bottle 1	3.60	3.12	2.05	2.06	0.93	0.52	0.59	0.32	0.38	0.59	1.90	4.51	1.82	1.78	1.76	1.39
2	2.54	3.21	2.62	2.24	1.18	.72	.20	.45	.60	.61	2.48	2.11	1.94	1.96	1.38	1.52
3	2.77	3.08	2.90	2.52	.98	.63	.23	.36	.16	.23	3.66	2.36	1.82	1.93	1.52	1.55
Mean	3.05		2.40		0.83		0.36		0.43		2.84		1.88		1.52	
Mean sum of squares between bottles	.142		.216		.0260		.0145		.0889		.459		.0112		.00747	
Mean sum of squares within bottles	.129		.0482		.0837		.0254		.00818		1.440		.00235		.0267	
Analytical standard deviation	.359		.219		.289		.159		.0905		1.200		.0485		.163	
Bottle standard deviation	.0809		.290		Neg.		Neg.		.201		Neg.		.0667		Neg.	
F ratio	1.10 (NS)		4.49 (NS)		.311 (NS)		.570 (NS)		10.9 (S)		.319 (NS)		4.79 (NS)		.279 (NS)	
Barium																
Bottle 1	397	107	479	439	427	314	639	445	N.d.	N.d.	1,290	1,550	500	583	761	882
2	199	202	379	519	320	228	440	469	N.d.	N.d.	1,410	1,250	561	639	789	812
3	202	242	446	585	351	228	633	554	N.d.	N.d.	1,380	1,280	556	466	800	797
Mean	225		474		311		530		----------		1,360		551		807	
Mean sum of squares between bottles	1,338		2,571		5,371		9,877		----------		5,399		4,091		324.8	
Mean sum of squares within bottles	14,285		6,754		6,060		7,453		----------		17,200		3,512		2,530	
Analytical standard deviation	120		82.2		77.8		86.3		----------		131		59.3		50.3	
Bottle standard deviation	Neg.		Neg.		Neg.		34.8		----------		Neg.		17.0		Neg.	
F ratio	0.094 (NS)		0.381 (NS)		0.886 (NS)		1.33 (NS)		----------		0.314 (NS)		1.16 (NS)		0.128 (NS)	
Cerium																
Bottle 1	32.0	31.2	55.3	66.3	94.9	88.0	115	106	36.2	40.3	60.1	63.5	88.8	75.4	44.4	45.1
2	32.2	30.3	60.2	62.3	104.0	96.6	100	105	41.7	42.4	55.4	63.9	76.2	58.5	47.5	43.0
3	28.4	33.3	65.6	62.8	91.3	97.0	106	106	40.9	32.4	56.9	59.0	75.5	64.1	49.6	48.1
Mean	31.2		62.1		95.3		106		39.0		59.8		73.1		46.3	
Mean sum of squares between bottles	.282		6.82		41.1		32.2		15.4		7.44		125		10.0	
Mean sum of squares within bottles	4.710		22.2		22.5		17.7		14.9		14.70		104		3.83	
Analytical standard deviation	2.17		4.71		4.74		4.20		3.86		3.83		10.2		1.96	
Bottle standard deviation	Neg.		Neg.		3.05		2.69		0.481		Neg.		3.25		1.76	
F ratio	.060 (NS)		0.30 (NS)		1.83 (NS)		1.82 (NS)		1.0 (NS)		0.506 (NS)		1.20 (NS)		2.61 (NS)	
Cesium																
Bottle 1	4.55	4.30	6.21	7.21	7.20	7.50	3.98	3.98	N.d.	N.d.	1.91	1.47	1.37	1.42	10.2	10.3
2	4.30	5.00	6.67	7.51	7.85	7.66	3.27	3.77	N.d.	N.d.	1.74	1.67	1.36	1.37	10.5	10.5
3	4.51	5.00	7.18	6.15	7.61	7.35	3.90	4.02	N.d.	N.d.	1.73	2.04	1.77	1.51	10.2	10.3
Mean	4.61		6.82		7.53		3.85		---------		1.76		1.47		10.3	
Mean sum of squares between bottles	.057		.109		.0855		.166		---------		.0235		.0455		.0417	
Mean sum of squares within bottles	.132		.461		.0323		.0567		---------		.0491		.0117		.00334	
Analytical standard deviation	.363		.679		.180		.238		---------		.222		.108		.0578	
Bottle standard deviation	Neg.		Neg.		.163		.234		---------		Neg.		.130		.138	
F ratio	.430 (NS)		.236 (NS)		2.65 (NS)		2.93 (NS)		---------		.480 (NS)		3.89 (NS)		12.5 (S)	
Chromium																
Bottle 1	35.7	29.0	69.2	76.6	99.9	103	81.0	77.1	269	275	11.3	9.00	67.2	63.6	36.7	39.5
2	31.6	33.6	81.4	80.0	103	106	74.2	75.5	259	259	12.4	10.5	83.0	86.3	47.8	41.1
3	30.7	34.2	76.2	68.6	102	105	75.5	80.8	253	270	9.12	7.54	75.8	68.5	36.9	35.1
Mean	32.5		75.3		103		77.4		264		9.98		74.1		39.5	
Mean sum of squares between bottles	.0318		43.3		4.84		9.78		95.2		4.91		191		38.7	
Mean sum of squares within bottles	10.2		19.1		4.60		7.50		54.2		1.90		12.8		9.33	

TABLE 58.—*Data for the new (1971 series) USGS silicate standards, in parts per million*—(Continued)

Rock Sample	SGR–1		SCo–1		MAG–1		SDC–1		BHVO–1		QLO–1		STM–1		RGM–1	
Duplicate No	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Chromium—Continued																
Analytical standard deviation	3.19		4.37		2.14		2.74		7.36		1.38		3.59		3.05	
Bottle standard deviation	Neg.		3.48		.343		1.07		4.53		1.23		9.43		3.83	
F ratio	.003 (NS)		2.27 (NS)		1.05 (NS)		1.30 (NS)		1.76 (NS)		2.59 (NS)		14.8 (S)		4.15 (NS)	
Cobalt																
Bottle 1	10.6	10.1	9.30	9.18	18.7	18.5	18.4	16.4	41.9	42.5	6.82	7.08	0.260	0.310	1.63	2.04
2	9.90	10.9	10.0	9.96	19.0	18.8	15.5	15.6	41.8	43.2	6.94	6.99	.370	.290	1.89	2.04
3	9.67	10.4	10.0	9.54	18.8	18.9	17.0	16.4	41.4	41.6	6.76	6.93	.310	.410	1.78	1.89
Mean	10.3		9.66		18.8		16.6		42.1		6.92		0.325		1.88	
Mean sum of squares between bottles	.078		.291		.052		1.745		.526		.009		.003		.011	
Mean sum of squares within bottles	.297		.038		.015		.728		.393		.016		.003		.034	
Analytical standard deviation	.545		.195		.122		.853		.627		.128		.056		.184	
Bottle standard deviation	Neg.		.356		.135		.713		.258		Neg.		Neg.		Neg.	
F ratio	.510 (NS)		7.67 (NS)		3.44 (NS)		2.40 (NS)		1.34 (NS)		.519 (NS)		.905 (NS)		.333 (NS)	
Europium																
Bottle 1	0.510	0.310	1.15	1.28	1.67	1.65	2.00	1.96	2.32	2.42	1.51	1.62	3.90	4.01	0.770	0.710
2	.430	.610	1.31	1.24	1.73	1.68	1.81	1.75	2.40	2.56	1.51	1.57	4.14	4.05	.700	.720
3	.540	.520	1.22	1.25	1.63	1.51	1.86	1.80	2.27	2.21	1.49	1.50	4.09	4.01	.760	.690
Mean	0.520		1.24		1.64		1.86		2.36		1.53		4.03		0.725	
Mean sum of squares between bottles	.0002		.0019		.0094		.0217		.0289		.00252		.0102		.00045	
Mean sum of squares within bottles	.0055		.0038		.0029		.00147		.0065		.00263		.0044		.00148	
Analytical standard deviation	.0739		.0615		.0537		.0383		.0808		.0513		.0666		.0385	
Bottle standard deviation	Neg.		Neg.		.0573		.101		.106		Neg.		.0538		Neg.	
F ratio	.0366 (NS)		.493 (NS)		3.28 (NS)		14.8 (S)		4.42 (NS)		.956 (NS)		2.30 (NS)		.303 (NS)	
Hafnium																
Bottle 1	1.32	1.63	4.50	5.00	3.26	3.00	8.15	7.36	3.80	4.33	4.53	4.81	25.4	26.4	5.73	6.29
2	.97	1.41	4.14	4.66	3.52	3.34	7.87	8.17	3.90	3.76	4.69	4.27	27.0	26.7	5.71	6.05
3	1.10	1.42	4.00	3.99	2.86	2.93	9.08	8.18	2.66	4.17	4.53	3.99	26.6	26.1	6.11	5.93
Mean	1.31		4.38		3.15		8.14		3.77		4.47		26.4		5.97	
Mean sum of squares between bottles	.0441		.286		.144		.403		.217		.0842		.452		.0122	
Mean sum of squares within bottles	.0654		.0868		.0175		.254		.430		.0911		.223		.0769	
Analytical standard deviation	.256		.295		.132		.504		.656		.302		.473		.277	
Bottle standard deviation	Neg.		.315		.251		.273		Neg.		Neg.		.388		Neg.	
F ratio	.675 (NS)		3.29 (NS)		8.23 (NS)		1.58 (NS)		.504 (NS)		.925 (NS)		2.02 (NS)		.159 (NS)	
Iron																
Bottle 1	19,300	18,400	31,700	33,700	45,000	44,400	50,900	48,100	85,300	85,900	30,800	31,300	33,100	32,900	12,800	13,400
2	17,900	19,500	34,900	34,700	45,900	45,200	46,100	45,500	84,100	85,400	30,200	30,200	35,000	33,900	13,300	13,300
3	18,300	19,400	34,300	32,400	45,500	45,000	49,100	48,000	83,100	84,900	29,400	30,300	34,800	33,400	13,300	12,900
Mean	18,800		33,617		45,167		47,950		84,783		30,367		33,850		13,167	
Mean sum of squares between bottles	15,064		2,312,128		371,712		7,384,832		1,280,000		761,216		1,144,544		26,728	
Mean sum of squares within bottles	763,339		1,275,029		183,338		1,568,427		882,347		176,683		535,061		86,648	
Analytical standard deviation	874		1,129		428		1,252		939		420		731		294	
Bottle standard deviation	Neg.		720		307		1,705		446		541		552		Neg.	
F ratio	0.02 (NS)		1.81 (NS)		2.03 (NS)		4.71 (NS)		1.45 (NS)		4.31 (NS)		2.14 (NS)		0.308 (NS)	

TABLE 58.—*Data for the new (1971 series) USGS silicate standards, in parts per million*—(Continued)

Rock Sample	SGR-1		SCo-1		MAG-1		SDC-1		BHVO-1		QLO-1		STM-1		RGM-1	
Duplcate No	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Rubidium																
Bottle 1	75.3	66.4	61.8	88.0	89.0	89.0	72.2	77.3	0.16	0.16	49.3	35.6	54.6	49.7	197	195
2	53.5	72.2	78.0	59.8	94.0	105	65.7	55.7	.14	.16	20.0	23.0	60.1	63.5	184	195
3	70.0	61.5	73.9	51.7	66.1	62.7	71.2	65.4	.13	.13	40.7	39.8	57.0	51.3	209	179
Mean	66.5		68.9		84.3		67.9		0.147		34.7		56.0		193	
Mean sum of squares between bottles	32.81		73.2		649		98.9		.00047		265		51.9		22.2	
Mean sum of squares within bottles	83.52		252		22.1		26.6		.00007		32.9		11.3		171	
Analytical standard deviation	9.14		15.9		4.70		5.16		.0082		5.74		3.37		13.1	
Bottle standard deviation	Neg.		Neg.		17.7		6.01		.0141		10.8		4.50		Neg.	
F ratio	.393 (NS)		.291 (NS)		[1] 29.4 (S)		3.72 (NS)		7.00 (NS)		8.05 (NS)		4.57 (NS)		.130 (NS)	
Scandium																
Bottle 1	4.91	4.74	10.8	11.4	16.1	16.0	16.8	15.6	32.2	32.5	9.13	9.28	0.66	0.67	4.54	4.81
2	4.60	4.94	11.8	11.8	16.6	16.4	15.3	15.1	31.8	32.6	8.90	8.96	.67	.72	4.81	4.84
3	4.59	4.87	11.8	11.0	16.4	16.1	16.1	15.8	31.2	31.9	8.70	8.80	.66	.67	4.78	4.74
Mean	4.78		11.4		16.3		15.8		32.0		8.96		0.675		4.75	
Mean sum of squares between bottles	,00455		.247		.102		.542		.362		.105		.00060		.0113	
Mean sum of squares within bottles	.0372		.167		.0233		.262		.203		.00602		.00045		.0126	
Analytical standard deviation	.193		.408		.153		.512		.451		.0776		.0212		.112	
Bottle standard deviation	Neg.		.200		.198		.374		.282		.222		.0087		Neg.	
F ratio	.122 (NS)		1.48 (NS)		4.36 (NS)		2.07 (NS)		1.78 (NS)		[1] 17.4 (S)		1.33 (NS)		.900 (NS)	
Tantalum																
Bottle 1	0.15	0.23	0.56	0.56	0.74	0.64	0.97	0.67	0.92	0.91	0.68	0.71	17.3	18.1	0.90	0.98
2	.29	.24	.61	.64	.77	.90	1.00	.95	.60	1.01	.71	.65	18.7	17.9	.90	.82
3	.26	.18	.53	.47	.66	.71	.92	.86	.84	.90	.67	.76	17.9	17.9	.84	.80
Mean	0.22		0.56		0.74		0.90		0.86		0.70		18.0		0.87	
Mean sum of squares between bottles	.00285		.00782		.0145		.0120		.00612		.00062		.187		.00747	
Mean sum of squares within bottles	.00255		.00075		.00490		.0160		.0286		.00210		.213		.00240	
Analytical standard deviation	.0505		.0274		.0700		.127		.169		.0458		.462		.0490	
Bottle standard deviation	.0122		.0594		.0693		Neg.		Neg.		Neg.		Neg.		.0503	
F ratio	1.12 (NS)		10.4 (S)		2.96 (NS)		.752 (NS)		.214 (NS)		.294 (NS)		.875 (NS)		3.11 (NS)	
Terbium																
Bottle 1	0.35	0.40	0.83	0.85	0.96	0.94	1.35	1.23	1.23	1.53	0.74	0.97	2.22	2.10	N.d.	N.d.
2	.43	.20	.80	.85	.74	.92	1.24	1.38	1.21	1.63	.97	.94	2.04	2.10	N.d.	N.d.
3	.20	.45	.65	.67	1.00	1.14	1.57	1.33	1.35	1.50	.95	.97	1.99	2.00	N.d.	N.d.
Mean	0.34		0.78		0.95		1.35		1.41		0.92		2.10			
Mean sum of squares between bottles	.00207		.0200		.0288		.0152		.0012		.00702		.0288			
Mean sum of squares within bottles	0.196		.00055		.00873		.0153		.0482		.00903		.00068			
Analytical standard deviation	.140		.0235		.0934		.124		.219		.0950		.0261			
Bottle standard deviation	Neg.		.0985		.100		Neg.		Neg.		Neg.		.119			
F ratio	.105 (NS)		[2] 36.3 (S)		3.30 (NS)		.996 (NS)		.0253 (NS)		.777 (NS)		[2] 42.2 (S)			
Thorium																
Bottle 1	5.18	4.80	10.1	10.5	12.8	13.0	14.8	14.1	2.90	3.21	6.24	6.39	37.6	38.3	18.0	19.2
2	4.74	5.03	10.8	11.0	13.3	12.9	13.9	13.8	3.16	3.08	6.13	6.11	40.2	39.3	19.3	18.9
3	4.54	4.85	10.6	9.8	13.2	12.8	14.1	14.4	3.13	3.64	6.19	6.11	39.3	38.3	18.1	18.2
Mean	4.86		10.5		13.0		14.2		3.19		6.20		38.8		18.6	
Mean sum of squares between bottles	.0447		.287		.0200		.187		.0611		.022		1.622		.452	
Mean sum of squares within bottles	.0541		.140		.0600		.0983		.0604		.00488		0.383		.268	
Analytical standard deviation	.232		.374		.245		.314		.246		.0699		0.619		.518	
Bottle standard deviation	Neg.		.271		Neg.		.210		.0185		.0926		0.787		.303	
F ratio	.827 (NS)		2.05 (NS)		0.333 (NS)		1.90 (NS)		1.01 (NS)		4.52 (NS)		4.23 (NS)		1.68 (NS)	

[1] At $F_{0.975}$.

[2] At $F_{0.99}$.

TABLE 59.—*Deviations, in percent, between the new and the selected data of the "primary" standards*

[The entries were calculated using the formula: 100·[selected data (table 56) minus new data (table 57)]/selected data]

Element	Sample								
	W–1	G–1	BCR–1	G–2	AGV–1	SP–1	PCC–1	DTS–1	GSP–1
Fe	—1.49	+12.2	+1.48	+0.27	—3.20	—5.21	—3.42	—2.74	—4.61
Ba	---	—15.8	+25.5	—1.05	+14.2	+5.76	---	---	+1.26
Ce	---	—20.3	—.10	—21.9	—11.0	+15.0	---	---	—7.63
Co	+11.0	—4.17	+3.85	+6.14	+7.14	+7.45	+8.11	+7.20	—2.93
Cr	+6.82	---	+35.4	---	—72.5	+.87	+4.18	—1.23	---
Cs	+30.8	—24.0	—1.67	+14.1	—1.60	—4.93	---	---	+29.2
Eu	—9.26	—24.6	—12.8	—17.2	—17.1	+2.07	---	---	+9.84
Hf	+10.4	—30.6	+8.58	—7.52	+8.19	+2.09	---	---	—10.14
Rb	---	—65.7	---	—27.5	+24.9	—6.86	---	---	+3.86
Sb	—5.24	—11.2	+45.8	---	+2.15	+14.6	+14.9	---	—7.87
Sc	—4.28	—22.2	+1.49	—1.52	+.81	+3.64	+1.27	+1.12	+5.96
Ta	---	+1.67	+38.2	—14.7	+18.1	—1.94	---	---	+39.6
Tb	—34.6	—47.5	+6.19	—27.9	—19.5	---	---	---	—18.1
Th	—6.8	—8.08	—3.99	—19.7	—11.9	—19.3	---	---	—8.05

REDUCTION OF DATA FOR THE NEW STANDARDS

The concentration of each element in the new standards was defined as:

$$X_{ij}=\frac{A_{ij}}{S_i\cdot W_j},$$

where X_{ij} is the concentration (in parts per million), and A_{ij} is the time-corrected activity of the ith element in the jth new standard. S_i denotes the mean specific activity of the ith element as calculated from the primary standards, and W_j is the weight (in grams) of the jth new standard. The data for the new standards, plus statistical estimates when available, are given in table 58.

DISCUSSION AND SUMMARY

The new data for the primary and new silicate standards are presented in tables 57 and 58, respectively. Since all the data were obtained by recalibration of the primary standards, it is of interest to compare the data obtained by our recalibration method to the literature data which we have selected for these standards. Table 59 lists the differences between the selected and the new values. Iron, cobalt, and scandium show the smallest differences between the two data sets. Co and Sc have very good counting statistics because of their high neutron capture cross sections, and for most samples the data selected were obtained by techniques similar to those of the present study. Iron, although less favorable for INAA, is a major element in all of the standards, and its determination by either chemical or physical means should yield similar results. Relatively large differences were found for the two oldest standards, G–1 and W–1, and these include the highest deviation for Co in W–1, for Sc in G–1 and for Fe in G–1. We do not think that these differences are the result of heterogeneities in the samples. These two samples have been used for a long time in our laboratory, and during this time the samples may have been contaminated by frequent reopening and sampling. The standard pottery sample (SP–1), for which only one set of data entirely based on INAA was available from the originator of the artificially made standard (Perlman and Asaro, 1969), appears to show the least difference except for Ce, Sb and Th.

The statistical analysis of the new USGS standards (table 58) demonstrates that all samples may be considered homogeneous for most elements. The mean sum of squares for portions taken from different bottles of the same sample is not significantly larger than that for portions sampled from the same bottle at the 95-percent confidence level. There are a few exceptions to this rule: Tb is heterogeneously distributed at the 1-percent level in bottles of both SCo–1 and STM–1; a similar heterogeneity was found for Ta in SCo–1 at the 5-percent level; Rb is heterogeneous in MAG–1, Sc in QLO–1, Eu in SDC–1, and Cr in STM–1, all at the 5-percent level. In all but one analysis (Sc in QLO–1), these heterogeneities occurred for elements having relatively poor counting statistics, whereas statistically "better" elements in the same standards did not show the same deviations, and it is hard to decide whether these heterogeneities are real. In any case, even if they are real, they may have resulted from minor contamination of selected elements during the processing of the standards rather than by large-scale sampling errors. Had the latter occurred, its effects might have been more evident by a larger proportion of conclusions of heterogeneity. Our variance analysis, which is based solely on the new USGS standards, is independent of the values adopted for the primary standards and thus is valid for the new standards in any case.

The new values given for both the primary and the new standards are self-consistent, and we believe they can be reproduced in other laboratories, provided the counting geometry is identical for both standards and unknowns. The wide chemical and mineralogical composition spectrum covered by the standards used in our study enables one to choose suitable reference samples for future work that match more closely both the matrix of the unknown samples and the concentrations of the elements to be determined.

ACKNOWLEDGMENTS

The many helpful suggestions of Karl T. Turekian of Yale University, in whose laboratory this work was performed, are greatly appreciated. The authors wish to thank L. Chan, J. Corliss, and D. P. Kharkar for their valuable advice. The technical assistance of T. Eisensmith, J. Hasbrouck, and M. Applequist is gratefully acknowledged. This work was supported by the U.S. Atomic Energy Commission grant, No. AT(11–1)3573.

REFERENCES

Flanagan, F. J., 1969, U.S. Geological Survey standards—II. First compilation of data for the new U.S.G.S. rocks: Geochim. et Cosmochim. Acta, v. 33, p. 81–120.

Flanagan, F. J., 1970, Sources of geochemical standards—II: Geochim. et Cosmochim. Acta, v. 34, p. 121–125.

Fleischer, M., 1969, U.S. Geological Survey standards—I. Additional data on rocks G–1 and W–1, 1965–1967: Geochim. et Cosmochim. Acta, v. 33, p. 65–80.

Gordon, G. E., Randle, Keith, Goles, G. G., Corliss, J. B., Beeson, M. H., and Oxley, S. S., 1968; Instrumental activation analysis of standard rocks with high-resolution γ-ray detectors: Geochim. et Cosmochim. Acta, v. 32, p. 369–396.

Perlman, I. and Asaro, F., 1969, Pottery analysis by neutron activation: Archaeometry, v. 11, p. 21–52.

Schmitt, R. A., Linn, T. A. and Wakita, H., 1970, The determination of fourteen common elements in rocks via sequential instrumental activation analysis: Radiochim. Acta, v. 13, p. 200–212.

BISMUTH CONTENTS OF USGS ROCK SAMPLES RGM–1 AND BHVO–1

By P. M. SANTOLIQUIDO[1] and W. D. EHMANN[1]

ABSTRACT

The bismuth contents of three bottles of two new USGS standard rocks have been determined by thermal neutron activation analysis and radiochemical separation and counting of the Po^{210} daughter activity of Bi^{210}. Mean values of 217 ppb Bi and 11.2 ppb Bi were obtained for RGM–1 and BHVO–1, respectively. Analyses of the variance show that the bottles of each sample are homogeneous for their bismuth contents. No estimates can be made for the standard deviations among bottles of either sample because the bottle variances are negative, but the coefficient of variation for the analyses of both samples averages approximately 12 percent.

As part of a program to acquire analytical data for the eventual standardization of a new series of USGS standard rock samples described in this volume, we have determined the bismuth contents of samples RGM–1 and BHVO–1. Three bottles of each sample were received, and two portions from each bottle were analyzed for bismuth by thermal neutron activation analysis. The six portions from the two samples were analyzed in random order. Bismuth was determined by alpha-particle counting of the Po^{210} daughter activity of the Bi^{210} produced by thermal neutron irradiation of the samples for 100 to 200 hours at fluxes ranging from 1 to 5×10^{13} neutrons cm^{-2} sec^{-1}. The University of Missouri Research Reactor, Columbia, Mo., was used for these irradiations.

Rock powder portions of 500–800 mg were weighed into clean quartz vials that were then heat sealed for irradiation. High-purity bismuth metal was dissolved in concentrated HNO_3, and a standard flux-monitor solution was prepared on a weight basis by successive dilution with 4 M HNO_3. Aliquots of this standard solution were evaporated onto 200 mg of Specpure SiO_2 in quartz vials for irradiation and chemical processing identical to that used for the rock samples. At least 20 days were allowed to elapse between the end of irradiation and the beginning of the polonium separation to permit essentially complete decay of Bi^{210} to Po^{210}. The irradiated sample was then transferred to a Teflon dish, and an aliquot of a standard solution of Po^{208} was added to permit the determination of the chemical yield of the separation procedures. The sample was then dissolved with H_2SO_4-HF followed by aqua regia. The aqueous solution obtained was treated with hydroxylamine, sodium citrate, and sulfur dioxide gas and was adjusted to pH 4 with dilute NH_4OH.

Polonium was plated out of the solution onto a silver metal disk, without the use of applied potential, for a period of 4 hours at a temperature of 65°C. After it was cleaned, the silver disk was counted with a surface-barrier silicon detector coupled to a multichannel pulse-height analyzer. A more detailed description of the chemical procedures may be found in Santoliquido (1971). These procedures have also been used to analyze six older USGS standard rocks (AGV–1, BCR–1, DTS–1, G–2, GSP–1, PCC–1) and a large collection of chondritic meteorites (Santoliquido and Ehmann, 1972). The data for the rocks analyzed in this study are given in table 60.

TABLE 60.—*Neutron activation determinations and estimates of bismuth in USGS standard rocks RGM–1 and BHVO–1*

[d.f., degrees of freedom; Neg., negative bottle variance. Conclusions from the analysis of variance. The calculated F ratio was tested against $F_{0.95}$(d.f. 2,3)=9.55. NS, not significant]

Rock Sample	RGM–1			BHVO–1		
Bottle No	57/26	51/1	57/21	19/10	22/5	62/2
Bismuth ppb	201	208	226	11.0	13.2	11.4
	211	262	196	11.4	10.2	9.9
Mean	217.3			11.18		
Standard deviation:						
Bottles (d.f.=2)	Neg.			Neg.		
Error (d.f.=3)	25.5			1.38		
Coefficient of variation for error percent	11.8			12.3		
Conclusions	NS			NS		

The data obtained were treated by the analysis of variance with the bottles of either sample as the

---

[1] Department of Chemistry, University of Kentucky, Lexington, Ky. 40506.

single variable of classification, and a summary of the estimates is given in table 60. For both samples, the mean sum of squares for bottles was less than the "within" mean sum of squares that we equate with the analytical error. Hence, we could not calculate a standard deviation for the bottles of either sample, since the subtraction involved in the separation of average mean squares (as shown, for example, by Koch and Link, 1970, table 5.8) results in a negative variance for bottles. Since the variation attributable to bottles was not greater than the analytical variation, these analyses suggest that bismuth in the bottles of either sample is distributed homogeneously among the bottles. The coefficients of variation (analytical error) for RGM–1 and BHVO–1 are 11.8 percent and 12.3 percent, respectively.

In comparison with our analyses (Santoliquido and Ehmann, 1972) of the old set of USGS standard rocks, it may be noted that the bismuth content of basalt BHVO–1 is only approximately one-third of that for basalt BCR–1. The rhyolite RGM–1 contains approximately four times as much bismuth as the standard granite G–2 that previously represented the highest bismuth content among the USGS standard rocks. The factor of 20 range in bismuth content of these two new standard rocks and the apparent homogeneity of the samples should make them valuable reference standards for analysts determining bismuth in geologic materials.

ACKNOWLEDGMENTS

This work was supported in part by U.S. Atomic Energy Commission Contract AT–(40–1)–2670. The authors wish to acknowledge the assistance of F. J. Flanagan for the statistical treatment of the data.

REFERENCES

Koch, G. S., Jr., and Link, R. F., 1970, Statistical analysis of geological data: New York, John Wiley and Sons, 375 p.

Santoliquido, P. M., 1971, The determination of bismuth in meteorites and rocks by neutron activation analysis: Lexington, Kentucky Univ. Dept. of Chemistry, Ph. D. dissert.

Santoliquido, P. M., and Ehmann W. D., 1972, Bismuth in stony meteorites and standard rocks: Geochim. et Cosmochim. Acta, v. 36, no. 8, p. 897–902.

DETERMINATION OF URANIUM AND THORIUM IN USGS STANDARD ROCKS BY THE DELAYED NEUTRON TECHNIQUE

By H. T. MILLARD, JR.

ABSTRACT

Uranium and thorium were determined in 12 USGS standard rocks by the delayed neutron technique. Duplicates from three bottles of each standard rock were analyzed in random order. The averages are:

	Parts per million	
	Uranium	Thorium
AGV–1	2.05	5.37
BCR–1	1.81	5.26
BHVO–1	.48	.90
G–2	2.15	24.0
GSP–1	2.56	106.9
MAG–1	2.82	12.2
QLO–1	2.01	3.24
RGM–1	5.85	13.1
SCo–1	3.15	9.52
SDC–1	3.12	11.4
SGR–1	5.60	7.66
STM–1	9.10	26.6

The thorium and uranium contents of the bottles of samples, except SCo–1, may be accepted as homogeneous at $F_{0.95}$. The uranium content of SCo–1 may be declared heterogeneous at $F_{0.95}$ or accepted as homogeneous at $F_{0.975}$.

INTRODUCTION

The concentrations of uranium and thorium were determined in the new USGS standard rocks (BHVO–1, MAG–1, QLO–1, RGM–1, SCo–1, SDC–1, SGR–1, and STM–1) as well as in four of the older USGS standard rocks (AGV–1, BCR–1, G–2, and GSP–1). The analytical technique used was that of neutron activation-delayed neutron counting (Amiel, 1962; Dyer and others, 1962; Gale, 1967), which relies upon the property of the fission daughters of uranium and thorium of continuing to emit "delayed" neutrons for a short time after their formation. The fact that these neutrons can be detected and counted with good discrimination and efficiency makes the technique both specific and sensitive. It allows rapid, precise, and nondestructive determinations of uranium to about 0.1 ppm and thorium to about 1 ppm in a 10-g sample of rock. Lower detection limits for uranium can be realized by recycling the same sample several times and thus improving the counting statistics.

EXPERIMENTAL METHODS

STANDARD SOLUTIONS

A uranium standard solution was prepared from National Bureau of Standards Standard Reference Material 950a Uranium Oxide (99.94 percent U_3O_8). The isotopic ratio of this oxide, as determined by mass spectrometry, is $U^{238}/U^{235}=137.8$ (J. N. Rosholt, oral commun., 1972) and the solution contained 0.987 mg U/g solution if a stoichiometric composition is assumed for the oxide. The uranium concentration of the solution was also measured on two separate occasions by isotope dilution-mass spectrometry and found to be 0.982 and 0.998 mg U/g solution (Prijana and J. N. Rosholt, written commun., 1972). The value 0.982 was used.

A thorium standard solution was prepared using reagent grade $Th(NO_3)_4 \cdot 4H_2O$. Assuming a stoichiometric composition for the nitrate, the solution contained 1.003 mg Th/g solution. This value was checked by isotope dilution-mass spectrometry, which gave 1.013 mg Th/g solution (Prijana, oral commun., 1972).

PREPARATION AND CALIBRATION OF MONITORS

The uranium monitor (500 μg U) was prepared from dunite powder (DTS–1), which contains 3 ppb U and 10 ppb Th, by alternately adding powder and weighed aliquot portions of the uranium standard solution. This procedure resulted in a uniform distribution of the uranium throughout the powder. A low-level thorium monitor (500 μg Th) was prepared by the same procedure as the uranium monitor. A high-level thorium monitor (10,000 μg Th) was prepared by mixing dunite powder with a weighed portion of thorium oxide powder (99.9 percent pure, −100+325 mesh, Code 116, American Potash and Chemical Corp., Lindsay Chemical Division). Rather than relying entirely on the concentration values for the standard solutions, we then calibrated these monitors against a set of laboratory standard rocks using the delayed neutron technique. For most of these rocks, the uranium and thorium concentrations had been determined by isotope dilution-mass spectrometry, and their homogeneity had been established by delayed neutron analysis of carefully prepared splits.

The results of this calibration are given in table 61. It was found necessary to increase the value of uranium in the uranium monitor by 3.8 percent from the value based on the concentration of the uranium standard solution in order to obtain better agreement between the delayed neutron values and the literature values for the standard rocks, that is, to make the average of the ratios of the delayed neutron values and the literature values closer to 1. The delayed neutron values shown in tables 61 and 64 were computed using this calibrated value for the uranium monitor. No adjustment was made in the value of the thorium monitor. This method of calibration results in the values used for the uranium and thorium monitors being dependent on determinations obtained by isotope dilution-mass spectrometry.

PREPARATION OF SAMPLES

Tared 2-dram polyethylene snap-cap vials were filled with the sample powders (6 to 10 g of sample), were weighed, and were heat sealed. Two portions from each of three bottles were analyzed for each USGS standard rock.

GEOLOGICAL SURVEY TRIGA FACTOR

The neutron fluxes available in the pneumatic tube facility of the Geological Survey TRIGA reactor (GSTR) are given in table 62. The vertical flux gradients at this position in the reactor are: thermal, 1.9 percent/cm, and fast, <0.7 percent/cm. Transit times for the polyethylene rabbits range from 6 seconds for an empty rabbit to 7 seconds for a rabbit containing a 10-g sample. The temperature coefficient for the uranium determination in this reactor was determined to be −0.43 percent/degree at 25°C and −0.30 percent/degree at 42°C, where the temperature is that of the water at the top of the reactor tank. This relatively large temperature coefficient requires that the temperature of the reactor be held as constant as possible throughout a run.

TABLE 62.—*Neutron fluxes in the Geological Survey TRIGA reactor for pneumatic tube irradiations in the "G" ring, in neutrons per square centimeter per second*

[Values are nominal fluxes 0.5 cm above the bottom of the rabbit. Data from W. M. Quam and T. M. Devore, E. G. and G., Inc. written commun, 1969]

Flux	Reactor power level	
	100 kW	1 MW
Thermal	5.9×10^{11}	5.9×10^{12}
Fast (>0.6 MeV)	2.7×10^{11}	2.7×10^{12}

BF_3 NEUTRON COUNTER

The assembly used to count the delayed neutrons is similar to those described by Amiel (1962) and

TARLE 61.—*Calibration of uranium and thorium monitors against a set of laboratory standard rocks by the delayed neutron technique*

[In parts per million. Delayed neutron value: Mean (ppm)±coefficient of variation (percent). The value for the U monitor has been changed by 3.8 percent from that calculated from the concentration of U in the U standard solution to achieve better agreement between the delayed neutron and litrature values]

Laboratory standard rock	U			Th		
	Delayed neutron	Literature value	Delayed neutron / Literature	Delayed neutron	Literature value	Delayed neutron / Literature
Hinsdale basalt (Ds 29–B)	0.84±6.0	[1] 0.88	0.954	3.4±8.7	[1] 3.5	0.971
BCR–1	1.75±2.9	[2] 1.73	1.012	5.5±9.4	[2] 5.99	.918
GSP–1	2.50±1.0	[3] 2.4	1.042	107.4±1.1	[3] 106	1.013
FF–4	3.11±1.2	[4] 3.07	1.013	10.4±3.2	[4] 10.4	1.000
JNR–6379	7.73±3.0	[5] 7.59	1.018	3.2±65	[5] 3.01	1.063
RM–1	15.7±1.0	[6] 15.3	1.026	37.5±5.5	[6] 37.7	.995
3633	23.5±0.8	[7] 23.4	1.004	84.1±4.1	[7] 82.0	1.026
GD–5–4–1	31.5±1.7	[8] 30.6	1.029	21±15	[8] 22	.954
AEC–NBL–80	39.9±1.0	[9] 40	.997	996±1.3	[9] 1,000	.966
AEC–NBL–76	100.4±0.5	[9] 101	.994	---------	-------	----
AEC–NBL–1	229±0.7	[8] 225	1.017	---------	-------	----
Average			1.010			.990

[1] ID–MS (isotope dilution-mass spectrometric), Doe and others (1969).

[2] ID–MS, M. Tatsumoto (oral commun., 1968).

[3] ID–MS, Peterman and others (1967).

[4] ID–MS, Rosholt and others (1966).

[5] ID–MS, J. N. Rosholt (oral commun., 1969)

[6] ID–MS, Rosholt and Noble (1969).

[7] ID–MS, Rosholt and others, (1970).

[8] Gamma-counting, C. Bunker (oral commun., 1970).

[9] Synthetic standard, prepared value.

Gale (1967). When returned from the reactor, the rabbit containing the sample is allowed to drop into the center of an array of six $^{10}BF_3$ detectors (each 2 in. in diameter by 28 in. long, sensitive length = 26 in. fill pressure = 70 cm Hg). The array, which has a radius of 12.7 cm, is completely embedded in paraffin except for the volume around the rabbit, which contains a 6.4-cm-thick lead shield to reduce the biological hazard from gamma radiation. A 0.08-cm-thick cadmium sheet and 7.6 cm of borated paraffin (25 percent H_3BO_3 by weight) are used to shield the detectors from external neutrons. The efficiency of the counter for neutrons is estimated to be 15 percent, and the background, which is probably due to cosmic ray interactions within the array, averages 4.0 cps. The effect of the gamma flux from 2.3-min Al^{28} in the sample was found to be negligible; the Al in a 12-g sample containing 15 percent Al_2O_3 is equivalent to less than 0.017 ppm U (3-sigma limit).

IRRADIATION AND COUNTING PROCEDURE

The samples and monitors are first irradiated for 1 minute at a power level of 100 kW using a bare pneumatic tube terminus in the GSTR. The activity is allowed to decay for 20 seconds, and the sample is counted for 1 minute in the BF_3 counter. After all samples have been run, a cadmium-lined pneumatic tube terminus is installed in the GSTR, and the samples and monitors are reirradiated at a power level of 1 MW and are counted as in the first irradiation. The cadmium reduces the flux of slow neutrons and thus increases the count rate due to thorium relative to the rate due to uranium. A boron-lined counter is used to detect the passage of the rabbit into and out of the reactor (Helfer, 1971). This timing signal and the counting signals are transmitted to a minicomputer that stores the data on magnetic tape and paces the operation of the system so a sample can be run every 90 seconds.

The analytical parameters for a single cycle of two irradiations and countings are listed in table 63.

CORRECTIONS TO THE DATA

The dead time of the counting system at high count rates is dominated by the recovery time of the BF_3 detectors. The correction was found (Stevenson, 1966, p. 112) to follow the relation:

$$\frac{\text{cps}_t}{\text{cps}_o} = \frac{\text{cps}_o}{1-(t\times \text{cps}_o)}$$

where t is 7.8 μs, cps is counts per second, and the subscripts t and o indicate the true and observed counting rates, respectively.

TABLE 63.—*Analytical parameters for the determination of uranium and thorium using one cycle of two irradiations and countings with the delayed neutron system*

Parameters	Reactor power level: 100 kW, U	100 kW, Th	1 MW (Cd-lined terminus), U	1 MW (Cd-lined terminus), Th
Sensitivity ....cps/μg..	1.24	0.0173	1.00	0.142
Counter background ..cps..	4.0±0.25	4.0±0.25	4.0±0.25	4.0±0.25
Weight of element equivalent to counter background ....μg..	3.2±0.20	....	....	28±1.8
3-sigma detection limits equivalent to counter background:				
Weight of element.μg..	0.60	....	....	5.4
Concentration in 1-g sample ....ppm..	0.60	....	....	5.4
Concentration in 10-g sample ....ppm..	0.060	....	....	0.54

The reaction ^{17}O (n,p) ^{17}N causes an interference during the second irradiation due to emission of delayed neutrons by ^{17}N. This interference results in erroneously high values for the thorium concentration. The magnitude of this interference is equal to 0.30 cps/g oxygen, which, in turn, is equivalent to 0.89 ppm Th for a 10-g sample containing 44 percent oxygen.

CALCULATIONS

The calculations are performed off-line by the minicomputer using the data for the two irradiations stored on magnetic tape. After the counter background has been subtracted and the dead time and oxygen corrections applied, the following simultaneous equations are solved for the weights of uranium (wt U) and thorium (wt Th):

$$(\text{cps})_1 = (\text{wt U})(\text{cps}/\mu\text{g U})_1 + (\text{wt Th})\ (\text{cps}/\mu\text{g Th})_1,$$

and

$$(\text{cps})_2 = (\text{wt U})(\text{cps}/\mu\text{g U})_2 + (\text{wt Th})(\text{cps}/\mu\text{g Th})_2.$$

The subscripts 1 and 2 denote the irradiation, and cps/μg U and cps/μg Th are computed from the counting data for the U and Th monitors, respectively. In addition, the standard deviations for wt U and wt Th are computed from the counting statistics, and the results are then reduced to (ppm U) ± C.V._{cs} and (ppm Th) ± C.V._{cs}, where C.V._{cs} is the coefficient of variation based on the counting statistics.

RESULTS AND DISCUSSION

The concentrations of uranium and thorium determined in the USGS standard rocks are listed in table 64. The values for both portions from each of the three bottles for each standard are shown. The coefficient of variation for a single determination, based on counting statistics, is indicated along with the mean of the six determinations for each standard rock. The coefficients of variation based on the scatter about the means are not shown in the table,

TABLE 64.—*Concentrations of uranium and thorium in USGS standard rocks*

[C.V.$_{cs}$ is the coefficient of variation based on counting statistics for a single determination]

Standard rock	Bottle (split/position)	U			Th		
		Ppm	C.V.$_{cs}$ (percent)	Mean ppm	Ppm	C.V.$_{cs}$ (percent)	Mean ppm
G–2	50/19	2.13, 2.21	5	2.15	23.4, 25.6	5	24.0
	85/29	2.25, 2.07			24.3, 23.9		
	23/19	2.12, 2.10			23.6, 23.2		
GSP–1	66/26	2.67, 2.55	5	2.56	105.6, 103.9	2	106.9
	36/31	2.48, 2.68			105.7, 108.4		
	71/03	2.45, 2.54			108.9, 109.1		
AGV–1	99/03	2.07, 1.94	4	2.05	4.03, 5.98	20	5.37
	86/20	2.10, 2.18			5.49, 4.74		
	38/07	2.05, 1.96			5.47, 6.51		
BCR–1	68/05	1.83, 1.80	5	1.81	5.15, 5.36	17	5.26
	39/28	1.78, 1.76			5.76, 6.40		
	68/16	1.93, 1.81			3.87, 5.05		
STM–1	42/09	9.18, 9.08	3	9.10	25.8, 2.67	4	26.6
	38/19	9.02, 9.15			27.5, 26.5		
	35/29	9.27, 8.87			25.0, 28.4		
RGM–1	27/11	5.70, 5.81	3	5.85	11.1, 15.3	13	13.1
	01/20	5.90, 5.99			12.3, 12.4		
	10/06	5.86, 5.82			13.4, 14.2		
QLO–1	02/24	2.14, 2.04	5	2.01	2.56, 3.60	37	3.24
	61/20	1.96, 1.84			4.08, 4.08		
	28/20	2.02, 2.08			2.72, 2.38		
SCo–1	29/02	3.08, 3.12	4	3.15	10.15, 9.68	10	9.52
	63/12	3.29, 3.24			9.11, 9.12		
	45/15	3.12, 3.05			8.82, 10.24		
MAG–1	29/06	2.85, 2.74	4	2.82	12.4, 13.0	10	12.2
	20/12	2.86, 2.71			11.7, 12.6		
	2/22	2.98, 2.78			10.9, 12.7		
SDC–1	49/19	3.21, 2.97	4	3.12	10.7, 12.9	10	11.4
	116/32	3.14, 3.15			11.0, 11.3		
	44/20	3.16, 3.12			11.6, 10.8		
BHVO–1	8/04	0.45, 0.43	11	.48	0.92, 1.82	60	.90
	7/32	.62, .42			.17, 1.55		.90
	24/09	.49, .44			.45, .52		
SGR–1	18/04	5.58, 5.84	3	5.60	6.37, 6.91	22	7.66
	24/23	5.34, 5.55			9.18, 9.83		
	40/24	5.90, 5.41			4.91, 8.76		

but in all cases they agree quite well with those based on counting statistics. The values for BCR–1 and GSP–1, which appear in both tables 61 and 64, are for different bottles but do agree within counting statistics.

Table 65 summarizes the results of one-way analyses of variance applied to the uranium and thorium data in table 64. According to the model used, the "within bottle" mean square is an estimate of the analytical variance and the "between bottle" mean square is an estimate of the analytical variance plus n times the bottle variance, where n $(=2)$ is the number of determinations per bottle. The F ratios calculated for both elements in all rocks, except uranium in SCo–1, do not exceed $F_{0.95}$ in the tables. Therefore, the bottles for these samples are homogenous for uranium and thorium at $F_{0.95}$. Similarly, the uranium in bottles of SCo–1 is heterogeneous at $F_{0.95}$ or homogeneous at $F_{0.975}$.

ACKNOWLEDGMENTS

Colleagues who helped in this work include the reactor staff of the GSTR; A. J. Bartel, who prepared the samples for irradiation; P. J. Aruscavage, who helped run the samples; and F. J. Flanagan, who calculated the analysis of variance. I am indebted to V. J. Janzer and J. G. Haffty for their many suggestions for improving the manuscript.

TABLE 65.—*Estimates for uranium and thorium in USGS standard rocks*

[d.f., degrees of freedom. Neg., negative bottle variance. *F* ratio tested against $F_{0.95}$ or $F_{0.975}$. NS, not significant]

Sample	Mean (ppm)	Standard deviation		*F* ratio
		Between bottles (d.f.=2)	Within bottles (d.f.=3)	
		Uranium		
G-2	2.15	Neg.	0.081	0.32 (NS)
GSP-1	2.56	Neg.	.102	.68 (NS)
AGV-1	2.05	0.059	.072	2.32 (NS)
BCR-1	1.81	.035	.051	1.92 (NS)
STM-1	9.10	Neg.	.176	.06 (NS)
RGM-1	5.85	.085	.060	4.99 (NS)
QLO-1	2.01	.088	.068	4.30 (NS)
SCo-1	3.15	.096	.039	13.3
MAG-1	2.82	Neg.	.112	.44 (NS)
SDC-1	3.12	Neg.	.099	.19 (NS)
BHVO-1	.48	Neg.	.085	.47 (NS)
SGR-1	5.60	Neg.	.242	.67 (NS)
		Thorium		
G-2	24.0	Neg.	0.927	0.72 (NS)
GSP-1	106.9	1.92	1.30	5.3 (NS)
AGV-1	5.37	Neg.	.953	.64 (NS)
BCR-1	5.26	.709	.554	4.26 (NS)
STM-1	26.6	Neg.	1.49	.13 (NS)
RGM-1	13.1	Neg.	1.75	.35 (NS)
QLO-1	3.24	.710	.447	6.05 (NS)
SCo-1	9.52	Neg.	.611	.85 (NS)
MAG-1	12.2	Neg.	.86	.56 (NS)
SDC-1	11.4	Neg.	.973	.27 (NS)
BHVO-1	.90	Neg.	.673	.87 (NS)
SGR-1	7.66	1.126	1.609	1.98 (NS)

REFERENCES

Amiel, S., 1962, Analytical applications of delayed neutron emission in fissionable elements: Anal. Chemistry, v. 34, p. 1683–1692.

Doe, B. R., Lipman, P. W., Hedge, C. E., and Kurasawa, Hajime, 1969, Primitive and contaminated basalts from the southern Rocky Mountains, U.S.A.: Contr. Mineralogy and Petrology, v. 21, p. 142–156.

Dyer, F. F., Emery, J. F., and Leddicote, G. W., 1962, A comprehensive study of the neutron activation analysis of uranium by delayed-neutron counting: U.S. Atomic Energy Comm. Rept. ORNL–3342, 71 p.

Gale, N. H., 1967, Development of delayed neutron technique as rapid and precise method for determination of uranium and thorium at trace levels in rocks and minerals, with applications to isotope geochronology, *in* Radioactive dating and methods of low-level counting—IAEA-ICSU Symposium, Monaco, 1967, Proceedings: Vienna, Austria, Internat. Atomic Energy Agency, p. 431–452.

Helfer, P. G., 1971, A precise timing system for pneumatically transferred samples, *in* American Nuclear Society Reactor Operations Division Conference on reactor operating experience, Denver, Colo., Aug. 8–11, 1971: Am. Nuclear Soc. Trans., v. 14, supp. no. 2, p. 22–23.

Peterman, Z. E., Doe, B. R., and Bartel, A. J., 1967, Data on the rock GSP-1 (granodiorite) and the isotope-dilution method of analysis for Rb and Sr, *in* Geological Survey research 1967: U.S. Geol. Survey Prof. Paper 575–B, p. B181–B186.

Rosholt, J. N., Doe, B. R., and Tatsumoto M., 1966, Evolution of the isotopic composition of uranium and thorium in soil profiles: Geol. Soc. America Bull., v. 77, p. 987–1004.

Rosholt, J. N., and Noble, D. C., 1969, Loss of uranium from crystallized silicic volcanic rocks: Earth and Planetary Sci. Letters, v. 6, p. 268–270.

Rosholt, J. N., Peterman, Z. E., and Bartel, A. J., 1970, U-Th-Pb and Rb-Sr ages in granite reference sample from southwestern Saskatchewan: Canadian Jour. Earth Sci., v. 7, p. 184–187.

Stevenson, P. C., 1966, Processing of counting data: Natl. Acad. Sci.—Natl. Research Council Nuclear Sci. Ser. Rept. NAS–NS 3109, 167 p.

THE DETERMINATION OF ANTIMONY, HAFNIUM, AND TANTALUM IN THE NEW USGS STANDARD ROCKS

By L. J. Schwarz and J. J. Rowe

ABSTRACT

The new USGS standard rocks, SGR–1, SDC–1, MAG–1, BHVO–1, QLO–1, RGM–1, STM–1, SCo–1, and the older standard rocks, G–2, GSP–1, AGV–1 and BCR–1, were analyzed for antimony, hafnium, and tantalum by instrumental neutron activation analysis. The analysis of variance shows that the three elements in the standard rock samples may be considered homogeneous at $F_{0.05}$ except for sample MAG–1 for which antimony and hafnium may be declared homogenous at $F_{0.975}$.

The new USGS standard rocks, SGR–1, SDC–1, MAG–1, BHVO–1, QLO–1, RGM–1, STM–1, and SCo–1, and the older standard rocks, G–2, GSP–1, AGV–1, and BCR–1, were analyzed for antimony, hafnium, and tantalum by instrumental neutron activation analysis. These analyses were made as part of the program to establish values for the composition of the standard rocks and to estimate the homogeneity of the bottles, the variation between bottles, and the analytical error.

The development of high-resolution Ge(Li) detectors has made the instrumental neutron activation analysis a practical method for the determination of many elements without chemical separations. Although our procedure is not unique, the data herein are valuable for the evaluation of comparability between laboratories. Variations between laboratories using instrumental neutron activation analysis may be due to differences in instrumentation, preparation of standards, irradiation conditions, and data-handling techniques.

Standard solutions were prepared from tantalum metal, hafnium dioxide, and potassium antimonyl tartrate hemihydrate. Monitors to be used as standards for the irradiations were prepared by pipetting each standard solution onto about 0.1 g of Specpure SiO_2 in a ⅖-dram polyethylene vial. Each monitor contained 10 μg of antimony and tantalum and 5 μg of hafnium. After being dried at 50°C, the polyvials were heat sealed.

Two 0.3-g samples from each of three randomly selected bottles of each standard were weighed into ⅖-dram polyethylene vials and were then heat sealed. A random sequence was used for the weighing of samples and the packing of irradiation rabbits. Each rabbit contained six samples plus three monitors and was irradiated for 8 hours at the National Bureau of Standards reactor which has a flux of 5×10^{13} neutrons $cm^{-2}s^{-1}$.

Samples and monitors were allowed to cool for 4 weeks to permit short-lived isotopes to decay. Each sample was counted for 2.2 hours at a distance of 12.5 cm above a 10-percent efficient Ge(Li) detector (resolution = 2.4 keV for the 1.33 MeV peak of Co^{60}). Spectra were collected on a 4,096-channel multichannel analyzer and were transferred automatically to magnetic tape. Samples were changed automatically using a device designed and constructed by us. The magnetic tape was read back into the analyzer, and selected portions of each spectrum were printed out on a line printer. The areas of pertinent peaks were calculated using Covell's (1959) method.

The area under the 1,690 keV peak for Sb^{124} was used for the calculation of antimony content. The 604 keV peak is subject to interference from Cs^{134} and Ir^{192}, whereas the 1,690 keV peak is virtually interference free. The 482 keV peak for Hf^{181} was used for the determination of hafnium. The only interference encountered that might affect the results is the 484 keV peak of Ir^{192}. However, concentrations of iridium are very low, and this interference may be disregarded.

Although Gordon and others (1968) reported that the 67.7 keV peak for Ta^{182} is more sensitive than the 1,221.3 keV peak, Hertogen and Gijbels (1971) found that the hafnium and gold X-rays interfered. The use of a low-energy photon detector for the measurement of the 67.7 keV peak was also subject to geometric and absorption problems for the sample size (0.3 g) used for this study. The interferences to the 1,221.3 keV peak of Ta^{182} from 17.4-hour Ir^{194} and 26.5-hour As^{76} are eliminated by the cooling time used.

The entire suite of samples and standards were counted three times. Each result shown in table 66 is the average of the three counts. The results carry one additional significant figure for calculation purposes. They could be rounded at the discretion of the reader.

The analysis of variance for a single variable of classification was made on the data to yield the estimates and conclusions that are also given in table 66 for antimony, hafnium, and tantalum. The square root of the mean sum of squares for within bottles has been equated to analytical error. Dixon and Massey (1951, p 154) show the population values estimated by each mean sum of squares, and we have calculated, wherever possible, the bottle variances from which are derived the standard deviations. If the mean sum of squares for within bottles is larger than the mean sum of squares for between bottles, a negative bottle variance will result, which is meaningless. This occurrence is noted by "Neg." in the table.

TABLE 66.—*Determinations of antimony, hafnium, and tantalum in USGS standard rocks*

[In parts per million. d.f., degrees of freedom. "Neg.," a negative bottle variance. Conclusions from analysis of variance ($F_{0.95}$); NS, not significant]

Standard rock	Bottles			Mean (ppm)	Standard deviation		Coefficient of variation (percent)	Conclusions
	1	2	3		Bottles (d.f.=2)	Error (d.f.=3)		
				Antimony				
AGV-1	3.94	4.28	4.12	4.17	Neg.	0.159	3.8	NS
	4.22	4.11	4.33					
BCR-1	.56	.69	.40	.49	Neg.	.130	26.5	NS
	.39	.43	.47					
G-2	.087	.090	.093	.08	Neg.	.027	35.1	NS
	.073	.086	.029					
GSP-1	3.48	2.82	2.94	3.22	Neg.	.349	10.9	NS
	3.23	3.57	3.27					
BHVO-1	.14	.14	.11	.16	Neg.	.048	30.2	NS
	.20	.15	.21					
MAG-1	.91	.98	.79	.88	0.107	.048	5.5	NS(.975)
	.80	1.01	.76					
QLO-1	1.69	1.92	1.67	2.03	Neg.	.515	27.1	NS
	2.79	1.84	2.28					
RGM-1	1.31	1.28	1.32	1.30	0.033	.094	7.2	NS
	1.43	1.33	1.13					
SCo-1	2.75	2.51	2.67	2.51	.062	.132	5.3	NS
	2.51	2.60	2.50					
SDC-1	.63	.51	.58	.53	.022	.100	19.1	NS
	.42	.39	.62					
SGR-1	----	3.61	3.60	3.70	----	----	---	--------
	3.80	3.78	----					
STM-1	1.68	1.70	1.66	1.67	Neg.	.064	3.8	NS
	1.68	1.56	1.73					
				Hafnium				
AGV-1	4.96	5.27	5.06	5.17	Neg.	0.239	4.6	NS
	5.50	5.06	5.15					
BCR-1	4.62	4.77	4.89	4.80	Neg.	.195	4.1	NS
	5.07	4.67	4.77					
G-2	8.33	8.10	8.14	8.15	.104	.129	1.6	NS
	8.23	8.23	7.87					
GSP-1	15.77	14.66	14.98	15.41	Neg.	.613	4.0	NS
	15.35	15.68	16.00					
BHVO-1	4.23	4.25	4.55	4.43	Neg.	.214	4.8	NS
	4.59	4.58	4.36					
MAG-1	3.42	3.58	3.53	3.52	.107	.052	1.5	NS(.975)
	3.40	3.69	3.47					
QLO-1	4.77	4.64	4.64	4.68	Neg.	.103	2.2	NS
	4.63	4.55	4.83					
RGM-1	5.89	5.98	5.96	5.93	.124	.131	2.2	NS
	5.65	6.18	5.89					

TABLE 66.—*Determinations of antimony, hafnium, and tantalum in USGS standard rocks*—Continued

Standard rock	Bottles			Mean (ppm)	Standard deviation		Coefficient of variation (percent)	Conclusions
	1	2	3		Bottles (d.f.=2)	Error (d.f.=3)		
SCo–1	4.55	4.73	4.78	4.73	Neg.	.167	3.5	NS
	4.88	4.85	4.57					
SDC–1	8.72	7.92	8.63	8.30	Neg.	.042	5.1	NS
	7.96	8.43	8.10					
SGR–1	----	1.43	1.34	1.41	----	----	---	--------
	1.43	1.44	----					
STM–1	28.73	28.77	26.97	28.87	Neg.	1.620	5.6	NS
	30.92	27.70	30.10					
				Tantalum				
AGV–1	0.84	0.74	0.81	0.79	0.070	0.055	7.0	NS
	.78	.66	.91					
BCR–1	.74	.70	.62	.69	Neg.	.055	8.0	NS
	.63	.73	.69					
G–2	.75	.74	.81	.74	.003	.039	5.21	NS
	.74	.69	.73					
GSP–1	.77	1.27	.78	.89	.066	.179	20.2	NS
	.84	.84	.84					
BHVO–1	1.09	1.07	1.04	1.10	Neg.	.048	4.4	NS
	1.18	1.10	1.11					
MAG–1	.92	1.01	1.08	1.00	Neg.	.075	7.5	NS
	1.00	1.05	.92					
QLO–1	.91	.74	.82	.81	Neg.	.063	7.7	NS
	.77	.80	.84					
RGM–1	.87	.87	.90	.90	Neg.	.035	3.9	NS
	.93	.93	.91					
SCo–1	1.00	.82	.86	.82	.030	.109	13.4	NS
	.81	.66	.76					
SDC–1	1.14	1.13	1.12	1.15	Neg.	.057	5.0	NS
	1.07	1.24	1.17					
SGR–1	----	.93	.42	.57	----	----	---	--------
	.47	.45	----					
STM–1	17.56	17.83	16.59	17.26	Neg.	.474	2.8	NS
	17.38	16.92	17.29					

The F ratio of the mean sum of squares for bottles to the mean sum of squares for within bottles is, in almost all cases, not significant when tested against $F_{0.95}$. For the combinations of elements and bottles for which such nonsignificant ratios were obtained, we may conclude that the bottles of a specified standard rock sample are homogeneous for the element determined. Because of the random selection of bottles, this conclusion may be extrapolated to the entire lot of bottles of the specific standard rock.

The F ratios for antimony and hafnium in MAG–1 were found to be significant at $F_{0.95}$ with the ratio for hafnium just barely significant, but it may be concluded that bottles of MAG–1 are homogeneous for antimony and hafnium at $F_{0.975}$. Two portions of SGR–1 were spoiled during processing, hence only the raw data and the average for this sample are shown in the tables.

REFERENCES CITED

Covell, D. F., 1959, Determination of gamma-ray abundance directly from total absorption peak: Anal. Chemistry v. 31, p. 1785–1790.

Gordon, G. E., Randle, Keith, Goles, G. G., Corliss, J. B., Beeson, M. H., and Oxley, S. S., 1968, Instrumental activation analysis of standard rocks with high-resolution gamma-ray detectors: Geochim. et Cosmochim. Acta, v. 32, p. 369–396.

Dixon, W. J., and Massey, F. J., Jr., 1951, Introduction to statistical analysis: New York, McGraw Hill, 370 p.

Hertogen, J., and Gijbels, R., 1971, Instrumental neutron activation analysis of rocks with a low energy photon detector: Anal. Chim. Acta, v. 56, p. 61–82.

GOLD CONTENT OF USGS STANDARD ROCKS

By L. J. Schwarz and J. L. Barker

ABSTRACT

Gold was determined in eight new USGS standard rocks, SGR–1, MAG–1, SCo–1, SDC–1, BHVO–1, QLO–1, STM–1, and RGM–1, and in the four older rocks, GSP–1, G–2, AGV–1, and BCR–1, by neutron activation, using fire assay for the radiochemical separation. The gold content of these standard rocks ranges from 0.4 to 10 ppb. Analyses of variance indicate that, except for BCR–1 and SDC–1, gold is distributed homogeneously among the bottles of any one of the rocks.

As part of a program to evaluate powdered rocks as analytical standards for the determination of elements, the gold contents of 12 USGS standard rocks were measured. The major objectives of the study were: (1) to determine the gold contents of the new standard rocks; (2) to test for the homogeneity of the gold among randomly selected bottles; and (3) to estimate analytical precision.

Gold was determined by the neutron activation method of Rowe and Simon (1968), using fire assay for the radiochemical separation. This method is adequately sensitive to determine less than 1 ng of gold in a 1-g rock sample and is currently used in this laboratory for the routine determination of gold in igneous rocks (Gottfried and others, 1972).

Three bottles from the stock of any specific rock standard were randomly selected for the determinations, and these three bottles were used as the single variable of classification in the one-way analysis of variance (Dixon and Massey, 1951). Determinations were made in random order on replicate portions taken from each of the three bottles of any standard. Duplicate portions were taken from bottles of those standards for which previous estimates were available, whereas triplicate or quadruplicate portions were taken of those standards for which preliminary data had been inconclusive or for which the gold contents could only be inferred from data on similar samples previously analyzed.

The determinations of gold, the estimates derived therefrom, and the conclusions from the analysis of variance are given in table 67. The partitioning of the mean sum of squares for between bottles for several samples resulted in a negative bottle variance, thus precluding the calculation of a bottle standard deviation, and such occurrences are indicated by "Neg."

The F ratios calculated in the analysis of variance for 9 of the 12 samples are not equal to or greater than the tabled value of the 0.95 fractile of the F distribution with the appropriate degrees of freedom, and the bottles of these standards may be considered to have a homogeneous gold content. For the determinations of gold in G–2, the computed F ratio is greater than the value for $F_{0.95}$ but does not equal or exceed that for $F_{0.975}$; the user may decide whether the gold content of the bottles is heterogeneous at $F_{0.95}$ or homogenous at $F_{0.975}$. For the gold determinations in SDC–1 and BCR–1, the computed F ratios exceed the allowable values at $F_{0.99}$, and the gold contents of the bottles of these samples should be considered heterogeneous.

The coefficients of variation for analytical error calculated from the standard deviations for within bottles agree generally with the estimates by Gottfried and others (1972). The coefficients for the two basalts, 6.5 percent for BCR–1 and 4.6 percent for BHVO–1, are much lower than one would predict on the basis of their average gold contents, but we presently have no explanation for this excellent analytical precision.

The data in table 67 show that the igneous rocks, except for the Hawaiian basalt BHVO–1, have average gold contents between 0.4 and 1.2 ppb, and the single metamorphic rock SDC–1 has an average of 1.9 ppb. The average gold contents are higher for the two shales and the marine mud; the Green River Shale SGR–1 has the highest average, 8.9 ppb.

TABLE 67.—*Gold in standard rocks*

[Gold and standard deviations in parts per billion. F ratios were tested against $F_{0.95}$ or the fractile of the F distribution indicated. The degrees of freedom for within bottles are 3, 6, or 9 for the 2, 3, or 4 determinations per bottle, respectively. S, significant; NS, not significant; Neg, negative bottle variance]

Standard rock	Gold in bottle—			Mean	Standard deviation		F ratio
	1	2	3		Within bottles	Among bottles	
SGR–1	8.4	9.2	8.9	8.9	0.2	0.3	NS
	8.9	9.3	8.7				
MAG–1	1.54	2.76	1.95	2.58	.47	.33	NS
	1.86	2.97	2.62				
	2.34	3.04	2.64				
	3.01	3.04	3.14				
SCo–1	1.83	1.73	2.06	2.11	.22	Neg.	NS
	2.32	2.01	2.23				
	2.38	2.15	2.30				
SDC–1	2.24	0.93	0.99	1.89	.52	.94	S. ($F_{0.99}$)
	2.51	1.00	1.33				
	3.55	1.31	1.58				
	3.75	1.61	1.91				
BHVO–1	1.54	1.62	1.43	1.57	.07	.10	NS
	1.70	1.69	1.47				
GSP–1	.82	1.09	1.15	1.18	.20	Neg.	NS
	1.36	1.11	1.17				
	1.40	1.11	1.40				
G–2	.76	1.21	.81	1.02	.16	.21	NS ($F_{0.975}$)
	.81	1.13	.87				
	.96	1.50	1.15				
QLO–1	.61	.96	1.07	.95	.13	.16	NS
	.90	1.00	1.19				
BCR–1	.61	.363	.425	.490	.032	.130	S. ($F_{0.99}$)
	.66	.414	.457				
AGV–1	.402	.345	.397	.442	.103	Neg.	NS
	.630	.453	.424				
STM–1	.362	.353	.340	.430	.141	Neg.	NS
	.431	.422	.67				
RGM–1	.354	.288	.380	.386	.074	.04	NS
	.391	.365	.54				

Jones (1969) listed determinations of gold in rocks made since the beginning of this century and has estimated the average gold content of rocks to be: igneous, 3.0 ppb; metamorphic, 4.3 ppb; and sedimentary, 5.0 ppb. The averages of the data in this study for igneous rocks (0.8 ppb) and for the single metamorphic rock (1.9 ppb) are lower than the estimates of Jones, but the average for the two shales agrees with his estimate of 5.0 ppb for sedimentary rocks. In his discussion of the accuracy of the data he listed, Jones pointed out that the determinations of gold before 1955 were generally made by less sensitive methods, that there may have been high reagent blanks that influenced some determinations, and that the data obtained before 1955 seem higher than those determined by more recent methods.

The averages of the gold contents of the four older USGS standard rocks (G–2, GSP–1, AGV–1, and BCR–1) do not differ markedly from averages previously reported; the average gold contents of the 12 samples may serve as a baseline for future determinations of gold in rocks.

REFERENCES

Dixon, W. J., and Massey, F. J., Jr., 1951, Introduction to statistical analysis: New York, McGraw Hill, 370 p.

Gottfried, David, Rowe, J. J., and Tilling, R. I., 1972, Distribution of gold in igneous rocks: U.S. Geol. Survey Prof. Paper 727, 42 p.

Jones, Robert S., 1969, Gold in igneous, sedimentary, and metamorphic rocks; U.S. Geol. Survey Circ. 610, 28 p.

Rowe, J. J., and Simon, F. O., 1968, The determination of gold in geologic materials by neutron-activation analysis using fire assay for the radiochemical separations: U.S. Geol. Survey Circ. 599, 4 p.

THE BERYLLIUM, FLUORINE, LITHIUM, COPPER, ZINC, AND STRONTIUM CONTENTS OF USGS STANDARD ROCK SAMPLES STM–1, RGM–1, QLO–1, SCo–1, MAG–1, SDC–1, AND SGR–1

By V. MACHÁČEK,[1] I. RUBEŠKA,[1] V. SIXTA,[1] and Z. ŠULCEK [1]

ABSTRACT

Six trace elements are reported for seven new USGS standard rock samples. Beryllium was determined fluorimetrically, fluorine by pyrohydrolysis and indirect spectrophotometry, lithium by atomic absorption spectrometry, and copper, zinc, and strontium by both X-ray fluorescence and atomic absorption spectrometry. The analysis of variance for a single variable of classification was used to determine whether the samples were homogeneous for the several elements. Estimates of the average trace element contents, of standard deviations for bottles of sample, where possible, and of the standard deviations for analytical error are tabulated.

Standard rock samples are important for testing and calibrating newly developed chemical or instrumental methods as well as those in current use. The variety of available standard materials is rather limited, and the 1971 series of USGS standard rock samples is a valuable contribution.

The Chemical Laboratory of the Czechoslovakia Geological Survey is assisting in the standardization of these samples by providing analyses for several trace elements. To ensure reliable data, we have selected methods that have been proven to be correct in previous analyses of international rock samples issued by the U.S. Geological Survey, the Zentrales Geologisches Institut, and other institutions. These methods include fluorimetry for beryllium, spectrophotometry for fluorine, atomic absorption spectrometry for lithium, copper, zinc, and strontium, and X-ray fluorescence for copper, zinc, and strontium. The methods are briefly described here.

The main purposes of the program of analyses were to determine if the samples could be considered homogeneous from bottle to bottle for the several elements and techniques and to obtain estimates of the average trace-element contents and of bottle error and analytical error where possible. Three bottles of each of the seven samples, STM–1, RGM–1, QLO–1, SCo–1, MAG–1, SDC–1, and SGR–1, were received, and determinations of the several elements were made on two portions from each bottle to fit a one-way experimental design with the three bottles of each sample as the variable of classification.

Before the determinations, the two portions from each bottle of all samples were arranged in a random order that was used for the determinations of all elements. For convenience in handling, the 42 portions, 6 from each of the 7 samples, were divided into 3 groups of 14, and each group was analyzed for an element on a different day within a period of 2 weeks.

Beryllium was determined fluorimetrically with morin after chromatographic separation on a silica-gel column as described by Šulcek, Doležal, and Michal (1961). A 1-g sample is decomposed by fusion with Na_2CO_3 in a platinum crucible. The melt is dissolved in dilute HCl, and silica is removed by filtration. The filtrate is evaporated to about 50 ml. Before sorption, this solution is adjusted to concentrations of 0.1 *M* EDTA (sodium salt of ethylenediaminetetraacetic acid), 0.03 *M* tartaric acid, and 0.2 *M* sodium acetate at a pH of 5.5 in a final volume of about 200 ml. The solution is then passed at a flow rate of 2–3 ml/min through a column of silica gel (10 ml of silica, +50—100 mesh) previously washed with sodium acetate buffer at pH 5.5. After the column is washed with 150 ml of distilled water, the sorbed beryllium is eluted with 5 ml 1 *M* HCl and 80 ml of distilled water into a 100-ml volumetric flask. The eluate is neutralized with sodium hydroxide using pentamethoxyl red indicator. Then 4

---

[1] Geological Survey, Kostelní 26, Prague, Czechoslovakia.

ml of 10-percent NaOH, 2 ml of 2.5-percent sodium stannite, and 2 ml of 0.02-percent morin in acetone are added, and the flask is made up to the mark and is thoroughly mixed. The fluorescence of the solution is measured on a Hilger and Watts H 960 Fluorimeter, and the beryllium content is estimated from a calibration line.

Fluorine was determined by indirect spectrophotometry of the attenuation of the absorption of the Zr-xylenol orange complex at 540 nm (Valach, 1961). The samples were decomposed by pyrohydrolysis (Heřman and Weiss, 1971). A sample of 0.1–1 g is mixed in a 1:2 ratio with U_3O_8. The mixture is transferred to a platinum boat that is placed in the platinum tube of a combustion furnace. The horizontal inlet side of this tube has an electric heating tape to prevent steam condensation. The outlet of the tube is led to a water-cooled condensor whose lower end dips under the surface of the absorbing solution.

The sample is ignited at 1,150°C for 17 min in a stream of oxygen at a flow rate of 3 l/min. The oxygen is saturated with water vapor by bubbling it through a 15-cm water layer. The reaction is completed by passing a mixture of oxygen and steam through the tube for 3 more min. During the reaction period, the solution in the absorption vessel is kept alkaline to phenolphthalein by titrating, when necessary, with 0.1 *M* NaOH. The volume of the NaOH consumed gives a rough estimate of the fluorine content.

An aliquot of the absorbing solution containing 5–20 μg of fluorine is pipetted into a solution of 10 ml of 1×10^{-3}-percent $ZrOCl_2 \cdot 8H_2O$ in 7 *M* $HClO_4$ in a 50-ml volumetric flask. After 30 min, 2 ml of 0.1-percent xylenol orange are added, and the flask is filled to the mark. The absorbance at 540 nm is measured within 30–90 min after mixing, and the fluorine content is estimated from a calibration line. The procedure is not applicable to samples high in organic matter, such as MAG–1 and SGR–1.

Lithium, copper, zinc, and strontium were determined by atomic absorption from one stock solution after the samples were decomposed. A 1-g sample in a platinum dish is treated with nitric acid and then with hydrofluoric and perchloric acids. The residue is dissolved in 5 ml of concentrated HCl and transferred to a 100-ml volumetric flask. Aliquots for the individual determinations are taken from this stock solution.

For lithium, an aliquot of the stock solution is pipetted into a 25-ml volumetric flask containing 2.5 ml of a buffer (0.2 *M* $Al(NO_3)_3$ in 1 *M* HCl), and the flask is filled to the mark with distilled water. Reference samples contain the same amount of buffer (Šulcek and Rubeška, 1969). The response at 670.7 nm is read, and the Li content is estimated from calibration lines.

Copper and zinc are measured at 324.7 nm and 213.8 nm, respectively, on aliquots directly from the stock solution or after appropriate dilution (Mikšovský and Mouldan, 1971). The concentration of HCl is maintained at 0.6 *M* for all solutions including reference samples.

For the determination of strontium, an aliquot of up to 10 ml of the sample stock solution is pipetted into a 25-ml flask, 2.5 ml of a buffer solution containing 1 percent La and 10 percent oxine in 6 *M* HCl are added, and the flask is filled to the mark. The reference samples contain the same amount of buffer (Moldan and Mikšovský, 1971).

All measurements were made on a Perkin-Elmer 303 atomic absorption spectrometer using an air-acetylene flame. Instrumental conditions recommended by the manufacturer were used. A recorder and scale expansion are used when samples read less than about 3-percent absorption.

The X-ray fluorescence procedure for copper, zinc, and strontium routinely used in this laboratory for the determination of 14 trace elements in silicate samples (Macháček, 1971) is a variation of procedures described by Wedepohl (1958). A 1-g sample is thoroughly mixed with 0.5 g of polyvinyl alcohol containing 0.1 percent molybdenum or 0.71 percent cobalt. The latter are used as internal reference elements. The mixture is pressed at 1,500 kp/cm² (21,000 psi) into tablets of 31 mm diameter. The measurement is carried out on a Phillips PW 1540 X-ray spectrometer with a topaz crystal and a scintillation counter with a discriminator. G–1, W–1, and T–1 were used as standards, and the concentration range was extended using synthetic standards prepared from a mixture of sodium silicate and oxides of the major elements. Instrumental conditions are as follows:

Instrumental conditions for X-ray fluorescence

Lines measured	Anode	Voltage (kV)	Current (mA)	Medium
Cu-$K\alpha_{1,2}$/Co-$K\beta_1$ --------	Au	50	20	Vacuum.
Zn-$K\alpha_{1,2}$/Co-$K\beta_1$ -------	Au	50	20	Do.
Sr-$K\alpha_{1,2}$/Mo-$K\alpha_{1,2}$ ------	W	50	20	Air.

The data obtained by these methods are given in table 68. Hygroscopic water (H_2O-) was also determined on one portion of the sample from each bottle of all rocks and, our estimates—the average of three determinations—are:

TABLE 68.—*Analytical data for seven USGS standard rock samples*

[In parts per million. AAS, atomic absorption spectrometry; XRF, X-ray fluorescence. N.d., not determined]

Rock sample	Bottle No.	Be	F	Li	Cu (AAS)	Cu (XRF)	Zn (AAS)	Zn (XRF)	Sr (AAS)	Sr (XRF)
STM–1	2/22	9.0	888	34	3.7	<10	248	242	735	673
		9.0	918	31	5.2	<10	245	243	710	675
	13/17	9.2	880	33	4.5	<10	243	242	720	678
		8.9	888	30	5.2	<10	240	243	710	674
	28/20	9.0	922	33	4.0	<10	247	241	710	668
		9.0	908	33	5.5	<10	246	243	715	670
RGM–1	5/20	2.2	323	58	12.5	11	39	37	108	95
		2.1	342	55	12.0	12	39	39	108	98
	13/02	2.1	367	55	11.2	11	39	39	110	94
		2.2	337	59	10.5	11	37	40	120	99
	16/01	2.2	339	53	10.7	10	40.5	40	110	95
		2.2	346	58	12.5	11	39	38	115	97
QLO–1	20/23	1.6	239	23	26.0	27	66.5	68	350	320
		1.7	260	24	27.0	28	63.5	66	330	323
	42/07	1.7	233	23	28.0	29	64.5	69	330	332
		1.6	282	23	26.2	30	64	67	385	328
	47/13	1.6	265	22	26.0	30	64	68	360	327
		1.7	256	23	26.2	30	65	67	370	325
SCo–1	5/24	1.6	754	41.5	28.7	35	108	120	172	158
		1.6	790	41.5	27.7	33	118	118	180	155
	55/05	1.6	780	41.5	27.7	33	102	125	177	158
		1.6	790	43	28.2	32	106	122	180	159
	55/24	1.6	786	39	27.5	34	102	123	190	155
		1.5	774	43	28.2	35	103	121	177	152
MAG–1	3/07	2.6	N.d.	77	29.5	32	133	151	145	129
		2.7	N.d.	69	27.5	33	124	152	138	132
	10/16	2.8	N.d.	71	27.7	32	116	153	157	126
		2.8	N.d.	69	27.5	33	120	154	155	128
	29/02	2.6	N.d.	74	27.5	30	122	153	155	125
		2.8	N.d.	72	27.7	32	117	155	148	128
SDC–1	21/18	2.5	612	32	28.2	27	106	107	192	172
		2.4	612	32	28.2	29	106	109	172	169
	50/22	2.7	622	33	28.5	30	100	107	185	169
		2.6	626	30	31.0	29	108	110	184	166
	115/24	2.6	626	33	29.5	26	104	105	184	174
		2.6	628	34	28.5	27	104	106	182	173
SGR–1	36/26	0.90	N.d.	123	65.0	58	81	84	430	415
		.90	N.d.	123	65.5	59	80	86	420	419
	38/30	.88	N.d.	123	63.0	60	83	86	450	416
		.88	N.d.	123	63.0	61	82	87	425	415
	39/26	.94	N.d.	125	65.2	58	80	84	420	419
		.95	N.d.	120	63.5	59	83.5	85	450	417

	Percent
STM–1	0.13
RGM–1	.30
QLO–1	.27
SCo–1	2.90
MAG–1	3.41
SDC–1	.11
SGR–1	.57

Each set of six observations (table 68) for all combinations of elements and methods was treated by the analysis of variance for a single variable of classification as described in introductory texts on statistics. A standard deviation for bottles was calculated after separating the components of the mean sum of squares for bottles as shown by Davies (1949, p. 78). Conclusions from the analysis of variance, averages, and standard deviations are given in table 69. An estimate of the "bottle variance" is relevant only if the F ratio is greater than 1; that is, if the bottle standard deviation is positive. Samples SGR–1 for Be and SDC–1 for F are heterogeneous for those elements by the methods used. One conclusion, QLO–1 for Cu, is listed as $NS_{0.975}$. This may be declared heterogeneous when tested against $F_{0.95}$, or accepted as homogeneous when tested against $F_{0.975}$, depending on the risk that the reader will accept. For all other combinations that are listed as "NS" (against $F_{0.95}$), or with negative bottle standard deviation, the samples are declared homogeneous.

TABLE 69.—*Conclusions from the analysis of variance, averages, and standard deviations for USGS standard rock samples*

[Method: Fluor, fluorimetric; Pyr-sptr, pyrohydrolysis-indirect spectrophotometry; AAS, atomic absorption spectrometry; XRF, X-ray fluorescence. Conclusions from the analysis of variance: NS, not significant at the fractile of the F distribution shown or at $F_{0.95}$ where none is indicated; d.f., degrees of freedom; Neg., negative bottle variance]

Element	Method	Conclusion	Standard deviation		Average content (ppm)
			Bottles, d.f.=2	Error, d.f.=3	
		STM-1			
Be	Fluor	NS	Neg.	0.12	9.02
F	Pyr-sptr	NS	12.2	13.9	900
Li	AAS	NS	Neg.	1.7	32.3
Cu	AAS	NS	Neg.	.91	4.78
Cu	XRF	----	----	----	<10
Zn	AAS	NS	2.6	1.8	245
Zn	XRF	NS	Neg.	1.0	242
Sr	AAS	NS	Neg.	11.2	717
Sr	XRF	NS	3.3	2.0	673
		RGM-1			
Be	Fluor	NS	Neg.	0.06	2.16
F	Pyr-sptr	NS	Neg.	14.8	342
Li	AAS	NS	Neg.	2.9	56.3
Cu	AAS	NS	0.4	.8	11.6
Cu	XRF	NS	.3	.6	11.0
Zn	AAS	NS	.5	1.0	38.9
Zn	XRF	NS	Neg.	1.2	38.8
Sr	AAS	NS	1.5	4.6	112
Sr	XRF	NS	Neg.	2.5	96.3
		QLO-1			
Be	Fluor	NS	Neg.	0.07	1.65
F	Pyr-sptr	NS	Neg.	22.1	256
Li	AAS	NS	0.3	.6	23.0
Cu	AAS	NS	Neg.	.8	26.6
Cu	XRF	NS, 0.075	1.3	.6	29.0
Zn	AAS	NS	Neg.	1.3	64.6
Zn	XRF	NS	Neg.	1.2	67.5
Sr	AAS	NS	Neg.	24.2	354
Sr	XRF	NS	4.0	2.2	326
		SCo-1			
Be	Fluor	NS	Zero	0.04	1.58
F	Pyr-sptr	NS	Neg.	16.0	779
Li	AAS	NS	Neg.	1.7	41.6
Cu	AAS	NS	Neg.	.5	28.0
Cu	XRF	NS	0.8	1.0	33.7
Zn	AAS	NS	4.7	4.4	107
Zn	XRF	NS	2.0	1.7	122
Sr	AAS	NS	Neg.	6.4	179
Sr	XRF	NS	2.2	1.8	156
		MAG-1			
Be	Fluor	NS	0.04	0.09	2.72
F	----	----	----	----	-----
Li	AAS	NS	Neg.	3.5	72.0
Cu	AAS	NS	Neg.	.8	27.9
Cu	XRF	NS	.5	1.0	32.0
Zn	AAS	NS	4.7	4.5	122
Zn	XRF	NS	1.1	1.0	153
Sr	AAS	NS	6.8	4.1	150
Sr	XRF	NS	1.7	1.9	128

TABLE 69.—*Conclusions from the analysis of variance, averages, and standard deviations for USGS standard rock samples*—Continued

Element	Method	Conclusion	Standard deviation		Average content (ppm)
			Bottles, d.f.=2	Error, d.f.=3	
		SDC-1			
Be	Fluor	NS	0.10	0.06	2.57
F	Pyr-sptr	S, 0.99	7.8	1.8	621
Li	AAS	NS	.5	1.3	32.3
Cu	AAS	NS	Neg.	1.1	29.0
Cu	XRF	NS	1.3	1.0	28.0
Zn	AAS	NS	Neg.	3.3	105
Zn	XRF	NS	1.2	1.5	107
Sr	AAS	NS	Neg.	8.2	183
Sr	XRF	NS	2.7	1.8	171
		SGR-1			
Be	Fluor	S, 0.99	0.03	0.004	0.91
F	----	----	----	----	-----
Li	AAS	NS	Neg.	2.0	123
Cu	AAS	NS	1.0	.7	64.2
Cu	XRF	NS	1.0	.7	59.2
Zn	AAS	NS	Neg.	1.5	81.6
Zn	XRF	NS	.8	1.0	85.3
Sr	AAS	NS	Neg.	16.4	433
Sr	XRF	NS	Neg.	1.9	417

REFERENCES CITED

Davies, O. L., 1949, Statistical methods in research and production: London, Oliver and Boyd, 292 p.

Heřman, M., and Weiss, D., 1971, Pyrohydrolytische Zersetzung der Mineralrohstoffe und Fluorbestimmung mittels der Fluoridelektrode, *in* Proceedings of the symposium on the methods for determination of low concentrations of elements in raw materials, Smolenice, 1969: Bratislava, Comenium Univ., p. 55–66.

Macháček, V., 1971, Röntgenspektrometrische Bestimmung von Spurenelementen in Silikatgesteinen, *in* Proceedings of the symposium on the methods for determination of low concentrations of elements in raw materials, Smolenice, 1969: Bratislava, Comenium Univ., p. 253–272.

Mikšovský, M., and Moldan, B., 1971, Determination of copper, zinc, manganese, and iron in silicate samples by atomic absorption spectroscopy: Chem. Zvesti v. 24, p. 128–133.

Moldan, B., and Mikšovský, M., 1971, On the determination of strontium in silicates, carbonates, and sulphates by atomic absorption spectroscopy: Colln. Czechoslov. Chem. Commun., v. 36, p. 1673–1677.

Šulcek, Z., Doležal, J., and Michal, J., 1961, Analytische Schnellmethoden zur Untersuchung von Metallen und anorganischen Rohstoffen, XII. Bestimmung der Spurenmengen von Beryllium in Mineralwässern und mineralischen Rohstoffen: Colln. Czechoslov. Chem. Commun., v. 26, p. 246–254.

Šulcek Z., and Rubeška I., 1969. Bestimmung des Lithiumspurengehaltes in Gesteinen: Colln. Czechoslov. Chem. Commun. v. 34, p. 2048–2056.

Valach R., 1961, Die Bestimmung von Fluor in Mineralwässern mittels Zr-Xylenolorange: Talanta v. 8, p. 443–444.

Wedepohl K. H., 1958, Röntgen-spektral-analyse von geochemischen Proben, *in* Anwendung der Röntgenbeugungsmethoden und der Röntgenspektroskopie. Vorträge der III: Informationstagung der C.H.F. Müller GMBH Hamburg in Darmstadt, p. 68–75.

INSTRUMENTAL ANALYSES OF MAJOR AND MINOR OXIDES IN USGS STANDARD ROCKS BHVO–1, QLO–1, SDC–1, AND RGM–1

P. W. WEIGAND,[1] K. THORESEN,[2] W. L. GRIFFIN,[2] and K. S. HEIER [2]

ABSTRACT

The contents of nine major and minor oxides in four new USGS standard rocks were estimated by X-ray fluorescence, atomic absorption, and flame photometry. Analysis of variance with three bottles of any standard as the variable of classification indicates that the bottles are homogeneous at $F_{0.95}$ for all nine oxides, except for Na_2O, by either flame photometry or atomic absorption, in the mica schist, SDC–1. Estimates of the averages, and the standard deviations for error and for bottles, are tabled.

We have analyzed new USGS standard rocks basalt BHVO–1, quartz latite QLO–1, mica schist SDC–1, and rhyolite RGM–1 for nine major and minor oxides by instrumental methods, following analytical procedures that are routinely used at the Geologisk Museum. For each method two portions were prepared from three bottles of each rock, yielding six determinations per rock.

Three analytical methods were used in this work —X-ray fluorescence (XRF), atomic absorption (AA), and flame photometry (FP). Silica, TiO_2, Al_2O_3, Fe_2O_3 (T) (total Fe as Fe_2O_3), CaO, and K_2O were analyzed on a Philips model 1410 manual vacuum X-ray spectrometer and the operating conditions are given in table 70. A pulse height analyzer was used for all oxides except Fe_2O_3. Samples and standards were fused with sodium tetraborate ($Na_2B_4O_7$) in a 1:9 ratio. Calibration curves were prepared from USGS, CRPG, ZGI, and SSC standard rocks (see Flanagan, 1970). The technique of counting a reference sample after each sample and using an intensity ratio of standard or unknown to the reference sample was used to correct instrumental drift.

Magnesia and Na_2O were analyzed on a Perkin-Elmer model 303 atomic absorption spectrometer. The spectral lines used were 2,850 A and 5,890 A, respectively, the lamps used were hollow cathode and Osram spectral, and an acetylene-air flame was used for both oxides. Samples and standards were dissolved in $HF+HNO_3$, evaporated to dryness, redissolved in $HCl+HNO_3$, and diluted to yield rock solutions of 0.001 percent by weight. Calibration curves were prepared from USGS and CRPG standard rocks. A reference solution was determined periodically, and intensity ratios, assuming linear drift, were used to correct instrumental drift. All samples were run twice.

Alkalis were analyzed with a Beckman model B flame photometer with an atomizer-burner. Samples were dissolved in $HF+H_2SO_4$, evaporated to dryness, and redissolved in diluted H_2SO_4. Calibration curves were prepared from mixtures of Na_2O, K_2O, and Li_2SO_4 solutions. Again, a reference standard determined after every second sample was used to correct instrumental drift.

In spite of pleas to the contrary, we failed to pre-

TABLE 70.—*Operating conditions for X-ray analyses*

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	K_2O
Target	Cr	Cr	Cr	W	W	Cr	Cr
Crystal	KAP	LiF	PE	LiF	LiF	LiF	KAP
Detector	Flow	Flow	Flow	Scintillation	Flow	Flow	Flow
Medium	Vacuum	Vacuum	Vacuum	Air	Air	Vacuum	Vacuum
Collimator	Coarse	Fine	Coarse	Fine	Fine	Fine	Fine
Peak 2θ	31.23	85.32	144.85	57.48	62.95	113.01	16.16
Background 2θ	----	84.00	147.50	----	62.20	----	17.00

---

[1] Dept. of Geological and Geophysical Sciences, Princeton University, Princeton, N.J. 08540.

[2] Mineralogisk-Geologisk Museum, Sarsgate 1, Oslo 5, Norway.

pare random number tables as a guide for the sequence of analyzing the samples. For the XRF (X-ray fluorence) and AA (atomic absorption) analyses, a person other than the analyst prepared and coded the samples in a nonsystematic sequence. The XRF pellets were run in the coding sequence, while the AA solutions were run nonsystematically with respect to the coding sequence. The FP (flame photometry) solutions were not coded, but were run in a completely nonsystematic order. In all methods, standards were run as a group at the beginning of the run or periodically through the run; they were not run in a random sequence intermixed with the unknowns. It was sometimes necessary to group samples according to elemental concentrations for analytical reasons, that is, all six portions of the same standard rock were run together. In such cases, the six portions were run in a nonsystematic sequence. Despite these limitations, we feel that the chance of systematic errors in the data arising from operator bias or from departures from randomness in the analytical sequence is small.

The six determinations for each standard rock are given in table 71. Also included are single determinations of total H_2O for a random bottle of each rock. For SiO_2 and Al_2O_3 in all samples and for MgO and CaO in BHVO-1, the second decimal place is not significant.

Summaries of the estimates and conclusions from the analysis of variance of the data for the four rocks are also given in table 71. The calculated F ratios of the mean sum of squares for the bottles to that for error were generally tested at $F_{0.95}$ (d.f.=2,3) = 9.55. If the conclusion is nonsignificant (NS), the three bottles of sample are declared homogeneous for the oxide. Because of the random selection of the bottles, this conclusion of homogeneity may then be extrapolated to the entire lot of bottles of a sample.

We conclude from this study that the bottles of the four standards that we analyzed are homogeneous at $F_{0.95}$ for most of the nine oxides. The bottles of the mica schist SDC-1 are heterogeneous at $F_{0.95}$ for the determination of Na_2O by either flame photometry or by atomic absorption. This heterogeneity for Na_2O may be due to bottle 39/20 because the extreme values seem to have been determined on this bottle. On the other hand, these seemingly extreme values agree well with preliminary data reported by Shapiro and others (this volume, table 36), and we are unable to assign a cause for the heterogeneity. For those who might wish to accept

TABLE 71.—*Determination of oxides, in percent, and summary of estimates for USGS standard rock samples BHVO-1, QLO-1, SDC-1, and RGM-1*

[Method: XRF, X-ray fluorescence; AA, atomic absorption; FP, flame photometry. Conclusions from the analysis of variance: NS, not signicant at the fractile of the F distribution shown or at $F_{0.95}$ where none is indicated; d.f., degrees of freedom; Neg., negative bottle variance]

BHVO-1

Oxide	Method	Bottle						Conclusion	Mean	Standard deviation	
		19/26		5/26		19/4				Bottles (d.f.=2)	Error (d.f.=3)
SiO_2	XRF	50.57	51.12	50.81	50.64	50.73	51.41	NS	50.88	Neg.	0.364
TiO_2	XRF	2.83	2.72	2.79	2.77	2.79	2.76	NS	2.78	Neg.	.047
Al_2O_3	XRF	13.72	13.71	13.75	13.80	13.59	13.71	NS	13.71	0.050	.053
Fe_2O_3(T)	XRF	12.48	12.33	12.41	12.48	12.50	12.49	NS	12.42	Neg.	.068
MnO	XRF	.17	.17	.17	.17	.16	.17	NS	.17	Neg.	.004
MgO	AA	7.00	7.14	6.93	7.03	6.83	7.05	NS	7.00	Neg.	.114
CaO	XRF	11.50	11.46	11.80	11.75	11.90	11.62	NS	11.67	0.144	.117
Na_2O	AA	2.18	2.10	2.16	2.36	2.22	2.25	NS	2.21	0.008	.089
Na_2O	FP	2.10	2.03	2.22	2.09	2.08	2.16	NS	2.11	Neg.	.069
K_2O	XRF	.48	.47	.46	.49	.46	.49	NS	.475	0	.018
K_2O	FP	.44	.45	.49	.42	.43	.50	NS	.455	Neg.	.041
H_2O(T)	----	.17	----	----	----	----	----	----	----	----	----

QLO-1

Oxide	Method	Bottle						Conclusion	Mean	Standard Deviation	
		45/4		46/18		51/28				Bottles (d.f.=2)	Error (d.f.=3)
SiO_2	XRF	65.79	64.91	65.39	65.09	64.98	65.16	NS	65.22	Neg.	0.387
TiO_2	XRF	.63	.67	.64	.68	.63	.67	NS	.653	Neg.	.028
Al_2O_3	XRF	16.48	16.67	16.66	16.28	16.19	16.36	NS	16.44	0.076	.187
Fe_2O_3(T)	XRF	4.34	4.66	4.56	4.63	4.31	4.40	NS	4.48	0.071	.139
MnO	XRF	.10	.10	.10	.10	.10	.10	(1)	.100	----	----
MgO	AA	1.05	1.08	1.10	1.11	1.07	1.06	NS	1.08	0.021	.014
CaO	XRF	3.26	3.22	3.26	3.21	3.25	3.23	NS	3.24	Neg.	.027
Na_2O	AA	4.12	3.98	4.18	4.19	4.16	4.13	NS	4.13	0.056	.059
Na_2O	FP	4.28	4.32	4.28	3.97	4.25	4.34	NS	4.24	0.033	.133
K_2O	XRF	3.58	3.66	3.60	3.70	3.60	3.60	NS	3.62	Neg.	.052
K_2O	FP	3.67	3.58	3.67	3.50	3.83	3.59	NS	3.64	Neg.	.126
H_2O(T)	----	.60	----	----	----	----	----	---	----	----	----

See footnote at end of table.

TABLE 71.—*Determination of oxides, in percent, and summary of estimates for USGS standard rock samples BHVO–1, QLO–1, SDC–1, and RGM–1*—Continued

SDC–1

Oxide	Method	Bottle						Conclusion	Mean	Standard deviation	
		14/7		67/13		39/20				Bottles (d.f.=2)	Error (d.f.=3)
SiO_2	XRF	66.25	66.39	66.00	65.56	66.19	66.29	NS	66.11	0.258	0.193
TiO_2	XRF	1.03	1.09	1.01	1.07	1.05	1.06	NS	1.05	Neg.	.035
Al_2O_3	XRF	16.15	16.12	16.06	15.85	15.86	16.00	NS	16.01	0.084	.104
Fe_2O_3(T)	XRF	7.33	7.42	7.52	7.30	7.33	7.19	NS	7.35	Neg.	.113
MnO	XRF	.13	.12	.12	.12	.12	.12	NS	.122	~0	.004
MgO	AA	1.72	1.75	1.62	1.69	1.70	1.70	NS	1.70	0.034	.031
CaO	XRF	1.46	1.44	1.46	1.42	1.45	1.46	NS	1.45	Neg.	.019
Na_2O	AA	1.94	1.94	2.01	1.98	1.90	1.86	NS 0.975	1.94	0.056	.020
Na_2O	FP	2.08	2.02	2.03	1.97	2.16	2.16	NS 0.975	2.07	0.078	.035
K_2O	XRF	3.28	3.26	3.25	3.31	3.26	3.30	NS	3.28	Neg	.031
K_2O	FP	3.33	3.23	3.24	3.15	3.33	3.37	NS	3.28	0.066	.057
H_2O(T)	----	1.68	----	----	----	----	----	----	---	----	----

RGM–1

Oxide	Method	Bottle						Conclusion	Mean	Standard deviation	
		20/3		2/21		18/4				Bottles (d.f.=2)	Error (d.f.=3)
SiO_2	XRF	71.48	72.49	72.22	71.82	71.51	72.56	NS	72.01	Neg.	0.617
TiO_2	XRF	.29	.29	.29	.34	.28	.33	NS	.303	Neg.	.029
Al_2O_3	XRF	13.82	14.27	13.87	13.83	13.54	14.19	NS	13.92	Neg.	.319
Fe_2O_3(T)	XRF	1.81	1.83	1.80	1.97	1.92	1.94	NS	1.88	0.024	.070
MnO	XRF	.04	.04	.04	.04	.04	.04	(1)	.040	----	----
MgO	AA	.29	.27	.26	.28	.27	.29	NS	.276	Neg.	.014
CaO	XRF	1.19	1.20	1.23	1.18	1.20	1.18	NS	1.20	Neg.	.022
Na_2O	AA	3.99	3.97	4.03	4.08	3.99	4.18	NS	4.04	Neg.	.081
Na_2O	FP	3.91	3.90	3.99	4.07	4.11	4.00	NS	4.00	0.070	.056
K_2O	XRF	4.25	4.38	4.34	4.33	4.42	4.36	NS	4.35	Neg.	.059
K_2O	FP	4.22	4.09	4.33	4.30	4.32	4.55	NS	4.40	0.118	.109
H_2O(T)	----	0.71	----	----	----	----	----	----	----	----	----

[1] The six values are identical, and thus there is no variation.

the slightly greater risk, Na_2O by both methods may be declared homogeneous when tested against $F_{0.975}$. The mean sums of squares for bottles for both SiO_2 in RGM–1 and TiO_2 in BHVO–1 were significantly smaller than the appropriate mean sum of squares for error when tested at $F_{0.99}$, but the bottles of these samples are declared homogeneous for the elements specified. The mean sum of squares for bottles is significantly smaller than that for error for CaO in QLO–1, but as above, we still declare the bottles of QLO–1 homogeneous for CaO as the mean sum of squares for bottles is not significantly larger than that for error.

The variances of the Na_2O data by flame photometry and atomic absorption, and of the K_2O data by X-ray fluorescence and atomic absorption, were tested at $F_{0.95}$ by the ratio of the larger variance over the smaller; it was concluded that the eight respective pairs of variances did not differ significantly. The differences between the respective pairs of means were not tested in view of the generally good agreement, and because of this good agreement, we feel that these data are accurate.

ACKNOWLEDGMENTS

We thank F. J. Langmyhr for the use of the atomic absorption unit at the Kjemisk Institutt at Blindern. B. El-Bouseilly and Y. Thomasson assisted with the determinations by flame photometry, and B. Bruum kindly made single determinations of total H_2O for us.

REFERENCE

Flanagan, F. J., 1970 Sources of geochemical standards—II: Geochim. et Cosmochim. Acta, v. 34, p. 121–125.

THE DETERMINATION OF SELECTED ELEMENTS IN THE USGS STANDARD ROCKS STM–1 AND RGM–1

By A. C. S. SMITH[1] and J. N. WALSH[2]

ABSTRACT

Selected minor oxides and trace elements have been determined in USGS standard rocks STM–1 and RGM–1 by atomic absorption and flame emission spectroscopy. One-way analysis of variance has shown the rocks to be homogeneous by both analysts for all elements, with the possible exception of sodium in STM–1 and calcium in RGM–1. Two-way analysis of variance has shown the variation between analysts to be significant for sodium and calcium as minor oxides and for copper, zinc, lithium, and manganese as trace elements.

This study was designed not only to estimate concentrations of some minor oxides and trace elements in the nepheline syenite STM–1 and the rhyolite RGM–1 but also to assess the degree of homogeneity within each set of sample bottles and to obtain standard deviations both for bottles and analytical methods. These same data were then used to compare the error for the two analysts whose determinations were made on identical samples with similar methods and equipment in different laboratories.

All minor oxides and trace elements were determined by atomic absorption spectrophotometry, except sodium and potassium oxides which were determined by flame emission spectroscopy. Both analysts used similar Pye-Unicam spectrophotometers. Two portions from each of three sample bottles per rock were analyzed in both laboratories in random order; that is, six determinations per element per rock for each analyst. Samples were decomposed by double evaporation with hydrofluoric and perchloric acids, sample-solution ratios being 1:1,000 and 1:50 for minor oxides and trace elements, respectively.

Replicate data are given in tables 72 and 73 for minor oxides and trace elements, respectively, in RGM–1 and STM–1. Minor oxides are expressed as percent of the oxide and "total" iron as percent Fe_2O_3. Trace elements are expressed in parts per million. Manganese in RGM–1 was determined as a trace element as well as a minor oxide because of its relatively low concentration.

Calculations for the one-way analysis of variance with the bottles as the variable of classification were made on each set of data. The homogeneity of either sample for any element or oxide was determined by comparing the ratio of the mean sum of squares for bottles to the mean sum of squares for analytical error with the upper 5 percent of the *F* distribution for the appropriate degrees of freedom. If the calculated *F* ratio was not significantly greater than the value in the table, the bottles of sample were declared to be homogeneous for the element or oxide.

TABLE 72.—*Replicate data for minor oxides in RGM–1 and STM–1, in percent*

RGM–1

	King's College			University College		
Bottle	13/32	15/21	21/16	13/32	15/21	21/16
CaO	1.04	1.02	1.05	1.09	0.95	0.98
	.99	1.03	1.05	.99	1.09	1.09
MgO	.24	.27	.25	.27	.25	.23
	.26	.27	.26	.26	.27	.27
Fe_2O_3	1.84	1.86	1.84	1.81	1.72	1.82
	1.86	1.83	1.83	1.90	1.72	1.79
MnO	.037	.036	.033	.031	.041	.036
	.034	.035	.036	.031	.031	.036
Na_2O	4.07	4.08	4.06	4.04	4.10	4.10
	4.10	4.07	4.08	4.04	4.16	4.04
K_2O	4.37	4.39	4.36	4.42	4.33	4.40
	4.34	4.34	4.38	4.40	4.33	4.33

STM–1

	King's College			University College		
Bottle	15/7	20/12	29/6	15/7	20/12	29/6
CaO	0.99	0.96	1.01	1.02	1.04	1.02
	1.00	.98	.98	1.04	1.05	1.02
MgO	.06	.07	.09	.08	.08	.07
	.06	.08	.08	.08	.08	.07
Fe_2O_3	5.08	5.17	5.09	5.08	5.14	5.20
	5.26	5.02	5.13	5.14	5.14	5.14
MnO	.22	.23	.22	.23	.23	.22
	.22	.22	.23	.23	.22	.20
Na_2O	8.92	8.95	9.01	8.90	8.46	8.64
	8.95	8.85	9.03	8.78	8.40	8.50
K_2O	4.28	4.33	4.29	4.41	4.26	4.33
	4.29	4.31	4.29	4.35	4.33	4.35

---

[1] University College, London, England.
[2] King's College, London, England.

TABLE 73.—*Replicate data for trace elements in RGM–1 and STM–1, in parts per million*

	King's College			University College		
RGM–1						
Bottle	13/32	15/21	21/16	13/32	15/21	21/16
Li	46	46	47	40	43	40
	47	45	44	40	43	40
Zn	32	30	33	38	38	38
	33	31	32	38	38	37
Cu	13	9	10	16	17	15
	11	11	11	17	17	17
Co	5	5	5	8	7	7
	5	5	5	9	4	8
Ni	5	5	5	15	5	4
	5	5	5	6	5	2
Mn	283	282	278	248	260	260
	323	273	272	260	245	265
STM–1						
Bottle	15/7	20/12	29/6	15/7	20/12	29/6
Li	28	27	26	20	20	20
	27	27	28	19	20	21
Zn	214	211	214	290	277	260
	209	212	214	271	281	285
Cu	3	3	3	6	5	6
	4	3	4	6	6	6
Co	9	4	9	14	10	9
	6	6	11	11	15	8
Ni	5	7	5	2	2	2
	5	5	5	5	3	2

Our estimates and conclusions for the data from each laboratory are given in tables 74 and 75.

Standard deviations for analytical error given in tables 74 and 75 are the square roots of the mean sum of squares for error. Partitioning of the mean sum of squares of the variation attributable to the variable of classification in the one-way analysis of variance has been discussed by Davies (1949), who showed that this mean sum of squares, in our case for bottles, is composed of analytical (within) variance plus *n* times the "bottle" variance, where *n* is the number of determinations per bottle. The "bottle" standard deviations in the tables are the square roots of the variances obtained after rearranging the above relation and solving for the "bottle" variance.

Calculations for a two-way analysis of variance were made on the combined data from both laboratories, using the bottles as one variable of classification and the two laboratories as the other, after Bennett and Franklin (1954). These calculations showed that the between-laboratory variances for the trace elements in both samples and for CaO and Na_2O in STM–1 were significant when tested against $F_{0.95}$. The remaining between-laboratory variances were not significant.

STM–1 was found to be homogeneous for calcium oxide at $F_{0.95}$, but the data for RGM–1 for University College indicates it to be heterogeneous at $F_{0.95}$, but homogeneous at $F_{0.975}$. The mean of the estimates of the calcium oxide content of the rocks are in good agreement between laboratories, but analysis of variance shows that variation attributable to the laboratories is significant for STM–1 and therefore the laboratories should estimate calcium oxide independently.

The good agreement between the two laboratories for the determination of magnesium oxide in the two rocks may well be a reflection of the extreme sensitivity and reliability of the determination of magnesium by atomic absorption spectrophotometry. It was impossible to determine the *F* ratio for the magnesium oxide data of STM–1 deter-

TABLE 74.—*Results of analysis of variance of minor-oxide data for RGM–1 and STM–1*

[Conclusions from analysis of variance; NS, not significant at $F_{0.95}$ or fractile shown; d.f., degrees of freedom; Neg., negative variance]

Oxide	King's College				University College			
			Standard deviation				Standard deviation	
	Conclusion	Mean (percent)	Bottles (d.f.=2)	Error (d.f.=3)	Conclusion	Mean (percent)	Bottles (d.f.=2)	Error (d.f.=3)
RGM–1								
CaO	NS	1.03	0.010	0.021	NS 0.975	1.03	Neg.	0.083
MgO	NS	.26	.008	.009	NS	.26	Neg.	.019
Fe_2O_3	NS	1.84	Neg.	.015	NS	1.78	0.063	.039
MnO	NS	.04	Neg.	.002	NS	.04	.004	.004
Na_2O	NS	4.08	Neg.	.015	NS	4.08	.039	.035
K_2O	NS	4.36	Neg.	.025	NS	4.37	.034	.030
STM–1								
CaO	NS	0.99	0.010	0.015	NS	1.03	0.011	0.009
MgO	NS	.07	.012	.006	[1]	.08	.006	.000
Fe_2O_3	NS	5.13	Neg.	.097	NS	5.14	.017	.035
MnO	NS	.22	Neg.	.006	NS	.22	.008	.009
Na_2O	NS	8.95	.054	.043	NS 0.975	8.61	.201	.079
K_2O	NS	4.30	.018	.009	NS	4.34	.033	.039

[1] No test; replicate pairs of data identical.

TABLE 75.—*Results of analysis of variance of trace-element data for RGM–1 and STM–1*

[Conclusions from analysis of variance: NS, not significant at $F_{0.95}$ or fractile shown; d.f., degrees of freedom; Neg., negative bottle variance]

	King's College				University College			
			Standard deviation				Standard deviation	
Element	Conclusion	Mean (ppm)	Bottles (d.f.=2)	Error (d.f.=3)	Conclusion	Mean (ppm)	Bottles (d.f.=2)	Error (d.f.=3)
				RGM–1				
Li	NS	45.8	Neg.	1.35	(1)	41.0	------	-----
Zn	NS	31.8	1.04	.71	NS	37.8	0.0001	0.41
Cu	NS	10.8	.58	1.23	NS	16.5	Neg.	.91
Co	(2)	-----	----	-----	NS 0.995	7.2	1.19	1.35
Ni	(2)	-----	----	-----	NS	6.0	3.04	3.87
Mn	NS	285.2	9.85	16.92	NS	256.3	Neg.	8.10
				STM–1				
Li	NS	27.2	Neg.	0.91	NS	20.0	0.29	0.58
Zn	NS	212.3	Neg.	2.08	NS	277.3	Neg.	12.92
Cu	NS	3.3	Neg.	.58	NS	5.8	.00	.41
Co	NS	7.5	2.20	1.68	NS	11.2	1.56	2.42
Ni	(2)	-----	----	-----	(2)	-----	------	-----

[1] No test; replicate pairs of data identical.
[2] No test; Some replicate data at the limit of estimation of the method.

mined at University College because each duplicate pair of determinations was exactly the same, resulting in a mean sum of squares for error of zero. The remaining F ratios indicate that the rocks are homogeneous for magnesium oxide at the upper 5 percent of the F distribution.

The estimates for the iron contents of both rocks for the two analysts agree well. Analytical standard deviations are small, as are the standard deviations for bottles, and the F ratios for both rocks indicate that they are homogeneous at $F_{0.95}$.

Agreement between laboratories is good for estimates of the concentrations of manganese when determined as a minor oxide, but variation attributable to laboratories is significant, even at $F_{0.99}$, when determined as a trace element. However, standard deviations within the sample bottles are small, except when manganese is determined as a trace element in one laboratory (King's College) where it was found to be 21 ppm at the 285 ppm level. The samples can be considered homogeneous for manganese both as a trace element and as a minor oxide.

Replicate data for sodium, determined by flame emission spectroscopy, showed some variability between laboratories for STM–1, with two replicate values ranging from 8.40 percent to 9.03 percent Na_2O between laboratories. Even though the mean values between laboratories are not grossly different, analysis of variance shows the between-laboratory variation to be significant for Na_2O in STM–1 even at $F_{0.99}$. STM–1 was found to be heterogeneous for Na_2O at the upper 5 percent of the F distribution for the data from University College, but in contrast RGM–1 was found by both laboratories to be homogeneous at $F_{0.95}$ for this oxide.

Potassium data, determined by the flame emission method, are in good agreement between laboratories for both rocks and the samples are found to be homogeneous for potassium at $F_{0.95}$.

Trace element data for copper, nickel, and cobalt were close to their limits of estimation by the method used. Data for cobalt and nickel for RGM–1 by one laboratory (King's College) are reported as a single value, 5 ppm, whereas the nickel data for STM–1 by both laboratories show scatter that might be expected when the concentration is at the limit of estimation. No estimates for these elements are given in table 75.

The laboratories should estimate lithium independently because the between-laboratory variation is significant at $F_{0.99}$. One-way analysis of variance shows both rocks to be homogeneous at $F_{0.95}$ for lithium by King's College and for lithium in STM–1 only by University College. The data obtained for RGM–1 by University College could not be used because replicate pairs of data were identical and give a zero mean sum of squares for error and thus preclude a test of significance.

The between-laboratory variation is significant for zinc, although there is fair agreement in mean values. Analytical standard deviations are 13 ppm at the 213-ppm level. The rocks by both analysts are homogeneous for zinc at $F_{0.95}$.

The data obtained for copper give significant between-laboratory variation even at $F_{0.99}$, but because the determinations are so near the limit of detection of the method it is considered inadvisable to draw any conclusions from this limited amount of data. Considerable discrepancies between the laboratories exist for the averages of cobalt and nickel.

Overall, 9 of the 20 elements show significant variation between laboratories at $F_{0.95}$, and it may be concluded that laboratories should estimate these elements independently.

REFERENCES CITED

Bennett, C. A., and Franklin, N. L., 1954, Statistical analysis in chemistry and the chemical industry: London, John Wiley and Sons, 724 p.

Davies, O. L., 1949, Statistical methods in production and research: London, Oliver and Boyd, 292 p.

HOMOGENEITY OF NIOBIUM CONTENT OF EIGHT USGS STANDARD ROCKS

By E. Y. Campbell and L. P. Greenland

ABSTRACT

Niobium was determined in two portions of three bottles of eight USGS standard rocks by a spectrophotometric technique. A one-way analysis of variance of the data showed that the niobium contents of RGM–1, AGV–1, QLO–1, GSP–1, SDC–1, BCR–1 BHVO–1, and G–2 are homogeneous within the limits set by the analytical precision.

The continuing niobium-tantalum resources program of the U.S. Geological Survey entails a very large number of niobium determinations in igneous rocks. The quality of the analyses is controlled by inclusion of several standard rocks in each batch of samples. It is necessary, therefore, to be certain that different bottles of the standard rocks all have the same niobium content. This section presents data from an analysis of variance experiment to determine if the niobium contents of eight standard rocks that are in routine use in this laboratory are homogeneous among bottles.

Three bottles of each of eight standard rocks were selected at random. Two portions were taken from each bottle, numbered, and randomized. The portions, about 250 mg (milligrams), were then analyzed for their niobium content.

The analytical method has been described by Greenland and Campbell (1974). In brief, samples were decomposed with HF-HNO_3, evaporated to dryness, and fused with $K_2S_2O_7$. The fusion cake was dissolved in HCl, the iron was reduced with thioglycollic acid, and the CNS complex of niobium was extracted into amyl alcohol. Niobium was stripped from the organic phase with dilute HF, the residual iron was extracted as the CNS complex, and the niobium color with PAR was developed in the presence of EDTA and tartrate masking agents. The absorbance of the sample solutions was compared with that of pure niobium standard solutions taken through the entire procedure.

The analytical data and statistical estimates are given in table 76. A one-way analysis of variance of these data was made to determine if the variance in the niobium content among bottles was significantly greater than the variance within bottles for any given standard rock. In no case was the mean sum of squares for bottles significantly greater (95-percent confidence level) than the variation within bottles.

TABLE 76.—*Niobium content, in parts per million, of USGS standard rocks*

[Neg., negative bottle variance; NS, not significant at $F_{0.95}$ (2, 3) = 9.55]

Sample	Bottle	Nb	Mean	Standard Deviation		F
				Bottles (d.f.=2)	Error (d.f.=3)	
QLO–1	A	11.2, 11.8	11.7	0.526	0.476	3.4 NS
	B	11.2, 11.2				
	C	11.9, 12.9				
GSP–1	A	27.8, 29.0	28.7	Neg.	.853	<1 NS
	B	27.9, 29.6				
	C	29.1, 28.9				
SDC–1	A	20.9, 21.6	21.1	Neg.	1.268	<1 NS
	B	21.4, 21.0				
	C	22.4, 19.4				
BCR–1	A	16.0, 14.7	15.6	.231	.727	1.2 NS
	B	15.7, 16.9				
	C	15.2, 15.4				
BHVO–1	A	22.5, 21.0	21.0	Neg.	1.067	<1 NS
	B	21.5, 19.8				
	C	21.2, 19.9				
G–2	A	12.8, 13.7	13.4	.338	.389	2.5 NS
	B	13.9, 14.0				
	C	13.0, 13.7				
RGM–1	A	9.5, 9.5	9.4	.076	.289	1.1 NS
	B	8.8, 9.5				
	C	9.6, 9.5				
AGV–1	A	15.3, 15.5	15.7	Neg.	1.004	<1 NS
	B	16.0, 15.5				
	C	14.8, 17.2				

It may be concluded, then, that the niobium contents of these standard rocks are homogeneous within the limits set by the analytical precision. The original randomization of the experimental design ensures that this conclusion may be extrapolated to the entire lot of bottles of a given standard rock.

REFERENCES CITED

Greenland, L. P., and Campbell, E. Y., 1974, Spectrophotometric determination of niobium in rocks; U.S. Geol. Survey Jour. Research, v. 2, no. 3, p. 353–355.

X-RAY FLUORESCENCE ANALYSIS OF 21 SELECTED MAJOR, MINOR, AND TRACE ELEMENTS IN EIGHT NEW USGS STANDARD ROCKS

By B. P. FABBI and L. F. ESPOS

ABSTRACT

X-ray fluorescence techniques were used to determine the SiO_2, Al_2O_3, total iron as Fe_2O_3, MgO, CaO, Na_2O, K_2O, TiO_2, P_2O_5, MnO, total sulfur as S, Cl, As, Ba, Ni, Rb, Sc, Sr, V, Zn, and Zr contents of the USGS standard rocks STM–1, RGM–1, QLO–1, MAG–1, SDC–1, BHVO–1, SCo–1, and SGR–1. Duplicate splits from each of three bottles of each rock were analyzed in random order. Analysis of variance suggests that the bottles are homogeneous at $F_{0.95}$ for all oxides and elements except for K_2O and Rb in STM–1, Na_2O in MAG–1, and Zn in BHVO–1.

As part of a continuing program to provide reference standards for geochemical investigations, eight new USGS standard rocks—nepheline syenite STM–1, rhyolitic obsidian RGM–1, quartz latite QLO–1, marine mud MAG–1, mica schist SDC–1, Hawaiian basalt BHVO–1, Cody Shale SCo–1, and shale of the Green River Formation, SGR–1—have been analyzed for 21 selected major and minor oxides and for trace elements by X-ray fluorescence methods of Fabbi and Moore (1970), Fabbi (1971, 1972), and Fabbi and Espos (1972a, b). Two portions from three randomly selected bottles of each rock were analyzed for each element. Calculations for a one-way experimental design with the three bottles of samples as the variable of classification were made for the data reported.

Silica, Al_2O_3, total iron as Fe_2O_3, MgO, CaO, K_2O, TiO_2, and P_2O_5 were determined simultaneously on a multichannel Quantometer (Applied Research Laboratories VXQ–25000). Sodium oxide, MnO, total sulfur as S, Cl, As, Ba, Ni, Rb, Sc, Sr, V, Zn, and Zr were determined on a single-channel vacuum spectrograph (General Electric XRD–6) with a dual target (Cr and W) tube and a pulse-height analyzer. Operating conditions for the Quantometer and spectrograph are given in tables 77 and 78, respectively. Matrix effects were avoided in the major and minor oxide determinations by fusing the standards and samples with $LiBO_2$ in a sample-flux ratio of 1:14. After the button resulting from the fusion has been powdered, three parts of binder for each part of sample were added to assist in forming the pellet. Other minor and trace elements were determined on pellets prepared by direct dilution using one part of sample to one part of binder. Sodium oxide was determined using the direct dilution technique because matrix effects were found to be nearly negligible and the detection limit and counting rates were more favorable. Calibration curves were prepared using 17 USGS, SSC, MRT, CRPG, and Len–X standard rocks (Flanagan, 1970).

The determinations in table 79 for the major, minor, and trace constituents of the six portions of each rock standard were made in random order for any specific oxide or element. Antimony is one of seven trace elements that we can determine routinely but the antimony content of all these samples was found to be less than 70 ppm. Arsenic was found to be greater than 5 ppm only in the two shales, SCo–1 and SGR–1.

Estimates of means, conclusions resulting from the analysis of variance, and standard deviations are also given in table 79. The calculated F ratios of MSS (bottles)/MSS (error) were tested at $F_{0.95}$ (d.f. = 2, 3) = 9.55. For those conclusions for which a fractile of the F distribution is specified, for example, NS (0.99), the calculated ratio is not significant (NS) at $F_{0.99}$, but is significant at both $F_{0.95}$ and $F_{0.975}$. A comparison of the calculated F ratios with appropriate F values in table 79 indicates that

TABLE 77.—*X-ray Quantometer operating conditions*

[X-ray tube operated at 30 kV and 50 ma]

Element	Crystal	Counter and voltage	Path
Si	EDDT	Ne Minitron, fixed	Vacuum.
Al	EDDT	do	Do.
Fe	LiF	Ar Multitron, fixed	Air.
Mg	ADP	Ne Minitron, fixed	Vacuum.
Ca	LiF	Ne Multitron, fixed	Do.
K	LiF	do	Do.
Ti	LiF	do	Do.
P	EDDT	Ne Minitron, fixed	Do.

TABLE 78.—*X-ray spectrograph operating conditions*

[Pulse height analyzer was used for all elements]

Element	Target	Crystal	Peak, 2θ	Background, 2θ	Line	Detector	Path
Na	Cr	RAP	54.23	----	K_α	Flow	Vacuum.
Mn	W	LiF–4.08A	62.97	----	K_α	do	Air.
S	Cr	PE	75.76	----	K_α	do	Vacuum.
Cl	Cr	PE	65.42	----	K_α	do	Do.
As	W	LiF–2.85A	48.83	47.8 49.8	K_α	Flow + Xenon	Air.
Ba	W	LiF–4.08A	87.13	88.4	L_α	Flow	Do.
Ni	W	LiF–2.85A	71.26	70.2	K_α	Flow + Xenon	Do.
Rb	W	LiF–2.85A	37.99	37.0 39.0	K_α	Flow + Xenon	Do.
Sb	Cr	LiF–4.08A	106.46	108.0	L_β	Flow	Do.
Sc	W	LiF–4.08A	97.71	97.0	K_α	do	Vacuum.
Sr	W	LiF–2.85A	35.85	34.8 37.0	K_α	Flow + Xenon	Air.
V	W	LiF–2.85A	123.16	120.6	K_α	Flow	Do.
Zn	Cr	LiF–2.85A	60.58	59.3 61.5	K_α	Flow + Xenon	Do.
Zr	W	LiF–2.85A	32.10	31.2 33.0	K_α	Xenon	Do.

TABLE 79.—*X-ray fluorescence determinations and estimates for standard samples*

[T, total. Conclusions from the analysis of variance: S or NS, significant or not significant at $F_{0.95}$ or at the fractile of the *F* distribution shown; d.f., degrees of freedom; Neg., negative bottle variance]

STM-1, NEPHELINE SYENITE

Oxide or element	Bottle 16/16		Bottle 27/27		Bottle 40/60		Conclusions	Mean	Standard deviation: Bottles (d.f.=2)	Standard deviation: Error (d.f.=3)
					In percent					
SiO_2	60.37	60.24	60.14	60.00	60.26	59.93	NS	60.15_7	0.06_7	0.15_6
Al_2O_3	18.94	18.82	18.16	18.89	18.79	18.81	NS	18.73_5	Neg.	$.30_2$
Fe_2O_3(T)	5.40	5.40	5.33	5.36	5.38	5.36	NS	5.37_2	0.02_5	$.01_5$
MgO	.48	.25	.31	.29	.37	.37	NS	$.34_5$	Neg.	$.09_4$
CaO	1.17	1.14	1.16	1.16	1.15	1.16	NS	1.15_7	Neg.	$.13_0$
Na_2O	8.69	8.73	8.83	9.19	9.02	9.07	NS	8.92_2	$.15_0$	$.14_9$
K_2O	4.28	4.26	4.22	4.20	4.31	4.31	S 0.99	4.26_3	$.05_0$	$.01_2$
TiO_2	.16	.17	.17	.15	.16	.17	NS	$.16_3$	Neg.	$.01_0$
P_2O_5	.17	.16	.15	.15	.18	.15	NS	$.16_0$	Neg.	$.01_3$
MnO	.255	.252	.253	.253	.254	.255	NS	.254	Neg.	$.001_3$
S(T)	<.005	<.005	<.005	<.005	<.005	<.005	------	--------	------	--------
Cl	.0415	.0415	.0425	.0415	.0425	.0425	NS	$.0420_0$	$.0004_1$	$.0004_1$
					In parts per million					
As	<5	<5	<5	<5	<5	<5	------	--------	------	--------
Ba	610	620	620	610	610	600	NS	611.7	2.9	7.1
Ni	<4	<4	6	~4	8	6	------	--------	------	--------
Rb	113	114	110	109	115	116	S 0.99	112.8	3.01	.71
Sc	<5	<5	<5	<5	<5	<5	------	--------	------	--------
Sr	714	706	714	699	718	717	NS	711.3	2.7	7.0
V	<10	<10	<10	<10	<10	<10	------	--------	------	--------
Zn	262	264	267	250	264	253	NS	260.0	Neg.	8.3
Zr	1,246	1,238	1,240	1,219	1,220	1,224	NS	1,231	7.7	9.3

RGM-1, RHYOLITE

Oxide or element	Bottle 1/27		Bottle 62/13		Bottle 16/15		Conclusions	Mean	Standard deviation: Bottles (d.f.=2)	Standard deviation: Error (d.f.=3)
					In percent					
SiO_2	73.03	73.24	73.15	73.63	72.90	72.99	NS	73.15_6	0.16_2	0.21_7
Al_2O_3	14.11	13.90	13.81	13.88	13.83	13.80	NS	13.88_8	$.07_9$	$.09_1$
Fe_2O_3(T)	1.94	1.98	1.93	1.94	1.96	1.95	NS	1.95_0	.005	.017
MgO	.44	.41	.36	.48	.27	.42	NS	$.39_7$	Neg.	$.07_9$
CaO	1.22	1.27	1.22	1.26	1.22	1.25	NS	1.24_0	Neg.	$.02_9$
Na_2O	3.92	3.94	3.82	4.01	3.90	3.95	NS	3.92_3	Neg.	$.08_1$
K_2O	4.12	4.25	4.13	4.36	4.12	4.31	NS	4.21_5	Neg.	$.13_3$
TiO_2	.29	.30	.30	.29	.29	.29	NS	$.29_3$	Neg.	.006
P_2O_5	.06	.04	.05	.05	.05	.04	NS	$.04_8$	Neg.	.009
MnO	.038	.035	.038	.038	.038	.037	NS	.037	Neg.	$.001_3$
S(T)	<.005	<.005	<.005	<.005	<.005	<.005	------	--------	------	--------
Cl	.0445	.0410	.0460	.0415	.0470	.0440	NS	.0440	Neg.	$.0026_3$

TABLE 79.—*X-ray fluorescence determinations and estimates for standard samples*—Continued

RGM-1, RHYOLITE—Continued

Oxide or element	Bottle						Conclusons	Mean	Standard deviation	
	1/27		62/13		16/15				Bottles (d.f.=2)	Error (d.f.=3)
	In parts per million									
As	<5	<5	<5	<5	<5	<5	------	--------	------	--------
Ba	800	820	820	840	840	840	NS	826.7	12.9	11.5
Ni	14	∼4	12	15	27	12	NS	14.0	Neg.	7.5
Rb	157	137	156	158	158	159	NS	154.2	2.3	8.2
Sc	6	6	8	6	7	∼5	NS	6.3	Neg.	1.2
Sr	115	103	117	120	122	121	NS	116.5	5.6	5.0
V	∼10	21	14	16	13	14	NS	14.7	Neg.	4.6
Zn	24	10	29	23	22	23	NS	21.8	1.1	6.2
Zr	221	196	215	203	217	218	NS	211.7	Neg.	11.3

QLO–1, QUARTZ LATITE

Oxide or element	Bottle						Conclusions	Mean	Standard deviation	
	63/6		3/7		17/3				Bottles (d.f.=2)	Error (d.f.=3)
	In percent									
SiO_2	64.96	65.41	65.15	64.50	65.39	65.52	NS	65.15_5	0.21_5	0.32_7
Al_2O_3	15.82	16.41	16.22	15.99	16.02	16.29	NS	16.12_5	Neg.	$.28_1$
Fe_2O_3(T)	4.39	4.43	4.42	4.41	4.32	4.60	NS	4.42_8	Neg.	$.11_6$
MgO	.94	.83	.97	.92	.97	1.03	NS	$.94_3$	$.04_2$	$.05_5$
CaO	3.16	3.18	3.18	3.17	3.18	3.19	NS	3.17_7	$.00_3$	.010
Na_2O	4.13	4.12	4.10	3.93	4.00	4.18	NS	4.07_7	Neg.	$.10_1$
K_2O	3.52	3.49	3.55	3.44	3.56	3.43	NS	3.49_8	Neg.	$.07_1$
TiO_2	.64	.64	.64	.63	.63	.63	NS	$.63_5$	$.00_4$	$.00_4$
P_2O_5	.21	.27	.23	.20	.22	.25	NS	$.23_0$	Neg.	$.03_0$
MnO	.098	.098	.095	.098	.097	.100	NS	$.097_7$	Neg.	$.001_7$
S(T)	<.005	<.005	<.005	<.005	<.005	<.005	------	--------	------	--------
Cl	.0182	.0187	.0191	.0196	.0195	.0202	NS	$.0192_2$	0.0006_5	$.0004_1$
	In parts per million									
As	<5	<5	<5	<5	<5	<5	------	--------	------	--------
Ba	1,400	1,400	1,350	1,400	1,400	1,400	NS	1,391.7	0	20.4
Ni	11	10	13	∼4	6	11	NS	9.2	Neg.	4.2
Rb	67	67	61	72	74	66	NS	67.8	Neg.	5.6
Sc	9	12	9	11	13	14	NS	11.3	1.6	1.5
Sr	332	339	296	339	334	336	NS	329.3	Neg.	17.8
V	55	50	57	49	55	49	NS	52.5	Neg.	4.6
Zn	52	52	22	48	50	43	NS	44.5	3.8	11.0
Zr	182	169	163	180	178	180	NS	175.3	Neg.	8.8

MAG–1, MARINE MUD

Oxide or element	Bottle						Conclusions	Mean	Standard deviation	
	60/26		13/17		56/14				Bottles (d.f.=2)	Error (d.f.=3)
	In percent									
SiO_2	50.89	52.09	50.18	50.87	50.71	50.49	NS	50.87_2	0.35_3	0.57_2
Al_2O_3	16.54	16.67	16.72	16.63	17.33	16.75	NS	16.77_3	$.15_6$	$.24_5$
Fe_2O_3(T)	7.06	7.13	7.09	7.12	7.07	7.09	NS	7.09_3	Neg.	$.03_2$
MgO	2.93	2.75	2.76	2.72	3.01	2.85	NS	2.83_7	$.06_4$	$.01_0$
CaO	1.40	1.39	1.42	1.43	1.39	1.47	NS	1.41_7	Neg.	$.03_3$
Na_2O	3.50	3.46	3.33	3.22	3.55	3.53	NS 0.99	3.43_2	$.13_5$	$.04_8$
K_2O	3.56	3.59	3.55	3.53	3.62	3.58	NS	3.57_2	$.02_6$	$.02_2$
TiO_2	.75	.75	.76	.76	.75	.75	------	$.75_3$	------	0
P_2O_5	.17	.18	.16	.17	.15	.21	NS	$.17_3$	Neg.	$.02_5$
MnO	.113	.112	.114	.114	.113	.113	NS	$.113_2$	$.0007_1$	$.0004_1$
S(T)	.47	.45	.46	.46	.47	.46	NS	$.46_2$	Neg.	$.00_9$
Cl	3.19	3.12	3.07	2.98	3.24	3.16	NS	3.12_7	$.08_1$	$.05_7$
	In parts per million									
As	<5	8	<5	<5	9	∼5	------	--------	------	--------
Ba	500	520	530	530	500	500	NS	513.3	14.1	8.2
Ni	55	54	54	53	53	54	NS	53.8	.29	.71
Rb	191	181	187	187	186	186	NS	186.3	Neg.	4.1
Sc	19	19	19	22	22	20	NS	20.2	0	1.47
Sr	174	169	164	169	165	164	NS	167.5	2.96	2.92
V	147	145	141	138	141	138	NS	141.7	3.50	1.91
Zn	156	149	148	144	146	144	NS	147.8	3.29	3.39
Zr	131	128	132	125	132	135	NS	130.5	1.19	3.34

TABLE 79.—*X-ray fluorescence determinations and estimates for standard samples*—Continued

SDC-1, MICA SCHIST

Oxide or element	Bottle						Conclusions	Mean	Standard deviation	
	106/8		76/9		65/5				Bottle (d.f.=2)	Error (d.f.=3)
In percent										
SiO_2	64.72	64.97	65.11	65.48	65.75	66.35	NS	65.39_6	0.56_9	0.30_5
Al_2O_3	16.37	16.79	16.61	16.41	16.77	17.14	NS	16.68_2	$.16_7$	$.24_3$
Fe_2O_3(T)	7.20	7.09	7.20	7.12	7.20	7.42	NS	7.20_5	$.05_2$	$.10_6$
MgO	1.67	1.54	1.57	1.52	1.59	1.59	NS	1.58_0	Neg.	$.05_7$
CaO	1.45	1.40	1.52	1.46	1.50	1.53	NS	1.47_7	$.04_0$	$.03_4$
Na_2O	1.98	1.98	1.94	2.00	1.97	2.02	NS	1.98_2	Neg.	$.03_2$
K_2O	3.18	3.35	3.16	3.26	3.21	3.45	NS	3.26_8	Neg.	$.12_7$
TiO_2	1.04	1.02	1.04	1.03	1.05	1.08	NS	1.04_3	$.01_6$	$.01_5$
P_2O_5	.15	.17	.16	.14	.15	.13	NS	$.15_0$	0	.014
MnO	.121	.119	.120	.118	.120	.120	NS	$.119_7$	Neg.	.0012
S(T)	.05	.05	.05	.05	.05	.04	NS	.048	0	.004
Cl	.0053	.0041	.0038	.0035	.0030	.0034	NS	$.0038_5$	$.0006_7$	$.0005_3$
In parts per million										
As	<5	<5	<5	<5	<5	<5	------	---------	------	--------
Ba	690	680	700	670	670	640	NS	675.0	11.9	17.8
Ni	41	41	41	40	40	41	NS	40.7	Neg.	.58
Rb	128	128	127	133	126	132	NS	129.0	Neg.	3.46
Sc	20	20	21	17	18	18	NS	19.0	Neg.	1.6
Sr	199	201	207	201	192	202	NS	200.3	.82	4.83
V	108	102	105	99	108	113	NS	105.8	3.2	4.0
Zn	106	108	110	106	93	104	NS	104.5	3.9	4.8
Zr	301	301	288	300	294	310	NS	299.0	Neg.	8.2

BHVO-1, BASALT

Oxide or element	Bottle						Conclusions	Mean	Standard deviation	
	28/19		19/12		11/31				Bottle (d.f.=2)	Error (d.f.=3)
In percent										
SiO_2	51.63	50.67	51.50	50.30	50.37	50.55	NS	50.83_7	Neg.	0.632
Al_2O_3	13.93	14.09	13.30	14.11	13.93	14.40	NS	13.96_0	Neg.	.388
Fe_2O_3(T)	11.89	11.97	11.92	11.86	11.91	11.95	NS	11.91_7	Neg.	.044
MgO	6.84	6.98	6.84	6.87	7.04	7.12	NS	6.94_8	.107	.067
CaO	11.44	11.54	11.55	11.46	11.45	11.43	NS	11.47_8	Neg.	.056
Na_2O	2.37	2.47	2.32	2.39	2.39	2.16	NS	2.35_0	Neg.	.106
K_2O	.51	.49	.50	.52	.58	.54	NS	$.52_3$	$.02_9$	.020
TiO_2	2.74	2.73	2.69	2.73	2.74	2.72	NS	2.72_5	0	.019
P_2O_5	.23	.23	.19	.27	.22	.27	NS	$.23_5$	Neg.	.038
MnO	.162	.162	.160	.161	.161	.164	NS	$.161_6$	.0005	.0013
S(T)	<.005	<.005	<.005	<.005	<.005	<.005	------	--------	------	--------
Cl	.0091	.0102	.0089	.0085	.0106	.0084	NS	$.0092_8$	Neg.	$.0010_2$
In parts per million										
As	<5	<5	<5	<5	<5	<5	------	--------	------	--------
Ba	131	105	133	111	144	135	NS	126.5	5.2	14.4
Ni	128	122	118	120	118	123	NS	121.5	2.1	3.3
Rb	10	7	7	10	8	10	NS	8.7	Neg.	1.9
Sc	28	29	27	27	29	28	NS	28.0	.76	.58
Sr	376	371	370	381	381	369	NS	374.7	Neg.	6.95
V	330	310	320	315	315	305	NS	315.8	Neg.	9.35
Zn	83	84	89	86	89	90	NS 0.975	86.8	2.90	1.35
Zr	158	155	152	158	152	161	NS	156.0	Neg.	4.58

SCo-1, CODY SHALE

Oxide or element	Bottle						Conclusions	Mean	Standard deviation	
	10/16		19/18		21/15				Bottle (d.f.=2)	Error (d.f.=3)
In percent										
SiO_2	63.30	63.14	62.88	62.63	61.48	63.42	NS	62.80_8	Neg.	0.80_1
Al_2O_3	13.84	14.00	13.86	13.81	13.53	13.80	NS	13.80_7	0.92_2	$.13_0$
Fe_2O_3(T)	5.22	5.24	5.19	5.27	5.29	5.21	NS	5.23_7	Neg.	$.04_7$
MgO	2.38	2.48	2.31	2.22	2.29	2.27	NS	2.32_5	$.08_2$	$.05_6$
CaO	2.58	2.59	2.55	2.54	2.59	2.55	NS	2.56_7	$.01_6$	$.01_7$
Na_2O	.83	.73	.82	.76	.79	.76	NS	$.78_2$	Neg.	$.04_9$
K_2O	2.62	2.69	2.65	2.65	2.62	2.70	NS	2.65_5	Neg.	$.04_3$
TiO_2	.61	.61	.60	.61	.62	.59	NS	$.60_7$	Neg.	$.01_3$
P_2O_5	.16	.21	.18	.21	.21	.22	NS	$.19_8$	Neg.	$.02_4$
MnO	.060	.060	.060	.061	.060	.061	NS	.060	Neg.	.00058
S(T)	.06	.06	.06	.06	.06	.06	NS	.06	0	0
Cl	.0077	.0072	.0068	0063	.0053	.0073	NS	$.0067_7$	Neg.	$.0008_7$
In parts per million										
As	9	12	10	14	8	12	NS	10.8	Neg.	2.61
Ba	620	630	600	620	610	650	NS	621.7	Neg.	18.7
Ni	28	30	28	26	29	30	NS	28.5	1.0	1.22
Rb	124	122	121	120	122	124	NS	122.2	1.15	1.22
Sc	23	19	19	16	19	20	NS	19.3	.96	2.08
Sr	194	194	190	193	196	193	NS	193.3	1.04	1.73
V	138	140	136	138	135	140	NS	137.8	Neg.	2.34
Zn	112	115	115	117	119	115	NS	115.5	.91	2.20
Zr	176	178	172	179	175	185	NS	177.5	Neg.	5.05

TABLE 79.—*X-ray fluorescence determinations and estimates for standard samples*—Continued

SGR-1, SHALE OF THE GREEN RIVER FORMATION

Oxide or element	Bottle						Conclusions	Mean	Standard deviation	
	54/17		57/28		34/15				Bottle (d.f.=2)	Error (d.f.=3)
				In percent						
SiO_2	28.15	28.48	28.89	27.90	28.82	27.50	NS	28.29_0	Neg.	0.68_7
Al_2O_3	7.11	7.69	7.17	7.47	7.03	7.01	NS	7.24_7	0.06_8	$.26_7$
Fe_2O_3(T)	3.18	3.23	3.11	3.25	3.19	3.25	NS	3.20_2	Neg.	$.06_5$
MgO	4.28	4.81	4.59	4.38	4.83	4.16	NS	4.50_8	Neg.	$.35_9$
CaO	8.88	8.91	8.99	8.75	8.88	8.83	NS	8.87_3	Neg.	$.10_1$
Na_2O	2.67	2.69	2.69	2.55	2.67	2.72	NS	2.66_5	Neg.	$.06_1$
K_2O	1.69	1.78	1.71	1.71	1.64	1.73	NS	1.71_0	Neg.	$.05_2$
TiO_2	.36	.36	.36	.35	.35	.36	NS	$.35_7$	Neg.	$.00_6$
P_2O_5	.33	.30	.29	.28	.28	.31	NS	$.29_8$	.009	$.01_8$
MnO	.042	.043	.043	.042	.043	.043	NS	$.042_7$	Neg.	$.000_6$
S(T)	1.90	1.89	1.90	1.90	1.87	1.91	NS	1.89_5	Neg.	$.01_7$
Cl	.0039	.0041	.0045	.0050	.0043	.005	NS	$.0044_7$	$.0003_2$	$.0003_6$
				In parts per million						
As	75	74	75	75	73	75	NS	74.5	Neg.	0.91
Ba	320	330	325	340	330	325	NS	328.3	Neg.	7.64
Ni	43	40	36	39	39	38	NS	39.2	1.7	1.8
Rb	92	90	94	93	92	92	NS	92.2	1.08	.91
Sc	10	~5	11	<5	11	9	------	--------	------	--------
Sr	442	441	440	454	450	443	NS	445.0	Neg.	6.4
V	134	139	134	133	134	130	NS	134.0	1.3	2.6
Zn	99	100	105	94	77	98	NS	95.5	1.04	9.7
Zr	60	62	65	54	56	58	NS	59.2	Neg.	4.6

there are only a few departures from the null hypothesis at $F_{0.95}$ in any of the samples. When the F ratio is not significant, one can conclude that the content of the bottles is homogeneous for each of the standard rocks. The K_2O and Rb contents of STM–1 are heterogeneous at $F_{0.99}$. Users of the samples may decide if they wish to accept the Na_2O content of MAG–1 as homogeneous at $F_{0.99}$ and the Zn content of BHVO–1 as homogeneous at $F_{0.975}$. The conclusions reached from these analyses of variance may also be extended to the entire lot of bottles of any sample because of the original random selection of the bottles. Analyses of variance were not calculated for those determinations where an observation $<X$ occurred more than once. For Sc in SGR–1 where $<X$ occurred only once and all other values were quantitative, the $<X$ was discarded, and the average of the five remaining data inserted in its place so that the analysis of variance could be completed. Where such substitutions were made, the conclusions and estimates from the analysis of variance may differ slightly from those that might have been obtained had all the data been quantitative. All values given in the tables as $\sim X$ were assumed to be a definite value, and the analyses of variance were made under that assumption.

Seventy-nine of the 151 variances for bottles are listed as negative and these have been noted "Neg." in the columns for bottle standard deviation in table 79. No F test could be made and therefore a conclusion not reached for the TiO_2 data in MAG–1 because the error mean square was zero. The negative values for the bottle variance may be attributed to sample fluctuations of the variance about an average value of zero. This may be anticipated in about half the tests.

REFERENCES CITED

Fabbi, B. P., 1971, X-ray fluorescence determination of barium and strontium in geologic samples: Appl. Spectroscopy, v. 25, p. 316–318.

———1972, A refined fusion X-ray flourescence technique, and determination of major and minor elements in silicate standards: Am. Mineralogist, v. 57, p. 237–245.

Fabbi, B. P., and Espos, L. F.., 1972a, X-ray fluorescence determination of arsenic, antimony, nickel, rubidium, scandium, vanadium, and zinc in rock standards and other rock samples: U.S. Geol. Survey Prof. Paper 800–B, p. B147–B150.

———1972b, X-ray fluorescence determination of chlorine in standard silicate rocks: Appl. Spectroscopy, v. 26, p. 293–295.

Fabbi, B. P., and Moore, W. J., 1970, Rapid X-ray flourescence determination of sulfur in mineralized rocks from the Bingham mining district, Utah: Appl. Spectroscopy, v. 24, p. 426–428.

Flanagan, F. J., 1970, Sources of geochemical standards—II: Geochim. et Cosmochim. Acta, v. 34, p. 121–125.

TITANIUM AND TRACE ELEMENT DATA IN USGS STANDARD ROCKS SCo–1 AND SGR–1

By ISAAC B. BRENNER [1] and A. HAREL [2]

ABSTRACT

Titanium and 12 trace elements (B, Ba, Co, Cr, Cu, Ga, Mn, Ni, Pb, Sr, V and Zr) were determined in shales SGR–1 and SCo–1 by direct-current emission spectroscopy. Standardization was achieved by use of SiO_2 matrices containing 8 percent Na+K as carbonates spiked with known amounts of Specpure compounds. For SGR–1 and SCo–1, analyses were usually made on three portions of each of four bottles to evaluate sample homogeneity. Variance analysis confirms that both samples are homogeneous for most elements but that SGR–1 is heterogeneous for B and Co.

INTRODUCTION

Three portions of four different bottles of two new USGS standards—the shale of the Green River Formation, SGR–1, and the Cody Shale, SCo–1—were analyzed by direct-current emission spectroscopy as part of a program to furnish data for standardization of these samples. Titanium and 12 trace elements (B, Ba, Co, Cr, Cu, Ga, Mn, Ni, Pb, Sr, V, and Zr) were determined. The detailed description of the procedure used is given by Avni, Harel, and Brenner (1972), and only the highlights are described herein.

The methods of trace-element analysis of silicate rocks and minerals, described by Avni, Harel, and Brenner (1972), are calibrated by synthetic silica-based standards. This new approach was established after studying volatilization rates and several plasma parameters (temperature, electric field, electron density, and line intensity) of the direct-current-arc plasmas of silica and silicates containing impurities. Addition of graphite to the silica and silicates (1 part sample plus 5 parts graphite) resulted in equal volatilization rates of material from the electrode into the arc plasma and equal values of temperature, electric field, electron density, and line intensity of the impurities in the central part of the plasma (~2 mm). The values are independent of the concentration of the major components (Al, Mg, Ca, Fe, Na, and K). This method, evaluated by analyzing several international geochemical standards, was shown to be reliable (Avni and others, 1972).

ANALYTICAL PROCEDURE

Synthetic standards were prepared by adding the desired amounts of Johnson Matthey Specpure compounds to Specpure SiO_2; 4 percent Na and 4 percent K (both as carbonates) were added, and the bulk was mixed with graphite in a ratio of 1:5 (100 mg of standard and 500 mg of graphite).

The silicate samples having a particle size less than 200 mesh were mixed with graphite in a ratio of 1:5 (100 mg sample and 500 mg graphite).

The spectrographic conditions previously published (Avni and others, 1972) were used except for the substitution of a slit width of 0.025 mm and of a vertical aperture of 2 mm in the central portion of the 6-mm gap. The several analytical lines used and their working ranges and the statistics for the standard working curves are also given in Avni, Harel, and Brenner (1972, table 2).

RESULTS

Three portions from each of the four bottles of SGR–1 and of SCo–1 were arced in random order onto several plates that were processed under stringent darkroom conditions. Line densities were measured on a Jarrell-Ash nonrecording microphotometer. Seidel conversion of percentage transmission, intensities, working curves, and contents of samples

---

[1] Geological Survey of Israel.
[2] Israel Atomic Energy Commission.

TABLE 80.—*Quantitative spectrographic determinations of trace and minor elements in Cody Shale, SCo–1*

[In parts per million. Conclusions from the analysis of variance: NS, not significant when tested against $F_{0.95}$. d.f., degrees of freedom. d.f. for boron = 3 for bottles and 4 for error]

Element or oxide	Spectral line	Bottle				Conclusions	Mean	Standard deviation	
		40/20	16/16	8/18	14/19			Bottles (d.f. = 3)	Error (d.f. = 8)
B	2497.73	60	50	65	70	NS	64.4	Neg.	8.8
		70	70	70	----				
		----	----	*70*	60				
Ba	4554.04	730	665	700	820	NS	743.8	31.0	55.2
		760	780	780	855				
		640	700	750	745				
Co	3453.50	13	10	15	15	NS	11.3	Neg.	3.2
		13	15	9	11				
		9	8	10	8				
Cr	4254.35	73	64	66	78	NS	65.2	3.0	8.1
		61	57	64	77				
		50	71	56	*65*				
Cu	3273.96	35	35	36	32	NS	30.6	Neg.	4.1
		31	30	30	28				
		26	31	24	29				
Ga	2943.64	12	17	11	15	NS	13.9	Neg.	2.5
		15	12	17	16				
		15	13	12	12				
Mn	2933	360	425	380	380	NS	411.2	Neg.	39.5
		400	405	460	380				
		430	390	455	470				
Ni	3413.94	34	26	29	31	NS	29.8	.71	2.7
		30	29	29	29				
		32	32	32	24				
Pb	2833.07	27	28	27	27	NS	27.6	Neg.	2.1
		23	26	30	27				
		30	28	29	29				
Sr	4077.71	220	226	239	192	NS	223.6	Neg.	20.4
		214	220	232	250				
		212	195	224	259				
TiO_2	2956.13	7,100	7,000	7,700	7,200	NS	7,520	180	399
		7,100	7,100	7,800	8,100				
		7,500	8,000	8,200	7,500				
V	3183.41	105	105	105	120	NS	108.8	Neg.	8.3
		120	115	115	100				
		100	110	105	105				
Zr	3438	130	120	120	120	NS	132.5	Neg.	14.9
		140	125	140	120				
		150	155	120	150				

were obtained with the aid of a Control Data Corp. 6400 computer using a program (SPECS) written in Fortran IV. The data are given in tables 80 and 81. Computations of variance analysis for a single variable of classification were made for each element, under the usual assumptions that underlie the technique, and the conclusions and estimates are also given in tables 80 and 81. Blank spaces in these tables result from the omission of data that exhibit abnormal discrepancies probably because of laboratory contamination. As there are only two determinations of Cr for bottle 14/19 of SCo–1, the mean (in italics) of the other Cr determinations was inserted in place of the missing value so that the variance analysis could be completed without undue difficulty. Thus, the conclusion and estimates obtained may differ from those that might be obtained had the inserted value been an actual determination, and some caution should be exercised in the use of the statistical data. Again, the three values for Zr in bottle 34/9 of SGR–1 were anomalous and hence not reported, and the two data in italics for bottles 52/10 and 3/3 were randomly discarded to preserve the symmetry of the simple design.

TABLE 81.—*Quantitative spectrographic determinations of trace and minor elements in shale of the Green River Formation, SGR–1*

[In parts per million. Conclusions from the analysis of variance: S, significant; NS, not significant. when tested at $F_{0.95}$ or the fractile of the F distribution indicated; d.f., degrees of freedom; d.f. for zirconium are 2 for bottles and 3 for error]

Element or oxide	Spectral line	Bottle				Conclusions	Mean	Standard deviation	
		34/9	52/10	3/3	42/7			Bottles (d.f.=3)	Error (d.f.=8)
B	2497.73	32 32 28	33 30 34	26 26 24	32 31 30	S(0.99)	29.8	2.9	1.73
Ba	4554.04	300 334 308	335 340 339	315 315 340	315 314 308	NS	321.9	9.6	11.7
Co	3453.50	15 14 15	12 13 13	12 10 12	13 14 15	S(0.99)	13.2	1.39	.87
Cr	4254.35	41 34 42	29 30 42	31 30 32	26 31 34	NS	33.5	2.8	4.7
Cu	3273.94	60 60 75	70 72 74	65 70 73	69 70 75	NS	69.4	1.1	5.1
Ga	2943.64	10 11 14	10 15 12	10 18 13	10 11 13	NS	12.2	Neg.	2.7
Mn	2933	300 300 320	280 280 290	290 300 300	300 300 305	NS(0.99)	297.1	9.1	7.2
Ni	3413.94	31 33 30	32 30 35	30 33 32	29 30 32	NS	31.4	Neg.	1.8
Pb	2833.07	40 40 45	38 43 45	39 45 40	34 42 44	NS	41.2	Neg.	3.9
Sr	4077.71	290 340 320	300 310 325	310 310 325	280 330 350	NS	315.8	Neg.	23.3
TiO_2	2956.13	2,400 3,300 2,600	2,900 2,800 3,000	2,800 3,000 3,100	3,000 3,100 2,800	NS	2,900	Neg.	260
V	3183.41	120 125 120	110 110 125	105 110 122	110 125 125	NS	117.2	Neg.	7.7
Zr	------	n.d.	45 *46* 43	58 *58* 54	67 47 ----	NS	52.3	4.2	8.4

DISCUSSION

To provide an evaluation of the reliability and accuracy of this method, a series of international silicate standards having considerable variation of composition and containing different amounts of the trace elements in question were analyzed. The results are given in Avni, Harel, and Brenner (1972). A study of these data indicates that the overall accuracy of this method is good. Coefficients of variation based on 5 to 15 determinations vary from 5 to 20 percent, depending on the level of concentration.

The level of homogeneity of the new standards can be assessed from the data given in tables 80 and 81. The mean sum of squares for the variation attributable to portions sampled from different bottles is not significantly larger than the mean sum of squares for within bottles for all 13 elements determined in SCo–1. For 9 of the 13 elements, the mean sum of squares for within bottles was larger than that for between bottles, resulting in a negative bottle variance that has no meaning. We may therefore conclude that these elements are distributed homogeneously among the four bottles of SCo–1, and, because of random selection of bottles, this standard as a whole may be considered homogeneous.

For SGR–1, however, the variation attributable to the bottle means for both boron and cobalt is significantly larger than the within bottle variation when compared to $F_{0.99}$, and the bottles of SGR–1 must be declared heterogeneous for these two elements. Manganese in SGR–1 is distributed heterogeneously at $F_{0.975}$ or homogeneously at $F_{0.99}$. The remaining elements may be considered as distributed homogeneously among the bottles of this sample.

ACKNOWLEDGMENTS

Much of the work was done in the laboratory of Dr. R. Avni at the Nuclear Research Center, Negev. We are grateful for the help given by Mrs. H. Eldad and Miss L. Argov of the Geological Survey of Israel and Mr. M. Assous of the Nuclear Research Center, Negev.

REFERENCE

Avni, R., Harel. A., and Brenner, I. B., 1972, A new approach to the spectrochemical analysis of silicate rocks and minerals: Appl. Spectroscopy, v. 26, p. 641–645.

COMPUTERIZED SPECTROGRAPHIC DATA FOR USGS STANDARDS

By F. G. WALTHALL, A. F. DORRZAPF, JR., and F. J. FLANAGAN

ABSTRACT

Fifteen USGS standard rocks, including those described in this volume, have been analyzed by a semiquantitative spectrographic procedure in which a computer is programmed to select the best data. Analyses of variance show that 346 of 367 F ratios were not significant at $F_{0.95}$ and the bottles of any standard for the 346 ratios may be accepted as homogeneous by this method. Estimates of the averages and of the standard deviations for bottles and for error are included in the tables along with the data obtained with the computer.

The computerized analysis of spectrographic data from photographed optical emission spectra is now routine. Fifteen samples from the U.S. Geological Survey's standards program were analyzed by this technique, and the information obtained on precision and accuracy, as well as on spectral-line interferences, is being used to refine the computer program.

The basic recorder system and computer program have been described by Helz, Walthall, and Berman (1969), but a 4- by 20-in photographic plate is now used in place of the two 4- by 10-in plates. The analytical method is the semiquantitative procedure of Myers, Havens, and Dunton (1961), modified to use an argon-oxygen atmosphere. As a result of this change, the cyanogen bands have been eliminated, permitting the use of the full length of the spectrum and thus providing more analytical lines.

Duplicate 15-mg portions from each of three randomly selected bottles of each standard were mixed with 30 mg of graphite. The bottles of most USGS standards are individually numbered, but, because there was no method of distinguishing among the three available bottles of W–1, they were arbitrarily designated X, Y, and Z. After the electrodes were loaded, the 90 samples were analyzed in random order. The samples were arced in an atmosphere of 70 percent argon and 30 percent oxygen using a Helz jet (Helz, 1964) and were exposed on 20-in Kodak III–O plates. After the plates were developed, the spectra were recorded and analyzed as previously described (Helz and others, 1969).

The computer is programmed to search the transmittance data for the analytical lines, to perform the necessary calculations, and to determine the final value for each element in a predetermined order of priority. This priority is based on both the detectability of a line and its freedom from interference. Combinations of elements affect detectabilities and even prevent the determination of some elements. Interferences are often found for the most persistent lines of an element, and corrections for interferences will be made.

Copper estimates reported as <46.4 ppm for some samples are not satisfactory. The computer is programmed to consider first the two most sensitive copper lines (3247.54 and 3273.96 A). For concentrations greater than 10 ppm, these lines are normally too dark to provide reliable data, and the computer then considers a third line at 2824.37 A. When the two, more sensitive, lines are too dark and when no line is found at 2824.37 A, the lower limit, <46.4 ppm, of this last line is reported as the best available estimate. The copper content of the sample is then interpreted to be between 10 and 46.4 ppm. A thorough search for copper lines detectable in this concentration range is being undertaken, and the data obtained from these 15 samples will aid in the selection of the best lines.

Analyses of major elements by this method are presently neither as accurate nor as precise as analyses by wet chemical or X-ray fluorescence methods, but the method represents a significant improvement over the visual determinations that are restricted to about 10 percent of an element. Data for the major elements are generally within the ordinary accuracy and precision of a semiquantitative method in which the true value is expected to be not more than 50 percent, or less than 33 percent, of the reported value. Further refinements of this computer method are expected to reduce the analytical differences between this and other methods.

Tables 82 through 96 contain the data for elements found in the 15 USGS standard rocks. Concentrations greater than 1 ppm are printed with three significant figures, and for less than 1 ppm, with two significant figures. The third digit is not analytically significant but is printed only for programming convenience. We believe, however, that the data gotten by this computer technique are both more accurate and more precise than those obtained by visual methods. The following elements, included in the computer programs, were below the limit of detection in the samples reported in tables 82–96.

Element	*Limit of detection (ppm)*	*Element*	*Limit of detection (ppm)*
As	<100	Re	<10.0
Au	<6.81	Rh	<1.00
Cd	<14.7	Ru	<.46
Ge	<1.00	Sb	<68.1
Hf	<10.0	Ta	<316
In	<4.64	Tb	<46.4
Ir	<6.81	Te	<316
Lu	<3.16	Tl	<3.16
Os	<21.5	Tm	<3.16
Pd	<.22	U	<215
Pt	<6.81	W	<10.0

The computations for the analysis of variance with a single variable of classification were made for the data, except where one or more observations were missing or were reported as an upper or a lower limit. The estimates (the mean and the standard deviations for bottles and for error) and the conclusions from the F tests resulting from the calculations are included in the tables.

Most users of the samples will accept a conclusion of homogeneity of bottles for which the calculated ratio is not significantly larger than $F_{0.95}$, and most will declare the bottles heterogeneous for an element when the ratio is significantly larger than $F_{0.99}$. For conclusions other than these two, we have adopted the convention of listing the significance of the F ratio either as NS (0.975) where the user may wish to declare the ratio significant at $F_{0.95}$, or as NS (0.99) with the alternate conclusion of significant at $F_{0.975}$.

Of the combinations of elements and samples for which 367 F ratios were calculated, 346 ratios (94.3 percent) were not significant at $F_{0.95}$. Those samples for which no conclusion other than homogeneous at $F_{0.95}$ was obtained were W–1, AGV–1, PCC–1, BCR–1, MAG–1, and BHVO–1. There appears to be no single element primarily responsible for judgements other than that of homogeneity at $F_{0.95}$. Those elements with more than one conclusion at some fractile of the F distribution higher than 95 percent are: (1) Calcium—homogeneous at $F_{0.975}$ in SCo–1 and SDC–1, (2) chromium—homogeneous at $F_{0.975}$ in GSP–1 and STM–1, (3) nickel—homogeneous at $F_{0.99}$ in SGR–1 but heterogeneous in GSP–1 at $F_{0.99}$, (4) praseodymium—homogeneous at $F_{0.975}$ in G–2 and SGR–1 and at $F_{0.99}$ in STM–1, and (5) strontium—homogeneous at $F_{0.975}$ in GSP–1 and SGR–1 and heterogeneous at $F_{0.99}$ in G–2.

The precision of the method is generally the same as one might expect in quantitative spectrographic methods. Some 125 coefficients of variation calculated for several samples ranged from 1.3 to 29.1 percent, with one outlier of 37 percent and with an average coefficient estimated to be slightly less than 10 percent. Those coefficients greater than 20 percent generally occurred where the concentration of an element was 5 ppm or less.

The question of the accurancy of these data is more difficult to resolve. For the present we will restrict ourselves to the following qualitative comparisons of these data with estimates for the elements given elsewhere in this volume: (1) elements for which these data are generally lower than recent best estimates—Ba, Cr, Nb, Ni, and Zr—and (2) those elements for which these data are higher—Ce, Co, La, Pb, Sr, V, and Zn. Many of the data reported here are well within the general limits of acceptability for semiquantitative methods.

The data on the seven older rocks, W–1 through BCR–1, are presently being used in a study to extend detection limits, to include more analytical lines, and to program corrections for interferences for many lines. These improvements should result in more reliable data for our spectrographic analyses.

REFERENCES

Helz, A. W., 1964, A gas jet for d-c arc spectroscopy: U.S. Geol. Survey Prof. Paper 475–D, p. D176–D178.

Helz, A. W., Walthall, F. G., and Berman, Sol, 1969, Computer analysis of photographed optical emission spectra: Appl. Spectroscopy, v. 23, p. 508–518.

Myers, A. T., Havens, R. G., and Dunton, P. J., 1961, A spectrochemical method for the semiquantitative analysis of rocks, minerals, and ores: U.S. Geol. Survey Bull. 1084–I, p. 207–229.

TABLE 82.—*Computerized spectrographic data for diabase, W-1*

[Elements Si through Mn in percent, all others in parts per million. Asterisk indicates interference]

Bottle	X		Y		Z		Mean	Conclusions	Standard deviation	
Determination Element	1	2	1	2	1	2			Bottles (d.f.=2)	Error (d.f.=3)
Si	27.3	27.4	26.0	30.4	29.3	25.7	27.7	NS	Neg.	2.3
Al	10.7	9.61	8.61	11.3	9.29	9.11	9.77	NS	Neg.	1.2
Fe	9.01	9.36	9.08	8.80	9.84	9.66	9.29	NS	0.39	.20
Mg	6.03	6.29	5.86	6.12	6.29	6.21	6.13	NS	.07	.15
Ca	8.46	9.43	8.39	8.92	7.98	7.84	8.67	NS	.42	.45
Na	>.316	>.316	>.316	>.316	>.316	>.316	----------	--------	------	------
K	.687	.524	.719	.788	.673	.519	.652	NS	.057	.096
Ti	.790	.814	.706	.807	.649	.596	.727	NS	.087	.048
P	<.0464	<.0464	<.0464	<.0464	<.0464	<.0464	----------	--------	------	------
Mn	.187	.180	.186	.186	.196	.182	.186	NS	Neg.	.006
Ag	.12	.12	<.10	.15	<.10	<.10	----------	--------	------	------
B	<10.0	11.1	<10.0	<10.0	<10.0	<10.0	----------	--------	------	------
Ba	161	139	134	126	146	142	141	NS	7.6	9.7
Be	<1.00	<1.00	<1.00	<1.00	<1.00	1.00	----------	--------	------	------
Bi	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
Ce	<20.0	<20.0	<20.0	----------	<20.0	<20.0	----------	--------	------	------
Co	51.2	47.9	56.4	59.6	49.4	54.2	53.1	NS	3.9	2.7
Cr	154	160	168	154	156	150	157	NS	Neg.	6.7
Cu	*	*	*	*	*	*	----------	--------	------	------
Dy	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	----------	--------	------	------
Er	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	----------	--------	------	------
Eu	<1.00	<1.00	1.38	<1.00	1.35	<1.00	----------	--------	------	------
Ga	21.0	20.1	22.3	25.1	19.8	19.0	21.2	NS	2.0	1.2
Gd	9.50	8.10	7.50	7.50	9.20	10.3	8.68	NS	1.0	.73
Ho	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
La	14.7	16.0	19.4	23.9	15.5	17.2	17.8	NS	3.1	2.1
Mo	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	----------	--------	------	------
Nb	8.51	4.24	8.62	9.44	3.59	7.94	7.1	NS	Neg.	2.5
Nd	<14.7	<14.7	<14.7	<14.7	<14.7	<14.7	----------	--------	------	------
Ni	88.3	78.0	96.1	81.0	82.0	93.0	86.4	NS	Neg.	8.7
Pb	7.77	7.55	6.13	7.31	8.06	6.73	7.26	NS	Neg.	.73
Pr	<14.7	<14.7	<14.7	<14.7	<14.7	<14.7	----------	--------	------	------
Sc	>68.1	>68.1	>68.1	>68.1	>68.1	>68.1	----------	--------	------	------
Sm	<4.64	<4.64	<4.64	<4.64	<4.64	<4.64	----------	--------	------	------
Sn	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	----------	--------	------	------
Sr	270	240	242	236	261	238	248	NS	Neg.	15.6
Th	<21.5	<21.5	<21.5	<21.5	<21.5	<21.5	----------	--------	------	------
V	>215	>215	>215	>215	>215	>215	----------	--------	------	------
Y	28.0	25.9	27.2	31.1	21.4	24.9	26.4	NS	2.6	2.3
Yb	4.12	4.46	4.69	4.39	4.04	3.68	4.23	NS	.30	.24
Zn	144	135	150	157	146	150	147	NS	6.1	4.9
Zr	150	149	131	163	117	141	142	NS	Neg.	16.3

TABLE 83.—*Computerized spectrographic data for granite, G–2*

[Elements Si through Mn in percent, all others in parts per million]

Bottle	21/11		101/13		37/15		Mean	Conclusions	Standard deviation	
Determination Element	1	2	1	2	1	2			Bottles (d.f.=2)	Error (d.f.=3)
Si	>34.3	>34.3	>34.3	30.4	33.5	>34.3	----------	--------	------	------
Al	9.41	8.39	7.76	7.03	8.73	9.28	8.43	NS	0.81	0.56
Fe	2.53	2.20	2.38	2.26	2.50	2.78	2.44	NS	.11	.18
Mg	.799	.676	.589	.630	.645	.751	.682	NS	.044	.068
Ca	2.40	2.26	1.85	2.19	1.92	2.75	2.23	NS	Neg.	.37
Na	>.316	>.316	>.316	>.316	>3.16	>3.16	----------	--------	------	------
K	5.37	4.74	4.52	4.78	4.76	5.13	4.88	NS	Neg.	.32
Ti	.308	.258	.213	.217	.259	.289	.257	NS	.033	.024
P	.0597	.0528	.0549	.0533	.0611	.0656	.0579	NS	.004	.003
Mn	.0481	.0412	.0350	.0449	.0368	.0417	.0413	NS	Neg.	.005
Ag	<.10	<.10	<.10	<.10	<.10	<.10	----------	--------	------	------
B	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	----------	--------	------	------
Ba	1,880	1,490	1,270	1,440	1,430	1,680	1,532	NS	85.7	201
Be	3.20	2.52	1.85	2.34	2.45	2.75	2.52	NS	.29	.36
Bi	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
Ce	190	213	165	175	191	210	191	NS	15.4	12.8
Co	4.77	4.02	3.57	3.99	4.10	4.42	4.14	NS	.18	.37
Cr	8.44	8.03	7.22	7.71	7.59	9.03	8.00	NS	.11	.64
Cu	<46.4	9.21	<46.4	<46.4	<46.4	<46.4	----------	--------	------	------
Dy	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	----------	--------	------	------
Er	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	----------	--------	------	------
Eu	1.46	1.89	1.25	1.59	1.24	1.52	1.49	NS	Neg.	.25
Ga	32.3	24.3	24.3	28.0	25.1	26.3	26.7	NS	Neg.	3.6
Gd	<3.16	<3.16	<3.16	<3.16	<3.16	3.95	--------	--------	------	------
Ho	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
La	109	123	91.7	108	112	127	112	NS	7.25	10.7
Mo	2.55	1.15	2.04	1.76	1.19	2.02	1.78	NS	Neg.	.67
Nb	7.99	7.73	4.83	5.55	6.38	9.44	6.99	NS	1.26	1.29
Nd	53.0	51.0	40.0	42.0	44.0	57.0	47.8	NS	4.6	5.4
Ni	2.41	2.12	2.58	2.48	2.57	2.17	2.39	NS	Neg.	.21
Pb	36.0	33.4	29.4	26.6	27.7	34.5	31.3	NS	2.48	3.18
Pr	14.4	14.0	12.2	11.3	14.0	15.1	13.5	NS(.975)	1.46	.60
Sc	4.17	3.41	3.14	3.57	3.87	4.35	3.75	NS	.25	.41
Sm	10.2	10.1	8.21	9.15	9.53	11.1	9.72	NS	.73	.75
Sn	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	----------	--------	------	------
Sr	721	681	450	443	645	692	605	S(.99)	137	25.4
Th	21.9	21.5	<21.5	24.6	<21.5	<21.5	----------	--------	------	------
V	47.8	47.1	40.1	46.2	40.9	45.7	44.6	NS	.95	3.18
Y	8.96	9.44	7.34	8.42	9.81	10.3	9.04	NS	1.03	.52
Yb	1.17	1.01	<.68	.82	.83	1.10	----------	--------	------	------
Zn	75.7	68.3	65.7	66.1	62.9	70.3	68.2	NS	1.42	4.28
Zr	245	258	209	234	270	285	250	NS	26.5	13.0

TABLE 84.—*Computerized spectrographic data for granodiorite, GSP–1*

[Elements Si through Mn in percent, all others in parts per million]

Bottle No	42/10		13/20		21/3		Mean	Conclusions	Standard deviation	
Determination Element	1	2	1	2	1	2			Bottles (d.f.=2)	Error (d.f.=3)
Si	>34.3	>34.3	30.4	33.6	32.3	>34.3	----------	--------	------	------
Al	9.63	9.48	7.95	8.97	9.00	8.28	8.88	NS	0.46	0.51
Fe	4.23	4.01	3.06	4.76	4.37	4.64	4.18	NS	Neg.	.71
Mg	.925	.940	.913	.925	.933	.784	.903	NS	Neg.	.061
Ca	2.26	2.80	2.91	2.48	2.01	2.15	2.44	NS	.24	.29
Na	>.316	>.316	>.316	>.316	>.316	>.316	----------	--------	------	------
K	5.80	6.03	6.05	5.69	5.76	5.87	5.87	NS	Neg.	.18
Ti	.430	.373	.361	.403	.329	.404	.383	NS	Neg.	.042
P	.162	.168	.114	.142	.160	.145	.148	NS	.016	.013
Mn	.0585	.0370	.0453	.0476	.0484	.0426	.0466	NS	Neg.	.0092
Ag	<.10	<.10	<.10	<.10	<.10	<.10	----------	--------	------	------
B	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	----------	--------	------	------
Ba	1,200	1,160	1,240	1,230	1,040	1,120	1,163	NS	71.6	37.4
Be	1.24	1.45	1.17	1.37	1.27	<1.00	----------	--------	------	------
Bi	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
Ce	744	794	706	757	518	584	684	NS(.99)	113	39.7
Co	7.18	5.98	6.79	6.49	5.83	6.37	6.61	NS	.45	.26
Cr	12.2	12.6	14.2	11.9	8.98	8.94	11.5	NS(.975)	2.09	.95
Cu	<46.4	<46.4	<46.4	<46.4	<46.4	<46.4	----------	--------	------	------
Dy	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	----------	--------	------	------
Er	4.42	<2.15	4.22	<2.15	3.27	<2.15	----------	--------	------	------
Eu	2.53	2.75	2.55	2.46	1.98	1.98	2.38	NS(.99)	.34	.10
Ga	26.0	26.5	26.7	26.9	23.5	22.6	25.4	S(.99)	2.0	.43
Gd	19.1	16.6	16.1	16.0	17.1	13.6	16.4	NS	.35	1.76
Ho	<1.00	2.27	1.69	<1.00	<1.00	1.48	----------	--------	------	------
La	352	276	297	283	265	235	285	NS	21.7	33.8
Mo	1.95	1.18	1.34	1.81	1.30	1.00	1.43	NS	Neg.	.39
Nb	22.2	20.8	21.2	22.0	22.7	13.9	20.5	NS(.975)	Neg.	18.2
Nd	230	190	220	240	145	145	195	NS	42.5	3.65
Ni	8.41	8.14	7.17	7.17	7.03	6.93	7.48	S(.99)	.69	.18
Pb	71.9	68.4	63.4	65.5	68.3	70.9	68.1	NS	2.82	1.98
Pr	51.0	36.2	41.9	41.5	34.2	35.4	40.0	NS	1.75	6.06
Sc	6.13	7.18	7.89	7.26	5.75	6.90	6.85	NS	.43	.69
Sm	33.6	28.5	30.1	29.7	23.7	21.7	27.9	NS	4.24	2.24
Sn	10.0	10.3	8.68	9.57	9.97	8.62	9.51	NS	.22	.66
Sr	356	359	285	317	294	296	318	NS(.975)	33.2	13.1
Th	164	153	137	136	119	<100	----------	--------	------	------
V	72.6	72.1	74.1	83.4	65.8	69.4	72.9	NS	4.82	4.09
Y	38.3	31.2	30.2	33.7	25.9	29.3	31.4	NS	2.65	3.50
Yb	1.99	2.51	2.37	2.38	2.02	2.29	2.26	NS	Neg.	.24
Zn	99.0	97.3	82.0	80.9	93.3	83.3	89.3	NS	7.86	4.16
Zr	443	322	370	369	283	323	352	NS	21.6	52.0

TABLE 85.—*Computerized spectrographic data for andesite, AGV–1*

[Elements Si through Mn in percent, all others in parts per million]

Bottle	19/1		93/6		75/30		Mean	Conclusions	Standard deviation	
Determination / Element	1	2	1	2	1	2			Bottles (d.f.=2)	Error (d.f.=3)
Si	30.5	30.6	28.0	32.1	32.2	31.9	30.9	NS	Neg.	1.68
Al	12.8	11.7	10.9	12.5	11.8	13.2	12.2	NS	Neg.	.98
Fe	5.61	5.99	5.88	6.27	5.64	5.77	5.86	NS	0.10	.23
Mg	1.63	1.55	1.60	1.74	1.59	1.74	1.64	NS	Neg.	.09
Ca	4.32	4.33	4.36	4.29	3.85	4.55	4.28	NS	Neg.	.29
Na	>.316	>.316	>.316	>.316	>.316	>.316	----------	--------	------	------
K	>1.00	>1.00	>1.00	>1.00	>1.00	>1.00	----------	--------	------	------
Ti	.821	.744	.630	.755	.662	.768	.730	NS	Neg.	.074
P	.284	.303	.291	.305	.286	.317	.298	NS	Neg.	.016
Mn	.113	.121	.108	.113	.114	.116	.114	NS	.002	.004
Ag	.20	.13	.16	.19	.14	.18	952	NS	Neg.	.035
B	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	.167	--------	------	------
Ba	978	937	896	964	916	1,020	----------	NS	Neg.	53.3
Be	2.36	2.75	2.52	2.71	2.29	2.48	2.52	NS	Neg.	.19
Bi	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
Ce	122	119	111	130	102	113	116	NS	3.9	9.0
Co	21.0	19.8	18.5	19.2	15.9	17.7	18.7	NS	1.68	.93
Cr	8.63	8.92	7.69	9.93	9.01	7.59	8.63	NS	Neg.	1.09
Cu	<46.4	<46.4	<46.4	<46.4	<46.4	<46.4	----------	--------	------	------
Dy	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	----------	--------	------	------
Er	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	----------	--------	------	------
Eu	1.66	1.75	1.42	1.75	1.34	1.55	1.58	NS	.06	.16
Ga	22.5	21.1	25.4	23.2	19.4	24.0	22.6	NS	Neg.	2.2
Gd	5.4	4.1	6.2	7.2	<3.16	<3.16	----------	--------	------	------
Ho	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
La	55.8	56.9	47.6	61.0	44.9	48.8	52.5	NS	2.94	5.72
Mo	4.90	3.26	3.26	3.66	3.12	4.81	3.84	NS	Neg.	.98
Nb	9.05	10.6	9.27	11.1	5.99	10.4	9.40	NS	Neg.	2.05
Nd	51.0	48.0	49.0	62.0	49.0	44.0	50.5	NS	2.02	5.8
Ni	21.5	20.2	18.3	19.2	17.2	20.2	19.4	NS	.74	1.38
Pb	50.3	54.8	49.2	45.0	35.7	53.3	48.0	NS	Neg.	7.6
Pr	6.40	7.94	8.24	8.70	8.97	7.99	8.04	NS	.52	7.7
Sc	20.5	22.0	15.3	22.0	15.9	17.6	18.9	NS	.97	2.89
Sm	4.76	5.09	4.99	4.90	<4.64	<4.64	----------	--------	------	------
Sn	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	----------	--------	------	------
Sr	912	921	833	988	864	944	910	NS	Neg.	71.3
Th	<21.5	<21.5	<21.5	<21.5	<21.5	<21.5	----------	--------	------	------
V	>215	>215	148	>215	200	>215	----------	--------	------	------
Y	25.0	22.5	20.7	22.9	18.2	20.6	21.6	NS	1.83	1.68
Yb	2.37	2.42	2.23	2.78	2.44	2.38	2.44	NS	Neg.	.23
Zn	114	108	112	112	94.8	124	111	NS	Neg.	12.2
Zr	287	292	257	387	198	232	276	NS	38.8	54.9

TABLE 86.—*Computerized spectrographic data for peridotite, PCC–1*

[Elements Si through Mn in percent, all others in parts per million]

Bottle	70/13		15/11		42/21		Mean	Conclusions	Standard deviation	
Determination Element	1	2	1	2	1	2			Bottles (d.f.=2)	Error (d.f.=3)
Si	22.3	20.0	22.2	21.8	19.4	18.6	20.7	NS	1.37	1.01
Al	.440	.440	.380	.460	.480	.320	.42	NS	Neg.	.07
Fe	6.38	5.79	6.60	6.25	6.24	6.54	6.30	NS	Neg.	.30
Mg	22.0	26.9	23.2	29.7	21.9	21.9	24.3	NS	Neg.	3.3
Ca	.340	.376	.322	.358	.339	.273	.33	NS	.01	.03
Na	≤.00464	≤.00464	≤.00464	≤.00464	≤.00464	≤.00464	----------	--------	------	------
K	≤.0681	≤.0681	≤.0681	≤.0681	≤.0681	≤.0681	----------	--------	------	------
Ti	.00199	.00232	.00174	.00245	.00219	.00175	.0021	NS	Neg.	.0004
P	≤.0464	≤.0464	≤.0464	≤.0464	≤.0464	≤.0464	----------	--------	------	------
Mn	.124	.143	.127	.148	.136	.131	.135	NS	Neg.	.012
Ag	≤.10	≤.10	≤.10	≤.10	≤.10	.1	----------	--------	------	------
B	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	----------	--------	------	------
Ba	≤1.00	≤1.00	≤1.00	≤1.00	≤1.00	≤1.00	----------	--------	------	------
Be	≤1.00	≤1.00	≤1.00	≤1.00	≤1.00	≤1.00	----------	--------	------	------
Bi	≤1.00	≤1.00	≤1.00	≤1.00	≤1.00	≤1.00	----------	--------	------	------
Ce	<20.0	<20.0	43.2	<20.0	<20.0	<20.0	----------	--------	------	------
Co	148	>215	135	169	159	105	----------	--------	------	------
Cr	2.990	2.110	2,330	2,880	1.890	1,910	2,352	NS	253	424
Cu	8.11	5.80	5.87	5.61	5.60	4.53	5.92	NS	.61	1.04
Dy	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	----------	--------	------	------
Er	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	----------	--------	------	------
Eu	≤1.00	≤1.00	≤1.00	≤1.00	≤1.00	≤1.00	----------	--------	------	------
Ga	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	----------	--------	------	------
Gd	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	----------	--------	------	------
Ho	≤1.00	≤1.00	≤1.00	≤1.00	≤1.00	≤1.00	----------	--------	------	------
La	<14.7	<14.7	<14.7	<14.7	<14.7	<14.7	----------	--------	------	------
Mo	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	----------	--------	------	------
Nb	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	----------	--------	------	------
Nd	<14.7	<14.7	<14.7	<14.7	<14.7	<14.7	----------	--------	------	------
Ni	>1,000	>1.000	>1.000	>1.000	>1,000	>1,000	----------	--------	------	------
Pb	8.11	8.71	9.33	7.75	8.36	8.06	8.39	NS	Neg.	.70
Pr	<2.15	<2.15	<2.15	<2.15	<2.15	4.26	----------	--------	------	------
Sc	7.00	7.37	7.02	10.4	6.68	5.61	7.35	NS	.78	1.46
Sm	<4.64	<4.64	<4.64	<4.64	<4.64	<4.64	----------	--------	------	------
Sn	4.2	4.6	5.0	4.2	<3.16	<3.16	----------	--------	------	------
Sr	.51	.54	.47	.64	0.48	<0.46	----------	--------	------	------
Th	<21.5	<21.5	<21.5	<21.5	<21.5	<21.5	----------	--------	------	------
V	36.1	46.6	40.1	41.5	50.1	33.8	41.4	NS	Neg.	7.94
Y	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	----------	--------	------	------
Yb	1.57	1.74	1.72	1.64	1.53	1.27	1.58	NS	.12	.13
Zn	57.3	54.8	55.9	54.2	53.4	48.9	54.1	NS	2.06	2.21
Zr	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	----------	--------	------	------

TABLE 87.—*Computerized spectrographic data for dunite, DTS–1*

[Elements Si through Mn in percent, all others in parts per million]

Bottle	10/13		32/25		54/15		Mean	Conclusions	Standard deviation	
Determination Element	1	2	1	2	1	2			Bottles (d.f. = 2)	Error (d.f. = 3)
Si	19.1	17.6	17.5	18.0	18.6	19.6	18.4	NS	0.41	0.76
Al	.220	.200	.170	.220	.220	.220	.21	NS	Neg.	.02
Fe	6.55	6.87	7.15	6.06	6.33	6.57	6.59	NS	Neg.	.47
Mg	25.8	25.9	21.0	29.5	23.6	26.5	25.4	NS	Neg.	3.67
Ca	.115	.115	.108	.133	.105	.101	.113	NS	.005	.010
Na	<.00464	<.00464	<.00464	<.00464	<.00464	<.00464	------	------	------	------
K	<.0681	<.0681	<.0681	<.0681	<.0681	<.0681	------	------	------	------
Ti	.00183	.00159	.00115	.00185	.00139	.00119	.00150	NS	Neg.	.0003
P	<.0464	<.0464	<.0464	<.0464	<.0464	<.0464	------	------	------	------
Mn	.141	.131	.121	.140	.127	.135	.132	NS	Neg.	.009
Ag	<.10	<.10	<.10	<.10	<.10	<.10	------	------	------	------
B	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	------	------	------	------
Ba	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	------	------	------	------
Be	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	------	------	------	------
Bi	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	------	------	------	------
Ce	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	------	------	------	------
Co	>215	>215	>215	>215	>215	>215	------	------	------	------
Cr	5,800	4,020	3,930	4,480	4,520	3,750	4,417	NS	Neg.	823
Cu	2.88	2.10	<46.4	<46.4	2.61	1.92	------	------	------	------
Dy	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	------	------	------	------
Er	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	------	------	------	------
Eu	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	------	------	------	------
Ga	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	------	------	------	------
Gd	<3.16	<3.16	<3.16	<3.16	<3.16	3.6	------	------	------	------
Ho	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	------	------	------	------
La	<14.7	<14.7	<14.7	<14.7	<14.7	<14.7	------	------	------	------
Mo	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	------	------	------	------
Nb	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	------	------	------	------
Nd	<14.7	<14.7	<14.7	<14.7	<14.7	<14.7	------	------	------	------
Ni	>1,000	>1,000	>1,000	>1,000	>1,000	<1,000	------	------	------	------
Pb	9.49	12.4	7.05	3.05	<1.00	7.12	------	------	------	------
Pr	<2.15	2.84	<2.15	<2.15	<2.15	<2.15	------	------	------	------
Sc	5.58	5.39	3.71	5.00	4.49	4.90	4.84	NS	.42	.56
Sm	<4.64	<4.64	<4.64	<4.64	<4.64	<4.64	------	------	------	------
Sn	4.2	<3.16	9.0	6.8	<3.16	<3.16	------	------	------	------
Sr	.61	.49	<.46	.49	<.46	<.46	------	------	------	------
Th	<21.5	<21.5	<21.5	<21.5	<21.5	<21.5	------	------	------	------
V	10.9	21.2	13.7	20.1	11.8	16.6	15.7	NS	Neg.	5.3
Y	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	------	------	------	------
Yb	1.64	1.60	1.53	1.64	1.79	1.78	1.66	NS(.975)	.10	.05
Zn	57.8	59.9	62.6	56.9	58.8	56.7	58.8	NS	Neg.	2.62
Zr	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	------	------	------	------

TABLE 88.—*Computerized spectrographic data for basalt, BCR–1*

[Elements Si through Mn in percent, all others in parts per million. Asterisk indicates interference]

Bottle	39/22		23/25		68/7		Mean	Conclusions	Standard deviation	
Determination	1	2	1	2	1	2			Bottles (d.f. = 2)	Error (d.f. = 3)
Element										
Si	27.0	22.8	23.6	28.0	25.2	25.5	25.4	NS	Neg.	2.5
Al	9.43	6.87	6.33	9.25	8.60	7.03	7.9	NS	Neg.	1.7
Fe	10.4	10.7	10.3	11.3	10.6	10.9	10.7	NS	Neg.	.44
Mg	4.23	3.83	3.77	4.82	4.60	3.84	4.18	NS	Neg.	.55
Ca	5.37	4.69	4.72	6.15	6.05	4.47	5.24	NS	Neg.	.91
Na	>.316	>.316	>.316	>.316	>.316	>.316	----------	--------	------	------
K	>1.00	>1.00	>1.00	>1.00	>1.00	>1.00	----------	--------	------	------
Ti	1.31	1.33	1.20	1.70	1.51	1.24	1.38	NS	Neg.	.23
P	.260	.214	.217	.250	.267	.256	.244	NS	Neg.	.024
Mn	.195	.198	.203	.213	.205	.189	.200	NS	0.003	.008
Ag	.22	.16	.11	.22	.24	<.10	----------	--------	------	------
B	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	----------	--------	------	------
Ba	603	519	613	603	557	532	571	NS	20.9	36.0
Be	1.55	1.91	1.66	1.72	1.69	1.43	1.66	NS	Neg.	.18
Bi	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
Ce	127	126	*	139	*	119	----------	--------	------	------
Co	39.9	40.6	40.6	44.9	44.6	39.2	41.6	NS	Neg.	2.8
Cr	13.1	9.66	13.2	15.5	12.4	10.6	12.4	NS	1.06	1.84
Cu	<46.4	<46.4	<46.4	<46.4	<46.4	<46.4	----------	--------	------	------
Dy	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	----------	--------	------	------
Er	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	----------	--------	------	------
Eu	2.15	2.00	2.25	2.43	2.14	1.99	2.16	NS	.13	.11
Ga	23.8	23.5	23.9	23.0	25.1	18.1	22.9	NS	Neg.	2.9
Gd	9.5	12.7	9.30	11.0	7.10	8.60	9.70	NS	1.23	1.60
Ho	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
La	46.6	46.8	42.5	43.9	49.2	31.4	43.4	NS	Neg.	7.3
Mo	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	----------	--------	------	------
Nb	13.8	9.31	8.64	20.3	14.1	7.39	12.2	NS	Neg.	5.8
Nd	60.0	26.5	30.0	47.0	40.0	13.5	36.2	NS	Neg.	18.8
Ni	10.8	10.8	10.3	13.4	12.9	12.1	11.7	NS	Neg.	1.3
Pb	17.0	17.2	18.5	19.4	20.6	13.6	17.7	NS	Neg.	2.9
Pr	<14.7	<14.7	<14.7	<14.7	<14.7	<14.7	----------	--------	------	------
Sc	>68.1	>68.1	>68.1	>68.1	>68.1	53.8	----------	--------	------	------
Sm	<4.64	<4.64	<4.64	<4.64	<4.64	<4.64	----------	--------	------	------
Sn	<3.16	<3.16	<3.16	<3.16	4.1	<2.16	----------	--------	------	------
Sr	409	395	454	454	405	432	425	NS	25.1	12.4
Th	<21.5	<21.5	<21.5	<21.5	<21.5	<21.5	----------	--------	------	------
V	>215	>215	>215	>215	>215	>215	----------	--------	------	------
Y	44.0	40.8	35.9	43.0	40.1	35.1	39.8	NS	Neg.	3.8
Yb	5.30	5.17	6.20	7.21	5.52	4.79	5.70	NS	.79	.51
Zn	163	142	170	165	175	147	208	NS	Neg.	14.4
Zr	241	228	176	249	224	132	160	NS	Neg.	48

TABLE 89.—*Computerized spectrographic data for nepheline syenite, STM–1*

[Elements Si through Mn in percent, all others in parts per million]

Bottle	50/11		29/22		10/13		Mean	Conclusions	Standard deviation	
Determination Elemnt	1	2	1	2	1	2			Bottles (d.f.=2)	Error (d.f.=3)
Si	24.5	29.2	26.6	28.2	26.1	29.4	27.3	NS	Neg.	2.4
Al	8.54	9.83	9.68	10.5	9.51	9.91	9.67	NS	Neg.	.64
Fe	4.28	5.20	3.47	3.63	3.34	3.37	3.88	NS	0.70	.38
Mg	.112	.103	.0976	.107	.102	.0987	.103	NS	Neg.	.005
Ca	1.82	1.84	1.46	1.84	1.96	1.74	1.78	NS	Neg.	.179
Na	>.316	>.316	>.316	>.316	>.316	>.316	----------	--------	------	------
K	5.11	5.03	4.77	5.39	5.63	5.23	5.19	NS	Neg.	.30
Ti	.0835	.0864	.0871	.0940	.0988	.0902	.090	NS	.003	.005
P	.0517	.0704	.0720	.0787	.0901	.0724	.073	NS	.007	.011
Mn	.255	.250	.234	.241	.249	.244	.246	NS	.007	.004
Ag	.35	.35	.39	.43	.40	.45	.395	NS	.035	.026
B	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	----------	--------	------	------
Ba	774	750	616	844	890	752	771	NS	Neg.	109
Be	11.2	11.7	12.6	11.8	11.5	12.3	11.85	NS	.12	.50
Bi	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
Ce	328	351	346	358	381	359	354	NS	11.6	13.6
Co	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
Cr	2.19	2.79	3.05	3.61	1.80	1.82	2.54	NS(.975)	.72	.34
Cu	<1.00	1.91	2.17	2.27	2.12	3.01	----------	--------	------	------
Dy	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	----------	--------	------	------
Er	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	----------	--------	------	------
Eu	3.77	3.89	3.74	3.83	4.11	3.85	3.86	NS	.054	.122
Ga	58.3	62.8	65.6	72.6	66.5	60.1	64.3	NS	3.16	4.30
Gd	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	----------	--------	------	------
Ho	2.27	2.34	<1.00	2.45	2.88	<1.00	----------	--------	------	------
La	179	176	197	205	216	209	197	S(.99)	17.6	4.51
Mo	11.7	6.97	7.71	6.09	8.59	6.25	7.9	NS	Neg.	2.2
Nb	171	189	194	218	160	204	189	NS	Neg.	21.7
Nd	46.0	54.0	46.0	60.0	68.0	60.0	55.7	NS	5.2	7.3
Ni	1.71	1.74	1.73	1.96	1.62	1.15	1.65	NS	.18	.21
Pb	18.0	19.5	15.4	16.8	17.7	18.7	17.7	NS	1.23	.93
Pr	18.6	18.3	20.1	19.4	20.2	20.1	19.4	NS(.99)	1.24	.31
Sc	1.09	1.04	<1.00	1.09	1.17	<1.00	----------	--------	------	------
Sm	15.0	15.6	15.2	15.8	17.3	15.7	15.8	NS	.37	.74
Sn	10.4	10.8	10.2	11.8	12.2	11.9	11.2	NS	.57	.68
Sr	836	793	860	804	918	847	843	NS	20.3	40.9
Th	<21.5	<21.5	<21.5	<21.5	<21.5	<21.5	----------	--------	------	------
V	<1.47	1.63	<1.47	<1.47	<1.47	<1.47	----------	--------	------	------
Y	46.5	43.2	49.3	52.2	54.3	44.9	48.4	NS	.90	4.24
Yb	6.75	7.39	6.22	6.61	6.73	6.33	6.67	NS	.25	.35
Zn	173	183	181	175	170	177	177	NS	Neg.	5.4
Zr	>681	>681	>681	>681	>681	>681	----------	--------	------	------

TABLE 90.—*Computerized spectrographic data for rhyolite, RGM–1*

[Elements Si through Mn in percent, all others in parts per million]

Bottle	31/5		52/26		10/28		Mean	Conclusions	Standard deviation	
Determination Element	1	2	1	2	1	2			Bottles (d.f.=2)	Error (d.f.=3)
Si	32.4	>34.3	>34.3	>34.3	33.4	>34.3	----------	--------	------	------
Al	6.35	6.30	7.19	7.37	6.75	7.71	6.94	NS	0.46	0.40
Fe	1.50	1.31	1.37	1.47	1.35	1.62	1.44	NS	Neg.	.14
Mg	.178	.211	.172	.195	.187	.195	.190	NS	Neg.	.017
Ca	1.37	1.12	1.06	1.59	1.25	1.32	1.28	NS	Neg.	.24
Na	>.316	>.316	>.316	>.316	>.316	>.316	----------	--------	------	------
K	4.69	4.77	4.51	5.04	4.71	5.19	4.82	NS	Neg.	.29
Ti	.143	.105	.118	.158	.128	.152	.134	NS	Neg.	.025
P	<.0464	<.0464	<.0464	<.0464	<.0464	<.0464	----------	--------	------	------
Mn	.0405	.0339	.0438	.0421	.0378	.0408	.040	NS	.002	.003
Ag	<0.10	<0.10	<.10	<.10	<.10	<.10	----------	--------	------	------
B	26.2	23.4	31.4	35.7	29.4	33.7	30.0	NS	4.2	2.7
Ba	812	691	623	847	701	837	752	NS	Neg.	118
Be	2.79	2.23	2.45	2.82	2.51	2.53	2.56	NS	Neg.	.27
Bi	1.56	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
Ce	59.0	57.1	52.6	69.4	57.5	66.6	60.4	NS	Neg.	7.8
Co	1.72	1.59	1.70	1.99	1.69	1.87	1.76	NS	Neg.	.15
Cr	1.70	1.56	2.46	4.64	2.04	2.89	2.55	NS	.68	.96
Cu	<46.4	<46.4	<46.4	<46.4	<46.4	<46.4	----------	--------	------	------
Dy	4.62	4.37	4.02	4.23	3.67	5.13	4.34	NS	Neg.	.61
Er	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	----------	--------	------	------
Eu	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
Ga	12.8	10.5	12.4	17.7	13.0	14.5	13.5	NS	Neg.	2.4
Gd	<3.16	4.42	<3.16	3.80	<3.16	<3.16	----------	--------	------	------
Ho	<1.00	<1.00	<1.00	<1.00	<1.00	1.17	----------	--------	------	------
La	23.4	24.0	25.4	31.5	26.2	31.4	27.0	NS	1.65	3.28
Mo	3.00	2.13	2.99	2.54	3.30	3.28	2.87	NS	.24	.40
Nb	4.17	4.32	6.92	6.78	5.12	5.36	5.44	S(.99)	1.3	.13
Nd	19.0	15.5	15.5	23.5	16.5	22.5	18.8	NS	Neg.	4.3
Ni	1.79	1.49	2.10	2.46	1.99	2.11	1.99	NS	.29	.20
Pb	19.4	16.0	20.9	23.5	21.3	24.1	20.9	NS	2.3	2.1
Pr	4.58	4.11	4.54	3.76	3.90	3.48	4.06	NS	.17	.41
Sc	4.82	4.16	3.65	5.37	4.23	5.39	4.60	NS	Neg.	.89
Sm	<4.64	<4.64	<4.64	<4.64	<4.64	<4.64	----------	--------	------	------
Sn	3.44	3.22	3.51	4.35	3.71	4.14	3.73	NS	.20	.40
Sr	123	123	135	149	128	136	132	NS	8.3	6.6
Th	<21.5	<21.5	<21.5	22.5	<21.5	<21.5	----------	--------	------	------
V	15.3	12.9	15.1	15.9	14.9	15.1	14.9	NS	Neg.	1.04
Y	23.2	21.2	21.8	26.8	23.8	26.3	23.8	NS	Neg.	2.4
Yb	2.93	2.42	2.24	3.47	2.65	3.27	2.83	NS	Neg.	.60
Zn	20.9	20.1	21.1	24.4	20.8	22.0	21.5	NS	.43	1.48
Zr	309	267	297	345	269	336	304	NS	Neg.	37.8

TABLE 91.—*Computerized spectrographic data for quartz latite, QLO-1*

[Elements Si through Mn in percent, all others in parts per million]

Bottle	51/30		10/23		31/22		Mean	Conclusions	Standard deviation	
Determination Element	1	2	1	2	1	2			Bottles (d.f.=2)	Error (d.f.=3)
Si	33.9	29.1	>34.3	29.1	>34.3	33.0	----------	--------	------	------
Al	9.73	9.52	11.2	8.49	11.8	10.7	10.2	NS	0.25	1.20
Fe	4.21	3.88	3.51	4.11	3.81	4.87	4.08	NS	Neg.	.50
Mg	1.03	.994	1.04	.834	.969	.874	.957	NS	Neg.	.094
Ca	3.48	2.78	3.26	2.62	2.83	3.03	3.00	NS	Neg.	.40
Na	>.316	>.316	>.316	>.316	>.316	>.316	----------	--------	------	------
K	3.98	3.96	3.81	3.81	3.54	3.67	3.80	NS(.99)	.18	.05
Ti	.405	.375	.401	.313	.399	.374	.378	NS	Neg.	.039
P	.137	.139	.142	.126	.173	.144	.144	NS	.009	.014
Mn	.107	.100	.119	.109	.101	.110	.108	NS	.003	.006
Ag	.15	.17	.15	<.10	.16	<.10	----------	--------	------	------
B	37.0	42.5	45.7	37.4	41.4	42.1	41.0	NS	Neg.	4.1
Ba	1,280	1,260	1,200	1,100	1,100	1,100	1,173	NS	82.2	41.6
Be	2.02	2.09	2.43	2.16	2.10	2.01	2.14	NS	.11	.12
Bi	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
Ce	76.6	79.5	85.9	66.2	76.3	68.6	75.5	NS	Neg.	8.72
Co	7.63	7.57	7.55	6.82	7.41	6.86	7.31	NS	Neg.	.37
Cr	1.53	1.51	<1.00	<1.00	1.57	1.66	----------	--------	------	------
Cu	<46.4	<46.4	80.9	<46.4	<46.4	<46.4	----------	--------	------	------
Dy	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	----------	--------	------	------
Er	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	----------	--------	------	------
Eu	1.08	1.29	1.38	1.00	1.11	1.02	1.15	NS	Neg.	.18
Ga	19.4	18.9	20.0	16.4	20.0	18.0	18.8	NS	Neg.	1.7
Gd	<3.16	<3.16	4.39	<3.16	<3.16	<3.16	----------	--------	------	------
Ho	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
La	37.1	37.4	36.0	38.6	35.3	30.8	35.9	NS	1.92	2.12
Mo	4.70	3.55	3.37	2.91	3.30	2.54	3.40	NS	.49	.59
Nb	6.67	5.80	7.45	7.48	5.89	3.30	6.10	NS	1.20	1.12
Nd	40.0	33.0	38.0	32.0	34.0	35.0	35.3	NS	Neg.	3.8
Ni	2.34	2.38	1.96	1.59	2.04	1.65	1.99	NS	.28	.22
Pb	19.7	24.3	25.9	17.5	22.0	20.3	21.6	NS	Neg.	4.0
Pr	6.18	7.63	6.90	5.73	4.88	5.07	6.06	NS	.83	.76
Sc	11.4	12.5	11.9	10.5	10.9	11.1	11.4	NS	Neg.	.73
Sm	<4.64	<4.64	<4.64	<4.64	<4.64	<4.64	----------	--------	------	------
Sn	4.41	4.38	4.36	4.01	4.02	<3.16	----------	--------	------	------
Sr	437	439	510	395	446	391	436	NS	Neg.	52.0
Th	<21.5	<21.5	<21.5	<21.5	<21.5	<21.5	----------	--------	------	------
V	59.3	60.3	68.1	57.3	70.6	55.8	61.9	NS	Neg.	7.5
Y	26.6	25.8	26.2	23.9	28.1	21.5	25.4	NS	Neg.	2.9
Yb	3.45	3.27	3.57	3.08	2.77	3.61	3.29	NS	Neg.	.40
Zn	60.3	63.2	62.4	53.8	67.3	60.3	61.2	NS	Neg.	4.7
Zr	229	192	240	233	224	198	219	NS	6.8	18.6

TABLE 92.—*Computerized spectrographic data for mica schist, SDC–1*

[Elements Si through Mn in percent, all others in parts per million]

Bottle	49/10		19/3		33/17		Mean	Conclusions	Standard deviation	
Determination Element	1	2	1	2	1	2			Bottles (d.f.=2)	Error (d.f.=3)
Si	>34.3	33.6	>34.3	30.0	32.3	32.9	----------	--------	------	------
Al	10.7	9.30	9.96	8.50	10.2	10.6	9.88	NS	Neg.	0.84
Fe	6.04	5.87	6.08	5.64	6.22	5.97	5.97	NS	Neg.	.22
Mg	1.95	1.88	1.72	1.54	1.71	1.62	1.74	NS	0.14	.09
Ca	1.53	1.54	1.25	1.29	1.30	1.16	1.34	NS(.975)	.16	.06
Na	>.316	>.316	>.316	>.316	>.316	>.316	----------	--------	------	------
K	>1.00	>1.00	>1.00	>1.00	>1.00	>1.00	----------	--------	------	------
Ti	.580	.567	.430	.399	.448	.483	.484	S(.99)	.080	.020
P	.120	.110	.120	.0826	.0973	.104	.106	NS	Neg.	.016
Mn	.128	.135	.138	.125	.125	.115	.128	NS	.004	.007
Ag	.15	.16	.17	.16	.15	.14	.155	NS	.009	.007
B	10.8	<10.0	12.8	10.6	10.1	10.0	----------	--------	------	------
Ba	593	562	456	530	491	521	526	NS	38.1	34.8
Be	3.95	3.74	3.68	3.52	3.60	3.82	3.78	NS	.07	.14
Bi	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
Ce	134	136	118	113	128	113	124	NS	9.0	6.5
Co	22.1	21.4	17.3	17.9	23.6	19.6	20.3	NS	2.03	1.68
Cr	75.4	72.5	63.6	63.7	67.7	61.3	67.4	NS	5.34	2.87
Cu	<46.4	<46.4	<46.4	<46.4	<46.4	<46.4	----------	--------	------	------
Dy	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	----------	--------	------	------
Er	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	----------	--------	------	------
Eu	1.66	1.52	1.77	1.57	1.77	1.80	1.68	NS	.07	.10
Ga	24.2	19.8	19.6	19.1	20.3	18.7	20.3	NS	.61	1.9
Gd	6.50	<3.16	3.78	3.89	5.90	<3.16	----------	--------	------	------
Ho	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
La	59.4	57.3	59.1	46.2	53.7	52.6	54.7	NS	Neg.	5.35
Mo	1.51	1.98	2.09	1.33	2.77	1.74	1.90	NS	Neg.	.56
Nb	18.6	14.0	15.3	11.4	14.4	12.6	14.4	NS	Neg.	2.57
Nd	33.0	40.0	34.0	32.0	36.0	28.0	33.8	NS	Neg.	4.4
Ni	67.5	61.6	40.7	50.2	57.6	60.2	56.3	NS	9.23	4.69
Pb	25.9	23.8	24.2	24.3	22.8	25.8	24.5	NS	.96	1.50
Pr	11.6	8.73	8.12	8.39	7.71	7.81	8.73	NS	1.80	1,18
Sc	26.3	20.3	16.3	18.5	15.4	21.6	19.7	NS	Neg.	3.64
Sm	6.32	6.24	4.78	5.09	5.72	4.96	5.18	NS	.65	.34
Sn	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	----------	--------	------	------
Sr	239	241	232	229	240	254	239	NS	7.2	5.9
Th	<21.5	<21.5	<21.5	<21.5	<21.5	<21.5	----------	--------	------	------
V	148	148	117	121	112	121	128	S(.99)	17.3	4.0
Y	48.6	42.8	51.0	35.9	43.8	41.6	44.0	NS	Neg.	6.7
Yb	5.34	6.23	5.58	4.53	4.68	4.41	5.13	NS	.47	.57
Zn	115	97.5	101	102	111	120	108	NS	4.3	8.0
Zr	308	269	231	181	225	254	245	NS	36.3	28.3

TABLE 93.—*Computerized spectrographic data for Cody Shale, SCo–1*

[Elements Si through Mn in percent, all others in parts per million]

Bottle	39/30		38/19		68/12		Mean	Conclusions	Standard deviation	
Determination Element	1	2	1	2	1	2			Bottles (d.f.=2)	Error (d.f.=3)
Si	33.0	>34.3	33.8	32.0	>34.3	30.7	----------	--------	------	------
Al	7.19	7.64	8.33	7.12	7.11	6.39	7.30	NS	0.26	0.60
Fe	3.86	5.52	4.01	4.64	4.33	4.38	4.46	NS	Neg.	.73
Mg	2.27	2.30	2.53	2.53	1.93	1.84	2.23	S(.99)	.32	.04
Ca	1.65	1.85	2.53	2.27	2.00	1.81	2.02	NS(.975)	.32	.15
Na	>.316	>.316	>.316	>.316	>.316	>.316	----------	--------	------	------
K	>1.00	>1.00	>1.00	>1.00	>1.00	>1.00	----------	--------	------	------
Ti	.133	.148	.206	.168	.193	.161	.168	NS	.019	.021
P	.128	.125	.128	.141	.0990	.150	.128	NS	Neg.	.022
Mn	.0508	.0490	.0678	.0585	.0505	.0560	.0554	NS	.0061	.0045
Ag	<.10	<.10	.13	<.10	<.10	<.10	----------	--------	------	------
B	95.7	102	89.1	93.4	90.1	88.9	93.2	NS	4.4	3.2
Ba	338	377	516	418	438	410	416	NS	45.3	44.6
Be	1.51	1.77	2.12	2.33	1.79	1.96	1.90	NS	.25	.13
Bi	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
Ce	59.8	67.8	81.9	69.5	76.0	70.9	71.0	NS	4.43	6.37
Co	9.39	8.99	10.7	9.50	9.91	8.30	9.30	NS	.40	.86
Cr	48.9	51.5	72.0	61.4	59.8	60.7	59.0	NS	7.7	4.5
Cu	<46.4	<46.4	<46.4	<46.4	<46.4	<46.4	----------	--------	------	------
Dy	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	----------	--------	------	------
Er	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	----------	--------	------	------
Eu	<1.00	<1.00	1.02	1.10	<1.00	<1.00	----------	--------	------	------
Ga	10.6	10.3	14.6	11.3	9.20	9.30	10.9	NS	1.6	1.4
Gd	<3.16	<3.16	4.20	<3.16	<3.16	<3.16	----------	--------	------	------
Ho	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
La	23.9	29.8	36.3	40.4	33.4	41.5	34.2	NS	5.56	4.42
Mo	2.64	2.91	3.51	2.99	2.40	2.31	2.79	NS	.41	.24
Nb	3.77	5.90	10.6	7.35	6.86	9.05	7.26	NS	1.73	1.82
Nd	20.0	21.8	27.5	24.5	26.5	22.5	23.8	NS	2.1	2.2
Ni	26.0	26.2	33.9	28.2	29.8	24.6	28.1	NS	1.34	3.15
Pb	30.5	27.4	36.0	31.1	24.8	27.7	29.6	NS	3.18	2.65
Pr	5.92	5.78	5.28	5.98	5.06	4.57	5.43	NS	.48	.35
Sc	6.59	7.30	12.3	10.3	10.7	6.79	9.00	NS	1.77	1.82
Sm	<4.64	<4.64	<4.64	<4.64	<4.64	<4.64	----------	--------	------	------
Sn	4.33	4.08	5.44	5.30	4.84	5.59	4.93	NS	.59	.33
Sr	195	205	236	224	219	209	215	NS	14.0	7.57
Th	<21.5	<21.5	<21.5	<21.5	<21.5	<21.5	----------	--------	------	------
V	113	109	120	115	128	119	117	NS	5.38	4.51
Y	16.5	19.6	24.5	21.0	22.2	22.6	21.1	NS	2.24	1.92
Yb	2.11	2.20	2.68	2.20	2.30	1.76	2.21	NS	Neg.	.30
Zn	96.4	99.6	112	101	89.2	94.4	98.8	NS	6.42	5.14
Zr	162	181	237	158	198	184	187	NS	Neg.	33.7

TABLE 94.—*Computerized spectrographic data for Green River Shale, SGR-1*

[Elements Si through Mn in percent, all others in parts per million]

Bottle	26/29		57/9		52/20		Mean	Conclusions	Standard deviation	
Determination Element	1	2	1	2	1	2			Bottles (d.f.=2)	Error (d.f.=3)
Si	15.2	13.6	14.3	14.2	14.4	14.9	14.4	NS	Neg.	0.69
Al	3.45	3.16	3.55	3.81	3.57	3.86	3.57	NS	0.18	.20
Fe	2.51	1.82	2.09	2.24	2.14	2.69	2.25	NS	Neg.	.36
Mg	3.76	3.66	3.83	3.58	3.70	4.07	3.77	NS	Neg.	.19
Ca	4.69	5.07	5.51	5.14	5.11	5.39	5.15	NS	.16	.24
Na	>.316	>.316	>.316	>.316	>.316	>.316	----------	--------	------	------
K	>1.00	>1.00	>1.00	>1.00	>1.00	>1.00	----------	--------	------	------
Ti	.0677	.0726	.0622	.0697	.0668	.0773	.069	NS	Neg.	.006
P	.195	.162	.179	.181	.185	.168	.178	NS	Neg.	.015
Mn	.0322	.0264	.0304	.0289	.0340	.0292	.0302	NS	Neg.	.0031
Ag	<.10	<.10	<.10	<.10	<.10	.10	----------	--------	------	------
B	65.0	57.2	53.6	67.0	53.7	56.2	58.8	NS	Neg.	6.4
Ba	325	413	362	293	379	396	361	NS	Neg.	46.2
Be	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
Bi	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
Ce	58.6	50.8	57.0	58.4	59.2	70.0	58.9	NS	3.23	5.34
Co	9.51	9.38	10.3	9.91	9.83	10.8	9.96	NS	.34	.43
Cr	21.0	22.9	22.6	14.9	21.7	22.1	20.9	NS	Neg.	3.24
Cu	<46.4	<46.4	<46.4	<46.4	<46.4	<46.4	----------	--------	------	------
Dy	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	----------	--------	------	------
Er	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	----------	--------	------	------
Eu	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
Ga	6.01	5.98	5.55	4.78	5.53	5.26	5.52	NS	.36	.33
Gd	5.66	<3.16	4.78	4.85	4.53	6.10	----------	--------	------	------
Ho	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
La	31.9	29.3	28.4	28.8	30.2	41.7	31.7	NS	1.69	4.82
Mo	35.6	38.8	33.0	40.0	33.1	35.9	36.1	NS	Neg.	3.34
Nb	5.28	6.89	4.53	4.78	4.42	5.94	5.31	NS	.33	.91
Nd	40.0	37.0	36.0	34.0	36.0	39.0	37.0	NS	1.2	1.9
Ni	27.9	29.5	32.8	31.3	37.1	35.1	32.3	NS(.99)	3.60	1.21
Pb	34.1	33.0	34.6	32.3	30.8	27.0	32.0	NS	2.30	1.87
Pr	8.04	8.75	6.13	5.66	5.78	6.83	6.86	NS(.975)	1.28	.55
Sc	3.64	4.00	4.01	3.59	3.62	4.31	3.86	NS	Neg.	.36
Sm	<4.64	<4.64	<4.64	<4.64	<4.64	<4.64	----------	--------	------	------
Sn	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	----------	--------	------	------
Sr	461	443	595	565	600	687	558	NS(.975)	94	38
Th	<21.5	<21.5	<21.5	<21.5	<21.5	<21.5	----------	--------	------	------
V	125	109	100	132	129	139	122	NS	Neg.	15.2
Y	12.9	12.1	11.6	12.5	13.0	14.3	12.7	NS	.65	.72
Yb	1.04	1.32	1.35	1.01	1.05	1.27	1.17	NS	Neg.	.20
Zn	71.2	64.0	69.4	63.1	66.6	64.2	66.4	NS	Neg.	4.03
Zr	116	85.2	102	100	115	113	105	NS	Neg.	12.6

TABLE 95.—*Computerized spectrographic data for marine mud, MAG–1*

[Elements Si through Mn in percent, all others in parts per million]

Bottle	59/22		60/10		4/21		Mean	Conclusions	Standard deviation	
Determination Element	1	2	1	2	1	2			Bottles (d.f.=2)	Error (d.f.=3)
Si	23.9	24.6	23.3	19.9	23.5	22.9	23.0	NS	0.86	1.44
Al	9.86	8.70	8.07	7.54	8.86	7.81	8.47	NS	.58	.67
Fe	5.21	5.81	4.91	4.87	5.11	5.53	5.24	NS	.24	.30
Mg	3.07	2.62	2.44	2.51	2.65	2.70	2.66	NS	.13	.19
Ca	1.59	1.06	1.26	1.37	1.28	1.33	1.32	NS	Neg.	.22
Na	>.316	>.316	>.316	>.316	>.316	>.316	----------	--------	------	------
K	>1.00	>1.00	>1.00	>1.00	>1.00	>1.00	----------	--------	------	------
Ti	.358	.204	.241	.213	.234	.239	.248	NS	Neg.	.064
P	.102	.100	.113	.0787	<.0464	.0895	----------	--------	------	------
Mn	.110	.104	.0998	.0979	.104	.0972	.102	NS	.003	.004
Ag	.16	.11	.11	.10	.10	.10	.112	NS	.014	.021
B	159	163	147	131	156	177	155	NS	12.3	10.9
Ba	511	408	445	420	357	413	426	NS	15.0	48.9
Be	3.15	3.05	3.18	2.47	3.12	2.83	2.97	NS	Neg.	.32
Bi	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
Ce	128	107	98.3	98.9	103	91.9	104	NS	8.9	9.7
Co	28.3	20.3	23.3	18.5	19.3	20.2	21.6	NS	Neg.	3.8
Cr	125	87.5	106	98.4	108	102	104	NS	Neg.	15.8
Cu	<46.4	<46.4	<46.4	<46.4	<46.4	<46.4	----------	--------	------	------
Dy	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	----------	--------	------	------
Er	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	----------	--------	------	------
Eu	1.50	1.18	1.38	1.16	1.35	1.20	1.30	NS	Neg.	.17
Ga	24.3	25.9	21.7	18.3	20.2	20.6	21.8	NS	2.6	1.5
Gd	5.6	5.0	<3.16	<3.16	3.4	4.2	----------	--------	------	------
Ho	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
La	65.6	51.0	46.0	47.1	50.1	38.6	49.7	NS	5.2	7.6
Mo	3.62	2.91	2.56	2.39	3.01	2.36	2.80	NS	.30	.40
Nb	10.4	8.70	8.42	5.78	6.81	5.83	7.66	NS	1.39	1.34
Nd	34.0	26.5	24.5	26.5	24.5	24.5	26.8	NS	2.1	3.2
Ni	70.8	79.7	79.2	66.3	64.6	60.3	70.2	NS	4.9	6.6
Os	<21.5	<21.5	<21.5	<21.5	<21.5	<21.5	----------	--------	------	------
Pb	22.7	22.4	21.0	18.1	18.5	19.6	20.4	NS	1.7	1.3
Pr	7.57	8.02	8.07	6.68	8.45	7.57	7.72	NS	Neg.	.70
Sc	27.4	14.6	13.3	14.8	16.3	15.8	17.0	NS	Neg.	5.3
Sm	5.97	5.12	<4.64	<4.64	4.92	<4.64	----------	--------	------	------
Sn	7.33	6.23	6.34	6.77	6.18	5.77	6.43	NS	.21	.51
Sr	190	181	182	183	187	189	185	NS	.64	3.8
Th	<21.5	<21.5	<21.5	<21.5	<21.5	<21.5	----------	--------	------	------
V	149	143	146	140	149	133	143	NS	Neg.	7.4
Y	33.2	24.2	23.4	23.1	25.2	20.9	25.0	NS	1.4	4.1
Yb	3.11	2.45	2.46	2.75	2.75	2.58	2.68	NS	Neg.	.30
Zn	104	110	105	95.4	94.4	103	102	NS	1.65	5.8
Zr	181	154	131	125	138	120	142	NS	20.4	13.5

TABLE 96.—*Computerized spectrographic data for Hawaiian basalt, BHVO-1*

[Elements Si through Mn in percent, all others in parts per million. Asterisk indicates interference]

Bottle	11/22		10/14		32/15		Mean	Conclusions	Standard deviation	
Determination Element	1	2	1	2	1	2			Bottles (d.f.=2)	Error (d.f.=3)
Si	22.8	22.3	26.7	20.8	22.8	23.8	23.2	NS	Neg.	2.45
Al	7.71	7.85	7.74	7.43	7.57	7.76	7.68	NS	Neg.	.16
Fe	9.50	9.66	10.0	9.48	9.62	9.13	9.56	NS	Neg.	.30
Mg	7.45	6.92	7.50	6.68	7.41	7.56	7.25	NS	Neg.	.40
Ca	7.64	6.69	8.13	7.02	7.27	7.94	7.45	NS	Neg.	.66
Na	>.316	>.316	>.316	>.316	>.316	>.316	----------	--------	------	------
K	.670	.390	.673	.672	.411	.503	.553	NS	0.069	.120
Ti	2.03	1.56	1.73	1.41	1.74	2.30	1.80	NS	Neg.	.33
P	.193	<.0464	.190	.165	.187	<.0464	----------	--------	------	------
Mn	.190	.172	.192	.175	.175	.181	.181	NS	Neg.	.010
Ag	.39	.25	.32	.30	.36	.37	.332	NS	Neg.	.058
B	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	----------	--------	------	------
Ba	114	116	118	130	123	102	117	NS	Neg.	9.7
Be	<1.00	<1.00	1.20	<1.00	1.08	1.03	----------	--------	------	------
Bi	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
Ce	118	97.3	124	*	*	*	----------	--------	------	------
Co	51.5	42.7	51.8	48.4	42.4	48.0	47.4	NS	Neg.	4.5
Cr	292	254	389	356	296	345	322	NS	45.4	28.7
Cu	*	*	*	*	*	*	----------	--------	------	------
Dy	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	----------	--------	------	------
Er	<2.15	<2.15	<2.15	<2.15	<2.15	<2.15	----------	--------	------	------
Eu	1.70	1.46	1.76	1.54	1.40	1.69	1.59	NS	Neg.	.18
Ga	26.4	23.4	25.8	28.0	24.4	27.4	25.9	NS	Neg.	1.95
Gd	5.00	7.30	9.60	6.70	4.60	9.60	7.1	NS	Neg.	2.5
Ho	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	----------	--------	------	------
La	31.2	26.0	34.8	33.5	21.1	33.8	30.1	NS	Neg.	5.6
Mo	5.52	5.80	5.26	4.95	4.70	7.23	5.58	NS	Neg.	1.05
Nb	17.4	16.3	18.8	11.7	13.4	13.9	15.2	NS	Neg.	2.94
Nd	<14.7	<14.7	<14.7	<14.7	<14.7	<14.7	----------	--------	------	------
Ni	143	119	151	138	133	157	140	NS	Neg.	14.8
Pb	3.0	2.92	3.53	3.42	3.53	3.90	3.38	NS	.37	.16
Pr	<14.7	<14.7	<14.7	<14.7	<14.7	<14.7	----------	--------	------	------
Sc	>68.1	>68.1	>68.1	>68.1	63.7	>68.1	----------	--------	------	------
Sm	<4.64	<4.64	<4.64	<4.64	<4.64	<4.64	----------	--------	------	------
Sn	<3.16	<3.16	<3.16	<3.16	<3.16	<3.16	----------	--------	------	------
Sr	486	415	506	465	462	505	473	NS	Neg.	37.8
Th	<21.5	<21.5	<21.5	<21.5	<21.5	<21.5	----------	--------	------	------
V	>215	>215	>215	>215	>215	>215	----------	--------	------	------
Y	30.6	23.5	28.4	25.5	28.9	26.4	27.2	NS	Neg.	3.29
Yb	4.68	3.26	4.77	4.94	3.60	4.22	4.24	NS	.28	.64
Zn	190	154	189	182	164	192	178	NS	Neg.	18.8
Zr	218	181	207	204	223	184	203	NS	Neg.	22.0

DETERMINATIONS OF RARE ALKALIS AND ALKALINE EARTHS IN USGS STANDARD ROCKS

By SYDNEY ABBEY [1]

The determinations in the table 97 were made in the chemical laboratories of the Geological Survey of Canada, Ottawa. Portions of the samples were randomly inserted into batches of samples for routine analysis over a period of several months. Barium and strontium were determined by atomic absorption spectrophotometry, and cesium, lithium, and rubidium, by flame emission spectrophotometry. The methods have beed described by Abbey (1972). An extra digit has usually been retained in the estimates of the means and the standard deviations, and the user may round at his discretion. Data were obtained under the same conditions and assumptions, and with the same experimental design with a single variable of classification, used elsewhere in this volume. The analyses of variance and conclusions were calculated by F. J. Flanagan.

REFERENCE

Abbey, Sydney, 1972, Analysis of rocks and minerals by atomic absorption and flame emission spectrometry. Part IV. A composite scheme for the less common alkalies and alkaline earths. Geol. Survey Canada Paper 71–50, 18 p.

TABLE 97.—*Estimates of the less common alkali and alkaline-earth contents of USGS samples*

[In parts per million. Conclusions from the analysis of variance: NS, not significant at $F_{0.95}$ or the fractile of the F distribution indicated. d.f., degrees of freedom; d.f. for all elements in W–1 are 1 for bottles and 2 for error. Neg., negative bottle variance]

Sample	Element	Bottles 1	Bottles 2	Bottles 3	Mean	Conclusions	Standard Deviation Bottles (d.f.=2)	Standard Deviation Error (d.f.=3)
G–2	Ba	1780	1920	1880	1830	NS	Neg.	58.6
		1800	1810	1790				
	Cs	1.8	.9	1.4	1.32	NS	.27	.19
		1.4	1.1	1.3				
	Li	32	30	32	31.5	NS	Neg.	.9
		32	32	31				
	Rb	200	165	165	174.2	NS	11.3	10.6
		175	170	170				
	Sr	500	510	510	495	NS	0	17.8
		490	480	480				
GSP–1	Ba	1310	1350	1340	1345	NS	Neg.	38
		1400	1350	1320				
	Cs	1.1	1.1	1.3	1.08	NS	Neg.	.18
		.8	1.2	1.0				
	Li	29	27	30	28.7	NS	.96	.58
		29	28	29				
	Rb	275	235	270	264.2	NS (.975)	18.3	6.8
		280	250	275				
	Sr	260	260	250	245	NS	0	17.8
		230	230	240				
AGV–1	Ba	1360	1260	1220	1267	NS (.975)	90	33
		1370	1250	1140				
	Cs	1.5	1.2	1.3	1.16	NS	.08	.27
		1.3	1.0	.7				
	Li	10	10	9	10	NS	0	.8
		10	10	11				
	Rb	66	65	63	67.5	NS	Neg.	4.5
		72	74	65				
	Sr	660	670	630	652	NS	5.8	12.2
		650	650	650				

---

[1] Geological Survey of Canada.

TABLE 97.—*Estimates of the less common alkali and alkaline-earth contents of USGS samples*—Continued

Sample	Element	Bottles			Mean	Conclusions	Standard Deviation	
		1	2	3			Bottles (d.f. = 2)	Error (d.f. = 3)
BCR–1	Ba	790	710	730	732	NS	2.9	29
		720	720	720				
	Cs	1.3	1.1	1.2	1.1	NS	Neg.	.25
		.7	1.0	1.3				
	Li	13	17	12	13.7	NS	1.3	1.3
		13	14	13				
	Rb	48	46	49	47.8	NS	Neg.	3.2
		48	52	44				
	Sr	320	330	330	318.3	NS	Neg.	12.2
		310	310	310				
W–1	Ba	150	250	-----	208	NS(.975)	59	15
		180	250	-----				
	Cs	1.2	1.5	-----	1.2	NS	.29	.21
		.8	1.4	-----				
	Li	13	13	-----	12.5	NS	.9	1.6
		10	14	-----				
	Rb	22	22	-----	21.2	NS	0	1.5
		19	22	-----				
	Sr	175	200	-----	183.8	NS	11.2	7.5
		175	185	-----				

DESCRIPTIONS AND ANALYSES OF EIGHT NEW USGS ROCK STANDARDS

COPPER, LITHIUM, MANGANESE, STRONTIUM, ZINC, SODIUM, POTASSIUM, AND MAGNESIUM CONTENTS OF EIGHT NEW USGS STANDARD ROCK SAMPLES

By J. A. THOMAS, WAYNE MOUNTJOY, and CLAUDE HUFFMAN, JR.

Atomic absorption spectrometry and flame emission spectrometry techniques were used to determine the Cu, Li, Mn, Sr, Zn, Na_2O, K_2O, and MgO contents of USGS standard rock samples STM–1, RGM–1, QLO–1, SDC–1, BHVO–1, MAG–1, SCo–1, and SGR–1. Eight portions, two from each of four bottles of each reference sample, were analyzed in random order for the elements. The analyses of variance show the samples to be homogeneous for these elements by the methods used.

Eight new reference samples have recently been added to the USGS standard rock sample program. The new reference samples include: a nepheline syenite from Table Mountain, Ore. (STM–1); a rhyolite obsidian from Glass Mountain, Calif. (RGM–1); a quartz latite from Lake County, Ore. (QLO–1); a mica schist from Rock Creek Park, Washington, D.C. (SDC–1); a basalt from Hawaii (BHVO–1); a marine mud from the Wilkerson Basin, Gulf of Maine (MAG–1); a sample of the Cody Shale from Natrona County, Wyo. (SCo–1); and a shale from the Green River Formation (SGR–1).

This paper presents data on five trace elements—copper, lithium, manganese, strontium, and zinc—and for the minor oxides of sodium, potassium, and magnesium in the new reference samples. Eight portions, two from each of four bottles of each reference sample, were analyzed in random order to obtain the analytical data. Cu, Li, Mn, Sr, Zn, and Mg were determined by atomic absorption spectrometry; Na and K were determined by flame emission spectrometry.

ANALYTICAL METHODS

The atomic absorption procedure for determining Cu, Li, Mn, Sr, Zn, and Mg consists of decomposing 1 g of rock sample with nitric, hydrofluoric, and perchloric acids, fuming it to dryness, and finally taking the salts into solution in 100 ml of 5 percent v/v hydrochloric acid. This single sample solution was used to make both the atomic absorption and the flame photometer determinations for all elements looked for. Portions of the sample solution were aspirated into the air-acetylene flame of an atomic absorption spectrophotometer to determine Cu, Li, Mn, Sr, Zn, and Mg using the appropriate hollow cathode lamp. The aliquots taken for the determination of Sr and Mg were diluted with a lanthanum chloride solution so that the final volume of solution contained 1 percent w/v lanthanum, which acts as a releasing agent for these elements. Standard solutions containing known concentrations of the element to be determined were used for calibration.

The Cu, Li, Mn, Sr, Zn, and Mg data were obtained with a Perkin-Elmer model 303 atomic absorption spectrophotometer using the instrumental parameters recommended by the manufacturer:

Instrument parameters

Parameter	Cu	Li	Mn	Sr	Zn	Mg
Grating	UV	Vis	UV	Vis	UV	UV
Wavelength A	3247	6708	2794	4607	2138	2852
Slit nm	4	5	4	4	4	5
Lamp current mA	15	15	15	10	15	6
Flame (air-acetylene) condition	Oxidizing	Oxidizing	Oxidizing	Reducing	Oxidizing	Reducing
Filter	Out	In	Out	Out	Out	Out

The sodium and potassium data were obtained with an Instrumentation Laboratories model 143 flame photometer using an air-propane flame and the instrumental parameters recommended by the manufacturer. Lithium solution was added as an internal standard to an aliquot of the sample solution prior to aspiration into the flame of the instrument. Standard solutions containing known amounts of sodium, potassium, and lithium were used for calibration.

The values obtained for each element, their arithmetic mean, and the conclusions from the analysis of variance are given in table 98. The analysis of variance for the several sets of data show the mean sum of squares for the variation attributable to bottles is not significantly greater ($F_{0.95}$) than that for within bottles, and therefore we may consider the bottles of samples to be homogeneous for Cu, Li, Mn, Sr, Zn, Na, K, and Mg by the analytical methods used. The averages in table 98 are shown with an extra significant digit, and the user may round or not at his discretion.

TABLE 98.—*Determinations and estimates of several elements and oxides in eight USGS samples*

[Conclusions from the analysis of variance: NS, not significant at $F_{0.95}$; d.f., degrees of freedom; Neg., negative bottle variance]

Sample	Bottles				Mean	Standard Deviation		Conclusions
	1	2	3	4		Bottles (d.f.=3)	Error (d.f.=4)	
			Copper, in parts per million					
MAG-1	35	34	34	34	34.4	0.41	0.35	NS[a]
	35	35	34	34				
BHVO-1	143	143	143	143	143	----	-----	---
	143	143	143	143				
QLO-1	34	35	33	33	33.5	Neg.	.87	NS
	33	33	33	34				
STM-1	6	6	6	6	6	----	-----	---
	6	6	6	6				
SDC-1	35	32	32	32	32.6	.76	.79	NS
	33	33	32	32				
RGM-1	12	14	14	13	13.4	.46	.61	NS
	13	13	14	14				
SGR-1	67	69	68	68	68.4	Neg.	1.5	NS
	71	68	67	69				
SCo-1	30	31	30	30	30.1	.0	.35	NS
	30	30	30	30				
			Lithium, in parts per million					
MAG-1	78	78	77	77	77.6	0.41	0.35	NS
	78	78	77	78				
BHVO-1	5	5	5	5	5	----	-----	---
	5	5	5	5				
QLO-1	24	24	24	25	24.6	Neg.	.61	NS
	25	25	25	25				
STM-1	36	36	36	36	36.1	.0	.35	NS
	36	37	36	36				
SDC-1	36	36	36	36	36	----	-----	---
	36	36	36	36				
RGM-1	61	61	61	61	61	----	-----	---
	61	61	61	61				
SGR-1	131	131	131	131	131	.20	.50	NS
	131	130	132	131				
SCo-1	44	45	44	44	44.2	Neg.	.50	NS
	45	44	44	44				

TABLE 98.—*Determinations and estimates of several elements and oxides in eight USGS samples*—Continued

Sample	Bottles				Mean	Standard Deviation		Conclusions
	1	2	3	4		Bottles (d.f.=3)	Error (d.f.=4)	
Manganese, in parts per million								
MAG-1	723	720	714	714	713.0	Neg.	6.9	NS
	710	713	705	705				
BHVO-1	1,290	1,290	1,280	1,290	1,286	Neg.	6.1	NS
	1,280	1,280	1,290	1,290				
QLO-1	670	670	670	670	672.5	Neg.	4.3	NS
	675	675	680	670				
STM-1	1,570	1,570	1,555	1,574	1,568.9	2.4	5.4	NS
	1,570	1,570	1,570	1,572				
SDC-1	825	825	825	825	825.5	.46	1.8	NS
	825	825	824	830				
RGM-1	264	260	260	260	264.5	1.2	11.8	NS
	264	260	293	255				
SGR-1	250	250	250	250	250.5	Neg.	.7	NS
	251	251	251	251				
SCo-1	406	400	400	398	397.8	Neg.	4.6	NS
	399	393	393	393				
Strontium, in parts per million								
MAG-1	175	173	173	173	173.4	1.1	0.35	NS
	175	173	173	172				
BHVO-1	444	437	440	433	438.5	Neg.	4.5	NS
	437	440	435	442				
QLO-1	383	380	380	382	381.8	1.1	1.1	NS
	383	380	383	383				
STM-1	595	595	600	625	609.4	Neg.	16	NS
	610	610	635	605				
SDC-1	182	187	190	182	187.5	Neg.	6.0	NS
	198	187	187	187				
RGM-1	102	100	99	100	100.1	.29	.79	NS
	100	100	100	100				
SGR-1	325	333	330	350	332.2	6.0	9.8	NS
	325	315	345	335				
SCo-1	161	154	159	151	152.9	Neg.	5.1	NS
	151	148	151	148				
Zinc, in parts per million								
MAG-1	124	124	123	124	123.9	0.0	0.35	NS
	124	124	124	124				
BHVO-1	100	100	100	100	100	----	-----	---
	100	100	100	100				
QLO-1	57	57	57	57	57	----	-----	---
	57	57	57	57				
STM-1	245	245	245	245	243.8	Neg.	2.5	NS
	245	240	245	240				
SDC-1	100	100	100	100	99.9	.0	.35	NS
	100	99	100	100				
RGM-1	33	33	33	33	33	----	-----	---
	33	33	33	33				
SGR-1	73	72	72	72	72.1	.0	.35	NS
	72	72	72	72				
SCo-1	96	96	96	95	95.4	Neg.	.79	NS
	94	95	96	95				

TABLE 98.—*Determinations and estimates of several elements and oxides in eight USGS samples*—Continued

Sample	Bottles				Mean	Standard Deviation		Conclusions
	1	2	3	4		Bottles (d.f.=3)	Error (d.f.=4)	
			Sodium oxide, in percent					
MAG–1	3.79 3.78	3.84 3.77	3.79 3.80	3.78 3.79	3.792	Neg.	0.026	NS
BHVO–1	2.29 2.29	2.28 2.29	2.29 2.31	2.28 2.30	2.291	Neg.	.011	NS
QLO–1	4.17 4.21	4.17 4.19	4.20 4.21	4.17 4.16	4.185	.012	.016	NS
STM–1	8.76 8.73	8.74 8.71	8.73 8.71	8.74 8.72	8.730	Neg.	.018	NS
SDC–1	2.08 2.07	2.06 2.06	2.07 2.06	2.08 2.07	2.069	.006	.006	NS
RGM–1	4.01 4.00	4.03 4.00	4.01 3.96	4.02 3.99	4.002	Neg.	.023	NS
SGR–1	3.03 3.02	3.04 3.01	3.01 3.02	3.04 3.03	3.025	Neg.	.012	NS
SCo–1	0.90 .90	.92 .92	.92 .93	.94 .92	0.918	.012	.008	NS
			Potassium oxide, in percent					
MAG–1	3.52 3.52	3.55 3.52	3.53 3.53	3.53 3.52	3.528	Neg.	0.011	NS
BHVO–1	.516 .517	.512 .520	.514 .525	.514 .517	.5168	Neg.	.0049	NS
QLO–1	3.57 3.56	3.57 3.55	3.58 3.56	3.57 3.56	3.565	Neg.	.011	NS
STM–1	4.24 4.22	4.23 4.22	4.23 4.22	4.23 4.24	4.229	Neg.	.0093	NS
SDC–1	3.21 3.21	3.20 3.21	3.20 3.21	3.20 3.21	3.206	Neg.	.0061	NS
RGM–1	4.27 4.27	4.28 4.26	4.28 4.22	4.28 4.25	4.263	Neg.	.025	NS
SGR–1	1.60 1.60	1.60 1.58	1.60 1.60	1.60 1.60	1.598	0.0	.0071	NS
SCo–1	2.68 2.70	2.68 2.67	2.65 2.69	2.67 2.66	2.675	Neg.	.017	NS
			Magnesium oxide, in percent					
MAG–1	3.05 3.00	3.00 3.00	3.00 3.00	2.95 3.00	3.00	0.010	0.025	NS
BHVO–1	7.00 6.92	7.00 6.96	6.94 7.00	7.00 7.00	6.98	Neg.	.038	NS
QLO–1	.98 .96	.96 .95	.97 .97	.97 .95	.964	.0	.011	NS
STM–1	.099 .099	.097 .102	.096 .098	.099 .099	.0986	Neg.	.0019	NS
SDC–1	1.67 1.65	1.64 1.64	1.65 1.64	1.64 1.66	1.649	.004	.011	NS
RGM–1	.268 .267	.264 .267	.265 .267	.267 .265	.2662	Neg.	.0015	NS
SGR–1	4.31 4.35	4.30 4.26	4.34 4.33	4.31 4.35	4.319	.019	.025	NS
SCo–1	2.54 2.58	2.59 2.63	2.60 2.60	2.64 2.63	2.601	.028	.020	NS

THE CARBON CONTENTS OF USGS VOLCANIC ROCK STANDARDS

F. J. FLANAGAN, J. C. CHANDLER, I. A. BREGER, C. B. MOORE,[1]
and C. F. LEWIS[1]

The carbon contents of USGS volcanic rock standards have been determined in two laboratories by slightly different combustion methods. The carbon contents of the bottles of USGS sample BCR–1 used by Arizona State University are heterogeneous. If one accepts the risk of testing F ratios against $F_{0.99}$, the carbon contents of bottles of BHVO–1 and QLO–1 at Arizona State may be considered homogeneous. The carbon contents of bottles of USGS sample RGM–1 used by both laboratories may be accepted as homogeneous, and data obtained by the USGS laboratory indicate that the carbon contents of bottles of the two basalts, BCR–1 and BHVO–1, may also be considered homogeneous. The means of the carbon contents of RGM–1 determined in the two laboratories differ statistically but not analytically, whereas the laboratories should use their own averages for the basalts, BCR–1 and BHVO–1.

INTRODUCTION

Information on the concentration of carbon in the parts-per-million range in lunar and terrestrial rocks has been required for various geochemical studies. During the course of lunar studies, two of us (see Moore and others, 1970) reported five determinations of carbon in USGS sample BCR–1, a basalt, for an estimated average of 330 ppm C. When subsequent analyses of other basalts indicated that this value might be too great, additional determinations were made on USGS sample BCR–1 and on the following USGS samples: BHVO–1, a basalt from the 1919 Kilauea (Hawaii) flow; QLO–1, a quartz latite from Oregon; and RGM–1, a rhyolite from Glass Mountain, Calif. The last three samples are described elsewhere in this Professional Paper. Data obtained for these four samples at the Arizona State University are shown in table 99.

USGS samples BCR–1, BHVO–1, and RGM–1 were also analyzed in the laboratories of the U.S. Geological Survey by a different technique; these values are listed in table 100.

ANALYTICAL TECHNIQUES

ARIZONA STATE UNIVERSITY

Refractory crucibles (LECO 528–35 heavy duty) were heated for two hours at 1,100°C in a vented furnace. After the crucibles had cooled, 0.5 g of low-carbon iron chips and 1.25 g of copper metal were added to each crucible as accelerators. These crucibles were then reheated to 450°–500°C for 1 hour and allowed to cool. A sufficient amount of an open-hearth iron standard, NBS 55e, was weighed into a series of these crucibles to contain 11, 22, and 45 μg of carbon. This series was prepared in duplicate along with a series of blanks containing no iron standard.

The blanks were used first, and combustion was carried out in a LECO 521–000 1.5-kW induction furnace for 60 sec at 1,500°C, with a flow rate of 1 l of oxygen per minute. Combustion products were passed through a dust trap, a trap filled with MnO_2 to remove SO_2, and a rare-earth—copper oxide mixture heated in a furnace to oxidize CO to CO_2. Carbon dioxide was then determined in a LECO ELC–12 low-carbon analyzer in which CO_2 and oxygen are swept into a gas-chromatographic unit and through a thermal-conductivity detector by a stream of helium. The area of the absorption peak corresponding to CO_2 was integrated electronically. It was generally necessary to run four blanks to be certain of instrumental stability.

Sample weights of unknowns, 250–350 mg, were chosen so as to contain carbon contents falling in the center of the linear calibration curve that was estab-

---

[1] Center for Meteorite Studies, Arizona State University, Tempe, Ariz. 85281.

TABLE 99.—*Determinations of carbon and summary of estimates for USGS samples by Arizona State University*

[In parts per million. Conclusions from the analysis of variance: S, significant, or NS, not significant, at the fractile of the F distribution shown or at $F_{0.95}$ where none is indicated. d.f., degrees of freedom]

	Determinations			Mean	Conclusions	Standard deviation	
						Bottles (d.f.=2)	Error (d.f.=12)
			Basalt BCR-1				
	Bottle 63/9	Bottle 56/5	Bottle 3/10				
	66	78	92				
	65	74	85				
	62	74	92				
	72	80	90				
	75	81	88				
Average ---------	68.0	77.4	89.4	78.3	S, 0.99	10.6	4.0
	69	76	88				
	72	82	86				
	68	75	87				
	70	81	86				
	74	66	100				
Average ---------	70.6	76.0	89.4	78.7	S, 0.99	9.4	5.2
			Basalt BHVO-1				
	Bottle 57/9	Bottle 47/1	Bottle 17/11				
	105	110	101				
	111	105	101				
	105	108	100				
	114	102	98				
	108	94	98				
Average ---------	108.6	103.8	99.6	104.0	NS, 0.99	4.1	4.4
			Quartz Latite QLO-1				
	Bottle 20/12	Bottle 2/22	Bottle 21/10				
	73	72	62				
	73	80	64				
	67	71	66				
	64	67	65				
	79	69	56				
Average ---------	71.2	71.8	62.6	68.5	NS, 0.99	4.6	5.0
			Rhyolite RGM-1				
	Bottle 4/15	Bottle 10/25	Bottle 37/3				
	43	41	60				
	44	49	58				
	86	51	61				
	47	50	60				
	64	41	58				
Average ---------	56.8	46.4	59.4	54.2	NS	4.8	11.0
	45	41	58				
	43	45	60				
	46	50	61				
	84	56	54				
	51	46	57				
Average ---------	53.8	47.6	58.0	53.1	NS	2.3	10.5

lished from multiple analyses of standards and blanks by the method of least squares.

An analytical sequence consisted of 26 combustions of standards, blanks, and unknowns in a predetermined order so that blank values could be recorded against time to correct for instrumental drift, if necessary. Unknown samples were analyzed in random order.

U.S. GEOLOGICAL SURVEY

A Model 185 F and M Carbon-Hydrogen-Nitrogen Analyzer was used in which the sample was mixed with a mixture of manganese and tungsten oxides and then subjected to combustion in a closed chamber at 1,050°C. Combustion products were passed through a purifying train, and the effluent carbon dioxide, entrained in a stream of helium, was passed

TABLE 100.—*Determinations of carbon and summary of estimates for USGS samples by USGS laboratory*

[In parts per million. Conclusions from the analysis of variance: NS, not significant at $F_{0.95}$. d.f., degrees of freedom]

	Determinations			Mean	Conclusions	Standard deviation	
						Bottles (d.f.=2)	Error (d.f.=3)
			Basalt BCR-1				
	Bottle 32/27	Bottle 74/28	Bottle 80/30				
	35	52	68				
	51	56	57				
Average	43	54	62	53.2	NS	7.9	8.1
			Basalt BHVO-1				
	Bottle 52/11	Bottle 53/14	Bottle 60/11				
	84	69	64				
	79	82	70				
Average	82	76	67	74.7	NS	5.8	6.2
			Rhyolite RGM-1				
	Bottle 4/21	Bottle 29/31	Bottle 57/8				
	25	40	49				
	42	48	54				
Average	34	44	52	43.0	NS	7.1	7.9

through a chromatographic column and detector to isolate and measure the quantity of carbon dioxide produced.

Standards were prepared for calibration by mixing a sample of analyzed coal with fired quartz sand and then making dilutions with additional quartz sand to yield samples containing from 38.3 percent to 50.0 ppm of carbon. Values of carbon in these standards down to and including 275 ppm were confirmed by analysis in a non-USGS laboratory, using other instrumentation. Equipment in the non-USGS laboratory was, however, unable to accommodate samples large enough to obtain acceptable accuracy where the samples submitted contained less than 275 ppm carbon.

The F and M Analyzer was designed to accept samples of about 1 mg. When minor modifications were made in the sampling procedure, samples of about 80 mg of each coal standard or USGS rock were, however, used to achieve maximum accuracy for carbon contents in the parts-per-million range.

On the basis of analyses of the coal standards, it is known that less than 2.5 μg of carbon can readily be detected by this analytical procedure. To ensure complete combustion of carbon in samples containing carbon in the parts-per-million range, the combustion period was increased from the normal 10 seconds to 60 seconds. A series of analyses using the coal standards did not show any "tailing" of carbon dioxide when combustion periods were increased to more than 60 seconds, thus showing complete combustion of all the carbon in a sample within the 60-second interval. Calibration of the technique was based on analyses of these coal standards.

DISCUSSION

The data obtained independently by both laboratories were assembled, and the calculations of the analysis of variance for a single variable of classification were made. Estimates and conclusions resulting from these calculations are given in the tables with the raw data.

The duplicate sets of data for both BCR-1 and RGM-1 by Arizona State agree with each other. By inspection, the two estimates of both the bottle and the analytical (error) standard deviations for BCR-1 would not be significantly different if an *F* test were made, and a *t* test would confirm a conclusion reached by inspection, that the means of the two sets of data would not differ significantly. For both sets of data for BCR-1, however, we must conclude that the ratios of the mean sum of squares between bottles over the mean sum of squares within bottles are significantly larger than $F_{0.99}$ (degrees of freedom (d.f.) 2, 12) = 6.93; we must also conclude that the bottles of BCR-1 are heterogeneous for their carbon content. Arizona State should use the average of each bottle calculated from the 10 determinations.

Similarly, by inspection, the estimates obtained for RGM-1 from the duplicate sets of data by Arizona State will not differ significantly. The *F* test, against $F_{0.95}$ (d.f. 2, 12) = 3.89, in the analysis of variance for both sets of data results in a conclusion of nonsignificance, and we may accept the carbon contents for either set of data to be homogeneous among bottles. As the difference between the two means is less than half of the smaller of the estimated bottle standard deviations, the duplicate sets of data may be considered as sets from the same population of values to yield the following estimates:

	ppm
Mean	53.7
Bottle standard deviation	5.1
Error standard deviation	10.2

The sets of data from Arizona State for both BHVO–1 and QLO–1 must be declared heterogeneous if the F test were to be made against $F_{0.975}$ (d.f. 2, 12) = 5.10. If we are willing to accept the additional risk of testing against $F_{0.99}$ (d.f. 2, 12) = 6.93, the carbon contents of the bottles of these two samples may be accepted as homogeneous.

The data by the USGS laboratory for the three rocks yield F ratios that are not significantly larger than the tabled value at $F_{0.95}$. We may accept the carbon contents for bottles of each sample as homogeneous.

This study, like others, raises another problem-differences in the data between laboratories. When pooled variances are used for the duplicate sets of data for BCR–1 and RGM–1 by Arizona State, both the error and the bottle variances for BCR–1, BHVO–1, and RGM–1 are not significantly different from similar estimates obtained by the USGS. The means of the duplicate sets of data for BCR–1 and RGM–1 by Arizona State were pooled, and together with the single mean for BHVO–1, were used to test for differences between means with estimates for the same samples by the USGS. The differences between means by the two laboratories were significant, and the laboratories should use their own estimates for the three samples.

Although the average carbon contents of RGM–1 determined by the two laboratories differ statistically, we do not believe that the differences are analytically significant. Future studies may determine which of the two laboratories obtains the more correct estimates for the two basalts, BCR–1 and BHVO–1.

REFERENCE CITED

Moore, C. B., Gibson, E. K., Larimer, J. W., Lewis, C. F. and Nichiporuk, W., 1970, Total carbon and nitrogen abundances in Apollo 11 lunar samples and selected achondrites and basalts, *in* Apollo 11 Lunar Sci. Conf., Proc., v. 2: Geochim. et Cosmochim. Acta Suppl. No. 1, p. 1375–1382.

FINAL COMPILATION OF K-Ar AND Rb-Sr MEASUREMENTS ON P–207, THE USGS INTERLABORATORY STANDARD MUSCOVITE

By M. A. LANPHERE and G. B. DALRYMPLE

K-Ar analyses of P–207 in 33 laboratories and Rb-Sr analyses in 17 laboratories indicate that for this muscovite the average interlaboratory standard deviation is 1.2 percent for K-Ar ages and 2.8 percent for Rb-Sr ages and that the average intralaboratory standard deviation is 1.9 percent for K-Ar ages and 3.0 percent for Rb-Sr ages. The mean K-Ar age of P-207 is 80.6±0.2 m.y. ($s_{\bar{x}}$) and the mean Rb-Sr age is 87.5±0.7 m.y. ($s_{\bar{x}}$). The difference between these ages may be due to common Sr of anomalous composition.

In 1964 approximately 1,100 g of muscovite were separated from an 81-m.-y.-old granite and distributed to 21 K-Ar and Rb-Sr dating laboratories in six countries. The purpose of this standard mineral, known as P–207, was to provide a source of badly needed data on intralaboratory and interlaboratory precision. Although prepared primarily as a K-Ar standard, some laboratories also have found it useful as a Rb-Sr standard. The initial description and analyses of P–207 were published in 1965 (Lanphere and Dalrymple, 1965) and were followed 2 yr later by a compilation of results from 25 laboratories (Lanphere and Dalrymple, 1967).

P–207 has now been distributed to 55 laboratories in 15 countries, including Australia, Brazil, Canada, England, France, Holland, Italy, Japan, Rumania, the Union of South Africa, the Union of Soviet Socialist Republics, Switzerland, the United States, West Germany, and Yugoslavia, making P–207 the most extensive and successful K-Ar and Rb-Sr standard-mineral program to date. Unfortunately, however, the supply of this valuable standard is now depleted, and this will be the final compilation.

As of November 1971, 37 laboratories had reported data, which are presented in tables 101 and 102 along with the appropriate measures of central tendency and dispersion. For uniformity, all statistics presented in these tables were calculated by us using standard techniques (Crow and others, 1960) from the raw data reported by the individual laboratories. The symbols used in the statistical summaries are

n = total number of measurements,
$\bar{x}$ = arithmetic mean of laboratory means,
$\tilde{m}$ = median of laboratory means,
s = standard deviation of the mean of laboratory means,
$s_{\bar{x}}$ = standard error of the mean of laboratory means, and
s_o = pooled estimate of intralaboratory precision.

Three laboratories had used P–207 for calibration of their Ar^{38} tracers and these data, indicated by parentheses in table 101, were not used in calculating the interlaboratory statistics. We calculated K-Ar and Rb-Sr ages for each laboratory from the individual laboratory means using the constants shown in the tables.

For the K-Ar results, K measurements were made by five different techniques, and Ar measurements by two. In addition, two K-Ar ages were measured by us using the new Ar^{40}/Ar^{39} technique, and the mean of these are within 0.6 percent of the international mean. For K, Ar, and the calculated age, the results do not appear to vary significantly with analytical technique, and the interlaboratory and intralaboratory precision appears to be good. *F* tests indicate that the difference between the interlaboratory and intralaboratory precision is significant at the 5-percent level for calculated ages but not for the K and Ar measurements. Interlaboratory precision for calculated ages is significantly better than the intralaboratory precision. This precision is better probably because the interlaboratory statistics are calculated from laboratory means rather than on the basis of a single random date from each laboratory,

TABLE 101.—*Potassium and argon analyses of P–207*

[Method, FP, flame photometry; ID, isotope dilution; XR, X-ray fluorescence; GR, gravimetric; AA, atomic absorption; AC, activation analysis; FT, Ar^{40}/Ar^{39} technique. Tracer type: B, bulb system; M, manifold or "batch" system. Calibration: A, Ar from atmosphere; C, purified commercial air Ar; I, interlaboratory standard mineral; S, intralaboratory standard mineral. Data in parentheses were not included in interlaboratory statistics because P-207 was used for tracer calibration. C.V., coefficient of variation]

	Potassium analyses				Argon analyses					
Laboratory	Method	Number of analyses	K_2O (weight percent)	Mean K_2O (weight percent) and standard deviation	Method	Tracer type and calibration	Number of analyses	Mean Ar_{rad}^{40} (10^9 mol/g) and standard deviation		Calculated age[1] (m.y.)
Australian National University.	FP	3	----------	10.41 ± 0.07	ID	MAS	14	1.244 ± 0.013		79.2
Bundesanstalt für Bodenforschung (West Germany).	FP	6	----------	10.38 ± 0.04	ID	BIS	(24)	(1.259 ± 0.013)		(80.3)
California Institute of Technology.	---	--	----------	----------	ID	BC	2	1.259 ± 0.003		-------
Carleton University (Canada).	FP	6	----------	10.33 ± 0.06	ID	MS	2	1.263 ± 0.000		81.0
Cambridge University (England).	FP	6	----------	10.31 ± 0.07						
Eidgenossiche Technische Hochschule (Switzerland).	ID	7	----------	10.42 ± 0.07	ID	BC	13	1.268 ± 0.013		80.6
Geochron Labs (United States).	FP	4	----------	10.04 ± 0.17	ID	BACIS	3	1.251 ± 0.005		82.5
Geological Survey of Canada	XR ID	1 5	10.43 10.35 ± 0.15	10.36 ± 0.14	ID	MC	1	1.283		82.0
Geological Survey of Japan	GR FP AA	3 2 2	10.48 ± 0.10 10.22 ± 0.09 10.36 ± 0.04	10.37 ± 0.14	ID	MC	3	1.258 ± 0.005		80.4
Georgia Institute of Technology (United States).	AA	1	----------	10.32	ID	BA	4	1.253 ± 0.024		80.4
Institute for Atomic Physics (Rumania).	---	--	----------	----------	AC	-----	1	1.297		
Isotopes, Inc. (United States).	ID	4	----------	10.23 ± 0.17	ID	MA	2	1.244 ± 0.006		80.6
Lamont-Doherty Geological Observatory (United States).	ID AA	5 3	10.38 ± 0.08 10.48 ± 0.09	10.42 ± 0.09	ID	MA	7	1.275 ± 0.032		81.0
Max Planck Institute (W. Germany).	FP ID	6 2	10.40 ± 0.04 10.35 ± 0.07	10.39 ± 0.05	ID	MA	3	1.258 ± 0.008		80.2
Mineralogische Institut Universität (Switzerland).	FP	2	----------	10.36 ± 0.04	ID	BA	2	1.246 ± 0.009		79.7
Mobile Research and Devlopment Corp. (United States).	GR	4	----------	10.42 ± 0.02	ID	MC	3	1.245 ± 0.006		79.2
New Zealand Institute of Nuclear Science.	FP	12	----------	10.39 ± 0.04	ID	MA	3	1.241 ± 0.013		79.1
Oxford (England)	FP	12	----------	10.44 ± 0.21	ID	BA	4	1.264 ± 0.009		80.2
Pennsylvania State University (United States).	GR	1	----------	10.22	--	-----	--	-----------		-------
Shell Development Co. (United States).	---	--	----------	----------	ID	BC	3	1.245 ± 0.016		-------
Tohoku University (Japan)	FP AA	8 4	10.18 ± 0.09 10.28 ± 0.09	10.22 ± 0.10	ID	MA	11	1.271 ± 0.048		82.3
U.S. Geological Survey	FP ID	12 1	10.20 ± 0.09 10.39	10.21 ± 0.10	ID FT	BCIS	15 2	1.252 ± 0.010	81.2 80.2	81.1
University of Alberta (Canada).	FP GR	2 5	10.34 ± 0.02 10.34 ± .011	10.34 ± 0.09	ID	BACIS	3	1.263 ± 0.003		80.9
University of Amsterdam (Holland).	FP	6	----------	10.24 ± 0.16	ID	BAC	8	1.273 ± 0.023		82.3
University of Arizona (United States).	FP	7	----------	10.40 ± 0.10	ID	MA	3	1.270 ± 0.007		80.9
University of British Columbia (Canada).	FP	25	----------	10.33 ± 0.06	ID	BA	11	1.245 ± 0.015		79.9
University of California, Berkeley (United States).	FP	8	----------	10.29 ± 0.02	ID	MIS	1	1.265		81.4
University of California, La Jolla (United States).	AA	1	----------	10.16	ID	BA	4	1.245 ± 0.009		81.2
University of Cape Town (South Africa).	XR	1	----------	10.41	--	-----	--	-----------		-------
University of Hawaii (United States).	FP	7	----------	9.92 ± 0.16	ID	MI	(13)	(1.260 ± 0.018)		(84.0)
University of Rome (Italy)	---	--	----------	----------	ID	BI	3	1.281 ± 0.011		-------
University of São Paulo (Brazil).	---	--	----------	----------	ID	MIS	(14)	(1.256 ± 0.027)		-------
University of Tokyo (Japan)	GR	3	----------	10.40 ± 0.04	ID	BC	5	1.241 ± 0.029		79.1
University of Toronto (Canada).	---	--	----------	----------	ID	MCIS	5	1.273 ± 0.007		-------
Yale University (United States).	FP AA	2 4	10.30 ± 0.38 10.20 ± 0.05	10.23 ± 0.18	ID	BACI	5	1.234 ± 0.011		79.9
Statistical Summary:										
n		193	----------	----------	--	-----	146	-----------		-------
$\bar{x}$		--	----------	10.31	--	-----	--	1.259		80.6
$\mathfrak{M}$		--	----------	10.34		-----	--	1.258		80.6
s		--	----------	0.12 (C.V. = 1.2 percent)		-----	--	0.016 (C.V. = 1.2 percent)		1.0 (C.V. = 1.2 percent)
$s_{\bar{x}}$		--	----------	0.02 (C.V. = 0.2 percent)		-----	--	0.003 (C.V. = 0.2 percent)		0.2 (C.V. = 0.3 percent)
s_o		--	----------	1.1 percent of value		-----	--	1.6 percent of value		1.9 percent of value

---

[1] $\lambda_e = 0.585 \times 10^{-10}$ yr^{-1}; $\lambda_\beta = 4.72 \times 10^{-10}$ yr^{-1}; $K^{40}/K = 1.19 \times 10^{-4}$ mol/mol.

TABLE 102.—*Rubidium and strontium measurements of P-207*

[Measurements are by isotope dilution unless otherwise indicated. C.V., coefficient of variation]

Laboratory	Rubidium measurements		Strontium measurements			[1] Sr^{87}/Sr^{80}	[1] Rb^{87}/Sr^{86}	[1] $Sr^{87}_{rad}/Rb^{87} \times 10^{-3}$	[2] Age (m.y.)
	Number of measurements	Mean Rb (10^{-6} mol/g) and standard deviation	Number of measurements	Mean Sr_{rad}^{87} (10^{-9} mol/g) and standard deviation	Mean common Sr (10^{-6} mol/g) and standard deviation				
Australian National University	[3]7	9.309±0.165	4	3.151±0.066	[4]0.0958±0.0048	1.037	272	1.216	87.5
Bundesantalt für Bodenforschung (West Germany)	7	9.485±0.078	6	3.226±0.117	.1036±0.0094	1.022	258	1.221	87.8
Geological Survey of Canada	2	9.102±0.035	8	3.15 ±0.04	.1210±0.0247	0.9698	212	1.243	89.4
Institute for Nuclear Raw Materials (Yugoslavia)	1	9.569	5	3.219±0.133	.1005±0.0041	1.031	269	1.208	86.9
Institute of Precambrian Geology and Geochronology (U.S.S.R.).	5	9.490±0.050	2	3.209±0.021	.0988±0.0009	1.035	271	1.215	87.4
Mineralogische Institut Universität (Switzerland)	1	9.57	1	3.15	.0805	1.103	336	1.182	85.0
Mobil Research and Development Corp. (United States).	2	9.331±0.040	2	3.221±0.017	.1009±0.0052	1.030	261	1.239	89.0
Pennsylvania State University (United States)	[5]1	9.051	--	----------	-------------	-----	---	----	---
U.S. Geological Survey	3	9.594±0.131	3	3.489±0.072	.1338±0.0313	0.9704	202	1.306	93.9
University of Amsterdam (Holland)	2	9.03 ±0.13	2	3.09 ±0.08	.1077±0.0069	0.9770	237	1.229	88.3
University of Arizona (United States)	2	9.703±0.137	2	3.249±0.038	.0974±0.0018	1.044	281	1.202	86.4
University of Cape Town (South Africa)	[6]1	9.28	--	----------	-------------	-----	---	----	---
University of Kyoto (Japan)	3	9.314±0.107	3	3.190±0.059	.0996±0.0016	1.031	264	1.231	88.6
University of Pisa (Italy)	1	9.40	2	3.11 ±0.13	.096 ±0.010	1.034	276	1.189	85.5
University of São Paulo (Brazil)	2	9.66 ±0.23	2	3.11 ±0.14	.0932±0.0026	1.044	293	1.156	83.2
University of Tokyo (Japan)	3	10.58 ±0.07	2	----------	.1140±0.0050	-----	262	----	---
Yale University (United States)	1	9.373	1	3.12	.1247	.9440	198	1.20	86.3
Statistical Summary:									
n	44	----------	45	----------	-------------	-----	---	----	---
$\bar{x}$	--	9.461	--	3.192	0.1045	-----	---	----	87.5
$\tilde{m}$	--	9.40	--	3.17	0.100	-----	---	----	87.4
s	--	0.352 (C.V.= 3.7 percent)	--	0.100 (C.V.=3.1 percent)	0.0137 (C.V.=13.1 percent)	-----	---	----	2.5 (C.V.= 2.8 percent)
$s_{\bar{x}}$	--	0.085 (C.V.= 0.9 percent)	--	0.027 (C.V. =0.8 percent)	0.0035 (C.V.=3.4 percent)	-----	---	----	0.7 (C.V.= 0.8 percent)
s_o	--	1.2 percent of value	--	2.8 percent of value	12.4 percent of value	-----	---	----	3.0 percent)

---

[1] Calculated from mean values using $Rb^{85}/Rb^{87}=2.593$; $Sr^{87}=Sr_{rad}^{87}+Sr_{com}^{87}$; $(Sr^{86}/Sr^{88})_{com}=0.1194$; $(Sr^{87/86})_{com}=0.706$; and $(Sr^{84}/Sr^{88})_{com}=0.00675$.

[2] $\lambda\ Rb^{87}=1.39\times10^{-11}\ yr^{-1}$.

[3] Includes one measurement of 9.372×10^{-6} moles/g by X-ray fluorescence.

[4] Includes one measurement of 0.0927×10^{-6} moles/g by X-ray fluorescence.

[5] Measurement by flame photometry.

[6] Measurement by X-ray fluorescence.

and slight mineral inhomogeneities that would increase the intralaboratory dispersion would tend to average out in the laboratory means. Taken at face value, the statistics indicate that a difference in the K-Ar age of two samples similar to P–207 can be detected at the 95-percent level of confidence on the basis of single measurements from the average laboratory if the calculated ages differ by 5.8 percent, or 4.2 m.y. If duplicate measurements are made, then this critical value is only 3.7 percent, or 3.0 m.y. The critical values for measurements done in different laboratories should be similar.

Nearly all the Rb and Sr measurements were made using isotope dilution. The few measurements made by X-ray fluorescence and flame photometry agree with the isotope dilution data. *F* tests indicate that the difference between interlaboratory and intralaboratory precision is significant at the 5-percent level for Rb measurements but not for radiogenic Sr^{87}, common Sr, or calculated age. The interlaboratory precision for calculated ages is better than the intralaboratory precision as was observed for the K-Ar ages. The statistics indicate that a difference in the Rb-Sr age of two samples similar to P–207 can be detected at the 95-percent level of confidence on the basis of single measurements from the average laboratory if the calculated ages differ by 8.4 percent, or 7.4 m.y. If duplicate measurements are made then this critical value is only 5.9 percent, or 5.2 m.y.

A *t* test indicates that the mean K-Ar age is significantly different from the mean Rb-Sr age at the 5-percent level if the "geologically determined" half-life of 50×10^9 years (Aldrich and others, 1956) is used for Rb^{87}. The mean K-Ar and Rb-Sr ages (80.6 and 82.7 m.y., respectively) are in good agreement if the 47×10^9-year half-life (Flynn and Glendenin, 1959) of Rb^{87} determined by liquid scintillation counting is used, but comparative geological studies suggest that a value of the half-life close to 50×10^9 years is more likely. The calculated Rb-Sr ages are affected significantly by the isotopic composition of the common Sr in P–207 even though the Sr is quite radiogenic. A Sr^{87}/Sr^{86} value of 0.706 for the common Sr was used to calculate the ages in table 87. The composition of the common Sr has not been measured directly in another mineral in the rock. If the common Sr in P–207 has a Sr^{87}/Sr^{86} value of 0.732, the mean calculated Rb-Sr age would be 80.6 m.y. This Sr^{87}/Sr^{86} value is much higher than in normal common Sr. However, anomalous Sr having much higher Sr^{87}/Sr^{86} was redistributed during Cretaceous metamorphism in an area approximately 10–15 mi south of the small pluton from which P–207 was collected (Lanphere and others, 1964). It seems possible, therefore, that the muscovite may contain common Sr of anomalous isotopic composition and this could produce the observed difference between the K-Ar and Rb-Sr ages.

REFERENCES CITED

Aldrich, L. T., Wetherill, G. W., Tilton, G. R., and Davis, G. L., 1956, Half life of Rb^{87}: Phys. Rev., v. 103, p. 1045–1047.

Crow, E. L., Davis, F. A., and Maxfield, M. W., 1960, Statistics manual: New York, Dover Pubs., 288 p.

Flynn, K. F., and Glendenin, L. E., 1959, Half life and beta spectrum of Rb^{87}: Phys. Rev., v. 116, p. 744–748.

Lanphere, M. A., and Dalrymple, G. B., 1965, P–207—An interlaboratory standard muscovite for argon and potassium analyses: Jour. Geophys. Research, v. 70, p. 3497–3503.

——— 1967, K-Ar and Rb-Sr measurements on P–207, the U.S.G.S. interlaboratory standard muscovite: Geochim. et Cosmochim. Acta, v. 31, p. 1091–1094.

Lanphere, M. A., Wasserburg, G. J., Albee, A. L, and Tilton, G. R., 1964, Redistribution of strontium and rubidium isotopes during metamorphism, World Beater Complex, Panamint Range, California, Chap. 20, *in* Craig, Harmon, Miller, S. L., and Wasserburg, G. J., eds., Isotopic and cosmic chemistry: Amsterdam, North-Holland Publishing Co., p. 269–320.

1972 COMPILATION OF DATA ON USGS STANDARDS

By F. J. Flanagan

This is the sixth of a series of papers by U.S. Geological Survey personnel (Fairbairn and others, 1951; Stevens and others, 1960; Fleischer and Stevens, 1962; Fleischer, 1965, 1969) dealing with data on G–1 and W–1 and the third (Flanagan, 1967, 1969) on the series of samples, G–2 through BCR–1, first issued in 1964. There has been no G–1 available for distribution since 1965 and the supply of W–1 for distribution is now exhausted. The supplies of several of the 1964 series of samples are being depleted at an alarming rate.

The present format is similar to that of previous compilations in which the data are listed by rock analyses (table 103), major and minor oxides (table 104), and trace elements (table 105). For tables 104 and 105, the data for an element or oxide are first listed by methods, these data are then classified by the year of publication or of the receipt of a written communication, and finally the authors are listed alphabetically within the years.

Violations of this nested structure for the data reported have occurred despite attempts to maintain the chronological and alphabetical order when entering data received after the final manuscript tables had been typed. Some data obtained by methods less frequently used have been entered in convenient, rather than logical, places in the tables. Some data not entered in earlier compilations are listed here, as are references to data previously included from private communications.

A scan of the tables for major and minor oxides and for trace elements reveals that the samples on which the most data have been reported are W–1 and BCR–1 and that this seeming popularity is due to the frequency with which they were used in conjunction with the analysis of samples of Moon rocks. A large amount of the available data appeared in the issue of Science devoted to the Moon (v. 167, no. 3918, Jan. 30, 1970) as well as in the supplements to Geochimica et Cosmochimica Acta reporting the proceedings of Apollo Lunar Science Conferences.

Other sources of data were U.S. National Bureau Standards special Publication 312 (DeVoe and La Fleur, 1969) on modern trends in activation analysis, the Centre National de la Recherche Scientifique publication 923 reporting the colloquium, "Dosage des éléments a l'état de traces dans les roches et les autres substances minérales naturelles," held at Nancy, France, in December 1968 (Roubault and others, 1970), and the proceedings of the NATO Advanced Study Institute on activation analysis in geochemistry and cosmochemistry (Brunfelt and Steinnes, 1971a).

The general procedure for arriving at values was to compare the averages and the ranges of the data reported here with previous data and recommendations. Notable exceptions to this process may be seen in the data for Rb and Sr, tabulated below, in which the averages by different methods are in such good agreement that the final choices, influenced greatly by data obtained by some form of the isotope-dilution technique, were easily made.

There is nothing authoritative in the summary values listed in tables 106 and 107. They are what I consider the most reasonable values at this time but many analysts may wish to use preferred values of their choice. An example of such preferred values was published by Abbey (1970). The agreement or disagreement of the data could be discussed ad infinitum, but no real purpose would be served by belaboring the obvious. An extra digit has been included in many estimates, and the user may round at his discretion.

For the environmentalists among us, however, the mercury, lead, thallium, and perhaps the zinc contents of the rocks seem sufficiently well characterized so that they could be used as base levels for contamination by these elements. More data are necessary for good estimates of the arsenic and cadmium contents. Further data on the mercury content of miscellaneous natural inorganic materials, including rocks, are given in "Mercury in the Environment" (U.S. Geological Survey, 1970).

This compilation of data may be comprehensive, but there is an extremely high probability that it is not complete. I am grateful to all who have sent me published or unpublished data, and I am especially indebted to Michael Fleischer who continually calls to my attention data published in the less readily available foreign journals.

Averages of rubidium and strontium tabulated by method

	W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1
	Rubidium in parts per million							
Method:								
Optical spectrographic	22	214	188	305	69	----	----	47
Atomic absorption	23	213	179	279	73	----	----	45.2
X-ray fluorescence	22	215	166	246	69	----	----	45.2
Neutron activation	22	224	167	239	71	----	----	46.5
Isotope dilution	21	---	168	254	67	0.063	0.053	46.6
Preferred value	21	220	168	254	67	.063	.053	46.6
	Strontium in parts per million							
Method:								
Optical spectrographic	164	284	506	255	698	----	----	329
Atomic absorption	208	270	466	249	653	----	----	355
X-ray fluorescence	190	254	484	239	680	----	----	336
Neutron activation	180	251	427	226	631	----	----	327
Isotope dilution	188	---	479	233	657	0.41	0.35	330
Preferred value	190	250	479	233	657	.41	.35	330

TABLE 103.—*New rock analyses, in percent*

Analysts and methods:

27. Iwan Roelandts and Guy Bologne (written commun., 1970); method of Roelandts and Duchesne (1968); average of 2 analyses for DTS–1 and BCR–1 and of 3 for other samples.
28. R. Pouget, M. Carrier, M. Lautelin, and A. Vasseur; various methods (H. Agrinier, written commun., 1969).
29. Huber-Schausberger and others (1970); various methods.
30. Youh (1968); methods modified from Hillebrand and others (1953).
30.* G–2, Tien-fung Tsui; GSP–1, Show-yuan Chow; AGV–1, Bruce Huai-tzu Chai; BCR–1, Cheng-hong Chen; W–1, Annie An-nie Liu (Youh, 1970).
31. S. E. Hill and R. B. Reid; rapid methods; average of 2 analyses (J. C. van Moort, Univ. Tasmania, written commun., 1968).
32. R. Cioni, F. Innocenti, and R. Mazzuoli (1971); various methods.
33. D. C. Guido Friese; average of three analyses (K. Schmidt, Zentrales Geologisches Institut, Berlin, written commun., 1969).
34. E. L. Conwell and Co., Philadelphia (Lapham and Saylor, 1970).

	G–2, granite					
	27	28	29	30	30*	32
SiO_2	68.82	69.22	69.04	68.93	68.84	69.22
Al_2O_3	15.70	15.50	15.21	15.89	15.56	15.27
Fe_2O_3	1.09	1.03	1.01	1.17	1.10	1.23
FeO	1.44	1.42	1.52	1.55	1.56	1.39
MgO	.88	.73	.86	.74	.88	.77
CaO	1.96	1.93	1.99	1.90	2.15	1.98
Na_2O	4.23	4.15	4.03	3.87	4.48	4.13
K_2O	4.53	4.42	4.51	4.40	3.73	4.37
H_2O^+	35	----	.57	.46	.44	-----
H_2O^-	.25	.30	.15	.12	.17	.10
TiO_2	.50	.48	.55	.48	.41	.54
P_2O_5	.15	.15	.13	.14	.16	.16
MnO	.03	.04	.06	.04	.06	.04
CO_2	----	----	.10	.07	.07	-----
Loss on ignition	----	.52	----	-----	-----	.74
Total	----	99.89	----	[1] 100.04	[2] 99.81	99.94
Fe as Fe_2O_3	2.69	2.61	2.70	2.89	2.82	2.77

See footnotes at end of table.

TABLE 103.—*New rock analyses, in percent*—Continued

GSP-1, granodiorite

	27	28	29	30*	31	32
SiO_2	66.85	67.21	66.96	66.44	66.6	67.30
Al_2O_3	15.01	15.27	15.25	15.37	15.6	14.98
Fe_2O_3	1.84	1.70	1.65	1.78	1.2	1.84
FeO	2.23	2.35	2.35	2.48	2.8	2.24
MgO	1.09	.97	.99	1.05	.9	.93
CaO	2.00	2.01	2.07	2.04	2.0	2.03
Na_2O	3.12	2.75	2.79	3.92	2.8	2.71
K_2O	5.53	5.45	5.50	5.30	5.4	5.65
H_2O^+	.39	----	.61	.35	.40	-----
H_2O^-	.28	.53	.12	.10	.10	.08
TiO_2	.64	.65	.58	.74	.66	.72
P_2O_5	.29	.27	.28	.26	.30	.32
MnO	.03	.05	.06	.06	tr	.04
CO_2	----	----	.14	.03	-----	-----
Loss on ignition	----	.68	----	-----	-----	.74
Total	----	99.89	----	99.92	98.7	99.58
Fe as Fe_2O_3	4.32	4.31	4.26	4.41	4.3	4.33

AGV-1, andesite

	27	28	29	30*	31	32
SiO_2	58.82	58.97	58.76	58.80	59.0	59.11
Al_2O_3	16.94	17.17	17.86	17.36	17.2	16.81
Fe_2O_3	4.67	4.36	4.79	4.49	4.3	4.51
FeO	1.90	2.02	2.30	2.28	2.0	1.97
MgO	1.65	1.51	1.16	1.50	1.6	1.51
CaO	4.75	4.90	4.95	5.52	4.6	4.98
Na_2O	4.51	4.23	4.24	4.24	4.2	4.35
K_2O	2.94	2.90	2.85	2.43	2.8	2.91
H_2O^+	.96	----	.85	1.10	.98	-----
H_2O^-	.83	1.55	1.08	.80	.90	.85
TiO_2	1.02	1.04	1.07	1.09	1.1	1.08
P_2O_5	.53	.51	.53	.60	.52	.51
MnO	.10	.10	.12	.08	.10	.10
CO_2	----	----	07	.03	-----	-----
Loss on ignition	----	.67	----	-----	-----	1.33
Total	----	99.9	----	[3] 100.18	99.4	100.02
Fe as Fe_2O_3	6.78	6.60	7.35	7.00	6.5	6.70

PCC-1, peridotite

	27	28	29	30*	31	32	33
SiO_2	41.43	40.97	41.66	41.50	42.1	41.80	42.11
Al_2O_3	.29	.80	.68	1.62	.70	.98	.63
Fe_2O_3	2.74	2.68	3.09	2.21	2.6	2.91	2.49
FeO	5.37	4.93	4.85	5.27	5.2	4.81	5.11
MgO	43.69	43.34	43.40	43.44	42.6	43.10	43.50
CaO	.55	.44	.46	nil	.6	.53	.54
Na_2O	.08	.03	<.1	.12	.3	.05	<.01
K_2O	.03	.01	<.1	nil	.4	[4] .02	<.01
H_2O^+	4.57	----	4.80	5.04	4.69	----	4.68
H_2O^-	.35	.81	.49	.45	.46	.27	(5)
TiO_2	.02	.01	.01	nil	.00	<.02	<.01
P_2O_5	.01	(6)	<.1	-----	.02	.02	<.01
MnO	.10	.12	.10	.14	.12	.12	.11
CO_2	----	----	.13	.11	----	----	.20
Loss on ignition	----	4.78	----	-----	----	5.10	----
Total	(7)	98.9	----	[8] 100.00	99.7	99.71	99.37
Fe as Fe_2O_3	8.11	8.16	8.48	8.01	8.5	8.25	8.17

See footnotes at end of table.

TABLE 103.—*New rock analyses, in percent*—Continued

DTS-1, dunite

	27	28	29	30*	31	32	33
SiO_2	39.96	40.08	40.46	40.07	41.9	40.40	40.64
Al_2O_3	.07	.29	.43	1.38	.45	.68	.17
Fe_2O_3	2.23	.31	.83	.37	.36	1.16	.88
FeO	5.60	7.62	6.97	7.32	7.43	6.83	6.94
MgO	49.89	49.69	50.06	49.91	49.2	49.99	49.65
CaO	.22	.11	$<.1$	nil	.00	.17	.14
Na_2O	.12	.05	$<.1$	.07	.2	.02	$<.01$
K_2O	.04	.01	$<.1$	nil	.3	[9].01	$<.01$
H_2O^+	.25	----	.46	.25	.85	----	.38
H_2O^-	.18	.58	.08	.08	.04	.01	(5)
TiO_2	.03	.01	.02	nil	.00	$<.02$	$<.01$
P_2O_5	.02	(10)	$<.1$	-----	.03	.02	$<.01$
MnO	.09	.11	.13	.17	.13	.12	.12
CO_2	----	----	.07	.07	----	----	.07
Loss on ignition	----	.19	----	-----	----	.65	----
Total	(11)	99.0	----	[12]99.87	100.9	100.06	98.99
Fe as Fe_2O_3	8.45	8.77	8.57	8.42	8.61	8.75	8.59

BCR-1, basalt

	27	28	29	30	30*	31	32	34
SiO_2	53.80	54.07	54.24	54.00	54.60	53.1	54.46	54.62
Al_2O_3	13.47	13.65	13.50	14.14	13.54	14.4	13.57	13.99
Fe_2O_3	4.03	3.18	3.56	3.20	3.49	1.06	3.51	3.57
FeO	8.38	9.02	9.12	9.02	9.17	10.44	8.59	8.78
MgO	3.52	3.50	3.33	3.48				
					3.58	3.2	3.49	3.48
CaO	6.66	6.89	7.10	6.94	6.94	7.0	6.94	6.95
Na_2O	3.42	3.30	3.32	3.44	3.10	4.6	3.32	2.78
K_2O	1.69	1.70	1.75	1.42	1.70	1.8	1.69	1.45
H_2O^+	.55	----	.80	.90	.86	.13	-----	.54
H_2O^-	.73	1.37	.78	.80				
					,63	.97	.62	1.22
TiO_2	2.00	2.25	2.20	2.27	2.04	2.2	2.20	2.25
P_2O_5	.36	.34	.35	.43	.43	.40	.39	.35
MnO	.17	.19	.20	.18	.21	.20	.19	.20
CO_2	----	----	.01	.07	.06	-----	-----	.01
Loss on ignition	----	.43	----	----	-----	-----	1.17	-----
Total	----	99.8	----	100.29	100.39	99.44	100.14	100.19
Fe as Fe_2O_3	13.39	13.20	13.69	13.12	13.59	12.66	13.05	13.32

W-1, diabase

	30	30*		30	30*
SiO_2	52.52	52.07	H_2O^+	0.39	0.34
Al_2O_3	15.10	14.86	H_2O^-	.16	.10
Fe_2O_3	1.37	1.75	TiO_2	1.08	1.17
FeO	8.80	8.94	P_2O_5	.14	.21
MgO	6.60	6.63	MnO	.15	.15
CaO	10.97	11.18	CO_2	.05	.03
Na_2O	2.24	2.10	Loss on ignition	----	----
K_2O	.55	.49	Total	100.12	100.02
			Fe as Fe_2O_3	11.15	11.59

1. Includes F. 0.15; S, 0.01; BaO, 0.18.
2. Includes BaO, 0.27.
3. Inculdes BaO, 0.13.
4. K_2O as a trace, 0.0157.
5. Sample dried at 110°C.
6. P_2O_5, 128 ppm.
7. Insoluble residue, 0.49, also reported.
8. Includes Cr_2O_3, 0.10.
9. K_2O as a trace, 0.0063.
10. P_2O_5, 124 ppm.
11. Insoluble residue, 0.58, also reported.
12. Includes Cr_2O_3, 0.18.

TABLE 104.—*Determinations of major and minor constituents in eight USGS standard rock samples* (*percent*)

[Number of determinations is given in parentheses following the value. Method: AA, atomic absorption; Fl phot, flame photometry; FNAA, fast neutron activation analysis; ID, isotope dilution; INAA, instrumental neutron activation analysis; NAA, neutron activation analysis; OS, optical spectrographic; SSMS, spark source mass spectrometric; XRF, X-ray fluorescence]

W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1	Method	Reference
					SiO_2				
54.0	74.0	----------	----------	----------	----------	----------	----------	OS	Dümecke, 1968.
----------	----------	----------	----------	59.09	----------	----------	----------	OS	Ondrick and others, 1969.
----------	----------	----------	----------	----------	----------	----------	51.8	SSMS	Morrison and Kashuba 1969.
52.6(2)	71.9(2)	----------	----------	----------	----------	----------	----------	Chemical	Bernas, 1968.
52.6(2)	72.4(2)	69.2	67.2	----------	----------	----------	----------	Gravimetric	Borgen, 1967.
----------	----------	----------	----------	59.0	41.9	40.7	54.2	Chemical	Rayburn, 1968.
52.43	72.85	----------	----------	----------	----------	----------	----------	Gravimetric	Roelandts and Duchesne, 1968.
----------	----------	----------	----------	----------	----------	----------	54.48	Chemical	Maxwell and Abbey, in Maxwell and others, 1970.
----------	----------	69.22(10)	----------	59.75	----------	----------	----------	Colorimetric	Brown and others, 1969.
52.75(14)	73.35(18)	----------	----------	----------	----------	----------	----------	----do	Biagi, 1970.
----------	----------	69.2(4)	67.2(4)	59.5(4)	41.6(4)	40.2(4)	53.8(4)	Spectrophotometric	Langer, 1969, 25-mg samples.
----------	----------	----------	----------	59.6(8)	----------	40.4(8)	----------	----do	Langer, 1969, 5-mg samples.
53.0	72.3	69.1	67.7	59.0	41.6	40.4	54.2	----do	Casanova and others, 1968.
52.69(8)	72.66(8)	----------	----------	----------	----------	----------	----------	----do	Karkare, 1965.
52.65(5)	----------	69.10(5)	----------	----------	----------	----------	----------	AA	Langmyhr and Paus, 1968.
----------	----------	----------	67.07(5)	59.65(5)	----------	40.47(5)	54.36(5)	AA	Langmyhr and Paus, 1969.
52.7(3)	----------	69.4(3)	67.2(3)	59.1(3)	41.9(3)	40.4(3)	54.5(3)	AA	Van Loon and Parissis, 1969.
52.2	72.3	----------	----------	----------	----------	----------	----------	AA	Boar and Ingram, 1970.
----------	----------	68.80	67.20	59.20	42.40	40.80	53.60	AA	Foscolos and Barefoot, 1970.
48.2	----------	65.9	64.2	59.9	----------	----------	49.6	AA	Buckley and Cranston, 1971.
52.80(3)	----------	----------	----------	----------	----------	----------	54.11(3)	AA	Brimhall and Embree, 1971.
52.7	----------	----------	----------	----------	----------	----------	54.6	AA	Schnetzler and Nava, 1971.
----------	----------	68.5	66.5	59.5	42.1	41.6	53.9	AA	Randall, 1972.
52.7	----------	----------	----------	----------	42.3	----------	----------	AA	Schnetzler and others, 1972.
53.08	72.90	69.86	67.78	60.34	43.91	40.79	55.33	XRF	De Vecchi and others, 1968.
----------	----------	68.5	67.4	59.3	42.1	39.1	53.9	XRF	Rayburn, 1968.
----------	----------	69.40	67.70	59.80	42.70	----------	54.10	XRF	Sahores, 1968.
----------	----------	67.85(2)	66.10(2)	57.84(2)	38.80(2)	38.12(2)	51.46(2)	XRF uncorrected	Wright, 1968.
----------	----------	66.80	65.10	59.25	42.45	40.80	54.30	XRF	Hooper and Atkins, 1969.
52.8(2)	72.8(2)	69.7(2)	67.8(2)	59.7(2)	----------	----------	54.3	XRF	Schneider, 1969.
52.09	----------	68.70	67.10	58.64	----------	----------	55.56	XRF	Ragland, 1970.
----------	----------	69.0	66.4	59.5	----------	----------	54.0	XRF	Aubert and Desjardins, 1971.
----------	----------	----------	----------	60.06(9)	----------	----------	----------	XRF	Murad, 1971.
52.90	72.85	69.36	67.44	59.05	41.55	40.35	54.44	XRF	Fabbi, 1972a.
----------	----------	69.04	67.34	59.14	41.68	40.44	53.91	XRF	Kay and Chappell, 1972.
----------	----------	----------	----------	----------	----------	----------	54.6	FNAA	Ehmann and Morgan, 1970.
----------	----------	----------	----------	59.48(18)	----------	----------	54.85(18)	FNAA	Morgan and Ehmann, 1970.
----------	----------	69.88(8)	68.09(8)	59.12(8)	43.02(8)	41.07(8)	53.57(8)	FNAA	Gijbels, 1972.
----------	----------	69.00(4)	----------	----------	----------	----------	55.65(4)	INAA	Kuykendall and others, 1971.
52.3(10)	----------	69.0(10)	----------	60.8(10)	----------	----------	----------	Microprobe	Rucklidge and others, 1970.
----------	73.15(2)	67.70	68.58	60.04(2)	42.70	40.64	54.90(2)	----do	Mori and others, 1971.
					Al_2O_3				
15.5	14.1	----------	----------	----------	----------	----------	----------	OS	Dümecke, 1968.
----------	----------	----------	----------	16.90	----------	----------	----------	OS	Ondrick and others, 1969.
----------	----------	----------	----------	----------	----------	----------	11.9	SSMS	Morrison and Kashuba, 1969.
14.80	14.49(2)	----------	----------	----------	----------	----------	----------	Chemical	Bernas, 1968.
----------	----------	15.4	15.4	17.1	.74	.25	13.6	----do	Rayburn, 1968.
----------	----------	----------	----------	----------	----------	----------	13.62	----do	Maxwell and Abbey, in Maxwell and others, 1970.
15.01(4)	----------	----------	----------	17.07(4)	.711(4)	.211(4)	----------	Titration	Strelow and others, 1969.
14.78(2)	14.21(2)	----------	----------	----------	----------	----------	----------	Volumetric	Borgen, 1967.
15.01(4)	----------	----------	----------	17.07(4)	.711(4)	.211(4)	----------	Ion exchange	Toerien, 1969.
15.01	14.34	----------	----------	----------	----------	----------	----------	Colorimetric	Roelandts and Duchesne, 1968.
----------	----------	15.23(7)	----------	----------	----------	----------	----------	----do	Brown and others, 1969.
15.03(9)	13.81(9)	----------	----------	----------	.81(18)	----------	13.94(18)	----do	Biagi, 1970.
14.9	14.2	15.4	15.4	17.2	.72	.30	13.6	Spectrophotometric	Casanova and others, 1968.
----------	----------	14.9(2)	15.5(2)	16.0(4)	.73	.21	13.2(2)	----do	Chalmers and Basit, 1968.
15.03(3)	14.24(3)	15.41(3)	14.85(3)	17.04(3)	----------	----------	13.42(3)	----do	Meyrowitz, 1970.

TABLE 104.—*Determinations of major and minor constituents in eight USGS standard rock samples (percent)*—Continued

W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1	Method	Reference
					Al_2O_3—Continued				
14.78(8)	13.95(8)	----------	----------	----------	----------	----------	----------	Photometric	Karkare, 1965.
----------	----------	15.3(4)	14.9(4)	17.3(4)	1.00(4)	.36(4)	13.4(4)	do	Langer, 1971.
----------	----------	----------	15.27(4)	----------	.533(4)	.133(2)	14.45(4)	AA	Butler, 1968.
15.04	14.18	----------	----------	----------	.70	----------	13.72	AA	Galle, 1968.
15.27(5)	----------	15.60(5)	----------	----------	----------	----------	----------	AA	Langmyhr and Paus, 1968.
15.01(4)	14.15(4)	----------	15.27(4)	----------	.533(4)	.133(2)	14.45(4)	AA	Butler and Kokot, 1969.
----------	----------	----------	15.49(5)	17.50(5)	----------	----------	13.66(5)	AA	Langmyhr and Paus, 1969.
14.9(3)	----------	15.1(3)	14.9(3)	16.9(3)	----------	----------	13.4(3)	AA	Van Loon and Parissis, 1969.
15.1	13.9	----------	----------	----------	----------	----------	----------	AA	Boar and Ingram, 1970.
----------	----------	15.48	15.12	17.38	.94	.38	13.98	AA	Foscolos and Barefoot, 1970.
15.0	----------	16.2	14.8	17.4	----------	----------	13.4	AA	Ragland, 1970.
----------	----------	----------	----------	16.83	----------	----------	----------	AA	Brenner, 1971.
14.68(3)	----------	----------	----------	----------	----------	----------	13.34(3)	AA	Brimhall, and Embree, 1971.
15.49	----------	15.96	15.62	17.60	----------	----------	14.04	AA	Buckley and Cranston, 1971.
14.95	----------	----------	----------	----------	----------	----------	13.72	AA	Schnetzler and Nava, 1971.
----------	----------	15.27	15.00	16.95	.42	.19	13.60	AA	Terashima, 1971c.
----------	----------	15.4	15.4	17.2	.8	<.2	13.8	AA	Randall, 1972.
15.08	----------	----------	----------	----------	----------	----------	13.66	AA	Schnetzler and others, 1972.
----------	----------	----------	15.09(2)	16.89(2)	----------	----------	13.18(2)	AA	Vidal, 1972.
15.31	14.53	15.54	15.41	17.44	.82	.30	13.90	XRF	De Vecchi and others, 1968.
----------	----------	15.20	15.20	17.70	.52	----------	13.50	XRF	Sahores, 1968.
----------	----------	15.7	15.6	17.4	1.17	1.01	13.6	XRF	Rayburn, 1968.
----------	----------	15.40(2)	15.04(2)	16.99(2)	.60(2)	.25(2)	13.26(2)	XRF uncorrected	Wright, 1968.
----------	----------	----------	15.50	17.57	1.10	.40	14.23	XRF	Hooper and Atkins, 1969.
15.0(2)	14.4(2)	15.6(2)	15.3(2)	17.4(2)	----------	----------	13.6(2)	XRF	Schneider, 1969.
----------	----------	15.59	15.29	17.42	----------	----------	13.20	XRF	Aubert and Desjardins, 1971.
----------	----------	----------	----------	17.17(9)	----------	----------	----------	XRF	Murad, 1971.
14.91	14.35	14.95	15.02	17.06	.58	.16	13.32	XRF	Fabbi, 1972a.
----------	----------	15.11	14.98	16.99	.62	.16	13.51	XRF	Kaye and Chappell, 1972.
----------	----------	----------	----------	----------	----------	----------	13.6	FNAA	Ehmann and Morgan, 1970.
14.50	----------	15.1	16.1	17.4	.74	.30	14.6	INAA	Filby and Haller, 1969.
----------	----------	----------	----------	----------	.70	.25	----------	INAA	Gordon and others, 1969.
----------	----------	15.53(2)	15.34	17.74	.67	.168(2)	13.75(2)	INAA	Loveland and others, 1969.
----------	----------	15.40	----------	16.44	----------	----------	13.17(2)	INAA	Morrison and others, 1969; Morrison and Kashuba, 1969; Morrison, 1971.
14.96(4)	----------	----------	----------	----------	.665(4)	----------	13.45(4)	INAA	Wyttenbach, 1969.
14.49	----------	15.1	16.06	17.38	.74	.30	14.56	INAA	Filby and others, 1970.
14.3	----------	----------	----------	----------	----------	----------	13.1	INAA	Goles and others, 1971.
----------	----------	15.66(4)	----------	----------	----------	----------	13.94(4)	INAA	Kuykendall and others, 1971.
----------	----------	----------	----------	----------	.72	.16	----------	INAA	Oosterom and Das, 1971.
----------	----------	15.47	----------	----------	----------	----------	----------	NAA	Das and others, 1969, 1970.
14.96(20)	----------	15.31(10)	15.35(10)	16.94(10)	.631(10)	.187(10)	13.71(10)	NAA	Steinnes, 1969b.
----------	----------	----------	----------	----------	----------	----------	13.92(5)	NAA	Brunfelt and Steinnes, 1971b.
----------	----------	----------	----------	----------	----------	----------	13.98	NAA	Brunfelt and others, 1971.
15.0(10)	----------	15.7(10)	----------	17.5(10)	----------	----------	----------	Microprobe	Rucklidge and others, 1970.
----------	14.66(2)	15.19	15.16	17.17(2)	.93	.55	13.51(2)	do	Mori and others, 1971.
					FeO				
8.63(8)	1.00(8)	----------	----------	----------	----------	----------	----------		Karkare, 1965.
----------	----------	----------	----------	----------	5.59(24)	8.15(8)	9.01(17)	Dichromate	Peters, 1968.
----------	----------	----------	----------	----------	5.49(28)	7.36(12)	8.86(20)	Vanadate	Do.
8.55	----------	----------	----------	----------	----------	----------	----------	Volumetric	Roelandts and Duchesne, 1968.
----------	----------	1.42(2)	2.24(2)	2.04(2)	5.00(2)	7.08(2)	8.55(2)	Dichromate	Wright, 1968.
8.77(3)	.90(3)	1.46(4)	2.39(4)	2.14(4)	5.46(4)	7.37(4)	8.96(4)	Acid dissolution	Donaldson, 1969.
----------	----------	1.54(10)	2.70(10)	2.10(10)	5.49(10)	7.36(10)	8.91(10)	Titration	Peters, 1969.
----------	----------	1.44	2.29	2.04	4.92	7.02	8.93	do	Foscolos, 1971.
----------	----------	1.31	2.12	1.98	4.94	6.87	8.88	Volumetric	Sighinolfi, 1969.
----------	----------	1.66	2.44	2.19	5.04	6.92	9.02	Chemical	Stoch, 1969.
----------	----------	----------	----------	----------	----------	----------	8.65	do	Maxwell and Abbey, in Maxwell and others, 1970.
----------	----------	1.45(7)	2.32(6)	2.03(7)	5.07(7)	6.72(6)	8.37(3)	Spectrophotometric	Girardin and Thiel, 1970.
----------	----------	----------	----------	1.96	----------	----------	----------	do	Brenner, 1971.
----------	----------	1.49	2.10	2.12	5.10	6.29	8.82	do	Randall, 1972.

TABLE 104.—*Determinations of major and minor constituents in eight USGS standard rock samples (percent)*—Continued

W-1	G-1	G-2	GSP-1	AGV-1	PCC-1	DTS-1	BCR-1	Method	Reference
				Fe_2O_3					
1.87(8)	0.82(8)	----------	----------	----------	----------	----------	----------	Spectrophotometric	Karkare, 1965.
----------	----------	0.92(8)	1.25(8)	4.22(8)	1.96(13)	0.30(13)	3.22(8)	do	Peters, 1969.
----------	----------	.88	1.60	4.25	2.55	.80	3.32	Chemical	Stoch, 1969.
----------	----------	----------	----------	----------	----------	----------	3.77	do	Maxwell and Abbey in Maxwell and others, 1970.
1.99	----------	----------	----------	----------	----------	----------	----------	Difference	Roelandts and Duchesne, 1968.
----------	----------	1.09	1.72	4.80	3.12	1.07	3.76	do	Foscolos, 1971.
----------	----------	.78	1.93	4.15	2.61	1.63	3.37	do	Randall, 1972.
				Total Fe as Fe_2O_3					
11.2	2.0	----------	----------	----------	----------	----------	----------	OS	Dümecke, 1968.
----------	----------	2.7(10)	4.5(10)	6.5(10)	----------	----------	12.0(10)	OS	Fabbri and Vespignani-Balzani, 1969.
----------	----------	----------	----------	6.75	----------	----------	----------	OS	Ondrick and others, 1969.
----------	----------	----------	----------	----------	----------	----------	10.7	SSMS	Morrison and Kashuba, 1969.
10.75(2)	1.89(3)	----------	----------	----------	----------	----------	----------	Chemical	Bernas, 1968.
----------	----------	2.71	4.31	6.71	8.29	8.81	13.50	do	Rayburn, 1968.
11.02(4)	----------	----------	----------	6.70(4)	8.31(4)	8.31(4)	----------	Ion exchange	Toerien, 1969.
----------	----------	2.58(2)	4.22(2)	8.10(3)	8.56(3)	13.29(3)	6.85(3)	Potentiometric	Hetman, 1968.
11.02(4)	----------	----------	----------	6.70(4)	7.74(4)	8.31(4)	----------	Titration	Strelow and others, 1969.
----------	----------	2.69	4.36	7.09	8.60	8.90	13.70	do	Foscolos, 1971.
11.49	1.94	----------	----------	----------	----------	----------	----------	Volumetric	Roelandts and Duchesne, 1968.
10.95(2)	1.94(2)	----------	----------	----------	----------	----------	----------	Spectrophotometric	Borgen, 1967.
----------	1.88	2.66	4.30	6.96	8.23	8.72	13.4	do	Casanova and others, 1968.
----------	----------	2.62(8)	4.25(8)	6.55(8)	8.07(13)	8.51(13)	13.29(8)	do	Peters, 1969.
----------	----------	2.60	4.16	6.53	8.20	8.20	13.3	Photometric	Langer, 1971.
----------	----------	2.65	4.24	6.64	8.39	8.64	13.32	AA	Abbey, 1968.
----------	----------	2.72(4)	4.23(4)	6.71(4)	----------	8.54(2)	12.74(4)	AA	Butler, 1968.
11.30	2.01	----------	----------	----------	8.27	----------	13.63	AA	Galle, 1968.
11.20(5)	----------	2.70(5)	----------	----------	----------	----------	----------	AA	Langmhyr and Paur, 1968.
----------	----------	2.54	4.33	6.76	8.11	8.64	13.28	AA	Luhn, 1968.
10.72(2)	----------	----------	----------	----------	----------	----------	----------	AA	Bender and Schultz, 1969.
11.15(8)	1.86(5)	2.72(4)	4.23(4)	6.71(4)	----------	8.54(2)	12.74(4)	AA	Butler and Kokot, 1969.
----------	----------	----------	4.29(5)	6.73(5)	----------	8.43(5)	13.58(5)	AA	Langmyhr and Paus, 1969.
11.13	----------	2.75	4.35	6.77	8.56	8.71	13.65	AA	Sighinolfi, 1969.
11.12(3)	----------	2.90(3)	4.16(3)	6.69(3)	8.23(3)	8.74(3)	13.41(3)	AA	Van Loon and Parissis, 1969.
11.3	1.99	----------	----------	----------	----------	----------	----------	AA	Boar and Ingram, 1970.
----------	----------	2.63	4.29	6.80	8.52	8.98	13.67	AA	Foscolos and Barefoot, 1970.
10.38	1.90	2.74	4.27	6.76	7.93	8.74	13.12	AA	Iida and Yamasaki, 1970.
11.2(9)	1.77(2)	2.7(6)	4.4(4)	7.1(2)	7.9(4)	----------	14.1(2)	AA	A. C. S. Smith, 1970.
11.04(3)	----------	----------	----------	----------	----------	----------	13.24(3)	AA	Brimhall and Embree, 1971.
10.95	----------	2.59	4.18	6.55	----------	----------	12.84	AA	Buckley and Cranston, 1971.
----------	----------	2.63	4.29	6.80	8.52	8.98	13.67	AA	Foscolos, 1971.
10.97	----------	----------	----------	----------	----------	----------	13.21	AA	Schnetzler and Nava, 1971.
----------	----------	----------	----------	----------	----------	----------	13.28	AA	Schnetzler and others, 1972.
10.95	1.65	2.57	4.26	6.93	9.04	8.99	13.52	XRF	De Vecchi and others, 1968.
----------	----------	2.86	4.53	6.81	8.53	8.71	13.70	XRF	Rayburn, 1968.
----------	----------	2.75	4.20	6.70	8.10	----------	13.60	XRF	Sahores, 1968.
----------	----------	2.66	4.46	6.47	----------	----------	13.28	XRF	Franzini and Leoni, 1969.
----------	----------	2.58	4.34	6.77	8.42	9.10	----------	XRF	Hooper and Atkins, 1969.
----------	----------	2.79(4)	4.44(4)	----------	----------	----------	----------	XRF	Murad, 1969.
11.0(2)	1.92(2)	2.76(2)	4.32(2)	6.82(2)	----------	----------	13.2(2)	XRF	Schneider, 1969.
11.45	----------	2.82	4.68	7.32	----------	----------	14.02	XRF	Ragland, 1970.
----------	----------	2.66	4.32	6.93	----------	----------	13.30	XRF	Aubert and Desjardin, 1971.
----------	----------	----------	----------	6.98(9)	----------	----------	----------	XRF	Murad, 1971.
11.09	1.88	2.76	4.37	6.98	8.56	9.13	13.50	XRF	Fabbi, 1972a.
----------	----------	2.62	4.23	6.66	8.23	8.72	13.32	XRF	Kaye and Chappell, 1972.
----------	----------	2.77	4.33	6.83	8.54	8.85	13.51	Mössbauer	Herzenberg, 1970.
13.98(10)	----------	2.85(10)	----------	6.34(10)	----------	----------	----------	Microprobe	Ruckledge and others, 1970.
----------	2.04(2)	2.74	4.39	6.96(2)	8.25	8.57	13.44(2)	do	Mori and others, 1971.
----------	----------	2.64(5)	----------	----------	----------	----------	----------	INAA	Aruscavage, 1969.
10.87	----------	2.36	----------	----------	----------	----------	----------	INAA	Filby and Haller, 1969.
----------	----------	2.39	4.40	6.61	7.68	8.14	----------	INAA	Dale and others, 1970.

TABLE 104.—*Determinations of major and minor constituents in eight USGS standard rock samples (percent)*—Continued

W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1	Method	Reference
Total Fe as Fe_2O_3—Continued									
10.87	----------	2.36	4.18	6.58	8.31	8.46	13.15	INAA	Filby and others, 1970.
----------	----------	----------	----------	----------	----------	----------	13.38	INAA	Goles and others, 1971.
----------	----------	2.72(4)	----------	----------	----------	----------	13.77(4)	INAA	Kuykendall and others, 1971.
12.20	2.22	----------	----------	----------	----------	----------	----------	NAA	Norman and Haskin, 1968.
----------	----------	2.54	----------	6.76	----------	----------	13.81(2)	NAA	Morrison and others, 1969; Morrison and Kashuba, 1969; Morrison, 1971.
11.44(2)	1.86(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
10.7	----------	2.50	----------	----------	----------	----------	12.9	NAA	Peterson and others, 1969.
----------	----------	----------	----------	----------	----------	----------	13.3(2)	NAA	Allen and others, 1970; Haskin and others, 1970.
11.12(5)	----------	2.65(5)	4.31(5)	6.75(5)	----------	----------	13.40(5)	NAA	Johansen and Steinnes, 1970.
----------	----------	----------	----------	----------	----------	----------	12.9	NAA	Osawa and Goles. 1970.
----------	----------	----------	----------	----------	----------	----------	13.38	NAA	Brunfelt and others, 1971.
----------	----------	----------	----------	----------	----------	----------	13.41(5)	NAA	Brunfelt and Steinnes, 1971b.
----------	----------	2.35	----------	----------	----------	----------	----------	NAA	Das, Zonderhuis, and van der Marel, 1971.
11.18(6)	----------	2.73(6)	4.29(6)	6.78(6)	----------	----------	13.35(6)	Substoic RID	Gundersen and Steinnes, 1972.
10.87	----------	2.69	4.33	6.78	8.34	8.76	13.58	Photon activation	Kunzendorf, 1971.
----------	----------	----------	----------	6.87	8.58(2)	9.08(2)	13.2	----do	Van Zelst, 1971a.
----------	----------	----------	----------	6.89	8.60	8.92	13.18	----do	Van Zelst, 1971b.
----------	----------	----------	----------	----------	8.3	----------	12.6	Proton activation	Van Zelst, 1971a, b.
MgO									
6.84	0.37	----------	----------	----------	----------	----------	----------	OS	Dümecke, 1968.
----------	----------	0.74(10)	1.02(10)	1.43(10)	----------	----------	3.5(10)	OS	Fabbri and Vespignani-Balzani, 1969.
----------	----------	----------	----------	1.46	----------	----------	----------	OS	Ondrick and others, 1969.
----------	----------	----------	----------	----------	----------	----------	2.3	SSMS	Morrison and Kashuba, 1969.
----------	----------	----------	----------	----------	----------	----------	3.46	Chemical	Maxwell and Abbey in Maxwell and others, 1970.
6.37(2)	.40	----------	----------	----------	----------	----------	----------	----do	Bernas, 1968.
6.79	.50	----------	----------	----------	----------	----------	----------	EDTA	Roelandts and Duchesne, 1968.
6.71(8)	.46(8)	----------	----------	----------	----------	----------	----------	Titration	Karkare, 1965.
----------	----------	.72(5)	.97(5)	1.51(5)	43.3(10)	49.7(10)	3.49(5)	EDTA	Peters, 1969.
6.57(4)	----------	----------	----------	1.50(4)	43.09(4)	49.89(4)	----------	Titration	Strelow and others, 1969.
----------	----------	.79	.98	1.47	43.18	49.80	3.52	AA	Abbey, 1968.
----------	----------	.78(3)	.95(2)	1.46(2)	----------	----------	3.30(2)	AA	Butler, 1968.
6.63	.40	----------	----------	----------	43.20	----------	3.52	AA	Galle, 1968.
6.59(5)	----------	.748(5)	.97(5)	1.50(5)	----------	49.82(5)	3.57(5)	AA	Langmyhr and Paus, 1968, 1969.
----------	----------	.76	.96	1.50	44.13	51.84	3.49	AA	Luhn, 1968.
6.50(4)	.40(4)	.78(3)	.95(2)	1.46(2)	----------	----------	3.30(2)	AA	Butler and Kokot, 1969.
----------	----------	.80	1.01	1.54	----------	----------	3.45	AA	Sighinolfi, 1969.
6.56(3)	----------	.74(3)	.96(3)	1.43(3)	42.9(3)	49.8(3)	3.40(3)	AA	Van Loon and Parissis, 1969.
6.59	.38	----------	----------	----------	----------	----------	----------	AA	Boar and Ingram, 1970.
----------	----------	.80	.93	1.48	42.78	49.41	3.17	AA	Foscolos and Barefoot, 1970.
----------	----------	.77(2)	1.04(2)	1.92(2)	----------	----------	3.81(2)	AA	Govindaraju, 1970a.
6.51	----------	.78	.98	1.56	----------	----------	3.38	AA	Ragland, 1970.
6.60(7)	.34(2)	.69(5)	.91(4)	1.38(2)	43.5(2)	----------	3.46(2)	AA	A. C. S. Smith, 1970.
----------	----------	----------	----------	1.51(3)	----------	----------	----------	AA	Brenner, 1971.
6.62(3)	----------	----------	----------	----------	----------	----------	3.51(3)	AA	Brimhall and Embree, 1971.
6.81	----------	.70	.91	1.59	----------	----------	3.48	AA	Buckley and Cranston, 1971.
6.77	----------	----------	----------	----------	----------	----------	3.40	AA	Schnetzler and Nava, 1971.
----------	----------	.75	.97	1.56	43.83	49.80	3.43	AA	Terashima, 1971c.
----------	----------	.78	.96	1.54	42.4	49.1	3.57	AA	Randall, 1972.
6.63	----------	----------	----------	----------	----------	----------	----------	AA	Schnetzler and others, 1972.
----------	----------	----------	.95(2)	1.53(2)	----------	----------	3.41(2)	AA	Vidal, 1972.
----------	----------	.75	.95(3)	1.42(3)	43.2(3)	50.1(3)	3.33(2)	Fl phot	Langer, 1969.
6.78	.40	.83	.99	1.64	42.5	49.5	3.46	Complexometric	Casanova and others, 1968.
6.66(5)	.38(5)	----------	----------	----------	----------	----------	----------	Spectrophotometric	Evans, 1968.
6.46(2)	.41(2)	----------	----------	----------	----------	----------	----------	Photometric	Borgen, 1967.
6.57(4)	----------	----------	----------	1.50(4)	43.09(4)	49.89(4)	----------	Ion exchange	Toerien, 1969.
6.93	----------	.70	----------	1,76	45.78	49.97	3.61	XRF	De Vecchi and others, 1968.
----------	----------	.64	.94	1.62	43.6	----------	3.24	XRF	Sahores, 1968.

TABLE 104.—*Determinations of major and minor constituents in eight USGS standard rock samples (percent)*—Continued

W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1	Method	Reference
				MgO—Continued					
----------	----------	.74(2)	.97(2)	1.56(2)	42.42(2)	50.50(2)	3.65(2)	XRF uncorrected	Wright, 1968.
----------	----------	.73	.95	1.50	43.17	49.65	3.53	XRF	Hooper and Atkins, 1969.
6.72	.34	.75	.95	1.58	----------	----------	3.45	XRF	Schneider, 1969.
6.4	----------	----------	----------	----------	----------	----------	----------	XRF	Parker, 1970.
----------	----------	.78	1.05	1.59	----------	----------	3.46	XRF	Aubert and Desjardins, 1971.
6.61	.37	.81	.98	1.57	43.15	50.03	3.48	XRF	Fabbi, 1972a.
6.66(10)	----------	.92(10)	----------	1.49(10)	----------	----------	----------	Microprobe	Ruckledge and others, 1970.
----------	.24(2)	.90	1.14	1.59(2)	45.08	50.94	3.40(2)	----do	Mori and others, 1971.
----------	----------	.77	.95	1.46	43.24	49.73	3.40	XRF	Kaye and Chappell, 1972.
----------	----------	----------	----------	----------	42.6	46.9	----------	INAA	Filby and Haller, 1969; Filby and others, 1970.
----------	----------	----------	----------	----------	42.3	50.7	----------	INAA	Gordon and others, 1969.
----------	----------	----------	----------	----------	----------	----------	3.66	INAA	Morrison and others, 1969; Morrison and Kashuba, 1969 (NAA); Morrison, 1971.
6.17(4)	----------	----------	----------	----------	44.1(4)	----------	3.28(4)	INAA	Wyttenbach, 1969.
----------	----------	1.01(4)	----------	----------	----------	----------	3.48(4)	INAA	Kuykendall and others, 1971.
----------	----------	----------	----------	1.54	53.9	----------	----------	Photoactivation	Van Zelst, 1971a.
----------	----------	----------	----------	----------	----------	----------	3.18(2)	ID	Krähenbühl and others, 1972.
				CaO					
----------	1.51	----------	----------	----------	----------	----------	----------	OS	Kowalski, 1967.
11.3	1.35	----------	----------	----------	----------	----------	----------	OS	Dümecke, 1968.
----------	----------	----------	----------	4.92	----------	----------	----------	OS	Ondrick and others, 1969.
----------	----------	----------	----------	----------	----------	----------	6.8	SSMS	Morrison and Kashuba, 1969.
10.63	1.37(3)	----------	----------	----------	----------	----------	----------	Chemical	Bernas, 1968.
----------	----------	1.98	2.07	4.89	.44	0	6.92	----do	Rayburn, 1968.
----------	----------	----------	----------	----------	----------	----------	6.91	----do	Maxwell and Abbey in Maxwell and others, 1970.
10.72(8)	1.48(8)	----------	----------	----------	----------	----------	----------	Titration	Karkare, 1965.
10.41	1.28	----------	----------	----------	----------	----------	----------	EDTA	Roelandts and Duchesne, 1968.
10.87(4)	----------	----------	----------	4.97(4)	.528(4)	.158(4)	----------	Titration	Strelow and others, 1969.
10.87(4)	----------	----------	----------	4.97(4)	.528(4)	.121(4)	----------	Ion exchange	Toerien, 1969.
11.19	1.32	1.91	1.97	4.67	----------	.09	6.64	Colorimetric	King and Pruden, 1969.
10.82(2)	1.41(2)	----------	----------	----------	----------	----------	----------	Photometric	Borgen, 1967.
10.81	1.37	1.91	2.09	5.03	.55	.10	6.96	Complexometric	Casanova and others, 1968.
----------	----------	1.73(8)	1.84(8)	4.81(8)	.55(10)	.15(10)	6.89(8)	Fl phot	Peters, 1969.
----------	----------	1.97	2.06	4.63	.61	.16	6.97	----do	Langer, 1971.
----------	----------	2.03	2.07	4.92	.56	.14	6.89	AA	Abbey, 1968.
----------	----------	1.91(3)	1.97(2)	----------	.39(2)	.026(2)	----------	AA	Butler, 1968.
10.93	1.36	----------	----------	----------	.49	----------	6.88	AA	Galle, 1968.
10.83(5)	----------	1.85(5)	----------	----------	----------	----------	----------	AA	Langmhyr and Paus, 1968.
----------	----------	2.09	2.11	4.68	.52	.12	6.65	AA	Luhn, 1968.
----------	----------	1.91(2)	2.16(2)	5.12(2)	----------	----------	7.00	AA	Govindaraju 1970a.
----------	----------	----------	1.94(5)	4.94(5)	----------	0.053(5)	6.73(5)	AA	Langmyhr and Paus, 1969.
10.86(4)	1.32(4)	1.91(3)	1.97(2)	----------	.39(2)	.026(2)	----------	AA	Butler and Kokot, 1969.
10.90	----------	2.03	1.95	4.90	----------	----------	6.78	AA	Sighinolfi, 1969.
10.8(3)	----------	2.02(3)	2.10(3)	4.87(3)	.54(3)	.18(3)	6.95(3)	AA	Van Loon and Parissis, 1969.
11.0	1.38	----------	----------	----------	----------	----------	----------	AA	Boar and Ingram, 1970.
----------	----------	1.92	1.93	4.93	.52	.11	6.86	AA	Foscolos and Barefoot, 1970.
10.8(9)	1.42(2)	1.87(5)	1.96(4)	4.84(3)	----------	----------	6.90(2)	AA	A. C. S. Smith, 1970.
----------	----------	----------	----------	4.94(3)	----------	----------	----------	AA	Brenner, 1971.
10.77(3)	----------	----------	----------	----------	----------	----------	6.91(3)	AA	Brimhall and Embree, 1971.
11.25	----------	1.97	2.11	5.61	----------	----------	7.12	AA	Buckley and Cranston, 1971.
10.69	----------	----------	----------	----------	----------	----------	7.12	AA	Schnetzler and Nava, 1971.
----------	----------	1.91	2.00	5.09	.55	.14	7.00	AA	Terashima, 1971c.
10.90	----------	----------	----------	----------	----------	----------	----------	AA	Schnetzler and others, 1972.
----------	----------	1.91	1.92	4.90	.56	.19	6.84	AA	Randall, 1972.
10.99	----------	2.02	2.13	5.12	.41	----------	6.76	XRF	De Vecchi and others, 1968.
----------	----------	1.92	2.08	4.92	.22	0	7.56	XRF	Ravburn, 1968.
----------	----------	1.81	1.89	4.95	.45	----------	6.90	XRF	Sahores, 1968.
----------	----------	2.00(2)	2.04(2)	5.02(2)	.59(2)	.16(2)	7.06(2)	XRF uncorrected	Wright, 1968.

TABLE 104.—*Determinations of major and minor constituents in eight USGS standard rock samples (percent)*—Continued

W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1	Method	Reference
						CaO—Continued			
----------	----------	1.91	2.01	4.83	.51	.11	----------	XRF	Hooper and Atkins, 1969.
10.8(2)	1.31(2)	1.96(2)	2.04(2)	4.96(2)	----------	----------	6.97(2)	XRF	Schneider, 1969.
10.98	1.37	1.89	2.04	4.98	.68	.20	6.88	XRF	Schroll and Stepan, 1969.
10.72	----------	----------	----------	----------	----------	----------	----------	XRF	Parker, 1970.
10.98	----------	1.96	1.99	4.66	----------	----------	6.74	XRF	Ragland, 1970.
----------	----------	----------	----------	4.88(9)	----------	----------	----------	XRF	Murad, 1971.
----------	----------	1.89	1.95	4.94	----------	----------	6.84	XRF	Aubert and Desjardins, 1971.
10.94	1.33	1.97	2.01	5.01	.53	.16	6.98	XRF	Fabbi, 1972a.
----------	----------	1.91	2.00	4.92	.54	.12	7.01	XRF	Kaye and Chappell, 1972.
10.5(10)	----------	2.18(10)	----------	4.93(10)	----------	----------	----------	Microprobe	Ruckledge and others, 1970.
----------	1.41(2)	2.00	2.16	4.94(2)	0.55	0.15	7.08(2)	----do	Mori and others, 1971.
11.08	----------	1.82	1.68	4.74	----------	----------	6.98	INAA	Filby and Haller, 1969; Filby and others, 1970.
10.68(4)	----------	----------	----------	----------	----------	----------	7.12(4)	INAA	Wyttenbach, 1969.
10.8	----------	----------	----------	----------	----------	----------	6.6	INAA	Goles and others, 1971.
----------	----------	----------	----------	----------	----------	----------	6.98(5)	NAA	Brunfelt and Steinnes, 1969c.
10.5(2)	1.32(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
----------	----------	1.54	----------	5.42	----------	----------	6.60(2)	NAA	Morrison and others, 1969.
----------	----------	----------	----------	----------	----------	----------	7.0	NAA	Morrison and Kashuba, 1969; Morrison, 1971.
----------	----------	----------	----------	4.80	.60	.21	6.87	Photon activation	Van Zelst, 1971b.
----------	----------	----------	----------	4.92	----------	.15	6.87	----do	Van Zelst, 1971a.
----------	----------	----------	----------	----------	.46	----------	7.21	Proton activation	Van Zelst, 1971b.
----------	----------	----------	----------	----------	----------	----------	5.9	ID	Krähenbühl and others, 1972.
						Na_2O			
2.16	3.10	----------	----------	----------	----------	----------	----------	OS	Dümecke, 1968.
----------	----------	----------	----------	----------	----------	----------	2.2	SSMS	Morrison and Kashuba, 1969.
2.10(3)	3.38(2)	----------	----------	----------	----------	----------	----------	Chemical	Bernas, 1968.
----------	----------	----------	----------	----------	----------	----------	3.36	----do	Maxwell and Abbey in Maxwell and others, 1970.
2.19(6)	----------	----------	----------	----------	----------	----------	----------	Ion exchange	Strelow and others, 1968.
2.17(4)	----------	----------	----------	4.29(4)	0.0022(4)	0.0051	----------	----do	Toerien, 1969.
2.13(8)	3.26(8)	----------	----------	----------	----------	----------	----------	Fl phot	Karkare, 1965.
----------	3.26(2)	----------	----------	----------	----------	----------	----------	----do	Borgen, 1967.
2.16	3.59	----------	----------	----------	----------	----------	----------	----do	Roelandts and Duchesne, 1968.
----------	----------	----------	----------	----------	.0070(5)	.0076(5)	----------	----do	Schlocker, 1968.
----------	----------	4.38	2.77	4.36	.00	.03	3.23	----do	Wright, 1968.
----------	----------	4.07(8)	2.81(8)	4.24(8)	.008(10)	.010(10)	3.35(8)	----do	Peters, 1969.
2.33(7)	3.26(2)	4.11(5)	2.78(4)	4.50(3)	----------	----------	3.56(2)	----do	A. C. S. Smith, 1970.
----------	----------	4.23(4)	2.77(4)	4.22	.11(4)	.07(4)	3.2(4)	----do	Langer, 1971.
2.22(6)	----------	----------	----------	----------	.0091(3)	.0079(3)	----------	----do	McCabe and others, 1972.
----------	----------	3.98	2.80	4.27	.00	.03	3.31	AA	Abbey, 1968.
----------	----------	3.56	2.53	4.03	.27	.27	3.06	AA	Butler, 1968 (5890 Na).
2.09	3.21	4.00	2.53	4.03	----------	----------	----------	AA	Butler and Kokot, 1969 (5890 Na).
----------	----------	4.04	2.76	4.21	1.34	1.34	3.38	AA	Butler, 1968 (3303 Na).
2.14	3.29	4.04	2.76	4.20	----------	----------	3.38	AA	Butler and Kokot, 1969 (3303 Na).
2.11(5)	----------	4.00(5)	----------	----------	----------	----------	----------	AA	Langmyhr and Paus, 1968.
----------	----------	4.11	2.91	4.20	.0100	.0067	3.35	AA	Luhn, 1968.
----------	----------	----------	2.86(5)	4.25(5)	----------	.068(5)	3.12(5)	AA	Langmyhr and Paus, 1969.
2.19	----------	3.89	2.90	4.11	----------	----------	3.04	AA	Sighinolfi, 1969.
2.17(4)	----------	----------	----------	4.29(4)	<0.02	<0.02	----------	AA	Strelow and others, 1969.
2.10(3)	----------	4.10(3)	2.80(3)	4.28(3)	----------	----------	3.26(3)	AA	Van Loon and Parissis, 1969.
2.17	3.67	----------	----------	----------	----------	----------	----------	AA	Boar and Ingram, 1970.
----------	----------	4.16	2.86	4.37	.03	.01	3.29	AA	Foscolos and Barefoot, 1970.
2.19	----------	4.26	2.70	4.33	----------	----------	3.27	AA	Ragland, 1970.
----------	----------	----------	----------	----------	.0022(4)	.0050(4)	----------	AA	Strelow and others, 1970.
----------	----------	----------	----------	4.30(2)	----------	----------	3.44	AA	Brenner, 1971.
2.14(3)	----------	----------	----------	----------	----------	----------	3.25(3)	AA	Brimhall and Embree, 1971.
2.03	----------	4.08	2.61	4.18	----------	----------	2.91	AA	Buckley and Cranston, 1971.
2.16	----------	----------	----------	----------	----------	----------	3.33	AA	Schnetzler and Nava, 1971.
----------	----------	4.11	2.81	4.23	.014	.008	3.28	AA	Randall, 1972.

TABLE 104.—*Determinations of major and minor constituents in eight USGS standard rock samples (percent)*—Continued

W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1	Method	Reference
Na_2O—Continued									
2.11	----------	----------	----------	----------	----------	----------	3.34	AA	Schnetzler and others, 1972.
----------	----------	----------	2.77(2)	4.20(2)	----------	----------	3.29(2)	AA	Vidal, 1972.
----------	----------	----------	3.18	4.68	.00	.60	4.05	XRF	Hooper and Atkins, 1969.
2.17	3.28	4.01	2.84	4.26	----------	----------	3.21	XRF	Schneider, 1969.
2.0	----------	----------	----------	----------	----------	----------	----------	XRF	Parker, 1970.
----------	----------	4.15	2.88	4.33	----------	----------	3.30	XRF	Aubert and Desjardins, 1971.
2.37(10)	----------	4.58(10)	----------	4.45(10)	----------	----------	----------	Microprobe	Ruckledge and others, 1970.
----------	3.36(2)	3.96	2.79	4.15(2)	.02	.08	3.24(2)	----do	Mori and others, 1971.
----------	----------	4.15(5)	----------	----------	----------	----------	----------	INAA	Aruscavage, 1969.
2.17	----------	4.06	2.61	4.15	0.030	0.036	2.84	INAA	Filby and Haller, 1969; Filby and others, 1970.
----------	----------	3.81	----------	4.10	----------	----------	3.32	INAA	Morrison and others, 1969; Morrison and Kashuba, 1969; Morrison, 1971.
2.20(4)	----------	----------	----------	----------	----------	----------	3.21	INAA	Wyttenbach, 1969.
----------	----------	----------	----------	----------	.0117(6)	.0134(6)	----------	INAA	Das, de Koning, and Oosterom, 1971.
2.13	----------	----------	----------	----------	----------	----------	3.18	INAA	Goles and others, 1971.
----------	----------	----------	----------	----------	.0088	----------	----------	INAA	Oosterman and Das, 1971.
2.05(2)	3.15(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
2.26	----------	3.77	----------	----------	.05	----------	2.29	NAA	Peterson and others, 1969.
2.11	----------	----------	----------	----------	.0055	.0058	----------	NAA	Müller, 1970.
----------	----------	----------	----------	----------	----------	----------	3.26	NAA	Brunfelt and others, 1971.
----------	----------	----------	----------	----------	----------	----------	3.17(2)	NAA	Krähenbühl and others, 1972.
K_2O									
0.57	5.18	----------	----------	----------	----------	----------	----------	OS	Dümecke, 1968.
.67(11)	6.3(6)	4.8(8)	6.6(4)	2.6(4)	----------	----------	1.80(5)	OS	Brenner, 1971.
----------	----------	----------	----------	----------	----------	----------	1.3	SSMS	Morrison and Kashuba, 1969.
.634(2)	5.83(4)	----------	----------	----------	----------	----------	----------	Chemical	Bernas, 1968.
----------	----------	4.46	5.50	2.87	0	0	1.69	----do	Rayburn, 1968.
----------	----------	----------	----------	----------	----------	----------	1.76	----do	Maxwell and Abbey in Maxwell and others, 1970.
.64(6)	----------	----------	----------	----------	----------	----------	----------	Ion exchange	Strelow and others, 1968.
.66(4)	----------	----------	----------	2.64(4)	.0038(4)	.0017(4)	----------	----do	Toerien, 1969.
.60	5.60	----------	----------	----------	----------	----------	----------	Fl phot	Roelandts and Duchesne, 1968.
----------	----------	----------	----------	----------	.0011(5)	.0011(5)	----------	----do	Schlocker, 1968.
.61(8)	5.52(8)	----------	----------	----------	----------	----------	----------	----do	Karkare, 1965.
----------	5.54(2)	----------	----------	----------	----------	----------	----------	----do	Borgen, 1967.
----------	5.51	----------	----------	----------	----------	----------	----------	----do	Jones and others, 1969.
----------	----------	4.44(8)	5.48(8)	2.82(8)	<.005	<.005	1.69(8)	----do	Peters, 1969.
.64(7)	5.55(2)	4.49(5)	5.47(4)	2.98(3)	<.05	----------	1.78(2)	----do	A. C. S. Smith, 1970.
----------	----------	4.48(2)	5.60(2)	2.90(2)	<.01	<.01	1.70(2)	----do	Bell and Doyle, 1971.
----------	----------	4.87(4)	5.61(4)	2.96	.10(4)	.08(4)	1.68(4)	----do	Langer, 1971.
----------	----------	----------	----------	2.96(2)	----------	----------	1.77(2)	----do	Ozima and Zashu, 1971.
.649(6)	----------	4.53(12)	5.58(12)	2.96(12)	.0016(10)	<.0013(9)	1.72(12)	----do	McCabe and others, 1972.
----------	----------	4.57	5.49	2.88	0.00	0.00	1.70	AA	Abbey, 1968.
----------	----------	4.23	5.48	2.93	.37	.37	1.80	AA	Butler, 1968 (7665K).
0.63	5.47	4.13	5.34	2.85	----------	----------	1.76	AA	Butler and Kokot, 1969 (7665 K).
----------	----------	4.45	5.68	2.87	.25	.25	1.74	AA	Butler, 1968 (4044K).
.61	5.48	4.34	5.54	2.79	----------	----------	1.70	AA	Butler and Kokot, 1969 (4044K).
.598(5)	----------	4.45(5)	----------	----------	----------	----------	----------	AA	Langmyhr and Paus, 1968.
----------	----------	4.44	5.51	2.93	.0020	.0014	1.71	AA	Luhn, 1968.
----------	----------	----------	5.56(5)	2.72(5)	----------	----------	1.72(5)	AA	Langmyhr and Paus, 1969.
.72	----------	4.42	5.30	2.92	----------	----------	1.66	AA	Sighinolfi, 1969.
.66(4)	----------	----------	----------	2.84(4)	<.005	<.005	----------	AA	Strelow and others, 1969.
.64(3)	----------	4.56(3)	5.43(3)	2.85(3)	----------	----------	1.73(3)	AA	Van Loon and Parissis, 1969.
.63	5.55	----------	----------	----------	----------	----------	----------	AA	Boar and Ingram, 1970.
----------	----------	4.28	5.60	2.88	.00	.06	1.61	AA	Foscolos and Barefoot, 1970.
----------	----------	----------	----------	----------	.0037(4)	.0017(4)	----------	AA	Strelow and others, 1970.
----------	----------	----------	----------	2.87(2)	----------	----------	----------	AA	Brenner, 1971.
.63(3)	----------	----------	----------	----------	----------	----------	1.73(3)	AA	Brimhall and Embree, 1971.
.64	----------	4.47	5.65	2.82	----------	----------	1.54	AA	Buckley and Cranston, 1971.
.71	----------	----------	----------	----------	----------	----------	1.73	AA	Schnetzler and Nava, 1971.

TABLE 104.—*Determinations of major and minor constituents in eight USGS standard rock samples (percent)*—Continued

W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1	Method	Reference
					K_2O—Continued				
----------	----------	4.34	5.57	2.91	.008	.007	1.70	AA	Randal, 1972.
----------	----------	----------	----------	----------	.02	----------	----------	AA	Schnetzler and others, 1972.
----------	----------	----------	5.49(4)	2.93(2)	----------	----------	1.69(2)	AA	Vidal, 1972.
0.60	----------	4.62	5.58	3.17	----------	----------	1.71	XRF	De Vecchi and others, 1968.
----------	----------	4.46	5.55	2.80	----------	----------	1.71	XRF	Rayburn, 1968.
----------	----------	4.69	5.75	2.99	0.04	----------	1.77	XRF	Sahores, 1968.
----------	----------	4.50(2)	5.47(2)	2.97(2)	.002(2)	0.003(2)	1.76(2)	XRF uncorrected	Wright, 1968.
----------	----------	4.71	----------	2.97	.02	.03	1.72	XRF	Hooper and Atkins, 1969.
.68(2)	5.38(2)	4.40(2)	5.46(2)	2.90(2)	----------	----------	1.70(2)	XRF	Schneider, 1969.
.64	5.48	4.46	5.60	2.71	.0035	.0017	1.72	XRF	Schroll and Stepan, 1969.
.65	----------	----------	----------	----------	----------	----------	----------	XRF	Parker, 1970.
.63	----------	4.58	5.35	2.93	----------	----------	1.82	XRF	Ragland, 1970.
----------	----------	4.53	5.38	3.00	----------	----------	1.61	XRF	Aubert and Desjardins, 1971.
----------	----------	----------	----------	3.04(9)	----------	----------	----------	XRF	Murad, 1971.
.61	5.46	4.38	5.46	2.93	.00	.00	1.70	XRF	Fabbi, 1972a.
----------	----------	4.48	5.53	2.92	<.003	<.003	1.71	XRF	Kaye and Chappell, 1972.
.67(10)	----------	4.95(10)	----------	3.04(10)	----------	----------	----------	Microprobe	Ruckledge and others, 1970.
----------	----------	4.38	----------	3.02(2)	.04	.09	1.82(2)	----do	Mori and others, 1971.
.65(2)	5.65(2)	----------	----------	----------	----------	----------	----------	γ-counting	de Ruyter, 1968.
----------	----------	4.51(4)	5.59(4)	2.92(4)	----------	----------	1.75(4)	----do	Gasparini, 1969.
.63	5.52	4.58	5.64	2.84	----------	----------	1.67	----do	Cherry and others, 1970.
----------	----------	4.58(5)	----------	----------	----------	----------	----------	INAA	Aruscavage, 1969.
----------	----------	4.5	----------	2.8	----------	----------	1.63(2)	INAA	Morrison and others, 1969.
0.55	----------	----------	5.40	2.71	0.014	0.022	1.44	INAA	Filby and others, 1970.
----------	----------	----------	----------	----------	----------	----------	1.60	NAA	Brunfelt and others, 1971.
----------	----------	3.76(2)	----------	----------	----------	----------	1.57(2)	INAA	Kuykendall and others, 1971.
----------	----------	----------	----------	----------	<.0012	<.0018	----------	INAA	Oosterman and Das, 1971.
----------	----------	4.53	----------	----------	----------	----------	----------	NAA	Das and others, 1969, 1970.
.55	----------	----------	4.76	2.71	.014	.022	1.44	NAA	Filby and Haller, 1969.
----------	----------	----------	----------	----------	----------	----------	1.7	NAA	Morrison and Kashuba, 1969; Morrison, 1971.
.54	----------	6.5	----------	----------	.14	----------	1.2	NAA	Peterson and others, 1969.
----------	----------	----------	----------	----------	----------	----------	1.10(3)	NAA	Allen and others, 1970; Haskin and others, 1970.
.64	----------	----------	----------	----------	.0013	.0009	----------	NAA	Müller, 1970.
----------	----------	4.66	----------	----------	----------	.0008	----------	NAA	Rey and others, 1970.
----------	----------	----------	----------	----------	----------	----------	1.60(5)	NAA	Brunfelt and Steinnes, 1971b.
----------	----------	----------	5.60	----------	----------	.0012	1.710	ID	Hart, 1968.
----------	----------	----------	----------	----------	----------	----------	1.70(2)	ID	Gast and others, 1970.
.63	----------	----------	----------	----------	----------	----------	1.72(2)	ID	Philpotts and Schnetzler, 1970.
----------	----------	----------	----------	----------	.0073(2)	----------	----------	ID	Ozima and Zashu, 1971.
----------	----------	----------	----------	----------	----------	----------	1.68	ID	Schnetzler and Nava, 1971.
----------	----------	----------	----------	----------	----------	----------	1.70(2)	ID	Krähenbühl and others, 1972.
						H_2O^+			
0.46	----------	----------	----------	0.80	----------	----------	----------	Infrared	Breger and Chandler, 1969.
----------	----------	----------	----------	----------	4.7	----------	0.61	Chemical	Cattermole and Fuge, 1969.
----------	----------	----------	----------	----------	----------	----------	.66	----do	Maxwell and Abbey in Maxwell and others, 1970.
----------	----------	0.54	0.49	.46	4.81	0.23	1.11	----do	Randall, 1972.
----------	----------	.58(5)	.72(5)	.98(5)	4.75(8)	.35(5)	.93(5)	Modified Penfield	Peters, 1969.
----------	----------	.61	.56	.94	5.00	.53	1.59	----do	Foscolos, 1971.
						H_2O^-			
0.15	----------	0.16	0.04(5)	0.05(5)	----------	0.03(5)	0.04(5)	----------	Langmyhr and Paus, 1968, 1969.
----------	----------	.11(5)	.02(5)	1.03(5)	0.56(5)	.10(5)	.74(5)	----------	Peters, 1969.
----------	----------	.06	.12	.94	.22	.02	.68	----------	Foscolos and Barefoot, 1970.
----------	----------	----------	----------	----------	----------	----------	.86	----------	Maxwell and Abbey, in Maxwell and others, 1970.
----------	----------	----------	----------	.77	----------	----------	----------	----------	Murad, 1971.
.17	----------	----------	----------	----------	----------	----------	.86	----------	Schnetzler and Nava, 1971.
----------	----------	.05	<.05	1.22	.09	<.05	.27	----------	Randall, 1972.
						TiO_2			
1.12	0.28	----------	----------	----------	----------	----------	----------	OS	Dümecke, 1968.
----------	----------	0.45(10)	0.69(10)	1.07(10)	----------	----------	2.4(10)	OS	Fabbri and Vespignani-Balzani, 1969.
----------	----------	----------	----------	1.04	----------	----------	----------	OS	Ondrick and others, 1969.
----------	----------	.47	.63	1.14	----------	----------	2.51	OS	Avni, Harel, and Brenner, 1972.

TABLE 104.—*Determinations of major and minor constituents in eight USGS standard rock samples (percent)*—Continued

W-1	G-1	G-2	GSP-1	AGV-1	PCC-1	DTS-1	BCR-1	Method	Reference
					TiO_2—Continued				
1.09(12)	----------	.50(14)	.69(8)	1.10(8)	0.009(4)	----------	2.10(14)	OS	Brenner, 1971.
----------	----------	----------	----------	----------	----------	----------	1.82	SSMS	Morrison and Kashuba, 1969.
----------	----------	.48	.60	.99	.02	0.01	2.23	Chemical	Das, 1969.
1.03	.25	----------	----------	----------	----------	----------	----------	do	Bernas, 1968.
----------	----------	.47	.66	1.05	.01	.01	2.26	do	Rayburn, 1968.
----------	----------	----------	----------	----------	----------	----------	2.26	do	Maxwell and Abbey in Maxwell and others, 1970.
1.09(4)	----------	----------	----------	1.03(4)	.007(4)	.018(4)	----------	Ion exchange	Toerien, 1969.
.89	.23	----------	----------	----------	----------	----------	----------	Colorimetric	Roelandts and Duchesne, 1968.
----------	----------	----------	----------	----------	.02	----------	2.19	do	Schnetzler and others, 1972.
1.06(8)	.25(8)	----------	----------	----------	----------	----------	----------	Spectrophotometric	Karkare, 1965.
1.07(2)	.27(2)	----------	----------	----------	----------	----------	----------	do	Borgen, 1967.
1.12	.25	.46	.68	1.06	----------	----------	2.31	do	Casanova and others, 1968.
----------	----------	.46(5)	.62(5)	.98(5)	.010(8)	.006(8)	2.13(5)	do	Peters, 1969.
1.09(4)	----------	----------	----------	1.03(4)	.007(4)	.018(4)	----------	do	Strelow and others, 1969.
----------	----------	----------	----------	1.19	----------	----------	----------	do	Brenner, 1971.
----------	----------	.52(3)	.66(3)	1.03(3)	.014(3)	.034(3)	2.23(3)	do	Langer, 1971.
----------	----------	.60	.58	1.20	<.02	<.02	2.40	do	Randall, 1972.
1.12	0.27	----------	----------	----------	0.03	----------	2.25	AA	Galle, 1968.
1.08(5)	----------	0.46(5)	0.64(5)	1.01(5)	----------	----------	2.19(5)	AA	Langmyhr and Paus, 1968, 1969.
1.07(3)	----------	.46(3)	.63(3)	1.02(3)	----------	----------	2.23(3)	AA	Van Loon and Parissis, 1969.
1.08	.24	----------	----------	----------	----------	----------	----------	AA	Boar and Ingram, 1970.
----------	----------	.50	.67	1.17	.00	0.00	2.34	AA	Foscolos and Barefoot, 1970.
1.13	----------	.50	.70	1.08	----------	----------	2.17	AA	Buckley and Cranston, 1971.
.94	----------	----------	----------	----------	----------	----------	2.19	AA	Schnetzler and Nava, 1971.
----------	----------	.51	.68	1.03	<.01	<.01	2.21	AA	Terashima, 1971c.
----------	----------	----------	.62(2)	1.05(2)	----------	----------	2.24(2)	AA	Vidal, 1972.
1.07	.28	.48	.66	1.03	.03	----------	2.31	XRF	De Vecchi and others, 1968.
----------	----------	.48	.65	1.03	.02	.02	2.16	XRF	Rayburn, 1968.
----------	----------	.46(2)	.62(2)	1.02(2)	.01(2)	.004(2)	2.27(2)	XRF uncorrected	Wright, 1968.
1.06(3)	.28(3)	.51(3)	.68(3)	1.05(3)	----------	----------	2.26(3)	XRF	Schneider, 1969.
1.05	.27	.50	.67	1.08	.0083	.0073	2.20	XRF	Schroll and Stepan, 1969.
----------	----------	.48	.66	1.05	.01	.00	----------	XRF	Hooper and Atkins, 1969.
1.05	----------	.53	.70	1.06	----------	----------	2.30	XRF	Ragland, 1970.
----------	----------	.57	.75	1.13	----------	----------	2.29	XRF	Aubert and Desjardins, 1971.
----------	----------	----------	----------	1.07(9)	----------	----------	----------	XRF	Murad, 1971.
1.06	.25	.50	.67	1.08	.02	.02	2.25	XRF	Fabbi, 1972a.
1.01(10)	----------	.52(10)	----------	1.13(10)	----------	----------	----------	Microprobe	Ruckledge and others, 1970.
----------	.26(2)	.47	.64	1.06(2)	.02	.02	2.18(2)	do	Mori and others, 1971.
----------	----------	.48	.66	1.05	.006	.002	2.25	XRF	Kaye and Chappell, 1972.
----------	----------	----------	----------	----------	<0.02	----------	2.68	Proton activation	Van Zelst, 1971a, b.
1.08	----------	----------	----------	----------	----------	----------	2.22	INAA	Goles and others, 1971.
----------	----------	0.52	----------	1.23	----------	----------	2.25(2)	NAA	Morrison and others, 1969.
----------	----------	----------	----------	----------	----------	----------	2.3	NAA	Morrison and Kashuba, 1969; Morrison, 1971.
----------	----------	----------	----------	----------	----------	----------	2.15	NAA	Brunfelt and others, 1971.
					P_2O_5				
----------	----------	----------	----------	----------	----------	----------	0.396	SSMS	Morrison and Kashuba, 1969.
----------	----------	----------	----------	----------	----------	----------	.347	Chemical	Maxwell and Abbey in Maxwell and others, 1970.
0.12	0.08	----------	----------	----------	----------	----------	----------	Colorimetric	Roelandts and Duchesne, 1968.
.15	----------	----------	----------	----------	----------	----------	.37	do	Schnetzler and Nava, 1971.
.12	----------	----------	----------	----------	----------	----------	----------	do	Schnetzler and others, 1972.
.20(8)	.09(8)	----------	----------	----------	----------	----------	----------	Spectrophotometric	Karkare, 1965.
----------	.09(2)	----------	----------	----------	----------	----------	----------	do	Borgen, 1967.
.15	----------	----------	----------	----------	<0.02	<0.02	.38	do	Cattermole and Fuge, 1969.
----------	----------	0.13(8)	0.27(8)	0.49(8)	<.005	<.005	.35(8)	do	Peters, 1969.
----------	----------	----------	----------	.48	----------	----------	----------	do	Brenner, 1971.
----------	----------	.15	.28	.48	.003(2)	.006	.36	do	Langer, 1971.
----------	----------	.14	.30	.51	.03	.02	.40	XRF	Hooper and Atkans, 1969.
.13	.07	.13	.26	.50	----------	----------	.36	XRF	Schneider, 1969.
.14	.09	.14	.28	.45	----------	----------	.36	XRF	Fabbi, 1971a.
.14	.09	.12	.29	.49	.03	.02	.36	XRF	Fabbi, 1972a.

TABLE 104.—*Determinations of major and minor constituents in eight USGS standard rock samples (percent)*—Continued

W-1	G-1	G-2	GSP-1	AGV-1	PCC-1	DTS-1	BCR-1	Method	Reference
P_2O_5—Continued									
.14(10)	----------	.17(10)	----------	.52(10)	----------	----------	----------	Microprobe	Ruckledge and others, 1970.
.132(7)	----------	.132(7)	.295(4)	.501(4)	.0010(4)	.0016(4)	.361(4)	NAA, β counting	Steinnes, 1971b.
.130(3)	----------	.133(3)	.273(3)	.481(3)	----------	----------	.347(3)	NAA	Steinnes, 1971b.
.130(2)	----------	.140(2)	.280(2)	.470(2)	.0019(2)	.0022(2)	.377(2)	NAA	Steinnes, 1972b.
----------	----------	.13	.28	.50	<.003	<.003	.37	XRF	Kaye and Chappell, 1972.
MnO									
----------	----------	0.033(10)	0.034(10)	0.078(10)	----------	----------	0.169(10)	OS	Fabbri and Vespignani-Balzani, 1969.
----------	----------	----------	----------	.100	----------	----------	----------	OS	Ondrick and others, 1969.
----------	----------	.034	.043	.10	----------	----------	.18	Chemical	Stoch, 1969.
----------	----------	----------	----------	----------	----------	----------	.165	----do	Maxwell and Abbey in Maxwell and others, 1970.
0.16	0.02	----------	----------	----------	----------	----------	----------	Colorimetric	Roelandts and Duchesne, 1968.
----------	----------	----------	----------	----------	----------	----------	.18	----do	Schnetzler and others, 1972.
.19(8)	.04(8)	----------	----------	----------	----------	----------	----------	Spectrophotometric	Karkare, 1965.
----------	.03(2)	----------	----------	----------	----------	----------	----------	----do	Borgen, 1967.
.17	.025	.036	.039	.10	.11	.12	.18	----do	Casanova and others, 1968.
----------	----------	.044(5)	.042(5)	.09(5)	.12(89)	.12(8)	.19(5)	----do	Peters, 1969.
----------	----------	.03	.04	.09	.12	.12	.18	----do	Langer, 1971.
.123(4)	----------	----------	----------	.101(4)	.121(4)	.122(4)	----------	Ion exchange	Toerien, 1969.
.17	.02	----------	----------	----------	.12	----------	.19	AA	Galle, 1968.
.167(5)	----------	.033(5)	.040(5)	.096(5)	----------	.110(5)	.181(5)	AA	Langmyhr and Paus, 1968, 1969.
.173	----------	.035	.039	.100	.116	.114	.182	AA	Sighinolfi, 1969.
.123(4)	----------	----------	----------	.101(4)	.121(4)	.122(4)	----------	AA	Strelow and others, 1969.
.16(3)	----------	.03(3)	.03(3)	.08(3)	.12(3)	.11(3)	.19(3)	AA	Van Loon and Parissis, 1969.
----------	----------	.02	.03	.08	.12	.13	.17	AA	Foscolos and Barefoot, 1970.
.15(10)	.03(2)	.045(4)	.05(3)	.09(2)	.12(4)	----------	.18(2)	AA	A. C. S. Smith, 1970.
----------	----------	.052	.051	.091	.082	.093	.18	AA	Warr and Dinnin, 1970.
.17	----------	----------	----------	----------	----------	----------	.16	AA	Schnetzler and Nava, 1971.
----------	----------	.038	.043	.10	.15	.17	.19	AA	Randall, 1972.
----------	----------	----------	.04(2)	.10(2)	----------	----------	.19(2)	AA	Vidal, 1972.
.16	0.03	0.04	0.04	0.10	0.13	0.12	0.18	XRF	De Vecchi and others, 1968.
----------	----------	.04(2)	.04(2)	.10(2)	.13(2)	.14(2)	.19(2)	XRF uncorrected	Wright, 1968.
----------	----------	.05	.05	.10	.12	.12	.19	XRF	Hooper and Atkins, 1969.
.18(2)	.02(2)	.04(2)	.04(2)	.10(2)	----------	----------	.18(2)	XRF	Schneider, 1969.
.17	----------	.03	.04	.10	----------	----------	.18	XRF	Ragland, 1970.
.18	.026	----------	----------	----------	----------	----------	----------	XRF	Wolfe and Zeitlin, 1970.
----------	----------	.037	.044	.098	----------	----------	.176	XRF	Aubert and Desjardins, 1971.
.167	.026	.034	.040	.094	.135	.145	.185	XRF	Fabbi, 1972a.
.18(10)	----------	.00(10)	----------	.11(10)	----------	----------	----------	Microprobe	Ruckledge and others, 1970.
----------	0.1(2)	.05	.04	.06(2)	.09	.11	.18(2)	----do	Mori and others, 1971.
----------	----------	.03	.04	.10	.13	.14	.19	XRF	Kaye and Chappell, 1972.
CO_2									
0.044(4)	0.063(4)	0.062(4)	0.098(4)	0.0038(2)	.16(4)	0.065(4)	0.0041(2)	Gas chromatographic	Marinenko and May, 1970.
----------	----------	.04(3)	.07(3)	.02(3)	.09(3)	.04(3)	.02(3)	Chemical	Shapiro, 1971.
----------	----------	.12(2)	.21(2)	.10(2)	.20(2)	.11(2)	.10(2)	----------	Stoch, 1969.
----------	.12	.08	.12	.04	.18	.08	.02	Titrimetric, acetone medium.	Sen Gupta, 1970.
----------	.12	.09	.13	.04	.17	.07	----------	Titrimetric, pyridine medium.	Do.
O									
----------	----------	48.58	47.91	47.23	42.00	42.87	45.72	XRF	Fabbi and Volborth, 1968.
----------	----------	----------	----------	47.7(18)	----------	----------	45.8(18)	FNAA	Morgan and Ehmann, 1970; Ehmann and Morgan, 1970.
44.77(10)	----------	48.10(10)	47.66(10)	46.80(10)	46.54(10)	44.14(10)	44.91(10)	FNAA	Bibby, 1972.
----------	----------	48.11(26)	47.46(24)	47.71(23)	46.42(22)	43.81(22)	44.69(23)	FNAA	Gijbels, 1972.
----------	----------	----------	----------	----------	----------	----------	41	SSMS	Morrison and Kashuba, 1969.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*

[In parts per million, unless otherwise indicated. Number of determinations is given in parentheses following the value. Method: AA, atomic absorption; Chromat, chromatographic; EpINAA, epithermal instrumental neutron activation analysis; FA, fire assay; Fl phot, flame photometry; ID isotope dilution; IDMS, isotope dilution mass spectrographic; INAA instrumental neutron activation analysis; MS, mass spectrographic; NAA, neutron activation analysis; OS, optical spectrographic; RID, radioisotope dilution; SIE, selective ion electrode; SQ, semiquantitative; SSMS, spark source mass spectrometric; XRF, X-ray fluorescence]

W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1	Method	Reference
						Ag			
<10	<10	----------	----------	----------	----------	----------	----------	OS	Mikšovský, 1968.
----------	----------	<1	<1	<1	<1	<1	<1	OS	Ropert, Lecable, and Monjaux, 1968.
<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	OS	Huber-Schausberger and others, 1970.
----------	----------	<1	<1	<1	<1	<1	<1	OS	Moal and others, 1970.
<1	<1	<1	<1	<1	<1	<1	<1	OS	Thompson and others, 1970.
----------	----------	<.05	.11(15)	.10(15)	<.05	<.05	<.05	OS	Blackburn and others, 1971.
.07	----------	----------	----------	----------	----------	.03	----------	AA	Bratzel and others, 1972.
----------	----------	----------	----------	----------	----------	----------	.02	SSMS	Morrison and Kashuba, 1969.
----------	----------	.012(4)	.015(4)	.012(4)	.014(4)	.010(4)	.011(4)	NAA	Anoshin and Perezhogin, 1969.
.068(4)	----------	.040(2)	.084(2)	.094(2)	.0091(2)	.0104(2)	.036(2)	NAA	Brunfelt and Steinnes, 1969d.
----------	----------	----------	----------	----------	----------	----------	.018	NAA	Allen and others, 1970.
----------	----------	----------	----------	----------	----------	----------	.0266(2)	NAA	Ganapathy and others, 1970.
----------	----------	----------	----------	----------	----------	----------	.018(3)	NAA	Haskin and others, 1970.
----------	----------	----------	----------	----------	----------	----------	.028(4)	NAA	Anders and others, 1971.
----------	----------	----------	----------	----------	----------	----------	.031	NAA	Brunfelt and others, 1971.
----------	----------	----------	----------	----------	----------	----------	.028(5)	NAA	Brunfelt and Steinnes, 1971a.
.081(3)	.052(3)	.049(3)	.10(3)	.11(3)	.005(2)	.008(15)	.036(3)	NAA–FA	Greenland and Fones, 1971.
----------	----------	----------	----------	----------	----------	----------	.022(2)	NAA	Laul and others, 1972.
						As			
2.41(12)	----------	----------	----------	----------	----------	----------	----------	Photometric	Boström and Valdes, 1969.
1.31(3)	----------	----------	----------	----------	----------	----------	----------	NAA	Case and others, 1969.
2.8	0.74(2)	----------	----------	----------	----------	----------	----------	NAA	Hamaguchi and others, 1969.
1.7(2)	.52(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
----------	----------	0.33	----------	1.0	----------	----------	1.0(2)	NAA	Morrison and others, 1969.
----------	----------	----------	----------	----------	----------	----------	.840	NAA	Allen and others, 1970.
----------	----------	----------	----------	----------	----------	----------	.840(3)	NAA	Haskin and others, 1970.
1.31(3)	.43(3)	.2(2)	0.092(2)	.68(2)	0.05(2)	0.03	.58	NAA	Laul, Case, Wechter, and others, 1970.
----------	----------	----------	----------	----------	----------	----------	.60	NAA	Brunfelt and others, 1971.
----------	----------	----------	----------	----------	----------	----------	1.0	NAA	Morrison, 1971.
2.22(2)	----------	.26(2)	.093(2)	1.07(2)	.057(2)	.040(2)	.67(2)	NAA	Steinnes, 1972a.
						Au (ppb)			
1.6(3)	----------	----------	----------	----------	----------	----------	----------	Fluorimetric	Marinenko and May, 1968.
5.8(12)	3.3(10)	----------	----------	----------	----------	----------	----------	NAA	Crocket and others, 1968.
3.6(4)	----------	----------	----------	----------	----------	----------	----------	FA–NAA	Simon and Millard, 1968.
3.4(6)	----------	----------	----------	----------	----------	----------	----------	NAA	Simon and Millard, 1968.
----------	----------	1.2(4)	1.0(4)	0.66(4)	0.89(4)	0.70(4)	0.75(4)	NAA	Anoshin and Perezhogin, 1969.
4.4	2.2	.75	1.56	.66	.76	.85	.92	NAA Substoichiometric	Bartel, 1969.
4(2)	----------	----------	----------	----------	----------	----------	----------	NAA	Case and others, 1969.
4.6(8)	4.0(8)	----------	----------	----------	----------	----------	----------	NAA	Fritze and Robertson, 1969.
----------	----------	----------	----------	----------	----------	----------	.9	NAA	Allen and others, 1970.
----------	----------	1.1(3)	1.3(3)	.6(3)	.8(3)	.8(3)	.9(3)	NAA	Ehmann and others, 1970.
----------	----------	----------	----------	----------	----------	----------	.88(2)	NAA	Ganapathy and others, 1970.
----------	----------	1.09(2)	1.14(2)	.51(2)	2.28(2)	.91(2)	1.22(2)	NAA	Green, Law, and Campbell, 1970.
----------	----------	----------	----------	----------	----------	----------	.9(3)	NAA	Haskin and others, 1970.
4.2(2)	7.8(2)	1.2(2)	2.6(2)	.7(2)	3.2(2)	.8(2)	2.1(2)	NAA	Laul, Case, Wechter, and others, 1970.
3.62(2)	2.43(3)	----------	----------	----------	----------	----------	----------	NAA	Nomura and others, 1970.
2.0	----------	.86	----------	----------	----------	----------	.72(2)	NAA	Wasson and Baedecker, 1970.
----------	----------	----------	----------	----------	----------	----------	.51(4)	NAA	Anders and others, 1971.
4.3(5)	2.8(4)	.96(8)	----------	----------	----------	----------	----------	NAA	Anoshin and Perezhogin, 1971.
----------	----------	----------	----------	----------	----------	----------	.75	NAA	Brunfelt and others, 1971.
----------	----------	----------	----------	----------	----------	----------	.65(5)	NAA	Brunfelt and Steinnes, 1971b.
----------	----------	.67	1.1	.19	.8	.60	.57	NAA Substoichiometric	Gillum and Ehmann, 1971.
----------	----------	----------	----------	----------	1.02(2)	----------	----------	NAA	Millard and Bartel, 1971.
----------	----------	----------	----------	----------	----------	----------	.88(2)	NAA	Laul and others, 1972.
						B			
----------	----------	<20	<20	<20	<20	<20	<20	OS	Moal and others, 1970.
14.5(4)	2.2(5)	2.1(4)	<3	13(3)	<10	<10	9.5(4)	OS	Huber-Schausberger and others, 1970.
15(3)	----------	----------	----------	5(3)	----------	----------	2(3)	OS	Suhr and Smith, 1970.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1	Method	Reference
					B—Continued				
10(10)	<5	<5	<5	6(10)	6(10)	<5	6(10)	OS	Thompson and others, 1970.
9.0	1.7	----------	----------	----------	----------	----------	----------	Fluorimetric	Quijano-Rico and Wänke, 1969.
8.9(6)	1.7(4)	----------	----------	----------	----------	----------	----------	----do	Quijano-Rico, 1970.
----------	----------	----------	----------	----------	----------	----------	2.4	SSMS	Morrison and Kashuba, 1969.
					Ba				
----------	1,300	----------	----------	----------	----------	----------	----------	OS	Kowalski, 1967.
----------	----------	3,000	2,100	1,400	----------	----------	700	OS–SQ	Clark, 1968.
----------	----------	1,600(10)	1,180(10)	1,000(10)	----------	----------	675(10)	OS	Fabbri and Vespignani-Balzani, 1969.
----------	----------	2,062(3)	1,477(3)	1,217(3)	----------	----------	680	OS	Floyd and others, 1968.
172(2)	1,190(4)	----------	----------	----------	----------	----------	----------	OS	Murad, 1968.
----------	----------	1,500(2)	1,255(2)	1,075(2)	<10	<10	830(5)	OS	Dutra, 1969.
----------	----------	----------	----------	1,230	----------	----------	----------	OS	Ondrick and others, 1969.
----------	----------	----------	----------	----------	----------	----------	700	OS	Champ, in Maxwell and others, 1970.
----------	----------	1,860(2)	1,282(2)	1,250(2)	----------	----------	685	OS	Govindaraju, 1970b.
120(10)	----------	----------	----------	----------	----------	----------	----------	OS	Martin and Quintin, 1970.
----------	----------	1,715	1,220	1,250	<5	<5	720	OS	Moal and others, 1970.
167(3)	----------	----------	----------	----------	----------	----------	----------	OS	Suhr and Smith, 1970.
118(10)	>1,000	>1,000	>1,000	>1,000	2(10)	3(10)	>500	OS	Thompson and others, 1970.
150	1,140	----------	----------	----------	----------	----------	----------	OS	de Albuquerque, 1971.
----------	----------	1,750	1,300	1,300	5	6	710	OS	Avni, Harel, and Brenner, 1972.
184(4)	1,184(4)	2,289(5)	1,365(5)	1,377(5)	4(5)	3(5)	821(5)	OS	Blackburn and others, 1971.
140(6)	----------	2,100(5)	----------	----------	----------	----------	800(2)	OS	Brenner, 1971.
170(3)	1,140(4)	----------	----------	1,680	----------	----------	820	OS	Murad, 1971.
----------	----------	1,900	1,380	1,250	----------	----------	680	AA	Abbey, 1971.
----------	----------	1,820	1,220	1,190	<4	<4	650	AA	Terashima, 1971c.
170(2)	1,205(2)	2,035(2)	1,480(2)	1,210(2)	----------	----------	660(4)	AA	Luecke, 1971.
----------	----------	1,700	1,200	1,000	100	100	500	XRF	Guillemaut, 1968.
190	1,180	----------	----------	----------	----------	----------	----------	XRF	Fabbi, 1969.
228(2)	----------	2,000(2)	1,377(2)	1,272(2)	----------	----------	742(2)	XRF	Gunn, 1969.
----------	----------	2,350(2)	2,060(2)	1,340(2)	<20	<20	560(2)	XRF	Parker, 1969.
150	1,130	2,000	1,360	1,250	----------	----------	670	XRF	Schneider, 1969.
181	1,075	1,920	1,335	1,242	----------	----------	725	XRF	Willis and others, 1969.
170	1,060	----------	1,250	1,240	<10	<10	700	XRF	Fabbi, 1971c.
----------	----------	1,723	1,236	1,182	----------	----------	718	XRF	Heier and Thoresen, 1971.
----------	1,260(2)	----------	----------	----------	----------	----------	----------	XRF	Hirst and Kaye, 1971.
----------	----------	1,825	1,254	1,161	----------	----------	654	XRF	Sceal and Weaver, 1971.
----------	----------	----------	----------	----------	----------	----------	730	SSMS	Morrison and Kashuba, 1969.
----------	----------	1,950(5)	----------	----------	----------	----------	----------	INAA	Aruscavage, 1969.
187(2)	----------	1,703(2)	1,193(2)	1,071(2)	----------	----------	575(2)	EpINAA	Brunfelt and Steinnes, 1969c.
161	----------	----------	----------	----------	----------	----------	655	INAA	Goles and others, 1971.
----------	----------	1,780	1,010	1,100	----------	----------	----------	INAA	Whitley and others, 1971.
----------	----------	----------	960	1,240	100	100	----------	NAA	Filby and Haller, 1969.
167(2)	1,015(2)	1,627(2)	1,137(2)	1,060(2)	----------	----------	625(2)	NAA	Higuchi, Tomura, Takahashi, and others, 1969a, b.
----------	----------	1,310	----------	1,040	----------	----------	855(2)	NAA	Morrison and others, 1969.
----------	----------	----------	----------	----------	----------	----------	840	NAA	Morrison and Kashuba, 1969.
----------	----------	----------	----------	----------	----------	----------	656	NAA	Allen and others, 1970.
----------	----------	----------	----------	----------	----------	----------	656(3)	NAA	Haskin and others, 1970.
----------	----------	----------	----------	----------	----------	----------	580(5)	NAA	Brunfelt and others, 1971.
----------	----------	----------	----------	----------	----------	----------	840	NAA	Morrison, 1971.
160.5(3)	----------	1,869(2)	1,301(2)	1,208(2)	1.2(2)	2.4(2)	678(2)	IDMS	deLaeter and others, 1969.
----------	----------	----------	----------	----------	----------	----------	700(2)	IDMS	Gast and others, 1970.
157(4)	----------	----------	----------	----------	----------	----------	646(2)	IDMS	Philpotts and Schnetzler, 1970.
----------	----------	----------	----------	----------	----------	----------	685	ID	Schnetzler and Nava, 1971.
----------	----------	----------	----------	----------	----------	----------	670(3)	ID	Krähenbühl and others, 1972.
					Be				
0.6(4)	3.7(4)	3.0(15)	2.1(15)	3.5(15)	<1	<1	<1	OS	Blackburn and others, 1971.
----------	----------	2(2)	<2	<2	<2	<2	<1	OS	Dutra, 1969.
1.0(4)	3.4(5)	2.8(4)	.5(5)	1.9(3)	<1	<1	2.2(4)	OS	Huber-Schausberger and others, 1970.
----------	----------	3	<3	5	<3	<3	<3	OS	Moal and others, 1970.
.5(3)	----------	----------	----------	2.1(3)	----------	----------	1.7(3)	OS	Suhr and Smith, 1970.
.7	3.0	2.6	1.5	2.3	<.5	<.5	----------	OS	Hofmeyr, 1972.
.63	----------	2.07	----------	----------	----------	----------	1.53	Gas chromotographic	Eisentraut and others, 1971.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1	Method	Reference
Be—Continued									
.63	----------	----------	----------	----------	----------	----------	1.53	----do	Sievers and others, 1971.
~1	2.7	2.3	~1	1.6	----------	----------	2.3	AA	Luecke, 1971.
----------	----------	3.20(2)	1.76(2)	1.23(2)	.03(2)	.07(2)	1.59(2)	Fluorimetric	Meehan, 1969.
Bi									
<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	OS	Huber-Schausberger and others, 1970.
----------	----------	<3	<3	5	<3	<3	6	OS	Moal and others, 1970.
<2	<22	<2	<2	<2	<2	<2	<2	OS	Thompson and others, 1970.
.044(2)	----------	----------	----------	----------	----------	----------	----------	NAA	Case and others, 1969.
----------	----------	----------	----------	----------	----------	----------	.0423(2)	NAA	Ganapathy and others, 1970.
.0435(2)	.046(2)	.0376(2)	.0368(2)	.0564(2)	.0008(2)	.0048(2)	.0467(2)	NAA	Laul, Case, Schmidt-Bleek, and Lipschutz, 1970.
----------	----------	----------	----------	----------	----------	----------	.047(4)	NAA	Anders and others, 1971.
.048	.083	.100	.018	.053	<.001	.029	.050	NAA	Marowsky, 1971a, c.
.050(2)	----------	----------	----------	.053(2)	----------	----------	----------	NAA	Marowsky and Wedepohl, 1971.
----------	----------	----------	----------	----------	----------	----------	.046(2)	NAA	Laul and others, 1972.
.0516(8)	.0519(8)	.0410(16)	.0367(16)	.0555(16)	.0057(8)	.0051(8)	.0496(16)	ID	Greenland and Campbell, 1972.
Br									
1.1	1.2	----------	----------	----------	----------	----------	----------	NAA	Walters, 1967.
.42(2)	.17(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
.15	----------	----------	----------	----------	----------	----------	----------	NAA	Reed and Jovanovic, 1969.
----------	----------	0.18	----------	0.31	----------	----------	0.24(2)	NAA	Morrison and others, 1969.
----------	----------	----------	----------	----------	----------	----------	.187	NAA	Allen and others, 1970.
----------	----------	----------	----------	----------	----------	----------	.124(2)	NAA	Ganapathy and others, 1970.
----------	----------	----------	----------	----------	----------	----------	.187(3)	NAA	Haskin and others, 1970.
----------	----------	----------	----------	----------	----------	----------	.046(2)	NAA	Anders and others, 1971.
----------	----------	----------	----------	----------	----------	----------	<.2	NAA	Brunfelt and Steinnes, 1971b.
----------	----------	----------	----------	----------	----------	----------	.25	NAA	Morrison, 1971.
----------	----------	----------	----------	----------	----------	----------	.093(2)	NAA	Laul and others, 1972.
Total C									
----------	----------	----------	----------	----------	----------	----------	330(5)	Combustion-gas chromatographic.	Moore and others, 1970.
----------	----------	----------	----------	----------	----------	----------	78.5(30)	----do	Moore and Lewis, this volume, p. 124.
----------	----------	----------	----------	----------	----------	----------	53.2(6)	----do	Chandler and Breger, this volume, p. 125.
Cd									
0.164	0.047	0.030	0.068	0.089	0.029	0.154	0.037	AA	Iida and Yamasaki, 1970.
----------	----------	----------	----------	----------	----------	----------	.099	NAA	Ganapathy and others, 1970.
----------	----------	.059(2)	----------	----------	----------	----------	.160	NAA	Rey and others, 1970.
----------	----------	----------	----------	----------	----------	----------	.129(5)	NAA	Anders and others, 1971.
.155	----------	.027	.064	.075	.017	.010	.082	NAA	Baedecker and others, 1971.
.151	.022	----------	.050	.115	.195	.110	----------	NAA	Marowsky, 1971a, c.
.153	----------	----------	----------	----------	----------	----------	----------	NAA	Marowsky and Wedepohl, 1971.
----------	----------	----------	----------	----------	----------	----------	.3	SSMS	Morrison and Kashuba, 1969.
Ce									
20	200	----------	----------	----------	----------	----------	----------	OS	Cohen and others, 1968.
----------	----------	165.0(3)	396.0(2)	58.5(3)	----------	----------	51.9(3)	Ion exchange-XRF	Eby, 1972.
----------	----------	161	351	76	----------	----------	67	XRF	Sceal and Weaver, 1971.
22	----------	----------	----------	----------	----------	----------	56	XRF	Kaye, 1972.
----------	----------	137	----------	56	----------	----------	----------	INAA	Green and others, 1969.
----------	----------	141	356	59	----------	----------	43	INAA	Scott, 1969.
19	----------	130	400	55	----------	----------	49	INAA	Filby and others, 1970.
27.4	----------	157	----------	----------	----------	----------	----------	INAA	Melson, 1970.
----------	----------	----------	----------	109	----------	----------	74	INAA	B. C. Smith, 1970.
23	----------	----------	----------	----------	----------	----------	52	INAA	Goles and others, 1971.
----------	----------	139	399	56	----------	----------	----------	INAA	Whitley and others, 1971.
26.3(5)	192(5)	180(2)	494(2)	82.2(2)	.094	.039	62.2(2)	NAA	Higuchi, Tomura, Onuma, and Hamaguchi, 1969.
24(2)	130(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
----------	----------	----------	----------	----------	----------	----------	43	NAA	Morrison and Kashuba, 1969.
----------	----------	110	----------	58	----------	----------	43(2)	NAA	Morrison and others, 1969.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1	Method	Reference
						Ce—Continued			
21	----------	140	----------	----------	----------	----------	35	NAA	Peterson and others, 1969.
27	208	----------	----------	----------	----------	----------	----------	NAA	Schilling and Winchester, 1969.
----------	----------	----------	----------	----------	----------	----------	54	NAA	Allen and others, 1970.
----------	----------	----------	----------	----------	----------	----------	54.22(3)	NAA	Denechaud and others, 1970.
22.9	184	----------	----------	----------	----------	----------	----------	NAA	Graber and others, 1970.
----------	----------	----------	----------	----------	----------	----------	54.2(3)	NAA	Haskin and others, 1970.
23.5	170	----------	----------	----------	----------	----------	----------	NAA	Higuchi and others, 1970.
----------	----------	170(2)	----------	----------	----------	0.076	51(2)	NAA	Rey and others, 1970.
----------	----------	----------	----------	----------	----------	----------	53	NAA	Brunfelt and others, 1971.
----------	----------	150	----------	----------	----------	----------	----------	NAA	Das and Zonderhuis, 1971.
----------	----------	----------	----------	----------	----------	----------	43	NAA	Morrison, 1971.
22.1	----------	----------	----------	----------	----------	----------	52	NAA	Ragland and others, 1971.
----------	----------	165	364	69	----------	----------	----------	NAA	Whitley and others, 1971.
----------	----------	175	----------	----------	----------	----------	45(2)	NAA	Krähenbühl and others, 1972.
19	----------	----------	----------	----------	----------	----------	----------	SSMS	Graham and Nicholls, 1969.
----------	----------	----------	----------	----------	----------	----------	45	SSMS	Morrison and Kashuba, 1969.
----------	----------	----------	----------	----------	----------	----------	54.9(2)	IDMS	Gast and others, 1970.
23.4(4)	----------	----------	----------	----------	----------	----------	53.9(2)	IDMS	Philpotts and Schnetzler, 1970.
----------	----------	----------	----------	----------	----------	----------	52.9	ID	Schnetzler and Nava, 1971.
						Cl			
188	----------	----------	----------	----------	85	10	62	Spectrophotometric	Cattermole and Fuge, 1969.
188	----------	99	305	----------	----------	----------	----------	do	Fuge and Power, 1969.
219	75	54	305	108	59	11	64	XRF	Fabbi, 1971b; Fabbi and Espos, 1972b.
212	----------	----------	----------	120	----------	----------	43	SQ–XRF	B. C. Smith, 1970.
----------	----------	----------	----------	----------	----------	----------	72	SSMS	Morrison and Kashuba, 1969.
----------	----------	49	----------	110	----------	----------	99(2)	INAA	Morrison and others, 1969.
93	30	----------	----------	----------	----------	----------	----------	NAA	Walters, 1967.
16.3	----------	----------	----------	----------	----------	----------	----------	NAA	Reed and Jovarovic, 1969.
----------	----------	----------	----------	----------	----------	----------	30.5	NAA	Allen and others, 1970.
----------	----------	----------	----------	----------	----------	----------	30.5(3)	NAA	Haskin and others, 1970.
----------	----------	----------	----------	----------	----------	----------	99	NAA	Morrison and Kashuba, 1969
156(4)	54.8(4)	----------	----------	----------	----------	----------	----------	NAA	Quijano-Rico, 1970.
----------	----------	84(4)	347(2)	----------	----------	----------	----------	Spectrophotometric	Haynes and Clark, 1972.
----------	----------	75(4)	351(2)	----------	----------	----------	----------	SIE	Do.
						Co			
----------	----------	8	8	15	100	150	28	OS–SQ	Clark, 1968.
----------	----------	4(3)	5(3)	17(3)	195(3)	221(3)	45(3)	OS	Floyd and others, 1968.
39	<10	----------	----------	----------	----------	----------	----------	OS	Mikšovský, 1968.
----------	----------	5	5	9	95	100	20	OS	Ropert and others, 1968.
----------	----------	4.4(5)	7(3)	17(4)	120(2)	145(2)	42.5(6)	OS	Dutra, 1969.
----------	----------	25(2)	<20	22(2)	----------	----------	55(2)	OS	Govindaraju, 1970b.
38(10)	----------	----------	----------	----------	----------	----------	----------	OS	Martin and Quintin, 1970.
----------	----------	<5	7	17	112	133	41	OS	Moal and others, 1970.
48(10)	2(10)	8(10)	2(10)	23(10)	95(10)	110(10)	42(10)	OS	Thompson and others, 1970.
39	----------	----------	----------	----------	----------	----------	----------	OS	de Albuquerque, 1971.
----------	----------	4	7	20	126	149	36	OS	Avni, Harel, and Brenner, 1972.
43(9)	----------	7(12)	8(6)	22(9)	127(6)	150(9)	40(11)	OS	Brenner, 1971.
45(4)	2.6(4)	9.7(15)	8.8(15)	9.7(15)	120(15)	164(15)	36(15)	OS	Blackburn and others, 1971.
60.0	----------	----------	8.4	----------	----------	----------	34	OS	Gerasimovskiy and Laktionova, 1971.
53(17)	2.0(9)	4.4(7)	5.7(7)	15.7(9)	123(10)	137(10)	36.2(9)	OS	Huber-Schausberger and others, 1970.
51	<6	<6	6.0	13	125	150	35	OS	Hofmeyr, 1972.
44	<20	<20	<20	<20	110	----------	45	OS	Murad, 1971.
----------	----------	4.02(3)	6.40(6)	14.2(6)	----------	----------	34.5(6)	Colorimetric	Bodart, 1970.
----------	----------	5.0	7.8	15.0	105.0	113.0	7.0	Photometric	Stähle, 1970.
----------	----------	5	8	12	120	130	40	SQ–paper chromat	Agrinier, 1968.
----------	----------	21.6(6)	22.5(6)	25(6)	110(6)	144(6)	38.8(6)	AA	Balous and Thiel, 1968.
48	2.1	4.1	8.3	16	104	123	36	AA	Nagura and Iida, 1968.
65(2)	----------	----------	----------	----------	----------	----------	----------	AA	Bender and Schultz, 1969.
46	----------	11	14	23	97	106	45	AA	Price, 1969.
47.3	----------	10.4	9.2	22.5	----------	----------	40.9	AA	Fletcher, 1970.
48	2.1	4.1	8.3	16	104	123	36	AA	Iida and Yamasaki, 1970.
44(2)	----------	5.0(2)	6.9(2)	15.0(2)	115(2)	138(2)	36(2)	AA	Mountjoy, 1970.
45(4)	7(4)	7(4)	10(4)	22(4)	----------	----------	39(4)	AA	Rose, 1970.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W-1	G-1	G-2	GSP-1	AGV-1	PCC-1	DTS-1	BCR-1	Method	Reference
Co—Continued									
48.5(8)	----------	----------	----------	22(2)	----------	----------	43(2)	AA	Smith and Rose, 1970.
55	----------	20	24	32	----------	----------	46	AA	Buckley and Cranston, 1971.
----------	----------	6(3)	8(3)	16(3)	88(3)	120(3)	38(3)	AA	Cioni and others, 1971.
----------	----------	9.2(5)	14(5)	24(5)	109(5)	131(5)	39(5)	AA	Terashima, 1971a, b.
52	----------	----------	----------	----------	116	133	----------	AA	Beccaluva and Venturelli, 1972.
47	<5	<5	<5	20	----------	----------	45	AA	Walsh, 1972.
----------	----------	8(2)	19(2)	25(2)	119(2)	148(2)	30(2)	XRF	Parker, 1969.
48	----------	7	12	----------	----------	----------	----------	XRF	Feather, 1971.
45	----------	5	8	20	140	149	35	XRF	Goodman, 1971.
----------	----------	----------	----------	17.1(3)	107.1(3)	186.6(3)	47.1(3)	XRF	Blount and others, 1972.
48	----------	----------	----------	----------	131	----------	39	XRF	Kaye, 1972.
----------	----------	----------	----------	----------	----------	----------	45	SSMS	Morrison and Kashuba, 1969.
50	----------	5.0	5.0	17.0	100	90	30	INAA	Filby and Haller, 1969; Filby and others, 1970.
49.4	----------	5.5	7.6	15.3	121	145	41.2	INAA	Dale and others, 1970.
----------	----------	----------	----------	----------	----------	----------	37.9	INAA	Goles and others, 1971.
----------	----------	6.8	5.8	20.2	----------	----------	----------	INAA	Whitley and others, 1971.
----------	----------	4.7	7	14	105	126	38	NAA	Schiltz, 1968.
43.5	----------	----------	----------	----------	----------	----------	----------	NAA	Case and others, 1969.
43(2)	2.7(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
----------	----------	----------	----------	----------	----------	----------	43	NAA	Morrison and Kashuba, 1969.
----------	----------	4.9	----------	17	----------	----------	43(2)	NAA	Morrison and others, 1969.
50	----------	5.7	----------	----------	116	----------	36.5	NAA	Peterson and others, 1969.
----------	----------	----------	----------	----------	----------	----------	35.8	NAA	Allen and others, 1970.
----------	----------	----------	----------	----------	----------	----------	36.0(2)	NAA	Ganapathy and others, 1970.
----------	----------	----------	----------	----------	----------	----------	35.8(3)	NAA	Haskin and others, 1970.
44.5(5)	----------	4.35(5)	6.40(5)	14.8(5)	----------	----------	36.2(5)	NAA	Johansen and Steinnes, 1970.
43.5	2.5	4.2	----------	12.0	111	162	41.3	NAA	Laul, Case, Wechter, and others, 1970.
----------	----------	----------	----------	----------	----------	----------	36.3	NAA	Osawa and Goles, 1970.
----------	----------	----------	----------	----------	----------	----------	37(4)	NAA	Anders and others, 1971.
----------	----------	----------	----------	----------	----------	----------	36.2	NAA	Brunfelt and others, 1971.
----------	----------	----------	----------	----------	----------	----------	43	NAA	Morrison, 1971.
----------	----------	----------	----------	----------	----------	----------	36.0(2)	NAA	Laul and others, 1972.
Cr									
----------	----------	15	15	15	2,000	3,000	20	OS-SQ	Clark, 1968.
----------	----------	8(3)	12(2)	9(3)	3,350(3)	3,400(3)	11(3)	OS	Floyd and others, 1968.
120	42	----------	----------	----------	----------	----------	----------	OS	Mikšovský, 1968.
----------	----------	20	20	20	----------	----------	50	OS	Ropert and others, 1968.
----------	----------	8.2(2)	17(2)	45(4)	2,370(2)	3,900(2)	10.8(3)	OS	Dutra, 1969.
----------	----------	<20	<20	<20	----------	----------	52(2)	OS	Govindaraju,, 1970b.
125(17)	17	10	13.1(7)	13.8(9)	2,840(10)	4,230(10)	15.1(9)	OS	Huber-Schausberger and others, 1970.
112(10)	----------	----------	----------	----------	----------	----------	----------	OS	Martin and Quintin, 1970.
----------	----------	9	11	10	2,870	3,870	15	OS	Moal and others, 1970.
105	20	----------	----------	----------	----------	----------	----------	OS	de Albuquerque, 1971.
----------	----------	26	14	15	3,000	4,700	10	OS	Avni, Harel and Brenner, 1972.
130(4)	13(4)	10(5)	14(15)	16.5(15)	2,440(15)	3,715(15)	23(15)	OS	Blackburn and others, 1971.
117(11)	----------	----------	----------	----------	3,300(10)	4,750(13)	----------	OS	Brenner, 1971.
108.8	----------	----------	15.8	----------	----------	----------	18.5	OS	Gerasimovskiy and Lakionova, 1971.
116(10)	7(10)	5(10)	6(10)	6(10)	2,850(10)	3,970(10)	28(10)	OS	Thompson and others, 1970.
----------	----------	----------	----------	----------	----------	3,530	----------	Colorimetric	Fuge, 1967.
----------	----------	----------	----------	----------	2,700	4,100	----------	do	Pouget and others, 1968.
----------	----------	----------	----------	----------	2,860(20)	4,298(20)	----------	do	Huffman and others, 1971.
----------	----------	----------	----------	----------	2,800(4)	5,300(4)	----------	Photometric	Langer, 1971.
112	----------	7	11	9	----------	----------	15	AA	Price, 1969.
128	----------	10	14	12	----------	----------	15	AA	Sighinolfi, 1969.
----------	----------	10(4)	12(4)	10(4)	----------	----------	----------	AA	Rose, 1970.
117(2)	----------	----------	----------	----------	----------	----------	----------	AA	A. C. S. Smith, 1970.
122.5(8)	----------	----------	----------	8(2)	----------	----------	12(2)	AA	Smith and Rose, 1970.
174	----------	20	54	20	----------	----------	56	AA	Buckley and Cranston, 1971.
----------	----------	----------	----------	----------	2,868(20)	4,253(20)	----------	AA	Huffman and others, 1971.
123	----------	----------	----------	----------	----------	----------	<34	AA	Schnetzler and Nava, 1971.
----------	----------	8.6(5)	13(5)	12.6(5)	2,690(5)	4,160(5)	17(5)	AA	Terashima, 1971b.
132	----------	11	17	14	2,760	3,960	16	AA	Beccaluva and Venturelli, 1971.
136(2)	~30(2)	<10	~10	26	----------	----------	30	AA	Luecke, 1971.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1	Method	Reference
Cr—Continued									
120	16	18	18	25	----------	----------	16	AA	Walsh, 1972.
----------	----------	6(2)	10(2)	21(2)	----------	----------	19(2)	XRF	Parker, 1969.
125(2)	22(2)	<10	~10(2)	14(2)	----------	----------	34	XRF	Schneider, 1969.
----------	----------	7	10	10	2,700	4,000	20	XRF	Goodman, 1971.
----------	----------	9	5.3	9.5(2)	2,550(2)	3,665(2)	36(2)	XRF	Webber and Newbury, 1971.
----------	----------	----------	----------	----------	----------	----------	10.5	SSMS	Morrison and Kashuba, 1969.
----------	----------	----------	----------	----------	2,730	3,940	----------	Gas chromatographic	Sievers and others, 1971.
----------	----------	----------	----------	----------	2,660	4,010	----------	MS, volatile chelate	Frew and others, 1972.
95	----------	7.2	----------	10	2,400	3,600	----------	INAA	Filby and Haller, 1969.
99	----------	15	----------	----------	2,150	----------	24	INAA	Peterson and others, 1969.
89	----------	----------	----------	----------	2,660	4,210	----------	INAA	Dale and others, 1970.
95	----------	7.2	12	10	2,400	3,600	23	INAA	Filby and others, 1970.
----------	----------	----------	----------	----------	----------	----------	10.7	INAA	Goles and others, 1971.
----------	----------	4.0	----------	7.0	----------	----------	----------	INAA	Whitley and others, 1971.
----------	----------	7.1	----------	----------	----------	----------	----------	NAA	Das and others, 1969, 1970.
105(2)	14(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
----------	----------	----------	----------	----------	----------	----------	16	NAA	Morrison and Kashuba, 1969.
----------	----------	8.4	----------	10	----------	----------	14(2)	NAA	Morrison and others, 1969.
----------	----------	----------	----------	----------	----------	----------	19	NAA	Allen and others, 1970.
----------	----------	----------	----------	----------	----------	----------	19(3)	NAA	Haskin and others, 1970.
----------	----------	----------	----------	----------	----------	----------	<19	NAA	Osawa and Goles, 1970.
----------	----------	----------	----------	----------	----------	----------	10.6(5)	NAA	Brunfelt and Steinnes, 1971b.
----------	----------	----------	----------	----------	----------	----------	16	NAA	Morrison, 1971.
119	----------	----------	----------	----------	3,062	----------	----------	NAA	Nadkarni and Haldar, 1971a.
----------	----------	----------	----------	----------	2,550	----------	<100	Photon activation	Van Zelst, 1971a, b.
----------	----------	----------	----------	----------	2,700	3,700	----------	Photon activation	Van Zelst, 1971a, b.
117(4)	----------	7.8(2)	10.9(2)	9.3(2)	2,670(4)	4,100(4)	13.4(2)	NAA	Steinnes, 1972.
Cs									
----------	----------	1.4	1.0	1.2	----------	----------	1.0	Fl phot	Abbey, 1971.
----------	----------	7	9	2	5	9	3	Fl phot	Pouget and others, 1968.
2.2(6)	----------	----------	----------	----------	----------	----------	----------	(Ion Exch)	Strelow and others, 1968.
----------	----------	----------	----------	----------	----------	----------	1.1	SSMS	Morrison and Kashuba, 1969.
----------	----------	1.5(5)	----------	----------	----------	----------	----------	INAA	Aruscavage, 1969.
.95(3)	----------	1.33(3)	.95(3)	1.27(3)	----------	----------	.99(3)	EpINAA	Brunfelt and Steinnes, 1969c.
.90	----------	1.5	.7	1.7	----------	----------	.9	INAA	Filby and others, 1970.
----------	----------	----------	----------	2.2	----------	----------	1.4	INAA	B. C. Smith, 1970.
----------	----------	1.4	.9	.8	----------	----------	----------	INAA	Whitley and others, 1971.
.8(2)	1.2(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
----------	----------	----------	----------	----------	----------	----------	1.0	NAA	Morrison and Kashuba, 1969.
----------	----------	1.4	----------	1.3	----------	----------	1.0(2)	NAA	Morrison and others, 1969.
----------	----------	----------	----------	----------	----------	----------	.925(2)	NAA	Ganapathy and others, 1970; Keays and others, 1970.
----------	----------	----------	----------	----------	----------	----------	.91(3)	NAA	Allen and others, 1970; Haskin and others, 1970.
----------	----------	1.1	1.5	1.7	<.1	<.1	1.6	NAA	Laul, Case, Wechter, and others, 1970.
.98(3)	----------	----------	----------	----------	.0058(2)	.0060(2)	----------	NAA	Müller, 1970.
----------	----------	----------	----------	----------	----------	----------	.910(5)	NAA	Anders and others, 1971.
----------	----------	----------	----------	----------	----------	----------	.97(4)	NAA	Brunfelt and others, 1971.
----------	----------	1.4(3)	1.1(3)	1.4(2)	----------	----------	.9(3)	NAA	Pant and Parekh, 1971.
----------	----------	----------	----------	----------	----------	----------	1.0	NAA	Morrison, 1971.
.99(10)	----------	1.33(10)	1.00(10)	1.25(10)	<.03	<.03	.95(10)	NAA	Steinnes, 1972b.
----------	----------	----------	.978	----------	----------	----------	.935	ID	Hart, 1968.
----------	----------	----------	----------	----------	----------	----------	.925(2)	NAA	Laul and others, 1972.
Cu									
----------	----------	10	30	40	8	4	15	OS–SQ	Clark, 1968.
----------	----------	10(3)	26(3)	68(3)	17(3)	11(3)	25(3)	OS	Floyd and others, 1968.
100	10	----------	----------	----------	----------	----------	----------	OS	Mikšovský, 1968.
----------	----------	8	10	15	10	5	8	OS	Ropert and others, 1968.
----------	----------	11(5)	38(13)	56(4)	12(2)	5.9(2)	24.6(5)	OS	Dutra, 1969.
----------	----------	----------	----------	----------	----------	----------	10	OS	Champ, in Maxwell and others, 1970.
----------	----------	21(2)	38(2)	65(2)	----------	----------	15(2)	OS	Govindaraju, 1970b.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W-1	G-1	G-2	GSP-1	AGV-1	PCC-1	DTS-1	BCR-1	Method	Reference
					Cu—Continued				
116.5(17)	11(9)	9.8(7)	49(7)	57(9)	4.9(10)	1.85(10)	15.3(9)	OS	Huber-Schausberger and others, 1970.
135(10)	----------	----------	----------	----------	----------	----------	----------	OS	Martin and Quintin, 1970.
----------	----------	10	33	67	8	5	24	OS	Moal and others, 1970.
114(10)	12(10)	10(10)	29(10)	58(10)	14(10)	9(10)	12(10)	OS	Thompson and others, 1970; Thompson and Bankston, 1970.
100	9	----------	----------	----------	----------	----------	----------	OS	de Albuquerque, 1971.
----------	----------	12	38	65	11	5	18	OS	Avni, Harel, and Brenner, 1972.
106(4)	13(4)	13(15)	41(15)	65(15)	12(15)	6.7(15)	23(15)	OS	Blackburn and others, 1971.
162(9)	----------	15(12)	33(8)	74(9)	14(5)	12(8)	28(11)	OS	Brenner, 1971.
115.0	----------	----------	34.8	----------	----------	----------	24.0	OS	Gerasimovskiy and Laktionova, 1971.
----------	----------	13	34	55	11	8	24	Colorimetric	Pouget and others, 1968.
----------	----------	10.2(3)	32.7(6)	60.7(6)	----------	----------	16.8(6)	do	Bodart, 1970.
----------	----------	15	40	60	10	5	25	SQ-paper chromat	Agrinier, 1968.
----------	----------	10.1(6)	31.7(6)	62(6)	13.7(6)	9.5(6)	15.2(6)	AA	Balous and Thiel, 1968.
----------	----------	13(4)	33.5(8)	54(4)	10(4)	8(4)	15(4)	AA	Butler, 1968.
115	13	10	31	59	3	2	16	AA	Nagura and Iida, 1968.
----------	----------	12	40	60	15	10	25	AA	Ropert and Broudic, 1968.
120(2)	----------	----------	----------	----------	----------	----------	----------	AA	Bender and Schultz, 1969.
117	----------	14	38	67	16	14	22	AA	Price, 1969.
108	----------	5	35.5	59	10	5	14	AA	Sighinolfi, 1969.
113.7	9	11.4	31.6	61.0	----------	----------	19.3	AA	Fletcher, 1970.
117.1(8)	13	10	31	59	3	2	16	AA	Iida and Yamasaki, 1970.
107(4)	12(4)	8(4)	35(4)	60(4)	----------	----------	17(4)	AA	Rose, 1970.
117.1(8)	----------	----------	----------	58(2)	----------	----------	16(2)	AA	Smith and Rose, 1970.
120	----------	16	19	43	----------	----------	16	AA	Buckley and Cranston, 1971.
----------	----------	12(3)	31(3)	56(3)	12(3)	5(3)	21(3)	AA	Cioni and others, 1971.
----------	----------	11(5)	34(5)	61(5)	11(5)	8.4(5)	20(5)	AA	Terashima, 1971a, b.
116	12	10	30	56	----------	----------	17	AA	Walsh, 1972.
----------	----------	12(2)	33(2)	57(2)	9(2)	<5	16(2)	XRF	Parker, 1969.
180	----------	----------	----------	----------	----------	----------	----------	XRF	Quintin, 1970.
115	----------	5	31	59	7	6	----------	XRF	Feather, 1971.
110(2)	16(2)	----------	----------	----------	----------	----------	----------	XRF	Hirst and Kaye, 1971.
----------	----------	17.7(2)	48.7(2)	86.2(2)	25.1(2)	17.2(2)	28.4(2)	XRF	Webber and Newbury, 1971.
106	----------	----------	----------	53	5	----------	13	XRF	Kaye, 1972.
72.5	----------	----------	28.8	49.0	14.0	5	17.0	NAA	Filby and Haller, 1969.
----------	----------	9.8	----------	62	----------	----------	16(2)	NAA	Morrison and others, 1969.
----------	----------	----------	----------	----------	----------	----------	16	NAA	Morrison and Kashuba, 1969.
110	----------	14	----------	----------	11	----------	17	NAA	Peterson and others, 1969.
----------	----------	----------	----------	----------	----------	----------	14.6(3)	NAA	Allen and others, 1970; Haskin and others, 1970.
72.5	----------	17	28.8	49.0	14.0	5.0	17.0	NAA	Filby and others, 1970.
----------	----------	----------	----------	----------	----------	----------	18.0	NAA	Ganapathy and others, 1970; Keays and others, 1970.
113.6(5)	----------	9.14(5)	32.7(5)	57.9(5)	----------	----------	15.7(5)	NAA	Johansen and Steinnes, 1970.
----------	----------	----------	----------	----------	----------	----------	15.7	NAA	Brunfelt and others, 1971.
----------	----------	----------	----------	----------	----------	----------	16	NAA	Morrison, 1971.
104(2)	12.8(2)	----------	----------	----------	9.23(2)	----------	----------	NAA	Nadkarni and Haldar, 1972a.
115	----------	----------	----------	----------	----------	----------	----------	$\gamma\gamma$ coincidence	Michelson and Steinnes, 1968.
----------	----------	----------	----------	----------	----------	----------	24	SSMS	Morrison and Kashuba, 1969.
----------	----------	----------	----------	----------	----------	----------	18.0(2)	NAA	Laul and others, 1972.
					Dy				
2	2	----------	----------	----------	----------	----------	----------	OS	Cohen and others, 1968.
----------	----------	2.6(3)	5.0(2)	3.2(3)	----------	----------	6.0(3)	XRF	Eby, 1972.
----------	----------	2.28(5)	----------	----------	----------	----------	----------	INAA	Aruscavage, 1969.
----------	----------	5.2	----------	4.5	----------	----------	6	INAA	Morrison and others, 1969.
4.7	----------	2.8	5.6	----------	----------	----------	8.1	INAA	Filby and others, 1970.
----------	----------	----------	----------	3.9	----------	----------	9.1	INAA	B. C. Smith, 1970.
3.67(3)	2.63(3)	2.05(2)	5.66(2)	3.46(2)	----------	----------	6.25(7)	NAA	Tomura, Higuchi, Onuma, and Hamaguchi, 1968.
3.67(3)	2.63(3)	4.04	5.66	3.45	----------	----------	6.25	NAA	Higuchi, Tomura, Onuma, and Hamaguchi, 1969.
----------	----------	----------	----------	----------	----------	----------	6	NAA	Morrison and Kashuba, 1969.
3.8	2.9	----------	----------	----------	----------	----------	----------	NAA	Schilling and Winchester, 1969.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1	Method	Reference
Dy—Continued									
----------	----------	----------	----------	----------	----------	----------	6.32	NAA	Allen and others, 1970.
3.50	1.80	----------	----------	----------	----------	----------	----------	NAA	Graber and others, 1970.
----------	----------	----------	----------	----------	----------	----------	6.55(3)	NAA	Denechaud and others, 1970; Haskin and others, 1970.
4.4	----------	2.9	----------	----------	----------	----------	----------	NAA	Melson, 1970.
----------	----------	2.5	----------	----------	----------	0.0026	6.2(2)	NAA	Rey and others, 1970.
----------	----------	----------	----------	----------	----------	----------	5.65(5)	NAA	Brunfelt and others, 1971.
----------	----------	1.8	----------	----------	----------	----------	----------	NAA	Das and Zonderhuis, 1971.
3.95(4)	----------	----------	----------	----------	----------	----------	6.36	IDMS	Philpotts and Schnetzler, 1970; Schnetzler and Nava, 1971.
----------	----------	----------	----------	----------	----------	----------	6.20	IDMS	Gast and others, 1970.
7.70	2.6	----------	----------	----------	----------	----------	----------	SSMS	Carver and Johnson, 1968.
3.0	----------	----------	----------	----------	----------	----------	----------	SSMS	Graham and Nicholls, 1969.
----------	----------	----------	----------	----------	----------	----------	7	SSMS	Morrison and Kashuba, 1969.
Er									
2.5	1.4	----------	----------	----------	----------	----------	----------	OS	Cohen and others, 1968.
----------	----------	1.7(3)	3.0(2)	1.2(3)	----------	----------	3.2(3)	XRF	Eby, 1972.
2.8	.73	----------	----------	----------	----------	----------	----------	SSMS	Carver and Johnson, 1968.
2.3	----------	----------	----------	----------	----------	----------	----------	SSMS	Graham and Nicholls, 1969.
----------	----------	----------	----------	----------	----------	----------	5	SSMS	Morrison and Kashuba, 1969.
2.24	1.23	----------	----------	----------	----------	----------	----------	NAA	Higuchi, Tomura, Onuma, and Hamaguchi, 1969; Higuchi and others, 1970.
----------	----------	----------	----------	----------	----------	----------	3.5(3)	NAA	Denechaud and others, 1970.
2.21	1.26	----------	----------	----------	----------	----------	----------	NAA	Graber and others, 1970.
----------	----------	----------	----------	----------	----------	----------	3.87	NAA	Allen and others, 1970.
----------	----------	----------	----------	----------	----------	----------	3.51(3)	NAA	Haskin and others, 1970.
----------	----------	.96(2)	----------	----------	----------	<0.003	3.5(2)	NAA	Rey and others, 1970.
----------	----------	----------	----------	----------	----------	----------	4.5(5)	NAA	Brunfelt and others, 1971.
2.30(4)	----------	----------	----------	----------	----------	----------	3.58(2)	IDMS	Philpotts and Schnetzler, 1970.
----------	----------	----------	----------	----------	----------	----------	3.71(2)	IDMS	Gast and others, 1970.
----------	----------	----------	----------	----------	----------	----------	3.48	IDMS	Schnetzler and Nava, 1971.
Eu									
1.5	0.9	----------	----------	----------	----------	----------	----------	OS	Cohen and others, 1968.
----------	----------	2.3(3)	2.4(2)	2.2(3)	----------	----------	2.2(3)	XRF	Eby, 1972.
3.10	1.4	----------	----------	----------	----------	----------	----------	SSMS	Carver and Johnson, 1968.
1.0(5)	----------	----------	----------	----------	----------	----------	----------	SSMS	Graham and Nicholls, 1969.
----------	----------	----------	----------	----------	----------	----------	1.5	SSMS	Morrison and Kashuba, 1969.
1.07	----------	----------	----------	----------	----------	----------	1.95	INAA	Goles and others, 1971.
----------	----------	1.05	----------	1.17	----------	----------	----------	INAA	Green and others, 1969.
----------	----------	1.3	2.1	1.6	----------	----------	1.8	INAA	Scott, 1969.
1.11	----------	1.46	----------	----------	----------	----------	----------	INAA	Melson, 1970.
----------	----------	----------	----------	1.35	----------	----------	2.15	INAA	B. C. Smith, 1970.
1.0	----------	1.5	2.48	1.92	----------	----------	2.23	NAA	Filby and Haller, 1969.
1.25(5)	1.34(5)	1.55(2)	2.58(2)	1.98(2)	0.0019	0.00072	2.38(2)	NAA	Higuchi, Tomura, Onuma, and Hamaguchi, 1969.
1.2(2)	1.5(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
----------	----------	1.3	----------	1.6	----------	----------	2.0(2)	NAA	Morrison and others, 1969; Morrison and Kashuba, 1969; Morrison, 1971.
1.1	----------	1.15	----------	----------	----------	----------	.80	NAA	Peterson and others, 1969.
1.03	1.20	----------	----------	----------	----------	----------	----------	NAA	Schilling and Winchester, 1969.
----------	----------	----------	----------	----------	----------	----------	1.93	NAA	Allen and others, 1970.
----------	----------	----------	----------	----------	----------	----------	1.97(3)	NAA	Denechaud and others, 1970; Haskin and others, 1970.
1.08	1.06	----------	----------	----------	----------	----------	----------	NAA	Graber and others, 1970.
1.18	1.23	----------	----------	----------	----------	----------	----------	NAA	Higuchi and others, 1970.
----------	----------	1.52(2)	----------	----------	----------	.0011	2.0(2)	NAA	Rey and others, 1970.
----------	----------	----------	----------	----------	----------	----------	1.94(5)	NAA	Brunfelt and others, 1971.
----------	----------	2.4	----------	----------	----------	----------	----------	NAA	Das and Zonderhuis, 1971.
.99	----------	----------	----------	----------	----------	----------	1.75	NAA	Ragland and others, 1971.
----------	----------	1.38	----------	----------	----------	----------	1.97(3)	NAA	Krähenbühl and others, 1972.
1.112(4)	----------	----------	----------	----------	----------	----------	1.942(2)	IDMS	Philpotts and Schnetzler, 1970.
----------	----------	----------	----------	----------	----------	----------	1.96(2)	IDMS	Gast and others, 1970.
----------	----------	----------	----------	----------	----------	----------	1.943	IDMS	Schnetzler and Nava, 1971.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1	Method	Reference
F									
----------	----------	2,090(3)	6,633(3)	<100	<100	<100	1,170(3)	OS	Floyd and others, 1968.
171(4)	723(6)	----------	----------	----------	----------	----------	----------	OS	Martini and Tonani, 1968.
215	680	----------	----------	----------	----------	----------	----------	OS	Gerasimovskiy and Savinova, 1969.
260	650	980	3,700	460	----------	----------	670	OS	Schoenfeld, 1970.
----------	----------	----------	3,600	----------	----------	----------	----------	Colorimetric	Hall and Walsh, 1969.
----------	----------	----------	2,330(2)	----------	----------	----------	----------	Chemical	Murad, 1971.
----------	----------	1,220(4)	3,800(4)	350(4)	----------	----------	450(4)	Spectrophotometric	Sen Gupta, 1968.
230	----------	----------	----------	----------	17	17	455	do	Cattermole and Fuge, 1969.
230	----------	1,215	3,300	----------	----------	----------	----------	do	Fuge and Power, 1969.
230	640	----------	----------	----------	----------	----------	----------	Pyrohydrolysis	Clements and others, 1971.
180	600	1,120	2,400	500	<40	<40	510	SIE	Ficklin, 1970.
240	724	1,480	3,863(2)	----------	----------	----------	----------	SIE	Ingram, 1970.
----------	----------	----------	----------	----------	----------	----------	460	SSMS	Morrison and Kashuba, 1969.
285(4)	----------	----------	----------	----------	----------	----------	----------	Prompt γ	Bewers and Flack, 1969.
----------	----------	1,400	----------	----------	----------	----------	800(2)	INAA	Kuykendall and others, 1971.
263	800	----------	----------	----------	----------	----------	----------	NAA	Reed and Jovanovic, 1969.
262(4)	----------	----------	----------	----------	----------	----------	----------	NAA	Quijano-Rico, 1970.
315	723	----------	----------	----------	----------	----------	----------	γ, n	Carpenter, 1969.
221(5)	638(5)	----------	----------	----------	----------	----------	----------	γ activation	Hislop and others, 1971.
Ga									
----------	----------	28	25	25	----------	----------	20	OS–SQ	Clark, 1968.
----------	----------	21(3)	20(3)	30(3)	<5	<5	26(3)	OS	Floyd and others, 1968.
11	13	----------	----------	----------	----------	----------	----------	OS	Mikšovský, 1968.
----------	----------	20(2)	20(2)	15(2)	≤10	≤10	20(6)	OS	Dutra, 1969.
14(17)	20(9)	23(7)	23(7)	17(9)	≤10	≤10	18(9)	OS	Huber-Schausberger and others, 1970.
16(10)	----------	----------	----------	----------	----------	----------	----------	OS	Martin and Quintin, 1970.
----------	----------	27	26	24	<2	<2	28	OS	Moal and others, 1970.
19(3)	----------	----------	----------	22(3)	----------	----------	28(3)	OS	Suhr and Smith, 1970.
20(10)	24(10)	23(10)	26(10)	24(10)	10(10)	11(10)	23(10)	OS	Thompson and others, 1970.
18	17	----------	----------	----------	----------	----------	----------	OS	de Albuquerque, 1971.
18(4)	21(4)	21(15)	20(15)	19(15)	4.7(15)	4.3(15)	23(15)	OS	Blackburn and others, 1971.
----------	----------	----------	----------	----------	----------	----------	24	SSMS	Morrison and Kashuba, 1969.
----------	----------	32(2)	18(2)	28(2)	<10	<10	34(2)	XRF	Parker, 1969.
22	----------	----------	----------	----------	----------	----------	----------	XRF	Quintin, 1970.
17	----------	21	22	20	1	1	22	XRF	Goodman, 1971.
17	----------	----------	----------	20	----------	----------	20	XRF	Kaye, 1972.
16.5(2)	----------	----------	----------	----------	----------	----------	19.7(2)	NAA	Tandon and Wasson, 1968.
16.2(2)	----------	----------	----------	----------	----------	----------	----------	NAA	Case and others, 1969.
12.8	----------	28	16.4	16.6	1.2	.89	16.2	NAA	Filby and Haller, 1969; Filby and others, 1970.
16(2)	18(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
----------	----------	20	----------	18	----------	----------	20(2)	NAA	Morrison and others, 1969; Morrison and Kashuba, 1969; Morrison, 1971.
16	----------	27	----------	----------	----------	----------	21	NAA	Peterson and others, 1969.
----------	----------	----------	----------	----------	----------	----------	25.3(3)	NAA	Allen and others, 1970; Haskin and others, 1970.
----------	----------	22.0(2)	----------	----------	.63(2)	----------	19.8(2)	NAA	Baedecker and Wasson, 1970.
18.4(5)	----------	22.5(5)	21.7(5)	21.0(5)	----------	----------	22.2(5)	NAA	Johansen and Steinnes, 1970; Brunfelt and others, 1971.
----------	----------	----------	----------	----------	----------	----------	21.3	NAA	Ganapathy and others, 1970; Keays and others, 1970.
16.2(2)	20(2)	24.5(2)	24.8(2)	23.6(2)	.32(2)	.11(2)	20.7(2)	NAA	Laul, Case, Wechter, and others, 1970.
17.3	----------	22.0	----------	----------	----------	----------	20.6	NAA	Wasson and Baedecker, 1970.
----------	----------	----------	----------	----------	----------	----------	22(4)	NAA	Anders and others, 1971.
17.9	----------	23.3	24.3	21.7	.66	.45	21.7	NAA	Baedecker and others, 1971.
----------	----------	----------	----------	----------	----------	----------	21.3(2)	NAA	Laul and others, 1972.
15.9	19.6	22.9	22.3	20.5	.42	.15	19.8	IDMS	de Laeter, 1972.
Gd									
4	7	----------	----------	----------	----------	----------	----------	OS	Cohen and others, 1968.
----------	----------	6.0(3)	15.0(2)	5.3(3)	----------	----------	7.8(3)	XRF	Eby, 1972.
8.20	11.8	----------	----------	----------	----------	----------	----------	SSMS	Carver and Johnson, 1968.
4.0	----------	----------	----------	----------	----------	----------	----------	SSMS	Graham and Nicholls, 1969.
----------	----------	----------	----------	----------	----------	----------	6	SSMS	Morrison and Kashuba, 1969.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W-1	G-1	G-2	GSP-1	AGV-1	PCC-1	DTS-1	BCR-1	Method	Reference
Gd—Continued									
----------	----------	4.25	----------	7.2	----------	----------	----------	INAA	Green and others, 1969.
3.84(5)	5.39(5)	6.38(2)	14.8(2)	5.76(2)	----------	----------	7.02(2)	NAA	Higuchi, Tomura, Onuma, and Hamaguchi, 1969.
----------	----------	3	----------	5	----------	----------	5(2)	NAA	Morrison and others, 1969; Morrison and Kashuba, 1969; Morrison, 1970.
----------	3.6	----------	----------	----------	----------	----------	----------	NAA	Schilling and Winchester, 1969.
----------	----------	----------	----------	----------	----------	----------	6.68	NAA	Allen and others, 1970.
----------	----------	----------	----------	----------	----------	----------	8.02(3)	NAA	Denechaud and others, 1970; Haskin and others, 1970.
3.7	<5.5	----------	----------	----------	----------	----------	----------	NAA	Graber and others, 1970.
3.71	5.30	----------	----------	----------	----------	----------	----------	NAA	Higuchi and others, 1970.
4.3	----------	4.8	----------	----------	----------	----------	----------	NAA	Melson, 1970.
----------	----------	3.7(2)	----------	----------	----------	<.01	6.5(2)	NAA	Rey and others, 1970.
----------	----------	5	----------	----------	----------	----------	----------	NAA	Das and Zonderhuis, 1971.
4.03(4)	----------	----------	----------	----------	----------	----------	6.47	IDMS	Philpotts and Schnetzler, 1970.
----------	----------	----------	----------	----------	----------	----------	6.80	IDMS	Schnetzler and Nava, 1971.
Ge									
≤2	1.1(5)	1.0(4)	0.7(5)	<2	<1	<2	<2	OS	Huber-Schausberger and others, 1970.
----------	----------	<6	<6	----------	<6	<6	<6	OS	Moal and others, 1970.
1.6(3)	----------	----------	----------	2.5(3)	----------	----------	3.9(3)	OS	Suhr and Smith, 1970.
----------	----------	----------	----------	----------	----------	----------	2.2	SSMS	Morrison and Kashuba, 1969.
1.0	1.1	.90	.99	1.4	.88	.77	1.2	NAA β-counting	Greenland and McLane, 1969.
1.4	1.2	1.0	1.3	1.1	.79	.85	1.7	NAA γ-counting	Do.
1.62(2)	----------	----------	----------	----------	----------	----------	1.67(2)	NAA	Tandon and Wasson, 1968.
----------	----------	1.2(2)	----------	----------	1.0(2)	1.0(2)	1.5(2)	NAA	Baedecker and Wasson, 1970.
1.9	----------	1.3(2)	----------	----------	----------	----------	1.6(3)	NAA	Wasson and Baedecker, 1970.
1.74	----------	1.36	1.74	1.36	1.07	.97	1.55	NAA	Baedecker and others, 1971.
Hf									
----------	----------	----------	----------	----------	----------	----------	3.4	SSMS	Morrison and Kashuba, 1969.
----------	----------	8.6(5)	----------	----------	----------	----------	----------	INAA	Aruscavage, 1969.
2.45(3)	----------	7.64(3)	13.9(3)	4.75(3)	----------	----------	4.72(3)	EpINAA	Brunfelt and Steinnes, 1969c.
----------	----------	----------	----------	5.6	----------	----------	4.1	INAA	B. C. Smith, 1970.
2.3	----------	----------	----------	----------	----------	----------	4.57	INAA	Goles and others, 1971.
2.2(2)	5.8(2)	7.7(2)	16.8(2)	6.5(2)	.08(2)	.010(2)	5.4(2)	NAA	Brooks, 1968.
----------	5.3(2)	----------	----------	----------	----------	----------	----------	NAA	Esson and others, 1968.
3.4(2)	5.6(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
----------	----------	7	----------	5	----------	----------	4.8(2)	NAA	Morrison and others, 1969; Morrison and Kashuba, 1969; Morrison, 1971.
3.0(3)	4.2(2)	5.8(2)	17(2)	4.1	.03(2)	.01(2)	2.8	NAA	Rebagay, 1969; Rebagay and Ehmann, 1970.
----------	----------	----------	----------	----------	----------	----------	5.23(3)	NAA	Allen and others, 1970; Haskin and others, 1970.
----------	----------	----------	----------	----------	----------	----------	4.72	NAA	Brunfelt and others, 1971.
----------	----------	----------	----------	----------	----------	----------	5.33	IDMS	Schnetzler and Nava, 1971.
Hg (ppb)									
180(2)	95(2)	----------	----------	----------	----------	----------	----------	AA	Hatch and Ott, 1968.
290	80	50	17	26	11	10	10	AA	Learned, 1970.
----------	----------	39(9)	16(4)	6(5)	4(4)	9(6)	7(6)	AA	Ando, 1971.
175(4)	87.3(4)	39.8(4)	14.5(4)	9.4(4)	19.7(4)	6.6(4)	17.5(4)	AA	Marinenko and others, 1972.
180	----------	----------	----------	15	----------	----------	----------	AA	Muscat and others, 1972.
260	----------	----------	----------	27	----------	----------	----------	AA	Omang and Paus, 1971.
280(10)	97(9)	40(10)	15(9)	25(9)	5(9)	12(9)	18(10)	AA	Weissberg, 1971.
----------	30(2)	68(2)	----------	22(2)	----------	----------	11	AA	Aston and Riley, 1972.
240(2)	----------	64(2)	19(2)	24(2)	6(2)	10(2)	5(2)	AA	Cranston and Buckley, 1972.
94(2)	----------	----------	----------	----------	----------	----------	----------	NAA	Case and others, 1969.
330(2)	120(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
----------	----------	120(3)	----------	----------	----------	----------	----------	NAA	Ishida and others, 1970.
94(2)	70(2)	29(2)	41(2)	16(2)	3.6(2)	6	4	NAA	Laul, Case, Wechter, and others, 1970.
250	----------	----------	----------	----------	----------	----------	----------	NAA	Kennedy and others, 1971.
225	59	38	106	6	3	55	8	NAA	Marowsky, 1971a, c.
225(2)	----------	----------	----------	5(2)	4.2(2)	----------	----------	NAA	Marowsky and Wedepohl, 1971.
----------	----------	----------	----------	----------	----------	----------	<50	NAA	Morrison, 1971.
103	----------	----------	----------	----------	----------	----------	----------	NAA	Nadkarni and Haldar, 1972b.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W-1	G-1	G-2	GSP-1	AGV-1	PCC-1	DTS-1	BCR-1	Method	Reference
Ho									
3	0.4	----------	----------	----------	----------	----------	----------	OS	Cohen and others, 1968.
----------	----------	<0.3	<0.5	0.5(3)	----------	----------	1.0(3)	XRF	Eby, 1972.
3.50	.28	----------	----------	----------	----------	----------	----------	SSMS	Carver and Johnson, 1968.
.67	----------	----------	----------	----------	----------	----------	----------	SSMS	Graham and Nicholls, 1969.
----------	----------	----------	----------	----------	----------	----------	1	SSMS	Morrison and Kashuba, 1969.
----------	----------	----------	----------	----------	----------	----------	1.15	INAA	Goles and others, 1971.
.801	.417	----------	----------	----------	----------	----------	----------	NAA	Higuchi, Tomura, Onuma, and Hamaguchi, 1969; Higuchi, Tomura, and Hamaguchi, 1970.
----------	----------	.7	----------	.8	----------	----------	1(2)	NAA	Morrison and others, 1969; Morrison and Kashuda, 1969; Morrison, 1971.
.69	.49	----------	----------	----------	----------	----------	----------	NAA	Schilling and Winchester, 1969.
----------	----------	----------	----------	----------	----------	----------	1.22	NAA	Allen and others, 1970.
----------	----------	----------	----------	----------	----------	----------	1.34(3)	NAA	Denechaud and others, 1970; Haskins and others, 1970.
.61	.16	----------	----------	----------	----------	----------	----------	NAA	Graber and others, 1970.
----------	----------	.36(2)	----------	----------	----------	.0026	1.32(2)	NAA	Rey and others, 1970.
(1.0)	----------	(.7)	----------	----------	----------	----------	----------	NAA	Melson, 1970.
----------	----------	----------	----------	----------	----------	----------	1.20(5)	NAA	Brunfelt and others, 1971.
----------	----------	.08	----------	----------	----------	----------	----------	NAA	Das and Zonderhuis, 1971.
I									
0.038	0.035	----------	----------	----------	----------	----------	----------	NAA	Walters, 1967.
----------	----------	----------	----------	----------	----------	----------	(.8)	SSMS	Morrison and Kashuba, 1969.
In									
0.050	0.022	----------	----------	----------	----------	----------	----------	OS	Rösler and others, 1968.
.025	.02	----------	----------	----------	----------	----------	----------	Colorimetric	V. V. Ivanov and V. N. Cholodov, quoted in Rösler and others, 1968.
----------	----------	0.04	----------	0.03	----------	----------	0.08(2)	INAA	Morrison and others, 1969.
----------	----------	----------	----------	<.1	----------	----------	≤.1	INAA	B. C. Smith, 1970.
.064(2)	----------	----------	----------	----------	----------	----------	.095(2)	NAA	Tandon and Wasson, 1968.
----------	----------	----------	----------	----------	----------	----------	.113(3)	NAA	Allen and others, 1970; Haskin and others, 1970.
----------	----------	----------	----------	----------	----------	----------	.1012(2)	NAA	Ganapathy and others, 1970; Keays and others, 1970.
----------	----------	.032(2)	----------	----------	----------	0.0026(2)	.079(2)	NAA	Rey and others, 1970.
.066(2)	----------	.033(2)	----------	----------	----------	----------	.095(3)	NAA	Wasson and Baedecker, 1970.
----------	----------	----------	----------	----------	----------	----------	.092(4)	NAA	Anders and others, 1971.
.064	----------	.030	0.055	.045	0.0034	.0025	.094	NAA	Baedecker and others, 1971.
----------	----------	----------	----------	----------	----------	----------	.103	NAA	Brunfelt and others, 1971.
----------	----------	----------	----------	----------	----------	----------	.102(2)	NAA	Laul, Case, Wechter, and others, 1972.
Ir (ppb)									
----------	----------	----------	----------	----------	----------	----------	<0.1	SSMS	Morrison and Kashuba, 1969.
0.26(8)	0.044(6)	----------	----------	----------	----------	----------	----------	NAA	Crocket and others, 1968.
----------	----------	----------	(1.1)	(0.7)	(6.6)	(0.5)	(1.1)	NAA	Ehmann and others, 1970.
.32	----------	0.12(2)	----------	----------	----------	----------	----------	NAA	Wasson and Baedecker, 1970.
----------	----------	----------	----------	----------	----------	----------	≤.03(5)	NAA	Anders and others, 1971.
.32	----------	.07	≤.16	≤.20	5.7	.56	≤.12	NAA	Baedecker and others, 1971.
----------	----------	----------	----------	----------	----------	----------	<.1	NAA	Brunfelt and others, 1971.
----------	----------	----------	4(4)	6(4)	5(4)	.5(4)	2(2)	NAA	Das, Janssen, and Zonderhuis, 1971.
----------	----------	----------	----------	----------	6.6(2)	1.0(2)	----------	NAA	Gijbels and others, 1971.
.24(4)	.008(4)	.0020(4)	.012(3)	.011(4)	3.0(4)	1.12(14)	.004(4)	FA-NAA	Greenland and others, 1971.
----------	----------	----------	----------	----------	5.5(2)	----------	----------	NAA	Millard and Bartel, 1971.
----------	----------	.005	----------	.005	----------	----------	.14	NAA	Gijbels, 1972.
La									
----------	----------	150	300	<100	----------	----------	----------	OS-SQ	Clark, 1968.
10	100	----------	----------	----------	----------	----------	----------	OS	Cohen and others, 1968.
----------	----------	108(3)	242(3)	60(3)	<5	<5	<5	OS	Floyd and others, 1968.
----------	----------	95(2)	200(2)	80(2)	<50	<50	31.6(3)	OS	Dutra, 1969.
<50	111(9)	97(7)	238(7)	51(9)	<100	<100	<50	OS	Huber-Schausberger and others, 1970.
12	----------	----------	----------	----------	----------	----------	----------	SSMS	Graham and Nicholls, 1969.
----------	----------	----------	----------	----------	----------	----------	23	SSMS	Morrison and Kashuba, 1969.
----------	----------	121(2)	214(2)	<25	<25	<25	<25	XRF	Parker, 1969.
----------	----------	81.5(3)	176.7(2)	29.9(3)	----------	----------	25.9(3)	XRF	Eby, 1972.
----------	----------	89	144	37	----------	----------	28	XRF	Sceal and Weaver, 1971.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1	Method	Reference
La—Continued									
10	----------	----------	----------	----------	----------	----------	26	XRF	Kaye, 1972.
----------	----------	94(5)	----------	----------	----------	----------	----------	INAA	Aruscavage, 1969.
----------	----------	75	----------	32	----------	----------	----------	INAA	Green and others, 1969.
----------	----------	102	201	44	----------	----------	28	INAA	Scott, 1969.
10.9	----------	85	----------	----------	----------	----------	----------	INAA	Melson, 1970.
----------	----------	----------	----------	32	----------	----------	20	INAA	B. C. Smith, 1970.
10.8	----------	----------	----------	----------	----------	----------	----------	INAA	Goles and others, 1971.
----------	----------	78	181	36	----------	----------	----------	INAA	Whitley and others, 1971.
6.7	----------	----------	105	23.9	.17	.05	15.4	NAA	Filby and Haller, 1969; Filby and others, 1970.
12.2(5)	108(5)	91(2)	212(2)	43.6(2)	.072	.036	23.8(2)	NAA	Higuchi, Tomura, Onuma, and Hamaguchi, 1969.
----------	----------	78	----------	37	----------	----------	23(2)	NAA	Morrison and others, 1969; Morrison and Kashuba, 1969; Morrison, 1971.
10.5(2)	82(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
12	----------	84	----------	----------	.2	----------	24	NAA	Peterson and others, 1969.
8.5	89	----------	----------	----------	----------	----------	----------	NAA	Schilling and Winchester, 1969.
----------	----------	----------	----------	----------	----------	----------	24.0	NAA	Allen and others, 1970.
----------	----------	----------	----------	----------	----------	----------	25.18(3)	NAA	Denechaud and others, 1970.
12.7	115	----------	----------	----------	----------	----------	----------	NAA	Graber and others, 1970.
----------	----------	----------	----------	----------	----------	----------	25.2(3)	NAA	Haskin and others, 1970.
11.6	103	----------	----------	----------	----------	----------	----------	NAA	Higuchi and others, 1970.
----------	----------	----------	----------	----------	----------	----------	23.7	NAA	Osawa and Goles, 1970.
----------	----------	93(2)	----------	----------	----------	.026	26(2)	NAA	Rey and others, 1970.
----------	----------	----------	----------	----------	----------	----------	23.7(5)	NAA	Brunfelt and others, 1971.
----------	----------	80	----------	----------	----------	----------	----------	NAA	Das and Zonderhuis, 1971.
10.2	----------	----------	----------	----------	----------	----------	23.7	NAA	Ragland and others, 1971.
----------	----------	78	----------	----------	----------	----------	20.7(2)	NAA	Krähenbühl and others, 1972.
----------	----------	----------	----------	----------	----------	----------	26.1(2)	IDMS	Gast and others, 1970.
Li									
----------	----------	38(3)	39(3)	32(3)	<1	<1	32(3)	OS	Floyd and others, 1968.
15(10)	28(10)	45(10)	40(10)	15(10)	1(10)	2(10)	15(10)	OS	Thompson and others, 1970.
----------	16	----------	----------	----------	----------	----------	----------	OS	de Albuquerque, 1971.
12(8)	27(17)	44(11)	53(7)	9(7)	<.3	<.3	11(8)	OS	Bircz, 1971.
12(4)	23(4)	48(5)	37(5)	11(5)	.07(5)	.05(5)	18(5)	OS	Blackburn and others, 1971.
11(16)	30(6)	46(9)	35(4)	15(4)	----------	----------	13(7)	OS	Brenner, 1971.
----------	----------	32	35	14	10	14	15	Fl phot	Pouget and others, 1968.
12.5	20	----------	----------	----------	----------	----------	----------	Fl phot	Šulcek and Rubeška, 1968.
----------	----------	31	28	11	----------	----------	14	Fl phot	Abbey, 1971.
13.3(6)	----------	----------	----------	----------	----------	1.79(3)	----------	Fl phot	McCabe and others, 1972.
15.2(6)	----------	----------	----------	----------	----------	----------	----------	Ion exchange	Strelow and others, 1968.
----------	----------	----------	----------	----------	----------	1.73(4)	----------	----do	Toerien, 1969.
----------	----------	28.2(6)	27.9(6)	7.5(6)	<1	1.2(6)	12.2(6)	AA	Balous and Thiel, 1968.
----------	----------	36.5(6)	32.0(6)	12.4(6)	2(6)	----------	14.4(6)	AA	Butler, 1968.
----------	----------	40	45	30	13	11	35	AA	Ropert and Broudic, 1968.
12.9	----------	32.5	29.9	12.1	5	5	15	AA	Sighinolfi, 1969.
----------	----------	35(4)	33(4)	13(2)	----------	----------	16(2)	AA	Stone and Chesher, 1969.
12	----------	41	36	9	<.5	2	13	AA	Price, 1969.
----------	----------	----------	----------	----------	----------	----------	15	AA	Abbey, in Maxwell and others, 1970.
20	15	----------	----------	----------	----------	----------	----------	AA	Govindaraju, 1970b.
----------	----------	----------	26	14	----------	----------	13	AA	Langmyhr, 1970.
25	----------	30	29	11	----------	----------	14	AA	Buckley and Cranston, 1971.
----------	----------	36(3)	29(3)	12(3)	<3	<3	14(3)	AA	Cioni and others, 1971.
17	24	35	30	15	----------	----------	12	AA	O'Gorman and Suhr, 1971.
----------	----------	41(5)	36(5)	12(5)	1.1(5)	2.3(5)	13(5)	AA	Terashima, 1971a, b.
13	24	33	30	11	----------	----------	12	AA	Walsh, 1972.
----------	----------	----------	----------	----------	----------	----------	13	SSMS	Morrison and Kashuba, 1969.
12.7(6)	20.4(4)	----------	----------	----------	----------	----------	----------	NAA	Quijano-Rico and Wänke, 1969; Quijano-Rico, 1970.
----------	----------	----------	----------	----------	----------	----------	12.8	IDMS	Schnetzler and Nava, 1971.
Lu									
0.3	0.1	----------	----------	----------	----------	----------	----------	OS	Cohen and others, 1968.
----------	----------	<0.5	<0.8	<0.4	----------	----------	<0.4	XRF	Eby, 1972.
.21	.20	----------	----------	----------	----------	----------	----------	SSMS	Carver and Johnson, 1968.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1	Method	Reference
Lu—Continued									
.39	----------	----------	----------	----------	----------	----------	----------	SSMS	Graham and Nicholls, 1969.
----------	----------	----------	----------	----------	----------	----------	.5	SSMS	Morrison and Kashuba, 1969.
----------	----------	.14(5)	----------	----------	----------	----------	----------	INAA	Aruscavage, 1969.
----------	----------	.07	----------	.18	----------	----------	----------	INAA	Green and others, 1969.
----------	----------	.08	.14	----------	----------	----------	.5	INAA	Scott, 1969.
.30	----------	.32	.31	.30	----------	----------	1.0	INAA	Filby and others, 1970.
.42	----------	.08	----------	----------	----------	----------	----------	INAA	Melson, 1970.
.360	----------	----------	----------	----------	----------	----------	.535	INAA	Goles and others, 1971.
.35(5)	----------	.092(4)	.26(5)	.27(5)	<0.03	<0.03	.54(5)	NAA	Brunfelt and Steinnes, 1969b.
.353(5)	.146(5)	.131	.22(2)	.256(2)	.0057	.0014	.545(2)	NAA	Higuchi, Tomura, Onuma, and Hamaguchi, 1969.
.51(2)	.16(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
----------	----------	.13	----------	.36	----------	----------	.54(2)	NAA	Morrison and others, 1969; Morrison and Kashuba, 1969; Morrison, 1971.
.44	----------	.16	----------	----------	----------	----------	.70	NAA	Peterson and others, 1969.
.32	.165	----------	----------	----------	----------	----------	----------	NAA	Schilling and Winchester, 1969.
----------	----------	----------	----------	----------	----------	----------	.527	NAA	Allen and others, 1970.
----------	----------	----------	----------	----------	----------	----------	.526(3)	NAA	Denechaud and others, 1970; Haskin and others, 1970.
.28	.22	----------	----------	----------	----------		----------	NAA	Graber and others, 1970.
.322	.144	----------	----------	----------	----------	----------	----------	NAA	Higuchi and others, 1970.
----------	----------	----------	----------	----------	----------	----------	.60	NAA	Osawa and Goles, 1970.
----------	----------	.12(2)	----------	----------	----------	.0031	.58(2)	NAA	Rey and others, 1970.
----------	----------	----------	----------	----------	----------	----------	.535(5)	NAA	Brunfelt and others, 1971.
----------	----------	.05	----------	----------	----------	----------	----------	NAA	Das and Zonderhuis, 1971.
.26	----------	----------	----------	----------	----------	----------	.38	NAA	Ragland and others, 1971.
----------	----------	----------	----------	----------	----------	----------	.586(2)	IDMS	Gast and others, 1970.
.031	----------	----------	----------	----------	----------	----------	.536(2)	IDMS	Philpotts and Schnetzler, 1970.
----------	----------	----------	----------	----------	----------	----------	.548	IDMS	Schnetzler and Nava, 1971.
Mn									
----------	----------	350	350	650	700	750	1,250	OS–SQ	Clark, 1968.
----------	220(9)	247(7)	350(7)	----------	----------	----------	----------	OS	Huber-Schausberger and others, 1970.
----------	----------	235	262	780	1,020	990	1,870	OS	Moal and others, 1970.
----------	----------	260	330	785	860	1,010	1,370	OS	Avni, Harel, and Brenner, 1972.
1,300(14)	----------	260(16)	360(8)	745(8)	1,070(10)	900(13)	1,600(14)	OS	Brenner, 1971.
----------	----------	259(6)	312(6)	772(6)	859(6)	969(6)	1,544(6)	AA	Balous and Thiel, 1968.
----------	----------	250(4)	300(2)	750(2)	----------	800(4)	1,200(4)	AA	Butler, 1968.
----------	----------	280	350	750	850	900	1,600	AA	Ropert and Broudic, 1968.
1,347(8)	241(5)	250(4)	300(2)	750(2)	----------	800(4)	1,200(4)	AA	Butler and Kokot, 1969.
1,330	----------	250	310	730	----------	----------	1,380	AA	Buckley and Cranston, 1971.
1,320(4)	238(3)	279(4)	365(4)	742(2)	----------	----------	1,360(4)	AA	Luecke, 1971.
----------	----------	332	395	745	----------	----------	1,350	XRF	Franzini, and Leoni, 1969.
----------	----------	274(2)	345(2)	878(2)	1,229(2)	1,145(2)	1,771(2)	XRF	Parker, 1969.
1,640	----------	280	330	830	1,030	1,150	1,410	XRF	Goodman, 1971.
----------	----------	245(2)	285(2)	770(2)	958	968(2)	1,393(2)	XRF	Webber and Newbury, 1971.
----------	----------	----------	----------	----------	----------	----------	1,420	SSMS	Morrison and Kashuba, 1969.
1,345(4)	----------	----------	----------	----------	893(4)	----------	1,465(4)	INAA	Wyttenbach, 1969.
1,350(2)	----------	----------	----------	----------	----------	----------	----------	INAA	Bender and Schultz, 1969.
1,175(2)	170(2)	----------	----------	----------	----------	----------	----------	INAA	Landstrom and others, 1969.
----------	----------	246	----------	674	----------	----------	1,385(2)	INAA	Morrison and Kashuba, 1969.
1,130	----------	253	307	773	895	988	1,330	INAA	Dale and others, 1970.
1,368	----------	248	294	735	921	904	1,365	INAA	Filby and others, 1970.
1,300	----------	----------	----------	----------	----------	----------	1,380	INAA	Goles and others, 1971.
1,368	----------	248	----------	735	921	904	1,365	NAA	Filby and Haller, 1969.
----------	----------	----------	----------	----------	----------	----------	1,380	NAA	Morrison and Kashuba, 1969.
----------	----------	----------	----------	----------	----------	----------	1,343(3)	NAA	Allen and others, 1970; Haskin and others, 1970.
----------	----------	----------	----------	----------	----------	----------	1,420	NAA	Brunfelt and Steinnes, 1971b.
----------	----------	----------	----------	----------	----------	----------	1,419	NAA	Brunfelt and others, 1971.
----------	----------	----------	----------	----------	----------	----------	1,400	NAA	Morrison, 1971.
Mo									
----------	----------	1	1	2	----------	----------	2	OS–SQ	Clark, 1968.
----------	5.5	----------	----------	----------	----------	----------	----------	OS	Ivanova, 1966.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1	Method	Reference
Mo—Continued									
<10	<10	----------	----------	----------	----------	----------	----------	OS	Mikšovský, 1968.
----------	----------	4	----------	4	----------	----------	4	OS	Ropert, Lecable, and Monjanx, 1968.
----------	----------	<1	<1	3(2)	<1	1.5(2)	3.1(2)	OS	Dutra, 1969.
<5	7.4(5)	<3	<3	<5	<5	<5	<5	OS	Huber-Schausberger and others, 1970.
<2	<1	<2	<2	<2	<2	<2	6(10)	OS	Thompson and others, 1970.
.7(4)	6.7(4)	3.6(15)	3.9(15)	4.5(15)	5.3(15)	5.1(15)	7.1(15)	OS	Blackburn and others, 1971.
----------	----------	2.0(2)	.6(2)	2.1(3)	2.8(2)	.2(2)	2.0(2)	AA	Butler, 1968.
----------	----------	.9	1.4	3.4	.4	3.2	----------	Colorimetric	Fuge, 1970.
.52	5.44(2)	.15(2)	.30(2)	1.66(2)	.03(2)	.04(2)	1.20(2)	Spectrophotometric	Kawabuchi and Kuroda, 1970.
----------	----------	----------	----------	----------	----------	----------	.9	SSMS	Morrison and Kashuba, 1969.
.5	----------	1.2	1.6	3.7	5.5	6.6	3.9	X-ray activation	Kunzendorf, 1971.
----------	----------	.7	----------	1	----------	----------	1	NAA	Morrison and Kashuba, 1969; Morrison and others, 1969; Morrison, 1971.
.55(2)	----------	----------	----------	----------	----------	----------	----------	NAA	Case and others, 1969.
1.5(2)	13.5(2)	6.2(2)	8.3(2)	13.0(2)	.2	.2	5.3(2)	NAA	Laul, Case, Wechter, and others, 1970.
.57	----------	.13	.27	1.71	.02	.04	1.15	EpNAA	Steinnes, 1971a, c.
N									
52(3)	59(3)	56(3)	48(3)	44(3)	43(3)	27(3)	30(3)	Combustion-gas chromotographic.	Gibson and Moore, 1970.
----------	----------	----------	----------	----------	----------	----------	29(5)	----do	Moore and others, 1970.
Nb									
----------	----------	14(3)	24(3)	18(2)	<10	<10	18.4(5)	OS	Dutra, 1969.
----------	----------	8(2)	19(2)	10(2)	<5	<5	10(2)	XRF	Parker, 1969.
11.2	----------	----------	----------	10.5	----------	----------	20.4	XRF	B. C. Smith, 1970.
5	----------	9	20	11	1	<1	9	XRF	Goodman, 1971.
----------	----------	10	19	13	----------	----------	13	XRF	Sceal and Weaver, 1971.
6	----------	----------	----------	13	----------	----------	11	XRF	Kaye, 1972.
----------	----------	8	20	8	1	1	10	Paper chromat–SQ	Agrinier, 1968.
----------	----------	----------	----------	----------	----------	----------	19	SSMS	Morrison and Kashuba, 1969.
10	----------	16.1	28.3	21.7	1.1	4	34.1	X-ray activation	Kunzendorf, 1971.
9.4(3)	23.3(4)	13.7(3)	----------	----------	----------	----------	----------	Chemical	Campbell, 1969.
9.5(3)	23.7(3)	13.3(3)	29.4(3)	15.0(2)	<2	<3	13.5(3)	ID-spectrophotometric	Greenland and Campbell, 1970.
Nd									
16	60	----------	----------	----------	----------	----------	----------	OS	Cohen and others, 1968.
33.0	80	----------	----------	----------	----------	----------	----------	SSMS	Carver and Johnson, 1968.
12	----------	----------	----------	----------	----------	----------	----------	SSMS	Graham and Nicholls, 1969.
----------	----------	----------	----------	----------	----------	----------	21	SSMS	Morrison and Kashuba, 1969.
----------	----------	65.5(3)	213.8(2)	32.5(3)	----------	----------	32.3(3)	Ion exchange–XRF	Eby, 1972.
----------	----------	70	177	42	----------	----------	17	XRF	Sceal and Weaver, 1971.
11	----------	----------	----------	----------	----------	----------	25	XRF	Kaye, 1972.
----------	----------	51	----------	30.5	----------	----------	----------	INAA	Green and others, 1969.
17	----------	69	----------	----------	----------	----------	----------	INAA	Melson, 1970.
18	----------	----------	----------	----------	----------	----------	30.1	INAA	Goles and others, 1971.
18.2(5)	56(5)	46.5(2)	174(2)	43(2)	----------	----------	28.2(2)	NAA	Higuchi, Tomura, Onuma, and Hamaguchi, 1969.
----------	----------	67	----------	49	----------	----------	32(2)	NAA	Morrison and others, 1969; Morrison and Kashuba, 1969; Morrison, 1971.
12.1	58	----------	----------	----------	----------	----------	----------	NAA	Schilling and Winchester, 1969.
----------	----------	----------	----------	----------	----------	----------	31.3	NAA	Allen and others, 1970.
----------	----------	----------	----------	----------	----------	----------	30.50(3)	NAA	Denechaud and others, 1970; Haskin and others, 1970.
<16	62.5	----------	----------	----------	----------	----------	----------	NAA	Graber and others, 1970.
11.0	55.7	----------	----------	----------	----------	----------	----------	NAA	Higuchi and others, 1970.
----------	----------	50(2)	----------	----------	----------	<0.024	30(2)	NAA	Rey and others, 1970.
----------	----------	15	----------	----------	----------	----------	----------	NAA	Das and Zonderhuis, 1971.
12	----------	----------	----------	----------	----------	----------	26	NAA	Ragland and others, 1971.
15.1(4)	----------	----------	----------	----------	----------	----------	32.1(2)	IDMS	Philpotts and Schnetzler, 1970.
----------	----------	----------	----------	----------	----------	----------	28.8(2)	IDMS	Gast and others, 1970.
----------	----------	----------	----------	----------	----------	----------	27.5	IDMS	Schnetzler and Nava, 1971.
Ni									
----------	----------	7	15	25	2,500	2,700	15	OS–SQ	Clark, 1968.
----------	----------	5(3)	10(3)	16(3)	1,525(3)	1,443(3)	15(3)	OS	Floyd and others, 1968.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1	Method	Reference
					Ni—Continued				
77	11	----------	----------	----------	----------	----------	----------	OS	Mikšovský, 1968.
----------	----------	9	10	11	----------	----------	13	OS	Ropert, Lecable, and Monjaux, 1968.
----------	----------	3.3(4)	7(3)	36(4)	2,880(2)	2,550(2)	13.2(5)	OS	Dutra, 1969.
----------	----------	16(2)	<10	32(2)	----------	----------	35(2)	OS	Govindaraju, 1970b.
76(17)	1.2(9)	2.75(7)	8.7(7)	15.3(9)	2,650(10)	2,475(10)	9.9(9)	OS	Huber-Schausberger and others, 1970.
68(10)	----------	----------	----------	----------	----------	----------	----------	OS	Martin and Quintin, 1970.
----------	----------	<5	7	19	2,370	2,350	13	OS	Moal and others, 1970.
79(10)	4(10)	6(10)	8(10)	17(10)	2,440(10)	2,160(10)	12(10)	OS	Thompson and others, 1970.
----------	----------	7.5	13	21	2,750	2,690	13	OS	Avni, Harel and Brenner, 1972.
70	----------	----------	----------	----------	----------	----------	----------	OS	de Albuquerque, 1971.
91(4)	6.4(4)	7.6(15)	9.3(15)	16(15)	2,210(15)	2,366(15)	14(15)	OS	Blackburn and others, 1971.
70(9)	----------	8(12)	17(8)	24(9)	2,100(7)	2,200(9)	19(10)	OS	Brenner, 1971.
62.0	----------	----------	9.5	----------	----------	----------	16.4	OS	Gerasimovskiy and Laktionova, 1971.
----------	----------	2.61(3)	7.72(6)	16.1(6)	----------	----------	10.1(6)	Colorimetric	Bodart, 1970.
----------	----------	1.5	4.5	12.0	2,260	2,210	7.0	Photometric	Stähle, 1970.
----------	----------	----------	----------	----------	2,400	2,350	----------	----do	Langer, 1971.
----------	----------	4	8	15	2,000	2,000	8	Paper Chromat–SQ	Agrinier, 1968.
----------	----------	13.7(6)	21.3(6)	26.3(6)	2,697(6)	2,253(6)	30.2(6)	AA	Balous and Thiel, 1968.
79	----------	----------	----------	----------	2,300	2,300	----------	AA	Iida and Nagura, 1968.
80	1	2	7.6	15.7	2,390	2,310	9.6	AA	Nagura and Iida, 1968.
91(2)	----------	----------	----------	----------	----------	----------	----------	AA	Bender and Schultz, 1969.
56	----------	5	5	15	----------	----------	15	AA	Sighinolfi, 1969.
73.4	----------	8.1	10.1	16.2	----------	----------	21.6	AA	Fletcher, 1970.
80	1.0	2.9	11.9	12.8	2,330	2,250	13.2	AA	Iida and Yamasaki, 1970.
83	----------	3.6	6	13	----------	----------	14	AA	Langmyhr, 1970.
77(4)	1(4)	3(4)	7(4)	16(4)	----------	----------	15(4)	AA	Rose, 1970.
78.6(8)	----------	----------	----------	15(2)	----------	----------	7(2)	AA	Smith and Rose, 1970.
84	----------	2	8	16	2,410	2,220	10	AA	Beccaluva and Venturelli, 1971.
63	----------	20	31	63	----------	----------	27	AA	Buckley and Cranston, 1971.
----------	----------	4(3)	9(3)	16(3)	1,975(3)	1,903(3)	10(3)	AA	Cioni and others, 1971.
----------	----------	4.4(5)	9.6(5)	18(5)	2,320(5)	2,340(5)	10(5)	AA	Terashima, 1971a, b.
72	<5	<5	5	20	----------	----------	15	AA	Walsh, 1972.
----------	----------	4(2)	8.5(2)	14(2)	----------	----------	13(2)	XRF	Parker, 1969.
76(2)	<5	~5(2)	11(2)	19(2)	----------	----------	11(2)	XRF	Schneider, 1969.
88	----------	----------	----------	----------	----------	----------	----------	XRF	Quintin, 1970.
76	----------	7	16	22	2,400	2,470	27	XRF	Feather, 1971.
77	----------	2.5	8	13	2,670	2,455	12	XRF	Goodman, 1971.
66(2)	(22)(2)	----------	----------	----------	----------	----------	----------	XRF	Hirst and Kaye, 1971.
----------	----------	7.3(2)	15.0(2)	19.1(2)	2,518(2)	2,447(2)	14.6(2)	XRF	Webber and Newbury, 1971.
83	<3	7	10	18	2,480	2,360	15	XRF	Fabbi and Espos, 1972a.
----------	----------	----------	----------	23.8(3)	2,451(3)	2,306(3)	19.2(3)	XRF	Blount and others, 1972.
70	----------	----------	----------	14	2,400	----------	7	XRF	Kaye, 1972.
----------	----------	7.5	----------	34	----------	----------	38(2)	INAA	Morrison and others, 1969; Morrison, 1971.
----------	----------	----------	----------	----------	----------	----------	12.4(3)	NAA	Allen and others, 1970; Haskin and others, 1970.
----------	----------	<18	----------	----------	----------	----------	<18	NAA	Krähenbühl and others, 1972.
----------	----------	----------	----------	----------	2,670	----------	<200	Photon activation	Van Zelst, 1971a, b.
----------	----------	----------	----------	----------	2,320	2,280	----------	Photon activation	Van Zelst, 1971b.
----------	----------	----------	----------	----------	2,280	2,450	----------	----do	Van Zelst, 1971a.
					Os (ppb)				
----------	----------	----------	----------	----------	----------	----------	<1,000	SSMS	Morrison and Kashuba, 1969.
0.25(2)	0.074(2)	----------	----------	----------	----------	----------	----------	NAA	Crocket and others, 1968.
<98	<26	<100	<32	<34	<58	<60	<1,000	NAA	Laul, Case, Wechter, and others, 1970.
----------	----------	----------	----------	----------	8.8(2)	.98(2)	----------	NAA	Gijbels and others, 1971.
----------	----------	----------	----------	----------	.46	----------	≤.11	NAA	Lovering and Hughes, 1971.
----------	----------	----------	----------	----------	12.3	----------	----------	NAA	Millard and Bartel, 1971.
					Pb				
----------	----------	30	60	30	----------	----------	----------	OS–SQ	Clark, 1968.
----------	49	----------	----------	----------	----------	----------	----------	OS	Ivanova, 1966.
----------	25.4	----------	----------	----------	----------	----------	----------	OS	Kowalski, 1967.
----------	----------	24(3)	38(3)	34(3)	<10	<10	36(3)	OS	Floyd and others, 1968.
<10	41	----------	----------	----------	----------	----------	----------	OS	Mikšovský, 1968.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W-1	G-1	G-2	GSP-1	AGV-1	PCC-1	DTS-1	BCR-1	Method	Reference
					Pb—Continued				
----------	----------	30(3)	61(3)	34(3)	11(2)	12(2)	14(3)	OS	Murad, 1968.
9(8)	47(8)	31(3)	58(3)	35(4)	15(3)	16(3)	13(3)	OS	Murad, 1969.
----------	----------	30	65	50	23	27	30	OS	Ropert, Lecable, and Monjaux, 1968.
----------	----------	33(3)	51(3)	38(2)	<20	20(2)	<10	OS	Dutra, 1969.
8.5(10)	----------	----------	----------	----------	----------	----------	----------	OS	Martin and Quintin, 1970.
----------	----------	32	55	42	17	20	22	OS	Moal and others, 1970.
6.1(3)	----------	----------	----------	----------	----------	----------	22(3)	OS	Suhr and Smith, 1970.
8(17)	47.5(9)	28(7)	55(7)	20(9)	14(10)	13(10)	17(9)	OS	Huber-Schausberger and others, 1970.
7(10)	58(10)	37(10)	65(10)	46(10)	13(10)	14(10)	11(10)	OS	Thompson and others, 1970.
10	54	----------	----------	----------	----------	----------	----------	OS	de Albuquerque, 1971.
----------	----------	32	60	38	8	8	20	OS	Avni, Harel, and Brenner, 1972.
6(4)	45(4)	28(15)	32(15)	31(15)	14(15)	13(15)	26(15)	OS	Blackburn and others, 1971.
----------	----------	----------	----------	----------	----------	----------	13	SSMS	Morrison and Kashuba, 1969.
8.6(26)	50.1(48)	29.8(39)	----------	----------	----------	----------	----------	Chem.	Jenkins and Moore, 1970.
----------	----------	40	60	60	30	25	40	Paper chromat-SQ	Agrinier, 1968.
----------	----------	36	----------	43	----------	----------	----------	Anodic stripping	Khasgiwale and others, 1972.
10	45	35	41	26	13	13	13	AA	Nagura and Iida, 1968.
8.4	47.9	36.6	53.1	32.4	9.2	11.1	20.7	AA	Tanaka and Iida, 1969.
16	----------	44	44	30	22	29	14	AA	Price, 1969.
----------	----------	20.6	50.5	35.5	----------	----------	----------	AA	Fletcher, 1970.
8.8	50	----------	----------	----------	----------	----------	----------	AA	Moldan and others, 1970.
----------	----------	26(5)	50(5)	32(5)	7.8(5)	8.4(5)	13(5)	AA	Terashima, 1971a, b.
10	45	28	55	35	----------	----------	15	AA	Walsh, 1972.
5	----------	28.5(3)	44	32	10	7	12	XRF	Murad, 1968.
6(12)	----------	28.4(26)	44(7)	33(6)	10(6)	8(6)	13(6)	XRF	Murad, 1969.
----------	----------	31(2)	48(2)	42(2)	<10	<10	14(2)	XRF	Parker, 1969.
8	48	28	55	36	----------	----------	15	XRF	Cherry and others, 1970.
9	----------	----------	----------	----------	----------	----------	----------	XRF	Quintin, 1970.
----------	----------	32.9	60.7	36.2	----------	----------	15.5	XRF	Heier and Thoresen, 1971.
~8(2)	47(2)	----------	----------	----------	----------	----------	----------	XRF	Hirst and Kaye, 1971.
7	44	----------	47	----------	----------	----------	----------	XRF	Murad, 1971.
----------	----------	32.3(2)	50.8(2)	36(2)	11.8(2)	8.8(2)	14.9(2)	XRF	Webber and Newbury, 1971.
8.4	----------	----------	----------	38	----------	----------	15	XRF	Kaye, 1972.
----------	----------	----------	----------	----------	----------	----------	13.53(4)	IDMS	Gale, 1972.
					Pd (ppb)				
----------	----------	----------	----------	----------	----------	----------	30	SSMS	Morrison and Kashuba, 1969.
----------	----------	----------	----------	----------	5.5(4)	2(4)	----------	FA-OS	Heady, 1969.
15.4(10)	----------	----------	----------	----------	5.5	.7	----------	FA-OS	Dorrzapf and Brown, 1970.
11.5(17)	1.6(6)	----------	----------	----------	----------	----------	----------	NAA	Crocket and others, 1968.
41(13)	----------	----------	----------	----------	28(13)	----------	----------	ID substoichiometric	Briscoe and Humphries, 1971.
39(4)	----------	----------	----------	----------	29(5)	----------	----------	NAA substoichiometric	Briscoe and Humphries, 1970.
----------	----------	----------	----------	----------	----------	----------	12.0(2)	NAA	Ganapathy and others, 1970; Keays and others, 1970.
----------	----------	----------	----------	----------	6.0(2)	----------	----------	NAA	Millard and Bartel, 1971.
12.2(12)	----------	<0.5	<0.5	<0.5	4.7(3)	<.5	<.5	FA-NAA	Rowe and Simon, 1971.
					Pr				
2.4	15	----------	----------	----------	----------	----------	----------	SSMS	Carver and Johnson, 1968.
4.0	----------	----------	----------	----------	----------	----------	----------	SSMS	Graham and Nicholls, 1969.
----------	----------	----------	----------	----------	----------	----------	8	SSMS	Morrison and Kashuba, 1969.
5	19	----------	----------	----------	----------	----------	----------	OS	Cohen and others, 1968.
3	----------	----------	----------	----------	----------	----------	7	XRF	Kaye, 1972.
----------	----------	18.7(3)	49.9(2)	7.6(3)	----------	----------	7.1(3)	Ion exchange-XRF	Eby, 1972.
2.9	20.0	----------	----------	----------	----------	----------	----------	NAA	Schilling and Winchester, 1969.
2.6	21.8	----------	----------	----------	----------	----------	----------	NAA	Graber and others, 1970.
----------	----------	18.7(2)	----------	----------	----------	0.0058	7.3(2)	NAA	Rey and others, 1970.
					Pt (ppb)				
----------	----------	----------	----------	----------	11(4)	4(4)	----------	FA-OS	Heady, 1969.
14.9(11)	----------	----------	----------	----------	10.5	3.7(3)	----------	FA-OS	Dorrzapf and Brown, 1970.
----------	----------	----------	----------	----------	3.5	----------	----------	NAA	Millard and Bartel, 1971.
9.8(6)	----------	<0.5	<0.5	1.1	5.8(4)	1.7	2.3	FA-NAA	Rowe and Simon, 1971.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W-1	G-1	G-2	GSP-1	AGV-1	PCC-1	DTS-1	BCR-1	Method	Reference
						Ra ($\mu\mu$ g/g)			
----------	----------	0.71	0.66	0.69	0.0018	0.0013	0.56	Radon counting	Nishimura, 1970b.
						Rb			
----------	400	----------	----------	----------	----------	----------	----------	OS	Kowalski, 1967.
----------	----------	192(3)	403(3)	53(3)	<1	<1	34(3)	OS	Floyd and others, 1968.
28(10)	226(10)	195(10)	260(10)	100(10)	<10	<10	55(10)	OS	Thompson and others, 1970.
----------	225	----------	----------	----------	----------	----------	----------	OS	de Albuquerque, 1971.
14(5)	200(7)	163(9)	300(8)	40(8)	<1	<1	28(8)	OS	Bircz, 1971.
22(4)	211(4)	220(5)	283(5)	109(5)	.6(5)	<.5	69(5)	OS	Blackburn and others, 1971.
23(12)	210(5)	170(8)	280(4)	44(4)	----------	----------	47(7)	OS	Brenner, 1971.
----------	----------	190	220	170	1	2	36	Fl phot	Pouget and others, 1968.
----------	----------	170	250	66	----------	----------	47	Fl phot	Abbey, 1971.
22.0(6)	----------	----------	----------	----------	----------	----------	----------	Ion exchange	Strelow and others, 1968.
----------	----------	199(6)	305(6)	71(6)	<10	<10	42(6)	AA	Balous and Thiel, 1968.
19	209	160	245	61	<10	<10	43	AA	Butler and Kokot, 1969.
22	----------	167	256	67	----------	----------	(50)	AA	Price, 1969.
25	----------	151	308	43	10	10	32	AA	Sighinolfi, 1969.
----------	----------	185(3)	245(3)	73(3)	<5	<5	78(3)	AA	Cioni and others, 1971.
----------	----------	170(4)	251(3)	----------	----------	----------	----------	AA	Gamot and others, 1970.
68	223	167(7)	267	55	----------	----------	37	AA	Govindaraju, 1970a.
----------	----------	167(2)	274(2)	63(2)	----------	----------	41(2)	AA	Govindaraju and others, 1971.
----------	----------	----------	----------	68(2)	----------	----------	50(2)	AA	Do.
----------	----------	182	237	70	1	3.5	47	AA	Roelandts, 1972.
----------	----------	----------	----------	----------	----------	----------	37	SSMS	Morrison and Kashuba, 1969.
----------	----------	120	150	<50	<50	<50	<50	XRF	Guillemaut, 1968.
22.0	----------	----------	----------	----------	----------	----------	----------	XRF	Bell and Powell, 1969.
----------	----------	----------	----------	----------	.077(8)	.062(8)	----------	XRF	Chappell and others, 1969.
20	208	159	248	65	----------	----------	43	XRF	Hattori and Shibata, 1969.
----------	----------	169	248	67.5	----------	----------	47	XRF	Heier and Thoresen, 1971.
22(2)	212(2)	----------	----------	----------	----------	----------	----------	XRF	Hirst and Kaye, 1971.
19(2)	----------	156(3)	223(2)	51	<3	<3	40	XRF	Murad, 1969.
----------	----------	172(2)	270(2)	74(2)	<5	<5	46(2)	XRF	Parker, 1969.
21	240	180	250	72	----------	----------	46	XRF	Schneider, 1969.
22	220	175	261	74	<5	<5	57	XRF	Schroll and Stepan, 1969.
22.3	----------	174	262	70	----------	----------	50	XRF	Cherry and others, 1970.
25	----------	----------	----------	----------	----------	----------	----------	XRF	Quintin, 1970.
30	----------	----------	----------	89	----------	----------	56	XRF	B. C. Smith, 1970.
----------	----------	171	253	67.7	----------	----------	48.2	XRF	Fairbairn and Hurley, 1971.
21	----------	170	260	70	.5	3	50	XRF	Feather, 1971.
22	----------	173	259	70	<.2	<.2	51	XRF	Goodman, 1971.
22	200	----------	235	64	----------	----------	----------	XRF	Murad, 1971.
----------	----------	178	262	69	----------	----------	48	XRF	Sceal and Weaver, 1971.
----------	----------	----------	257(2)	68.2(2)	1.4(2)	1.8(2)	50.5(2)	XRF	Webber and Newbury, 1971.
22	220	174	245	67	<10	<10	49	XRF	Fabbi and Espos, 1972a.
21.44	213.0	170.0	253.0	67.09	.077	.062	46.76	XRF	Chappell, 1972.
22.2(3)	----------	161(3)	227(3)	65(3)	----------	----------	46(3)	EpINAA	Brunfelt and Steinnes, 1969c.
----------	----------	140	237	70	----------	----------	----------	INAA	Filby and others, 1970.
----------	----------	160	241	76	----------	----------	----------	INAA	Whitley and others, 1971.
22(2)	224(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
----------	----------	190	----------	78	----------	----------	44(2)	NAA	Morrison and others, 1969; Morrison and Kashuba, 1969; Morrison, 1971.
----------	----------	----------	----------	----------	----------	----------	44.9(3)	NAA	Allen and others, 1970; Haskin and others, 1970.
----------	----------	----------	----------	----------	----------	----------	46(2)	NAA	Ganapathy and others, 1970; Keays and others, 1970.
----------	----------	184(2)	----------	----------	----------	0.040	----------	NAA	Rey and others, 1970.
----------	----------	----------	----------	----------	----------	----------	46(5)	NAA	Anders and others, 1971.
----------	----------	----------	----------	----------	----------	----------	50	NAA	Brunfelt and others, 1971.
----------	----------	170(2)	254(2)	61(3)	----------	----------	46.5(2)	NAA	Pant and Parekh, 1971.
21.8(10)	----------	170(10)	251(10)	66(10)	<0.2	<.2	49(10)	NAA	Steinnes, 1972b.
----------	----------	----------	----------	----------	----------	----------	46(2)	NAA	Laul, Case, Wechter, and others, 1972.
----------	----------	----------	255.7	----------	----------	0.055	46.9	ID	Hart, 1968.
----------	----------	----------	----------	----------	0.064(2)	.053(2)	----------	ID	Chappell and others, 1969.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1	Method	Reference
						Rb—Continued			
----------	----------	170(6)	256(6)	66.9(2)	----------	----------	47.4(2)	ID	Loveridge and Wanless, 1969.
21.5(2)	----------	167.6(2)	254.5(2)	66.6(2)	.062(2)	.050(2)	46.9(2)	ID	deLaeter and Abercrombie, 1970.
----------	----------	164(2)	250(2)	----------	----------	----------	----------	ID	Gamot and others, 1970.
----------	----------	----------	----------	----------	----------	----------	46.6(2)	ID	Gast and others, 1970.
21.0	----------	----------	----------	----------	----------	----------	46.6(2)	ID	Philpotts and Schnetzler, 1970.
----------	----------	----------	255.6(8)	----------	----------	----------	----------	ID	Welin, 1970.
----------	----------	174.5(2)	----------	67.4(3)	.063(3)	----------	47.4(3)	ID	Ozima and Zashu, 1971.
----------	----------	----------	----------	----------	----------	----------	46.3	ID	Schnetzler and Nava, 1971.
----------	----------	----------	----------	----------	----------	----------	45.1(2)	ID	Krähenbühl and others, 1972.
----------	----------	168.4(4)	255.0	----------	----------	----------	----------	ID	Vidal, 1972.
						Re (ppb)			
----------	----------	----------	----------	----------	----------	----------	<0.1	SSMS	Morrison and Kashuba, 1969.
<1.8	<1.8	<7	<2.5	<5	<1	<0.4	<5	NAA	Laul, Case, Wechter, and others, 1970.
----------	----------	----------	----------	----------	.070(2)	----------	.83(2)	NAA	Lovering and Hughes, 1971.
						Rh (ppb)			
----------	----------	----------	----------	----------	----------	----------	(0.2)	SSMS	Morrison and Kashuba, 1969.
<1	----------	----------	----------	----------	1.0	0.87(3)	----------	FA–OS	Dorrzapf and Brown, 1970.
						Ru (ppb)			
----------	----------	----------	----------	----------	----------	----------	(1)	SSMS	Morrison and Kashuba, 1969.
----------	----------	----------	----------	----------	11.2	----------	----------	NAA	Gijbels, 1971.
----------	----------	----------	----------	----------	10.0(3)	2.5(3)	----------	NAA	Gijbels and others, 1971.
----------	----------	----------	----------	----------	7.4(2)	----------	----------	NAA	Millard and Bartel, 1971.
						S			
123	58	24	162	<10	<10	<10	392	SQ–XRF	B. C. Smith, 1970.
220	----------	250	520	130	140	50	570	XRF	Richter, 1972.
						Sb			
0.89(6)	----------	<0.07	3.01(6)	4.18(6)	----------	----------	0.52(6)	EpINAA	Brunfelt and Steinnes, 1969a, c.
.8	----------	.2	3.0	----------	----------	----------	----------	INAA	Filby and Haller, 1969.
.98(2)	.20(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
----------	----------	----------	----------	4.85	----------	----------	.60	INAA	B. C. Smith, 1970.
.8	----------	.2	3.0	4.9	1.0	1.2	.8	INAA	Filby and others, 1970.
1.12(3)	.37(3)	.040(3)	3.35(3)	4.6(3)	1.37(3)	.50(3)	.67(3)	INAA	Lombard and others, 1971.
1.15(4)	----------	----------	----------	----------	----------	----------	----------	NAA	Case and others, 1969.
1.2	.26(2)	----------	----------	----------	----------	----------	----------	NAA	Hamaguchi and others, 1969.
----------	----------	.055	----------	4.3	----------	----------	.68(2)	NAA	Morrison and others, 1969; Morrison and Kashuba, 1969; Morrison, 1971.
1	----------	.06	----------	----------	1.3	----------	.75	NAA	Peterson and others, 1969.
----------	----------	----------	----------	----------	----------	----------	.620(3)	NAA	Allen and others, 1970; Haskin and others, 1970.
1.2(2)	.35(2)	.12(2)	3.0(2)	4.12(2)	1.56(2)	.44(2)	.93(2)	NAA–extraction	Laul, Case, Wechter, and others, 1970.
1.1(2)	.39(2)	.10(2)	3.0(2)	4.2(2)	1.53(2)	.44(2)	.77(2)	NAA–distillation	Do.
----------	----------	----------	----------	----------	----------	----------	.60	NAA	Brunfelt and others, 1971.
.94(2)	----------	.054(2)	3.20(2)	4.07(2)	1.40(2)	.47(2)	.63(2)	NAA	Steinnes, 1972a.
----------	----------	----------	----------	----------	----------	----------	.9	SMSS	Morrison and Kashuba, 1969.
						Sc			
----------	----------	----------	10	10	10	----------	10	OS–SQ	Clark, 1968.
----------	----------	6(3)	12(3)	20(3)	19(3)	3(3)	55(3)	OS	Floyd and others, 1968.
----------	----------	5.3(3)	----------	10(4)	5.1(2)	4.6(2)	30.5(4)	OS	Dutra, 1969.
----------	----------	----------	----------	----------	----------	----------	23	OS	Champ and others, in Maxwell and others, 1970.
44.4(17)	3.6(9)	4.3(7)	7.2(7)	13.2(9)	≤10	≤10	38.8(9)	OS	Huber-Schausberger and others, 1970.
----------	----------	4	5	15	12	7	40	OS	Moal and others, 1970.
40(3)	----------	----------	----------	16(3)	----------	----------	30(3)	OS	Suhr and Smith, 1970.
39	----------	----------	----------	----------	----------	----------	----------	OS	de Albuquerque, 1971.
----------	----------	----------	6.8	----------	----------	----------	30.0	OS	Gerasimovskiy and others, 1971.
33	2.8	3.4	6.4	11.3	9.8	4.2	31	OS	Hofmeyr, 1972.
33(4)	2.8	3.7(3)	6.0(3)	11(3)	5.7(3)	2.6(3)	32(3)	Spectrophotometric	Shimizu, 1969; Shimizu and Kuroda, 1969.
34	~4	7	9	16	13	7	32	XRF	Fabbi and Espos, 1972a.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1	Method	Reference
						Sc—Continued			
----------	----------	3.29(5)	----------	----------	----------	----------	----------	INAA	Aruscavage, 1969.
33	----------	4.0	----------	12	1	1.0	36	INAA	Filby and Haller, 1969.
33.7	----------	3.6	5.8	12.2	9.2	3.8	34.9	INAA	Dale and others, 1970.
33.4	----------	3.55	----------	----------	----------	----------	----------	INAA	Melson, 1970.
----------	----------	----------	----------	----------	----------	----------	30.8	INAA	Goles and others, 1971.
35	2.4	----------	----------	----------	----------	----------	----------	NAA	Norman and Haskin, 1968.
----------	----------	4.3	6.8	12	7.9	3.2	37	NAA	Schiltz, 1968.
32.1	----------	----------	----------	----------	----------	----------	----------	NAA	Case and others, 1969.
37(2)	2.9(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
----------	----------	3.0	----------	11	----------	----------	31(2)	NAA	Morrison and others, 1969; Morrison, 1971.
34	----------	4.5	----------	----------	1.3	----------	32	NAA	Peterson and others, 1969.
----------	----------	----------	----------	----------	----------	----------	31.9(3)	NAA	Allen and others, 1970; Haskin and others, 1970.
32.1	3.0	5.0	7.9	16.7	9.9	3.7	30.1	NAA	Laul, Case, Wechter, and others, 1970.
32.1(9)	2.75(9)	----------	----------	----------	----------	----------	----------	NAA	Nomura and others, 1970.
----------	----------	----------	----------	----------	----------	----------	32.5	NAA	Osawa and Goles, 1970.
----------	----------	----------	----------	----------	----------	----------	30.7	NAA	Brunfelt and others, 1971.
----------	----------	3.1	----------	----------	----------	----------	----------	NAA	Das, Zonderhuis, and Marel, 1971.
						Se			
.48	----------	----------	----------	----------	----------	----------	0.2	SSMS	Morrison and Kashuba, 1969.
----------	----------	----------	----------	----------	----------	----------	----------	NAA	Case and others, 1969.
.17(2)	<0.1	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
----------	----------	----------	----------	----------	----------	----------	.105(3)	NAA	Allen and others, 1970; Haskin and others, 1970.
< .18	< .36	<0.7	<0.04	<0.14	<0.18	<0.3	< .3	NAA	Laul, Case, Wechter, and others, 1970.
----------	----------	----------	----------	----------	----------	----------	.092(5)	NAA	Anders and others, 1971.
----------	----------	----------	----------	----------	----------	----------	.116	NAA	Brunfelt and others, 1971.
----------	----------	----------	----------	----------	----------	----------	.121(5)	NAA	Brunfelt and Steinnes, 1971b.
.115(3)	.0075(2)	----------	----------	----------	----------	----------	----------	NAA	Gregory and Lavrakas, 1971.
.10	----------	----------	----------	----------	----------	----------	----------	NAA	Nadkarni and Haldar, 1971b.
----------	----------	----------	----------	----------	----------	----------	.094(2)	NAA	Laul and others, 1972.
						Sm			
5.00	6.8	----------	----------	----------	----------	----------	----------	SSMS	Carver and Johnson, 1968.
3.9(5)	----------	----------	----------	----------	----------	----------	----------	SSMS	Graham and Nicholls, 1969.
----------	----------	----------	----------	----------	----------	----------	6	SSMS	Morrison and Kashuba, 1969.
----------	----------	10.0(3)	31.2(2)	6.0(3)	----------	----------	7.3(3)	Ion exchange–XRF	Eby, 1972.
----------	----------	8.3(5)	----------	----------	----------	----------	----------	INAA	Aruscavage, 1969.
3.16(3)	----------	6.87(3)	24.7(2)	5.68(3)	----------	----------	6.14(3)	EpINAA	Brunfelt and Steinnes, 1969c.
----------	----------	5.4	----------	4.95	----------	----------	----------	INAA	Green and others, 1969.
----------	----------	6.3	20.6	5.2	----------	----------	5.7	INAA	Scott, 1969.
3.31(12)	----------	7.66(12)	25.8(12)	6.08(12)	<0.03	<0.03	6.61(12)	EpINAA	Steinnes, 1969a.
3.55	----------	6.9	----------	----------	----------	----------	----------	INAA	Melson, 1970.
----------	----------	----------	----------	5.9	----------	----------	6.4	INAA	B. C. Smith, 1970.
3.5	----------	----------	----------	----------	----------	----------	----------	INAA	Goles and others, 1971.
3.77(5)	8.02(5)	7.20(2)	28.2(2)	6.69(2)	.0076	.0028	7.30(2)	NAA	Higuchi, Tomura, Onuma, and Hamaguchi, 1969.
4.1(2)	7.4(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
----------	----------	7.0	----------	6.5	----------	----------	6(2)	NAA	Morrison and others, 1969; Morrison and Kashuba, 1969; Morrison, 1971.
3.2	6.8	----------	----------	----------	----------	----------	----------	NAA	Schilling and Winchester, 1969.
3.0	----------	10.0	32.2	5.9	----------	----------	6.9	NAA	Filby and others, 1970.
----------	----------	----------	----------	----------	----------	----------	7.23(3)	NAA	Denechaud and others, 1970; Haskin and others, 1970.
----------	----------	----------	----------	----------	----------	----------	7.46	NAA	Allen and others, 1970.
4.18	11.2	----------	----------	----------	----------	----------	----------	NAA	Graber and others, 1970.
3.62	7.87	----------	----------	----------	----------	----------	----------	NAA	Higuchi and others, 1970.
----------	----------	----------	----------	----------	----------	----------	5.9	NAA	Osawa and Goles, 1970.
----------	----------	7.2(2)	----------	----------	----------	.005	6.9(2)	NAA	Rey and others, 1970.
----------	----------	----------	----------	----------	----------	----------	6.52	NAA	Brunfelt and others, 1971.
----------	----------	----------	----------	----------	----------	----------	6.60(5)	NAA	Brunfelt and Steinnes, 1971b.
----------	----------	5.8	----------	----------	----------	----------	----------	NAA	Das and Zonderhuis, 1971.
3.40	----------	----------	----------	----------	----------	----------	----------	NAA	Ragland and others, 1971.
----------	----------	6.65	----------	----------	----------	----------	6.42(3)	NAA	Krähenbühl and others, 1972.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W-1	G-1	G-2	GSP-1	AGV-1	PCC-1	DTS-1	BCR-1	Reference	Method
						Sm—Continued			
3.76(3)	----------	----------	----------	----------	----------	----------	7.44(2)	ID	Philpotts and Schnetzler, 1970.
----------	----------	----------	----------	----------	----------	----------	6.74(2)	ID	Gast and others, 1970.
----------	----------	----------	----------	----------	----------	----------	6.57	ID	Schnetzler and Nava, 1971.
						Sn			
----------	3.4	----------	----------	----------	----------	----------	----------	OS	Ivanova, 1966.
----------	----------	3(3)	4(3)	<1	----------	----------	<1	OS	Floyd and others, 1968.
<10	<10	----------	----------	----------	----------	----------	----------	OS	Mikšovský, 1968.
----------	----------	<4	6.7(2)	6(2)	<4	4(2)	<5	OS	Dutra; 1969.
2.9(4)	5(5)	1.1(4)	6.1(5)	3.6(3)	1.45(2)	1.7(2)	2.5(4)	OS	Huber-Schausberger and others, 1970.
----------	----------	3	8	9	3	2	9	OS	Moal and others, 1970.
<5	<5	<5	<5	<5	<5	<5	8(10)	OS	Thompson and others, 1970.
3.2(3)	----------	----------	----------	4.7(3)	----------	----------	2.8(3)	OS	Suhr and Smith, 1970.
6.1(4)	5.6(4)	3.0(15)	5.9(15)	3.5(15)	3.6(15)	3.5(15)	4.2(15)	OS	Blackburn and others, 1971.
----------	----------	1.32	4.35	3.03	.88	.74	1.81	Spectrophotometric	Smith, J. D., 1971; Smith and Burton, 1972.
----------	----------	----------	----------	----------	----------	----------	3	SSMS	Morrison and Kashuba, 1969.
2.4	3.1	1.2	4.5	3	.5	.5	1.5	NAA	Das and others, 1969.
3.8(2)	3.8(2)	----------	----------	----------	----------	----------	----------	NAA	Hamaguchi and others, 1969.
3.13(5)	----------	----------	----------	----------	----------	----------	----------	NAA	Johansen and Steinnes, 1969.
3.4(2)	----------	----------	----------	----------	----------	----------	----------	NAA	Schmidt and Starke, 1969.
3.3(2)	----------	2.0(2)	8.6(2)	5.65(2)	1.68(2)	.68(2)	2.71(3)	NAA	Schmidt, 1970.
						Sr			
----------	----------	800	400	900	----------	----------	400	OS-SQ	Clark, 1968.
----------	----------	590(10)	295(10)	690(10)	----------	----------	385(10)	OS	Fabbri and Vespignani-Balzani, 1969.
----------	----------	413(3)	255(3)	756(3)	<5	<5	260(3)	OS	Floyd and others, 1968.
----------	----------	435(2)	250(2)	750(2)	<10	<10	481(6)	OS	Dutra, 1969.
----------	----------	----------	----------	670	----------	----------	----------	OS	Ondrick and others, 1969.
----------	----------	----------	----------	----------	----------	----------	220	OS	Champ and others, in Maxwell, and others, 1970.
----------	----------	490(2)	218(2)	760(2)	----------	----------	340(2)	OS	Govindaraju, 1970b.
125(10)	----------	----------	----------	----------	----------	----------	----------	OS	Martin and Quintin, 1970.
----------	----------	545	250	700	<5	<5	330	OS	Moal and others, 1970.
156(10)	364(10)	570(10)	295(10)	680(10)	2(10)	3(10)	265(10)	OS	Thompson and others, 1970.
170	240	----------	----------	----------	----------	----------	----------	OS	de Albuquerque, 1971.
----------	----------	519	270	645	<5	<5	332	OS	Avni, Harel and Brenner, 1972.
182(4)	248(4)	465(5)	210(5)	632(5)	.3(5)	1.5(5)	336(5)	OS	Blackburn and others, 1971.
186(5)	----------	530(6)	----------	----------	----------	----------	340(4)	OS	Brenner, 1971.
----------	----------	----------	----------	----------	----------	----------	270	SSMS	Morrison and Kashuba, 1969.
----------	----------	493(6)	236(6)	666(6)	<8	<8	342(6)	AA	Balous and Thiel, 1968.
235	----------	447	302	668	<1	<1	412	AA	Price, 1969.
178	----------	396	253	720	20	----------	307	AA	Sighinolfi, 1969.
----------	----------	----------	245(3)	----------	----------	----------	----------	AA	Gamot and others, 1970.
215	270	508(2)	208	718	----------	----------	325	AA	Govindaraju, 1970a.
----------	----------	479	251	651	----------	----------	341	AA	Roelandts and Bologne, 1970.
----------	----------	430	220	700	----------	----------	310	AA	Abbey, 1971.
202	----------	397	230	625	----------	----------	368	AA	Beccaluva and Venturelli, 1971.
205	----------	473	274	631	----------	----------	319	AA	Buckley and Cranston, 1971.
----------	----------	464(3)	248(3)	653(3)	<5	<5	342(3)	AA	Cioni and others, 1971.
----------	----------	502(5)	250(5)	670(5)	----------	----------	317(5)	AA	Terashima 1971a, b.
195(4)	239(2)	440(2)	231(4)	655(4)	----------	----------	337(4)	AA	Luecke, 1971.
----------	----------	680	280	780	<50	<50	280	XRF	Guillemaut, 1968.
----------	----------	498(2)	----------	----------	----------	----------	----------	XRF	Murad, 1968.
189	----------	----------	----------	----------	----------	----------	----------	XRF	Bell and Powell, 1969.
----------	----------	----------	----------	----------	.38(8)	.31(8)	----------	XRF	Chappell and others, 1969.
----------	----------	450	360	718	----------	----------	350	XRF	Franzini and Leoni, 1969.
180	256	472	230	658	----------	----------	303	XRF	Hattori and Shibata, 1969.
192(3)	----------	492(5)	240(2)	682(2)	<2	<2	322	XRF	Murad, 1969.
----------	----------	598(2)	266(2)	751(2)	<5	<5	400(2)	XRF	Parker, 1969.
190	260	490	220	700	----------	----------	340	XRF	Schneider, 1969.
183	250	431	218	649	<5	<5	343	XRF	Schroll and Stepan, 1969.
190	----------	471	229	656	----------	----------	333	XRF	Cherry and others, 1970.
209	----------	----------	----------	----------	----------	----------	----------	XRF	Quintin, 1970.
----------	----------	----------	----------	----------	----------	----------	339	XRF-SQ	B. C. Smith, 1970.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W-1	G-1	G-2	GSP-1	AGV-1	PCC-1	DTS-1	BCR-1	Reference	Method
Sr—Continued									
200	230	----------	250	690	<10	<10	400	XRF	Fabbi, 1971c.
----------	----------	480	235	663	----------	----------	331	XRF	Fairbairn and Hurley, 1971.
180	----------	----------	240	660	<5	<5	320	XRF	Feather, 1971.
196	----------	494	246	641	< .3	< .3	348	XRF	Goodman, 1971.
----------	----------	472	230	650	----------	----------	320	XRF	Heier and Thoresen, 1971.
184(2)	262(2)	----------	----------	----------	----------	----------	----------	XRF	Hirst and Kaye, 1971.
----------	268	----------	----------	----------	.8	.7	----------	XRF	Murad, 1971.
----------	----------	487	239	665	----------	----------	322	XRF	Sceal and Weaver, 1971.
----------	----------	462(2)	224(2)	640(2)	1.1(2)	1.3(2)	320(2)	XRF	Webber and Newbury, 1971.
188.5	251.6	482.5	234.5	659.8	.37	.34	329.4	XRF	Chappell, 1972.
162(2)	----------	410(2)	193(2)	606(2)	----------	----------	318(2)	EpINAA	Brunfelt and Steinnes, 1969c.
193(2)	256(2)	445(2)	224(2)	612(2)	----------	----------	327(2)	NAA	Higuchi, Tomura, Takahashi, and others, 1969a, b.
186(2)	246(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
----------	----------	400	----------	400	----------	----------	290(2)	NAA	Morrison and others, 1969; Morrison and Kashuba, 1969; Morrison, 1971.
----------	----------	----------	----------	----------	----------	----------	350(3)	NAA	Allen and others, 1970; Haskin and others, 1970.
----------	----------	420	240	650	----------	----------	----------	NAA	Filby and others, 1970.
----------	----------	----------	----------	----------	----------	----------	312	NAA	Brunfelt and others, 1971.
180	----------	463	247	657	.3	----------	330	X-ray activation	Kunzendorf, 1971.
----------	----------	----------	----------	----------	----------	.36	----------	ID	Hart, 1968.
----------	----------	----------	----------	----------	.38(2)	.31(5)	----------	ID	Chappell and others, 1969.
----------	----------	481(2)	236(2)	666(2)	----------	----------	336(2)	ID	Loveridge and Wanless, 1969.
189.3(2)	----------	474.8(2)	233.2(2)	656.8(2)	.42(2)	.39(2)	331.4(2)	ID	de Laeter and Abercrombie, 1970.
----------	----------	480(2)	228(2)	----------	----------	----------	----------	ID	Gamot and others, 1970.
----------	----------	----------	----------	----------	----------	----------	328(2)	ID	Gast and others, 1970.
186	----------	----------	----------	----------	----------	----------	325(2)	ID	Philpotts and Schnetzler, 1970.
----------	----------	----------	232.9(8)	----------	----------	----------	----------	ID	Welin, 1970.
----------	----------	----------	----------	646	.44	----------	326	ID	Ozima and Zashu, 1971.
----------	----------	----------	----------	----------	----------	----------	336(3)	ID	Krähenbühl and others, 1972.
----------	----------	478.9(4)	235.8	----------	----------	----------	----------	ID	Vidal, 1972.
Ta									
----------	----------	0.83(5)	----------	----------	----------	----------	----------	INAA	Aruscavage, 1969.
0.42(10)	----------	.73(10)	0.81(10)	0.80(10)	----------	----------	0.75(10)	EpINAA	Brunfelt and Steinnes, 1969c.
.5	----------	.8	1.2	1.7	----------	1.0	1.2	INAA	Filby and Haller, 1969; Filby and others, 1970.
----------	----------	----------	----------	1.06	----------	----------	.79	INAA	B. C. Smith, 1970.
----------	----------	----------	----------	----------	----------	----------	.99	INAA	Goles and others, 1971.
----------	----------	1.5	2.2	2.3	.2	.2	1.1	NAA	Schiltz, 1968.
.4(2)	1.5(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
----------	----------	.7	----------	.8	----------	----------	1(2)	NAA	Morrison and others, 1969; Morrison, 1971.
----------	----------	----------	----------	----------	----------	----------	.90(3)	NAA	Allen and others, 1970; Haskin and others, 1970.
----------	----------	----------	----------	----------	----------	----------	.74(5)	NAA	Brunfelt and others, 1971.
.49(4)	.88(4)	.86(4)	.98(4)	1.0(4)	<.05	<.05	.80(4)	NAA	Greenland and Campbell, 1971. Acid decomposition.
.54(3)	1.5(3)	.96(3)	.96(3)	.99(3)	<.1	<.1	.85(3)	NAA	Greenland and Campbell, 1971. Na_2O_2 decomposition.
----------	----------	.51(5)	.63(5)	.55(5)	.0056(4)	.0086(5)	.50(5)	NAA	Anoshin, Perezhogin, and Melnikova, 1970.
Tb									
<2	<2	----------	----------	----------	----------	----------	----------	OS	Cohen and others, 1968.
.7	.4	----------	----------	----------	----------	----------	----------	SSMS	Carver and Johnson, 1968.
.64	----------	----------	----------	----------	----------	----------	----------	SSMS	Graham and Nicholls, 1969.
----------	----------	----------	----------	----------	----------	----------	1	SSMS	Morrison and Kashuba, 1969.
----------	----------	0.9(3)	1.4(2)	1.2(3)	----------	----------	.9(3)	Ion exchange–XRF	Eby, 1972.
.57(2)	----------	.48(2)	1.41(2)	.56(2)	----------	----------	.96(2)	EpINAA	Brunfelt and Steinnes, 1969c.
----------	----------	.43	----------	.62	----------	----------	----------	INAA	Green and others, 1969.
----------	----------	.5	1.6	.6	----------	----------	.9	INAA	Scott, 1969.
.7	----------	.6	1.0	.8	----------	----------	1.1	INAA	Filby and others, 1970.
.72	----------	.75	----------	----------	----------	----------	----------	INAA	Melson, 1970.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W-1	G-1	G-2	GSP-1	AGV-1	PCC-1	DTS-1	BCR-1	Reference	Method
Tb—Continued									
0.61	----------	----------	----------	----------	----------	----------	----------	INAA	Goles and others, 1971.
.71(6)	----------	0.51(8)	1.31(7)	0.75(8)	<0.04	<0.04	1.22(8)	NAA	Brunfelt and Steinnes, 1969b.
.665(5)	0.538(5)	.50(2)	1.31(2)	.72(2)	.0014	.00030	1.17	NAA	Higuchi, Tomura, Onuma, and Hamaguchi, 1969.
.82(2)	.43(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
----------	----------	.5	----------	.8	----------	----------	1(2)	NAA	Morrison and others, 1969; Morrison and Kashuba, 1969; Morrison, 1971.
.57	----------	.40	----------	----------	----------	----------	.93	NAA	Petersen and others, 1969.
.60	.57	----------	----------	----------	----------	----------	----------	NAA	Schilling and Winchester, 1969.
----------	----------	----------	----------	----------	----------	----------	1.19	NAA	Allen and others, 1970.
----------	----------	----------	----------	----------	----------	----------	1.154(3)	NAA	Denechaud and others, 1970.
.61	.88	----------	----------	----------	----------	----------	----------	NAA	Graber and others, 1970.
----------	----------	----------	----------	----------	----------	----------	1.15(3)	NAA	Haskin and others, 1970.
----------	.30	----------	----------	----------	----------	<.0003	.87(2)	NAA	Rey and others, 1970.
----------	----------	----------	----------	----------	----------	----------	.96	NAA	Brunfelt and others, 1971.
----------	----------	.7	----------	----------	----------	----------	----------	NAA	Das and Zonderhuis, 1971.
.58	----------	----------	----------	----------	----------	----------	.95	NAA	Ragland and others, 1971.
Te									
----------	----------	----------	----------	----------	----------	----------	(0.4)	SSMS	Morrison and Kashuba, 1969.
0.48	----------	----------	----------	----------	----------	----------	----------	NAA	Reed and Jovanović, 1969.
<1	<1	<1	<1	<1	<1	<1	<1	NAA	Laul, Case, Wechter, and others, 1970.
Th									
1	30	----------	----------	----------	----------	----------	----------	OS	Cohen and others, 1968.
----------	52	23	108	7	----------	----------	8	XRF	Cherry and others, 1970.
<5	----------	26	----------	5	<5	<5	<6	XRF	Feather, 1971.
2.0	----------	----------	----------	5.7	----------	----------	5.4	XRF	Kaye, 1972.
----------	----------	----------	----------	----------	----------	----------	5	SSMS	Morrison and Kashuba, 1969.
3.7(2)	48(2)	----------	----------	----------	----------	----------	----------	γ counting	de Ruyter, 1968.
----------	----------	24.3(4)	103.1(4)	7.0(4)	----------	----------	6.8(4)	do	Gasparini, 1969.
2.0	49.7	26.6	107.6	6.3	----------	----------	6.1	do	Cherry and others, 1970.
----------	----------	24.3	103.1	7.0	----------	----------	6.8	do	Capaldi and others, 1971.
----------	----------	25.7	106	6.4	----------	----------	6.1	do	Heier and Thoresen, 1971.
2.11(3)	----------	23.3(3)	101(3)	5.88(3)	----------	----------	5.60(3)	EpINAA	Brunfelt and Steinnes, 1969c.
3.0	----------	26.5	144	6.2	----------	----------	9.0	INAA	Filby and others, 1970.
2.0(2)	56(2)	24(2)	104(2)	6.2(2)	----------	----------	5.0(2)	INAA	Simon, 1970.
2.35	----------	----------	----------	----------	----------	----------	6.02	INAA	Goles and others, 1971.
----------	----------	23.6	103	6.1	----------	----------	----------	INAA	Whitley and others, 1971.
----------	----------	21.2	----------	6.43	.014	.013	5.85	NAA	Gangadharam and Parekh, 1968.
----------	----------	19	102	7	1	1	6	NAA	Schlitz, 1968.
1.9(2)	33(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
----------	----------	26	----------	7.1	----------	----------	4.6(2)	NAA	Morrison and others, 1969; Morrison and Kashuba, 1969; Morrison, 1971.
----------	----------	----------	----------	----------	----------	----------	6.7	NAA	Osawa and Goles, 1970.
2.53	47.30	----------	103.2	----------	----------	----------	----------	NAA	Meyer, 1971.
2.28(2)	52.4(4)	25.0(4)	104(2)	6.20(2)	.0108(2)	.0100(2)	6.20(2)	NAA	Norton and Stoenner, 1971.
2.38(2)	46.1(6)	25.4(2)	102(2)	6.42(2)	----------	----------	6.14(2)	NAA	Norton and Stoenner, 1971.
Ti									
----------	----------	4,000	4,000	8,000	20	18	15,000	OS–SQ	Clark, 1968.
----------	----------	2,550	3,830	5,740	----------	----------	12,800	XRF	Franzini and Leoni, 1969.
6,710(2)	----------	2,890(4)	4,060(2)	6,240(2)	----------	----------	13,600(2)	XRF	Murad, 1969.
----------	----------	3,080(2)	4,060(2)	6,470(2)	70(2)	68(2)	13,600(2)	XRF	Parker, 1969.
6,900	----------	2,600	4,000	6,300	----------	----------	11,000	INAA	Filby and Haller, 1969; Filby and others, 1970.
Tl									
<1	1.4(5)	1.8(4)	2.1(5)	<1	<1	<1	<1	OS	Huber-Schausberger and others, 1970.
----------	----------	----------	----------	----------	----------	----------	.3	SSMS	Morrison and Kashuba, 1969.
----------	----------	1.02	1.87	.39	.35	.13	.59	Fluorescence	Matthews and Riley, 1969.
----------	----------	----------	----------	----------	----------	----------	.278(2)	NAA	Ganapathy and others, 1970; Keays and others, 1970.
.102(2)	1.060(2)	.890(2)	1.300(2)	.342(2)	.00075(2)	.00051(2)	.330(2)	NAA	Laul, Pelly, and Lipschutz, 1970.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1	Reference	Method
					Tl—Continued				
----------	----------	----------	----------	----------	----------	----------	0.280(4)	NAA	Anders and others, 1971.
0.108	1.415	1.200	1.215	1.630	0.0008	0.010	.350	NAA	Marowsky, 1971a.
.121	1.415	1.200	----------	1.630	----------	----------	.350	NAA	Marowsky, 1971c.
.116	1.080	1.200	1.288	----------	----------	----------	----------	NAA	Marowsky, 1971b.
.115(2)	----------	----------	----------	1.630(2)	.00075(2)	----------	----------	NAA	Marowsky and Wedepohl, 1971.
----------	----------	----------	----------	----------	----------	----------	.269(2)	NAA	Laul and others, 1972.
					Tm				
0.46	0.20	----------	----------	----------	----------	----------	----------	SSMS	Carver and Johnson, 1968.
.44	----------	----------	----------	----------	----------	----------	----------	SSMS	Graham and Nicholls, 1969.
----------	----------	----------	----------	----------	----------	----------	0.3	SSMS	Morrison and Kashuba, 1969.
----------	----------	<0.4	<0.8	<0.4	----------	----------	<.4	Ion exchange–XRF	Eby, 1972.
.336	.155	----------	----------	----------	----------	----------	----------	NAA	Higuchi, Tomura, Takahashi, and others, 1969a; Higuchi and others, 1970.
----------	----------	.3	----------	.4	----------	----------	.6	NAA	Morrison and others, 1969; Morrison and Kashuba, 1969; Morrison, 1971.
----------	----------	.12	----------	----------	----------	<0.0015	.56(2)	NAA	Rey and others, 1970.
(.7)	----------	(.4)	----------	----------	----------	----------	----------	NAA	Melson, 1970.
.26	.153	----------	----------	----------	----------	----------	----------	NAA	Schilling and Winchester, 1969.
----------	----------	.3	----------	----------	----------	----------	----------	NAA	Das and Zonderhuis, 1971.
					U				
1.5	2.6	----------	----------	----------	----------	----------	----------	OS	Cohen and others, 1968.
----------	----------	----------	----------	----------	----------	----------	1.1	SSMS	Morrison and Kashuba, 1969.
.44	3.14	----------	----------	----------	----------	----------	----------	Fission track	Bertine and others, 1970.
----------	----------	1.0	----------	1.90(4)	0.0047(4)	0.0032(3)	1.79(5)	----do	Fisher, 1970.
----------	----------	2.2	1.8	2.1	.006	.004	1.7	----do	Nishimura, 1970a.
----------	----------	2.01	----------	----------	----------	----------	1.64	----do	Murali and others, 1970.
----------	----------	----------	----------	----------	----------	.0041(5)	----------	----do	Aruscavage, 1972.
.66(2)	4.5(2)	----------	----------	----------	----------	----------	----------	γ-counting	de Ruyter, 1968.
----------	----------	2.5(4)	1.9(4)	2.0(4)	----------	----------	1.9(4)	----do	Gaspirini, 1969.
.63	3.2	2.2	2.1	1.4	----------	----------	1.5	----do	Cherry and others, 1970.
----------	----------	2.5	1.9	2.0	----------	----------	1.9	----do	Capaldi and others, 1971.
----------	----------	2.1	1.7	1.9	----------	----------	1.6	----do	Heier and Thoresen, 1971.
.59(3)	----------	1.93(3)	2.05(2)	1.90(3)	----------	----------	1.80(3)	EpINAA	Brunfelt and Steinnes, 1969c.
.61(3)	----------	2.06(3)	2.15(6)	1.93(3)	----------	----------	1.94(3)	EpINAA	Steinnes and Brune, 1969.
.53(2)	2.7(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
----------	----------	1.8	----------	1.9	----------	----------	1.8(2)	NAA	Morrison and others, 1969; Morrison and Kashuba, 1969; Morrison, 1971.
1.04	----------	----------	----------	----------	----------	----------	----------	NAA	Reed and Jovanovic, 1969.
----------	----------	----------	----------	2.0	.005	.004	1.6	NAA	Nishimura, 1970b.
----------	----------	----------	----------	----------	----------	----------	1.73	NAA	Osawa and others, 1971.
----------	----------	----------	----------	----------	----------	----------	1.68(5)	NAA	Brunfelt and others, 1971.
----------	----------	----------	----------	----------	.0039(5)	.0030(5)	----------	NAA	Steinnes, 1972c.
.58	3.36	----------	1.91	----------	----------	----------	----------	NAA	Meyer, 1971.
----------	----------	----------	----------	----------	----------	----------	1.70(4)	IDMS	Gale, 1972.
					V				
----------	----------	40	60	140	30	10	350	OS–SQ	Clark, 1968.
----------	----------	40(3)	48(3)	118(3)	29(3)	14(3)	355(3)	OS	Floyd and others, 1968.
250	16	----------	----------	----------	----------	----------	----------	OS	Mikšovský, 1968.
----------	----------	40	45	120	25	15	430	OS	Ropert and others, 1968.
----------	----------	40(5)	58(3)	145(4)	30(2)	9.5(2)	351(8)	OS	Dutra, 1969.
----------	----------	----------	----------	----------	----------	----------	420	OS	Champ and others, in Maxwell and others, 1970.
----------	----------	33	44	130	36	10	418	OS	Moal and others, 1970.
----------	----------	49(2)	50(2)	117(2)	----------	----------	377(2)	OS	Govindaraju, 1970b.
270(10)	----------	----------	----------	----------	----------	----------	----------	OS	Martin and Quintin, 1970.
300(3)	----------	----------	----------	150(3)	----------	----------	420(3)	OS	Suhr and Smith, 1970.
250(17)	15.9(9)	35(7)	60(7)	131(9)	26.3(10)	<25	337(9)	OS	Huber-Schausberger and others, 1970.
256(10)	15(10)	26(10)	40(10)	145(10)	23(10)	<10	495(10)	OS	Thompson and others, 1970.
240	15	----------	----------	----------	----------	----------	----------	OS	de Albuquerque, 1971.
----------	----------	28	45	105	40	5	380	OS	Avni, Harel, and Brenner, 1972.
248(4)	19(4)	28(15)	50(15)	119(15)	35(15)	27(15)	423(15)	OS	Blackburn and others, 1971.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1	Reference	Method
						V—Continued			
250(9)	----------	41(12)	55(8)	130(8)	27(4)	----------	430(11)	OS	Brenner, 1971.
260.0	----------	----------	56.3	----------	----------	----------	350.0	OS	Gerasimovskiy and Laktionova, 1971.
252	16	37	54	118	33	9.2	315	OS	Hofmeyr, 1972.
300(2)	----------	----------	60(2)	142(2)	----------	----------	440	OS	Murad, 1971.
----------	----------	----------	----------	----------	----------	----------	310	SSMS	Morrison and Kashuba, 1969.
230	----------	----------	----------	----------	----------	----------	----------	Chemical	Bernas, 1968.
----------	----------	32(3)	58(3)	147(3)	----------	----------	460(3)	Coulometric	Hetman and Puyo, 1968.
276(4)	----------	----------	----------	113(4)	29.1(4)	6.8(4)	----------	Ion Exchange	Toerien, 1969.
----------	----------	40	50	110	25	10	400	Paper chromat-SQ	Agrinier, 1968.
----------	----------	38	48	122	23	14	426	Colorimetric	Pouget and others, 1968.
----------	----------	----------	75(2)	125(2)	46(7)	37.5(2)	368(7)	do	Roberts, 1971.
274(4)	----------	----------	----------	123(4)	28.2(4)	6.8(4)	----------	Spectrophotometric	Strelow and others, 1969.
273(2)	16.0	35.5(2)	52.5(2)	122(2)	22.5(2)	6.2(2)	422(2)	do	Donaldson, 1970.
253	----------	36	57	120	26	<5	348	AA	Price, 1969.
209	----------	100	101	101	----------	----------	476	AA	Buckley and Cranston, 1971.
245(2)	~20	34(2)	51(2)	115(2)	----------	----------	402(2)	AA	Luecke, 1971.
----------	----------	22(2)	36(2)	105(2)	35(2)	<20	404(2)	XRF	Parker, 1969.
246	----------	31	55	110	36	15	430	XRF	Goodman, 1971.
240	13	41	56	121	32	20	403	XRF	Fabbi and Espos, 1972a.
304	----------	----------	----------	160	35	10	340	INAA	Filby and Haller, 1969; Filby and others, 1970.
----------	----------	----------	----------	----------	37	6	----------	INAA	Gordon and others, 1969.
----------	----------	52	----------	140	----------	----------	375(2)	INAA	Morrison and others, 1969.
256(4)	----------	----------	----------	----------	32(4)	----------	400	INAA	Wyttenbach, 1969.
285	----------	----------	----------	----------	----------	----------	458	INAA	Goles and others, 1971.
----------	----------	----------	----------	----------	----------	----------	380	INAA	Morrison, 1971; Morrison and Kashuba, 1969.
----------	----------	----------	----------	----------	----------	----------	476	NAA	Brunfelt and others, 1971.
----------	----------	26	65	95	12	1.7	320	NAA	Das and Zonderhuis, 1971.
240	----------	----------	----------	----------	27	----------	374	XRF	Kaye, 1972.
						W			
0.45	1.30(2)	0.00	0.30(2)	0.63(2)	0.06(2)	0.04(2)	0.54(2)	Spectrophotometric	Kawabuchi and Kuroda, 1970.
----------	----------	----------	----------	----------	----------	----------	.7	SSMS	Morrison and Kashuba, 1969.
.5(2)	.4(2)	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
----------	----------	.46	----------	.58	----------	----------	.44(2)	NAA	Morrison and others, 1969; Morrison and Kashuba, 1969; Morrison, 1971.
.38(3)	----------	.04(3)	.12(2)	.45(3)	----------	----------	.24(3)	NAA	Johanson and Steinnes, 1970.
----------	----------	----------	----------	----------	----------	----------	.38	NAA	Brunfelt and others, 1971.
----------	----------	----------	----------	----------	----------	----------	.381(5)	NAA	Brunfelt and Steinnes, 1971b.
----------	<.8	----------	----------	----------	----------	----------	----------	OS	Ivanova, 1966.
						Y			
11	12	----------	----------	----------	----------	----------	----------	OS	Cohen and others, 1968.
----------	----------	10	10	25	----------	----------	28	OS-SQ	Clark, 1968.
----------	----------	15(5)	35(3)	25(4)	<10	<10	45.4(7)	OS	Dutra, 1969.
----------	----------	----------	----------	----------	----------	----------	34	OS	Champ and others, in Maxwell and others, 1970.
----------	----------	<10	26	30	25	20	48	OS	Moal and others, 1970.
20(3)	----------	----------	----------	19(3)	----------	----------	29(3)	OS	Suhr and Smith, 1970.
30(10)	<20	<20	34(10)	30(10)	6(10)	5(10)	41(10)	OS	Thompson and others, 1970.
29	----------	----------	----------	----------	----------	----------	----------	OS	de Albuquerque, 1971.
27	12	12	29	25	<4	<4	48	OS	Hofmeyr, 1972.
----------	----------	13(2)	34(2)	10(2)	<5	<5	16(2)	XRF	Parker, 1969.
11	----------	----------	----------	----------	----------	----------	----------	XRF	Quintin, 1970.
----------	----------	14.4(3)	25.5(2)	17.4(3)	----------	----------	32.7(3)	XRF	Eby, 1972.
28	----------	10	41	22	<5	<5	44	XRF	Feather, 1971.
----------	----------	8	17	12	<2	<2	23	XRF	Goodman, 1971.
25	13	<8	34	25	<8	<8	44	XRF	Fabbi, 1972b.
----------	----------	11	26	19	----------	----------	----------	XRF	Sceal and Weaver, 1971.
20	----------	----------	----------	18	----------	----------	33	XRF	Kaye, 1972.
----------	----------	----------	----------	----------	----------	----------	39	SSMS	Morrison and Kashuba, 1969.
22.4	13.1	----------	----------	----------	----------	----------	----------	NAA	Schilling and Winchester, 1969.
----------	----------	9.4(2)	----------	----------	----------	.050	36(2)	NAA	Rey and others, 1970.
25	----------	12.2	36.6	24.3	----------	----------	46.2	X-ray activation	Kunzendorf, 1971.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W-1	G-1	G-2	GSP-1	AGV-1	PCC-1	DTS-1	BCR-1	Reference	Method
						Yb			
----------	----------	1.2(2)	2(2)	1.8(2)	<1	1(2)	4.1(6)	OS	Dutra, 1969.
2.8(17)	1.0(9)	.8(7)	2.3(7)	1.9(9)	<2	<1	5.8(9)	OS	Huber-Schausberger and others, 1970.
----------	----------	1	2	4	2	2	7	OS	Moal and others, 1970.
2.1(3)	----------	----------	----------	1.6(3)	----------	----------	3.2(3)	OS	Suhr and Smith, 1970.
2.3	.7	<.5	1.4	1.6	.9	.7	3.2	OS	Hofmeyr, 1972.
2.30	.37	----------	----------	----------	----------	----------	----------	SSMS	Carver and Johnson, 1968.
1.7	----------	----------	----------	----------	----------	----------	----------	SSMS	Graham and Nicholls, 1969.
----------	----------	----------	----------	----------	----------	----------	3.3	SSMS	Morrison and Kashuba, 1969.
----------	----------	----------	----------	----------	----------	----------	2.8(2)	XRF	Eby, 1972.
1.8(3)	----------	.9(3)	1.0(3)	1.4(3)	----------	----------	3.5(3)	EpINAA	Brunfelt and Steinnes, 1969c.
----------	----------	.86	----------	1.45	----------	----------	----------	INAA	Green and others, 1969.
----------	----------	----------	1.8	----------	----------	----------	----------	INAA	Scott, 1969.
2.5	----------	1.3	2.5	3.0	----------	----------	3.9	INAA	Filby and others, 1970.
2.4	----------	.9	----------	----------	----------	----------	----------	INAA	Melson, 1970.
2.1	----------	----------	----------	----------	----------	----------	----------	INAA	Goles and others, 1971.
2.08(4)	----------	----------	----------	----------	----------	----------	3.38(2)	ID	Philpotts and Schnetzler, 1970.
----------	----------	----------	----------	----------	----------	----------	3.68(2)	ID	Gast and others, 1970.
----------	----------	----------	----------	----------	----------	----------	3.44	ID	Schnetzler and Nava, 1971.
2.06(5)	.93(5)	.68(2)	1.74(2)	1.68(2)	.023	.0057	3.58(2)	NAA	Higuchi, Tomura, Onuma, and Hamaguchi, 1969.
2.29(5)	----------	.86(4)	1.93(5)	1.91(5)	<.05	<.02	3.69(5)	NAA	Brunfelt and Steinnes, 1969b.
1.5(2)	----------	----------	----------	----------	----------	----------	----------	NAA	Landstrom and others, 1969.
----------	----------	.90	----------	1.9	----------	----------	3.1(2)	NAA	Morrison and others, 1969; Morrison and Kashuba, 1969; Morrison, 1971.
2.2	----------	.85	----------	----------	----------	----------	3.1	NAA	Peterson and others, 1969.
2.18	1.04	----------	----------	----------	----------	----------	----------	NAA	Schilling and Winchester, 1969.
----------	----------	----------	----------	----------	----------	----------	3.51	NAA	Allen and others, 1970.
----------	----------	----------	----------	----------	----------	----------	3.48(3)	NAA	Denechaud and others, 1970; Haskin and others, 1970.
2.3	1.84	----------	----------	----------	----------	----------	----------	NAA	Graber and others, 1970.
1.71	.778	----------	----------	----------	----------	----------	----------	NAA	Higuchi and others, 1970.
----------	----------	----------	----------	----------	----------	----------	3.2	NAA	Osawa and Goles, 1970.
----------	.72(2)	----------	----------	----------	----------	.018	3.4(2)	NAA	Rey and others, 1970.
----------	----------	----------	----------	----------	----------	----------	3.21(5)	NAA	Brunfelt and others, 1971.
----------	----------	.7	----------	----------	----------	----------	----------	NAA	Das and Zonderhuis, 1971.
2.14	----------	----------	----------	----------	----------	----------	2.8	NAA	Ragland and others, 1971.
						Zn			
82(24)	46(5)	76(4)	55(5)	90(3)	57(2)	66(2)	140(4)	OS	Huber-Schausberger and others, 1970.
----------	----------	90	70	90	50	58	174	OS	Moal and others, 1970.
80(10)	54(10)	87(10)	95(10)	105(10)	26(10)	27(10)	110(10)	OS	Thompson and others, 1970.
----------	----------	100	135	120	70	80	190	AA	Ropert and Broudic, 1968.
99(2)	----------	----------	----------	----------	----------	----------	----------	AA	Bender and Schultz, 1969.
95	----------	58	77	77	40	46	135	AA	Price, 1969.
88	----------	101	120	95	42	40	145	AA	Sighinolfi, 1969.
----------	----------	----------	----------	----------	----------	----------	120	AA	Abbey, in Maxwell and others, 1970.
90.3	----------	89.0	108.9	95.8	----------	----------	141.7	AA	Fletcher, 1970.
83	33	----------	----------	----------	----------	----------	----------	AA	Govindaraju, 1970b.
----------	----------	----------	111	110	----------	72	139	AA	Langmyhr, 1970.
90(4)	52(4)	89(4)	112(4)	86(4)	----------	----------	131(4)	AA	Rose, 1970.
84.2(8)	----------	----------	----------	85(2)	----------	----------	128(2)	AA	Smith and Rose, 1970.
80	----------	73	83	78	----------	----------	112	AA	Buckley and Cranston, 1971.
----------	----------	113(3)	128(3)	120(3)	70(3)	67(3)	153(3)	AA	Cioni and others, 1971.
85(3)	----------	81(2)	104(3)	86	37(2)	39(2)	128(2)	AA	Rosman and Jeffrey, 1971.
87	47	80	101	90	----------	----------	130	AA	Walsh, 1972.
----------	----------	83(5)	103(5)	89(5)	26(5)	29(5)	125(5)	AA	Terashima, 1971a, b.
----------	----------	100	140	120	60	90	180	Paper chromat-SQ	Agrinier, 1968.
----------	----------	76(4)	114(4)	98(4)	48(4)	55(4)	128(4)	XRF	Butler, 1968.
69(3)	----------	85(5)	95(4)	75(3)	41(2)	42(2)	102(2)	XRF	Murad, 1968.
70(3)	----------	84(10)	98(5)	78(4)	41(4)	43(4)	102(4)	XRF	Murad, 1969.
----------	----------	89(2)	108(2)	93(2)	50(2)	50(2)	133(2)	XRF	Parker, 1969.
85(2)	51(2)	90(2)	110(2)	96(2)	----------	----------	130(2)	XRF	Schneider, 1969.
110	----------	----------	----------	----------	----------	----------	----------	XRF	Quintin, 1970.
79	----------	84	104	82	42	48	120	XRF	Feather, 1971.
82(2)	44(2)	----------	----------	----------	----------	----------	----------	XRF	Hirst and Kaye, 1971.

TABLE 105.—*Determinations of trace elements in eight USGS standard samples*—Continued

W-1	G-1	G-2	GSP-1	AGV-1	PCC-1	DTS-1	BCR-1	Reference	Method
Zn—Continued									
---	---	84.6(2)	101.5(2)	89.6(2)	48.4(2)	50(2)	123(2)	XRF	Webber and Newbury, 1971.
82(2)	47(2)	88(2)	105(2)	88(2)	44(2)	42(2)	122(2)	XRF	Fabbi and Espos, 1972a.
90	---	---	---	88	46	---	123	XRF	Kaye, 1972.
---	---	---	---	---	---	---	145	SSMS	Morrison and Kashuba, 1969.
80	---	---	---	---	---	---	---	NAA	Case and others, 1969.
89	---	---	64	---	30	---	---	NAA	Filby and Haller, 1969.
92(2)	43(2)	---	---	---	---	---	---	NAA	Landstrom and others, 1969.
---	---	83	---	85	---	---	131(2)	NAA	Morrison and others, 1969; Morrison and Kashuba, 1969; Morrison, 1971.
82	---	92	---	---	17	---	118	NAA	Peterson and others, 1969.
---	---	---	---	---	---	---	100(3)	NAA	Allen and others, 1970; Haskin and others, 1970.
92	---	93	107	96	45	53	133	NAA	Baedecker and others, 1971.
89	---	84	---	64	20	30	96	NAA	Filby and others, 1970.
---	---	---	---	---	---	---	126(2)	NAA	Ganapathy and others, 1970.
84.9(5)	---	80.6(5)	96.7(5)	81.1(5)	---	---	127.4(5)	NAA	Johansen and Steinnes, 1970.
80	44	79	116	88	44	61	117	NAA	Laul, Case, Wechter, and others, 1970.
---	---	---	---	---	---	---	116(5)	NAA	Anders and others, 1971.
---	---	---	---	---	---	---	127.4	NAA	Brunfelt and others, 1971.
80.1	---	---	---	---	54.9	---	---	NAA	Nadkarni and Haldar, 1971a.
---	---	---	---	---	---	---	124(2)	NAA	Laul and others, 1972.
89.3(6)	---	83.9(3)	105.1(5)	86.7(2)	38.6(4)	37.1(5)	129.4(2)	ID	Rosman and Jeffrey, 1971.
Zr									
---	---	300	500	200	---	---	200	OS-SQ	Clark, 1968.
---	---	295(3)	487(3)	180(3)	37(3)	30(3)	162(3)	OS	Floyd and others, 1968.
120(9)	---	---	---	---	---	---	---	OS	Sighinolfi, 1968
---	---	317(4)	643(3)	250(4)	<10	<10	199(7)	OS	Dutra, 1969.
103(17)	206(9)	356(7)	385(7)	205(9)	<20	<20	228(9)	OS	Huber-Schausberger and others, 1970.
94(3)	---	---	---	215(3)	---	---	94(3)	OS	Suhr and Smith, 1970.
95	195	---	---	---	---	---	---	OS	de Albuquerque, 1971.
113(10)	197(10)	220(10)	405(10)	220(10)	<5	<5	200(10)	OS	Thompson and others, 1970.
109(4)	218(4)	277(15)	525(15)	246(15)	<10	<10	186(15)	OS	Blackburn and others, 1971.
138(9)	---	256(12)	525(7)	250(9)	---	---	240(11)	OS	Brenner, 1971.
---	184	300	500	230	---	---	140	OS	Murad, 1971.
---	---	---	---	---	---	---	180	SSMS	Morrison and Kashuba, 1969.
111(4)	---	---	---	185(4)	5.9(4)	3.2(4)	---	Spectrophotometric	Strelow and others, 1969.
111(4)	---	---	---	188(4)	5.9(4)	4.3(4)	---	Ion exchange	Toerein, 1969.
---	---	250	220	100	<50	<50	60	XRF	Guillemaut, 1968.
---	---	394(2)	681(2)	280(2)	<5	<5	198(2)	XRF	Parker, 1969.
98(2)	210(2)	305(2)	540(2)	230(2)	---	---	185(2)	XRF	Schneider, 1969.
134	---	---	---	---	---	---	---	XRF	Quintin, 1970.
99	---	---	650	240	<5	<5	189	XRF	Feather, 1971.
101	---	282	525	230	<2	<2	182	XRF	Goodman, 1971.
---	---	307	502	228	---	---	182	XRF	Heier and Thoresen, 1971.
84(2)	232(2)	---	---	---	---	---	---	XRF	Hirst and Kaye, 1971.
---	---	321	545	206	---	---	172	XRF	Sceal and Weaver, 1971.
---	---	345(2)	574(2)	230(2)	---	---	198(2)	XRF	Webber and Newbury, 1971.
91	---	---	---	229	---	---	184	XRF	Kaye, 1972.
---	---	252	255	213	---	---	---	INAA	Whitley and others, 1971.
105(2)	202(2)	---	---	---	---	---	---	NAA	Landstrom and others, 1969.
---	---	236	---	244	---	---	272(2)	NAA	Morrison and others, 1969.
---	---	---	---	---	---	---	274	NAA	Morrison and Kashuba, 1969.
110(3)	219(3)	393(3)	645(2)	213	8.1(2)	1.4(2)	184(3)	NAA	Rebagay, 1969.
---	---	---	---	---	---	---	290	NAA	Morrison, 1971.
---	---	---	---	---	---	---	196(3)	NAA	Krähenbühl and others, 1972.
100	---	316	544	227	---	---	185	X-ray activation	Kunzendorf, 1971.
---	---	---	---	---	---	---	194	ID	Schnetzler and Nava, 1971.

TABLE 106.—*Estimates of components normally determined in a rock analysis, in percent*

[Data are listed as **recommended**, averages, or *magnitudes*]

	W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1
SiO_2	52.64	72.64	69.11	67.38	59.00	41.90	40.50	54.50
Al_2O_3	15.00	14.04	15.40	15.25	17.25	.74	.24	13.61
Fe_2O_3	1.40	.87	1.08	1.77	4.51	2.85	1.21	3.69
FeO	8.72	.96	1.45	2.31	2.05	5.24	7.23	8.80
MgO	6.62	.38	.76	.96	1.53	43.18	49.80	3.46
CaO	10.96	1.39	1.94	2.02	4.90	.51	.15	6.92
Na_2O	2.15	3.32	4.07	2.80	4.26	*.006*	.007	3.27
K_2O	.64	5.48	4.51	5.53	2.89	*.004*	.0012	1.70
H_2O^+	.53	.34	.55	.57	.81	4.70	.46	.77
H_2O^-	.16	.06	*.11*	*.12*	*1.03*	*.50*	*.06*	*.80*
TiO_2	1.07	.26	.50	.66	1.04	*.015*	*.013*	2.20
P_2O_5	.14	.09	.14	.28	.49	*.002*	*.002*	.36
MnO	.17	.03	.034	.042	.097	.12	.11	.18
CO_2	.06	.07	*.08*	*.15*	*.05*	*.12*	*.08*	*.03*
Total	100.26	99.93	99.73	99.84	99.91	99.89	99.86	100.28
Total Fe as Fe_2O_3	11.09	1.94	2.65	4.33	6.76	8.35	8.64	13.40
O	44.77	---	48.34	47.78	47.24	----	----	45.48

TABLE 107.—*Estimates for trace elements in USGS samples*

[Data are listed as **recommended**, averages, or *magnitudes;* in all parts per million, except for Au, Hg, Ir, Os, Pd, Pt, Re, Rh, and Ru, in parts per billion and for Ra in $\mu\mu g/g$]

Element	W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1
Ag	0.081	*0.05*	*0.049*	*0.10*	0.11	0.005	0.008	*0.036*
As	1.9	*.5*	*.25*	*.09*	*.8*	*.05*	*.03*	*.70*
Au	3.7	4.0	1.0	1.6	.6	*1.6*	*.8*	*.95*
B	*15*	*1.7*	*2.0*	<3	*5*	*6*	<5	*5*
Ba	160	*1,200*	1,870	1,300	1,208	1.2	2.4	675
Be	*.8*	*3*	2.6	*1.5*	*3*	--------	--------	*1.7*
Bi	.046	.065	.043	.037	.057	.013	.010	.050
Br	*.4*	*.4*	*.3*	--------	*.5*	*.6*	*.2*	*.15*
C	------	--------	--------	--------	--------	--------	--------	*65*
Cd	.15	*.03*	.039	*.06*	*.09*	*.1*	*.12*	*.12*
Ce	*23*	*170*	*150*	394	63	*.09*	*.06*	53.9
Cl	*200*	*70*	*60*	*300*	*110*	*60*	*11*	*50*
Co	47	*2.4*	5.5	6.4	14.1	112	133	*38*
Cr	114	*20*	*7*	12.5	12.2	2,730	4,000	17.6
Cs	.9	1.5	*1.4*	1.0	*1.4*	.006	.006	.95
Cu	110	13	11.7	33.3	59.7	11.3	7.0	18.4
Dy	4	2.4	2.6	5.4	3.5	--------	.003	6.3
Er	2.4	1.15	*1.3*	*3.0*	*1.2*	--------	<.003	3.59
Eu	1.11	1.3	1.5	2.4	1.7	.002	.0009	1.94
F	250	690	*1,290*	*3,200*	435	*15*	*15*	*470*
Ga	16	19.6	22.9	*22*	20.5	*.4*	*.2*	*20*
Gd	*4*	*5*	*5*	*15*	*5.5*	--------	<.01	6.6
Ge	*1.4*	1.1	1.15	*1.3*	*1.3*	.93	.90	1.54
Hf	2.67	5.2	7.35	15.9	5.2	*.06*	*.01*	4.7
Hg	*225*	97	39	15.5	15	7.2	8.7	10.7
Ho	.69	.35	*.4*	<.5	*.6*	--------	*.003*	*1.2*
I	<.03	<.03	--------	--------	--------	--------	--------	<1
In	.065	*.02*	.034	*.05*	*.04*	*.003*	*.0025*	.095
Ir	.28	*.008*	*.002*	*.012*	*.011*	5.2	*1.0*	*.004*
La	9.8	101	96	191	*35*	*.15*	*.04*	*26*
Li	14.5	22	34.8	32.1	12	*2*	*2*	12.8
Lu	.35	.19	.11	.23	.28	.006	*.002*	.55
Mn	1,278	195	260	331	763	959	969	1,406
Mo	.57	6.5	*.36*	*.90*	*2.3*	*.2*	*.2*	*1.1*
N	52	59	56	48	43	43	27	30
Nb	9.5	23.5	13.5	29	15	<2	<3	13.5
Nd	15	56	60	188	39	--------	<.02	29

TABLE 107.—*Estimates for trace elements in USGS samples*—Continued

Element	W–1	G–1	G–2	GSP–1	AGV–1	PCC–1	DTS–1	BCR–1
Ni	76	*1*	5.1	12.5	18.5	2,339	2,269	15.8
Os	*.25*	*.07*	--------	<32	<34	*11*	*1*	*.1*
Pb	7.8	48	31.2	51.3	35.1	13.3	14.2	17.6
Pd	*25*	*2*	<.5	<.5	<.5	*13*	*1*	*12*
Pr	*3.4*	*19*	*19*	*50*	*7*	--------	*.006*	*7*
Pt	*12*	*19*	<.5	<.5	*1*	*8*	*3*	*2*
Ra	--------	--------	.71	.66	.69	.0018	.0013	.56
Rb	21	220	168	254	67	.063	.053	46.6
Re	<2	<2	<7	<2	<5	.07	<.4	.8
Rh	<1	--------	--------	--------	--------	1.0	.9	.2
Ru	------	--------	--------	--------	--------	9.5	*2.5*	*1*
S	*123*	*58*	*24*	*162*	*<10*	*<10*	*<10*	*392*
Sb	1.0	.31	*.1*	3.1	4.5	1.4	*.46*	.69
Sc	35.1	2.9	3.7	7.1	13.4	6.9	*3.6*	*33*
Se	*.13*	*.007*	<.7	<.04	<.14	<.18	<.3	*.10*
Sm	3.6	8.3	7.3	27.1	5.9	*.008*	*.004*	6.6
Sn	3.2	3.5	*1.5*	6.3	4.2	*1*	*1*	*2.6*
Sr	190	250	479	233	657	*.41*	.35	330
Ta	.50	1.5	.91	1.0	.9	<.1	<.1	.91
Tb	.65	.54	.54	1.3	.70	*.001*	*.0003*	1.0
Te	<1	<1	<1	<1	<1	<1	<1	<1
Th	2.42	50	24.2	104	6.41	*.01*	*.01*	6.0
Ti	--------	--------	2,780	3,990	6,190	*70*	*71*	12,750
Tl	.11	1.24	*1.0*	*1.3*	*1*	*.0008*	*.0005*	.30
Tm	.30	.15	*.3*	--------	*.4*	--------	*.001*	.6
U	.58	3.4	2.0	1.96	1.88	*.005*	*.004*	1.74
V	264	17	35.4	52.9	125	30	10.3	399
W	*.5*	*.4*	*.1*	*.1*	*.55*	*.06*	*.04*	*.40*
Y	25	13	12	30.4	21.3	<5	*.05*	37.1
Yb	2.1	1.06	.88	1.8	1.7	*.02*	*.01*	3.36
Zn	86	45	85	98	84	36	45	120
Zr	105	210	300	500	225	*7*	*3*	*190*

REFERENCES

Abbey, Sydney, 1968, Analysis of rocks and minerals by atomic absorption spectroscopy. Pt 2. Determination of total iron, magnesium, calcium, sodium, and potassium: Canada Geol. Survey Paper 68–20, 21 p.

——— 1970, U.S. Geological Survey Standards—a critical study of published analytical data: Canadian Spectroscopy, v. 15, p. 10–16.

——— 1971, Written communication, Geol. Survey of Canada, Ottawa.

Agrinier, H., 1968, Written communication, Commisariat a L'Énergie Atomique, Chatillon-sous-Bagneux, France.

Allen, R. O., Haskin, L. A., Anderson, M. R., and Müller, O., 1970, Neutron activation analysis for 39 elements in small or precious geologic samples: Jour. Radioanal. Chemistry, v. 6, p. 115–137.

Anders, Edward, Ganapathy, R., Keays, R. R., Laul, J. C., and Morgan, J. W., 1971, Volatile and siderophile elements in lunar rocks; comparison with terrestrial and meteoritic basalts, *in* Lunar Sci. Conf., 2d, Houston, Tex., 1971, Proc., V. 2: Cambridge, Mass., MIT Press (Geochim. et Cosmochim. Acta Supp. 2), p. 1021–1036.

Ando, Atsushi, 1971, Written communication, Geol. Survey of Japan, Kawasaki.

Anoshin, G. N., and Perezhogin, G. A., 1969, 1971, Written communication, Inst. Geol. and Geophysics, Siberian Branch, U.S.S.R. Acad. Sci., Novosibirsk.

Anoshin, G .N., Perezhogin, G. A., and Melnikova, R. D., 1970, Written communication, Inst. Geol. and Geophysics, Siberian Branch, U.S.S.R. Acad. Sci., Novosibirsk.

Aruscavage, P. J., 1969, 1972, Written communication, U.S. Geol. Survey, Denver, Colo.

Aston, S. R., and Riley, J. P., 1972, The determination of mercury in rocks and sediments: Anal. Chim. Acta, v. 59, p. 349–355.

Aubert, Ch., and Desjardins, M., 1971, Written communication, Société Nationale des Pétroles d'Aquitaine, Paris, France.

Avni, R., Harel A., and Brenner, I. B., 1972, A new approach to the spectrochemical analysis of silicate rocks and minerals: Appl. Spectroscopy, v. 26, p. 641–645.

Baedecker, P. A., Schaudy, Rudolph, Elzie, J. L., Kimberlin, J., and Esson, J. T., 1971, Trace element studies of rocks and soils from Oceanus Procellarum and Mare Tranquillitatis, *in* Lunar Sci. Conf., 2d, Houston, Tex., 1971, Proc., V. 2: Cambridge, Mass., MIT Press (Geochim et Cosmochim. Acta, Supp. 2), p. 1037–1061.

Baedecker, P. A., and Wasson, J. T., 1970, Gallium, germanium, indium, and iridium in lunar samples: Science, v. 167, no. 3918, p. 503–505.

Balous, M., and Thiel, R., 1968, Dosage de sept éléments-traces par spectrophotométrie d'absorption atomique dans six standards U.S.G.S.: Centre Researches Pau Bull. v. 2, p. 179–182.

Bartel, Ardith, J., 1969, Written communication, U.S. Geological Survey, Denver, Colo.

Beccaluva, L., and Venturelli, G., 1971, Nickel, chromium, and strontium determination in some silicate rock standards by atomic absorption spectrophotometry: Atomic Absorption Newsletter, v. 10, no. 2, p. 50–52.

——— 1972, Written communication, Istituto di Mineralogia, Univ. di Parma, Italy.

Bell, Keith, and Doyle, R. J., 1971, K-Rb relationships in some continental alkalic rocks associated with the East African Rift Valley system: Geochim. et Cosmochim. Acta, v. 35, p. 903–915.

Bell, Keith, and Powell, J. L., 1969, Strontium isotopic studies of alkalic rocks; the potassium-rich lavas of the Birunga and Toto-Ankole regions, East and Central Equatorial Africa: Jour. Petrology, v. 10, p. 536–572.

Bender, M. L., and Schultz, Cynthia, 1969, The distribution of trace metals in cores from a traverse across the Indian Ocean: Geochim et Cosmochim. Acta, v. 33, p. 292–297.

Bernas, Bedrich, 1968, A new method for decomposition and comprehensive analysis of silicates by atomic absorption spectrometry: Anal. Chemistry, v. 40, p. 1682–1686.

Bertine, K. K., Chan, L. H., and Turekian, K. K., 1970, Uranium determinations in deep-sea sediments and natural waters using fission tracks: Geochim. et Cosmochim. Acta, v. 34, p. 641–648.

Bewers, J. M., and Flack, F. C., 1969, Determination of fluorine by prompt γ-radiation from proton bombardment. II. Results: Analyst, v. 94, p. 7–14.

Biagi, Laura, 1970, I limiti dei metodi rapidi in fotometria di assorbimento per il dosaggo di SiO_2 e Al_2O_3: Mineralog. et Petrog. Acta, v. 16, p. 33–44.

Bibby, D. M., 1972, written communication, Univ. of Witwatersrand, Johannesburg, South Africa.

Bircz, R., 1971, Spectrochemical determination of lithium, rubidium, and cesium in geological standards: Israel Atomic Energy Comm. Rept. IA–1244, 13 p.

Blackburn, W. H., Griswold, T. B., and Dennen, W. H., 1971, Spectrochemical determinations of trace elements in the U.S.G.S. silicate rock standards: Chem. Geology, v. 7, p. 143–147.

Blount, C. W., Leyden, D. E., Thomas, T. L., and Guill, S. M., 1972, Written communication, Dept. Geol., Univ. of Georgia, Athens.

Boar, P. L., and Ingram, L. K., 1970, The comprehensive analysis of coal ash and silicate rocks by atomic absorption spectrophotometry by a fusion technique: Analyst, v. 95, p. 124–130.

Bodart, D. E., 1970, Rapid colorimetric determinations of cobalt, nickel, and copper in silicate rocks: Chem. Geology, v. 6, p. 133–142.

Børgen, B. L., 1967, Analytical procedures used in the geochemical laboratory of the Survey: Grønlands Geol. Undersøgelse Rap. 10, 44 p.

Boström, Kurt, and Valdes, Sylvia, 1969, Arsenic in ocean floors: Lithos, v. 2, p. 351–360.

Bratzel, M. P., Jr., Chakrabarti, C. L., Sturgeon, R. E., McIntyre, M. W., and Agemain, Haig, 1972, Determination of gold and silver in parts-per-billion or lower levels in geological and metallurgical samples by atomic absorption spectrometry with a carbon rod atomizer: Anal. Chemistry, v. 44, p. 372–374.

Breger, I. A., and Chandler, J. C., 1969, Determination of fixed water in rocks by infrared absorption: Anal. Chemistry, v. 41, p. 506–510.

Brenner, I. B., 1971, Written communication, Geol. Survey of Israel, Jerusalem.

Brimhall, Willis H., and Embree, Glenn F., 1971, Rapid analysis of basalts by atomic absorption spectrophotometry: Brigham Young Univ. Geology Studies, v. 18, pt. 3 (Dec.), p. 123–130.

Briscoe, G. B., and Humphries, S., 1970, Substoichiometric determination of traces of palladium by neutron activation analysis: Talanta, v. 17, p. 371–380.

——— 1971, Substoichiometric determination of traces of palladium by radioactive isotope-dilution analysis: Talanta, v. 18, p. 39–49.

Brooks, C. K., 1968, A radiochemical separation for the determination of zirconium or hafnium in rocks and minerals by neutron activation analysis: Radiochim. Acta, v. 9, p. 157–160.

Brown, D. F. G., MacKay, A. M., and Turek, A., 1969, Preparation of stable silica standard solutions in rock analysis using lithium tetraborate: Anal. Chemistry, v. 41, p. 2091.

Brunfelt, A. O., Heier, K. S., and Steinnes, Eiliv, 1971, Determination of 40 elements in Apollo 12 materials by neutron activation analysis, *in* Lunar Sci. Conf., 2d, Houston, Tex., 1971, Proc., V. 2: Cambridge, Mass., MIT Press (Geochim. et Cosmochim. Acta, Supp. 2), p. 1281–1290.

Brunfelt, A. O., and Steinnes, Eiliv, 1969a Antimony content of some standard rocks: Earth and Planetary Sci. Letters, v. 5, p. 282–284.

——— 1969b, Determination of lutetium, ytterbium, and terbium in rocks by neutron activation and mixed solvent anion-exchange chromatography: Analyst, v. 94, p. 979–984.

——— 1969c, Instrumental activation analysis of silicate rocks with epithermal neutrons: Anal. Chim. Acta, v. 48, p. 13–24.

——— 1969d, A simple neutron activation method for silver in rocks: Radiochem. and Radioanal. Letters, v. 1, p. 219–224.

——— eds., 1971a, Activation analysis in geochemistry and cosmochemistry; Proceedings of the NATO Advanced Study Institute, Kjeller, Norway, 7–21 September 1970: Oslo, Universitetsforlaget, 468 p.

——— 1971b, A neutron activation scheme developed for the determination of 42 elements in lunar material: Talanta, v. 18, p. 1197–1208.

Buckley, D. E., and Cranston, R. E., 1971, Atomic absorption analysis of 18 elements from a single decomposition of aluminosilicate: Chem. Geology, v. 7, p. 273–284.

Butler, L. R. P., 1968, Written communication, Natl. Phys. Research Lab., Pretoria, South Africa.

Butler, L. R. P., and Kokot, M. L., 1969, The application of atomic absorption to the analysis of upper mantle and other rocks: Geol. Soc. South Africa Spec. Pub. 2, p. 449–462.

Campbell, E. Y., 1969, Written communication, U.S. Geological Survey, Washington, D.C.

Capaldi, G., Civetta, L., and Gasparini, P., 1971, Fractionation of the ^{238}U decay series in the zeolitization of volcanic ashes: Geochim. et Cosmochim. Acta, v. 35, p. 1067–1072.

Carpenter, Roy, 1969, Factors controlling the marine geochemistry of fluorine; Geochim. et Cosmochim. Acta, v. 33, p. 1153–1167.

Carver, R. D., and Johnson, P. G., 1968, Use of a spark source mass spectrograph for the general analysis of geological samples: Appl. Spectroscopy, v. 22, p. 431–433.

Casanova, L., Emiliani, F., Fanti, E., and Venturelli, G., 1968, Contributo alla conoscenza di nuovi standards silicatici naturali. Dosaggi di SiO_2, Al_2O_3, Fe tot. (come Fe_2O_3), CaO, MgO, TiO_2, MnO e relativi controlli di accuratezza: Atemeo Parmense, Segione 2, Acta Naturalia, v. 4, fasc. 3, p. 3–23.

Case, D. R., Laul, J. C., Lipschutz, M. E., and Schmidt-Bleek, F., 1969, Trace activation analysis of element groups with computer reduction of Ge(Li) spectra: Radiochem. and Radioanal. Letters, v. 1, p. 143–147.

Cattermole, P. J., and Fuge, R., 1969, The abundances and distribution of fluorine and chlorine in a layered intrusion at Rhiw, North Wales; Geochim. et Cosmochim. Acta, v. 33, no. 10, p. 1295–1298.

Chalmers, R. A., and Basit, M. A., 1968, Micro-analysis of silicate rocks; Part V, Spectrophotometric determination of alumina: Analyst, v. 93, p. 629–632.

Chappell, B. W., 1972, Written communication, Dept. Geol., Australian National Univ., Canberra.

Chappell, B. W., Compston, W., Arriens, P. A., and Vernon, M. J., 1969, Rubidium and strontium determinations by X-ray fluorescence spectrometry and isotope dilution below the part per million level: Geochim. et Cosmochim. Acta, v. 33, no. 8, p. 1002–1006.

Cherry, R. D., Hobbs, J. B. M., Erlank, A. J., and Willis, J. P., 1970, Thorium, uranium, potassium, lead, strontium, and rubidium in silicate rocks by gamma-spectroscopy and/or X-ray fluorescence: Canadian Spectroscopy, v. 15, p. 3–9.

Cioni, R., Innocenti, F., and Mazzuoli, R., 1971, Chemical analysis and some trace element data on standard silicate rocks. Chem. Geology, v. 7, p. 19–23.

Clark, Marie C., 1968, Investigation Report 237R, Commonwealth Scientific and Industrial Research Organization, Division of Mineral Chemistry, North Ryde, New South Wales, Australia.

Clements, R. J., Sergeant, G. A., and Webb, P. J., 1971, The determination of fluorine in rocks and minerals by a pyrohydrolitic method: Analyst, v. 96, p. 51–54.

Cohen, N. E., Reeves, R. D., and Brooks, R. R., 1968, Use of a large quartz spectrograph for the determination of thorium, yttrium, and the rare earths in silicates: Talanta, v. 15, p. 1449–1456.

Cranston, R. E., and Buckley, D. E., 1972, Mercury pathways in a river and estuary: Environmental Sci. and Technology, v. 6, p. 272–278.

Crocket, J. H., Keays, R. R., and Hsieh, S., 1968, Determination of some precious metals by neutron activation analysis: Jour. Radioanal. Chemistry, v. 1, p. 487–507.

Dale, I. M., Henderson, P., and Walton, A., 1970, Non-destructive neutron activation analysis for some transition elements in rocks: Radiochem. and Radionannal. Letters, v. 5, p. 91–101.

Das, H. A., 1969, Written communication, Reactor Centrum Nederland, Petten, North Holland, Netherlands.

——— 1970, Routine determinations of Al, K, Cr, and Sn in geochemistry by neutron activation analysis: Jour. Radioanal. Chemistry, v. 4, p. 21–33.

Das, H. A., de Koning J. and Oosterom M. G., 1971, Determination of sodium in ultrabasic rocks: Radiochem. and Radioanal. Letters, v. 6, p. 203–209.

Das, H. A., Janssen, R., and Zonderhuis, J., 1971, Determination of iridium in rocks; Radiochem. and Radioanal. Letters, v. 8, p. 257–265.

Das, H. A., van Raaphorst, J. G., and Umans, H. J. L. M., 1969, Routine determinations of Al, K, Cr, and Sn in geochemistry by neutron activation analysis: U.S. Natl. Bur. Standards Spec. Pub. 312, v. 1, p. 291–301.

Das, H. A., and Zonderhuis, J., 1971, Routine determinations on rocks and sediments by activation analysis, *in* Brunfelt, A. O., and Steinnes, Eiliv, eds., Activation analysis in geochemistry and cosmochemistry . . .: Oslo, Universitetsforlaget, p. 65–71.

Das, H. A., Zonderhuis, J., and van der Marel, H. W., 1971, Scandium in rocks, minerals, and sediments, and its relation to iron and aluminum: Contr. Mineralogy and Petrology, v. 38, p. 231–244.

de Albuquerque, C. A. R., 1971, Petrochemistry of a series of granitic rocks from northern Portugal: Geol. Soc. America Bull., v. 82, p. 2783–2798.

de Laeter, J. R., 1972, The isotopic composition and elemental abundance of gallium in meteorites and in terrestrial samples: Geochim. et Cosmochim. Acta, v. 36, p. 735–743.

de Laeter, J. R., and Abercrombie, I. D., 1970, Mass spectrometric isotope dilution analyses of rubidium and strontium in standard rocks: Earth and Planetary Sci. Letters., v. 9, p. 327–330.

de Laeter, J. R., Abercrombie, I. D., and Date, R., 1969, Mass spectrometric isotope dilution analyses of barium in standard rocks, Earth and Planetary Sci. Letters, v. 7, no. 1, p. 64–66.

Denechaud, E. B., Helmke, P. A., and Haskin, L. A., 1970, Analysis for the rare-earth elements by neutron activation and Ge(Li) spectrometry: Jour. Radioanal. Chemistry, v. 6, p. 97–113.

de Ruyter, A. W., 1968, Low level gamma counting by means of a 3×3 inch NaI(Tl) well-type crystal: Thesis, Univ. of Amsterdam, 63 p.

De Vecchi, Giampaolo, Piccirillo, Enzo, and Quareni, Sergio, 1968, Contributo all'analisi rapida di rocce mediante fluorescenza ai raggi X: Soc. Italiana Mineralogia e Petrologia Rend., v. 24, p. 3–14.

DeVoe, James R., and LaFleur, Philip D., eds., 1969, Modern trends in activation analysis: U.S. Natl. Bur. Standards Spec. Pub. 312, 2 v, 1334 p.

Donaldson, E. M., 1969, Study of Groves' method for the determination of ferrous oxide in refractory silicates: Anal. Chemistry, v. 41, p. 501–505.

Donaldson, E. M., 1970, Determination of vanadium in refractory metals, steel, cast iron, alloys, and silicates by extraction of an NBPHA complex from a sulfuric-hydrofluoric acid medium: Talanta, v. 17, p. 583–591.

Dorrzapf, A. F., Jr., and Brown, F. W., 1970, Direct spectrographic analysis for platinum, palladium, and rhodium in gold beads from fire assay: Appl. Spectroscopy, v. 24, No. 4, p. 415–418.

Dümecke, G., 1968, Anwendung der Lösungsspektralanalyse für die Untersuchung von Silikaten: Acta Geol. Geogr. Univ. Comenianae, Geol. no. 15, p. 211–218.

Dutra, C. V., 1969, Trace element determinations on six new U.S.G.S. rock standards: Rio de Janeiro Univ. Federal Inst. Geosciências, Geologia Bol., No. 3, p. 9–13.

Eby, G. N., 1972, Determination of rare-earth, yttrium, and scandium abundances in rocks and minerals by an ion-exchange–X-ray fluorescence procedure: Anal. Chemistry, v. 44, p. 2137–2143.

Ehmann, W. D., Baedecker, P. A., and McKown, D. M., 1970, Gold and iridium in meteorites and some selected rocks: Geochim. et Cosmochim. Acta, v. 34, no. 4, p. 493–507.

Ehmann, W. D., and Morgan, J. W., 1970, Oxygen, silicon, and aluminum in Apollo 11 rocks and fines by 14 MeV neutron activation, *in* Apollo 11 Lunar Sci. Conf., Houston, Tex., 1970, Proc., V. 2: New York, Pergamon Press (Geochim. et Cosmochim. Acta Supp. 1), p. 1071–1079.

Eisentraut, K. J., Griest, D. J., and Sievers, R. E., 1971, Ultratrace analysis for beryllium in terrestrial, meteoritic, and Apollo 11 and 12 lunar samples using electron capture gas chromatography: Anal. Chemistry, v. 43, p. 203–207.

Esson, J., Hahn-Weinheimer, P., and Johanning, H., 1968, Determination of hafnium by neutron activation and variation in the Zr/Hf ratio of some granite masses: Talanta, v. 15, p. 1111–1118.

Evans, W. H., 1968, The determination of magnesium in silicate and carbonate rocks by the titan yellow spectrophotometric method: Analyst, v. 93, p. 306–310.

Fabbi, B. P., 1969, Written communication, U.S. Geological Survey, Menlo Park, Calif.

——— 1971a, Rapid X-ray fluorescence determination of phosphorus in geologic samples: Appl. Spectroscopy, v. 25, p. 41–43.

——— 1971b, Written communication, U.S. Geol. Survey, Menlo Park, Calif.

——— 1971c, X-ray fluorescence determination of barium and strontium in geologic samples: Appl. Spectroscopy, v. 25, p. 316–318.

——— 1972a, A refined fusion X-ray fluorescence technique, and determination of major and minor elements in silicate standards: Am. Mineralogist, v. 57, p. 237–245.

——— 1972b, Written communication, U.S. Geol. Survey, Menlo Park, Calif.

Fabbi, B. P., and Espos, L. F., 1972a, X-ray fluorescence determination of arsenic, antimony, nickel, rubidium, scandium, vanadium, and zinc in rock standards and other rock samples: U.S. Geol. Survey Prof. Paper 800–B, p. B147–B150.

——— 1972b, X-ray fluorescence determination of chlorine in standard silicate rocks: Appl. Spectroscopy, v. 26, p. 293–295.

Fabbi, B. P., and Volborth, A., 1968, Ultra-soft X-ray fluorescence analysis for oxygen in fifteen igneous rocks: Norelco Reporter, v. 15, nos. 3–4 (July-Dec. 1968), p. 93–95.

Fabbri, Bruno, and Vespignani-Balzani, G. C., 1969, Spectrochemical data on some rock standards: Minerolog. et Petrogr. Acta, v. 14 (1968), p. 105–110.

Fairbairn, H. W., and others, 1951, A cooperative investigation of precision and accuracy in chemical, spectrochemical, and modal analysis of silicate rocks: U.S. Geol. Survey Bull. 980, 71 p.

Fairbairn, H. W., and Hurley, P. M., 1971, Evaluation of X-ray fluorescence and mass spectrometric analyses of Rb and Sr in some silicate standards: Geochim. et Cosmochim. Acta, v. 35, p. 149–156.

Feather, C. E., 1971, Written communication, Anglo American Research Laboratories, Johannesburg, South Africa.

Ficklin, W. H., 1970, A rapid method for the determination of fluoride in rocks and soils, using an ion-selective electrode: U.S. Geol. Survey Prof. Paper 700–C, p. C186–C188.

Filby, R. H., and Haller, W. A., 1969, Activation analysis of geochemical materials using Ge(Li) detectors: U.S. Natl. Bur. Standards Spec. Pub. 312, v. 1, p. 339–346.

Filby, R. H., Haller, W. A., and Shah, K. R., 1970, Determination of 32 elements in rocks by neutron activation analysis and high resolution gamma-ray spectroscopy; Jour. Radioanal. Chemistry, v. 5, no. 2, p. 277–290.

Fisher, D. E., 1970, Homogenized fission track determination of uranium in whole rock geologic samples: Anal. Chemistry, v. 42, p. 414–416.

Flanagan, F. J., 1967, U.S. Geological Survey silicate rock standards: Geochim. et Cosmochim. Acta, v. 31, p. 289–308.

——— 1969, U.S. Geological Survey standards—II. First compilation of data for the new USGS rocks: Geochim. et Cosmochim. Acta, v. 33, p. 81–120.

Fletcher, K., 1970, Some applications of background correction to trace metal analysis of geochemical samples by atomic absorption spectrophotometry: Econ. Geology, v. 65, no. 5, p. 588–589.

Fleischer, Michael, 1965, Summary of new data on rock samples G–1 and W–1, 1962–1965: Geochim. et Cosmochim. Acta, v. 29, p. 1263–1283.

——— 1969, U.S. Geological Survey standards—I. Additional data on rocks G–1 and W–1, 1965–1967: Geochim. et Cosmochim. Acta, v. 33, p. 65–79.

Fleischer, Michael, and Stevens, R. E., 1962, Summary of new data on rock samples G–1 and W–1: Geochim. et Cosmochim. Acta, v. 26, p. 525–543.

Floyd, P., Humphreys, A., and Aiken, M., 1968, Written communication, Univ. of Keele, Staffordshire.

Foscolos, A. E., 1971, Written communication, Dept. of Energy, Mines, and Resources, Calgary 44, Alberta, Canada.

Foscolos, A. E., and Barefoot, R. R., 1970, A buffering and standard addition technique as an aid in the comprehensive analysis of silicates by atomic absorption spectrometry: Canada Geol. Survey Paper 70-16, 15 p.

Franzini, M., and Leoni, L., 1969, X-ray fluorescence analysis of small samples; Soc. Toscana Sci. Nat. Atti, v. 76, p. 263–279.

Frew, N. M., Leary, J. J., and Isenhour, T. L., 1972, Isotopic analysis of chromium in lunar materials by mass spectrometry of the trifluoroacetylacetonate: Anal. Chemistry, v. 44, p. 665–671.

Fritze, K., and Robertson, R., 1969, Precision in the neutron activation analysis for gold in standard rocks G–1 and W–1: US. Natl. Bur. Standards Spec. Pub. 312, v. 2, p. 1279–1283.

Fuge, R., 1967, The determination of chromium in rocks and minerals: Chem. Geology, v. 2, p. 289–296.

——— 1970, An automated method for the determination of molybdenum in geological and biological samples: Analyst, v. 95, p. 171–176.

Fuge, R., and Power, G. M., 1969, Chlorine and fluorine in granitic rocks from S. W. England; Geochem. et Cosmochim. Acta, v. 33, p. 888–893.

Gale, N. H., 1972, Written communication, Oxford Univ., Oxford, England.

Galle, O. K., 1968, Routine determination of major constituents in geologic samples by atomic absorption: Appl. Spectroscopy, v. 22, p. 404–408.

Gamot, E., Philibert, J. and Vialette Y., 1970, Dosage par absorption atomique du potassium, du rubidium et du strontium en vue de mesures géochronologiques: France, Centre Natl. Recherche Sci. Colloques Nationaux, no. 923, p. 287–299.

Ganapathy, R., Keays, R. R., Laul, J. C., and Anders, Edward, 1970 Trace elements in Apollo 11 lunar rocks—implications for meteorite influx and origin of moon, *in* Apollo 11 Lunar Sci. Conf., Houston, Tex., 1970, Proc., V. 2: New York, Pergamon Press (Geochim. et Cosmochim. Acta, Supp. 1) p. 1117–1142.

Gangadharam, E. V., and Parekh, P. P., 1968, Neutron activation analysis of microgram and submicrogram quantities of thorium in ultramafic rocks: Radiochim. Acta, v. 10, p. 65–68.

Gasparini, Paolo, 1969, Written communication, Univ. di Napoli, Italy.

Gast, P. W., Hubbard, N. J., and Wiesmann, H., 1970, Chemical composition and petrogenesis of basalts from Tranquility Base, *in* Apollo 11 Lunar Sci. Conf., Houston, Tex., 1970, Proc., V. 2: New York, Pergamon Press (Geochim. et Cosmochim. Acta, Supp. 1), p. 1143–1163.

Gerasimovskiy, V. I., and Laktionova, N. V., 1971, Vanadium, chromium, cobalt, nickel, and copper in the volcanic rocks of the rift zones of East Africa: Geochemistry Internat., v. 8, p. 680–696.

Gerasimovskiy, V. I., Laktionova, N. V., and Ageyeva, L. V., 1971, Scandium in the effusives of the East African rift zones: Geochemistry Internat., v. 8, p. 248–258.

Gerasimovskiy, V. I., and Savinova, Ye. N., 1969, Fluorine contents of volcanic rocks in the rift zone of East Africa; Geochemistry Internat., v. 6, p. 1124–1128.

Gibson, E. K., Jr., and Moore, C. B., 1970, Inert carrier-gas fusion determination of total nitrogen in rocks and meteorites: Anal. Chemistry, v. 42 ,p. 461–464.

Gijbels, R., 1971, Determination of noble metals by neutron activation analysis: Talanta, v. 18, p. 587–601.

Gijbels, R., 1972, Written communication, Inst. voor Nucleaire Wetenschappen, Ruksuniversiteit-Gent, Belgium.

Gijbels, R., Millard, H. T., Jr., Desborough, G. A., and Bartel, J., 1971, Neutron activation analysis for osmium, ruthenium, and iridium in some silicate rocks and rock-forming minerals, *in* Brunfelt, A. O., and Steinnes, Eiliv, eds., Activation analysis in geochemistry and cosmochemistry . . .: Oslo, Universitetsforlaget, p. 359–370.

Gillum, David E., and Ehmann, William D., 1971, Noble metal determination in meteorites: Radiochim. Acta, v. 16, p. 123–128.

Girardin, J. L. and Thiel, R., 1970, Micro-analyse spectrophotometrique du fer ferreux dans les roches: Centre Recherches Pau Bull., v. 4, p. 513–516.

Goles, G. G., Duncan, A. R., Lindstrom, D. J., Martin, M. R., Beyer, R. L., Osawa, M., Randle, K., Meek, L. T., Steinborn, T. L., and McKay, S. M., 1971, Analyses of Apollo 12 specimens; compositional variations, differentiation processes, and lunar soil mixing models, *in* Lunar Sci. Conf., 2d, Proc. v. 2: Cambridge Mass., MIT Press (Geochim. et Cosmochim. Acta Supp. 2), p. 1063–1081.

Goodman, R .J., 1971, Analytical data on the U.S.G.S. standard rocks by X-ray fluorescence spectrometry: Canadian Spectroscopy, v. 16, p. 97–99.

Gordon, G. E., Dran, J. C., Baedecker, P. A., and Anderson, C. F. L., 1969, Extensions of the use of Ge(Li) detectors in instrumental neutron activation analysis of geological samples: U.S. Natl. Bur. Standards Spec. Pub. 312, v. 1, p. 399–403.

Govindaraju, K., 1970a, Emploi de complexants pour la mise en solution des silicates et séparations par résines échangeuses d'ions: France, Centre Natl. Recherche Sci. Colloques Nationaux, no. 923, p. 269–285.

——— 1970b, Emploi de fondants et de resines échangeuses d'ions pour l'élimination de l'effect de matrice et dosage quantométrique des éléments en traces dans les silicates: France, Centre Natl. Recherche Sci. Colloques Nationaux, no. 923, p. 133–142.

Govindaraju, K., Mevelle, G., and Chouard, C., 1971, Direct atomic absorption determination of rubidium on pulverized silicate rock samples: Chem. Geology, v. 8, no. 2, p. 131–137.

Graber, F. M., Lukens, H. R., and MacKenzie, J. K., 1970, Neutron activation analysis determination of all 14 stable rare-earth elements with group separation and Ge(Li) spectrometry: Jour. Radioanal. Chemistry, v. 4, p. 229–239.

Graham, A. L., and Nicholls, G. D., 1969, Mass spectrographic determinations of lanthanide element contents in basalts: Geochim. et Cosmochim. Acta, v. 33, no. 5, p. 555–568.

Green, T. E., Law, S. L., and Campbell, W. J, 1970, Use of selective ion exchange paper in X-ray spectrography and neutron activation: application to the determination of gold: Anal. Chemistry, v. 42, p. 1749–1753.

Green, T. H., Brunfelt, A. O., and Heier, K. S., 1969, Rare earth element distribution in anorthosites and associated high grade metamorphic rocks, Lofoten-Vesteraalen, Norway: Earth and Planetary Sci. Letters, v. 7, no. 2, p. 93–98.

Greenland, L. P., 1968a, Application of coincidence counting to neutron activation analysis: U.S. Geol. Survey Prof. Paper 600–B, p. B76–B78.

——— 1968b, Simultaneous determination of tantalum and hafnium in silicates by neutron activation analysis: Anal. Chim. Acta, v. 42, p. 365–370.

Greenland, L. P. and Campbell, E. Y., 1970, Determination of niobium in rocks by an isotope dilution-spectrophotometric method: Anal. Chim. Acta, v. 49, p. 109–114.

——— 1971. Substoichiometric determination of tantalum by neutron activation: U.S. Geol. Survey Prof. Paper 750–B, p. B191–B193.

——— 1972, Determination of nanogram amounts of bismuth in rocks by substoichiometric isotope dilution analysis: Anal. Chim. Acta, v. 60, p. 159–165.

Greenland, L. P., and Fones, R., 1971, Geochemical behavior of silver in a differentiated tholeiitic dolorite sheet; Neues Jahrb. Mineralogie Monatsh., hefte 9, p. 393–398.

Greenland, L. P., and McLane, J. E., 1969, Determination of germanium in silicates by neutron activation analysis: U.S. Geol. Survey Prof. Paper 650–C, p. C152–C154.

Greenland, L. P., and Rowe, J. J. and Dinnin J. I., 1971, Application of triple coincidence counting and of fire-assay separation to the neutron-activation determination of iridium; U.S. Geol. Survey Prof. Paper 750–B, p. B175–179.

Gregory, J. E., and Lavrakes, V., 1971, Written communication, Lowell Technological Inst., Lowell, Mass.

Guillemaut, A., 1968, Written communication, Commissariat a L'Energie Atomique, Chatillon-sous-Bagneux, France.

Gundersen, E., and Steinnes, Eiliv, 1972, Written communication, Institutt for Atomenergi, Kjeller, Norway.

Gunn, B. M., 1969, The determination of barium in silicate samples by X-ray fluorescence analysis: Canadian Spectroscopy, v. 14, p. 164–170.

Hall, A., and Walsh, J. N., 1969, A rapid method for the determination of fluorine in silicate rocks and minerals: Anal. Chim. Acta, v. 45, p. 341–342.

Hamaguchi, H., Onuma, N., Hirao, Y., Yokoyama, H., Bando, S., and Furukawa, M., 1969, The abundances of arsenic, tin, and antimony in chondritic meteorites: Geochim. et Cosmochim. Acta, v. 33, no. 4, p. 507–518.

Hart, S. R., 1968, Written communication, Dept. Terrestrial Magnetism, Carnegie Institution of Washington, Washington, D.C.

Haskin, L. A., Allen, R. O., Helmke, P. A., Paster, T. P., Anderson, M. R., Korotev, R. L., and Zweifel, K. A., 1970, Rare earths and other trace elements in Apollo 11 lunar samples, *in* Apollo 11 Lunar Sci. Conf., 1970, Proc. v. 2: New York, Pergamon Press, (Geochim. et Cosmochim. Acta, Supp. 1) p. 1213–1231.

Hatch, W. R., and Ott, W. L., 1968, Determination of submicrogram quantities of mercury by atomic absorption spectrophotometry: Anal. Chemistry, v. 40, p. 2085–2087.

Hattori, Hitoshi, and Shibata, Ken, 1969, Quantitative analysis of Rb and Sr in rocks by X-ray fluorescence spectrometry; Japan Geol. Survey Bull., v. 20, p. 51–76.

Haynes, S. J. and Clark, A. H., 1972, A rapid method for the determination of chlorine in silicate rocks using ion-selective electrodes: Econ. Geology, v. 67, p. 378–382.

Heady, H. H., 1969, Written communication, U.S. Bureau of Mines, Reno, Nevada.

Heier, K. S., and Thoresen, K., 1971, Geochemistry of high grade metamorphic rocks, Lofoten-Vesterålen, North Norway; Geochim. et Cosmochim. Acta, v. 33, p. 89–99.

Herzenberg, C. L., 1970, Mössbauer spectrometry as an instrumental technique for determinative mineralogy, *in* Symposium on Mössbauer effect methodology, 5th, New York, New York, Feb. 2, 1969: New York, Plenum Press, p. 209–230.

Hetman, J. S., 1968, Potentiometric determination of iron in silicate rocks: Centre Recherches Pau Bull., v. 2, p. 471–475.

Hetman, J. S., and Puyo, M., 1968, Dosage coulométrique du vanadium dans les roches et les minéraux: Centre Recherches Pau Bull., v. 2, p. 171–177.

Higuchi, H., Tomura, K., and Hamaguchi, H., 1970, Determination of rare-earth elements in rock samples by neutron activation analysis; use of Ge(Li) detector in conjunction with light-heavy lanthanides separation by cation exchange: Jour. Radioanal. Chemistry, v. 5, no. 2, p. 207–222.

Higuchi, H., Tomura, K., Onuma, N., and Hamaguchi, H., 1969, Rare earth abundances in several geochemical standard rocks: Geochem. Jour. (Japan), v. 3, p. 171–180.

Higuchi, H., Tomura, K., Takahashi, H., Onuma, N., and Hamaguchi, H., 1969a, Simultaneous determination of strontium and barium by neutron activation analysis with a Ge(Li) detector: Anal. Chim. Acta, v. 44, p. 431–436.

——— 1969b, Use of a Ge(Li) detector after simple chemical group separation in the activation analysis of rock samples. IV, Simultaneous determination of strontium and barium, *in* U.S. Natl. Bur. Standards Spec. Pub. 312, v. 1, p. 334–338.

Hillebrand, W. F., Lundell, G. E. F., Bright, H. A., and Hoffman, J. I., 1953, Applied inorganic analysis: 2d ed., New York, John Wiley and Sons, 1034 p

Hirst, D. M., and Kaye, M. J., 1971, Factors controlling the mineralogy and chemistry of an upper Visean sedimentary sequence from Rookhope, County Durham: Chem. Geology, v. 8, p. 37–59.

Hislop, J. S., Pratchett, A. G., and Williams, D. R., 1971, The determination of fluorine in rock materials by γ-activation and radiochemical separation: Analyst, v. 96, p. 117–122.

Hofmeyr, P. K., 1972, Some emission spectrographic trace element data for reference silicate materials: Chem. Geology, v. 9, p. 23–28.

Hooper, P. R., and Atkins, Lynne, 1969, The preparation of fused samples in X-ray fluorescence analysis: Mineralog. Mag., v. 37, no. 287, p. 409–413.

Huber-Schausberger, I., Janda, I., Dolezel, P., and Schroll, E., 1970, Chemische und spektrochemische Analyze internationaler Referenzgesteinsproben: Tschermaks Mineralog. u. petrog. Mitt., v. 14, p. 195–211.

Huffman, Claude, Jr., Shaw, V. E., and Thomas, J. A., 1971, Chromium content of U.S. Geological Survey standard rocks PCC–1 (peridotite) and DTS–1 (dunite): U.S. Geol. Survey Prof. Paper 750–B, p. B185–B187.

Iida, C., and Nagura, M., 1968, Determination of nickel in silicates by atomic absorption spectrophotometry: Japan Analyst, v. 17, p. 17–22.

Iida, C., and Yamasaki K., 1970, Atomic absorption spectrometric analysis of silicates by the absorption tube technique: Anal. Letters, v. 3, p. 251–257.

Ingram, B. L., 1970, Determination of fluoride in silicate rocks without separation of aluminum using a specific ion electrode: Anal. Chemistry, v. 42, p. 1825–1827.

Ishida, K., Kawamara, S., and Izawa, M., 1970, Neutron activation analysis for mercury: Anal. Chim. Acta, v. 50, p. 351–353.

Ivanova, G. F., 1966, Spectrochemical determination of molybdenum, tin, lead, and tungsten on the international standard G–1: Geochemistry Internat., v. 3, no. 6, p. 1198–1199; translated from Geokhimiya, 1966, no. 12, p. 1502–1505.

Jenkins, L. B., and Moore, R., 1970, Determination of lead in rocks and minerals after extraction with diethylammonium diethyldithio-carbamate: U.S. Geol. Survey Prof. Paper 700–D, p. D222–D224.

Johansen, O., and Steinnes, Eiliv, 1969, Determination of tin in geological material by neutron-activation analysis: Analyst, v. 94, p. 976–978.

——— 1970, Determination of Co, Cu, Fe, Ga, W, and Zn in rocks by neutron activation and anion-exchange separation: Talanta, v. 17, p. 407–414.

Jones, J. B., Nesbitt, R. W., and Slade, P. G., 1969, The determination of the orthoclase content of homogenized alkali feldspars using the $\bar{2}01$ X-ray method: Mineralog. Mag., v. 37, p. 489–496.

Karkare, S. G., 1965, Geochemical studies of the Deccan traps: Varanasi, Banaras Hindu Univ. Press, 128 p.

Kawabuchi, K., and Kuroda, R., 1970, Anion-exchange separation and spectrophotometric determination of molybdenum and tungsten in silicate rocks: Talanta, v. 17, p. 67–73.

Kaye, Maureen, 1972, Written communication, Dept. Geol., Australian Natl. Univ., Canberra.

Kaye, Maureen, and Chappell, B. W., 1972, Written communication, Dept. Geol., Australian Natl. Univ., Canberra.

Keays, R. R., Ganapathy, R., Laul, J. C., Anders, E., Herzog, G. F., and Jeffrey, P. M., 1970, Trace elements and radioactivity in Lunar rocks; implications for meteorite infall, solar-wind flux, and formation conditions of moon: Science, v. 167, no. 3918, p. 490–493.

Kennedy, E. J., Ruch, R. R., and Shimp, N. F., 1971, Distribution of mercury in unconsolidated sediments from southern Lake Michigan: Illinois Geol. Survey Environmental Geology Notes, no. 44, p. 1–18.

Khasgiwale, K. A., Parthasarathy, R., and Das, M. Sankar, 1972, Determination of lead in geological samples by anodic stripping analysis: Anal. Chim. Acta, v. 59, p. 485–489.

King, H. G. C., and Pruden, G., 1969, The colorimetric determination of calcium in silicate minerals: Analyst, v. 94, p. 39–42.

Kowalski, Wlodzimierz, 1967, Geochemistry of K, Na, Ca, Rb, Pb, Ba, and Sr in Sudeten granitoids and their pegmatites: Arch. Mineralog., v. 27, p. 53–244 [Polish with English summary].

Krähenbühl, U., Rolli, H. P., and von Gunten, H. R., 1972, Aktivierungsanalytische Bestimmung von selten Erden in Gesteinsstandards, und in Mondproben: Helvetica Chim. Acta, v. 55, p. 697–701.

Kunzendorf, H., 1971, An instrumental procedure to determine Fe, Rb, Sr, Y, Zr, Nb, and Mo in rock powders by Si(Li) X-ray spectrometry: Jour. Radioanal. Chemistry, v. 9, p. 311–324.

Kuydendall, W. E., Jr., Hoffman, B. W., and Wainerdi, R. E., 1971, Analysis of oceanographic samples from the *Glomar Challenger* voyage, *in* Brunfelt, A. O., and Steinnes, Eiliv., eds., Activation analysis in geochemistry and cosmochemistry . . .: Oslo, Universitetsforlaget, p. 321–332.

Landstrom, O., Samsahl, K., and Wenner, C. G., 1969, An investigation of trace elements in marine and lacustrine deposits by means of a neutron activation method: U.S. Natl. Bur. Standards Spec. Pub. 312, v. 1, p. 353–366.

Langer, K., 1969, On the semimicro determination of silica in natural silicates by photometry of β-molybdosilicic acid: Zeitschr. Anal. Chemie, v. 245, p. 139–148.

——— 1971, Some major and minor constituents of geochemical reference samples as determined by photometric methods: Zeitschr. Anal. Chemie, v. 255, p. 26–29.

Langmyhr, F. J., 1970, Written communication, Univ. of Oslo, Blindern.

Langmyhr, F. J., and Paus, P. E., 1968, The analysis of inorganic siliceous materials by atomic absorption spectrophotometry and the hydrofluoric acid decomposition technique, part 1, the analysis of silicate rocks: Anal. Chim. Acta, v. 43, p. 397–408.

——— 1969, Hydrofluoric acid decomposition-atomic absorption analysis of nine silicate mineral and rock reference samples: Anal. Chim. Acta, v. 47, p. 371–373.

Lapham, D. M., and Saylor, T. E., 1970, Chemical analyses of three Triassic diabase dikes in Pennsylvania: Pennsylvania Topographic and Geol. Survey Inf. Circ. 68, 16 p.

Laul, J. C., Case, D. R., Schmidt-Bleek, F., and Lipschultz, M. E., 1970, Bismuth contents of chondrites: Geochim. et Cosmochim. Acta, v. 34, no. 1, p. 89–103.

Laul, J. C., Case, D. R., Wechter, M., Schmidt-Bleek, F., and Lipschutz, M. E., 1970, An activation analysis technique for determining groups of trace elements in rocks and chondrites: Jour. Radioanal. Chemistry, v. 4, no. 2, p. 241–264.

Laul, J. C., Keays, R. R., Ganapathy, R, Anders, Edward, and Morgan, J. W., 1972, Chemical fractionations in meteorites; V, Volatile and siderophile elements in achondrites and ocean ridge basalts: Geochim. et Cosmochim. Acta, v. 36, no. 3, p. 329–345.

Laul, J. C., Pelly, I., and Lipschutz, M. E., 1970, Thallium contents of chondrites: Geochim. et Cosmochim. Acta, v. 34, p. 909–920.

Learned, R. E., 1970, Written communication, Dept. Sci. Indus. Research, Petone, New Zealand.

LeRiche, H. H., 1968, Ion-exchange concentration of trace elements for spectrochemical analysis of soils and rocks: Geochim. et Cosmochim. Acta, v. 32, p. 791–794.

Lombard, S. M., Marlow, K. W., and Tanner, J. T., 1971, The determination of antimony in standard rocks by instrumental neutron activation analysis: Anal. Chim. Acta, v. 55, p. 13–17.

Loveland, W., Schmitt, R. A., and Fisher, D. E., 1969, Aluminum abundances in stony meteorites: Geochim. et Cosmochim. Acta, v. 33, p. 375–385.

Loveridge, W. D., and Wanless, R. K., 1969, Written communication, Geol. Survey of Canada, Ottawa.

Lovering, J. F., and Hughes, T. C., 1971, Rhenium and osmium abundance determinations and meteoritic contamination levels in Apollo 11 and Apollo 12 lunar samples; *in* Lunar Sci. Conf., 2d, Houston, Tex., 1971, Proc., V. 2: Cambridge, Mass., MIT Press (Geochim. et Cosmochim. Acta, Supp. 2), p. 1331–1335.

Luecke, Werner, 1971, Zur Methode der Atomabsorptions-Spektralanalyse der Erdalkalien und refractären Oxide in geochemischen Referenzproben mit einer N_2O–C_2H_2–Flamme: Neues Jahrb. Mineralogie Monatsh., no. 6, p. 263–288.

Luhn, J. K., 1968, Written communication, Miami Univ., Oxford, Ohio.

McCabe, W. J., Ditchburn, R. G., and Adams, C. J. D., 1972, Written communication, Institute of Nuclear Sciences, Lower Hutt, New Zealand.

Marinenko, John, and May, Irving, 1968, Fluorimetric determination of gold in rocks with rhodamine B: Anal. Chemistry, v. 40, p. 1137–1139.

——— 1970, Gas chromatographic determination of carbonate carbon in rocks and minerals: U.S. Geol. Survey Prof. Paper 700–D, p. D103–D105.

Marinenko, John, May, Irving, and Dinnin, J. I., 1972, Determination of mercury in geologic materials by flameless atomic absorption spectrometry: U.S. Geol. Survey Prof. Paper 800–B, p. B151–B155.

Marowsky, Gerd, 1971a, Aktivierungsanalytische Bestimmung von Cadmium, Quecksilber, Thallium, und Wismut in Gesteinen: Zeitschr. Anal. Chemie, v. 253, p. 267–271.

——— 1971b, Aktivierungsanalytische Bestimmung von Thallium in Gesteinen, ein vergleich mehrerer Messmethoden: Jour. Radioanal. Chemistry, v. 8, p. 27–32.

——— 1971c, Sensitivity ranges in neutron activation analysis of some rare trace elements (Cd, Hg, Tl, Bi) in silicate samples, *in* Brunfelt, A. O., and Steinnes, Eiliv, eds., Activation analysis in geochemistry and cosmochemistry . . . :Oslo, Universitetsforlaget, p. 391–396.

Marowsky, Gerd, and Wedepohl, K. H., 1971, General trends in the behavior of Cd, Hg, Tl, and Bi, in some major rock forming processes: Geochim. et Cosmochim. Acta, v. 35, p. 1225–1267.

Martin, A., and Quintin, M., 1970, Utilisation du chlorure de sodium comme tampon spectral en spectrographie d'émission: application au dosage des éléments en traces dans les roches silicatées: France, Centre Natl. Recherche Sci. Colloques Nationaux, no. 923, p. 187–195.

Martini, Marino, and Tonani, Franco, 1968, Le fluor dans les roches—erreur d'analyse, èchantillons-standards, abondance; Distribution dans la granodiorite du Mte Capanne (ile d'Elbe, Toscane); *in* Ahrens, L. H., ed., Origin and distribution of the elements: New York, Pergamon Press, p. 1113–1126.

Matthews, A. D., and Riley, J. P., 1969, The determination of thallium in silicate rocks, marine sediments, and sea water: Anal. Chim. Acta, v. 48, p. 25–34.

Maurel, C., and Maurel, Pierre, 1967, Résultats d'analyses de six roches étalons, G–2, GSP–1, AGV–1, PCC–1, DTS–1, BCR–1: éléments majeurs et éléments en traces: Soc. Française Minéralogie et Crystallographie Bull., v. 90, no. 2 p. 260–261.

Maxwell, J. A., Peck, L. C., and Wiik, H. B., 1970, Chemical composition of Apollo 11 lunar samples 10017, 10020, 10072, and 10084, *in* Apollo 11 Lunar Sci. Conf., Houston, Tex., 1970, Proc., V. 2: New York, Pergamon Press (Geochim. et Cosmochim. Acta, Supp. 1), p. 1369–1374.

Meehan, W. R., 1969, Beryllium in six U.S.G.S. standard rocks: Earth and Planetary Sci. Letters, v. 7, no. 1, p. 1–2.

Melson, S., 1970, Precision and accuracy of rare earth determinations in rock samples using instrumental neutron activation analysis and a Ge(Li) detector: Jour. Radioanal. Chemistry, v. 4, no. 2, p. 355–363.

Meyer, H. G., 1971, Non-destructive determination of uranium and thorium in geological materials by resonance-neutron activation-analysis: Jour. Radioanal. Chemistry, v. 7, p. 67–79.

Meyrowitz, Robert, 1970, A pyrocatechol violet spectrophotometric procedure for the direct microdetermination of aluminum in silicate materials: U.S. Geol. Survey Prof. Paper 700–D, p. D225–D229.

Michelsen, O. B., and Steinnes, E., 1968, Determination of copper in geological material by neutron activation and gamma-gamma coincidence spectrometry: Talanta, v. 15, p. 574–578.

Mikšovský, Miroslav, 1968, Quantitative spektrographische Bestimmung von Spurenelementen in Silikaten: Acta Geol. Geogr. Univ. Comenianae, Geol. no. 15, p. 253–259.

Millard, H. T., Jr., and Bartel, A J., 1971, A neutron activation analysis procedure for the determination of the noble metals in geological samples, *in* Brunfelt, A. O., and Steinnes, Eiliv, eds., Activation analysis in geochemistry and cosmochemistry . . .: Oslo, Universitetsforlaget, p. 353–358.

Moal, J. Y., Beguinot, J., Ruel, G., and Vannier, M., 1970, Le quantometre pour le dosage des elements en traces dans les materiaux naturels: France, Centre Natl. Recherche Sci. Colloques Nationaux, no. 923, p. 107–132.

Moldan, Bedřich, Rubeška, Ivan, and Mikšovský, Miroslav, 1970, The determination of lead in silicate rocks by atomic absorption spectrophotometry with long-path absorption tubes: Anal. Chim. Acta, v. 50, p. 342–345.

Moore, C. B., Gibson, E. K., Larimer, J. W., Lewis, C. F., and Nichiporuk, W., 1970, Total carbon and nitrogen abundances in Apollo 11 lunar samples and selected achondrites and basalts, *in* Apollo 11 Lunar Sci. Conf., Houston, Tex., 1970, Proc. V.2: New York, Pergamon Press (Geochim. et Cosmochim. Acta Supp. 1) p. 1375–1382.

Morgan, J. W., and Ehmann, W. D., 1970, Precise determination of oxygen and silicon in chondritic meteorites by 14-MeV neutron activation with a single transfer system: Anal. Chim. Acta, v. 49, p. 287–299.

Mori, Yakeshi, Jakes, Petr, and Nagaoka, Masatoshi, 1971, Major element analysis of silicate rocks using electron probe microanalyzer: Kanazawa Univ. Sci. Rept., v. 16, No. 2, p. 113–120.

Morrison, G. H., 1971, Multielement neutron activation analysis of geological and lunar material using chemical group separations and high resolution gamma spectrometry, *in* Brunfelt, A. O., and Steinnes, Eiliv, eds., Activation analysis in geochemistry and cosmochemistry . . .: Oslo, Universitetsforlaget, p. 51–54.

Morrison, G. H., Gerard, J. T., Travesi, A., Currie, R. L., Peterson, S. F., and Potter, N. M., 1969, Multielement neutron activation analysis of rocks using chemical group separations and high resolution gamma spectrometry: Anal. Chemistry, v. 41, p. 1633–1637.

Morrison, G. H., and Kashuba, A. T., 1969, Multielement analysis of basaltic rock using spark source mass spectrometry: Anal. Chemistry, v. 41, p. 1842–1846.

Mountjoy, Wayne, 1970, Determination of cobalt in geologic materials by solvent extraction and atomic absorption spectrometry: U.S. Geol. Survey Prof. Paper 700–B, p. B174–B176.

Müller, O., 1970, Sodium, potassium, and cesium concentrations in U.S.G.S. standards, periodite PCC–1, dunite DTS–1, and diabase W–1 by neutron activation analysis: Earth and Planetary Sci. Letters, v. 8, no. 4, p. 283–284.

Murad, E., 1968, 1969, Written communications, Stat. Forschungsinst. für angew. Mineral., Regensburg.

——— 1971, Written communication, Mineralog.-Petrographisches Institut, Tübingen.

Murali, A. V., Parekh, P. P., and Das, M. S., 1970, On the fission track method for the determination of the uranium content of whole rock samples: Anal. Chim. Acta, v. 50, p. 71–77.

Muscat, V. I., Vickers, T. J., and Andren, Anders, 1972, Simple and versatile atomic fluorescence system for determination of nanogram quantities of mercury: Anal. Chemistry, v. 44, p. 218–221.

Nadkarni, R. A., and Halder, B. C., 1971a, Simultaneous determination of chromium and zinc by neutron activation analysis: Radiochem. and Radioanal. Letters, v. 8, p. 233–240.

——— 1971b, Substoichiometric determination of selenium by neutron activation analysis: Radiochem. and Radioanal. Letters, v. 7, p. 305–311.

——— 1972a, Neutron activation analysis of copper by substoichiometric extraction with neocuproine: Anal. Chemistry, v. 44, p. 1504–1506.

——— 1972b, Substoichiometric determination of mercury by neutron activation analysis: Radioanal. Chemistry, v. 10, p. 181–186.

Nagura, M., and Iida, C., 1968, Atomic absorption spectrophotometric determination of cobalt, nickel, lead, and copper in silicates with the absorption tube technique: Japan Analyst, v. 17, p. 1513–1518.

Nishimura, Susumu, 1970a, The determination of uranium content of standard rocks by fission-track registration in muscovite: Radioisotopes, v. 19, p. 30–32.

——— 1970b, Radium and uranium contents of standard rocks: Chem. Geology, v. 5, no. 2, p. 139–141.

Nomura, K., Mikami, A., Kato, T., and Oka, Y., 1970, The determination of scandium and gold in meteorites, tektites, and standard rocks by neutron activation analysis with an internal-reference method: Anal. Chim. Acta, v. 51, p. 399–408.

Norman, J. C., and Haskin, L. A., 1968, The geochemistry of Sc; A comparison to the rare earths and Fe: Geochim. et Cosmochim. Acta, v. 32, no. 1, p. 93–108.

Norton, E. F., and Stoenner, R. W., 1971, A neutron activation method for the determination of thorium in rocks and minerals using the 22-minute ^{233}Th activity: Anal. Chim. Acta, v. 55, p. 1–11.

O'Gorman, J. V., and Suhr, N. H., 1971, A rapid atomic-absorption technique for the determination of lithium in silicate materials: Analyst, v. 96, no. 1142, p. 335–337.

Omang, S. H., and Paus, P. E., 1971, Trace determination of mercury in geological materials by flameless atomic absorption spectroscopy: Anal. Chim. Acta, v. 56, p. 393–398.

Ondrick, C. W., Suhr, N. H., and Medlin, J. H., 1969, Investigation into increasing the precision of a rotating disk-solution technique for the analysis of silicates: Appl. Spectroscopy, v. 23, p. 111–115.

Oosterom, M. G., and Das, H. A., 1971, Determination by neutron activation analysis of alkali and other trace elements in ultramafic rocks, *in* Brunfelt, A. O., and Steinnes, Eiliv, eds., Activation analysis in geochemistry and cosmochemistry . . .: Oslo, Universitetsforlaget, p. 455–459.

Osawa, Masium, and Goles, G. G., 1970, Trace element abundances in Columbia River basalts: Columbia River Basalt Symposium, 2d, Cheney, Wash., 1969, Proc., p. 55–71.

Ozima, M., and Zashu, S., 1971, Written communication, Geophys. Inst., Univ. of Tokyo.

Pant, D. R., and Parekh, P. P., 1971, A new method for the radiochemical separation of rubidium and cesium: Jour. Radioanal. Chemistry, v. 9, p. 259–265.

Parker, A., 1969, Some trace element determinations on the new U.S.G.S. silicate rock standards: Chem. Geology, v. 4, no. 3–4, p. 445–449.

Parker, Andrew, 1970, Chemical and mineralogical analysis of some basic and ultrabasic rocks and their initial weathering products: Reading (England) Univ. Geol. Rept. No. 4, 41 p.

Peters, A., 1968, Ein neues Verfahren zur Bestimmung von Eisen(II)oxid in Mineralien und Gesteinen: Neues Jahrb. Mineralogie Monatsch., No. 3/4, p. 119–125.

Peters, Arnd, 1969, Neue Analysendaten von Standardgesteinen: Neues Jahrb. Mineralogie Monatsch. No. 4, p. 184–188.

Peterson, S. F., Travesi, A., and Morrison, G. H., 1969, Rapid group separation method for neutron activation analysis of geological materials: U.S. Natl. Bur. Standards Spec. Pub. 312, v. 1, p. 624–633.

Philpotts, J. A., and Schnetzler, C. C., 1970, Apollo 11 lunar samples—K, Rb, Sr, Ba, and rare-earth concentrations in some rocks and separated phases, *in* Apollo 11 Lunar Sci. Conf., Houston, Tex., 1970, Proc. V.2: New York, Pergamon Press (Geochim. et Cosmochim Acta, Supp. 1), p. 1471–1486.

Pouget, R., Carrier, M., Lautelin, M., and Vasseut, A., 1968, Written communication, Commissariat a L'Energie Atomique, Chatillon-sous-Bagneux, France.

Price, V., 1969, Written communication, Furman Univ., Greenville, S.C.

Quijano-Rico, M., 1970, Méthodes rapides à très haute sensibilité pour la détermination du bore et du lithium dans les météorites pierreuses et dans les roches: France, Centre Natl. Recherche Sci. Colloques Nationaux no. 923, p. 367–380.

Quijano-Rico, M., and Wänke, H., 1969, Determination of boron, lithium, and chlorine in meteorites, *in* Mellman, P. M., ed. Meteorite research: Proceedings of a symposium on meteorite research held in Vienna, Austria, 7–13 August 1968: Dordrecht, D. Reider Pub. Co., p. 132–145.

Quintin, M., 1970, Utilisation de la fluorescence X pour l'analyse quantitative non destructive des éléments en traces de N° atomique supérieur à 27 dans les roches silicatées, bauxites, et carbonates: France, Centre Natl. Recherche Sci. Colloques Nationaux, no. 923, p. 75–87.

Ragland, P. C., 1970, Written communication, Dept. Geol., Univ. of North Carolina, Chapel Hill.

Ragland, P. C., Brunfelt, A. O., and Weigand, P. W., 1971, Rare-earth abundances in Mesozoic dolerite dikes from eastern United States, *in* Brunfelt, A. O. and Steinnes, Eiliv, eds., Activation analysis in geochemistry and cosmochemistry . . .: Oslo, Universitetsforlaget, p. 227–235.

Randall, B. A., O., 1972. Written communication, The University, Newcastle-upon-Tyne, England.

Rayburn, K. A., 1968, Elemental analysis of cracking catalysts by X-ray fluorescence: Appl. Spectroscopy, v. 22, p. 726–729.

Rebagay, T. V,, 1969, The determination of zirconium and hafnium in meteorites and terrestrial materials by activation analysis: Dissertation, Univ. of Kentucky, Lexington.

Rebagay, T. V., and Ehmann, W. D., 1970, Simultaneous determination of zirconium and hafnium in standard rocks by neutron activation analysis: Jour. Radioanal. Chemistry, v. 5, p. 51–60.

Reed, G. W., and Jovanovic, S., 1969, Some halogen measurements on achondrites: Earth and Planetary Sci. Letters, v. 6, p. 316–320.

Rey, P., Wakita, H., and Schmitt, R. A., 1970, Radiochemical neutron activation analysis of indium, cadmium, yttrium, and the 14 rare earths in rocks: Anal. Chim. Acta, v. 51, p. 163–178.

Richter, P., 1972, Rontgenspektrometrische Bestimmung von Schwefel in silicatischen Proben: Zeitschr. Anal. Chemie, v. 258, p. 287–289.

Roberts, J. L., 1971, An improved colorimetric determination of vanadium in geochemical prospecting samples: Talanta, v. 18, p. 1070–1072.

Roelandts, Iwan, 1972, The determination of rubidium in rocks and minerals by atomic absorption spectrophotometry: Atomic Absorption Newsletter, v. 11, p. 48–49.

Roelandts, Iwan, and Bologne, Guy, 1970, Written communication, Inst. Petrologie, Univ. of Liege, Belgium.

Roelandts, Iwan, and Duchesne, J. C., 1968, Méthod d'analyse des roches silicatés principe et discussion de la précision et de l'exactitude obtenues: Soc. Géol. Belgique Annales, v. 91, p. 159–164.

Ropert, M. E., and Broudic, M., 1968, Written communication, Commissariat a L'Energie Atomique, Chatillon-sous-Bagneux, France.

Ropert, M. E., Lecable, N., and Monjaux, M., 1968, Written communication, Commissariat a L'Energie Atomique, Chatillon-sous-Bagneux, France.

Rose, A. W., 1970, Written communication, Pennsylvania State Univ., University Park, Pa.

Rösler, H. J., Schrön, W., and Voland, B., 1968, Germanium und Indium, ein Vergleich zwischen regionales Durchschnittsgehalten und den Clarke-Werten, *in* Ahrens, L. H., ed., Origin and distribution of the elements: New York, Pergamon Press, p. 1127–1138.

Rosman, K. J. R., and Jeffrey, P. M., 1971, The determination of zinc in standard reference materials by isotope dilution and atomic absorption analysis: Chem. Geology, v. 8, p. 25–32.

Roubault, M., and others, 1970, Dosage des éléments à l'état de traces dans les roches et les autres substances minérales naturelles: France: Centre Natl. Recherche Sci. Colloques Nationaux, no. 923, 464 p.

Rowe, J. J., and Simon, F. O., 1971, Determination of platinum and palladium in geological materials by neutron activation analysis after fire-assay preconcentration: Talanta, v. 18, p. 121–125.

Rucklidge, J. C., Gibb, F. G. F., Fawcett, J. J., and Gasparrini, E. L., 1970, Rapid rock analysis by electron probe: Geochim. et Cosmochim. Acta, v. 34, no. 2, p. 243–247.

Sahores, J., 1968, Dosage des éléments majeurs des roches par spectrofluorescence X: Centre Rech. Pau Bull., v. 2, no. 1, p. 137–162.

Sceal, J. S. C., and Weaver, S. D., 1971, Trace element data bearing on the origin of salic rocks from the quaternary volcano Paka, Gregory Rift, Kenya: Earth and Planetary Sci. Letters, v. 12, p. 327–331.

Schilling, Jean-Guy, and Winchester, J. W., 1969, Rare earth contribution to the origin of Hawaiian lavas: Contr. Mineralogy and Petrology, v. 23, no. 1, p 27–37.

Schiltz, J. C., 1968, Written communication, Commissariat a L'Energie Atomique, Chatillon-sous-Bagneux, France.

Schlocker, L., 1968, Written communication, U.S. Geol. Survey, Menlo Park, Calif.

Schmidt, D., 1970, Tin in some standard rocks. Earth and Planetary Sci. Letters, v. 10, p. 441–443.

Schmidt, D., and Starke, K., 1969, Radiochemische Trennung zur Bestimmung von Zinn in Gesteinen durch Neutronenaktivierungsanalyse: Radiochim. Acta, v. 11, p. 197–202.

Schmidt, K., 1969, Written communication, Zentrales Geologisches Institut, 104, Berlin, DDR.

Schneider, Gerwulf, 1969, Ergänsungen zur Anwendung der Röntgenfluoreszenzanalyse bei geochemischen Reihenuntersuchungen: Neues Jahrb. Mineralogie Monatsh., no. 11, p. 504–520.

Schnetzler, C. C., and Nava, D. F., 1971, Chemical composition of Apollo 14 soils 14163 and 14259: Earth and Planetary Sci. Letters, v. 11, p. 345–350.

Schnetzler, C. C., Philpotts, J. A., Nava, D. F., Schuhmann, Shuford, and Thomas, H. H., 1972, Geochemistry of Apollo 15 basalt 15555 and soil 15531: Science, v. 175, no. 4020, p. 426–428.

Schoenfeld, I., 1970, Spectrographic determination of fluorine in standard rocks: Appl. Spectroscopy, v. 24, p. 359–361.

Schroll, E., and Stepan, E., 1969, Zur Rontgenfluoreszenanalyse geologischen Materials: Tschermaks Mineralog. u. petrog. Mitt., v. 13, p. 131–147.

Scott, H. D., 1969, Written communication, Bellaire Research Laboratories, Texaco, Inc., Bellaire, Tex.

Sen Gupta, J. G., 1968, Determination of fluorine in silicate and phosphate rocks, micas, and stony meteorites: Anal. Chim. Acta, v. 42, p. 119–125.

——— 1970, Determination of carbon by non-aqueous titration after combustion in a high-frequency induction furnace: Anal. Chim. Acta, v. 51, p. 437–447.

Shapiro, Leonard, 1971, Rapid scanning technique for low levels of CO_2 in silicate rocks: U.S. Geol. Survey Prof. Paper 750–B, p. B161–B162.

Shimizu, Tsuneo, 1969, Scandium content of igneous rocks and some oceanic sediments: Chem. Soc. Japan Bull., v. 52, p. 1561–1569.

Shimuzu, Tsuneo, and Kuroda, Rokuro, 1969, Abundance of scandium in igneous rocks of Japan: Geochim. et Cosmochim. Acta, v. 33, no. 2, p. 290–292.

Sievers, R. E., Eisentraut, K. J., Griest, D. J., Richardson, M. F., Wolf, W. R., Ross, W. D., Frew, N. M., and Isenhour, T. L., 1971, Variations in beryllium and chromium contents in lunar fines compared with crystalline rocks, in Lunar Sci. Conf., 2d, Houston, Tex., 1971, Proc., V. 2: Cambridge, Mass., MIT Press (Geochim et Cosmochim Acta, Supp. 2), p. 1451–1459.

Sighinolfi, G. P., 1968, The zirconium content in some standard rock samples: Soc. Toscana Sci. Nat. Atti, Mem., Ser. A, v. 74, no. 2, p. 626–629.

——— 1969, Determination of some major and trace elements in new standard rock samples by atomic absorption spectroscopic routine analysis: Soc. Toscana Sci. Nat. Atti, Mem., Ser. A, v. 76, p. 312–325.

Simon, F. O., 1970, Written communication, U.S. Geol. Survey, Washington, D.C.

Simon, F. O., and Millard, H. T., Jr., 1968, Determinations of gold in rocks by neutron activation analysis using fire-assay preconcentration: Anal. Chemistry, v. 40, p. 1150–1152.

Smith, A. C. S., 1970, Written communication, Univ. College, London.

Smith, Bob C., II, 1970, Written communication, Pennsylvania State Univ., University Park, Pa.

Smith, Bob C., II, and Rose, A. W., 1970, Written communicacation, Pennsylvania State Univ., University Park, Pa.

Smith, J. D., 1971, Spectrophotometric determination of traces of tin in rocks, sediments, and soils: Anal. Chim. Acta, v. 57, p. 371–378.

Smith, J. D., and Burton, J. D., 1972, The occurrence and distribution of tin with particular reference to marine environments: Geochim. et Cosmochim. Acta, v. 36, p. 621–629.

Stähle, Volker, 1970, Nickel und Kobalt in Gesteinen des Nördlinger Ries: Contr. Mineralogy and Petrology, v. 28, no. 1, p. 72–88.

Steinnes, Eiliv, 1969a, Determination of samarium in rocks by epithermal neutron-activation analysis: Zeitschr. Anal. Chemie, v. 247, p. 23–27.

——— 1969b, Rapid determination of aluminum in rocks by reactor neutron activation analysis: Kjeller Rept. KR-131, Inst. for Atomenergi, Kjeller, Norway, 9 p.

——— 1971a, Determination of molybdenum in rocks by epithermal neutron activation analysis: Anal. Chim. Acta, v. 57, p. 249–255.

——— 1971b, Determination of phosphorus in silicate rocks by neutron activation and direct β-counting: Anal. Chim. Acta, v. 57, p. 451–456.

——— 1971c, Epithermal neutron activation analysis of geological materials, *in* Brunfelt, A. O., and Steinnes, Eiliv, eds., Activation analysis in geochemistry and cosmochemistry . . .: Oslo, Universitetsforlaget, p. 113–128.

——— 1972a, A rapid neutron-activation method for the simultaneous determination of arsenic and antimony in rocks: Analylst, v. 97, no. 1153, p. 241–244.

——— 1972b, Simultaneous determination of rubidium, cesium, chromium, and phosphorus in rocks by neutron activation and a simple group separation: Jour. Radioanal. Chemistry, v. 10, p. 65–73.

——— 1972c, Written communication, Inst. for Atomenergi, Kjeller, Norway.

Steinnes, E., and Brune, D., 1969, Determination of uranium in rocks by instrumental activation analysis using epithermal neutrons: Talanta, v. 16, p. 1326–1329.

Stoch, H., 1969, Written communication, Natl. Inst. for Metallurgy, Johannesburg, South Africa.

Stone, Maurice, and Chesher, S. E., 1969, Determination of lithium oxide in silicate rocks by atomic-absorption spectrophotometry: Analyst, v. 94, no. 1125, p. 1063–1067.

Strelow, F. W. E., Liebenberg, C. J., and Toerien, F. von S., 1968, Quantitative separation of the alkali metals by cation-exchange chromatography with Bio-Rex 40 resin: Anal. Chim. Acta, v. 43, p. 465–473.

——— 1969, Accurate silicate analysis based on separation by ion-exchange chromatography: Anal. Chim. Acta, v. 47, no. 2, p. 251–260.

Strelow, F. W. E., Toerien, F. von S., and Weinert, C. H., 1970, Accurate determination of traces of sodium and potassium in rocks by ion exchange followed by atomic absorption spectroscopy: Anal. Chim. Acta, v. 50, no. 3, p. 399–405.

Suhr, N. H., and Smith, B. C., II, 1970, Written communication, Pennsylvania State University, University Park, Pa.

Šulcek, Zdeněk, and Rubeška, Ivan, 1968, Die Bestimmung von Lithium-spuren in Gesteinen: Acta Geol. Geogr. Univ. Comenianae, Geol. no. 15 ,p. 177–183.

Tanaka, T., and Iida, C., 1969, Atomic absorption spectrophotometric determination of lead by the absorption tube technique: Japan Analyst, v. 18, p. 492–496.

Tandon, S. N., and Wasson, J. T., 1968, Gallium, germanium, indium, and irridium variations in a suite of L-group chondrites: Geochim. et Cosmochim. Acta. v. 32, no. 10, 1087–1109.

Terashima, S., 1971a, Atomic absorption analysis of minor elements in silicates: Japan Analyst, v. 20, p. 321–326 [in Japanese].

——— 1971b, Determination of cobolt, chromium, copper, lithium, nickel, lead, strontium, and zinc in silicates by atomic absorption spectrophotometry: Japan Geol. Survey Bull., v. 22, no. 5, p. 19–33.

——— 1971c, Written communication, Geol. Survey of Japan, Kawasaki.

Thompson, G., and Bankston, D. C., 1970, Apparent copper inconstancy in artificially prepared standards when determined by emission spectrometry: Appl. Spectroscopy, v. 24, p. 375–378.

Thompson, G., Bankston, D. C., and Pasley, S. M., 1970, Trace element data for U.S.G.S. reference silicate rocks: Chem. Geology, v. 5, no. 3, p. 215–221.

Toerien, F. v. S., 1969, Written communication, Natl. Chemical Research Laboratory, Council for Sci. Indus. Research, Pretoria, South Africa.

Tomura, K., Higuchi, H., Onuma, N., and Hamaguchi, H., 1968, Rapid determination of dysprosium in rock samples by neutron activation analysis with a Ge(Li) detector after chemical separation: Anal. Chim. Acta, v. 42, p. 389–395.

Tomura, Kenji; Higuchi, Hideo; Takahashi, Hiroshi; Onuma, N.; and Hamaguchi, H.; 1968, Simultaneous determination of rubidium and cesium in rock samples by neutron activation analysis with a lithium-drifted germanium detector after chemical group-separation: Anal. Chim. Acta, v. 43, no. 3, p. 523–526.

U.S. Geological Survey, 1970, Mercury in the environment: U.S. Geol. Survey Prof. Paper 713, 67 p.

Van Loon, J. C., and Parissis, C. M., 1969, Scheme of silicate analysis based on the lithium metaborate fusion followed by atomic absorption spectrophotometry: Analyst, v. 94, p. 1057–1062.

Van Moort, J. C., 1968, Written communication, Dept. Geology, Univ. of Tasmania, Hobart.

Van Zelst, L., 1971a, Instrumental photon and proton activation analysis of some elements in stony meteorites: Thesis, Univ. Amsterdam.

——— 1971b, Non-destructive activation analysis of some elements in stony meteorites by proton- and Bremsstrahlen-irradiation, *in* Brunfelt, A. O., and Steinnes, Eiliv, eds., Activation analysis in geochemistry and cosmochemistry . . .: Oslo, Universitetsforlaget, p. 99–104.

Vidal, F., 1972, Written communication, Inst. Geologie, Univ. de Rennes, France.

Walsh, J. N., 1972, Written communication, Dept. Geol., Kings College, London.

Walters, L. J., Jr., 1967, Bound halogen in sediments: Thesis, Massachusetts Institute of Technology, 224 p.

Warr, J. J., Jr., and and Dinnin, J. I., 1970, Written communication, U.S. Geol. Survey, Washington, D.C.

Wasson, J. T., and Baedecker, P. A., 1970, Ga, Ge, In, Ir, and Au in lunar, terrestrial, and meteoritic basalts, *in* Apollo 11 Lunar Sci. Conf., Houston, Tex., 1970, Proc., v. 2: New York, Pergamon Press (Geochim. et Cosmochim. Acta, Supp. 1), p. 1741–1750.

Webber, G. R., and Newbury, M. L., 1971, X-ray fluorescence determination of minor and trace elements in silicate rocks: Canadian Spectroscopy, v. 16, p. 90–93.

Weissberg, B. G., 1971, Determination of mercury in soils by flameless atomic absorption spectrometry: Econ. Geology, v. 66, p. 1042–1047.

Welin, E., 1970, Written communication, Naturhistoriska Riksmuseet, Stockholm, 50, Sweden.

Whitley, J. E., Bowden, P., and Angus, N. S., 1971, The determination of trace elements in igneous rocks by nuclear techniques, in Brunfelt, A. O., and Steinnes, Eiliv, eds., Activation analysis in geochemistry and cosmochemistry . . .: Oslo, Universitetsforlaget, p. 55–64.

Willis, J. P., Fesq, H. W., Kable, E. J. D., and Berg, G. W., 1969, The determination of barium in rocks by X-ray fluorescence spectrometry: Canadian Spectroscopy, v. 14, p. 150–157.

Wolfe, L. A., and Zeitlin, H., 1970, An X-ray fluorescence spectroscopic method for the determination of total manganese in rocks and marine sediments: Anal. Chim. Acta, v. 51, p. 349–354.

Wright, I. H., 1968, Written communication, Univ. Witwatersrand. [Uncorrected XRF data.]

Wyttenbach, A., 1969, Rapid instrumental nuclear activation analysis of rocks, cements, and meteorites: Helvetica Chim. Acta, v. 52, no. 8, p. 2458–2465.

Youh, Chang-Ching, 1968, A report on the chemical analyses of granite G–2 and diabase W–1: Geol. Soc. China Proc., No. 11, p. 143–146.

——— 1970, Chemical analysis of standard rock samples from U.S. Geological Survey: Geol. Soc. China Proc., no. 13, p. 161–163.

DETERMINATION OF GOLD, SILVER, AND TANTALUM IN THE NEW USGS STANDARDS BY NEUTRON ACTIVATION ANALYSIS

By G. N. ANOSHIN[1] and G. A. PEREZHOGIN[1]

Substoichiometric separations after neutron activation were used to determine gold, silver, and tantalum in the new USGS standard rocks. Au, Ag, and Ta were determined in two portions from each of three bottles of the standards. The rocks may be considered homogeneous for these elements except for Ag in QLO-1 and Au in MAG-1.

Modern physical and physico-chemical analytical methods do not always provide reliable data for geochemical samples, and many workers demonstrate the validity of their methods by determining the abundance of elements in USGS standard rocks. Most determinations on these standards are made on different bottles, and it cannot be decided whether the variance among the different sets of data is due to different analytical methods or to heterogeneity of the elements among bottles. Hence, it seemed necessary to determine elements in several bottles to obtain both an analytical variance that would characterize the analytical procedures and the variance of the abundance of the elements among bottles that would characterize the homogeneity of the distribution of the elements in the entire standard. Such an investigation seemed especially important for the neutron-activation analysis of gold in rocks, because relatively small portions (0.2–0.4 g) are usually taken for the determination.

The problem of the neutron-activation analysis of gold in rocks and minerals has been discussed (Perezhogin and Alimarin, 1965; Anoshin and others, 1971). Some workers (Rozhkov and others, 1970; Rakovsky and others, 1971) consider average abundances of gold in rocks by neutron-activation analysis to be of questionable value because of the heterogeneity of the distribution of gold in rocks. Analyses of the new USGS rocks may help to solve this problem.

The present and previous (G. N. Anoshin and G. A. Perezhogin, unpub. data, 1971) studies have been based on substoichiometric separations after neutron activation; our present procedure allows us to determine gold, silver, and tantalum in a single portion. Tantalum was not determined in shales SCo-1 and SGR-1 and in the schist SDC-1.

Samples (0.2–0.4 g) of the finely crushed rocks were put into aluminum foil packets, weighed, and placed in aluminum containers. Standards were prepared by applying 0.01 ml solutions of gold (10^{-4} g/ml), silver (10 mg/ml), and tantalum (10 mg/ml) to filter-paper strips. After drying, the strips were put between two similar strips of filter paper and wrapped in aluminum foil. These standards were then placed in the same aluminum containers as the rock samples. These containers were then irradiated in a nuclear reactor with a neutron flux of 10^{13}n/cm^2/sec for 3 days and were allowed to cool for 7 days.

Alundum crucibles were prepared by adding to each crucible 0.2 ml of carrier solutions of gold (5 mg/ml), silver (100 mg/ml), and tantalum (8 mg/ml), which were then adjusted with 5 M NaOH to alkaline pH and dried. Irradiated samples and standards were placed in such crucibles and were mixed with a tenfold excess of sodium peroxide. The crucibles were then placed in a muffle furnace for 8–10 min and the melt was stirred occasionally. The crucibles were then removed from the furnace, allowed to cool to room temperature, and treated with water. The solution with the hydroxide precipitate was transferred to a beaker, heated, and centrifuged. The precipitate was washed with hot water and again collected by centrifugation.

The combined supernatents were transferred to a beaker and acidified with concentrated HGl while being stirred. The solution was heated, 3–4 drops

---

[1] Institute of Geology and Geophysics, Siberian Branch, USSR Academy of Sciences, Novosibirsk 90, USSR.

TABLE 108.—*Determinations of gold, silver, and tantalum in USGS standard rocks.*

[d.f., degrees of freedom. Neg., negative bottle variance. Conclusions from the analysis of variance at $F_{0.95}$ or the fractile indicated: NS, not significant; S, significant (at $F_{0.99}$)]

Standard Rock	Bottles			Mean	Standard deviation		Coefficient of variation (error) (percent)	Conclusions
	1	2	3		Bottles (d.f.=2)	Error (d.f.=3)		
				Gold (parts per billion)				
QLO–1	1.75 1.7	1.8 1.3	2.0 1.4	1.66	Neg.	0.32	19.3	NS
RGM–1	0.23 .25	0.32 .20	0.42 .27	0.28	0.00	0.08	28.6	NS
STM–1	.27 .26	.26 .40	.44 .53	.36	.10	.07	19.4	NS
BHVO–1	1.7 1.7	1.9 1.9	1.8 1.9	1.82	.10	.04	2.2	NS (0.975)
MAG–1	2.6 2.4	2.8 3.0	1.9 1.9	2.43	.5	.11	4.5	S
SCo–1	2.7 2.3	2.9 2.2	3.2 3.0	2.72	.23	.34	12.5	NS
SDC–1	1.1 .8	.9 1.3	1.3 1.2	1.1	.03	.21	19.1	NS
SGR–1	9.7 11	11 13	12 8.4	10.8	Neg.	1.8	16.7	NS
				Silver (parts per billion)				
QLO–1	5.5 5.2	4.1 4.0	3.9 4.1	4.5	0.76	0.15	3.4	S
RGM–1	9.5 9.2	10 14	10 9.1	10.3	.88	1.7	16.5	NS
STM–1	8.0 8.2	6.4 9.1	6.6 10	8.0	Neg.	1.8	22.5	NS
BHVO–1	5.2 5.1	5.9 5.8	5.8 6.2	5.7	.44	.17	3.0	NS (0.975)
MAG–1	6.5 5.6	6.0 6.4	7.0 7.1	6.4	.46	.40	6.2	NS
SCo–1	23 20	18 17	18 17	19	2.1	1.3	6.8	NS
SDC–1	6.8 11	8.5 8.2	8.8 11	9.0	Neg.	1.9	21.1	NS
SGR–1	16 18	20 22	20 19	19.2	1.8	1.2	6.2	NS
				Tantalum (parts per million)				
QLO–1	0.85 .66	0.69 .66	0.45 .46	0.63	0.14	0.08	12.7	NS
RGM–1	.59 .65	.46 .50	.53 .52	.54	.06	.03	5.9	NS (0.975)
STM–1	8.5 8.5	6.4 7.0	[1] 29 9.1	7.9	.96	.55	7.0	NS
BHVO—	.95 1.0	1.0 .96	.96 .91	.96	.007	.033	3.4	NS
MAG–1	1.0 .65	1.1 .80	.80 .92	.88	Neg.	.19	22.7	NS

---

[1] This value does not belong to the same population as the other Ta data and the mean of the five other Ta values was substituted for the analysis of variance. Because of the substitution, the conclusion and the estimates should be considered provisional.

of antimony (20 mg/ml) and tellurium (15 mg/ml) solutions were added, and the gold and the tellurium reduced by ascorbic acid and hydrazine sulfate. The solution must be clear after the precipitate coagulates. The precipitate was collected on glass filters and washed with 10 percent HCl. The filtrate was discarded. The precipitate was treated with a hot freshly prepared mixture of $HCl:HNO_3$ (4:1), and the solution was rinsed with water into a 100-ml flask. The volume of the solution was adjusted with water to about 10 ml, 2 ml of 1.5×10^{-3} M tetraphenylarsonium chloride-chloroform solution was added, and the mixture was agitated for 2–3 min (the organic layer must become yellow). The contents of the flask were transferred to a centrifuge tube, the tube was centrifuged, and 1.6 ml of the organic layer was withdrawn for the gold determination.

The precipitate of the hydroxides containing tantalum and silver was washed with water and treated with 2–3 ml of concentrated nitric acid on a water bath. The mixture was centrifuged, and the precipitate was washed with concentrated ammonia. This precipitate is used for the tantalum determination.

To the combined solution resulting from the treatments with HNO_3 and NH_4OH above, 25 percent ammonia was added dropwise until ferric hydroxide precipitated. This precipitate was washed and discarded. The solution was acidified with HCl, and the precipitate of silver chloride filtered off. The precipitate was washed with 1 percent HCl and with water and then dissolved on the filter with concentrated ammonia. One ml of a 0.1–M KI solution was added to the filtrate, and the silver iodide precipitate was collected on a filter paper disc in a demountable funnel. Adhesive polyethylene film was then used to cover the filter paper to protect the precipitate.

The precipitate for the determination of tantalum was treated with 20–30 drops of hydrofluoric acid, 2–3 ml of saturated oxalic acid solution was added, and the mixture was centrifuged. The centrifugate was transferred to a 100–ml flask, diluted with water, and 0.5 ml of a 10^{-2} M tetraphenylarsonium chloride solution was added (a white precipitate must appear), followed by 2.5 ml of 1,-2-dichloroethane. The mixture was agitated until the complete dissolution of the precipitate. The solution was transferred to a tube and centrifuged. The aqueous layer was removed by pipette and discarded, and 2 ml of the organic phase was transferred to a graduated tube for the tantalum determination.

The activities of ^{198}Au ($E\gamma$=0.41 Mev, $T_{1/2}$=65 h), ^{110m}Ag ($E\gamma$=0.66 Mev, $T_{1/2}$=250 days) and ^{182}Ta ($E\gamma$=1.0–1.1 Mev, $T_{1/2}$=115 days) were measured on a 100×80 mm NaI crystal, and the data were recorded in a 256-channel analyzer. The counting rates of the nuclides determined the counting times, which were generally 10–30 min for Au, 30–100 min for Ag, and 5–15 min for Ta.

The data obtained and the estimates and conclusions resulting from the analysis of variance for a single variable of classification are given in table 108. The three elements may be considered homogenously distributed among bottles of sample except for silver in sample QLO–1 and gold in sample MAG–1. The problem of the accuracy of the analyses of sedimentary rocks for gold has been discussed by Clifton and others (1969) who demonstrated that the accuracy of the analysis for gold depends on the number and size of the gold particles present. The heterogeneity of gold in MAG–1 may be due to a heterogeneous distribution of numbers and sizes of gold particles in the bottles.

REFERENCES

Anoshin, G. N., Perezhogin, G. A., and Melnikova, R. D., 1971, [On some methodical problems of the application of radioactivation analysis to studies in the geochemistry of gold], *in* [Analysis and technology of noble metals], Conf. Chemistry, Analysis Technology Noble Metals, 8th, Novosibirsk, 1969, Trudy, p. 295–297 (in Russian).

Clifton, H. E., Hunter, R. E., Swanson, F. J., and Phillips, R. L., 1969, Sample size and meaningful gold analysis. U.S. Geol. Survey Prof. Paper 625–C, 17 p.

Perezhogin, G. A., and Alimarin, I. P., 1965. [The determination of gold in rocks and meteorites by neutron activation analysis]: Zhur. Analit. Khim. v. 20, p. 793–798 (in Russian).

Rakovsky, E. E., Behrenstein, L. E., Shilin, N. L., and Serebryany, B. L., 1971. [Method of radioactivation determination of gold and its application to studies of some problems in gold geochemistry], *in* [Analysis and technology of noble metals], Conf. Chemistry, Analysis, Technology Noble Metals, 8th, Novosibirsk, 1969, Trudy, p. 305–408 (in Russian).

Roskov, I. S., Rakovsky, E. E., Behrenstein, L. E., Shilin, N. L., and Serebryany, N. L., 1970. [On inhomogeneous distribution of gold in rocks and minerals (as revealed by radioactivation analysis)]: Akad. Nauk. SSSH Dokl., v. 191, p. 927–930 (in Russian).

G–1 ET W–1: REQUIESCANT IN PACE!

By F. J. FLANAGAN

A debate is occurring in the literature between Felix Chayes who, using correlation coefficients, attributes the wide spread of paired data for G–1 and W–1 to systematic interanalyst differences, and A. B. Vistelius who, using scatter diagrams, contends that sample heterogeneity is responsible. From analyses of four new rocks, paired silica data for G–2 (the replacement for G–1) and GSP–1 (a much coarser grained granodiorite) show less scatter than Vistelius' diagram for G–1 and W–1, whereas paired silica data for AGV–1 and BCR–1, both aphanitic rocks, are scattered at least as widely as those data for G–1 and W–1. The coarsest powder of these new rocks is GSP–1 that has 96 percent passing a 200-mesh sieve so that a claim of heterogeneity seems unwarranted. An experiment to determine which of the two viewpoints is correct cannot be made because of the complete depletion of G–1 and W–1; hence, Requiescant in Pace!

The eulogy delivered by Chayes (1969) in his "Last Look at G–1—W–1" appears to have been premature in view of the full-fledged fray of Chayes (1969, 1970) versus Vistelius (1970, 1971). Because the debate about G–1 and W–1 seems to be waxing rather than waning, several details of the program given insufficient attention and the subsequent change in particle size, some of which may have escaped the attention of a casual reader, should be listed:

1. The program was started to see how well rock analysts could perform. Obviously, as noted many times, analysts were not as good as had been believed.
2. No experimental design is mentioned in U.S. Geological Survey Bulletin 980 (Fairbairn and others, 1951).
3. The particle size of the samples (G–1 is described as passing an 80-mesh screen and W–1 as passing a 100-mesh screen) was known to be too large by many of us before Kleeman (1967) concluded that they were too coarse to be used as reference samples. In retrospect, authors up to the present time have been negligent in their literature searches because Behre and Hassialis (1945) published a method based on the binomial distribution for calculating the amount of sample necessary for a determination to be within specified limits at a predetermined probability, or alternately, for calculating the error that might be incurred in a determination, assuming a specified weight of sample.

   The particle size of the two samples was changed by some unknown person and unknown method during my assignment to other laboratories from 1957 to 1962. Upon my return, the particle size of the samples was finer than that of the samples of G–1 used in a lead study (Flanagan, 1960). The G–1 in the six bottles for the lead study had been purposely ground finer to obviate errors that might have been incurred because of the coarse particle size; I neglected to mention this fact in the paper. Ball (1965, p. 263) noted that the two rocks were supplied as powders that passed a 300-mesh sieve.
4. There is no description of what happened to the two samples between the mixing "by shoveling and by shifting on the canvas" (Fairbairn and others, 1951, p. 4) and the bottling of the samples. Either shoveling or shifting, assuming that the final form of the material was a cone, could induce segregation by particle size, shape, or density when particles tumbled down the surface of the cone. The method of transfer of the material from the cone(?) to the bottles is unknown, and, unless some better method of mixing had been used, the analysts may have started with an unknown but real handicap.

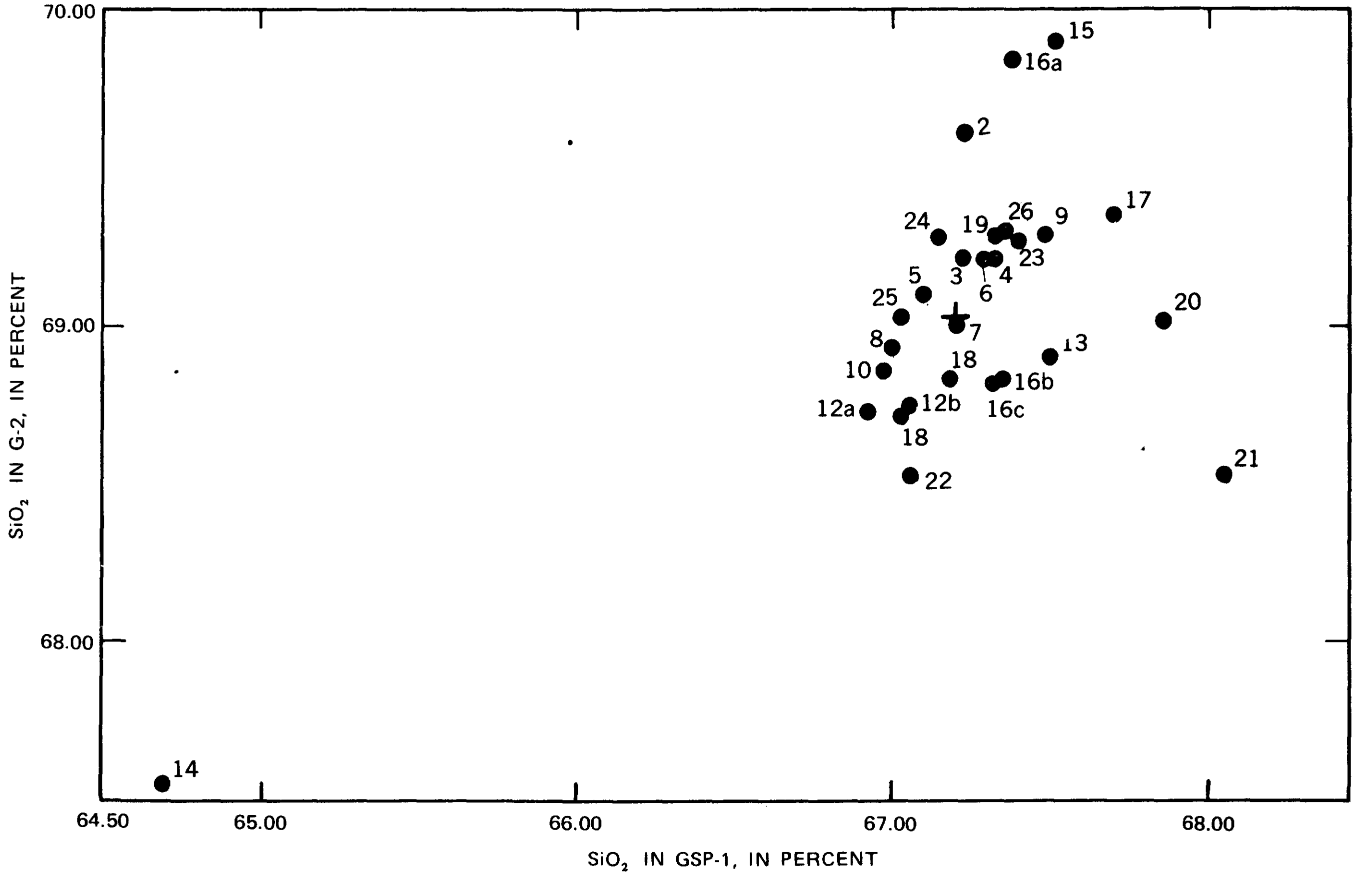


FIGURE 9.—Scatter diagram of SiO_2 determinations in G–2 and GSP–1. Data and analysts, identified by number, are from Flanagan (1969). The average of the data for G–2 and GSP–1 is indicated by +.

5. The bottles were distinguished from each other only by the numbers G–1 or W–1. There was therefore no way to store the bottles randomly, and the best one can expect is that they were stored haphazardly. Consequently, the selection of any bottles for analysis would have been haphazard, at best.
6. Although all rock analysts are reminded occasionally to mix the contents of their bottle before sampling, there is no assurance that they do.
7. The reasonable assumption by both Chayes and Vistelius that Collaborator 1 for G–1 is the same as Collaborator 1 for W–1 cannot be tested because I discarded the original data for the samples a year or two before Chayes wrote his "Last Look."
8. Neither author mentions that 13 pairs of those analyses of G–1 and W–1 under consideration were listed as the average of two analyses. Although nothing can be done to recover the information lost by averaging, one can wonder how much the correlation coefficient or diagram might have been changed.
9. At the beginning of the program that resulted in Geological Survey Bulletin 980 (Fairbairn and others, 1951), a bottle each of G–1 and W–1

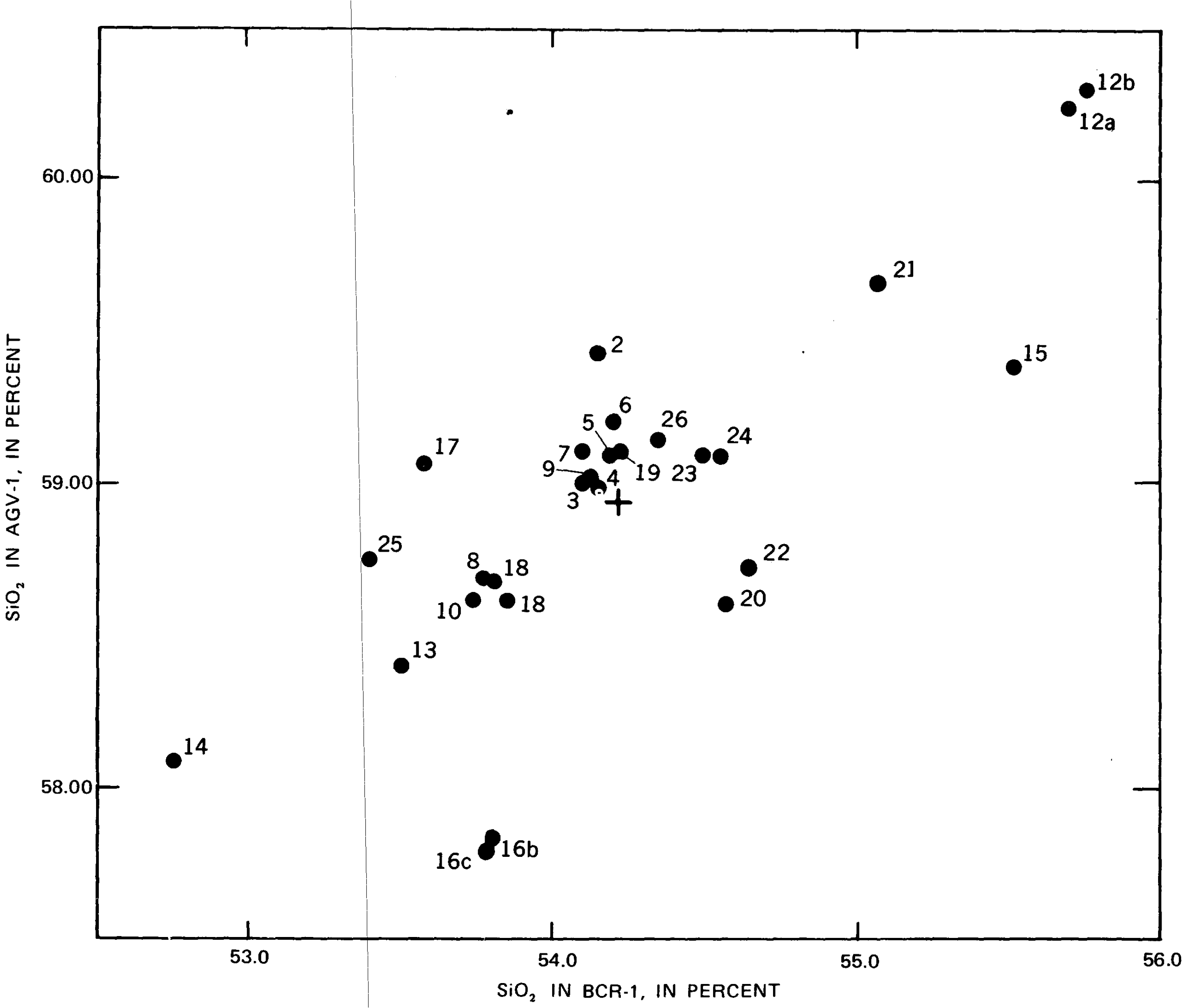


FIGURE 10.—Scatter diagram of SiO_2 determinations in AGV–1 and BCR–1. Data and analysts, identified by number, are from Flanagan (1969). The average of the data for AGV–1 and BCR–1 is indicated by +.

were mailed simultaneously to each analyst desiring to participate in the collaborative program (Michael Fleischer, oral commun., 1972). As a former rock analyst, I submit that there is an overwhelming temptation to analyze both samples simultaneously. A further temptation, equally strong, is to make duplicate analyses of both standards "just to be sure of the results," and the duplicate portions of each would likely be analyzed simultaneously simply because four analyses can be handled conveniently. Even excluding obvious blunders, there is an excellent chance of incurring correlated errors in the classical procedure for rock analysis if the standard samples were handled in this way. Based on such speculation, I agree with Chayes' contention that the published data exhibit large amounts of analytical error. Such speculation, however, does not obviate arguments by Vistelius based on particle shape, size, or density, or upon the possible distribution of monomineralic species within a given bottle.

A compilation of data on six USGS samples (Flanagan, 1969) gives some further evidence applicable to the theses of Chayes and Vistelius. These samples were processed so that a minimum of 85 percent passed a 200-mesh screen; the particle-size distribution of the powdered samples is shown in table 109. Among the six samples are G–2, a substitute for G–1 but a slightly coarser grained portion of the Westerly Granite, and GSP–1, a granodiorite (or better, an adamellite) whose grain size is much larger than those of G–1 or G–2. If one omits the data by analyst 1, who made spectrographic determinations, and plots the results of the determinations by the other analysts of SiO_2 in G–2 versus the paired determinations of SiO_2 in GSP–1, the plot (fig. 9) seems to lend support to the contentions of both Chayes and Vistelius, because the data, except for analyst 14, are well clustered.

Two other samples in the series of six are AGV–1, an andesite from southern Oregon, and BCR–1, a basalt from the Columbia River Group, which differ markedly from G–2 and GSP–1 in that they are both very fine grained rocks. If we plot the SiO_2 determinations for AGV–1 versus the paired data for BCR–1, the resulting plot (fig. 10) is similar to figure 1 of Vistelius (1971). This scatter diagram, like that for G–1 and W–1, can be best interpreted in terms of correlated errors, that is, when SiO_2 is low in AGV–1, it is also low in BCR–1, and conversely. Possible arguments by Vistelius that the scatter might be due to particle size, shape, or density or that the trend may have been generated by one or more monomineralic species would be untenable because of the fine particle size to which these four samples were ground and of the care with which the powders were sampled into bottles (Flanagan, 1967).

Because the supply of G–1 was depleted about 1965 and that of W–1 in 1972 and because the size distribution of the two samples was changed (Ball, 1965) since the original preparation, there is little or no likelihood that one can now test the subject of the debate by a well-designed experiment. Hence, G–1 et W–1, Requiescant in Pace!

TABLE 109.—*Particle-size distribution, in percent, of six USGS samples*

[Reprinted from Flanagan, 1967, table 1]

Rock sample	G-2	GSP-1	AGV-1	PCC-1	DTS-1	BCR-1
Number of sieve tests	2	3	3	3	3	3
Mesh size						
+100	0·1	0·2	tr	tr	0·1	tr
−100 +120	0·1	0·1	tr	tr	0·1	tr
−120 +170	0·4	1·1	0·5	1·6	1·5	0·1
−170 +200	0·9	2·5	0·4	5·6	4·0	0·6
−200	98·5	96·1	99·1	92·8	94·3	99·3

REFERENCES

Ball, D. F., 1965, Rapid analysis for some major elements in powdered rock by X-ray fluorescence spectrography: Analyst, v. 90, p. 258–265.

Behre, H. A., and Hassialis, M. D., 1945, Sampling and testing, Sec. 19 of Taggart, A. F., Handbook of mineral dressing—ores and industrial minerals: New York, John Wiley and Sons, p. 19–01—19–208.

Chayes, Felix, 1969, A last look at G–1—W–1: Carnegie Inst. Washington Year Book 67, 1967–68, p. 239–241.

——— 1970, Another last look at G–1—W–1: Internat. Assoc. Math. Geology Jour., v. 2, p. 207-209.

Fairbairn, H. W., and others, 1951. A cooperative investigation of precision and accuracy in chemical, spectrochemical, and modal analysis of silicate rocks: U.S. Geol. Survey Bull. 980, 71 p.

Flanagan, F. J., 1960, The lead content of G–1, Part 5 of Stevens, R. E., and others, Second report on a cooperative investigation of the composition of two silicate rocks: U.S. Geol. Survey Bull. 1113, p. 113–121.

——— 1967. U.S. Geological Survey silicate rock standards: Geochim. et Cosmochim. Acta, v. 31, p. 289–308.

——— 1969. U.S. Geological Survey standards—II. First compilation of data for the new U.S.G.S. rocks: Geochim. et Cosmochim. Acta, v. 33, p. 81–120.

Kleeman, A. W., 1967, Sampling error in the chemical analysis of rocks: Geol. Soc. Australia Jour., v. 14, pt. 1, p. 43–47.

Vistelius, A. B., 1970, Statistical model of silicate analysis and results of investigation of G–1 and W–1 samples: Internat. Assoc. Math. Geology Jour., v. 2, p. 1–14.

——— 1971, Some lessons of the G–1—W–1 investigation: Internat. Assoc. Math. Geology Jour., v. 3, p. 323–326.